Resting eggs of cladocerans in the Guanabara Bay – RJ, Brazil: horizontal, vertical and temporal distribution

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Abstract

The aim of this study was to analyze the occurrence, as well as temporal, horizontal and vertical distribution of resting eggs of cladocerans in Guanabara bay sediment. The highest incidence of *Penilia avirostris* eggs confirm the dominance of this species in the plankton found in the bay, followed by *Pseudevadne tergestina* and *Pleopis polyphemoides*. The temporal variation pattern, with the alternation of low and high densities peaks, points towards the need for further studies for a better understanding of this dynamics. The samples analyzed at each 3 cm, up to 21 cm depth, revealed a high density and heterogeneous vertical distribution of resting eggs of *P. avirostris*, and resting eggs of *P. polyphemoides* in lesser numbers and a more homogeneous distribution.
Key words: cladocera, resting eggs, distribution, Guanabara bay, Brazil

Introduction

So-called cladocerans are small crustaceans which inhabit freshwater mainly. Of the approximately 600 species, only 8 are truly marine, being distributed among the genera *Penilia* Dana, 1849, *Pseudevadne* (Claus, 1877), *Evadne* Lovén, 1836, *Pleopis* Dana, 1852 and *Podon* Lilljeborg, 1853 (Onbé, 1977). This reproductive strategy is responsible for the marked growth of the planktonic populations in certain periods of the year (Onbé, 1974). Cladocerans may reproduce through parthenogenesis or gamogenesis. Only parthenegenic females which produce other female individuals, are observed during most of the year. To believe that in unfarourable environmental conditions, females form eggs that give rise to both male and female individuals. After copulation and fecundation, the female generally produces a single large egg with a resistant external membrane. This resting egg deposits itself on the sea bottom and remains there during the adverse condition period. The animal which develops from the resting egg is always a female, which restarts the parthenogenetic cycle (Barth, 1972).

Available data on the dynamics of marine cladocerans stems from observations made mainly in temperate waters. The few papers on biology and ecology of Brazilian marine cladocerans focus only on the planktonic phase of these animals (Barth, 1972; Rocha, 1977; Resgalla Jr. and Montú, 1993; Marazzo, 1998; Gomes, 2000; Marazzo and Valentin, 2000; Marazzo and Valentin, 2001).

The present study aims to determine the occurrence and spatial-temporal distribution of resting eggs of marine cladocerans in the Guanabara bay sediment, and the relationship with seasonal variations of planktonic populations and to the bay's sediment type. This study is pioneer for tropical marine waters, and represents an important step towards the comprehension of the distribution of marine cladocerans in their benthic phase, therefore contributing to clarify the dynamics of these animals.

Material and Methods

Guanabara bay is located in the State of Rio de Janeiro (22°41'-22°56'S and 43°02' - 43°18'W). It is currently considered one of the most vulnerable Brazilian bays, being a typical example of an environment undergoing an accelerated eutrophication process. This condition is mainly due to the great amounts of organic matter (untreated domestic effluents) dumped everyday into the bay (Feema, 1990; Paranhos *et al.*, 1995).

To analyze temporal distribution, sediment samples without replicates were collected at three stations in Guanabara bay denominated 1, 2 and 3, chosen because of different sediment types, ranging from sand to clay (Fig.1). Samples were collected monthly, from September 1999 to July 2000, by means of an Ekman grab, and preserved with formaldehyde 10%.

