Selectivity of plankton nets over planktonic Copepoda in two sub-tropical estuaries

Seletividade de redes de plâncton sobre Copepoda planctônicos em dois estuários sub-tropicais

Favareto, LR.[1], Perbiche-Neves, G.[3], Serafim-Júnior, M.[2] and Sartori[3], LP.

[1]Departamento de Oceanografia Biológica, Instituto Oceanográfico, Universidade de São Paulo – USP, Praça do Oceanográfico, 191, CEP 055058-900, São Paulo, SP, Brazil
e-mail: lucianefavareto@yahoo.com, lpsartori@yahoo.com.br

[2]Departamento de Zoologia, Universidade Estadual Paulista – UNESP, Distrito de Rubião Júnior s/n, CEP 18618-000, Botucatu, São Paulo, Brazil
e-mail: gilmarpneves@yahoo.com

[3]Laboratório de Ecologia Aquática, Centro de Ciências Biológicas e da Saúde, Pontifícia Universidade Católica do Paraná – PUCPR, Rua Imaculada Conceição, 1155, Prado Velho, Curitiba, Paraná, Brazil
e-mail: m.serafim@pucpr.com

Abstract: Aim: This study was carried out to evaluate the planktonic copepod assemblages selected by the use of two different mesh sizes (64 and 200 µm) plankton nets, in two sub-tropical Brazilian estuaries (Paranaguá and Guaratuba – PR). **Methods:** For one year three stations were sampled monthly in each estuary, with 64 and 200 µm plankton nets. Ecological attributes were evaluated as species composition, richness, diversity, equitability and abundance. **Results:** A total of 30 taxa were recorded, including young and adult individuals. Three taxa occurred only in the 200 µm mesh size net, and only one was exclusive of the 64 µm net. Copepodites and nauplii were frequent and abundant in the 64 µm mesh size net. On the other hand, adult forms were dominant in the 200 µm net. The Oithonidae family dominated the samples from the 64 µm mesh size net, and in some months in the 200 µm mesh size, alternating with Acartidae, Clausocalanidae, and Paracalanidae. Higher richness and diversity were observed in the samples from the 200 µm net, and evenness suggested uniformity in the assemblages of the two nets in most of the studied months. **Conclusions:** Our results suggest the use of nets of different mesh sizes according to specific purposes and objectives related to the ecological attributes.

Keywords: zooplankton, Copepoda, net comparison, subtropical estuaries, Brazil.

Resumo: Objetivo: Este estudo está relacionado às diferenças entre as assembléias de Copepoda amostradas com redes de plâncton de 64 e 200 µm, em dois grandes estuários tropicais brasileiros (Paranaguá e Guaratuba – PR). **Métodos:** Por um ano foram amostrados mensalmente 3 pontos distribuídos em cada estuário, com auxílio de redes de 64 e 200 µm. Atributos ecológicos básicos foram evaluados, tais como composição, riqueza de espécies, diversidade, equitabilidade e abundância. **Resultados:** Um total de 30 táxons foi registrado, incluindo formas jovens e adultas. Três táxons ocorreram somente nas amostras com rede de 200 µm, apenas um foi exclusivo da rede de 64 µm. Copepoditos e náuplios foram freqüentes e abundantes nas amostras com rede de 64 µm, no entanto os adultos dominaram nas amostras realizadas com rede de 200 µm. A família Oithonidae foi dominante com a rede de 64 µm e em alguns meses com a rede de 200 µm, alternando-se com Acartidae, Clausocalanidae e Paracalanidae. Os maiores valores de riqueza e diversidade ocorreram nas amostras realizadas com a rede de 200 µm, e a equitabilidade sugeriu uniformidade nas assembléias nas duas redes em quase todos os meses de estudo. **Conclusões:** Os resultados sugerem o uso de diferentes tamanhos de rede para objetivos diferenciados, relacionado aos atributos ecológicos estudados.

Palavras-chave: zooplâncton, Copepoda, comparação de redes, estuários sub-tropicais, Brasil.

1. Introduction

Copepod (Crustacea Maxillopoda) comprehends the most abundant group of the marine and estuarine zooplankton and also presents the highest biomass (Bradford-Grieve et al., 1999). These organisms act efficiently and directly in the energy and biomass transfer between the primary producers and the higher trophic levels (Chang and Fang, 2004), also contributing to the organic matter flow to the decomposers (Feinberg and Dam, 1998; Zervoudaki et al., 2007).

Many Brazilian studies focused the spatial and temporal variability of the assemblages, based on the composition, species richness, abundance, diversity, biomass (Silva et al., 2003; Ara, 2004; Krumme and Liang, 2004), secondary productivity (Ara, 1998, 2001a,b, 2002; Lopes, 1997; Kaminski and Montú, 2005), or yet, anthropic activities, like environmental impacts (Souza-Pereira and Camargo, 2004) and important economic impoundments (Tundisi et al., 1978; Neumann-Leitão et al., 1992; Lopes, 1994; Aben-Athar and Costa-Bonecker, 1996; Resgalla-Júnior, 2001; Silva et al., 2004).

On the other hand, few studies have performed comparisons of copepod assemblages using different sampling methodologies (Omori and Ikeda, 1984; Ohman and Smith, 1995; Hopcroft et al., 2001; Lam-Hoai et al., 2006), like studies referring to plankton mesh size and the type of net used. In Brazil, Miyashita (2007) compared the use of plankton nets of 64 and 300 µm on copepod assemblages in the estuarine complex of Santos (SP). Commonly, there is no comparative information about the net size used, although it is known that nets of small mesh sizes proportionate high abundance of small-sized organisms (Neumann-Leitão et al., 1994; Souza-Pereira and Camargo, 2004).

In order to evaluate the plankton net selectivity in copepod communities, this study analyzed the differences in mesh sizes (64 and 200 µm) in a different temporal scale, testing the hypothesis that small-sized organisms are sampled in higher numerical abundance in the 64 µm mesh size, and higher diversity occur in 200 µm nets.

2. Material and Methods

The estuarine systems studied are located in the coast of Paraná State, Brazilian southeastern region, and are known for their wide environmental and economic importance. The estuarine complex of Paranaguá is one of the largest in the planet (area: 620 km^2), formed by the bays of Paranaguá, Antonina, Laranjeiras, Guaraqueçaba, and Pinheiros (Ipardes, 1995). There are important harbour impoundments (Paranaguá and Antonina harbours) and mariculture areas in expansion, mainly oysters and mussels culture. In Guaratuba Bay (area: 49 km^2) there are not harbour areas, and the oyster culture is growing even faster.

