DISTRIBUTION AND ANNUAL OCCURRENCE OF CHAETOGNATHA OFF CANANEIA AND SANTOS COAST (SÃO PAULO, BRAZIL)

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SYNOPSIS

Plankton samples were fortnightly taken at three fixed stations off Cananéia (1958, 1959, 1960) and off Santos (1960, 1961) by vertical hauling. They contained the following species: *Sagitta enflata, S. friderici, S. hispida, S. minima, S. serratodentata, Krohnitta pacifica* and *Pterosagitta draco*. *S. friderici* is a typical coastal water species. *S. enflata* is a typical shelf water species. *S. hispida* and *K. pacifica* were present more frequently in shelf water but they were sometimes very abundant in coastal water. *S. serratodentata, S. minima* and *P. draco* occurred sparingly in tropical water, however, very few samples were taken in this water mass. Three different maturity stages were established (juvenile, intermediate and adult) in order to study the annual variation of the Chaetognatha. A special breeding period throughout the year was not observed as great swarms of juveniles and intermediates were found in spite of the very small number of adults.

Two series of samples taken off Santos at a fixed station (Pt. III) during a period of 24 hours in three different levels were also counted to study the vertical distribution of the Chaetognatha in this area. The three most abundant species were: *S. enflata, S. hispida* and *K. pacifica*. *S. enflata* was more frequent at mid-water. *S. hispida* and *K. pacifica* seemed to prefer the surface layer. The thermocline did not affect their vertical migration except for *S. hispida*. There is indication that *S. serratodentata* performs vertical movements. *S. minima* seems to live below 25 m depth. *K. subtilis* occurred exceptionally in this vertical series of samples.

INTRODUCTION

This paper is a study on Chaetognatha from Cananéia and Santos regions, at the coast of S. Paulo State, Brazil (Table I). Two different environments were chosen, one in the open sea off Santos and the other off Cananéia more exposed to the influence of the outflow from the coastal lagoon system (Tavares, 1967 p. 88 fig. 1). The systematics and general distribution of this group in the western side of the South Atlantic were already studied by Vannucci & Hosoe (1952), Hosoe (1956) and Almeida Prado (1961 a, b). However only the spatial problen was considered and the annual variation of Chaetognatha was not investigated. There are several papers on annual variation and biological cycle of the Chaetognatha in cold waters (Russell, 1932-33) but for tropical water very few have been published, such as Owre's (1960) on seasonal variation of Chaetognatha from the Florida Current, and Reeve's (1964 a) on Chaetognatha from Biscayne Bay also in the Florida Current.

Another aspect treated in this paper is the establishment of the indicator species of different water masses and their vertical distribution.

MATERIAL AND METHODS

Three fixed points were established at the coastal adjacent waters of the lagoon region of Cananéia for collection of plankton during three years (1958, 1959, 1960). Samples were also collected at other three points off Santos during 1960 and 1961. In 1961 a fourth point was added off Santos over deeper waters (Table I). The plankton samples and the hydrographical data were taken every fortnight. Unfortunately there are some gaps due to bad weather or rehauling of the boat. However, those gaps are compensated by the great number of samples and some taken in other occasions. The samples were taken vertically by a Hensen net rigged with silk or nylon gauze, 58 mesh/inch.

As many as 419 samples were counted totally for Chaetognatha. All adults and all developmental

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TABLE I — Position of stations, depth of sampling and local depth

LOCALITY	STATION	POSITIONS		DEPTH OF SAMPLING (m)	LOCAL DEPTH (m)
CANANEIA	I	25º 07.9' S 47º 48.4' W	5.6 miles off Bom Abrigo Island	15	19
	II	25º 08.4' S 47º 44.2' W	9.5 miles off Bom Abrigo Island	15	20
	III	25º 09.5' S 47º 35.7' W	17.2 miles off Bom Abrigo Island	25	30
SANTOS	I	24º 04.8' S 46º 13.7' W	5.0 miles off Moela Island	25	28
	II	24º 10.0' S 46º 08.0' W	10.0 miles off Moela Island	35	37
	III	24º 16.8' S 46º 00.4' W	20.0 miles off Moela Island	45	49
	IV	24º 24.0' S 45º 52.9' W	30.0 miles off Moela Island	55	60

stages were counted. The density of the species per m^3 of water was determined by calculating the volume of water filtered through the net.

Two other series of samples taken off Santos Pt. III (Lat. 24°16.8'S; Long. 46°00.4'W) were counted totally in order to study the vertical distribution of Chaetognatha in this area. The samples were taken horizontally by means of a Closing Standard Plankton net rigged with nº 3 gauze (64 mesh to the inch) which was towed for fifteen minutes at three different levels 0 m, 25 m and 45 m over a depth of 50 m. These samples were taken on April 8, 1960 and July 6, 1961, and were towed at each of the different given depth, every four hours during the period of 24 hours (Table III). The speed of hauling was kept as near as possible to half a knot. The amount of water filtered was estimated by the evaluated volume of water filtered because data of the flowmeters were not reliable.

These samples are stocked in the Plankton Section of Instituto Oceanográfico da Universidade São Paulo.

HYDROGRAPHICAL NOTES

A brief account of the water masses of both areas is given for a better understanding of the Chaetognatha distribution. They can be described as follows, according to EMILSON (1959; 1961).

1 — The coastal water mass has salinity under 35.00$^0/_{00}$ and temperature above 20.00°C nearest the coast.

2 — The shelf water has salinity ranging from 35.00$^0/_{00}$ to 36.00$^0/_{00}$, temperature above 20.00°C and lies over the shelf immediately next to the coastal waters. Sometimes this water mass shows temperature as low as 10.00°C in deeper layers due to the mixing with the subtropical water mass which flows north and westwards under the tropical water.

3 — Tropical water has salinity above 36.00$^0/_{00}$ and temperature higher than 20.00°C. It flows southwards to the east of the shelf water.

The regions of Cananéia and Santos are hydrographically similar as to the presence of these water masses but they are different in the extent and frequency of occurrence of each water mass in each point. Cananéia is an extensive lagoon region with a large outflow and therefore the coastal water there has lower salinity than off Santos. The salinity at Pt. I off Santos was generally around 35.00$^0/_{00}$ and off Cananéia was always under 33.00$^0/_{00}$ and even as low as 29.50$^0/_{00}$, although the distance of the two points from the coastline is about the same. Altogether the fixed points off Cananéia suffer a higher influence of coastal water than those off Santos where the shelf water and to a less extent the tropical water come closer to land.

As these regions are very near to the coast the hydrographical variation and general condition of the environments are strikingly changeable due to the amount of rain and water drained from land.

DISTRIBUTION OF THE SPECIES ACCORDING TO WATER MASSES

Seven species of Chaetognatha belonging to three genera were taken off Santos and Cananéia. These are: *Sagitta enflata* Grassi; *S. friderici* R. Zahony, *S. hispida* Conant, *S. minima* Grassi, *S. serratodentata* Krohn, *Krohnitta pacifica* Aida, *Pterosagitta draco* Krohn.

The two most abundant and frequent species in both areas were *S. enflata* and *S. friderici*, followed by *S. hispida* and *K. pacifica*. *S. minina* and *S. serratodentata* appear last in abundance and frequency. These two species occurred scarcely at Cananéia and the latter was taken only in 1960 when the influence of tropical water was stronger. *Pterosagitta draco* occurred very seldom in quite small number. Earlier papers showed the relationship between the distribution of these species and salinity and temperature in the western South Atlantic (ALMEIDA PRADO 1961 a, p. 31).

The annual average of specimens/m^3 was calculated in order to give a concise picture of the occurrences and frequencies of each species.

The distribution of each species as shown in Table II varies gradually from Pt. I, the shallowest and neritic to Pt. III and IV the deepest and oceanic one or vice-versa, depending however, on the water mass.

The study of the association of each species with a water mass was made by selecting the samples which were hauled through only one water mass in order to be sure of the origin of the species. The two most abundant species were studied in more detail. Each species was considered separately to discuss its ecological parameters.

Sagitta friderici — Studied in the tropical Atlantic by ALMEIDA PRADO (1961 a, p. 21; 1961 b, p. 32)

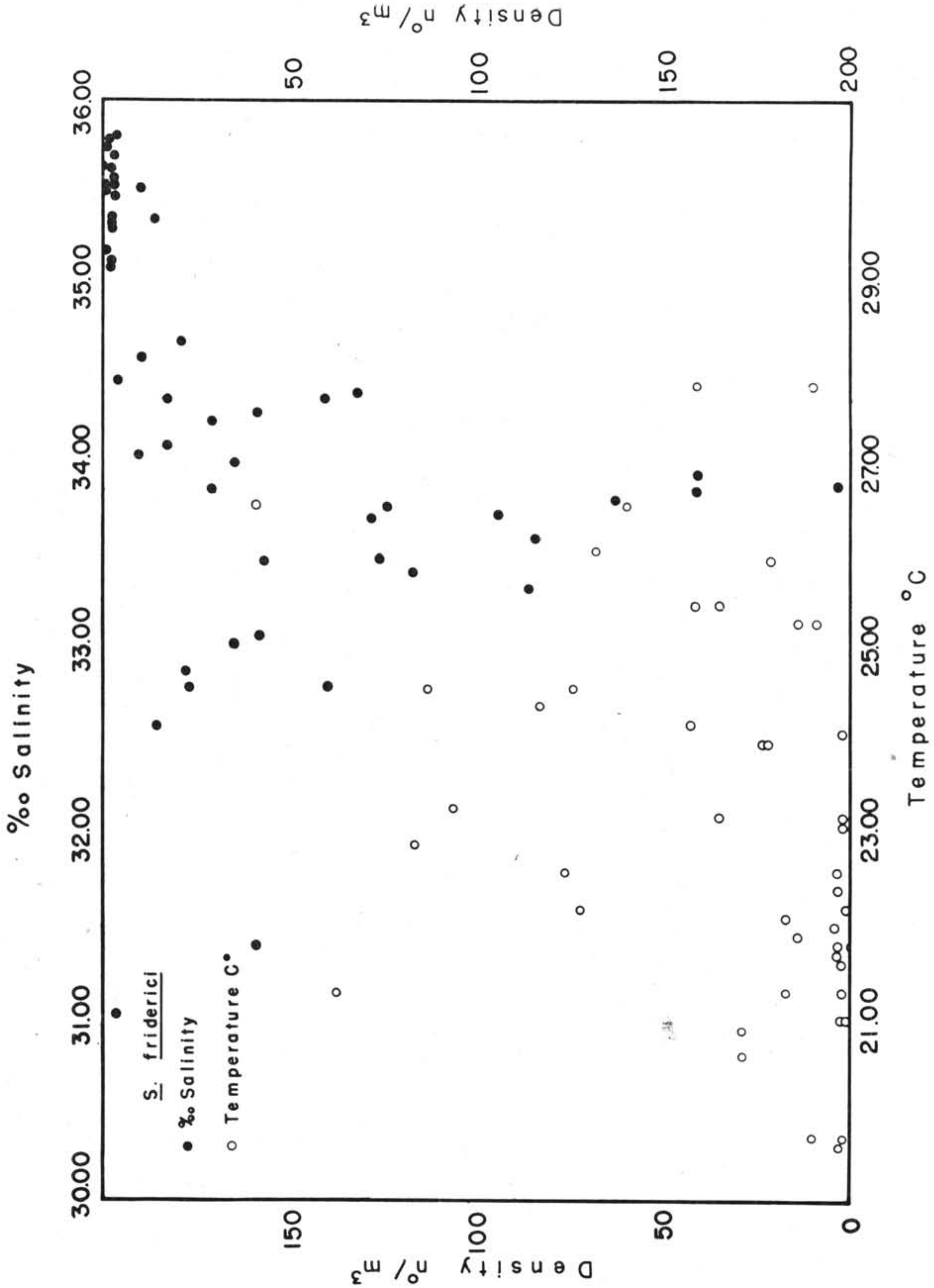

Fig. 1 — Density of *S. friderici* according to temperature and salinity.

