

Population structure of *Temora stylifera* (Dana, 1849) (Copepoda) off Ipanema and in Guanabara Bay (Rio de Janeiro, Brazil).

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Abstract

The neritic and abundant copepod *Temora stylifera* (Dana, 1849) was the only species of the genus found in Brazilian marine waters until 1990. From 1990 on *T. turbinata* (Dana, 1852) was also registered. Therefore the present data refer to the pre-*turbinata* period. Horizontal, surface plankton samples were collected in Rio de Janeiro coastal waters from February 1983 to January 1984 with nets of 320 mm and 40 mm of mesh size, with coupled flowmeters. The density, sex relation and individual lengths for *T. stylifera*, as well as total zooplankton and phytoplankton densities, chlorophyll *a*, temperature, salinity and dissolved oxygen were determined. The relationship between the species and the environmental variables is revealed by the PCA (principal component analysis). *T. stylifera* was constant and abundant in the neritic region but in the Guanabara Bay it was not always present. Sixteen generations of the species were registered during the studied period. The variability in size was mostly attributed to the variation of temperature. The distribution of nauplii, copepodids and adults were better correlated with lower values of temperature, salinity and dissolved oxygen.

Key words: Copepoda, *Temora stylifera*, population structure, Rio de Janeiro

Introduction

Temora stylifera (Dana, 1849) is a frequent and abundant species of the Brazilian neritic waters (Björnberg, 1981). Until 1990 *T. stylifera* was the only species of the genus occurring along the Brazilian coast.

Another species of the genus, *T. turbinata* being previously distributed mainly off Africa (Binet, 1977); it was also registered during the 90's by Lages de La Rocha (1998) in Segredo Bay, São Paulo.

For that reason, it would be interesting to register the *T. stylifera* annual cycle during the 80's (before *T. turbinata* invasion) in order to provide a comparison basis for current and future studies, also including the other species.

Studies on *T. stylifera* annual cycle were accomplished by Crisafi and Guglielmo (1969) in the Messina Sea; by Razouls and Guinness (1973), in Banyuls-sur-mer region; by Binet (1977), in Ivory Coast; and by Belfiquih (1980), in the Moroccan Atlantic.

Other studies carried out by several authors provide data about *Temora* species development under influence of different food conditions and temperatures (Abou Debs and Nival, 1983; Ianora *et al.*, 1995; van Duren and Videler, 1995; Hopcroft and Roff, 1998; Hopcroft *et al.*, 1998). Eskinazi-Sant'Ana (2000) studied *T. stylifera* feeding in São Sebastião waters, SP (Brazil) through the analysis of faecal pellets content.

The objective of this paper is to describe the population structure of *T. stylifera* during the period 1983-1984 (before the invasion of *T. turbinata*) to serve as groundwork for current and future studies including both species. The specimens used in this study were obtained in Rio de Janeiro, coastal and inshore waters at two collecting sites: one off Ipanema beach and the other inside Guanabara Bay. In two other papers (Schutze and Ramos, 1999; Schutze, 2000) phytoplankton, zooplankton with a list of taxa, environmental abiotic factors based on data collected in these two stations were published.

Material and Methods

Plankton was collected simultaneously with other environmental data at two stations located off Ipanema (I) at 43°12'W - 23°02'S and in Guanabara Bay (G) at 43°12'W - 23°52'S, Rio de Janeiro (Fig. 1). Samples were collected biweekly from February 1983 to January 1984. A total of 22 samples were collected at the station located off Ipanema (local depth 20m) and 23 at the station G (local depth 6m) (Schutze and Ramos, 1999). The results about the environmental factors collected inside Guanabara Bay and adjacent waters were published recently (Schutze, 2000). Adults and copepodids III to V were collected with a plankton net of 320 µm of mesh size coupled with a *General Oceanics* 2030 flowmeter. Nauplii (II to VI) and copepodids I and II were collected with a plankton net of 40 µm mesh size in horizontal hauls. The samples were preserved in a 4% buffered formaldehyde. The studies of Gaudy (1961) and Schutze (1987) were used to determine the development stages of *T. stylifera*. The total length of copepodids and adults was taken on a dorsal view, with a microscope (Leitz- Ortholux II) using an eye piece micrometer and a stage micrometer from the anterior limit of the prosome until the posterior edge of the last segment of the urosome. The nauplii were measured from the anterior to the posterior part of the body, excluding the setae. Copepodids, nauplii and adults were observed in semi-permanent preparations in glycerin.