Monthly samples were performed from June/05 to May/06, in three sampling stations in each estuary (Figure 1), located along the central area of each station. A total of 144 zooplankton samples were collected. Two

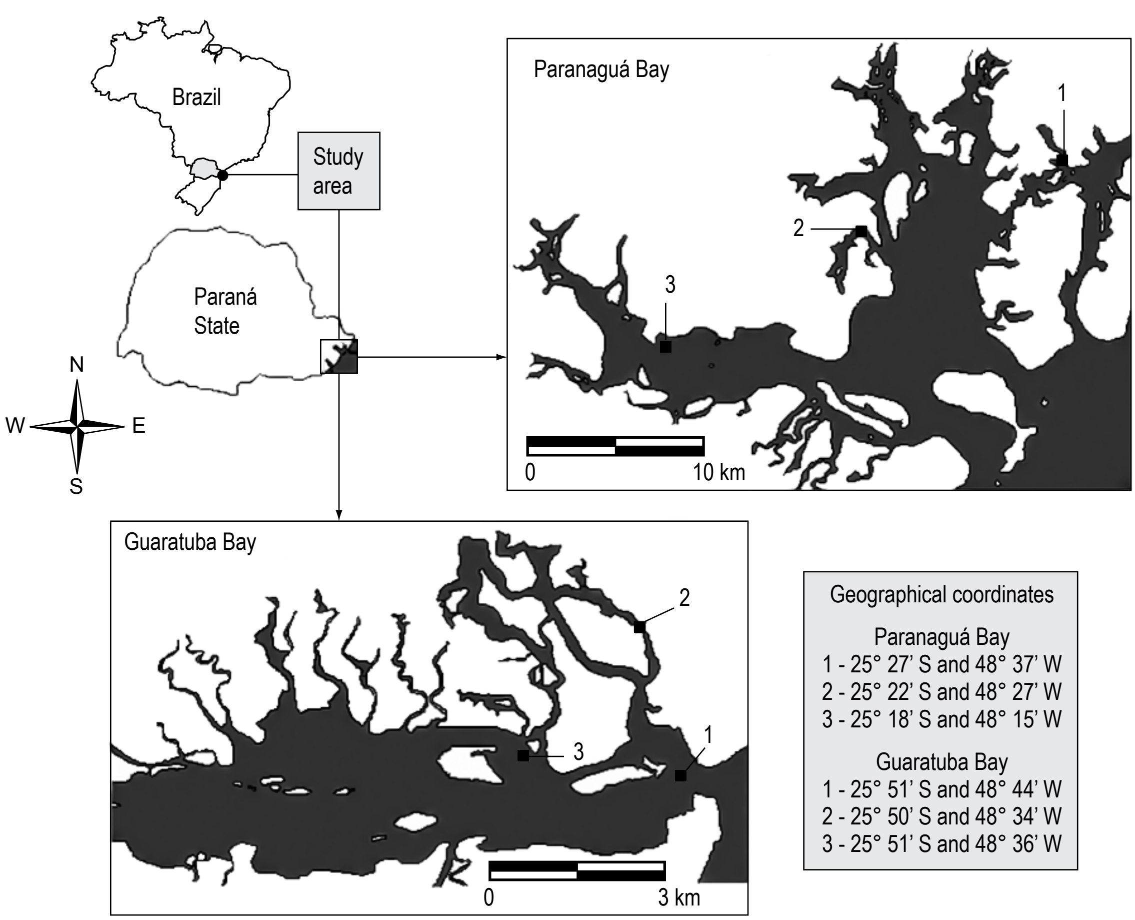

Figure 1. Sampling area and stations, with geographical coordinates.

conical zooplankton nets of 64 and 200 µm mesh sizes were used to collect the organisms, and 200 and 400 L of surface water were filtered through the nets, respectively. After collection, the samples were kept in plastic bottles and fixed with 4% formaldehyde, buffered with calcium tetraborate.

In the laboratory, qualitative and quantitative analyzes were carried out in a Sedgewick-Rafter chamber, under binocular microscope, using subsamples of 1 mL. Copepods were identified according to Bradford-Grieve et al. (1999), and the other groups according to Boltovskoy (1999). A minimum of 300 individuals per sample were counted and abundance data was expressed as ind.m^{-3}.

The Shannon-Wiener diversity and the Pielou's evenness were calculated only for the adult forms.

To test significant differences in copepods, Kruskal-Wallis H test (ANOVA) was performed using the total abundance means (Statistic 6.0 - Statsoft, 2000). The three sampling stations of each bay were used as replicates in order to obtain a greater number of samples (N = 144).

3. Results

A total of 30 Copepoda taxa were identified including immature forms (nauplii and copepodites) and adults (Table 1). Three taxa occurred only in the samples from the 200 µm mesh size, and only one species was exclusive from the samples of the 64 µm mesh size. In the samples from the 64 µm net, the immature forms were more frequent, represented by *Oithona* copepodites (100%), followed by *Acartia* (86%), *Euterpina,* and *Clausocalanus* (both 64%). Among the adults, *Oithona hebes* (67%), male of *Oithona* sp. and *Clausocalanus furcatus* (both 50%) presented higher frequencies.

In the samples from the 200 µm net, *Acartia* copepodites presented the highest frequency (92%) (Table 1). Copepodites of *Temora* (67%), *Pseudodiaptomus* (56%), and *Oithona* (58%) occurred in high frequencies. Among the adult forms, *O. hebes* (69%), *Clausocalanus furcatus* (67%), *Acartia tonsa* (58%), and *Euterpina acutifrons* (53%) were the most frequent.

In relation to the total abundance, it was observed a significant difference ($p < 0.05$) for 14 taxa between the two the nets (Table 1), and nine taxa presented higher values in the samples from the 64 µm net and five in the samples from the 200 µm net (Figure 2). Higher significant differences ($p < 0.000$) were observed to *Oithona hebes*, *O. oswaldocruzi, Oithona* copepodites, *Acartia tonsa, A. lilljeborgi, Clausocalanus* and *Euterpina* copepodites and nauplii.

In Figure 3, it is possible to observe the variation in species richness, Shannon-Wiener diversity, and evenness obtained with the two nets. Most of these values were observed in the samples obtained with the 200 µm net; however, the highest evenness occurred in the samples obtained with the 64 µm net (in January/06 in Guaratuba Bay). Values equal to zero were also observed in February/06 due to the low richness and diversity. In general, evenness was uniform to the samples from the two nets in most of the studied months, with values equal to zero and above 0.5.