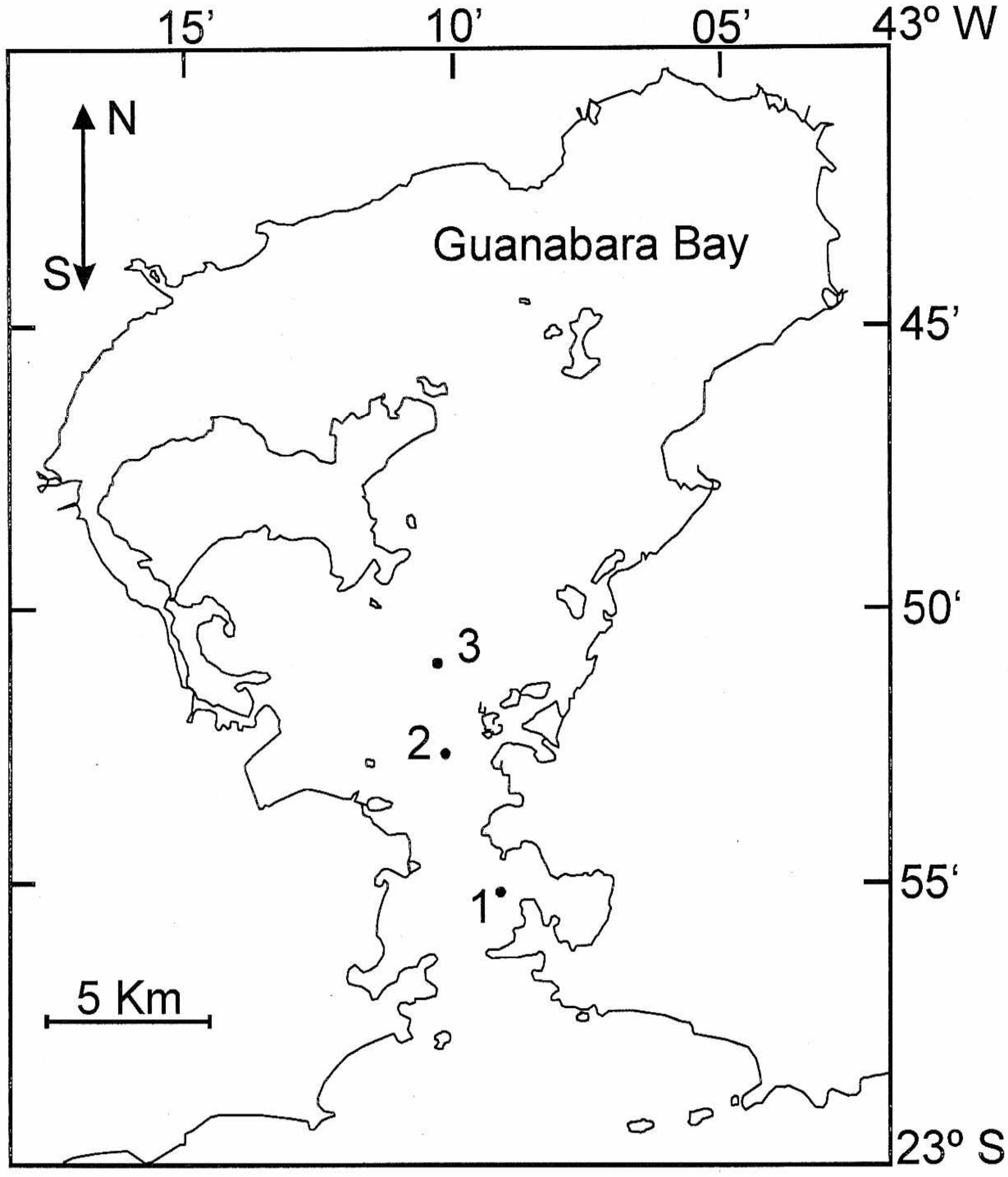

Figure 1: Location of the sampling stations in Guanabara bay.

In order to verify vertical distribution, sediment samples were collected in July 2000 with three replicates, at a single point in the bay with approximately 15 m depth (station 3), chosen because of its high percentage of sediment particles smaller than 50 µm. This type of sediment tend to show high densities of resting eggs (Onbé, 1985). A 1-inch diameter corer was used. Samples retained in the tubes were fractionated at each 3 cm depth, to a total of 21 cm, and fixed with formaldehyde 4%.

Separation of resting eggs was made by sieving samples through a net of 100 µm of mesh size. The sieved residue was transferred to centrifuge tubes, with a dense sugar solution (1 kg sucrose in 1 liter of water), and centrifuged at 3,500 rpm for 4 minutes (Onbé 1978). The centrifugation was performed three times and the floating material was collected for quantification of the eggs. The resting eggs were identified according to the description supplied by Onbé (1985), and densities were estimated and expressed in number of eggs.m^{-3}.

According to Onbé (1985), high densities of resting eggs are found in sediment samples with high percentage of particles smaller than 50 µm. So, determination of the granulometric characteristics of the sampled sediment was made based on this percentage: starting from an initial determined volume, samples from the three stations were washed through nets of 50, 100 and 200 µm of mesh size. Final sediment volume was determined as from the fraction of particles retained by the mesh.

Results

Horizontal and Temporal Distribution

Station 1 has a predominance of sandy, light colour sediment, comprising mainly particles over 200 μm in size (0% particles < 50 μm). Station 3 displays clay sediment, with approximately 60-80% of particles < 50 μm, whereas station 2 displayed intermediate features when compared to the other station (16-17% particles < 50 μm). (Table I).