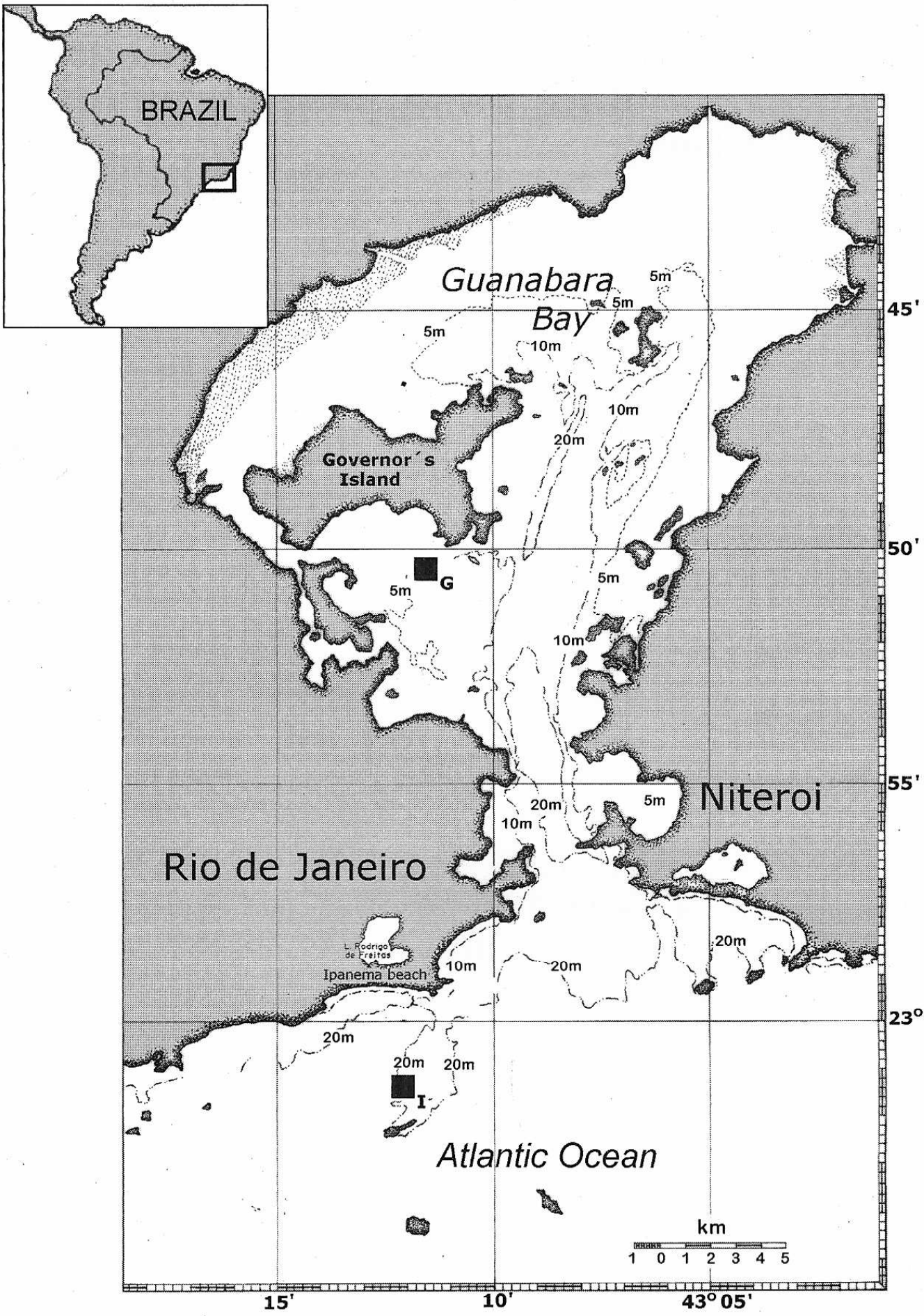


Figure 1: Map of the study area indicating sampling stations. Station I (offshore Ipanema) and station G (Guanabara Bay).

Temperature, salinity and dissolved oxygen were measured on the surface and at 15 meters depth at the station I and only on the surface at the station G. Temperature, salinity and dissolved oxygen were estimated by the Strickland and Parsons (1972) methods. Water transparency was measured with a Secchi disk, and chlorophyll *a* concentrations were estimated by spectrophotometer (Unesco, 1966). Environmental and biological data analysis were carried out in the Laboratories of the University Santa Ursula. Water temperature was obtained by the hydrological ARBA thermometer. Phytoplankton was counted by the Ütermöhl (1958) method with a Leitz Phaco inverted microscope after sedimentation during at least 6 hours.

A principal component analysis (PCA) was performed to assess the main trends of variability in the data. PCA included 7 abiotic variables (temperature, salinity, dissolved oxygen on surface and at 15m depth and transparency), 3 biotic variables (chlorophyll *a*, total phytoplankton and zooplankton abundance on surface) and abundance of the stages of *T. stylifera* (nauplii, copepodids and adults) measured in 20 samples collected off Ipanema (Table I). Abundances were previously transformed by log (x+1). The statistic analysis was accomplished using the software FITOPAC (G. Sheppard, UNICAMP) and EXCEL, STATISTICA and FITOPAC for graphic representations.

Table I: Codes of dates and variables included in multivariate analysis.

C ode	D ate	C ode	V ariables
Feb 8	February 8, 1983	TE s	Temperature surface (°C)
Feb 17	February 17, 1983	TE b	Temperature bottom (°C)
Mar 7	March 7, 1983	SA s	Salinity surface (‰)
Mar 17	March 17, 1983	SA b	Salinity bottom (‰)
Apr 7	April 7, 1983	TR	Transparency (m)
Apr 20	April 20, 1983	DO s	Dissolved Oxygen surface (mL/L)
May 5	May 5, 1983	DO b	Dissolved Oxygen bottom (mL/L)
May 17	May 17, 1983	CH	Chlorophyll <i>a</i> (ug.L ⁻¹)
Jun 8	June 8, 1983	PY	Phytoplankton (cells.L ⁻¹)
Jun 17	June 17, 1983	ZO	Zooplankton (ind.m ⁻³)
Jul 7	July 7, 1983	TS n	<i>Temora stylifera</i> nauplii (ind.m ⁻³)
Jul 27	July 27, 1983	TS c	<i>Temora stylifera</i> copepodids (ind.m ⁻³)
Aug 16	August 16, 1983	TS a	<i>Temora stylifera</i> adults (ind.m ⁻³)
Sep 13	September 13, 1983		
Nov 3	November 3, 1983		
Nov 24	November 24, 1983		
Dec 15	December 15, 1983		
Dec 22	December 22, 1983		
Jan 12	January 12, 1984		
Jan 27	January 27, 1984		

Results

The relationship between *T. stylifera* population and environmental variables obtained off Ipanema are shown in the PCA results (Fig.2).

The axis 1 is responsible for 30,07% of the variance, as a result of correlation of high values of dissolved oxygen on the surface and high values of salinity at 15 m depth and surface, high values of chlorophyll *a* and phytoplankton abundance during the rainy season. The negative quadrant of axis 1 shows that nauplii, copepodids and adults of *T. stylifera* occur mainly in the dry season and with lower values of salinity at 15 m depth.