The highest richness was observed in the samples from the 64 µm net, occurring in July/05, August/05 and November/05 in Guaratuba Bay, and June/06 and April/06 in the estuarine complex of Paranaguá. In Guaratuba, lower values were recorded in February/06, January/06 and September/05, and in Paranaguá in May/06, August/05, October/05 and November/05 (Figure 3). In the samples from the 64 µm net, the highest richness values were equal (10 species) in both estuaries samples, however, the lowest values were found in Guaratuba Bay.

In relation to the 200 µm net, higher richness were recorded in Guaratuba Bay, in March/06, July/05 and August/05, and the lowest in February/06, coinciding with the observed for the 64 µm net (Figure 3). In Paranaguá Bay, higher richness also occurred in March/06, followed by October/05 and January/06. Comparing the estuaries in relation to the results obtained with the 200 µm net, it was observed the highest value in Guaratuba Bay (14 species), resulting in higher Shannon-Wiener diversity values. However, in the remaining months, values above 10 species were found in this estuary, differing from Paranaguá, where in five of the 12 sampled months were observed values equal to or higher than 10.

Values higher than 2.0 bits.ind^{-1} were not observed for the Shannon-Wiener diversity. In the samples from the 200 µm net, mean values were observed in some months, but in general, lower than 1.0 bits.ind^{-1} in most months (Figure 3). In the samples from the 64 µm net, the highest values occurred in July/05 in both estuaries, also in September/05 and April/06, in Paranaguá estuarine complex. In the samples from the 200 µm net the highest values were recorded in March/06 for both estuaries.

In relation to the relative abundance, nauplii dominated in all sampled months, in both estuaries, with the 64 µm net (Figure 4). In the samples from the 200 µm net, it was observed the dominance of copepodites instead of nauplii, followed by adults in most sampled months.

In relation to the adult forms, it was observed that, in the samples from the 64 µm net, the Oithonidae family dominated in all the studied months in both estuaries (Figure 5). The only exception occurred in October/05 in Guaratuba Bay, where the proportion was similar to the Acartidae (50%), that together with Paracalanidae, were representative in most samples. From the 200 µm net samples, a higher number of families shifted in dominance (Oithonidae, Acartidae, Clausocalanidae, and Paracalanidae). Higher relative abundance of Temoridae was recorded in January/06.

Table 1. List of identified taxa, abbreviations, frequency of occurrence and results of Kruskal-Wallis test ANOVA (H and p) about the medians. Significant differences ($p < 0.05$) of abundance between the samples from the 64 and 200 µm nets are in bold.

Copepoda	Frequency %		Kruskal-Wallis ANOVA	
Taxa	64 µm	200 µm	H	P
Cyclopoida Oithonidae				
Oithona hebes Giesbrecht, 1891	67	69	33.17	**0.000**
Oithona oswaldocruzi Oliveira, 1945	-	6	0.334	**0.000**
Oithona sp. ♂	50	39	19.88	0.563
Copepodid of *Oithona*	100	58	86.81	**0.000**
Calanoida Paracalanidae				
Parvocalanus cf. *crassirostris* (Dahl, 1894)	3	6	0.661	0.415
Paracalanus cf. *aculeatus* Giesbrecht, 1888	14	25	0.645	0.421
Paracalanus sp.	6	8	6.894	**0.008**
Copepodid of *Paracalanus*	42	36	2.236	0.134
Calanoida Eucalanidae				
Subeucalanus pileatus (Giesbrecht, 1888)	-	6	2.589	0.076
Calanoida Temoridae				
Temora turbinata (Dana, 1849)	22	53	8.706	**0.003**
Copepodid of *Temora*	47	67	1.846	0.174
Calanoida Acartiidae				
Acartia tonsa Dana, 1840	22	58	11.21	**0.000**
Acartia lilljeborgii (Giesbrecht, 1889)	14	33	11.00	**0.000**
Copepodid of *Acartia*	86	92	5.000	**0.025**
Calanoida Centropagidae				
Copepodid of *Centropages*	6	17	0.037	**0.054**
Calanoida Pseudodiaptomidae				
Pseudodiaptomus acutus (Dahl, 1894)	3	22	9.051	**0.002**
Copepodid of *Pseudodiaptomus*	50	56	3.026	0.081
Calanoida Clausocalanidae				
Clausocalanus cf. *furcatus* (Brady, 1883)	50	67	0.281	0.595
Copepodid of *Clausocalanus*	64	22	17.71	**0.000**
Ctenocalanus cf. *vanus* Giesbrecht, 1888	6	17	5.316	0.211
Poecilostomatoida Oncaeidae				
Oncea cf. *venusta* Philippi, 1843	3	6	0.000	0.977
Copepodid of *Oncea*			1.014	0.313
Poecilostomatoida Corycaeidae				
Corycaeus cf. *amazonicus* Dahl, 1894	8	19	1.201	0.273
Copepodid of *Corycaeus*	3	3	0.971	0.992
Harpacticoida Euterpinidae				
Euterpina acutifrons (Dana, 1847)	25	53	3.759	**0.052**
Copepodid of *Euterpina*	64	14	41.49	**0.000**
Copepodid of other Harpacticoida	6	8	0.191	0.661
Harpacticoida Aegisthidae				
Copepodid of *Microsetella*	3	-	1.014	0.313
Nauplius (general)	100	86	101.39	**0.000**

