ON THE SEASONAL OCCURRENCE OF APPENDICULARIANS IN WATERS OFF THE COAST OF SÃO PAULO STATE

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SYNOPSIS

Studies were made on the seasonal variation and qualitative composition of the Appendicularia population from a limited area of the South Atlantic 25°09.5'S to 24°04.0'S latitude and 47°48.4'W to 46°00.4'W longitude at the São Paulo State coast off Cananéia and off Santos.

The pattern of the seasonal variation was irregular for the most important species (*O. longicauda*). Some qualitative differences regarding the species composition are discussed.

INTRODUCTION

Studies on distribution, specific composition, and abundance of Appendicularia from the South Atlantic have been made by several authors, namely LOHMANN (1896, 1931), LOHMANN & BUCKMANN (1926), LOHMANN & HENTSCHEL (1939), GARSTANG & GEORGESON (1935), UDVARDY (1958) and FENAUX (1967).

Papers by BJÖRNBERG & FORNERIS (1956a, 1956b, 1958) and FORNERIS (1965) give some indication of the association of certain species to some water-masses.

In the present note, an attempt has been made to indicate the seasonal variations of the Appendicularia population, from a limited region of the South Atlantic: 25°09.5S to 24°04.0'S latitude and 47°48.4'W to 46°00.4'W longitude. Also the relative abundance of the different species was studied.

MATERIAL AND METHODS

Three oceanographic stations were established in two regions off Cananéia and off Santos. Sampling was made fortnighthly during 1958, 1959 and 1960 off Cananéia, and during 1960 at the same time intervals off Santos.

Station position, local depth, and sampling depths are given in Table I.

Plankton samples were collected vertically with a Hensen net, with a mesh size aperture of 295 μ. They were fixed with formalin, 4% and examined with a binocular with magnification of 96x. All the results were calculated as number of individuals/m^3.

Water temperature was measured with reversing thermometers and salinity was determined with the Knudsen method. These two parameters were measured at surface and at the sampling depths given in Table I.

NOTES ON ENVIRONMENTAL DATA

The coast of the State of São Paulo was under the influence of three types of water masses. These waters were characterized by the following situations regarding temperature and salinity data (EMILSON 1959, 1961).

		Salinity	Temperature
1)	"Coastal waters"	< 35‰	> 19°C
2)	"Shelf waters"	35 — 36‰	< 22°C
3)	"Tropical waters"	> 36‰	> 20°C

"Coastal water" was present at the three stations off Cananéia. Occasionally "shelf water" was found at station III. This water type was quite constant off Santos but occasionally "tropical water" occurred (LEINEBÖ, 1969).

Temperature and salinity average monthly values for each station are given on Tables II and III.

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TABLE I — Station position and sampling depths

Region	Station	Position	Distance from the coast (n.m.)	Sampling depth (m)	Local depth (m)
Off Cananéia	I	25°07.9' S 47°48.4' W	5.6 from Bom Abrigo	15	19
	II	25°08.4' S 47°44.2' W	9.5 from Bom Abrigo	15	20
	III	25°09.5' S 47°35.7' W	17.2 from Bom Abrigo	25	30
Off Santos	I	24°04.8' S 26°13.7' W	5.0 from Ilha da Moela	25	28
	II	24°10.0' S 46°08.0' W	10.0 from Ilha da Moela	35	37
	III	24°16.8' S 46°00.4' W	20.0 from Ilha da Moela	45	49

RESULTS AND DISCUSSION

a) *Considerations on Appendicularia families*

In the area under investigation three families of Appendicularia with following genus and species were found (FENAUX, 1963):

Family Oikopleuridae

Genus Oikopleura Mertens
- *O. longicauda* Vogt
- *O. fusiformis* f. *typica* Fol
- *O. fusiformis* f. *cornutogastra* Aida
- *O. dioica* Fol
- *O. rufescens* Fol

Genus Stegosoma Chun
- *Stegosoma magnun* Langerhans

Family Fritillariidae

Genus Fritillaria Quoy & Gaimard
- *F. haplostoma* Fol
- *F. pellucida* Busch
- *F. formica* f. *digitata* Lohmann & Buckmann
- *F. formica* f. *tuberculata* Lohmann & Buckmann
- *F. borealis* f. *intermedia* Lohmann
- *F. borealis* f. *sargassi* Lohmann

Genus Appendicularia Fol
- *Appendicularia sicula* Fol

Family Kowalevskiidae

Genus Kowalevskia Fol
- *Kowalevskia tenuis* Fol

Studies on appendicularians from other regions have shown that the family Oikopleuridae constitutes the bulk of its population. The material studied showed that the family Oikopleuridae dominates the samples with a percentage of 85 — 99% of the total of Appendicularia. The other two families Fritillariidae and Kowalevskiidae were relatively poorly represented. This result seems to be a characteristic of tropical waters (FENAUX, 1969). However, at regions with a distinct seasonal cycle a succession in the relative abundance of the three families can be found (FENAUX 1959, 1963).

b) *Relative abundance of the species*

Qualitative and quantitative differences in species composition were found at the three stations studied off Cananéia and off Santos (Table IV).

Station I off Cananéia nearest to the coast showed a slight reduction in number of species and the occurrence of species from the genus Fritillaria was sporadic. Certain influences of the waters of the lagunar region of Cananéia may probably occur at this station (TAVARES, 1967). The three stations situated off Santos, showed no difference in specific composition of its Appendicularia fauna.

A small variation on the total density of Appendicularia at the three stations off Cananéia was found, except for station I (1958). Off Santos stations I and II showed a density relatively larger than the stations off Cananéia.