TABLE II — Annual average of each species per cubic meter

Locality	Year	Station	SPECIES						
			S.frid.	S.enfl.	S.hisp.	S.min.	S.serr.	K.pac.	P.drac.
CANANEIA	1958	I	85.05	13.40	1.29	----	----	0.26	-----
		II	50.55	34.61	2.08	----	----	1.13	-----
		III	19.27	40.57	2.86	0.01	----	2.67	-----
	1959	I	55.42	16.92	7.14	0.01	----	5.58	-----
		II	36.31	18.44	9.42	0.01	----	4.50	-----
		III	14.53	30.67	8.99	0.12	----	5.73	0.01
	1960	I	40.94	20.07	10.59	0.08	----	9.06	-----
		II	21.07	18.31	7.66	----	----	8.31	-----
		III	15.92	31.81	5.85	0.09	0.09	6.83	0.05
SANTOS	1960	I	13.90	44.35	6.24	0.28	0.04	8.08	-----
		II	5.89	70.08	5.35	2.45	0.10	6.63	-----
		III	4.14	55.68	4.40	2.82	0.74	3.11	-----
	1961	I	11.45	18.19	5.81	0.06	0.16	6.66	-----
		II	2.85	14.49	3.33	0.02	0.02	3.33	-----
		III	3.56	22.57	2.57	0.29	0.08	1.46	-----
		IV	1.11	15.26	1.27	0.29	0.01	0.75	-----

was also firstly recorded by FURNESTIN, (1953, p. 413) and ROSE & HAMON (1953, p. 168) in the Mediterranean, by BIERI (1959, p. 1) in Peru and California Current, in blue-green water off Lower California by TOKIOKA (1961, p. 11).

Sagitta friderici was more abundant off Cananéia than off Santos and its abundance decreases from Pt. I to III and IV in both areas showing its preference for coastal waters (Table II). The distribution of this species (Fig. 4) according to the distance from the coast, shows that the abundance decreases from Pt. I towards Pt. III in Cananéia and continues to decrease from Pt. I towards Pt. III in Santos, suggesting that Pt. III in Cananéia is similar to Pt. I in Santos. The new records used in this paper confirm previous ones by ALMEIDA PRADO (1961 a, p. 22) since the greatest abundance of S. *friderici* falls between 33.00 and 35.00‰ salinity and 21.00 and 27.00°C temperature in the T-S-P diagram (Figs. 1 and 2).

DUCRET (1962, p. 334) mentions the presence of *S. friderici* in the mouth of the Congo River in water of 32.61‰ salinity. CAVALIERI (1963, p. 233) registered this species as neritic preferring water of low salinity. He found *S. friderici* in Argentinean water of 15.95°C of temperature and 33.66‰ salinity. SAINT-BON (1963, p. 324) recorded this species abundantly in the Ivory Coast in salinity ranging from 33.33 to 35.48‰. Yet she mentioned the presence of *S. friderici* in higher salinity (39.72‰) as well as in the oriental Mediterranean off the coast of Israel. The present material shows a very rare occurrence of *S. friderici* in water with more than 36.00‰. These two data suggest that *S. friderici* is a typical neritic form and eurythermic as it endures higher salinities in coastal water off Israel than in the western South Atlantic because in this area the water mass with salinity above 36.00‰ is oceanic.

Sagitta enflata — according to PIERCE & WASS (1962, p. 409) is an epiplanktonic warm water species found in the Atlantic, Indian, Pacific Oceans and in the Mediterranean by FURNESTIN (1957, p. 213).

The two forms of *S. enflata* occurred here, one with short and the other with long ovaries, however the long-ovary form appeared always in small numbers and it was impossible to establish its relationship with the different water masses. DUCRET (1962, p. 332) observed the same in equatorial regions of the western side of Africa.

Sagitta enflata like *S. friderici* was one of two most abundant species (Table II). It occurred in all samples from Santos and Cananéia. In the T-S-P diagram (Fig. 2 and 3) the highest abundance of this species was found between 35.00‰ to 36.00‰ salinity and 21.00 to 23.00°C temperature. The present data confirm those recorded earlier by ALMEIDA PRADO (1961 a, p. 21, fig. 4). Figure 4 shows that the number of *S. enflata* increases from Pt. I towards Pt. III (Cananéia) and from Pt. I towards Pt. III and IV (Santos), in other words it increases from coastal water to shelf and tropical water. The difference in the distribution of *S. friderici* and *S. enflata* (Fig. 4) is very clear. The abundance of *S. enflata* is strikingly higher off Santos than off Cananéia. *S. enflata* has also been observed by SAINT-BON (1963, p. 317-318) in the Ivory Coast withstanding a range of salinity from 33.33 to 35.48‰ and temperature from 21.99 and 29.40°C. FURNESTIN & RADIGUET (1964, p. 61) found this species in water with temperature ranging from 21.00 to 29.00°C and salinity from 35.00 to 37.50‰. FURNESTIN (1957, p. 222-224) states that *S. enflata* is a neritic species in the Mediterranean where the environmental conditions are more stable, while it is an oceanic species in the oceans where its relationship with coastal waters is smaller especially in the subtropical regions. The present material also shows that here it is more oceanic than neritic since it is replaced by *S. friderici* in the inshore water off Cananéia where the salinity is lower.

Sagitta hispida — According to FURNESTIN & RADIGUET (1964, p. 68) the distribution of this species is Indian, Pacific and tropical Atlantic.

This species shares the second place in abundance with *Krohnitta pacifica.* The pattern of distribution of *S. hispida,* according to annual average, is different each year and does not show the same distribution in different water masses as the two previous

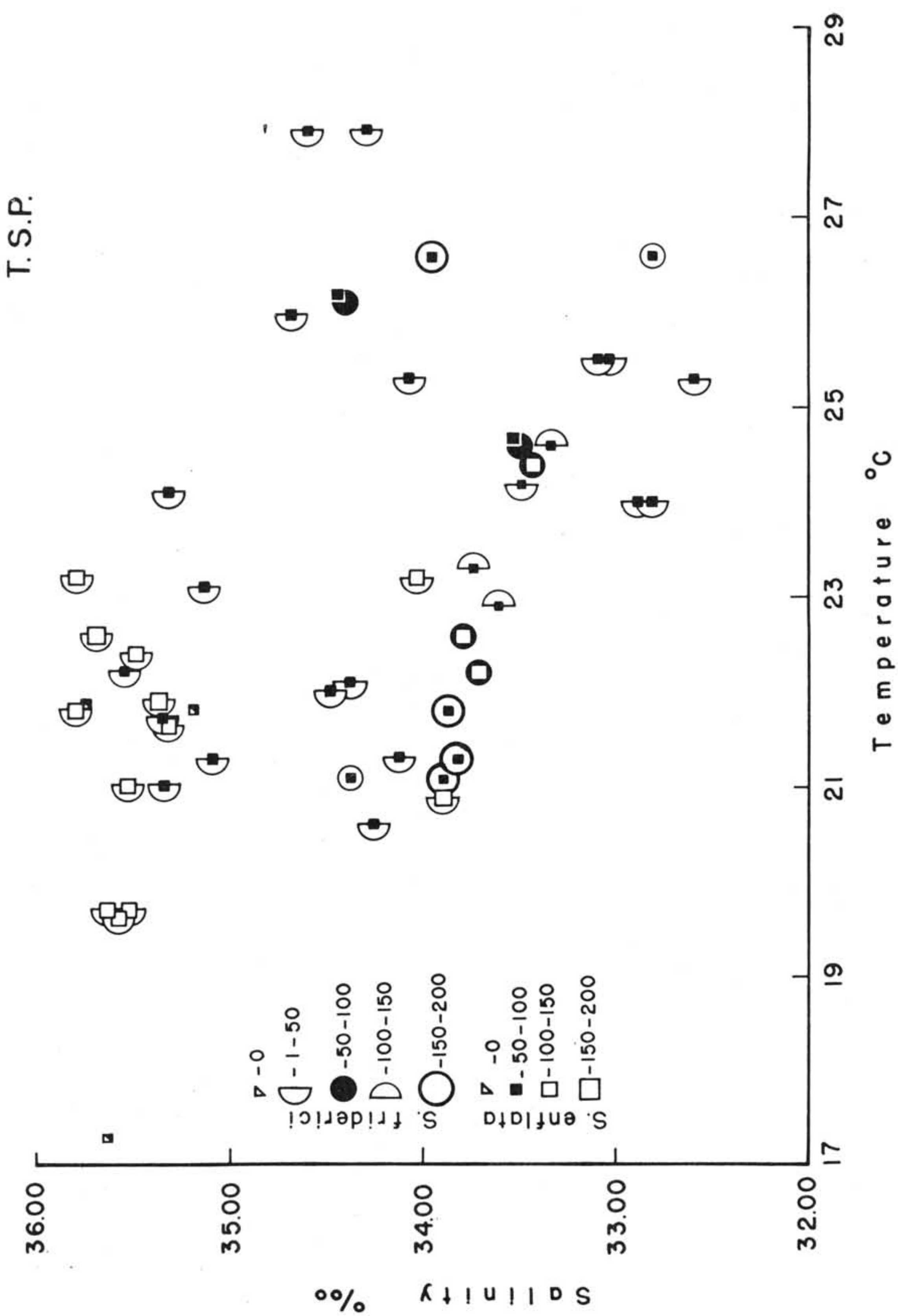

Fig. 2 — T-S-P diagram of *S. friderici* and *S. enflata*.

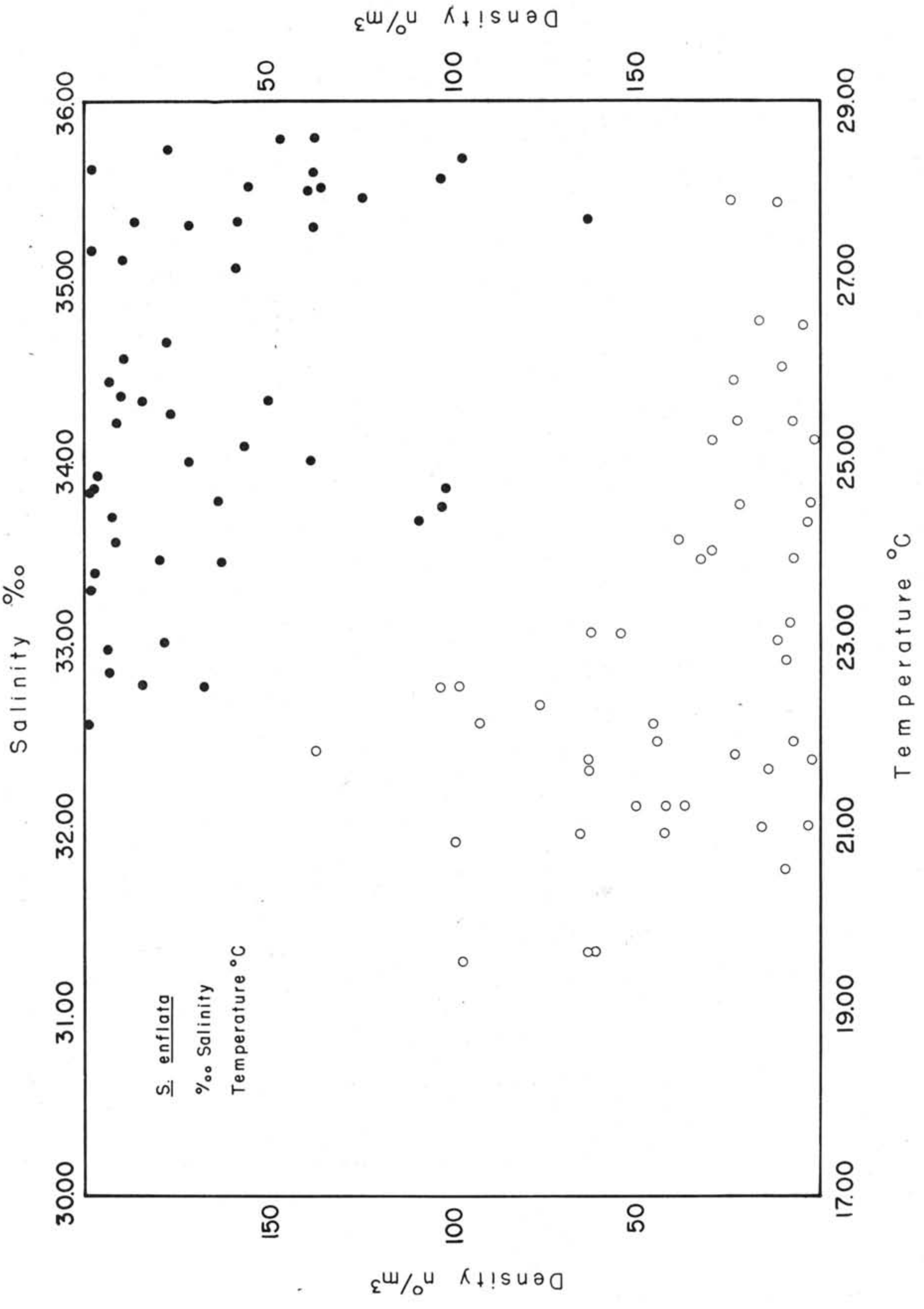

Fig. 3 — Density of *S. enflata* according to temperature and salinity.