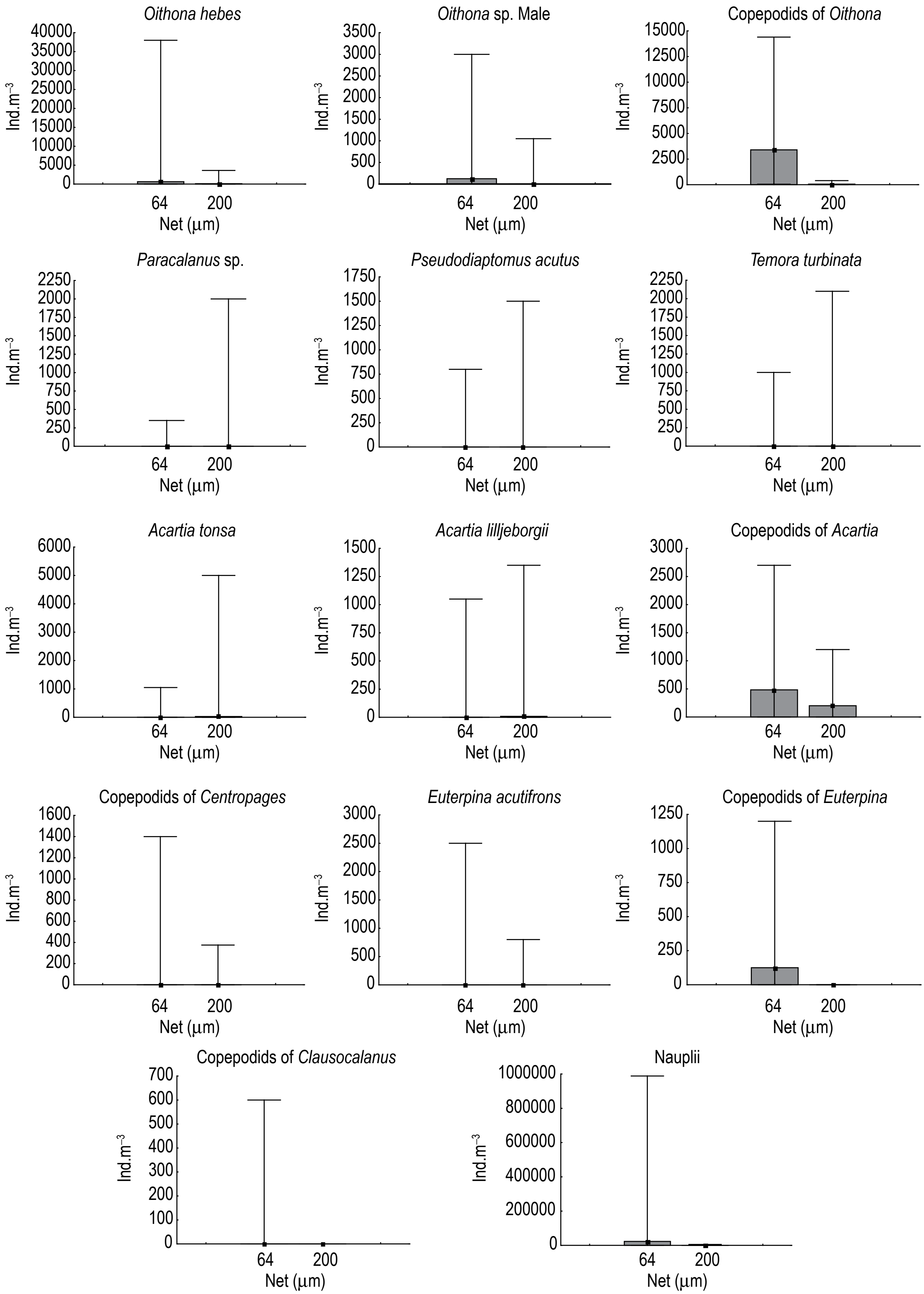

Figure 2. Median and variation range (maximum-minimum) of total abundance of Copepod taxa, for the ones with significant differences ($p < 0.05$) in the Kruskal-Wallis ANOVA test.

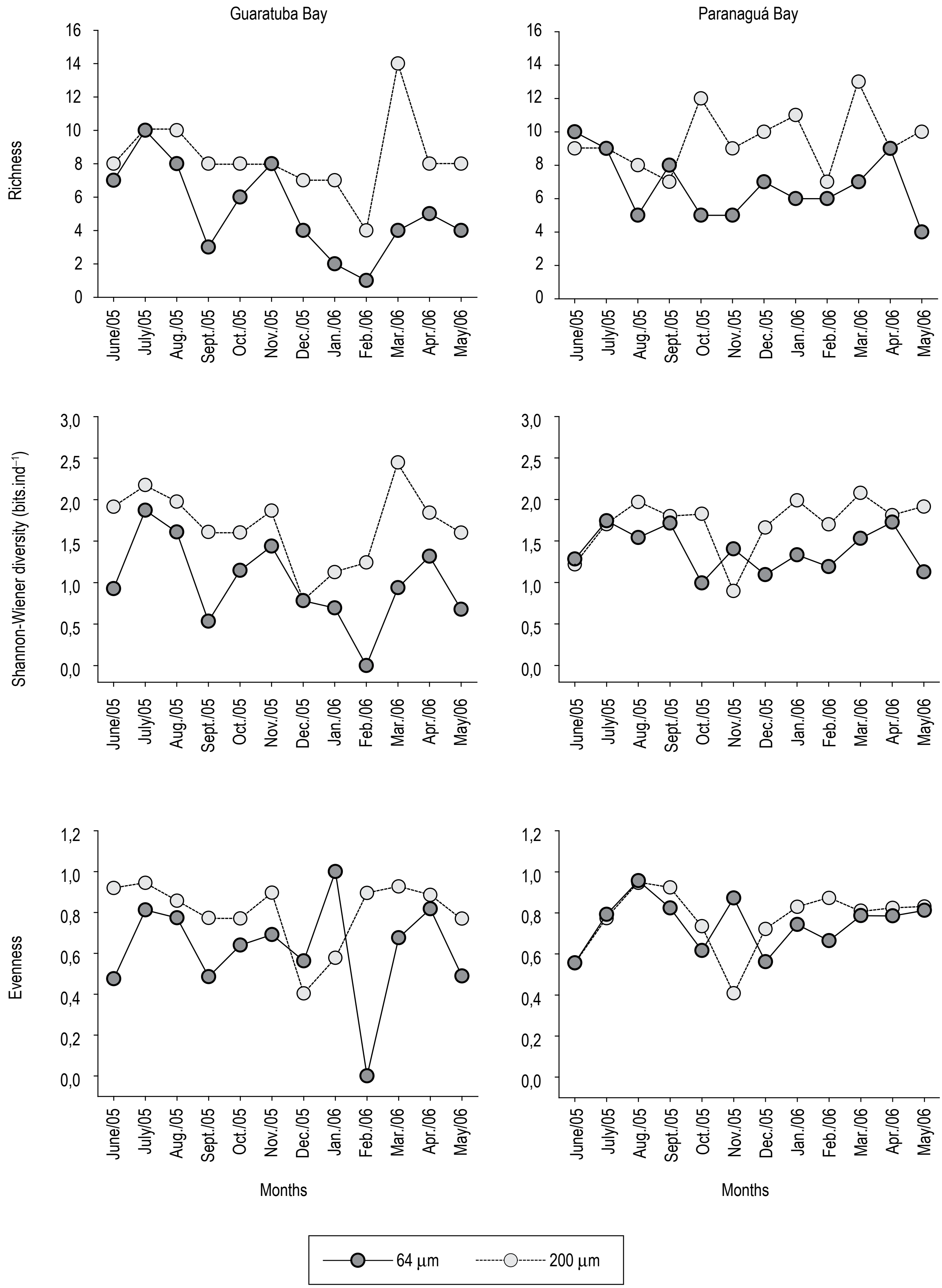

Figure 3. Species richness, Shannon-Wiener diversity (H') and Pielou's evenness (E) in the Bays of Guaratuba and Paranaguá during the study period.