From the eleven species present, *O. longicauda* was the commonest, with a percentage of 71.2% of

TABLE II — Average monthly values for temperature (°C) at the given depths for each station

Region	Cananéia																		Santos					
Year	1958						1959						1960						1960					
Station	I		II		III		I		II		III		I		II		III		I		II		III	
Month / Depth (m)	0	15	0	15	0	15	0	15	0	15	0	15	0	15	0	15	0	25	0	25	0	35	0	45
Jan	26.7	23.7	27.1	19.0	26.4	16.8	27.1	25.4	27.2	25.1	27.1	22.2	25.8	24.4	26.0	24.5	25.8	21.9	—	—	—	—	—	—
Feb	28.4	27.4	28.3	26.8	27.6	25.7	28.0	25.7	28.7	25.2	27.7	23.1	25.7	24.6	25.8	24.8	25.7	23.8	25.7	21.0	25.7	18.2	25.8	16.4
Mar	25.8	25.5	26.5	25.8	26.4	25.5	26.5	26.5	26.2	26.4	26.6	25.9	26.6	23.1	26.7	22.5	26.6	19.7	26.2	18.5	25.9	16.6	24.2	16.6
Apr	24.8	24.6	—	—	26.4	22.4	—	—	—	—	—	—	24.1	24.2	24.4	24.0	24.2	23.3	25.8	23.1	25.3	19.5	25.1	17.8
May	20.5	21.4	21.3	21.4	22.0	—	22.3	22.5	22.6	22.8	23.3	23.1	21.2	21.7	21.5	21.7	21.6	21.9	22.5	22.5	23.0	20.9	22.9	22.4
Jun	21.1	21.4	21.7	21.7	21.3	21.5	20.4	20.4	20.6	—	20.5	20.8	20.3	20.2	20.7	20.5	21.0	20.9	21.1	21.6	21.9	21.9	22.2	21.9
Jul	21.0	21.1	21.4	21.3	21.5	21.3	20.7	20.6	20.8	20.8	20.9	20.5	19.5	19.7	19.9	19.8	20.1	20.0	20.9	21.1	21.2	21.3	21.7	20.5
Aug	—	—	—	—	—	—	20.4	20.0	20.8	20.0	20.6	—	20.0	19.9	19.8	20.0	19.9	19.7	21.0	20.9	20.9	20.6	20.9	19.9
Sep	21.9	22.0	22.1	23.6	22.5	22.8	19.2	19.5	—	—	19.6	19.5	19.8	19.8	19.8	19.7	20.0	19.8	21.6	20.8	21.5	21.0	21.4	20.9
Oct	23.3	24.1	23.6	24.0	23.2	23.0	22.5	20.1	—	—	22.4	19.7	22.1	21.6	22.3	20.8	21.9	20.6	23.9	21.3	24.3	20.7	23.9	18.3
Nov	24.7	24.0	25.6	23.9	24.5	23.7	—	—	24.0	21.3	23.2	21.9	23.3	22.3	23.1	22.2	23.2	21.8	24.0	21.0	23.6	19.4	23.8	18.0
Dec	26.4	25.2	26.1	24.5	26.4	24.2	25.0	24.7	25.8	25.3	24.8	23.5	24.8	23.5	25.9	23.2	24.8	22.7	26.7	22.6	26.0	20.9	25.3	19.0

TABLE III — Average monthly values for salinity (‰) at the given dephts for each station

Region	Cananéia																		Santos					
Year	1958						1959						1960						1960					
Station	I		II		III		I		II		III		I		II		III		I		II		III	
Month / Depth (m)	0	15	0	15	0	15	0	15	0	15	0	15	0	15	0	15	0	25	0	25	0	35	0	45
Jan	34.57	35.06	34.11	35.48	34.79	35.55	32.88	34.47	33.31	34.79	33.50	35.57	32.94	34.32	33.22	34.72	34.32	35.41	—	—	—	—	—	—
Feb	33.78	35.16	33.86	34.79	34.52	35.42	31.45	34.51	32.55	34.29	33.23	35.28	30.51	34.43	31.68	34.24	32.56	35.66	33.21	36.31	33.67	36.04	35.33	35.63
Mar	30.28	34.25	32.40	34.63	33.38	34.86	33.68	34.95	32.92	34.51	34.03	35.28	32.02	35.38	33.62	35.31	34.85	35.71	34.28	35.63	33.89	35.52	35.14	35.56
Apr	32.15	33.69	—	—	32.07	35.15	—	—	—	—	—	—	34.07	34.24	33.83	34.81	34.87	35.67	34.26	35.13	34.18	35.46	35.29	35.74
May	32.63	33.89	34.13	34.12	34.75	34.71	33.55	34.64	34.07	34.76	35.10	35.17	34.16	34.81	34.51	34.94	34.94	35.34	34.10	35.21	34.38	35.44	35.38	35.75
Jun	32.27	34.51	32.21	34.81	32.99	35.05	34.13	34.46	34.40	34.55	35.88	34.68	33.70	34.55	34.49	34.62	33.98	34.92	33.88	35.03	34.41	35.27	35.19	35.78
Jul	33.87	33.93	34.34	34.40	34.25	35.01	33.12	33.72	33.16	33.59	33.42	33.83	34.76	34.02	34.34	34.31	34.49	34.94	33.86	35.16	34.23	35.54	35.23	36.36
Aug	—	—	—	—	—	—	33.10	33.44	33.08	33.62	33.72	33.79	32.49	33.77	34.44	34.00	33.46	33.93	33.91	35.56	34.28	35.60	35.04	35.67
Sep	33.19	34.29	33.20	34.58	34.00	34.78	32.94	33.08	—	—	33.43	33.33	33.45	33.68	33.69	33.91	34.19	34.47	33.75	35.07	34.24	35.49	35.31	35.43
Oct	32.65	33.33	32.82	33.28	33.14	33.93	33.26	33.36	—	—	33.29	34.31	33.69	34.33	35.57	34.20	33.96	34.30	33.93	35.54	34.53	35.69	35.48	35.87
Nov	32.23	34.20	32.84	34.52	33.86	34.81	—	—	33.76	33.44	33.57	34.65	33.38	34.10	33.32	34.11	34.49	35.15	34.79	35.82	35.12	35.92	35.51	35.86
Dec	32.32	34.22	33.05	34.79	34.01	34.34	33.41	33.59	33.56	33.54	33.66	34.67	32.56	34.47	32.70	34.59	34.35	35.46	34.97	35.99	35.47	35.95	35.44	35.55