Table I: Granulometric analysis of the sediment from the three sampling stations.

Station	X < 50 μm	Size of particles (X) 50 μm < X > 100 μm	100 μm < X > 200 μm	X > 200 μm
1	0 - 1%	-	-	99 - 100%
2	16 - 17%	4%	80%	-
3	60 - 80%	20 - 40%	-	-

Resting eggs belonging to the three species of marine cladocerans that occurs in Guanabara bay were found: *Penilia avirostris* Dana, 1852, *Pseudevadne tergestina* (Claus, 1877) and *Pleopis polyphemoides* Leuckart,1859 (Fig.2). The resting eggs of *P. avirostris* are ovoid and dorso-ventrally flattened. Their average length is 254 μm, and approximately 192 μm wide. Most eggs have a concavity on one face and display a whitish color under reflected light. Resting eggs of *P. tergestina* are spherical, brownish and have an average diameter of 200 μm. The external membrane does not display any ornaments under the light of the optical microscopy. Resting eggs of *P. polyphemoides* are similar to those of *P. tergestina,* with an average diameter of 205 μm. They display ornaments in the external membrane and a yellowish colour under reflected light.

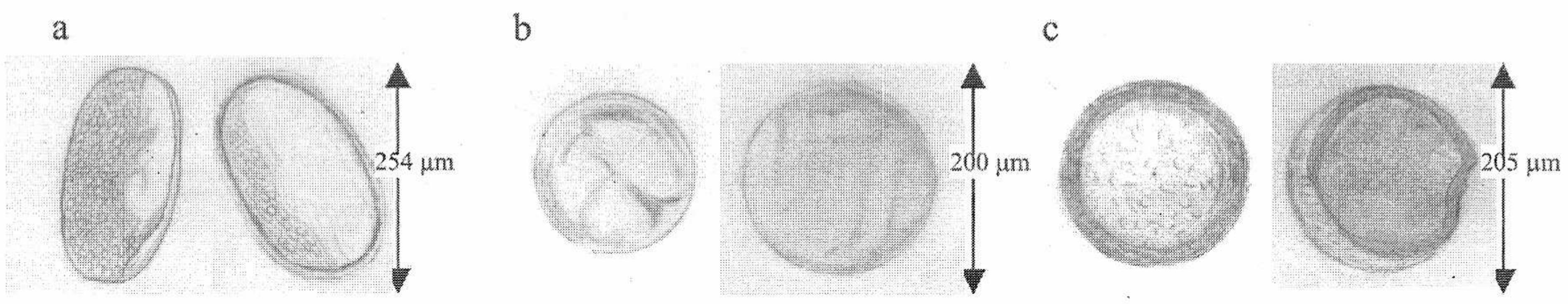

Figure 2: Schematic representation of the resting eggs of marine cladocerans occurring in the Guanabara bay sediment: a) *P. avirostris*, external view and detail of the concavity in one face; b) *P. tergestina*; c) *P. polyphemoides*, external view and detail of the thick external membrane.

The resting eggs of *P. avirostris* were the most abundant, with a maximum density of 6.4 x10^5 eggs.m^{-3} in June 2000. This variation followed a very peculiar pattern, with an alternate succession of high (6.3 x10^4 eggs.m^{-3}) and low (0-2.0 x10^4 eggs.m^{-3}) densities. Although the temporal distribution of *P. tergestina* and *P. polyphemoides* (Fig. 3) is not so clear due to its lower abundance, it displays a pattern similar to that of *P. avirostris*, with maxima (2.0 x10^4 eggs.m^{-3}), mainly observed from November to February. In plankton, density peaks of *P. avirostris* occurred in May (114 ind.m^{-3}, in average) and in June (average of 285 ind.m^{-3}); *P. tergestina* occurred in March (359 ind.m^{-3}, in average), and *P. polyphemoides* occurred in January (average of 980 ind.m^{-3}) (Fig. 4).

The greatest densities of resting eggs of *P. avirostris, P. tergestina* and *P. polyphemoides* were observed in the clayish sediment at station 3, which bears a high percentage (60-80%) of particles smaller than 50 μm. In the sandy sediment of station 1 (less than 1% of < 50 μm particles) it was observed the almost complete absence of eggs (Fig. 5).