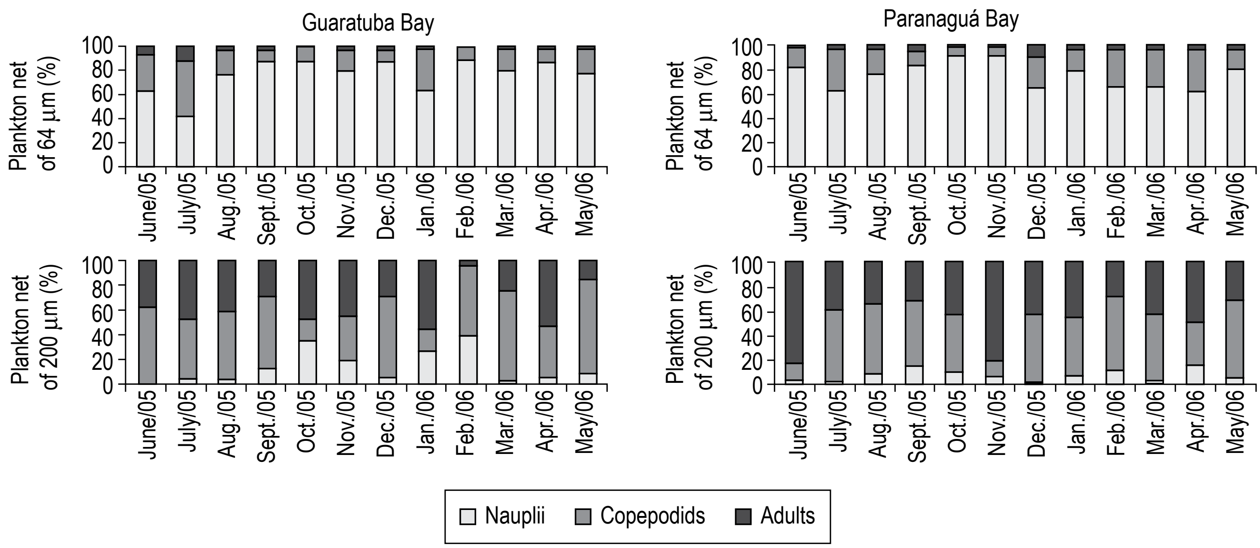

Figure 4. Relative abundance of nauplii, copepodites and adults from the 64 and 200-μm nets.

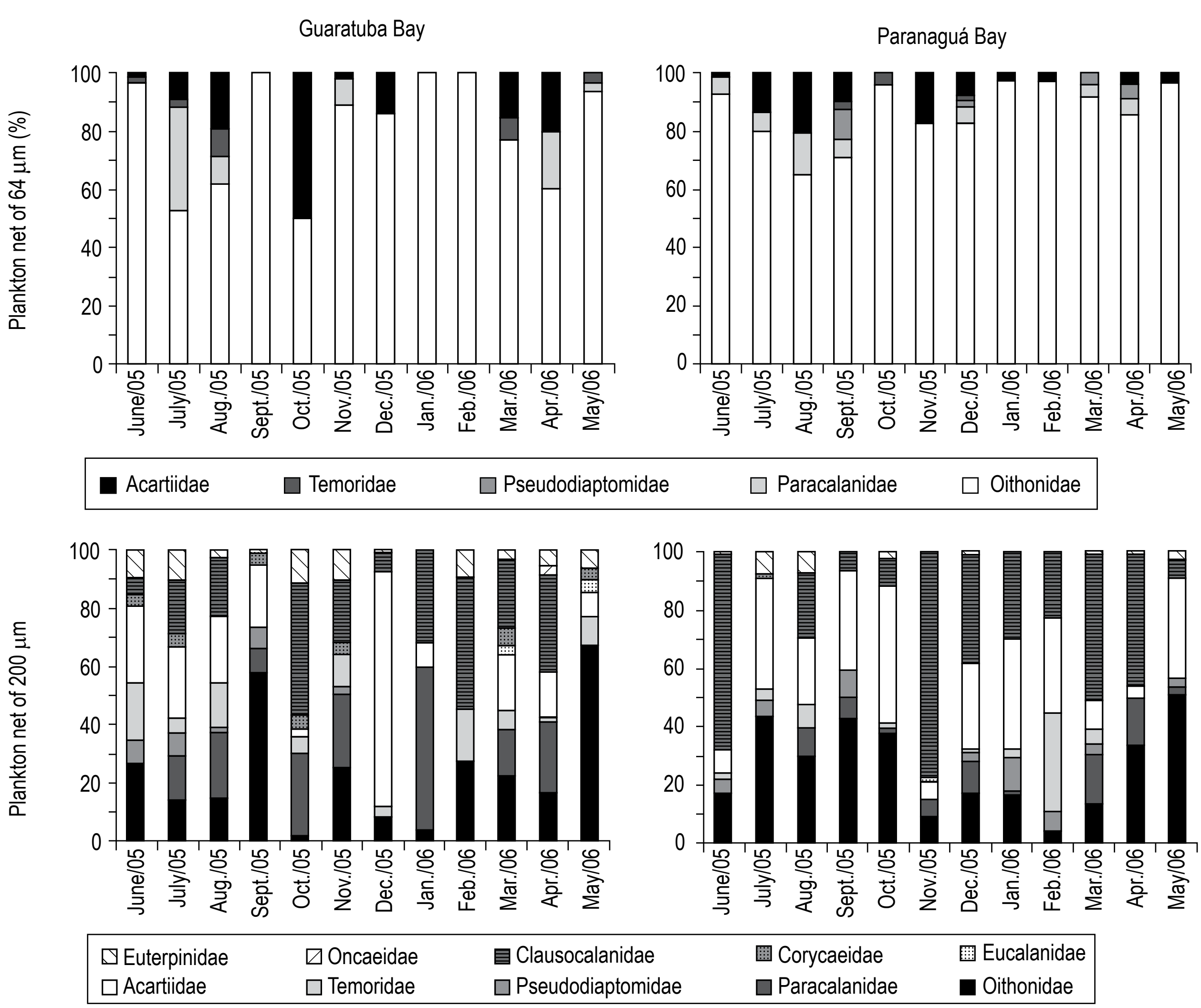

Figure 5. Relative abundance of the families from the 64 and 200-μm nets.