TABLE IV — The density of species expressed as number of organisms per cubic meter off Cananéia and off Santos

Region	Cananéia									Santos		
Year	1958			1959			1960			1960		
Species \ Station	I	II	III	I	II	III	I	II	III	I	II	III
O. longicauda	61.7	80.4	104.7	128.1	116.1	81.3	92.8	92.2	83.2	143.1	149.3	82.2
O. fusiformis	0.8	8.3	23.7	14.7	39.4	37.8	9.2	37.1	25.8	38.0	54.2	21.2
O. dioica	11.6	7.8	0.1	11.0	10.5	0.9	15.3	20.9	4.2	32.9	1.4	1.2
O. rufescens	—	—	—	—	—	0.2	0.4	2.2	2.9	0.6	0.8	0.4
F. haplostoma	0.7	1.3	0.1	0.2	1.2	1.6	2.3	1.5	2.4	6.7	8.4	8.4
F. borealis	—	—	+	—	+	0.7	+	+	1.4	1.4	3.3	8.2
F. pellucida	+	+	0.2	0.1	+	2.3	—	+	0.4	0.4	1.7	1.2
F. formica	—	—	0.1	—	0.1	0.8	0.5	1.0	5.4	0.4	1.0	0.4
K. tenuis	—	—	—	—	—	—	—	0.3	0.4	0.4	0.8	0.3
A. sicula	+	+	—	—	—	—	—	—	+	—	+	+
S. magnum	—	—	—	—	—	—	—	—	—	—	+	—
Total	74.8	97.8	128.9	154.1	167.3	125.6	120.5	155.2	126.1	223.9	220.9	123.5

\+ = Present but in density smaller than 0.1/m³.

TABLE V — Percentage of the two forms of *O. fusiformis* (f. *typica* and f. *cornutogastra*) at the three stations off Cananéia and off Santos

Cananéia	Species	Station I	Station II	Station III
1958	*O. fusiformis* f. *typica*	98%	96%	90%
	O. fusiformis f. *cornutogastra*	2%	4%	10%
1959	*O. fusiformis* f. *typica*	98%	98%	98%
	O. fusiformis f. *cornutogastra*	2%	2%	2%
1960	*O. fusiformis* f. *typica*	95%	93%	93%
	O. fusiformis f. *cornutogastra*	5%	7%	7%
Santos 1960	*O. fusiformis* f. *typica*	95%	93%	95%
	O. fusiformis f. *cornutogastra*	5%	7%	5%

the total. The percentage of this species, decreases from station I to station III off Cananéia, but remains at aproximately the same level at the stations off Santos.

Two other species with relative abundance were *O. fusiformis* and *O. dioica.*

O. fusiformis was present in its two forms: *typica* and *cornutogastra.* Table V shows the abundance of *cornutogastra* in relation to *typica.* This species was more abundant at stations II and III than at station I off Cananéia. Off Santos, it was more

TABLE VI — Absolute numbers for each sample of the two forms of *F. formica* (f. *tuberculata* (*) and f. *digitata* (§)

Region	Cananéia									Santos		
Year	1958			1959			1960			1960		
Station / Month	I	II	III	I	II	III	I	II	III	I	II	III
Jan	—	—	—	—	2 *	2 *	1 §	—	53 * 246 §	—	— 7 *	—
Feb	—	—	—	—	—	5 *	8 *	32 *	791 *	—	44 §	22 §
Mar	—	—	—	—	7 *	114 *	64 *	94 *	106 *	25 *	19 *	29 *
Apr	—	—	—	—	—	—	—	24 *	45 *	1 *	18 *	109 *
May	—	—	—	—	—	—	—	—	—	—	—	—
Jun	—	—	—	—	—	—	—	—	—	—	—	92 §
Jul	—	—	—	—	—	—	—	—	—	—	53 *	—
Aug	—	—	—	—	—	—	—	—	—	1 *	11 *	41 *
Sep	—	—	—	—	—	—	—	—	—	—	1 §	9 *
Oct	—	—	—	—	—	—	—	—	6 *	39 *	203 * 23 §	38 * 27 §
Nov	—	—	—	—	—	—	2 *	—	2 *	6 *	17 §	24 *
Dec	—	—	9 *	—	—	28 *	—	—	3 *	16 *	38 *	—

abundant at stations I and II. This fact seems to indicate that *O. fusiformis* prefers a certain distance from the coast.