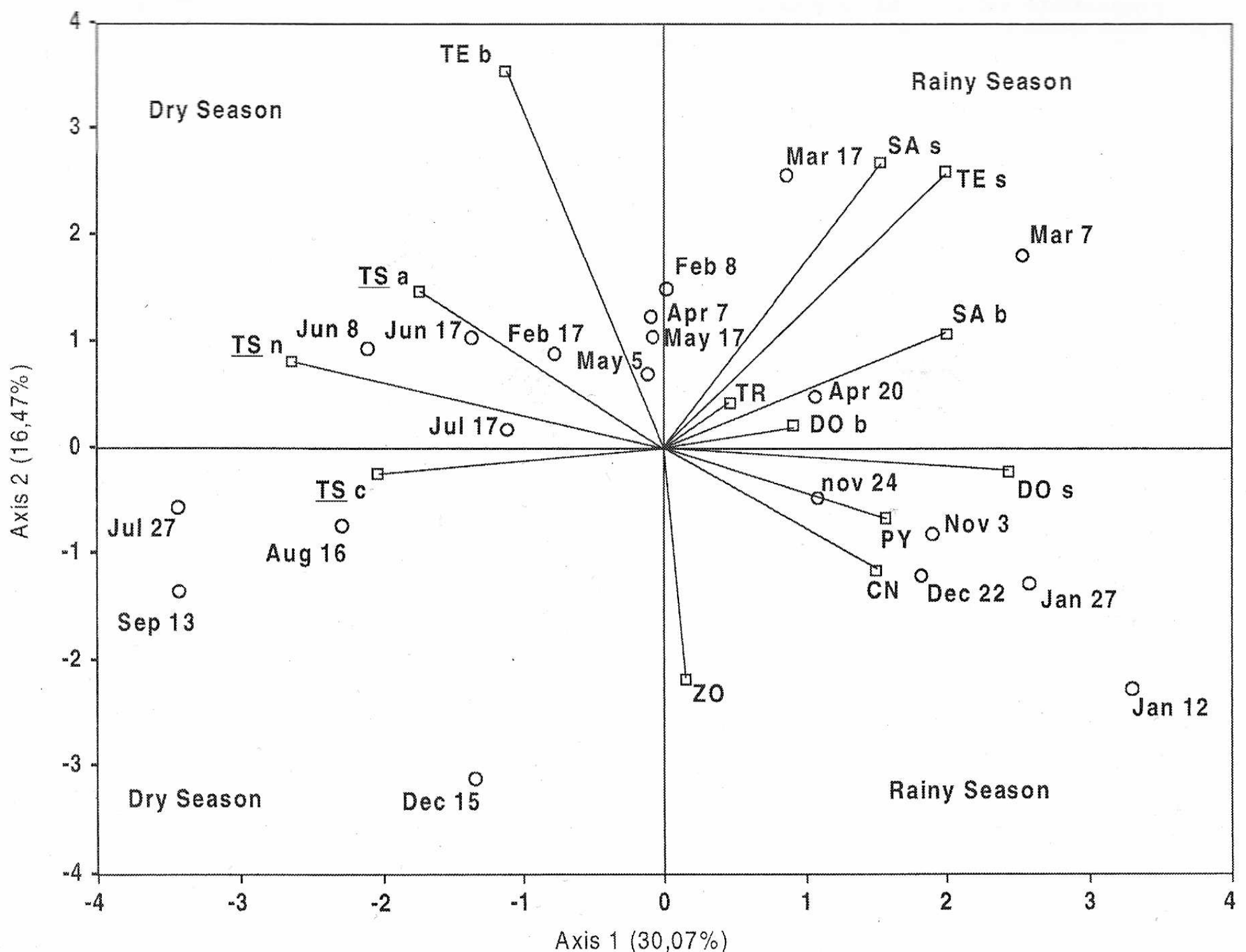


Figure 2: Results of principal component analysis. *Temora stylifera* stages, environmental variables (solid squares) and sampling dates (open circles) are listed in Table I.

Positively the Axis 2 represents the high values of temperature at 15 m depth during the dry season, and negatively it is correlated with the zooplankton.

In order to determine the number of *T. stylifera* generations, quantitative variation of the different development stages was used. The appearance of nauplius II was considered as the occurrence of a new generation. Sixteen generations were found during the studied period (Fig. 3). In January the species rest phase was observed.

Data from I show that adult sizes of males and females were larger during the summer (a maximum of 1,85 mm for females and 1,70 mm for males).

Figure 4 shows that female copepodids IV and V reached larger sizes than male copepodids in the same stage. Size variation for adult males is more accentuated than observed for females. "Small" males (reaching up to 1,30-1,38 mm) occur during the winter, or dry period, but did not occurred during the rest of the year.

Adult, copepodid V and copepodid IV stage, females were numerically dominant in relation to males (Fig. 5). The chi-squared (χ^2) test showed that, in only two months, this difference was not significant in adults (February, 17th and March, 07th, 1983). The sex-ratio difference in copepodids V was not significant in February, 17th, June, 17th, July, 7th and August, 16th, 1983. The same occurred with copepodids IV on March, 7th and July, 17th, 1983 (Table II).

In G we observed an increase of temperature, turbidity and chlorophyll *a* in relation to I (Fig. 6). *T. stylifera* was present only in 8 of the 23 samples collected, corresponding to the months of June, September, October and November. Nauplii stages were not found. Only copepodid stages and adults were present (Fig. 7). Because of this low number and frequency of *T. stylifera*, obtained in G samples, these data are not included in the statistical analysis.