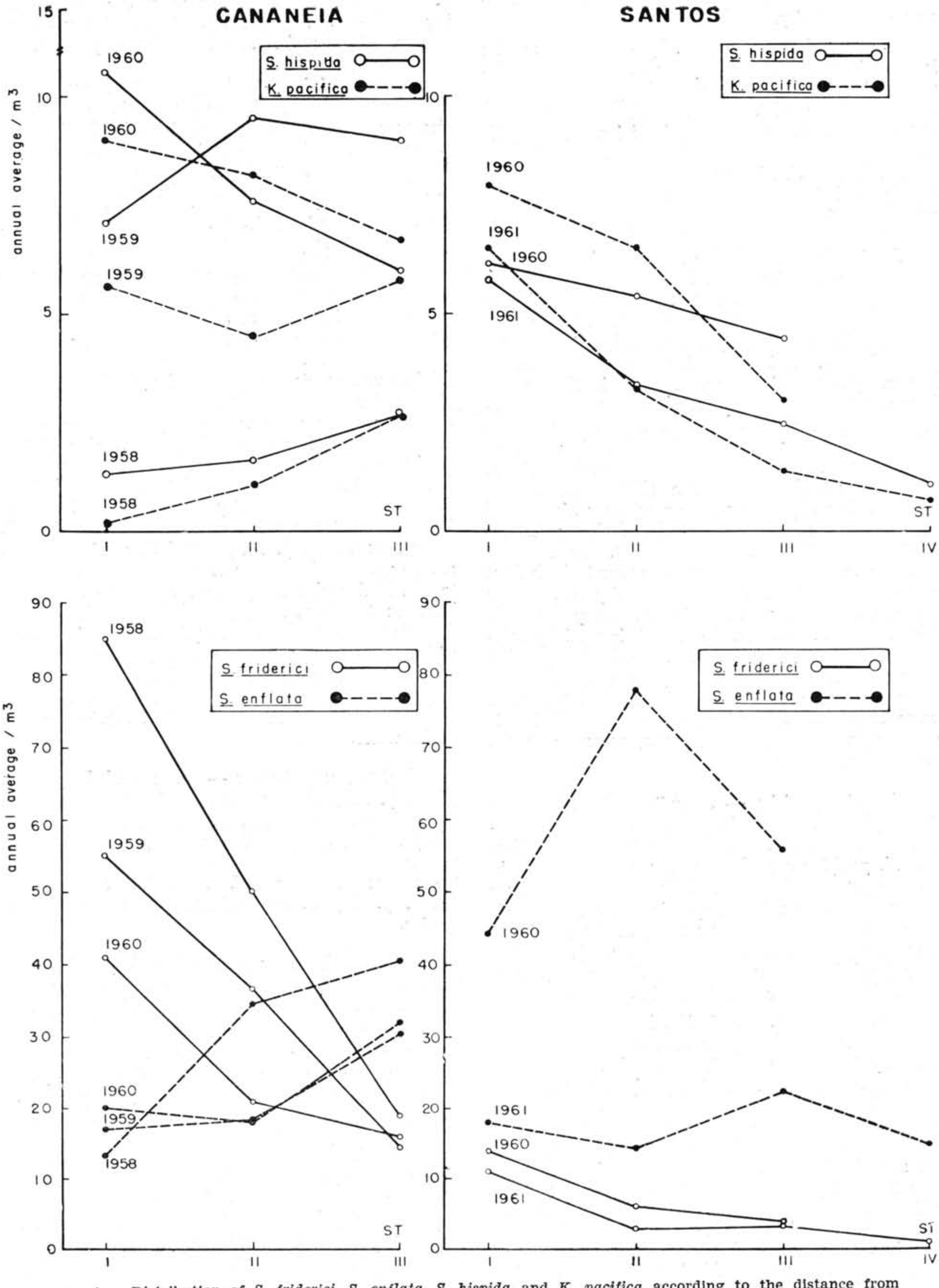

Fig. 4 — Distribution of *S. friderici*, *S. enflata*, *S. hispida* and *K. pacifica* according to the distance from the coast (Santos and Cananéia).

species. This fact suggests that there is another factor acting on its distribution which is neither temperature nor salinity.

The annual average of *S. hispida* per cubic meter is inconsistent in the three years of collection in Cananéia, but in Santos, it shows the general tendency to decrease from Pt. I to Pt. IV. Comparing the distribution of *S. enflata*, *S. friderici* and *S. hispida* according to the distance from the coast there is a suggestion that *S. hispida* endures a wider range of salinity and temperature as it does not show the regular distribution of the two other species (Fig. 4, Table II). The T-S-P diagram (Fig. 5 and 6) shows that *S. hispida* occurred more frequently in shelf water with salinity ranging from 35.00 to 36.00‰ and temperature from 20.00 to 22.00°C, but that it can successfully survive in coastal waters. Similar data were already recorded by ALMEIDA PRADO (1961 a, p. 25, fig. 8). It is interesting to observe (Fig. 5) that in spite of being more frequent in shelf water there are two samples taken in coastal water with salinity ranging from 33.00 to 34.40‰ and temperature from 25.00 to 27.00°C in which it was very abundant (19.6 and 16.8 number of specimens/m^3). These two samples were taken (March, 3 and 27, 1958) a few days after strong winds which could have caused a mixture of coastal and shelf water by pushing the latter towards the coast. In fact the thermal structure of the column of water in both days was homogeneous. The range of salinity recorded by SAINT-BON (1963, p. 313) in the Ivory Coast is from 33.00 to 34.48‰, therefore it is partially coincident with the present data. SAINT-BON (*op. cit.*) states that the temperature is not a very important factor in the distribution of this species, though it seems to prefer higher temperatures. *S. hispida* is a surface and diluted water species, according to the same author.

Krohnitta pacifica — Oceanic species in the tropical equatorial region in the three oceans (ALVARIÑO 1964 b, p. 70). "*S. bipunctata, S. serratodentata, K. pacifica* are also found more commonly in the Current (Florida) but their apparent tolerance for Coastal water raises a question concerning their value as indicator of recent mixing of the two kinds of water" (PIERCE & WASS 1962, p. 428). On the other hand SAINT-BON (1963, p. 333) attributes a semi-neritic character to this species.

This species, like *S. hispida*, has an inconsistent occurrence in the three-year collections at Cananéia especially in 1958 when it occurred very scarcely (Fig. 4, Table II). *Krohnitta pacifica* was already registered by ALMEIDA PRADO (1961 a, p. 32) in the western South Atlantic though it has not yet been possible to fix its ecological parameters. In the present material it does not show an oceanic preference since its density decreases from Pt. I towards Pt. III in Santos although the T-S-P diagram (Fig. 5 and 6) shows that *K. pacifica* was more frequent and abundant in shelf water and that it has a pattern of distribution similar to *S. hispida*. The highest frequency and abundance occurred in water of salinity ranging from 35.00 to 36.00‰ and temperature ranging from 21.00 to 23.00°C. SAIN-BON (1963, p. 332) found this species in water of salinity ranging between 33.64 and 35.46‰ and temperature between 22.00 and 29.40°C off the Ivory Coast.

Sagitta minima — According to FURNESTIN & RADIGUET (1964, p. 74) the distribution of this species ranges from 40°N to 40°S in the Atlantic, Pacific and Indian Oceans, and in the Red Sea and the Mediterranean. ALVARIÑO (1964 a, p. 344) recorded *S. minima* as a cosmopolitan and warm water species. OWRE (1960, p. 261) studying material from the Florida Current, states that its distribution off Miami shows that it is most abundant in the western edge of the Current, which flows over the outer part of the continental shelf and here also it was never found in typical coastal water. *S. minima* was represented by small number of specimens in a few samples of shelf water (Table II). This result was expected since *S. minima* was previously associated with shelf and tropical water (ALMEIDA PRADO 1961 a, p. 27) and the latter water mass was very seldom sampled in this collection. It was found also (*op. cit.*) that *S. minima* endures a small range of temperature from 18.00 to 21.00°C. It occurred in Santos and Cananéia in water with salinity ranging from 35.00 to 36.00‰ and temperature from 19.00 to 23.00°C. FURNESTIN (1957, p. 199) found *S. minima* in Moroccan water with a range of temperature from 15.80 to 20.40°C and salinity from 36.20 to 36.58‰. REYSSAC (1963, p. 263) recorded *S. minima* in the European Atlantic as an eurythermic species which withstands a range of temperature from 10.60 to 20.50°C and is a species of mixed coastal and oceanic water with salinity about 35.50‰. These data confirm our findings and show that *S. minima* prefers colder water.

Sagitta serratodentata — was recorded by OWRE (1960, p. 211) as an oceanic species, more abundant in open sea areas, than in coastal water. It is recorded by FRASER (1952, p. 8) as the commonest oceanic species in north European waters and found in all the oceans of the world. According to HEYDORN (1959, p. 12) *S. serratodentata* is a cosmopolitan species.

S. serratodentata was found mainly off Santos where the conditions, on the whole, are more oceanic than off Cananéia. It was represented by very few specimens (Table II) in water of salinity ranging from 35.00 to 36.00‰ and temperature ranging from 21.00 to 23.00°C. According to ALMEIDA PRADO (1961 a, p. 27, fig. 12) *S. serratodentata* is typical of the tropical water mass and only survives in shelf water. Therefore, I did not expect to collect it abundantly in these areas where the coastal and shelf water were predominant. PIERCE & WASS (1962, p. 412) remark that this species is noticeably absent in coastal water stations off Florida. In 1960 a few stray specimens of *S. serratodentata* occurred in Cananéia in rather low salinity. VANNUCCI (1962, p. 3) studying the zooplankton standing-stock off Cananéia during the period of three years (1958-1960) found that the 1960 curve has a quite different