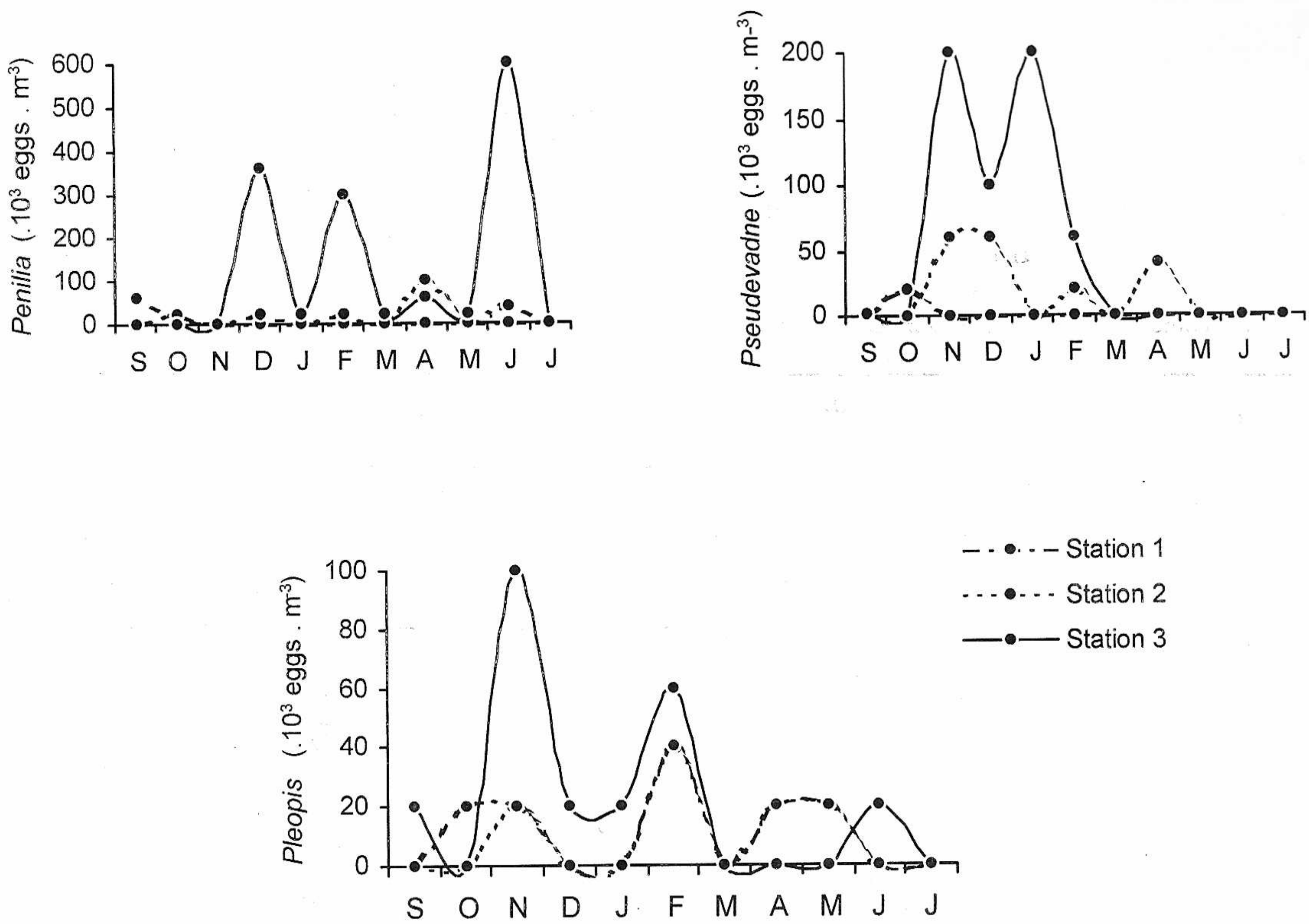

Figure 3: Density variation of resting eggs of *P. avirostris, P. tergestina* and *P. polyphemoides* in Guanabara bay sediment.