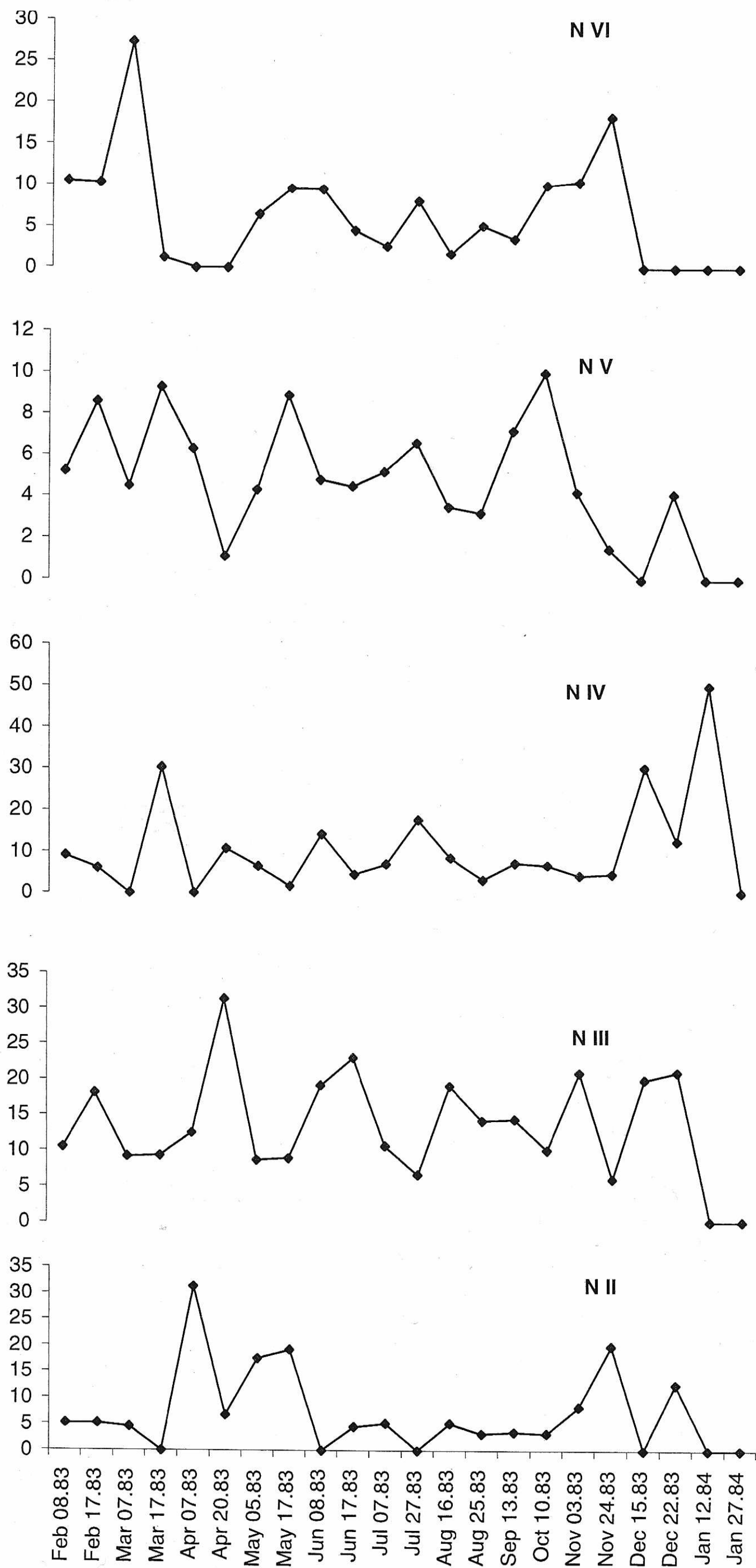


Figure 3: Annual variation of *Temora stylifera* from station I (offshore Ipanema), from February 1983 to January 1984. Vertical axis indicates percentage (%) of nauplii (stages II to VI).

Nauplius

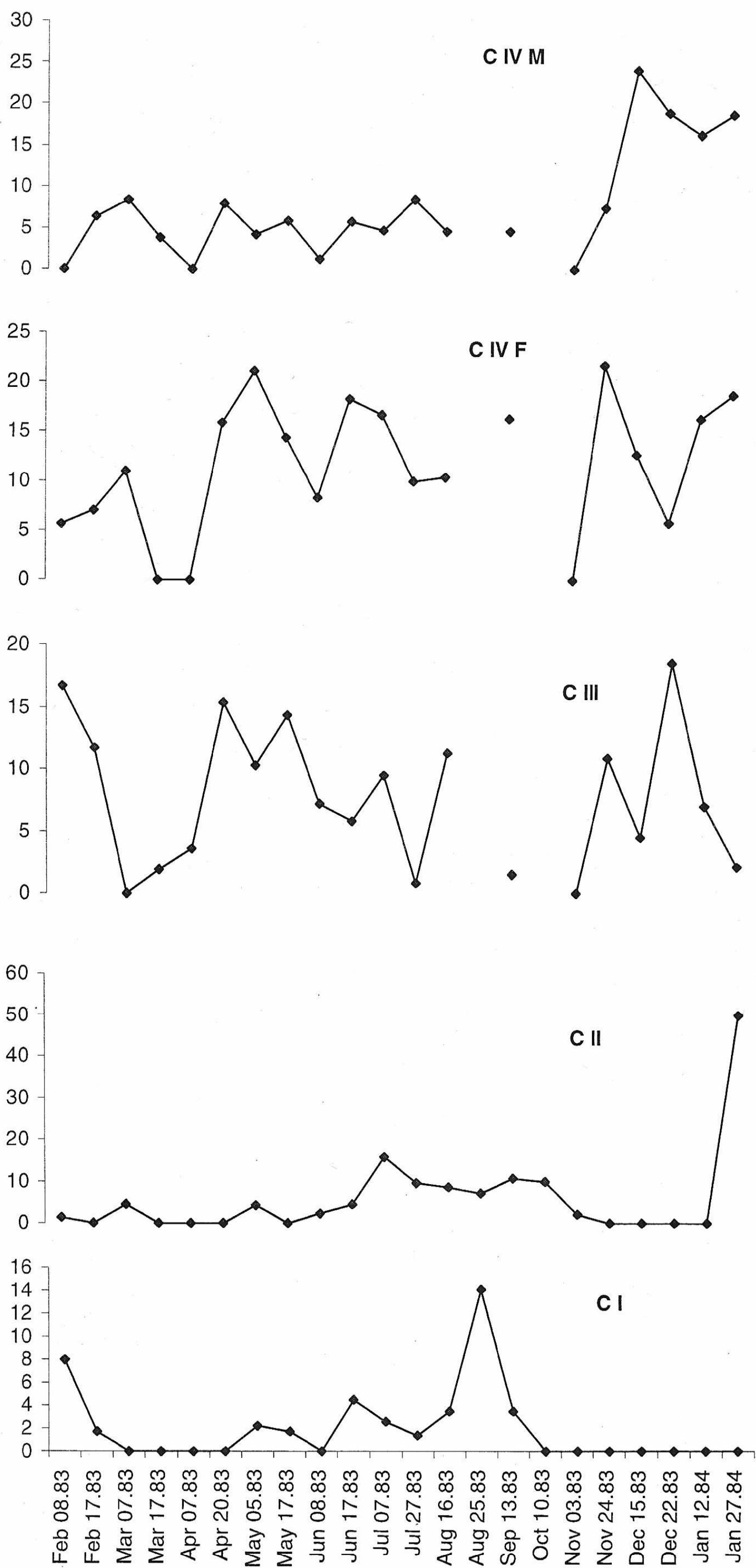


Figure 4: Annual variation of *Temora stylifera* from station I (offshore Ipanema), from February 1983 to January 1984. Vertical axis indicates percentage (%) of copepodid (stages I, II, III and IV females and males).