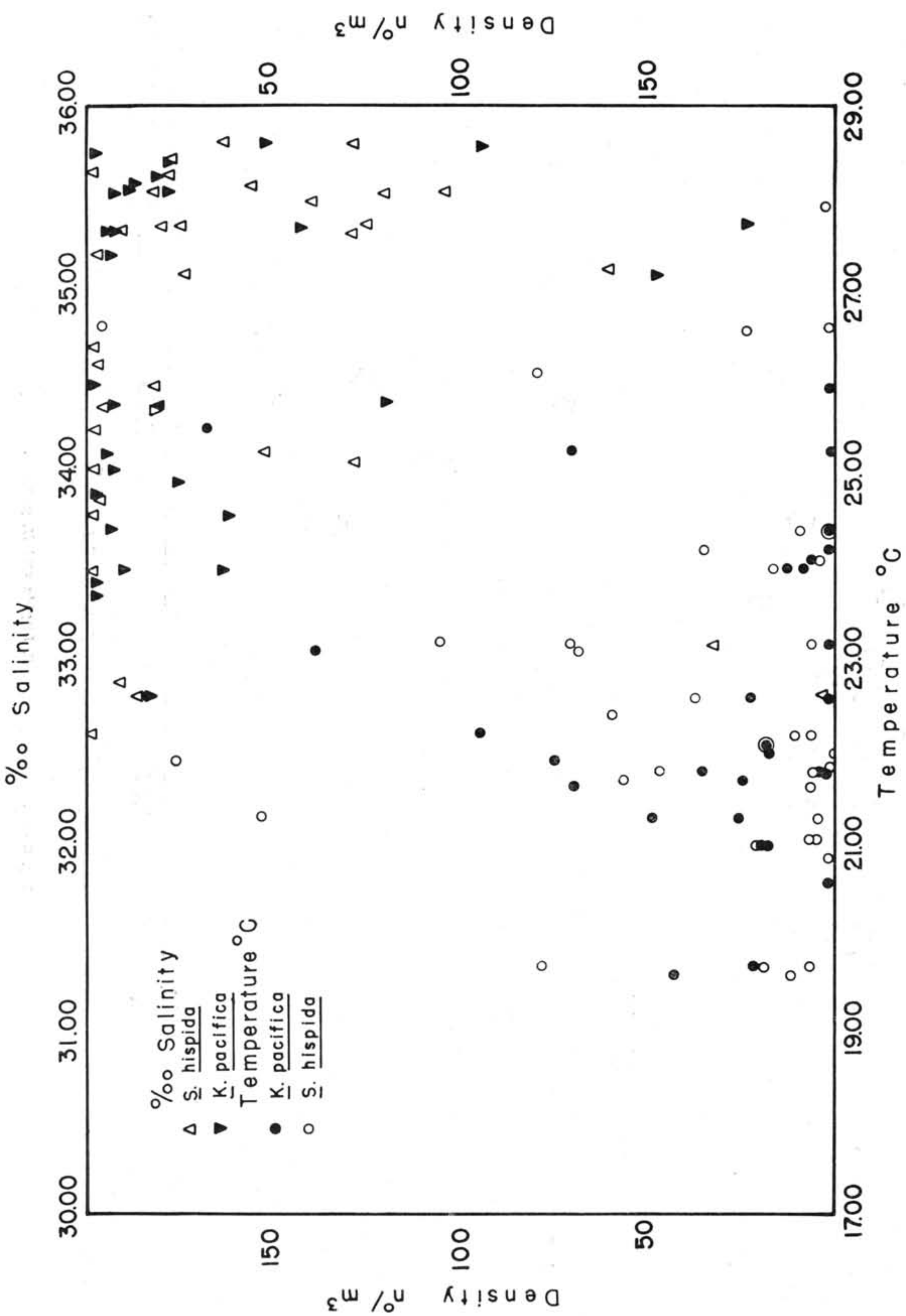

Fig. 5 — Density of *S. hispida* and *K. pacifica* according to temperature and salinity.

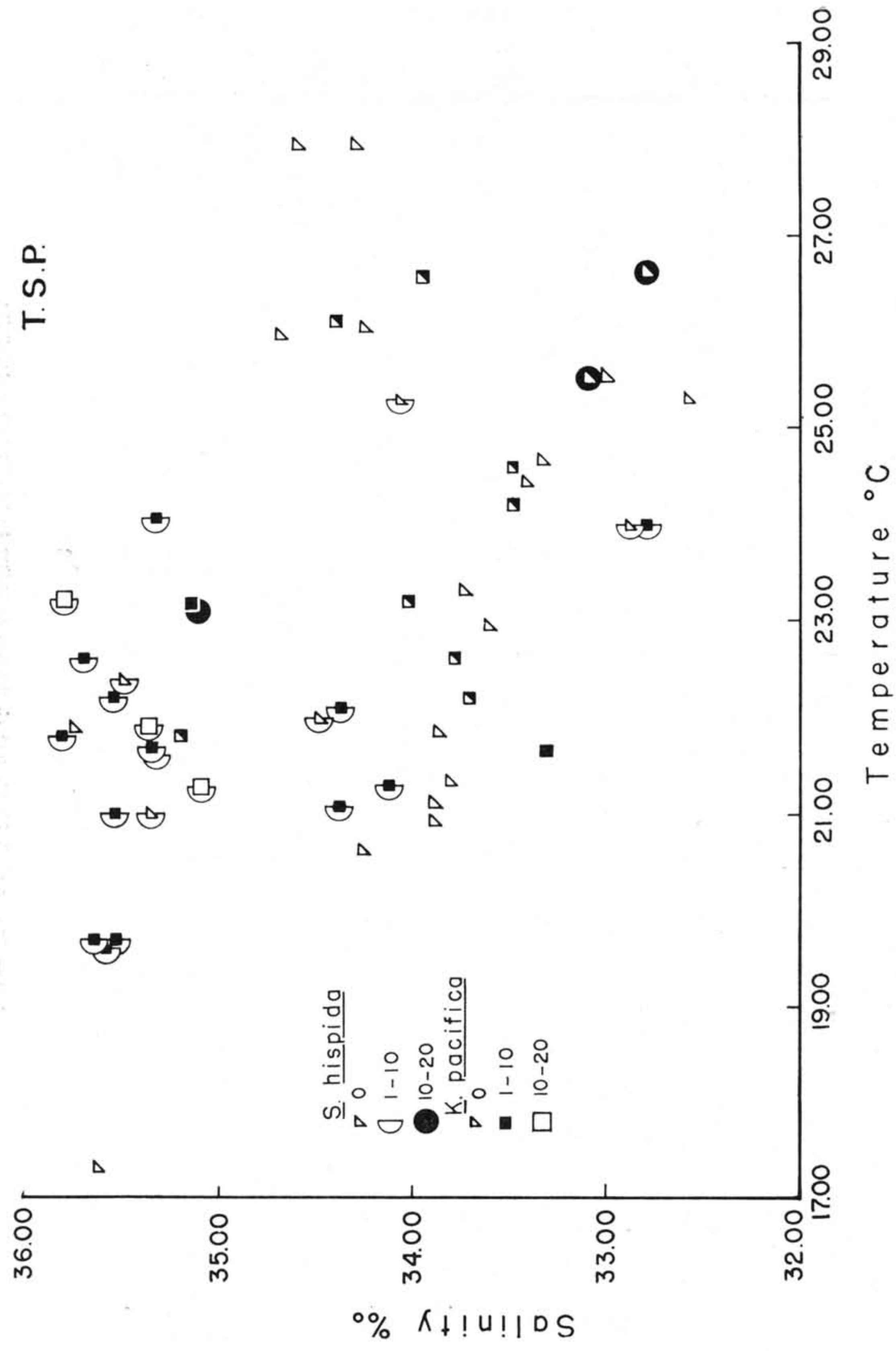

Fig. 6 — T-S-P diagram of *S. hispida* and *K. pacifica*.

pattern and a much lower mean value. She suggests that some different factors were present during that year which affected the annual distribution of zooplankton. The presence of *S. serratodentata* in this water mass may also be the result of the influence of different factors. *S. serratodentata* is associated with water of high salinity, although SAINT-BON (1963, p. 328) found it off the Ivory Coast in temperature ranging from 22.00 to 29.40°C and salinity ranging from 33.58 to 35.48‰ and explained the occurrence of this species in diluted water by a decrease of its halophyle character with the increase of temperature.

Pterosagitta draco — FURNESTIN (1957, p. 572) recorded this species as tropical and subtropical in the Atlantic, Indian and Pacific Oceans in the Red Sea and the Mediterranean. *Pterosagitta draco* was represented by a single specimen in three samples (Table II) in Pt. III off Cananéia and Santos during 1959 and 1960 in waters of salinity ranging from 34.41 to 36.60‰ and temperature ranging from 16.50 to 24.00°C. As recorded by ALMEIDA PRADO (1961 a, p. 31) this species is associated to tropical water, more abundant northward in higher temperature and therefore not expected in large numbers in these latitudes, in coastal and shelf water.

REYSSAC (1963, p. 271) found *P. draco* in water with temperature ranging from 18.00 to 24.00°C, more abundant at 23.20°C and salinity around 36.50‰. SAINT-BON (1963, p. 335) registered it in water of high temperature from 25.20 to 28.90°C and salinity lower than those already mentioned from 33.58 to 34.48‰.

REMARKS — The Chaetognatha in this area seem to be more tolerant to a wider variation of temperature than of salinity. The same was observed by VANNUCCI (1963, p. 180) for medusae from Cananéia: "As a whole these medusae are more temperature than salinity tolerant, this may be due to the samples coming from shallow water and thus the species present are those that are usually subjected to and adapted to relatively wide temperature changes". Among copepods there are some neritic species which have temperature as an important factor affecting their distribution, thus BJÖRNBERG (1963, p. 43-45) describes two neritic species, namely *Centropages furcatus* as thermophile occurring above 20.00°C and *C. branchiatus* as a cold water species occurring under 15.18°C. FORNERIS (1965, p. 87) studying the appendicularians in the western south Atlantic suggests that the physical properties analysed as temperature and salinity are less important for the explanation of their distribution than the knowledge of the history and biological dynamics of the water masses. She observed also that the majority of the appendicularian species found showed a strong eurythermy and euryhalinity. Apart from these specific relationships of each different group, BOGOROV (1958, p. 150) remarks that the temperature is a particularly important factor in subtropical and temperate seas, whereas the quantity of biogenic salts becomes more important in tropical areas.

VERTICAL DISTRIBUTION

An attempt is made here to establish the vertical distribution of the Chaetognatha in the area studied in order to obtain a clear picture of their distribution and migration besides their relationship to water masses. According to BOGOROV (1946-47, p. 30) it is impossible to assign any species or any age group to a definite water layer or to a definite physico-chemical conditions without a knowledge of the diurnal vertical migration of the particular group and so all the water layers in which the organisms dwell during the 24 hours must be considered as forming the ecological conditions characteristic of a given species. Many studies have been done on zooplankton vertical migration which should be mentioned, especially those which deal with Chaetognatha: MICHAEL (1911); HUNTSMAN & REID (1921); ROSE (1925); RUSSELL (1927, 1932-1933); CLARKE, BUMPUS and PIERCE (1943); BOGOROV (1946-1947, 1958); FURNESTIN (1957); OWRE (1960); LACROIX & MORISSET (1962). Most of them studied the problem from direct observation in nature but ROSE made some experiments on vertical migration in the laboratory.

This study is based on two series of samples taken at Pt. III (Table I). The first was taken when the thermal structure presented a marked thermocline and the second one, when the thermal structure was uniform. These two structures are respectively typical of summer and of winter (SOARES MOREIRA, in press). On April 8, 1960 there was shelf water and a mixture of shelf and subtropical water in the deeper layer where the temperature was markedly lower. On July 6, 1961, the shelf water was predominant but there was coastal water in the surface layer (Table III).

The Chaetognatha collected at Pt. III include seven species representing two genera: *Sagitta enflata, S. hispida, S. friderici, S. serratodentata, S. minima, Krohnitta pacifica* and *K. subtilis.*

TABLE III — Hydrographical data of the samples taken to study the vertical distribution of Chaetognatha

8-4-1960				6-7-1961			
Time	Depth/m	T°C	S ‰	Time	Depth/m	T°C	S‰
00.00	0	25.70	35.23	00.00	0	22.60	34.79
	25	16.60	35.49		25	22.36	35.34
	45	16.40	35.52		45	20.93	35.96
04.00	0	25.10	35.25	04.00	0	22.60	34.79
	25	16.50	35.52		25	22.50	35.35
	45	16.40	35.59		45	22.27	35.96
08.00	0	24.80	35.39	08.00	0	22.60	34.99
	25	17.90	35.91		25	22.34	35.41
	45	16.50	35.66		45	21.30	36.01
12.00	0	25.60	35.34	12.00	0	23.20	34.76
	25	16.70	35.58		25	22.42	35.81
	45	16.50	35.62		45	20.84	34.76
16.00	0	26.00	35.34	16.00	0	23.20	34.84
	25	17.10	35.66		25	22.41	35.31
	45	16.40	35.27		45	21.62	36.09
20.00	0	25.80	35.31	20.00	0	22.80	34.78
	25	17.10	35.61		25	22.15	35.32
	45	16.40	35.57		45	20.75	36.03

S. enflata and *S. hispida* were the most abundant species in this collection, as was expected, since both were shelf water indicators. These species will be treated in detail as they are abundant enough to give a good picture of their vertical distribution and vertical migration.