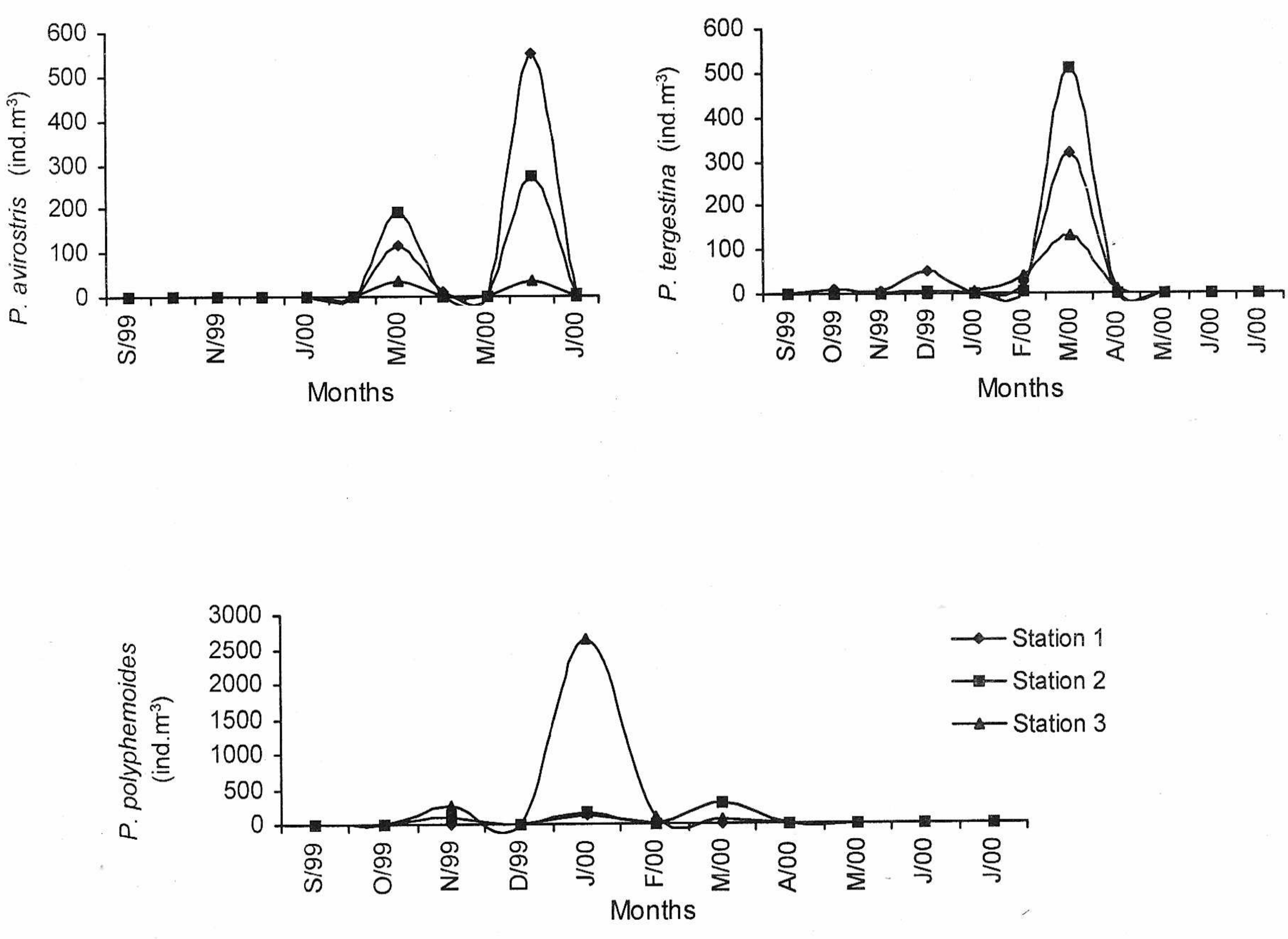

Figure 4: Density variation of *P. avirostris, P. tergestina* and *P. polyphemoides* in Guanabara bay.