O. dioica, showed a decrease in abundance from station I to station III of Cananéia. This species was present in greater number at station I off Santos. Therefore, it seems to be more neritic in habitat prefering to live close to the coast. Thus, station I off Santos and station III off Cananéia are different in relation to the occurrence of *O. fusiformis* and *O. dioica* (Almeida Prado, 1968).

The other species were most frequent at station III off Cananéia and at stations I, II and III off Santos. From these *Fritillaria haplostoma* was also present at stations I and II off Cananéia and during all the months sampled, f. *typica* considered oceanic form (Tokioka, 1955) was most frequent than *abjornseni* considered a neritic form (Björnberg & Forneris, 1956a; Tokioka, 1956).

O. rufescens, F. borealis, F. formica, F. pellucida and *K. tenuis* were more abundant in January, February, March and April.

Two forms of *F. borealis* mainly f. *intermedia* and *sargassi* were found but always in different samples, the former more frequent in "shelf-water" and the latter in "tropical water" (Forneris, 1965). Probably these two forms have different environmental requirements but no relationship could be established between these forms and the environmental parameters: temperature and salinity.

For *F. formica* the form *tuberculata* was more frequent than the form *digitata.* This latter form seems to be characteristic of the South Equatorial Current (Lohmann, 1896). Table VI shows the annual distribution of the two forms at stations off Cananéia and off Santos.

Kowalevskia tenuis occurred mostly in samples collected in "shelf waters".

Appendicularia sicula and *Stegosoma magnum* were rare.

c) *Seasonal variation of* O. longicauda, O. fusiformis *and* O. dioica.

Since these three species constituted the bulk of the Appendicularia population it is worth giving their seasonal variation.

The seasonal variation of *O. longicauda* was irregular (Fig. 1). Since it is the dominant species it sets the pattern for the seasonal variation of the total Appendicularia population at the three stations off Cananéia and off Santos.

Seasonal occurrence of *O. longicauda* for the years 1958 — 1960 was similar at stations I and II off Cananéia. Thus at station I maximum numbers occurred in Summer — Fall and minimum in Spring.

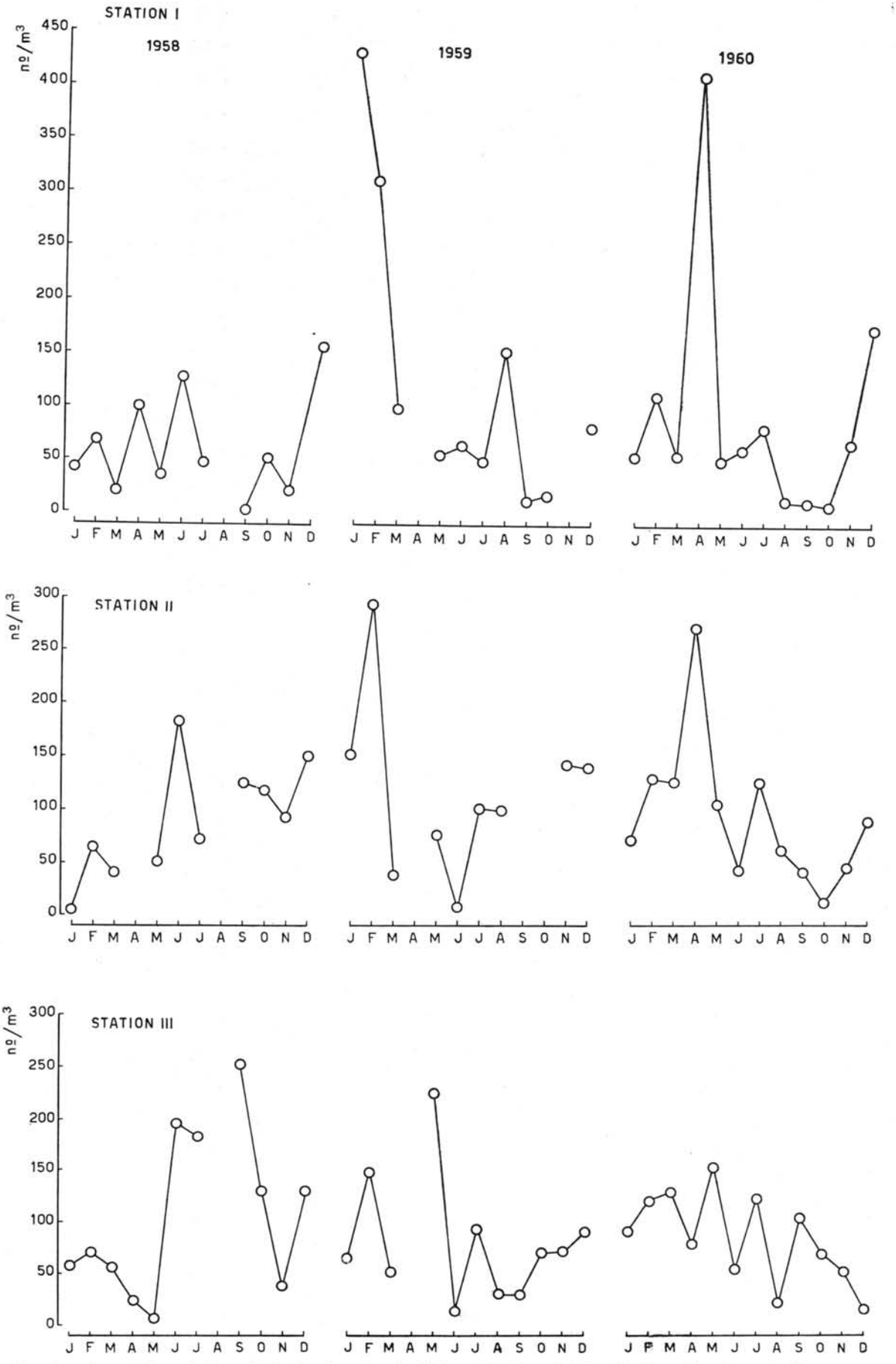

Fig. 1 — Seasonal variation of *O. longicauda* at stations I, II and III off Cananéia through the years 1958-1959-1960.