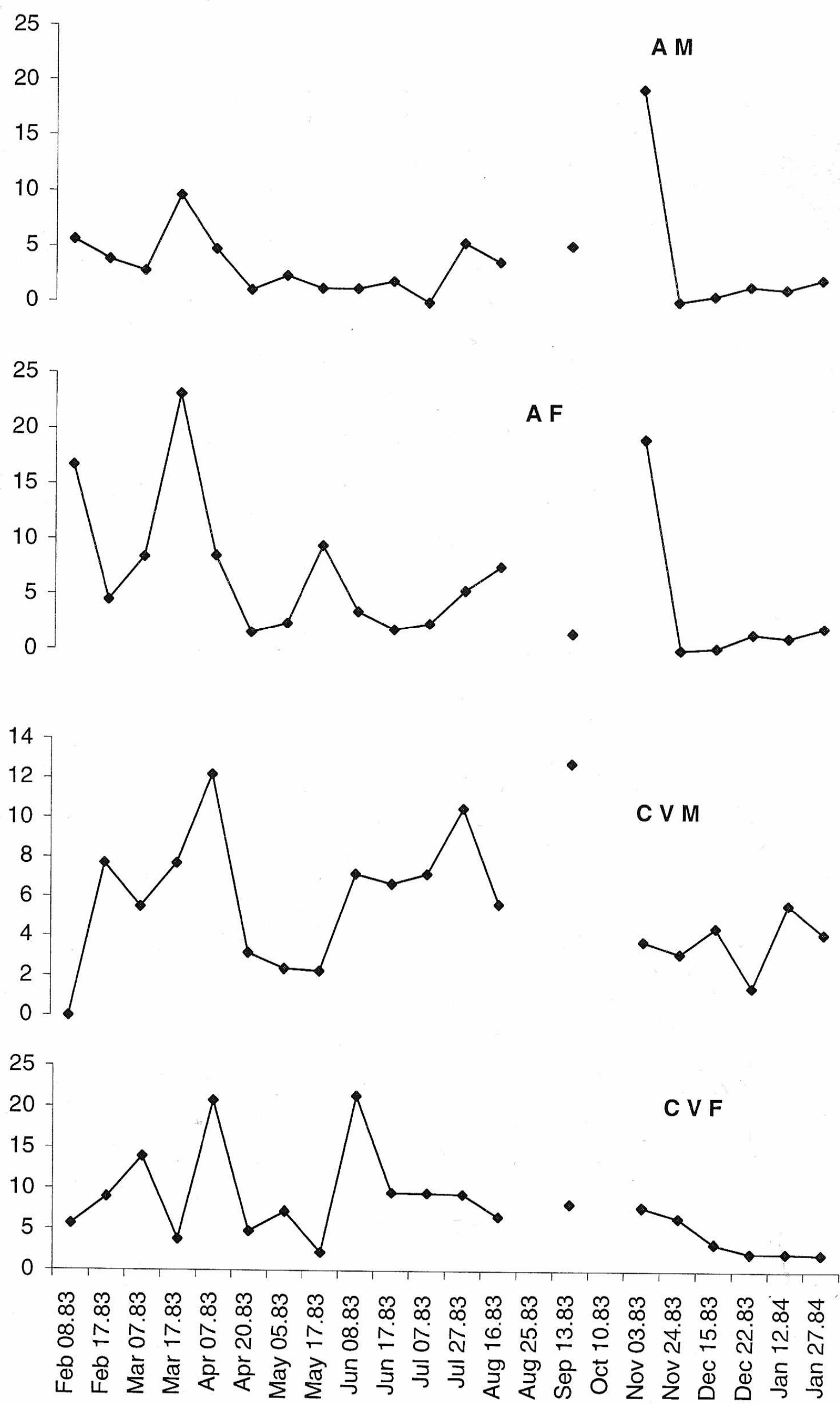


Figure 5: Annual variation of *Temora stylifera* from station I (offshore Ipanema), from February 1983 to January 1984. Vertical axis indicates percentage (%) of copepodid V, and adults (A) females and males.