Sagitta enflata — was the most abundant species and occurred in all the samples but one, which was taken at 04:00 hours in the deeper layer (Table IV). The records indicate that it performs vertical migration although not very markedly. Figure 7 shows a general tendency of the *Sagitta enflata* population to sink at noon whether there is a thermocline or not, while the highest percentage of specimens stays at mid-water for the rest of the period during which the collection was made. As mentioned before *S. enflata* has its optimum temperature in the area between 21.00 to 23.00°C although it may survive in higher and lower temperatures. Thus thermocline is not a barrier to its vertical migration. In the summer hauls only 49 adult specimens were found in 2.882 counted. These adults occurred indifferently at the three depths in 6 samples. In the winter hauls only

TABLE IV — Density of each species at three different depths off Santos

Date	Time	Depth/m	Number of specimens per cubic meter						
			S.enfl.	S.frid.	S.hisp.	S.serrat	S.min.	K.pac.	K.subt.
8-4-1960	00.00	0	1.02	0.13	1.86	0.33	-	-	0.20
		25	7.22	-	0.53	0.46	0.13	-	0.02
		45	0.53	0.51	0.20	0.07	-	-	0.02
	04.00	0	2.80	0.06	2.86	0.62	0.02	-	1.04
		25	8.46	0.22	0.28	0.20	0.13	-	-
		45	0.86	0.06	0.17	0.42	0.02	-	-
	08.00	0	0.20	-	0.17	-	-	-	0.01
		25	3.75	0.08	0.17	0.06	0.02	-	-
		45	2.17	0.17	0.68	0.57	0.02	-	-
	12.00	0	1.42	0.08	3.42	0.62	-	-	0.24
		25	5.62	0.06	0.06	0.37	0.33	-	-
		45	8.86	0.77	1.33	4.40	-	-	0.02
	16.00	0	3.17	0.02	2.02	0.53	-	-	0.08
		25	4.60	0.02	0.40	0.28	0.06	-	-
		45	1.22	0.64	0.24	0.08	-	-	-
	20.00	0	5.68	0.42	5.77	1.60	-	-	0.13
		25	10.50	0.33	0.17	0.37	0.06	-	-
		45	1.00	0.08	0.02	0.33	0.17	-	-
6-7-1961	00.00	0	0.86	0.02	0.68	0.80	-	0.17	0.02
		25	1.64	-	0.22	0.08	0.11	0.80	0.08
		45	1.00	0.04	0.04	0.15	0.17	0.04	-
	04.00	0	0.35	-	0.15	0.04	-	0.26	0.06
		25	0.62	-	0.20	0.11	0.06	0.33	-
		45	-	0.66	0.04	0.15	0.64	0.02	-
	08.00	0	0.26	-	0.37	0.02	-	0.51	-
		25	0.37	-	0.02	0.02	0.06	0.29	-
		45	0.25	-	0.04	0.08	0.04	0.02	-
	12.00	0	1.20	0.08	2.62	0.20	-	0.42	0.20
		25	2.71	0.04	0.02	0.20	0.06	1.87	0.04
		45	2.91	-	0.04	0.15	0.13	0.13	-
	16.00	0	0.66	0.08	0.24	0.60	-	0.86	0.02
		25	1.33	0.08	0.08	0.33	0.02	1.02	0.02
		45	2.82	0.02	0.06	0.20	-	0.06	-
	20.00	0	2.75	1.00	1.82	2.37	-	1.04	-
		25	0.97	0.15	0.08	-	0.02	0.42	0.04
		45	0.88	0.04	0.08	0.06	0.04	0.31	-

6 adults occurred in 1.018 counted, in one samples taken at noon at 45 m depth. In the summer collection the adults represented 1.70% of the total specimens and in the winter they represented only 0.58% of the total specimens.

FURNESTIN (1957, p. 221) says that *S. enflata* is an epiplanktonic species as it was caught very frequently off Morocco in diurnal hauls in surface layers. *S. enflata* seemed to be concentrated in the mid-water off Santos. However this area is considerably shallower than that studied by FURNESTIN. OWRE (1960, p. 278) studying the vertical migration of *S. enflata* over deeper areas than the present, found that most animals occurred in the upper 200 m and that its vertical distribution during a 24 hour-period clearly indicated diurnal migration.

Sagitta friderici — as a typical coastal water species was sparingly represented in these samples therefore it did not provide enough data to give an idea of its vertical distribution and migration (Table IV). The presence of some larger specimens of *S. friderici* was noticeable because they were not found before in this area. They occurred twice at 45 m depth, at midnight in cold water below the thermocline. An attempt was made to measure them but they were too badly preserved to take accurate measurement so only a comparison between the two lots was made and it was observed that they were visibly larger than the specimens usually found in this part of the Atlantic. The biggest size registered for this species in the southern western Atlantic is 8.5 mm (VANNUCCI & HOSOE 1952, p. 14; ALMEIDA PRADO 1961 b, p. 33). There is no doubt about the classification of the largest specimens since the adults, in spite of the difference in size, have exactly the same specific characters as the smaller specimens (ALMEIDA PRADO 1961 b, p. 33).

Sagitta hispida — occurred in all samples and showed a tendency to concentrate in the surface layer above 25 m even during the hours of more intense illumination. Migration to deeper layers was observed only once at 08:00 hours when the thermocline was absent (Fig. 8, Table IV) and then the migration was more marked than that performed by *S. enflata* at noon. This fact can be interpreted to a certain extent as a more restricted eurythermy of *S. hispida*. The vertical distribution of *S. hispida* in the Florida Current was irregular, the population was concentrated in the upper 200 m, and there is no information on the diurnal migration of this species according to OWRE (1960). Here only 33 adults were found in 1.288 specimens counted in the first series of samples, they occurred in five samples taken in the upper 25 m. In the second series only 7 adults were found in two surface hauls, in 313 specimens counted. In the summer collection the adults represented 2.69% and in the winter collection, 2.20% of the total specimens counted.

S. serratodentata and *S. minima* — were never abundant at the collecting point as they are indicators of tropical water. The highest density of *S. serra-*

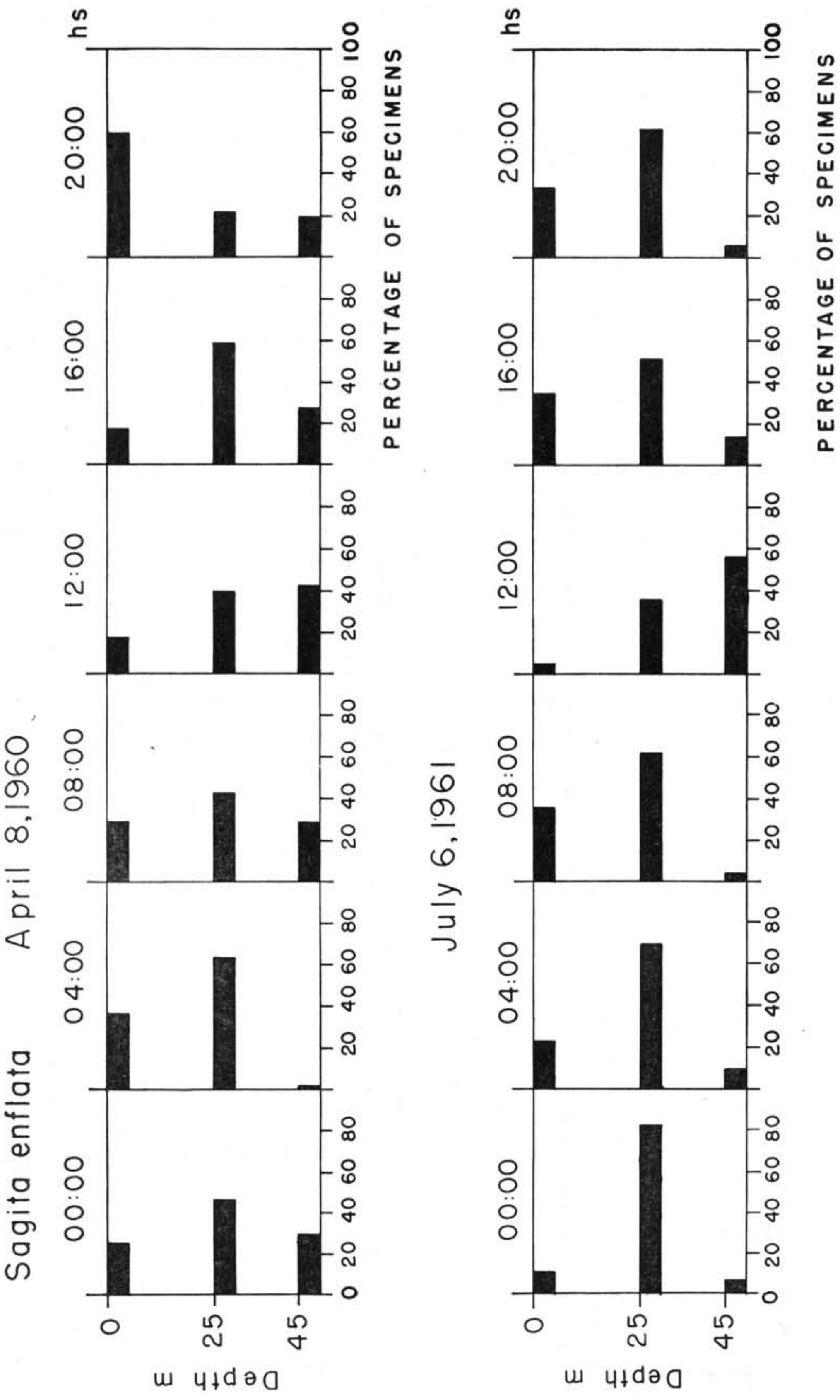

Fig. 7 — Vertical distribution of *S. enflata* off Santos.