4. Discussion

The nets used showed differences in some analyzed ecological attributes. These results confirmed our hypothesis that was based on the specialized literature (Omori and Ikeda, 1984; Ohman and Smith, 1995; Ré, 2000; Lam-Hoai et al., 2006; Miyashita, 2007), which indicates that the variation of zooplankton structure is related to the net mesh size. Miyashita (2007) stated that for a better characterization of the marine copepods structure it is necessary to use nets smaller than 100 µm. Zervoudaki et al. (2007) mentioned that the smaller size spectra of plankton have densities and biomass higher than larger copepods. In some studies about zooplankton, small immature copepods occurring in high abundance may have been ignored due to methodological problems (Hopcroft et al., 1998).

Therefore, the use of larger mesh size nets is also important for the capture of larger organisms. According to Hopcroft et al. (2001), in the tropical and sub-tropical region, the 64 µm net is efficient in the sampling of organisms with prossome smaller up to 450 µm, and the 200 µm net to lengths between 450 and 1400 µm.

The taxonomic composition was not significant different because the samples were obtained simultaneously. The occurrence of the genera *Acartia*, *Temora*, *Parvocalanus*, *Paracalanus*, *Oithona,* and *Euterpina* are common in tropical and sub-tropical estuaries. Robertson et al. (1988) observed the dominance of *Parvocalanus crassirostris*, *Paracalanus* spp., some *Oithona* species and *Euterpina acutifrons* in the zooplankton from an estuary in the northeast of Australia. In Brazil, Ara (1998, 2001a, 2004) recorded these species among others, as the most important in the estuary of Cananéia (São Paulo). Also in São Paulo State, other studies recorded these genera in high amounts (Lopes et al., 1986; Lansac-Tôha and Lima, 1993; Lopes, 1994). In the Paranaguá estuarine complex, Lopes (1997) and Lopes et al. (1999) registered these genera that occurred in high frequency together with *Acartia* and *Temora*. Sartori and Lopes (2000) also recorded these genera among 44 species in longitudinal gradients in the continental shelf of Paraná using a 200 µm net. Ré (2000) considered the genera *Acartia* and *Pseudodiaptomus* as typical of estuaries, and *Paracalanus*, *Centropages*, *Oithona*, *Pseudocalanus*, *Temora* and *Euterpina* as eurihaline taxa.

Small copepod species (e.g. Oncaeidae) are common members of marine plankton communities, occurring in all depth zones of the world's oceans, from the epipelagic to the bathypelagic regions, and their great ecological importance is reflected both in high numerical abundance and species diversity (Böttger-Schnack and Huys, 2001).

Higher species richness and diversity occurred in the larger mesh size net, as a result of sampling higher number of adult individuals. For evenness, slightly higher values occurred in the 200 µm net, indicating higher homogeneity in the assemblages, however, similar results were observed for the samples from the 64 µm net. Lower species richness and diversity values observed in the samples from the 64 µm net can be explained by the elevated abundance of young individuals captured compared to adults, because during the samples analysis, they have surpassed the adults. To minimize this problem and to obtain higher richness and diversity, it is suggested to double the number of individuals counted per sample (>600).

In both nets, the immature forms (nauplii and copepodites) presented the highest values of frequency and abundance. This fact can be explained by the selectivity of both nets and because there is an elevated abundance of young forms in estuarine systems, as part of their reproductive strategy (Turner, 1984; Dussart and Defaye, 1995; Lopes, 1997; Ré, 2000; Souza-Pereira and Camargo, 2004).

Net mesh size was also responsible for the total and relative Copepod abundance. Considering total abundance, higher medians of adult individuals occurred in the 200 µm net, which caused alternated dominances of various families in the relative abundance, opposite to the observed in the samples from the 64 µm net.

In smaller nets, clogging of the mesh pores occurs, resulting in an accumulation of a higher number of organisms. According to Ré (2000) the use of nets of small mesh size leads to clogging, implying in the decrease of filtering efficiency, contrary to the larger mesh size nets which loose, by extrusion, organisms of small size. Krumme and Liang (2004) found underestimated values of Oithonidae and Oncaeidae nauplii when studying copepods in an estuary in the northeast of Brazil with 300 µm net.

The 200 µm net is the most used in marine and estuarine zooplankton sampling (Ré, 2000). Studies that used nets smaller than 100 µm mesh size focused smaller-sized organisms, like nauplii and copepodites (Marcus, 1991; Eskinazi-Santana and Björnberg, 2006). In Brazil, most studies used nets larger than 150 µm mesh size, associated to the study of the mesozooplankton. Table 2 presents a list of some studies carried out in Brazil and the respective mesh size used, and a summary of the found results.

The results obtained in this study suggest that future studies should take into consideration the mesh size chosen, and also the number of individuals counted per sample. In quantitative studies about numerical dominance, the net with small mesh size retained most organisms, being more appropriate for this purpose. However, in qualitative studies, the net with larger mesh size seemed to be more appropriate, capturing more adult forms, easier to identify. The attention to the net size to be used must focus the size of the organisms that will be studied, and differences in some of the studied attributes could be indicated, related to the mesh size chosen.

Table 2. List of Brazilian studies performed with different mesh size nets, related to copepod assemblages (S: species richness).

Authors	Net mesh size (µm)	S	Abundance/dominance
Neumann-Leitão et al. (1994)	65	26 species	Nauplii
Reid and Esteves (1984)	54	22 species	-
Souza-Pereira and Camargo (2004)	62	4 species and 4 genera	Nauplii
Araújo (1996)	120	57 species	Nauplii dominance, and among adults *O. hebes* (78%), followed by *E. acutifrons*.
Ara (2002, 2004)	150	37 dominant species	Dominance of *O. hebes*, *O. oswaldocruzi*, *A. lilljeborgi*, *A. tonsa*, *P. acutus*, *P. crassirostris*, *E. acutifrons* and *T. turbinata.*
Montú and Cordeiro (1988)	180	23 species	Dominance of *A. lilljeborgi*, *O. oswaldocruzi* and *E. acutifrons.*
Pereira and Loureiro-Fernandes (1999)	200	19 species	*A. tonsa*, *O. hebes*, *A. lilljeborgi* and *Parvocalanus quasimodo* Bowman, 1971.
Resgalla-Júnior (2001)	200	24 species	Higher abundances of *A. tonsa* and copepodites.
Sterza and Fernandes (2006)	200	49 species	Higher abundances of *A. lilljeborgi*, *A. tonsa*, *Paracalanus parvus*, *P. quasimodo*, *Parvocalanus crassirostris*, *Temora turbinata*, *O. hebes*, *O. oculata* and *E. acutifrons.*
Vale (1999)	300	11 species	Dominance of *A. lilljeborgi*, *T. turbinata*, *Labidocera fluviatilis* (Dahl, 1894), *P. acutus* and *P. aculeatus.*
Silva et al. (2003)	300	18 species and 3 genera	Dominance of *A. lilljeborgi* (31% of total zooplankton) and frequent in 94% of the samples
Silva et al. (2004)	300	19 species	Dominance of *A. lilljeborgi, P. crasirostris, O. hebes, Corycaeus speciosus* Dana, 1849, and *T. turbinata.*
Krumme and Liang (2004)	300 µm	12 species	*Pseudodiaptomus marshi* Wright, 1936

Aknowledgements

The authors are thankful to the alliance SETI/PUCPR for the financial support; to PUCPR for the logistic support; to the technicians of the project "Produção de sementes de ostra nativa (*Crassostrea rizophorae*) no litoral do Paraná" for the help on the field; and the anonymous referees by valuable suggestions.