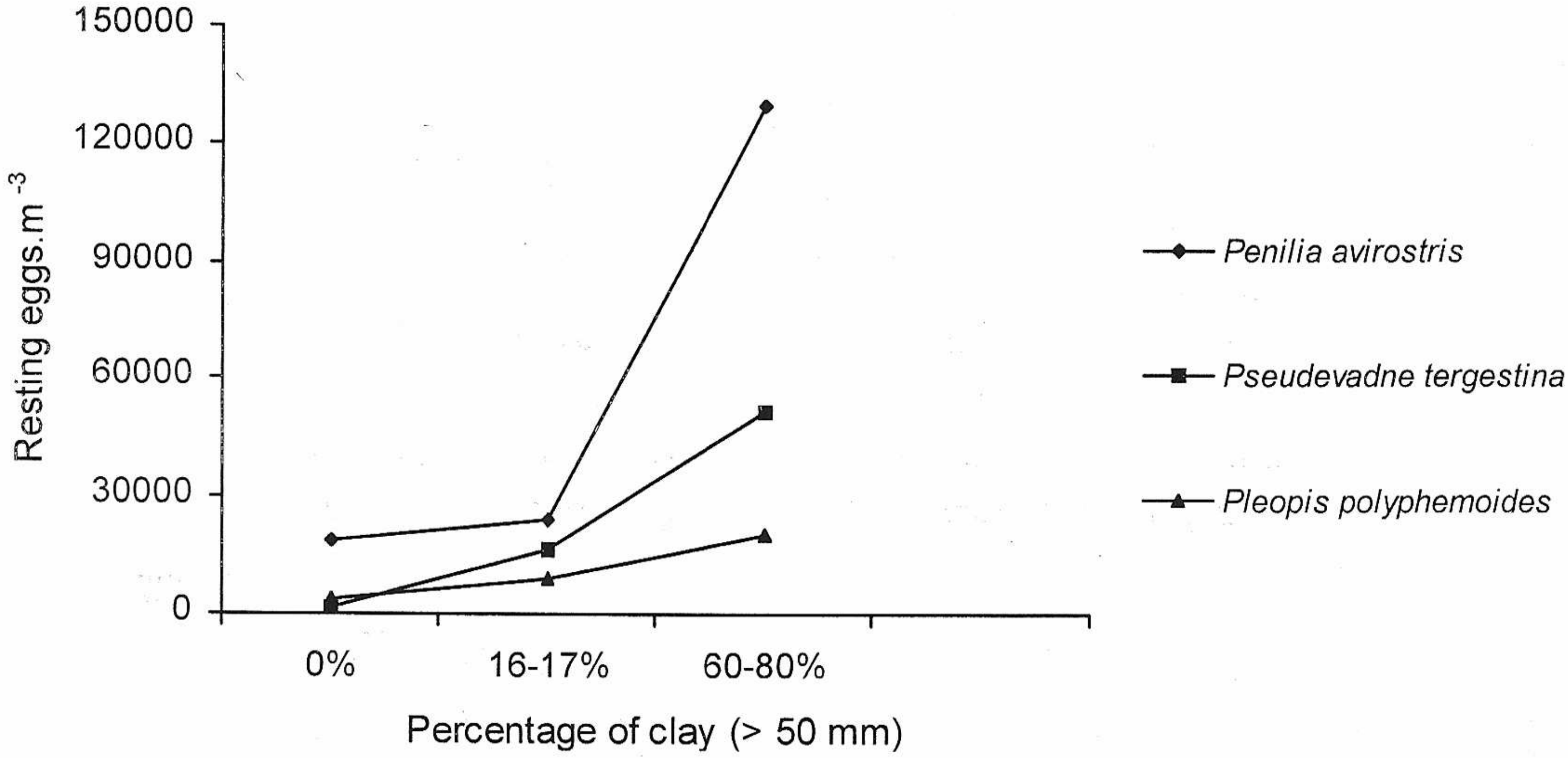

Figure 5: Distribution of resting eggs of marine cladocerans on account of different types of sediment on the bottom of Guanabara bay. Density values represent annual means.

Vertical Distribution

Resting eggs of *P. avirostris* and *P. polyphemoides* were observed in the first 21 cm depth of sediment column. Resting eggs of *P. avirostris* were abundant on the surface (1.5×10^3 eggs.m^{-2}). Their densities decreased up to 9 cm depth (minimum of 4.4×10^2 eggs.m^{-2}) and significantly increased afterwards up to 18 cm, where a maximum peak of 2.6×10^3 eggs.m^{-2} was recorded. The distribution of resting eggs of *P. polyphemoides* was relatively homogeneous in the sediment column with a maximum density reaching 6.6×10^2 eggs.m^{-2} at 9 cm depth (Fig. 6). The sample located at 9 cm depth showed a simultaneous decrease in the density of resting eggs of *P. avirostris* and an increase in density of resting eggs of *P. polyphemoides*.