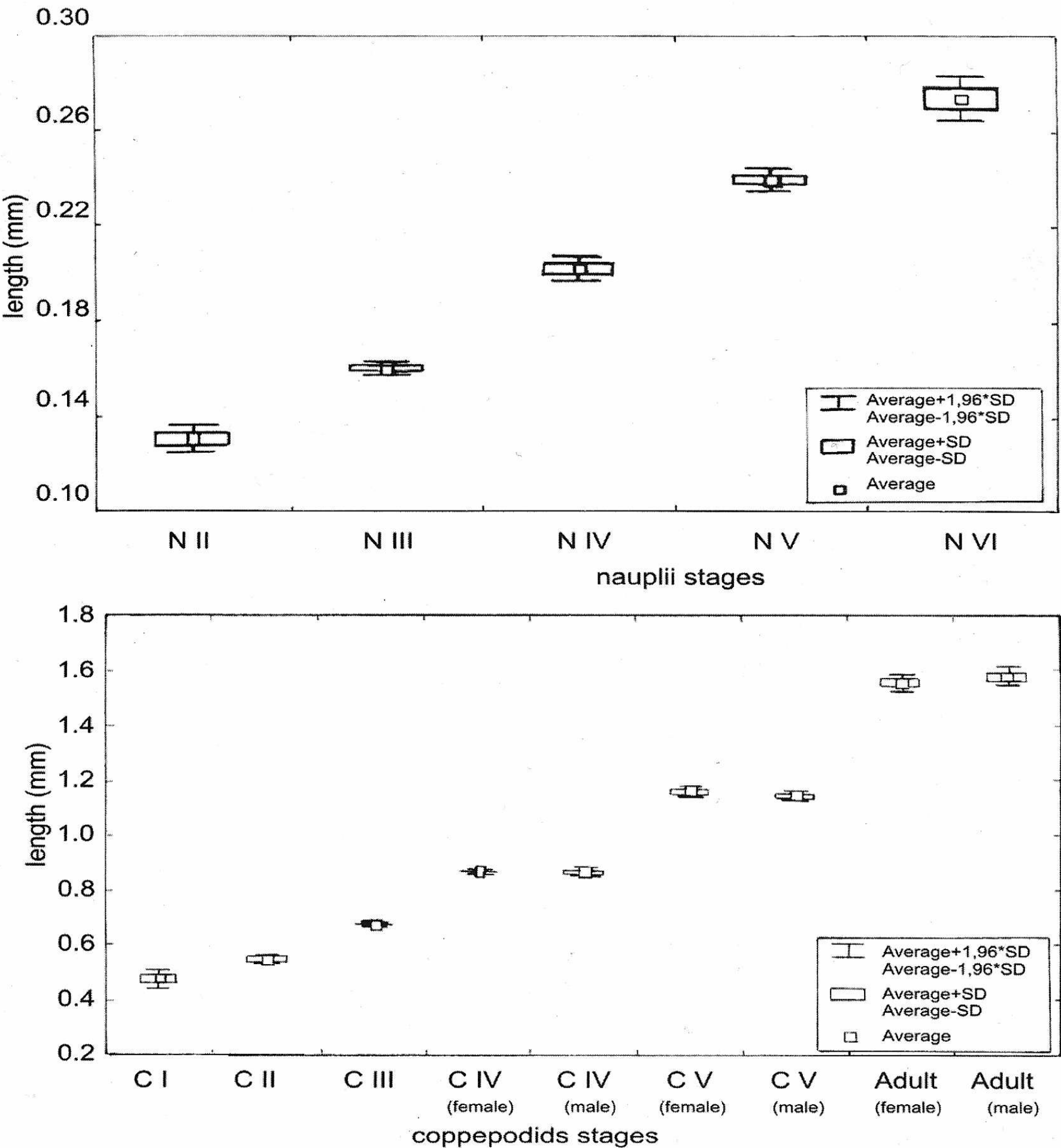


Figure 6: Length (mm) average and the standard deviation of nauplii, copepodids and adults of *Temora stylifera* of station I (Ipanema offshore).

Discussion

In temperate areas, populations annual evolution is marked by peaks that correspond to successive generations. This pattern is not verified in tropical seas (Woodmansee, 1958). *T. stylifera* lives in tropical waters of Brazil Current waters and in subtropical and coastal waters off Brazil (Björnberg, 1981; Lages de la Rocha, 1998). Schutze and Ramos (1999) found that *T. stylifera* was the most numerous copepod off the Ipanema seashore and *Acartia lilljeborgi* Giesbrecht, 1892 the most abundant in Guanabara Bay. Binet (1977) did not find significant correlation between *T. stylifera* length and water temperature in colder and warmer periods. In order to clarify this phenomenon, it would be necessary to breed species in warmer and lower temperatures. According to Deevey (1960), temperature is the most important known factor that influences copepodids seasonal size variation. Species living in higher temperatures are smaller than the ones living in lower temperatures (Sewell, 1948). Razouls & Guinness (1973) observed an increase in size of *T. stylifera*, during the winter (the dry season here). In general way, the animal size is larger when the temperature is lower and phytoplankton is richer. In Ipanema shore, *T. stylifera* showed the largest sizes during the summer (the wet season). This may be associated to the influence of cold waters during the summer in the coastal area (Emilsson, 1961). Adult individuals show larger length values in Guanabara Bay, where phytoplankton is richer (Schutze and Ramos, 1999).

Nauplius

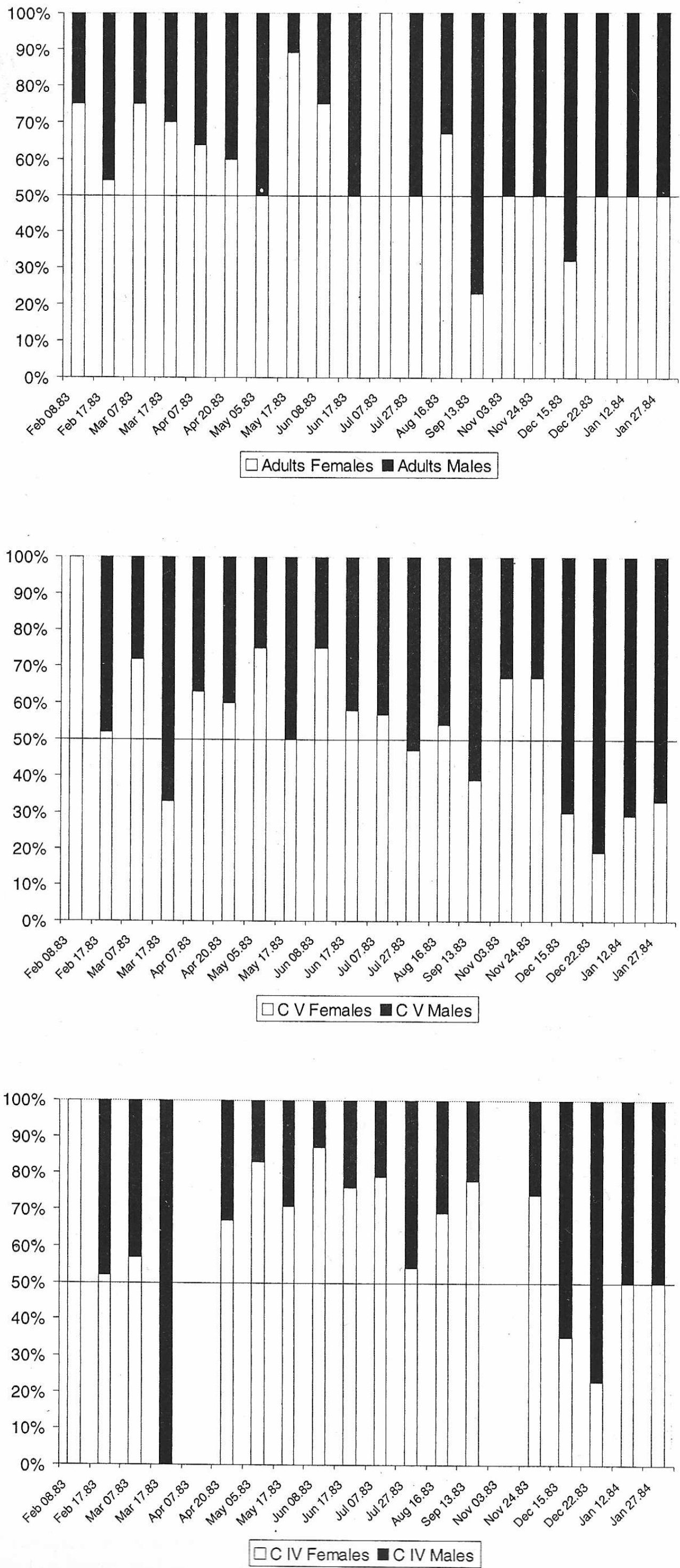


Figure 7: Sex- ratios in copepodid IV, copepodid V and adults of *Temora stylifera* of station I (Ipanema offshore).