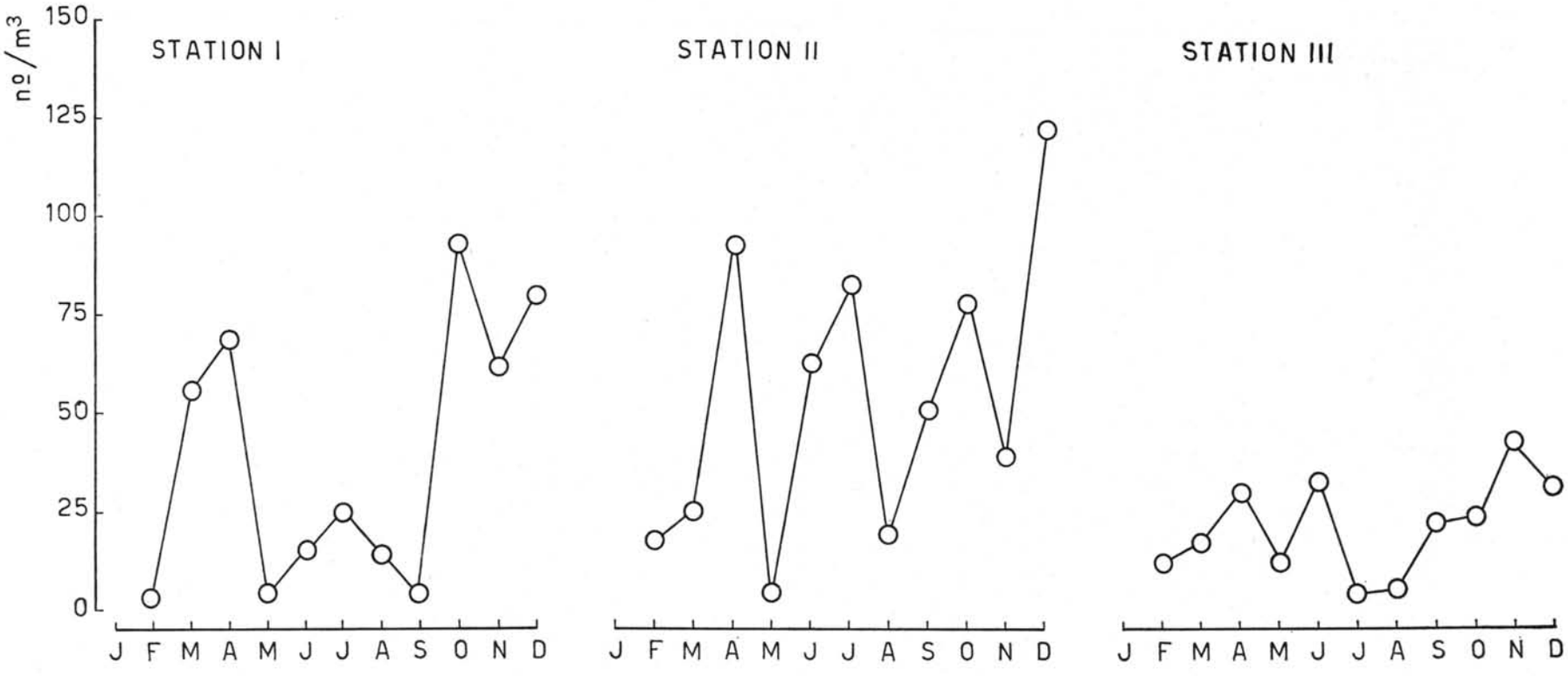

Fig. 2 — Seasonal variation of *O. longicauda* at stations I, II and III off Santos during 1960.