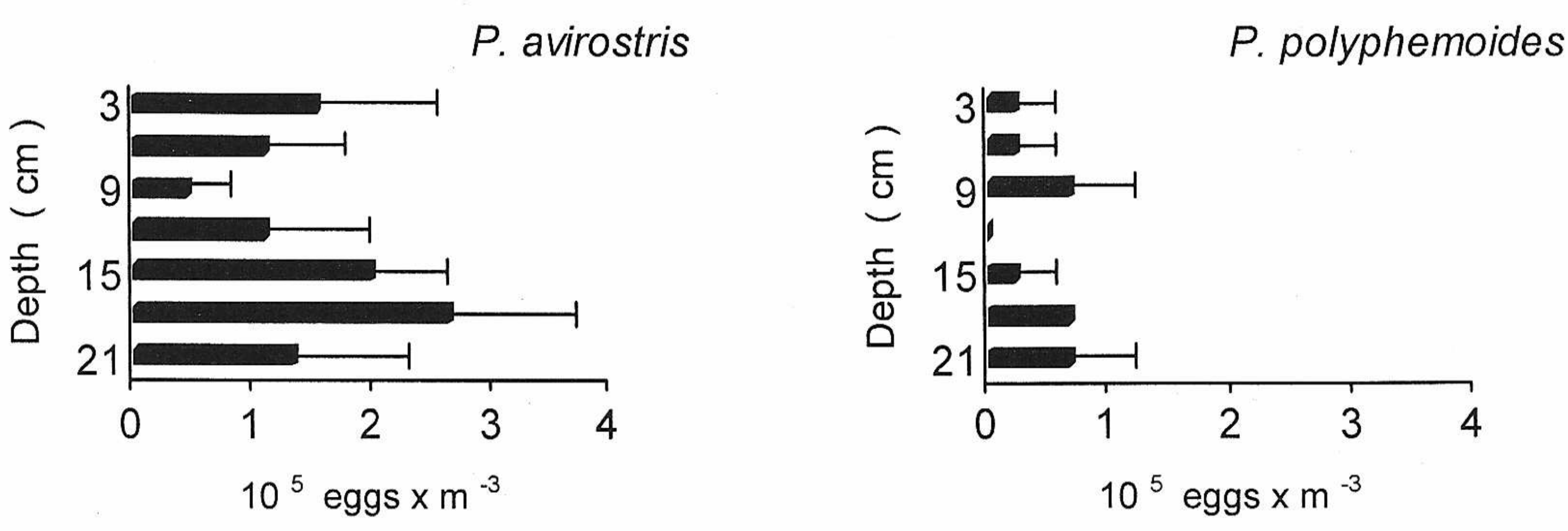

Figure 6: Vertical distribution of *P. avirostris* and *Podon polyphemoides* resting eggs in Guanabara bay. (boxes = mean; whiskers = standard deviation.).

Discussion

The factors conditioning the transition from parthenogenesis to sexual reproduction are still unknown for marine cladocerans. However, it is supposed that the change in reproductive strategy is caused by the influence of unfavourable external conditions, and that the determining factors should be temperature, food levels, population density, chemical agents, and excretion products. According to this hypothesis, these factors generate a state of 'depression' in parthenogenic females: they undergo a decrease in body mean length and in the number of embryos in the brood pouch, sexual reproduction starts and these organisms, formerly planktonic, go through adverse conditions in the form of resting eggs in sediment on the sea bottom. In temperate regions, researchers such as Onbé (1985), analyzing the dynamics of marine cladocerans have found a good relation between the change of reproductive strategy and the decline of temperature in winter. However, the few works performed in Brazil do not set a clear influence of temperature on inducing resting egg production in cladocerans, because of the low variation ranges of the factor (Marazzo, 1998; Gomes, 2000; Alecrim, 2000).

The close relationship between the temporal distribution of resting eggs and cladoceran populations in plankton matches the observations made by Onbé (1985) in the Inland Sea of Japan. According to this author, maximum abundance of resting eggs in sediment is recorded before the disappearance of the species from the plankton, followed by a considerable decrease in the substrate when the first population reappears in pelagical water. Based on this fact, Onbé (1985) suggested that marine cladocerans in the Inland Sea of Japan may pass through the winter period as resting eggs in the bottom sediment, and these eggs hatch in spring and beginning of summer, giving rise to parthenogenic females, which restart planktonic populations. *P. avirostris* is the dominating species of cladocerans in Guanabara bay and occur most of the year (Nogueira *et al.*, 1988; Marazzo, 1998; Alecrim, 2000; Marazzo and Valentin, 2000; Marazzo and Valentin, 2001). The occurrence of resting eggs in sediment through out the study period suggests a continuity of the sexual reproduction strategy and may indicate that the bay should be an unfavourable environment for these animals. Gomes (2000) detected the same phenomenon around the Submarine Sewage Discharge Pipeline in Ipanema, an environment marked by a high pollution degree.