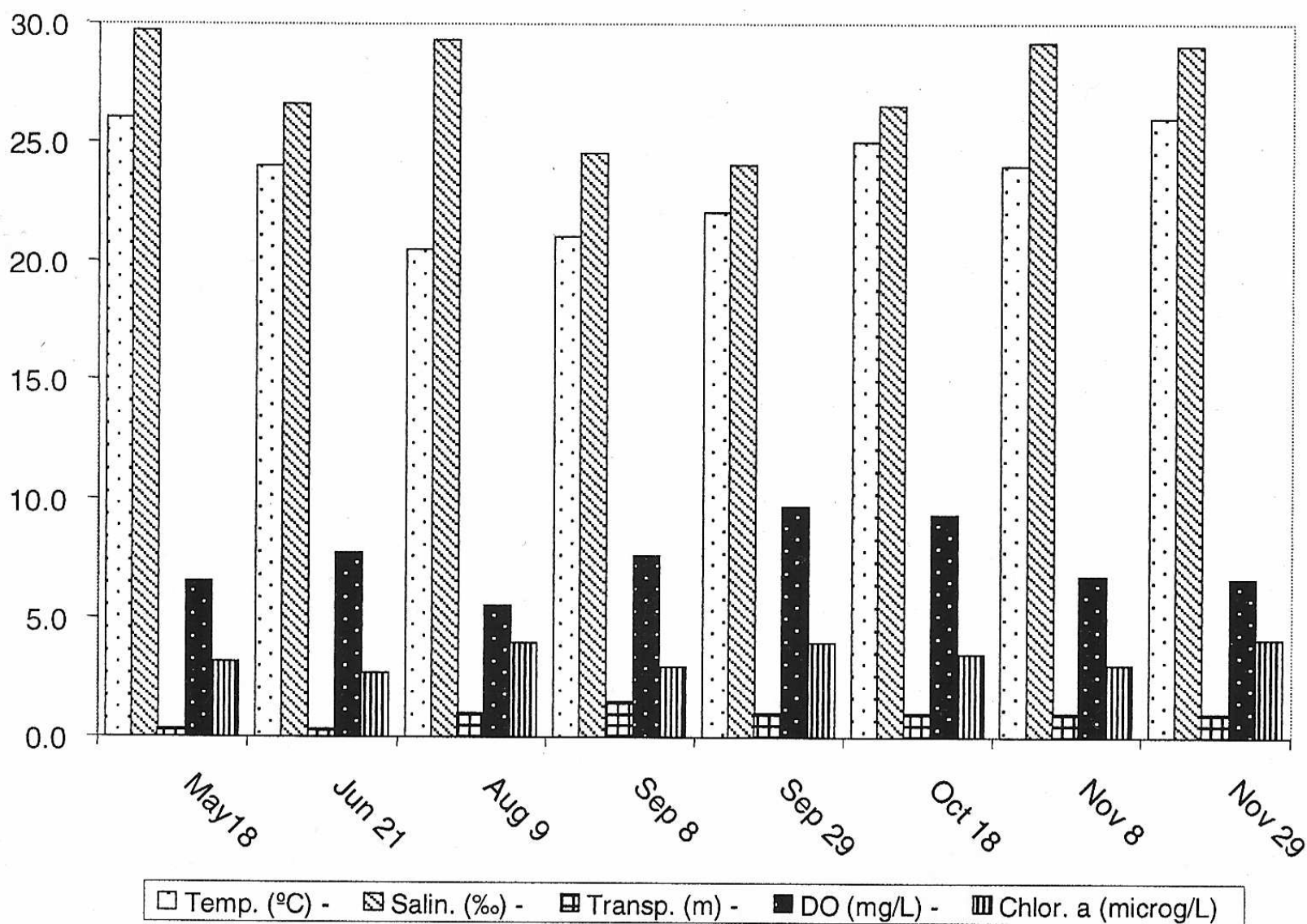


Figure 8: Variation of the water temperature, salinity, water transparence, dissolved oxygen and chlorophyll *a* concentration of Guanabara Bay.