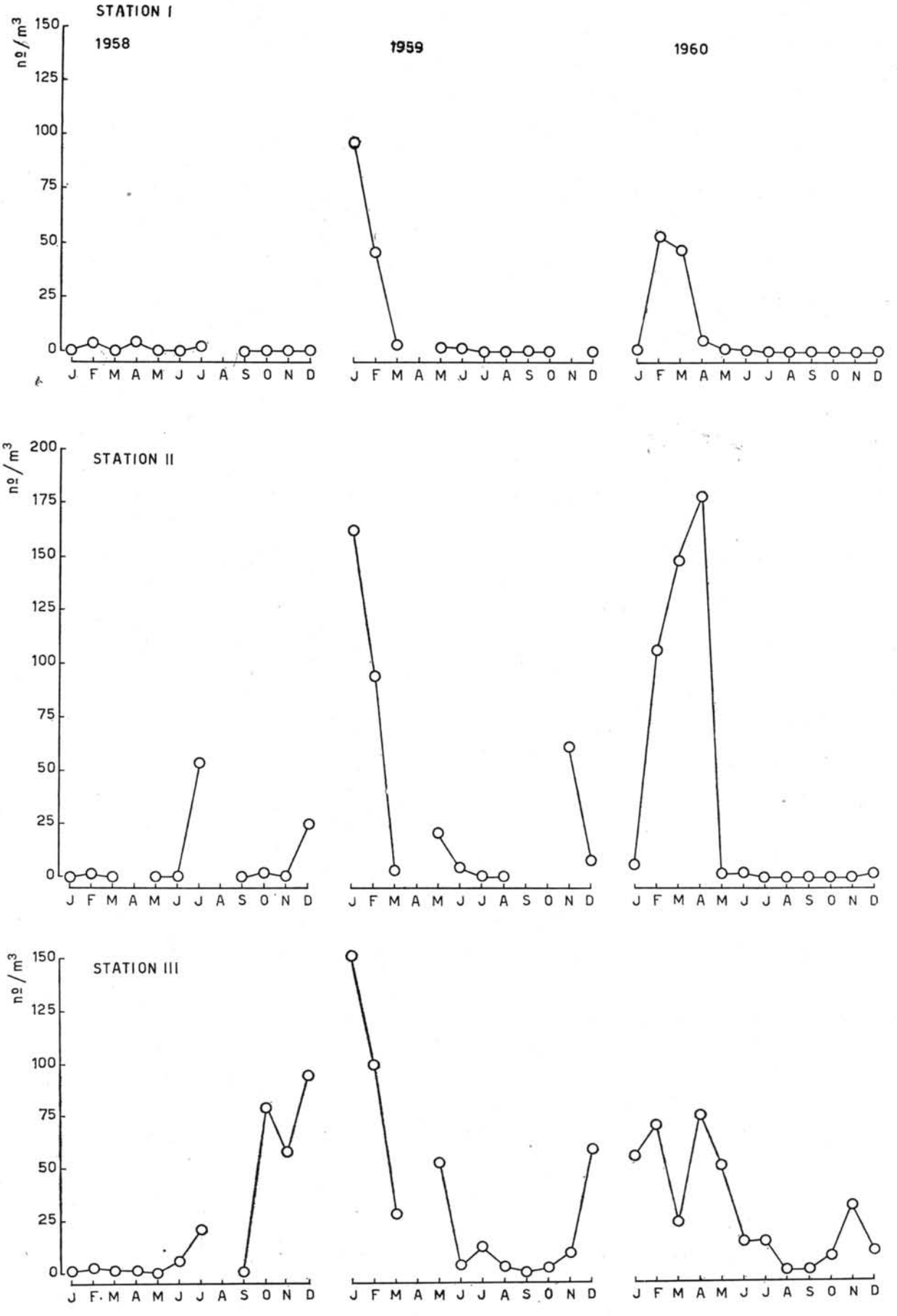

Fig. 3 — Seasonal variation of *O. fusiformis* at stations I, II and III off Cananéia through the years 1958-1959-1960.