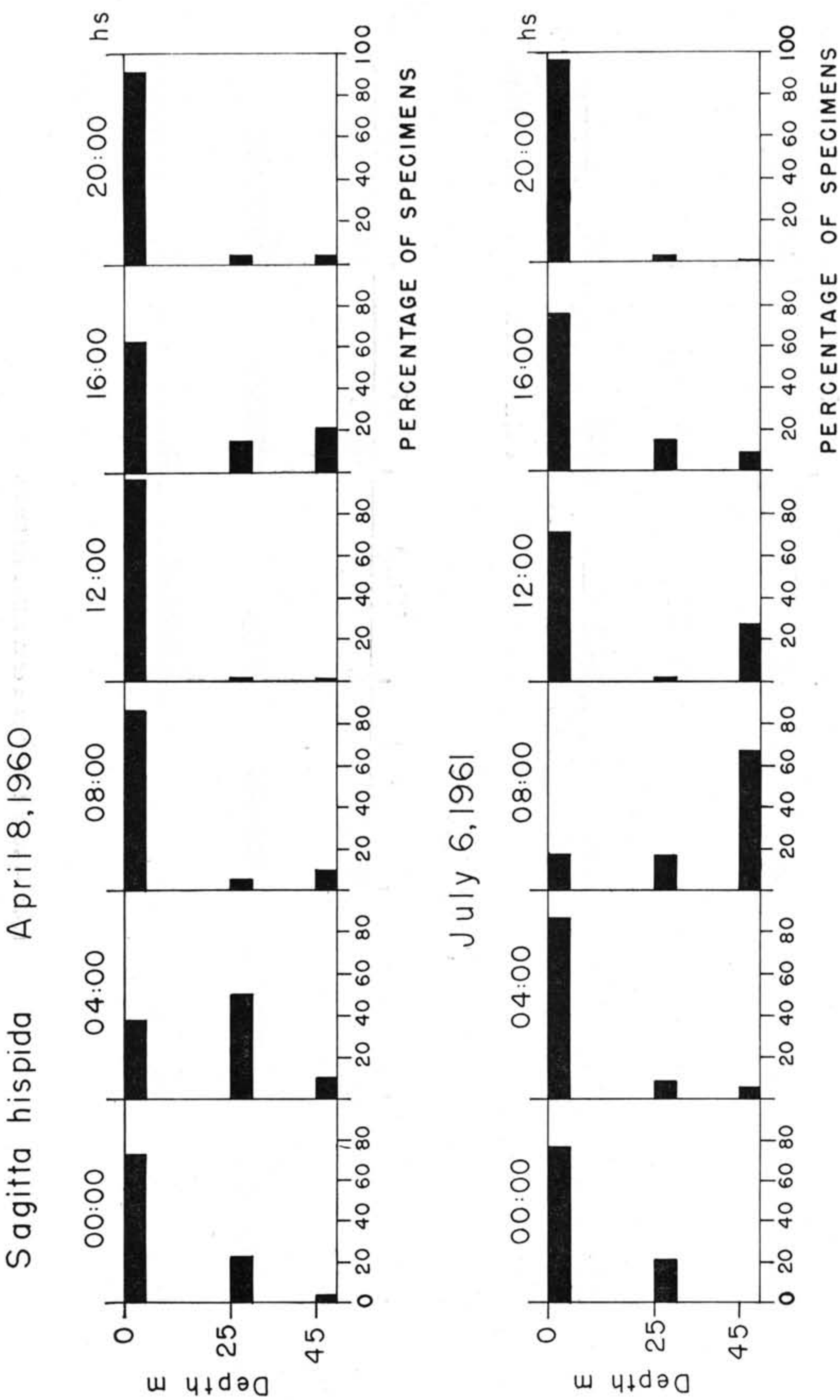

Fig. 8 — Vertical distribution of *S. hispida* off Santos.

todentata was found below the thermocline at 45 m depth at midday. On the other hand an homogeneous vertical distribution in the second series of samples which was taken in a column of water with a uniform thermal structure was observed (Table IV). FURNESTIN (1957, p. 163-164) studying plankton from the surface layer off Morocco and Mediterranean found that *S. serratodentata* was always more frequent and abundant in the nocturnal hauls. OWRE (1960, p. 283) records a definite diurnal migration of *S. serratodentata* in the Florida Current. She found that a large night surface population remained at the surface well into the morning, on the eastern side of the Current and although the majority retreated at midday a small number remained there all the time. MICHAEL (1911, p. 150) studying the Chaetognatha of the San Diego region states that *S. serratodentata* is a mesoplanktonic species for which optimum conditions are found between 100 and 200 fathoms and that it migrates toward the surface when twilight is very subdued, but rarely ascends above 10 fathoms.

Sagitta minima — was represented by few specimens in these two series of samples. It appeared only once in the surface layer at 04:00 hours where the salinity was always under 35.50‰ and the temperature higher than 22.00°C (Table IV). ALMEIDA PRADO (1961 a, p. 27) records the highest frequency of *S. minima* in waters of salinity ranging from 35.00 to 35.50‰ and temperature from 18.00 to 22.00°C. Although there are insufficient data to determine its vertical distribution, its constant absence in the surface layer suggests that this species lives in deeper waters than those mentioned. In fact FURNESTIN (1957, p. 198) considers *S. minima* a mesoplanktonic species and says that the predominance of this species in nocturnal hauls off Madeira indicates diurnal vertical migration. OWRE (1960, p. 285) records *S. minima* usually between 100 and 200 m and ocasionally in the upper 100 m, though he had no data on diurnal migration.

Krohnitta pacifica — occurred only in the second series in a sample taken when the thermal structure was homogeneous (Table IV). It was mentioned before that this species has inconsistent distribution during the three-year collection at Cananéia and that there are unknown factors affecting its distribution. It may need a mixture of water masses to survive well as suggested by its occurrence when the surface and deeper water masses were mixed and there was no thermocline (Fig. 9). At noon the lowest percentage of *K. pacifica* was recorded in the surface layer and the highest at 45 m depth and during the rest of the period of 24 hours the population remained in the upper 25 m. Although these data are insufficient to come to a definite conclusion there are indications that *K. pacifica* performs vertical migration. OWRE (1960, p. 288) records that most of the population is found in the upper 250 m at night and that it migrates below 250 m in daytime.

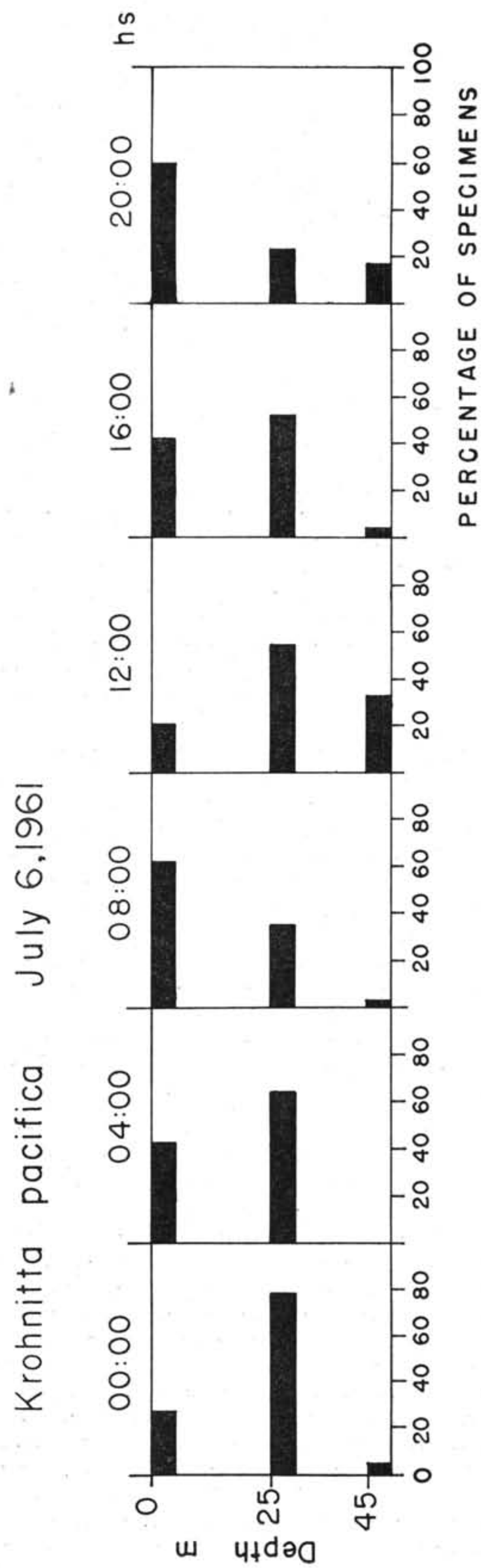

Fig. 9 — Vertical distribution of *K. pacifica* off Santos.

Krohnitta subtilis — though not abundant its occurrence was noted as it was never found in SANTOS during the two-year collection 1960-1961. *K. subtilis* was already registered off Ilha da Trindade (South western Atlantic) by VANNUCCI & HOSOE (1952, p. 24). The present data are insufficient to suggest any preference of water mass or to indicate vertical migration (Table IV). OWRE (1960, p. 286) reports that it frequently occurred below 200 m in the Florida Current and found also evidence indicating slight diurnal migration.

REMARKS — Although a differential vertical distribution of the different developmental stages was not found here, due to the scarcity of fully sexually developed specimens, there are many indications in other regions, especially in cold waters, that adult planktonic specimens live in deeper layers and younger specimens in the upper layers. In the Bay of Fundy and Gulf of St. Lawrence the adults are confined to lower levels during the breeding season but the eggs were found near the surface (HUNTSMAN & REID 1921, p. 108). With increasing age the species becomes gradually restricted to the darker and colder water which is deeper (HUNTSMAN 1919, p. 465). Off Plymouth young specimens may have a different vertical distribution from the adults (RUSSELL 1927, p. 239), younger *S. elegans* and *S. setosa* have a tendency to remain nearer the surface than the older ones (RUSSELL 1932-33, p. 561). The highest abundance of the largest specimens of *S. elegans* are found in the deeper layer during daylight and in intermediate layer at midnight (LACROIX & MORISSET 1962, p. 36) so that it was inferred that they perform vertical migration but never up to the surface. The area here studied and the Florida Current are similar when data are compared to those already cited (RUSSELL 1927, 1932-33; HUNTSMAN, 1919; HUNTSMAN & REID, 1921; LACROIX & MORISSET, 1962). Therefore our results cannot be compared to Owre's as the frequency of young specimens in Santos is remarkably higher than that of the adults. OWRE (1960, p. 313) did not find a special concentration of small juveniles in the surface layer even at a time when spawning appeared to have been intense.

According to CLARKE, PIERCE & BUMPUS (1943, p. 211) the vertical distribution of *Sagitta* depends on the seasons and is correlated to size and stage of maturity. The two series of samples do not show a special behaviour of the total population of Chaetognatha, characteristic of summer or of winter. Yet *S. enflata* the most representative species showed a similar pattern of vertical distribution on both occasions. Based on records obtained from Santos and Cananéia (Pt. I, II, III and IV) an appreciable variation between summer and winter was not to be expected. It seems that the thermocline is not a barrier to the vertical migrations of most Chaetognatha in the area considered. This fact can be explained to some extent as due to the eurythermy of the species of Chaetognatha found here specially: *S. enflata, K. pacifica.* SOARES MOREIRA (in press) studied the vertical migration of Hydromedusae from the same material and found that *Ectopleura dumortieri, Turritopsis nutricula, Cyteis tetrastyla, Proboscidactyla ornata* and *Aglaura hemistoma* did not migrate through the thermocline and explains that in spite of their wide spectrum of eurythermy they appear not to be able to stand sudden variation of temperature. SOARES MOREIRA (1965, p. 247-248) mentions that the thermocline does not act as a barrier for the following species: *Euphysora gracilis, Liriope tetraphylla, Cunina octonaria.* According to VANNUCCI (1963, p. 155) *Euphysora gracilis* is an indicator of shelf water so that it is interesting to observe that it behaves in the same way as *S. enflata* which is also an indicator of shelf water.

OCCURRENCE OF THE DEVELOPMENTAL STAGES

It is known that the zooplankton in higher latitudes has a marked seasonal variation and that in the equatorial and tropical regions this variation is only slight throughout the year. According to BOGOROV (1958, p. 155) seasonal variations are probably less marked in the tropical region, with its relatively insignificant climatic changes. This statement refers especially to surface layer which is more affected by seasonal changes. One of the purpose of this paper is to determine whether there is an annual variation of Chaetognatha in the present area. For these purpose three different developmental stages were considered in the collections of samples studied.

Three stages were established as follows: juvenile (completely without gonads), intermediate (gonads and seminal vesicles in development) and adult (completely full or emptied seminal vesicles) in order to simplify the nomenclature. The criteria for classification of maturity stages suggested by previous authors (RUSSELL, 1932-33, KRAMP, 1917, 1939, *in* ALVARIÑO, 1965; OWRE, 1960; GHIRARDELLI, 1960 and DUCRET, 1960) are not followed here for the difficulty of recognizing at first sight the different intermediate developmental stages of the gonads in the large number of specimens to be counted.

The data obtained here show that the variation in number of organisms is not directly affected by the different seasons of the year as great swarms of young specimens were commonly found all year round. Thus the slight changes due to the different seasons do not determine an annual rhythm in the quantitative variation (Fig. 10 and 11) and of the life cycles of all species in this region. The frequency of adults was noticeably small in relation to the juveniles and even to the intermediate stage specimens (Table V and VI). The scarcity of adults may be due to the sampling, as the number of adults found was never sufficient enough to produce such high frequency of juveniles, and also, to a smaller extent, due to mortality. Data from other places show that adults can occur in equal or higher frequency than juveniles. A higher number of large fully mature specimens of *S. serratodentata* were found from April to July in the Atlantic southwest of the British Isles and in August and September the large specimens occurred to the west of Ireland (BAINBRIDGE 1963, p. 46). Also the dis-

TABLE V — Occurrence of maturity stages of *S. friderici* off Santos and Cananéia throughout the year.