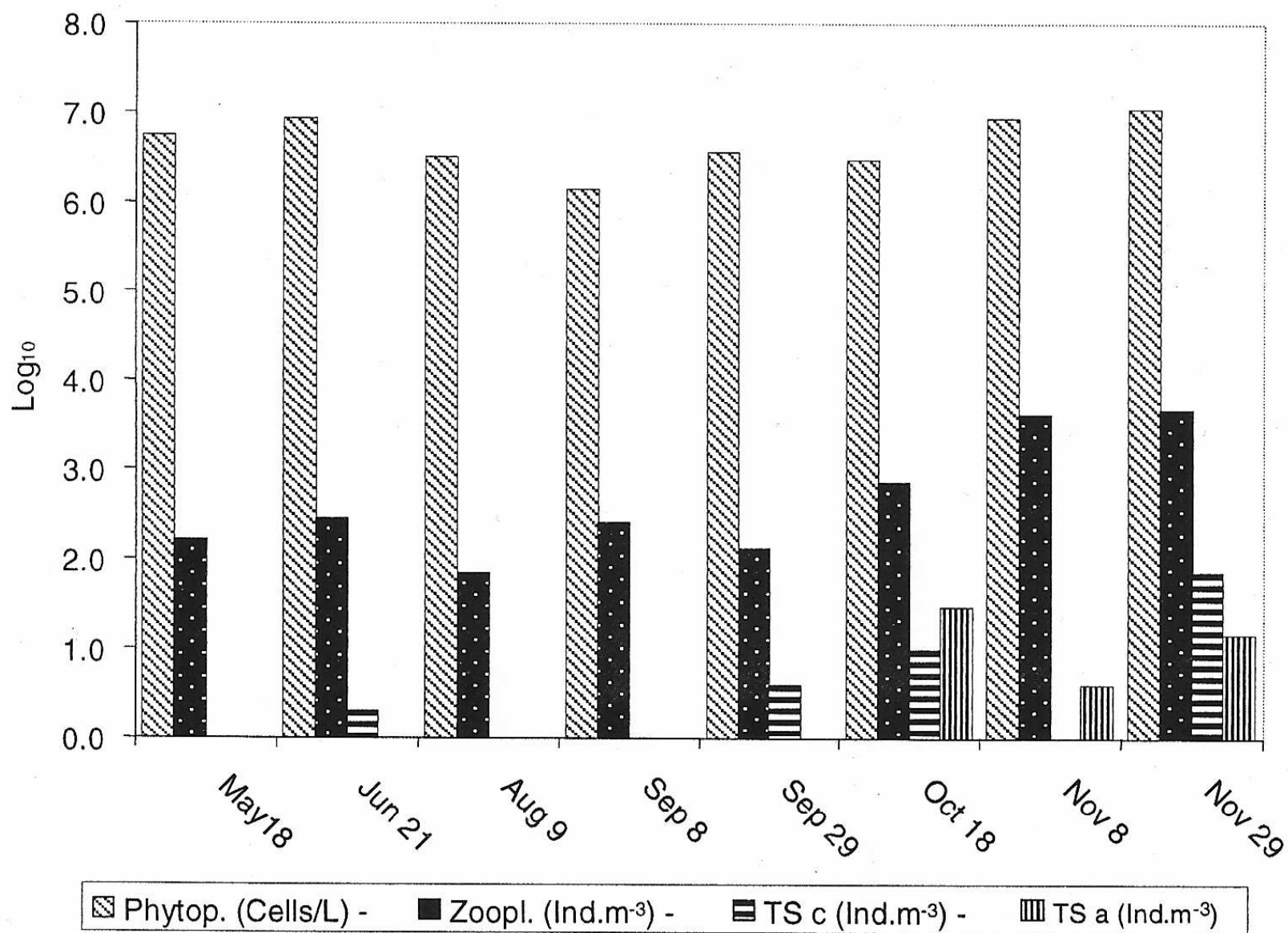


Figure 9: Variation of phytoplankton, zooplankton, *Temora stylifera* copepodids (TS c) and *T. stylifera* adults (TS a) of Guanabara Bay.

Probably due the influence to the South Atlantic Central Water current, which brings in colder water, adult individuals of *T. stylifera* occurred in waters of Segredo Bay (SP) in 41,67% of the samples being “more frequent during the winter and completely absent during the summer” (Lages de la Rocha, 1998). Naupliar stages of the genus *Temora* in São Sebastião waters predominated during summer and autumn, occurring in 77,98% of the samples. Lages de La Rocha results for *T. stylifera* agree with our data.

Table II: Chi-squared in copepodid IV, copepodid V and adults of *Temora stylifera* of Ipanema offshore.

Date	Adults	C V	C IV
Feb 08. 83	25.0	100.0	100.00
Feb 17.83	0.64	0.16	0.16
Mar 07. 83	25.0	19.36	1.96
Mar 17.83	16.0	11.56	100.0
Apr 07. 83	7.84	6.76	0.0
Apr 20. 83	4.0	4.0	11.56
May 05. 83	0.0	25.0	43.56
May 17.83	60.84	0.0	17.64
Jun 08. 83	25.0	25.0	54.76
Jun 17. 83	0.0	2.56	27.04
Jul 07. 83	100.0	1.96	33.64
Jul 27. 83	0.0	0.36	0.64
Aug 16. 83	11.56	0.64	14.44
Sep 13. 83	29.16	4.84	31.36
Nov 13. 83	0.0	11.56	0.0
Nov 24. 83	0.0	11.56	23.04
Dec 15. 83	12.96	16.0	9.00
Dec 22. 83	0.0	38.44	29.16
Jan 12. 84	0.0	17.64	0.0
Jan 27. 84	0.0	11.56	0.0

Binet (1977) obtained a lower number of adult *T. stylifera* in November and during the winter (December, January) in Ivory Coast offshore (Africa). Therefore the necessity of additional studies during other periods for several years, with registration of more environmental variables, in order to obtain a better understanding of *T. stylifera* distribution and annual cycle in tropical and subtropical waters.

The larger adults observed in I are probably due to colder deep water which reaches the surface during the summer and causes a slower reproductive activity.

The life cycle of copepods reproducing during the whole year is characteristic of tropical species (Heinrich, 1962). Water temperature and amount of food would not be the only factors that influence size variation, but also the alimentary competition (Eriksson, 1973). Hopcroft *et al.* (1998) verified that addition of more food to incubation experiments in microcosms (warm coastal waters $\pm 28^{\circ}\text{C}$) caused increase of *T. turbinata* growth rate and size.

Direct relationship between *T. stylifera* sex ratios and phytoplankton density was found. A female predominance number was verified.

The deep cold water presence has represented a decrease in the population and even an absence of nauplii.

Other environmental factors which diverged in G and I stations are: the quantities of chlorophyll *a* (mg/m^3) usually smaller in I (0,37 to 1,56) and from 2,00 to 4,10 in G; phosphate ($\mu\text{gat}/\text{L}$), saturated oxygen (%) and dissolved oxygen (mL/L), silicate ($\mu\text{gat}/\text{L}$) also occurred frequently in higher values in G and in I when observed at the same occasion. Thus, based on these results we can conclude that the environment in Guanabara Bay is different from the environment off Ipanema (Schutze, 2000; Sevrin-Reyssac *et al.*, 1979) and that it is not ideal for the development of *T. stylifera*. Consequently no nauplii and young copepodids of this species were observed in G. The few copepodids (older stages) and adults

present only in some months of the year probably did not develop in Guanabara waters and were introduced.

The results here presented confirm conclusions in other papers (Björnberg, 1963; Lopes *et al.*, 1999) that *T. stylifera* prefers waters off Brazil, with salinities of 30 ‰ or more and temperatures above 20°C, occurring mainly in the surface layer.

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