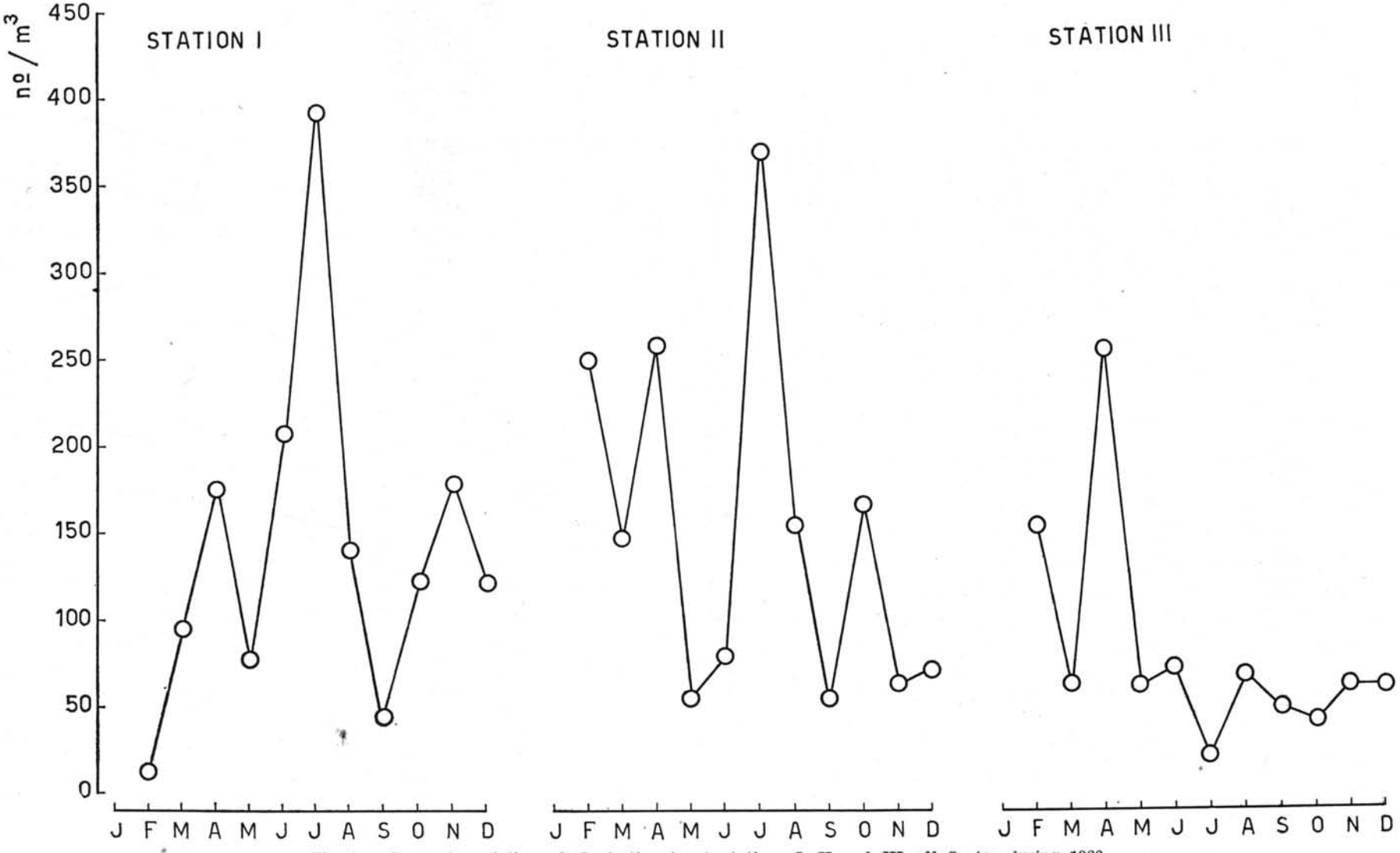

Fig. 4 — Seasonal variation of *O. fusiformis* at stations I, II and III off Santos during 1960.

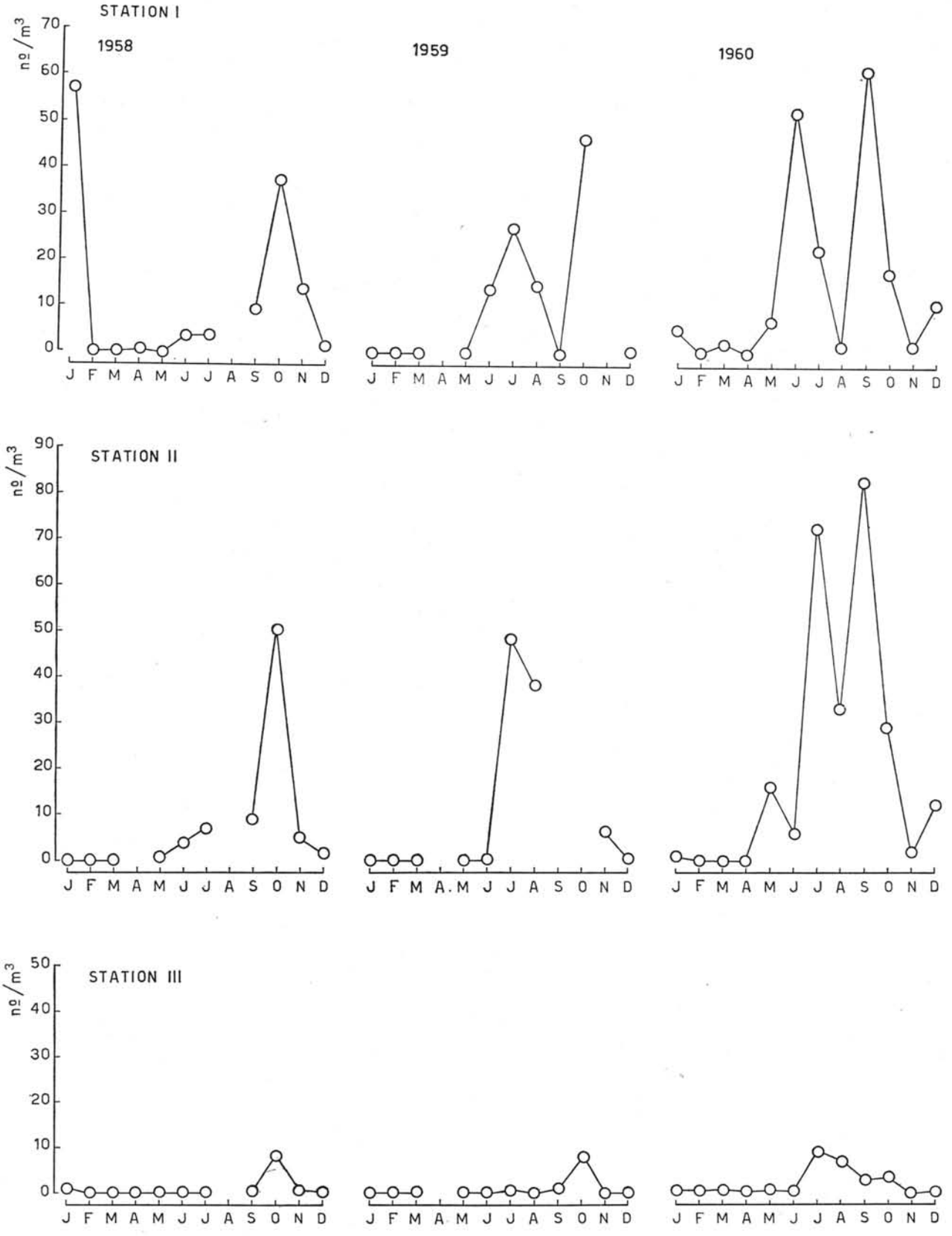

Fig. 5 — Seasonal variation of *O. dioica* at stations I, II and III off Cananéia through the years 1958-1959-1960.