In this research, it was thus verified that only the maximum density value of *P. avirostris* in plankton in July was concomitant with the peak of resting eggs, the other values have almost no correspondence to the populations fluctuation. The expected relation between the resting eggs and planktonic populations might only be confirmed by means of a sampling strategy compatible with the dynamics of populations of cladocerans in Guanabara bay. The various reproduction, production, fertility, hatching, and development rates comprise important parameters to infer on the determination of temporal fluctuations of cladocerans and thus for the establishing of the most appropriate sampling method for their study.

Since resting eggs may represent an evolutive adaptation of cladocerans under adverse conditions, a close relationship between the decline of planktonic populations and abundance of resting eggs in sediment is expected. However, the decline of *P. tergestina* and *P. polyphemoides* populations in plankton of Guanabara bay was followed by non-detection of their eggs in sediment samples. This fact may be related to the rapid hatching of the eggs, followed by a high mortality rate of the animals due to unfavourable conditions in pelagical water. Predation pressure on resting eggs and young animals, as well as the transport of these eggs through water currents may also constitute a feasible explanation for the decrease in density of these eggs in sediment.

In relation to vertical distribution, the resting eggs of *P. avirostris* and *P. polyphemoides* showed a marked vertical distribution. This fact may reflect, for example, the variations in the intensity of sexual reproduction of planktonic populations along time. Besides, resting eggs may be carried to deeper layers by current action (Onbé, 1985; Viitasalo and Katajisto, 1994). The sea bottom currents comprise the main factor regulating the vertical distribution and hatching rate of mesozooplankton resting eggs, as this event is responsible for the stratification of material in the sediment, oxygen distribution and necessary conditions to the survival of benthic organisms (Viitasalo and Katajisto, 1994; Albertsson and Leonardsson, 2000).

Guanabara bay sediment had displayed lower resting eggs densities on the surface than on the deeper layers, suggesting that the eggs may have been predated, hatched or, resuspended in the water-sediment interface. Eggs' disinterment is lead by important mechanisms: in shallow waters, such as lakes and bays, the resuspension of bottom sediment occurs due to tides and currents, which promote resuspension and hatching of eggs. In environments not subjected to these factors, bioturbation may play an important role in the recruiting process of mesozooplanktonic organisms. Such role may be either negative, by providing the sinking of eggs in the sediment column, or positive, by allowing the return of the eggs from deeper layers to the surface, thereby favouring their resuspension in the water column and hatching (Marcus, 1996; Marcus and Schmidt-Gengenbach, 1986, for copepods; Albertsson and Leonardsson, 2000). Thus, the variation in the abundance of resting eggs in sediment may reflect the distribution of benthic animals (Marcus, 1996). This relationship, however, has not been ascertained in Guanabara bay yet.

The ascertaining of the sedimentation rate on account of historical events taking place in the environment is of great importance, as it allows to date eggs located at various depths. Future investigation should verify the viability of resting eggs from different depth levels and, therefore, contribute to the knowledge on the role of resting eggs in the recruitment of populations of cladocerans in the plankton.

Conclusion

The resting eggs of marine cladocerans *P. avirostris, P. tergestina* and *P. polyphemoides* occurr in the sediment of the Guanabara bay. The temporal distribution of these resting eggs display a marked fluctuation, with periods of high densities followed by total absence in some sediment samples. In general, resting eggs show a decrease in densities just before planktonic populations display high densities. The resting eggs of *P. avirostris* are the most abundant in the sediment, thus reflecting the dominance of this species among the cladocerans of the Guanabara Bay.

Acknowledgements

We would like to thank Francisco Mattos and Luis Carlos for their help during field trips in Guanabara bay. The third author wishes to thank the 'Programa de Pós-graduação em Zoologia' for the opportunity to develop her doctoral research on cladocerans in Guanabara bay. Financial support was given by Conselho Nacional de Desenvolvimento Científico e Tecnológico, Fundação de Amparo à Pesquisa no Estado do Rio de Janeiro and the 'Programa de Apoio a Núcleos de Excelência'.

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Received: 15th Dec 2000
Accepted: 15th Dec 2001