References

ABEN-ATHAR, RV. and COSTA-BONECKER, SL. Zooplankton evaluation in the estuarine system of the Mucuri River, Bahia, on drought and flood situation. *Braz. Arch. Biol. Technol.*, 1996, vol. 39, no. 4, p.765-781.

ARA, K. *Variabilidade Temporal e produção dos copépodos no complexo estuarino lagunar da Cananéia, São Paulo, Brasil.* Universidade de São Paulo – USP, São Paulo, 1998. [Ph.D. Thesis].

ARA, K. Temporal variability and production of the planktonic copepods in the Cananéia Lagoon estuarine system, São Paulo, Brazil. II. Acartia lilljeborgi. *Plankton Biol. Ecol.*, 2001a, vol. 48, no. 2, p.35-45.

ARA, K. Length-weight relationships and chemical content of the planktonic copepods in the Cananéia Lagoon estuarine system, São Paulo, Brazil. *Plankton Biol. Ecol.*, 2001b, vol. 48, no. 2, p. 121-127.

ARA, K. Temporal variability and production of *Euterpina acutifrons* (Copepoda: Harpacticoida) in the Cananéia Lagoon estuarine system, São Paulo, Brazil. *Hydrobiologia,* 2001c, vol. 453, no 1, p. 177-187.

ARA, K. Temporal variability and production of *Temora turbinata* (Copepoda: Calanoida) in the Cananéia Lagoon estuarine system, São Paulo, Brazil. *Sci. Mar.,* 2002, vol. 66, no. 4, p. 399-406.

ARA, K. Temporal variability and production of the planktonic copepod community in the Cananéia Lagoon estuarine system, São Paulo, Brazil. *Zool. Stud.,* 2004, vol. 43, no. 2, p. 179-186.

ARAÚJO, HMP. *Zooplâncton do Estuário dos Rios Piauí e Fundo (Sergipe, Brasil): flutuações espaciais, sazonais e tidais.* Universidade Federal do Paraná – UFPR, Curitiba, 1996. [Ph.D. Thesis].

BOLTOVSKOY, D. *South Atlantic Zooplankton*. Leiden: Backhuys Publishers. 1999. 1627p.

BRADFORD-GRIEVE, JM., MARKHASEVA, EL., ROCHA, CEF. and ABIAHY, B. Copepoda. In: D. Boltovskoy (ed.), *South Atlantic Zooplankton*, Backhuys Publishers, Leiden. 1999; pp.869–1098.

BÖTTGER-SCHNACK, R. and HUYS, R. Taxonomy of Oncaeidae (Copepoda, Poecilostomatoida) from the Red Sea III Morphology and phylogenetic position of Oncaea subtilis Giesbrecht 1892, *Hydrobiology*, 2001, vol. 453, no. 7, p. 467-481.

CHANG, WB. and FANG, LS. Temporal and spatial variations in the species composition, distribution and abundance of copepods of the Kaohsiung Harbor, Taiwan. *Zool. Stud*. 2004, vol. 43, no. 2, p. 454-463.

DUSSART, BH. and DEFAYE, D. *Copepoda: Introduction to the Copepoda*. The Hague: SPB Academic Publishing, Amsterdã. 1995. 277p.

ESKINAZI-SANT'ANNA, EM. and BJÖRNBERG, TKS. Seasonal dynamics of microzooplankton in the São Sebastião Channel (SP, Brazil). *Braz. J. Biol*., 2006, vol. 66, no. 1B, p. 221-231.

FEINBERG, RL. and DAM, HG. Effects of diet on dimensions, density and sinking rates of fecal pellets of the copepod Acartia tonsa. *Mar. Ecol. Prog. Ser*., 1998, vol. 175, p. 87-96.

HOPCROFT, RR., ROFF, JC. and LOMBARD, D. Production of tropical copepods in Kingston Harbour, Jamaica: the importance of small species. *Mar. Biol.,* 1998, vol. 130, no. 4, p. 593-604.

HOPCROFT, RR., ROFF, JC. and CHAVEZ, FP. Size paradigms in copepod communities: a re-examination. *Hydrobiologia*, 2001, vol. 453/454, no. 1-3, p. 133-141.

Ipardes - Instituto Paranaense de Desenvolvimento Econômico e Social. *Diagnóstico Ambiental da APA de Guaraqueçaba*. Versão revista do Macrozoneamento da APA de Guaraqueçaba de 1990. Curitiba, 1995, 166 p.

KAMINSKI, S.M. and MONTÚ, MA. Produção de ovos de copépodes costeiros *Acartia tonsa, Temora stylifera* and *Temora turbinata*, da praia do Cassino – Rio Grande – RS. *Atlantica*, 2005, vol. 27, no. 2, p. 103-111.

KRUMME, U. and LIANG, TH. Tidal induced changes in a copepod-dominated zooplankton community in a macrotidal mangrove channel in northern Brazil. *Zool. Stud*., 2004, vol. 43, no. 2, p. 404-414.

LAM-HOAI, T., GUIRAL, D. and ROUGIER, C. Seasonal change of community structure and size spectra of zooplankton in the Kaw River estuary (French Guiana). *Estuar. Coast. Shelf Sci.,* 2006, vol. 68, p. 47-61.

LANSAC-TÔHA, FA. and LIMA, AF. Ecologia do zooplâncton do estuário do Rio Una do Prelado (São Paulo, Brasil). *Acta Limnol. Bras*., 1993, vol. 6, no. 1, p. 82-96.

LOPES, RM., POR, MSAP. and POR, FD. Zooplankton seasonality in Rio Verde estuary (Juréia, São Paulo, Brazil). *Rev. Hydrobiol. Trop*., 1986, vol. 19, no. 3-4, p. 207-214.