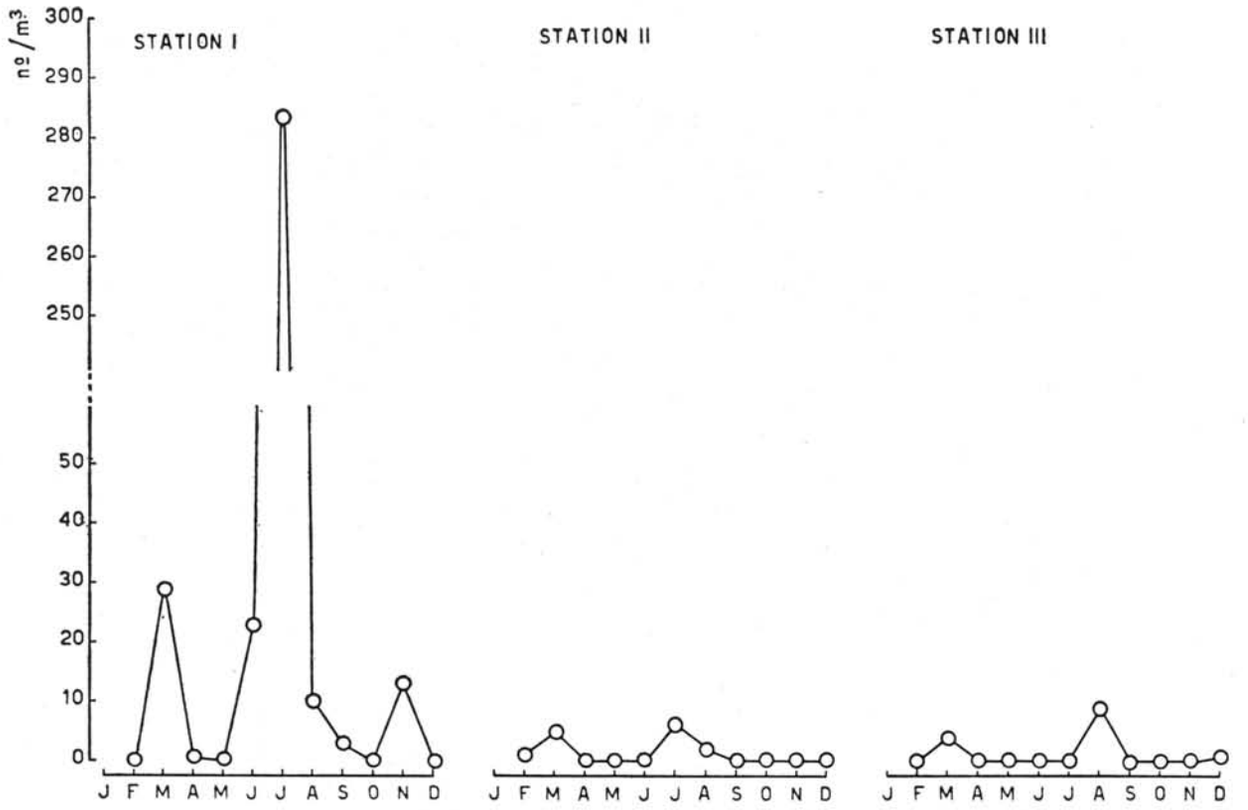

Fig. 6 — Seasonal variation of *O. dioica* at stations I, II and III off Santos during 1960.

The same occurred at station II. At station III maximum numbers were found in September and May (1958 — 1959), minimum numbers in May (1958) and in June, August, September (1959). In 1960 the occurrence varies considerably all through the year.

The variation in number of individuals was greater at stations I and II than at station III, probably due to the fact that the latter station is a more stable environment.

Figure 2 shows the seasonal variation of *O. longicauda* at the three stations off Santos.

O. fusiformis and *O. dioica* showed a more regular pattern of seasonal variation.

The greatest density of *O. fusiformis* was found from November to February sometimes until April off Cananéia (Fig. 3). Off Santos its seasonal variation was slightly irregular particularly at station II (Fig. 4). This species has been characterized by many authors as a warm water dweller.

O. dioica is a neritic species, with a maximum number of individuals during July, September and October. A peak occurred eventually at station I in January (1958) off Cananéia (Fig. 5). Off Santos, maximum values occurred in June at station I (Fig. 6).

This species is characterized as common in coastal waters of relatively low salinity and estuaries (Tokioka, 1960; Tokioka & Suarez Caabro, 1956; Hopkins, 1966). It is the only species found at the lagunar region of Cananéia (Teixeira, Tundisi & Kutner, 1965).

d) *Conclusions*

The region under study showed a small number of species comparing to other tropical or subtropical areas, probably due to the selectivity of environmental conditions. The three stations made both off Cananéia and off Santos were located very near to the coast and of small depth (maximum 49 m) and are unfavourable for the capture of certain species, specially those of the genus Fritillaria, most usually encountered at greater depths or in regions far from the coast.

The abundance of Appendicularia recorded both for the stations in Santos and Cananéia is based almost entirely on the occurrence of *O. longicauda,* the dominant species in the region. The density values at the referent stations were similar. The little variation on the environmental conditions of the region under study probably would not affect the "stock" of the Appendicularia population.

The present study did not show a regular pattern of seasonal variation except for *O. dioica* and *O. fusiformis,* which however did not affect significantly the total number of individuals present. An irregular seasonal variation seems to be a common pattern for the plankton from the tropical and subtropical waters (Heinrich, 1962). The present observations confirm this pattern for the abundance of Appendicularia.

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RESUMO

Amostras coletadas quinzenalmente em três estações fixas ao largo de Cananéia durante os anos de 1958-1959-1960 e ao largo de Santos em 1960 foram analisadas para o estudo da variação sazonal e composição qualitativa de Apendicularias.

O. longicauda foi a espécie dominante da região, apresentando uma variação sazonal irregular a qual foi padrão para a variação do total da população de Apendicularias.

O. fusiformis e *O. dioica* apresentaram uma variação sazonal mais regular, a primeira sendo mais abundante nos meses onde a temperatura da água foi mais elevada e a segunda nos meses onde a temperatura foi mais baixa.

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