Locality	Year	Month	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
		Stage \ Station	I	III	I	III	I	III	I	III	I	III	I	III	I	III	I	III	I	III	I	III	I	III	I	III
CANANEIA	1958	juvenile	59.0	85.5	51.5	80.3	60.9	71.1	49.9	76.7	38.3	59.4	79.1	67.4	66.0	71.7	—	—	97.3	70.6	75.2	85.2	66.6	74.7	43.7	64.8
		interm.	39.5	14.5	22.2	19.0	38.3	28.0	49.9	18.6	61.6	40.5	20.7	24.6	33.6	19.4	—	—	2.6	23.9	24.4	13.1	32.6	24.0	56.0	34.9
		adult	1.5	0.0	26.3	0.7	0.7	0.8	0.2	4.6	0.0	0.0	0.2	8.0	0.3	8.9	—	—	0.0	5.4	0.4	1.6	0.8	1.2	0.3	0.2
	1959	juvenile	72.9	77.6	51.7	87.6	19.5	68.4	—	—	35.9	19.0	53.7	84.8	63.7	70.0	57.5	95.8	91.3	70.8	86.9	81.5	32.7	69.1	57.9	62.0
		interm.	27.1	21.8	47.6	12.4	80.4	31.5	—	—	60.1	66.6	44.6	15.2	33.7	29.2	40.7	4.2	8.7	27.0	12.3	17.0	67.2	30.6	42.1	38.0
		adult	0.0	0.6	0.6	0.0	0.1	0.0	—	—	3.9	14.3	1.7	0.0	2.6	0.8	1.7	0.0	0.0	2.2	0.8	1.4	0.0	0.3	0.0	0.0
	1960	juvenile	45.6	46.7	57.2	67.5	75.0	100.0	30.7	79.3	40.7	55.5	55.6	63.1	84.7	57.8	0.0	89.7	97.9	90.1	78.7	76.3	58.9	38.9	67.3	76.2
		interm.	54.4	53.2	42.8	32.5	24.1	0.0	68.4	20.7	59.3	41.1	44.1	36.2	15.2	37.0	0.0	10.3	2.0	9.9	21.3	23.3	41.0	61.1	32.7	23.8
		adult	0.0	0.0	0.0	0.0	0.9	0.0	0.8	0.0	0.0	3.3	0.2	0.6	0.0	5.1	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
SANTOS	1960	juvenile	—	—	61.1	86.9	70.5	55.7	75.4	57.8	49.8	54.1	76.8	84.5	49.9	90.5	63.1	60.7	70.0	65.7	57.7	65.2	34.7	70.4	47.3	79.5
		interm.	—	—	35.5	13.0	29.4	43.6	24.6	41.9	48.8	43.5	21.6	15.5	39.0	9.4	36.0	39.2	29.9	34.3	42.3	33.3	65.3	27.1	52.7	20.4
		adult	—	—	3.4	0.0	0.0	0.7	0.0	0.3	1.3	2.4	1.6	0.0	11.1	0.0	0.8	0.0	0.0	0.0	0.0	1.4	0.0	2.4	0.0	0.0
	1961	juvenile	70.8	72.4	42.2	66.7	79.3	89.1	—	—	37.2	95.0	38.1	89.6	72.2	50.0	48.8	91.7	43.6	50.0	51.9	73.3	33.5	36.5	45.5	29.2
		interm.	29.2	27.6	57.5	33.3	20.7	10.7	—	—	62.4	5.0	51.4	10.4	27.8	50.0	51.2	8.3	56.3	50.0	47.7	26.7	64.3	52.8	52.7	68.9
		adult	0.0	0.0	0.3	0.0	0.0	0.1	—	—	0.4	0.0	10.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	2.2	10.6	1.8	1.9

TABLE VI — Occurrence of maturity stages of *S. enflata* off Santos and Cananéia throughout the year.

Locality	Year	Month / Station / Stage	Jan. I	Jan. III	Feb. I	Feb. III	Mar. I	Mar. III	Apr. I	Apr. III	May I	May III	Jun. I	Jun. III	Jul. I	Jul. III	Aug. I	Aug. III	Sep. I	Sep. III	Oct. I	Oct. III	Nov. I	Nov. III	Dec. I	Dec. III
CANANÉIA	1958	juvenile	96.9	33.3	91.2	55.6	70.6	61.2	65.5	69.8	33.3	70.8	78.2	82.7	100.0	82.6	---	---	84.5	58.3	94.2	74.9	60.1	73.7	76.7	80.0
		interm.	3.1	66.6	8.8	37.9	10.3	23.7	26.2	25.2	66.6	26.1	21.8	12.5	0.0	14.9	---	---	13.6	25.2	4.9	22.0	33.6	21.0	22.4	17.9
		adult	0.0	0.0	0.0	6.4	19.0	15.1	8.3	5.0	0.0	3.1	0.0	4.7	0.0	2.5	---	---	1.9	16.4	0.9	3.1	6.2	5.2	0.8	2.0
	1959	juvenile	76.1	75.6	77.5	72.1	71.9	69.7	---	---	68.8	72.5	77.3	80.0	45.9	69.1	94.2	77.9	84.6	36.4	58.9	72.8	74.4	72.0	87.5	55.5
		interm.	21.5	21.9	22.1	27.1	26.6	28.2	---	---	29.9	26.5	22.0	16.7	4.9	23.4	5.6	21.6	15.4	61.4	40.0	26.0	24.2	27.1	12.5	42.0
		adult	2.4	2.4	0.3	0.8	1.5	2.0	---	---	1.3	1.0	0.6	3.2	49.2	7.5	0.2	0.5	0.0	2.2	1.1	1.1	1.3	0.9	0.0	2.4
	1960	juvenile	76.4	71.2	52.5	74.8	82.7	46.1	61.3	70.0	84.7	73.5	89.4	82.1	95.7	87.5	1.2	88.2	100.0	83.1	100.0	79.0	93.7	88.2	60.9	87.5
		interm.	20.5	27.4	47.3	24.5	17.2	53.8	38.4	29.6	13.5	25.9	10.5	16.9	4.3	11.8	68.9	11.8	0.0	15.3	0.0	17.8	6.2	11.1	39.0	12.5
		adult	3.1	1.4	0.2	0.6	0.0	0.0	0.3	0.3	1.7	0.5	0.0	0.9	0.0	0.7	29.9	0.0	0.0	1.6	0.0	3.1	0.0	0.6	0.0	0.0
SANTOS	1960	juvenile	---	---	84.0	81.7	68.2	52.2	69.9	64.4	72.2	74.3	92.6	91.5	82.2	63.4	79.9	83.7	84.4	88.7	81.9	68.8	90.5	69.4	83.9	62.7
		interm.	---	---	15.8	16.9	31.4	47.8	28.9	32.9	26.5	25.3	7.2	8.1	15.9	31.4	19.3	16.1	15.4	10.9	18.1	30.7	9.4	28.8	16.1	37.2
		adult	---	---	0.2	1.4	0.3	0.0	1.2	2.7	1.3	0.3	0.1	0.4	1.9	5.1	0.8	0.1	0.2	0.4	0.0	0.5	0.1	1.8	0.0	0.1
	1961	juvenile	61.6	84.9	76.5	49.2	76.5	84.5	---	---	85.3	81.1	52.1	89.2	80.6	93.1	62.6	95.7	75.0	96.5	74.5	76.2	81.5	51.7	70.4	37.7
		interm.	38.0	14.8	22.0	49.9	22.8	14.7	---	---	14.5	18.9	44.2	10.8	19.4	6.9	37.4	4.3	25.0	3.8	25.0	23.7	18.5	45.7	29.6	60.2
		adult	0.3	0.3	1.5	0.9	0.7	0.8	---	---	0.2	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	2.6	0.0	2.1

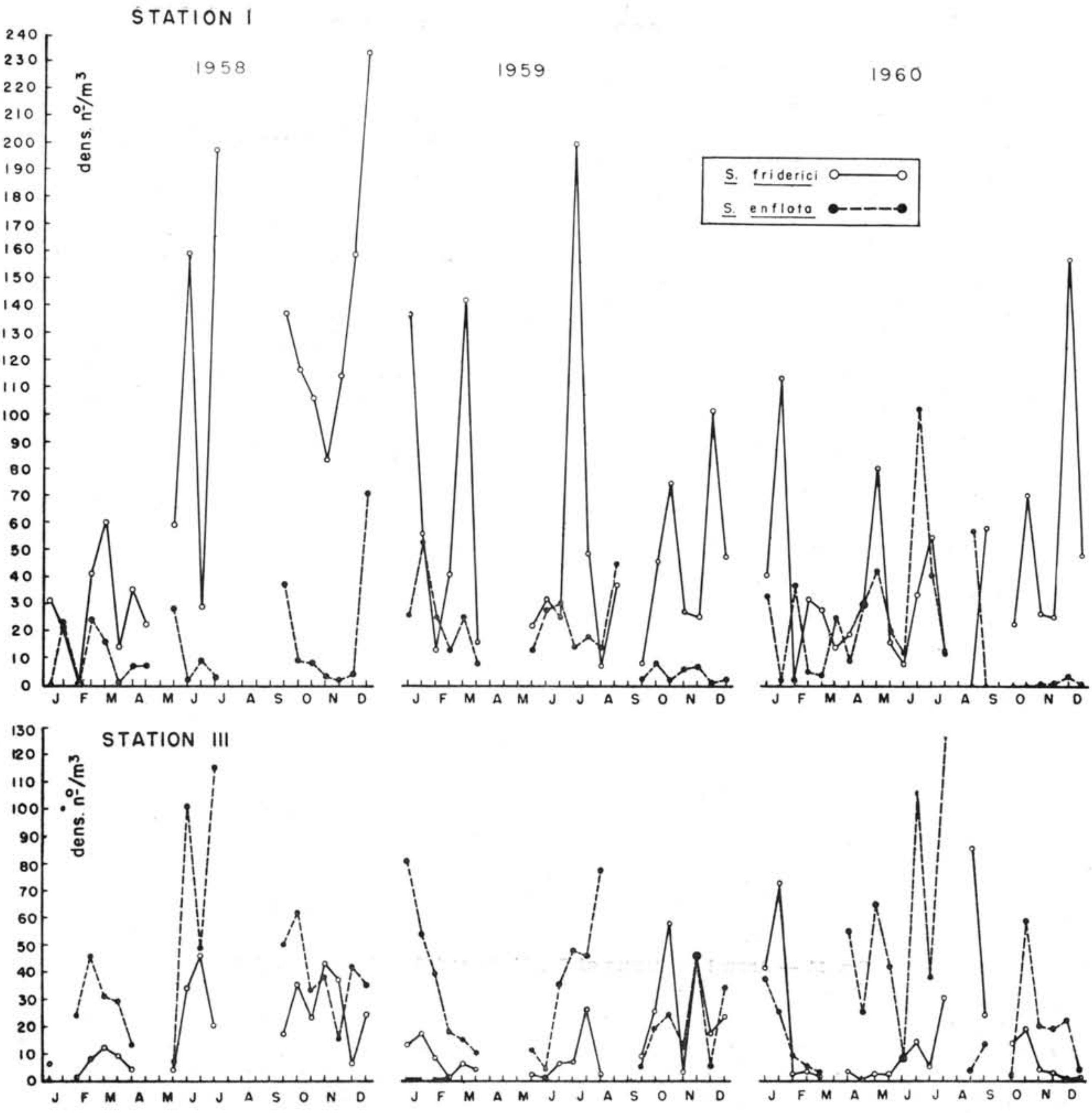

Fig. 10 — Annual occurrence of *S. friderici* and *S. enflata* off Cananéia.

tribution of small specimens followed slightly behind that of the larger individuals in each area. This fact could be interpreted as an effect of the marked seasonal variation in the area studied by BAINBRIDGE but the data recorded by FURNESTIN (1957) off Morocco show that adult specimens of *Sagitta* occur sometimes in higher frequency than juveniles. *S. friderici* (*op. cit.*, p. 144) breeds there throughout the year and the population in the surface water is almost composed only by adult specimens in stage III and the population of *S. minima* (*op. cit.*, p. 200) is composed by specimens in stages I, II and III. The latter stage is the most abundant. The scarcity of adults here may be due to sampling, because they live in more oceanic areas or very close to the bottom in the deeper layer where the net does not catch or also because the adults avoid the net. In fact in the annual series of collections the net was towed vertically leaving the deeper 4 or 5 m without sampling and among the samples taken on April 8, 1960 and July 6, 1961 the deepest tow was made horizontally 5 m above the bottom. As these collections were made above small depth, in not more than 60 m depth, it may be possible that the large specimens concentrate in a narrow layer above the bottom. There are also many indications in the literature that mature specimens of Chaetognatha go to deeper layers during their breeding periods. DAVID (1955, p. 242) observed that mature specimens of *S. gazellae* are rare in his collections due to the breeding migration to deeper water.