LOPES, RM. Zooplankton distribution in the Guaraú River estuary (South - Eastern Brazil*). Estuar. Coast. Shelf. Sci*., 1994, vol. 39, p. 287-302.

LOPES, RM. *Distribuição espacial, variação temporal e atividade alimentar do zooplâncton no Complexo Estuarino de Paranaguá.* Universidade Federal do Paraná – UFPR, 1997. [Ph.D. Thesis].

LOPES, RM.; BRANDINI, FP. and GAETA, SA. Distribution patterns of epipelagic copepods of Rio de Janeiro (SE Brazil) in summer 1991/1992 and winter 1992. *Hydrobiologia*, 1999, vol. 411, p. 161-174.

MARCUS, NH. Planktonic Copepods in a Sub-Tropical Estuary: Seasonal Patterns in the Abundance of Adults, Copepodites, Nauplii, and Eggs in the Sea Bed. *Biol. Bull*., 1991, vol. 181, no. 2, p. 269-274.

MIYASHITA, LK. *Produção secundária de copépodes pelágicos na plataforma interna de Santos.* Instituto Oceanográfico – USP, 2007. [Trabalho de Conclusão de Curso].

MONTÚ, M. and CORDEIRO, TA. Zoopláncton del complejo estuarial de la Bahía de Paranaguá. I. Composición, dinámica de las especies, ritmos reproductivos y acción de los factores ambientales sobre la comunidad. *Neritica*, 1988, vol. 3, no. 1, p. 61-83.

NEUMANN-LEITÃO, S., GUSMÃO, LMO. and NASCIMENTO-VIEIRA, DA. Zooplankton of the estuaries of the rivers Massangana and Tatuoca, Suape (PE Brazil). *Braz. Arch. Biol. Technol*., 1992, vol. 35, no. 2, p. 341-360.

NEUMANN-LEITÃO, S., GUSMÃO, LMO., NOGUEIRA-PARANHOS, JD. and NASCIMENTO-VIEIRA, DA. Zooplâncton da plataforma continental norte do Estado de Pernambuco (Brasil). *Trab. Oceanogr*. Univ. Fed. PE, 1994, vol. 22, p. 97-116.

OHMAN, MD. and SMITH, PEA. *A Comparison of Zooplankton Sampling Methods in the Calcofi Time Series.* CalCOFI Rep., 1995, p. 36: 153-158.

OMORI, M. and IKEDA, T. *Methods in marine zooplankton ecology*. John Wiley and Sons Publ., New York. 1984.

PEREIRA, JB. and LOUREIRO-FERNANDES, L. Variação temporal do zooplâncton da lagoa da UFES, Vitória, Espírito Santo. *Acta Limnol. Bras*., 1999, vol. 11, no. 2, p. 79-88.

RÉ, PMAB. *Biologia Marinha.* Faculdade de Ciências da Universidade de Lisboa, Lisboa. 2000. 94p.

REID, JW. and ESTEVES, FA. Considerações ecológicas e biogeográficas sobre a fauna de copépodos (Crustacea) planctônicos e bentônicos de 14 lagoas costeiras do estado do Rio de Janeiro, Brasil. In: Lacerda, L.D., D.S.D. de Araújo, R. de Cerqueira and B. Turcq (eds.). *Anais do Simpósio sobre Restingas Brasileiras,* Universidade Federal Fluminense, Niterói, vol. 1, p. 305-326. 1984.

RESGALLA-JÚNIOR, C. Estudo de Impacto ambiental sobre a comunidade do zooplâncton na enseada do saco dos limões, Baía Sul da Ilha de Santa Catarina, Brasil. *Atlantica*, 2001, vol. 23, no. 6, p. 5-16.

ROBERTSON, AI., DIXON, P. and DANIEL, PA. Zooplankton dynamics in mangrove and other nearshore habitats in tropical Australia. *Marine Ecol. Prog. Ser*., 1988, vol 43, p. 139-150.

SARTORI, LP. and LOPES, RM. Seasonal variability of pelagic copepod assemblages on the Inner shelf off Paraná, Brazil. *Nauplius*, 2000, vol. 8, no. 1, p. 79-88.

SILVA, TA., NEUMANN-LEITÃO, S., SCHWAMBORN, R., Gusmão, LMO. and NASCIMENTO-VIEIRA, DA. Diel and seasonal changes in the macrozooplankton community of a tropical estuary in Northeastern Brazil. *Rev. Bras. Zool.* 2003, vol. 20, no. 3, p. 439-446.

SILVA, AP., NEUMANN-LEITÃO, S., SCHWAMBORN, R., GUSMÃO, LMO. and SILVA, TA. Mesozooplankton of an Impacted Bay in North Eastern Brazil. *Braz. Arch. Biol. Technol.*, 2004, vol. 47, no. 3, p. 485-493.

SOUZA-PEREIRA, PE. and CAMARGO, AFM. Efeito da salinidade e do esgoto orgânico sobre a comunidade zooplanctônica, com ênfase nos copépodes, do estuário do rio Itanhaém, Estado de São Paulo. *Acta Scient. Biological Sciences*, 2004, vol. 26, no. 1: 9-17.

STERZA, JM. and LOUREIRO-FERNANDES, L. Zooplankton community of the Vitória Bay estuarine system (southeastern Brazil). Characterization during a three-year study. *Rev. Bras. Oceanog.*, 2006, vol. 54, no. 2-3, p. 95-105.

TUNDISI, J., TEIXEIRA, C., MATSUMURA-TUNDISI, T., KUTNER, MB. and KINOSHITA, L. Plankton studies in a mangrove environment. IX. Comparative investigations with coastal oligotrophic water. *Braz. J. Biol.*, 1978, vol 39, no. 2, p. 301-320.

TURNER, JT. *The feeding ecology of some zooplankters that are important prey items of larval fish.* NOAA Tech. Rept. NMFS. 1984. 28p.

VALE, R. *Variabilidade temporal nas taxas de produção de ovos de Acartia tonsa (Copepoda: Calanoida) na Baía de Paranaguá, Paraná.* Universidade Federal do Paraná – UFPR, Curitiba, 1999. [Master Thesis in Oceanography].

ZERVOUDAKI, S., CHRISTOU, ED., NIELSEN, TG., SIOKOU-FRANGOU, I., ASSIMAKOPOULOU, G., GIANNAKOUROU, A., MAAR, M., KRASAKOPOLOU, E., CHRISTAKI, U. and MORAITOU-APOSTOLOPOULOU, M. The importance of small sized copepods in a frontal area of the Aegean Sea. *J. Plankton Res.*, 2007, vol. 29 no. 4, p. 317-338.

Received: 03 September 2008
Accepted: 24 February 2009