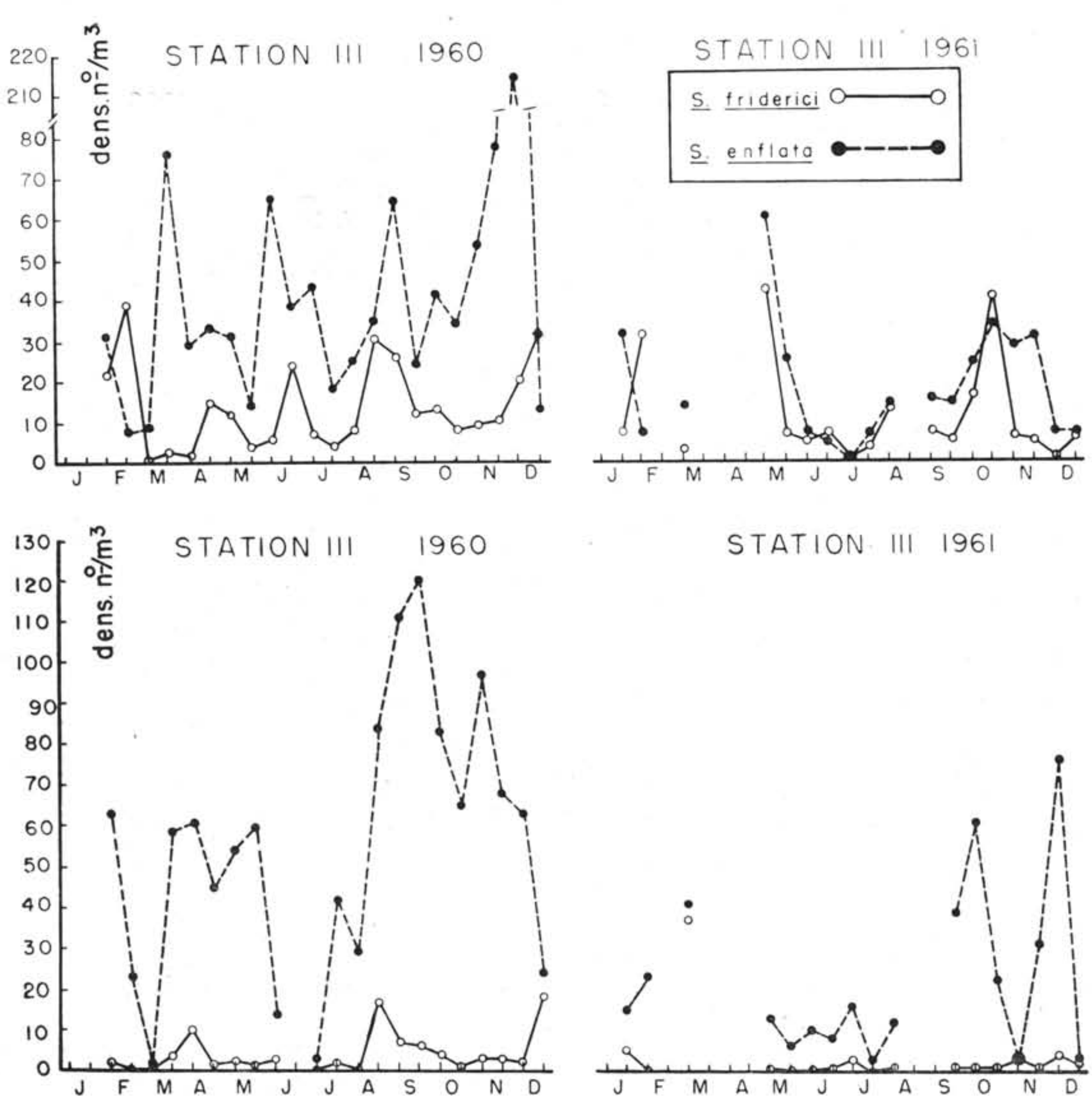

Fig. 11 — Annual occurrence of *S. friderici* and *S. enflata* off Santos.

As the whole population was not equally sampled it is not possible to make a definite statement about it. However the data is sufficient enough to state that the population of young Chaetognatha is steady since it shows only slight fluctuation throughout the year in this area but maintains a high frequency.

Russell (1932-33) studying *S. elegans* and *S. setosa* off Plymouth found four and probably five broods for the first species (*op. cit.*, p. 135) and at least six broods for the second species (*op. cit.*, p. 149) throughout the year. The mature specimens of *S. gazellae* are found only in deeper water in the Southern Ocean and therefore the eggs are laid also in a deeper layer and later on the young specimens rise to the surface (David 1955, p. 273-274). *S. gazellae* (*op. cit.*) has a long breeding period during the spring, autumn and to a small extent in the winter. Work on the seasonal variation of Chaetognatha was done in the Florida Current (Owre, 1960) and the general conclusion was that the specimens may mature at a smaller size in warm than in cold water, and that specimens breed to some extent throughout the year and spawn more than once a year (*op. cit.*, p. 316). *K. pacifica* has no special breeding season during the year in the region of the West Indian Archipelago (Schilp 1941, p. 96). Furnestin & Radiguet (1964, p. 84) worked the Chaetognatha from Nosi-Bé (Madagascar) and found, to some extent, the same picture found here in the Western South Atlantic. They registered in surface water a small number of adults and a large number of juveniles and immatures even for deep water species like *S. hexaptera* and *S. planctonis*. They found that *S. robusta*, *S. bedoti* and *S. bipunctata* have a breeding period in the beginning of the warm and rainy season.

All species had a slight tendency to be protandrous. This fact is already knwon and recorded by Ghirardelli (1960, p. 289) who says that the Chaetognatha can be considered as contemporaneous hermaphrodite animals and that this is more or less marked according to the species.

Remarks — Most of the reproductive problems can only be solved by rearing animals in the laboratory during a considerable time. This has been tried by several authors but usually without success. To the author's knowledge, except for *Spadella* (GHIRARDELLI 1953; 1954) which seems to survive well under laboratory conditions, only *S. hispida* was kept alive for two weeks in Biscayne Bay by REEVE (1964 b, p. 211-213), and *S. crassa* was reared in the laboratory by MURAKAMI (1959) cited by ALVARIÑO (1965, p. 132).

GENERAL CONCLUSION

Summing up the results obtained, the distribution of the Chaetognatha off the São Paulo coast can be described as follows: *S. friderici* is a coastal water indicator species which is the most abundant among Chaetognatha of inshore and less saline water in this area and therefore is more abundant off Cananéia than off Santos. *S. enflata* is a shelf water indicator species although it occurred in smaller number in coastal and in tropical water. It occurred in more saline and oceanic water than *S. friderici* and is more abundant in the samples off Santos than off Cananéia. There is indication that it lives mainly in mid--water and performs a slight migration to deeper water at noon and that the thermocline is not a barrier. The T-S-P diagram shows that *S. hispida* and *K. pacifica* prefer shelf water but their inconsistent annual occurrence off Santos and off Cananéia suggests that they require mixed water to thrive well. Both species live mainly in surface water and there is a suggestion that they migrate to deeper water during daylight. *S. serratodentata* and *S. minima* were sparingly represented in the few samples collected in tropical water. Among the species of Chaetognatha collected in this area, these two species show a stronger preference for the oceanic environment than *S. enflata*. Migration of *S. serratodentata* to a deeper layer at noon through the thermocline was observed. *S. minima* did not show vertical migration. It always occurred below 25 m depth in all samples but one in the vertical migration collection.

The present material suggests strongly that all the species collected, in the area studied, breed throughout the year.

Some remarks were made on the feeding habits of Chaetognatha. Inter and intra-specific cannibalism among different species such as *S. enflata*, *S. friderici* and *S. hispida* was commonly observed. It was also found that Chaetognatha feed on Appendicularia, Hydromedusae (*Liriope tetraphylla*), Cladocera (*Penilia avirostris*), copepods (*Corycaeus giesbrechti*), amphipods and fish larvae. Many *S. enflata* from two samples were unexpectedly found with *Stephanopyxis palmeriana* (diatom) in the gut. Among other carnivorous animals *Liriope tetraphylla*, *Corycaeus giesbrechti* and fish larvae were very often found preying on *Sagitta*.

S. enflata infested with trematode parasitas were also observed.

Bodies with heads being regenerated on *S. enflata*, *S. friderici* and *S. hispida* were frequentely found.

RESUMO

Foram tomadas amostras verticais de plâncton em três estações fixas ao largo de Cananéia (1958, 1959 e 1960) e ao largo de Santos (1960 e 1961). Em 1961 foi acrescentada uma quarta estação ao largo de Santos. O presente trabalho é um estudo dos Chaetognatha nesta área: distribuição das espécies segundo as diferentes massas de água e distribuição vertical. Abrange também o estudo da variação anual das espécies que visa a análise da ocorrência dos diferentes estágios de desenvolvimento.

As seguintes espécies foram encontradas: *Sagitta enflata, S. friderici, S. hispida, S. serratodentata, S. minima, Krohnitta pacifica, K. subtilis, Pterosagitta draco*. *S. friderici*: foi a espécie mais abundante em águas pouco salinas próximas à costa e assim mais abundante ao largo de Cananéia do que ao largo de Santos; é pois espécie indicadora de água costeira. *S. enflata*: sua maior ocorrência se encontra em águas mais oceânicas e salinas do que as de *S. friderici*. É, pois, espécie indicadora de água de plataforma embora também ocorra em menor quantidade em águas costeira e tropical. Há indícios de que a população vive principalmente a meia água e de que realiza, ao meio dia, migração para camadas mais profundas mesmo através da termoclina. *S. hispida* e *K. pacifica*: segundo o diagrama T-S-P preferem água da plataforma. Entretanto, a sua distribuição anual irregular ao largo de Santos e Cananéia sugere que elas precisam de massas de águas misturadas para a sua sobrevivência. As duas espécies são típicas de águas superficiais e há indicações de que realizam migrações verticais para camadas mais profundas durante o dia. *S. serratodentata* e *S. minima*: foram coletadas em pequeno número nas poucas amostras tomadas em águas tropicais. Entre tôdas as espécies de Chaetognatha coletadas nesta área, estas duas espécies mostraram preferência por águas mais oceânicas. Foi observada migração vertical de *S. serratodentata*, ao meio dia e através da termoclina. *S. minima*: não forneceu dados que demonstrassem migração vertical na série de amostras da migração vertical, entretanto, ela sempre ocorreu nas camadas de água abaixo de 25 m de profundidade. *K. subtilis*: ocorreu em pequeno número e sòmente na série de amostras da migração vertical. *P. draco*: também ocorreu excepcionalmente na série anual de amostras, porém, sempre em águas oceânicas. A pequena ocorrência destas duas últimas espécies não forneceu dados conclusivos a respeito de sua ecologia. Os dados obtidos do presente material não indicam que haja épocas especiais de reprodução mas que tôdas as espécies se reproduzem continuamente durante o ano.

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