

# Temporal and bathymetric distribution of benthic macroinvertebrates in the Ponte Nova Reservoir, Tietê River (São Paulo, Brazil).

PAMPLIN<sup>1</sup>, P.A.Z. & ROCHA<sup>2</sup>, O.

<sup>1</sup> Universidade Federal do Piauí, Campus Profa. Cinobelina Elvas, Rodovia BR-135 km 03, 64900-000, Bom Jesus, PI, Brasil. E-mail: pazpamplin@yahoo.com.br

<sup>2</sup> Universidade Federal de São Carlos, Departamento de Ecologia e Biologia Evolutiva, Rodovia Washington Luis km 235, 13565-905, São Carlos, SP, Brasil. E-mail: doro@power.ufscar.br

**ABSTRACT: Temporal and bathymetric distribution of benthic macroinvertebrates in the Ponte Nova Reservoir, Tietê River (São Paulo, Brazil).** The structure of macroinvertebrate benthic fauna in the Ponte Nova Reservoir, Tietê River, was investigated in January, April, July and November of 2001. Samplings of the benthic fauna and measurements of temperature, pH, electrical conductivity and dissolved oxygen concentration were carried out in 90 randomly selected sites of the reservoir. Ponte Nova is a warm-monomictic reservoir in which temperature ranges from 16.9°C to 29.0 °C and hypolimnion is anoxic (> 8 meters of depth) in January. Benthic community was composed of 36 taxa, and Chironomidae was the richest group, with 21 taxa. Chaoboridae (Chaoborus) was the dominant taxon, representing almost 70% of the total benthos, and the highest density of benthic fauna, 851 ind.m<sup>-2</sup>, was registered in July. Bathymetrically, the highest densities were usually observed in the deepest areas of the reservoir (> 8 meters) due to the greater abundance of Chaoborus. Chironomidae and Oligochaeta occurred at low densities and preferentially inhabited the shallowest areas. On the other hand, diversity indexes (Shannon-Wiener and Margalef) decreased with increased depth. Stepwise Multiple Regression analysis indicated that depth ( $b = -0.39$ ,  $p < 0.001$  for Chaoborus;  $b = -0.404$ ,  $p < 0.001$  for chironomids;  $b = -0.236$ ,  $p < 0.001$  for oligochaetes), temperature ( $b = -0.172$ ,  $p = 0.001$  for Chaoborus;  $b = -0.262$ ,  $p < 0.001$  for oligochaetes), fine sediment fraction ( $b = 0.218$ ,  $p = 0.038$  for oligochaetes), organic matter ( $b = -0.229$ ,  $p < 0.001$  for Chaoborus;  $b = -0.342$ ,  $p < 0.001$  for oligochaetes) and dissolved oxygen concentrations ( $b = 0.156$ ,  $p < 0.007$  for Chaoborus;  $b = -0.170$ ,  $p = 0.031$  for chironomids) were the major predictors of benthos distribution. The Ponte Nova reservoir has a diversified community of benthic invertebrates, with high taxonomic richness and low population densities.

**Key-words:** benthos, macroinvertebrate composition, depth distribution, Chironomidae, tropical reservoir.

**RESUMO: Distribuição temporal e batimétrica dos macroinvertebrados bentônicos na represa Ponte Nova, rio Tietê (São Paulo, Brasil).** A estrutura da fauna de macroinvertebrados bentônicos na represa Ponte Nova, rio Tietê, foi investigada em janeiro, abril, julho e novembro de 2001. Amostras da fauna bentônica e medidas da temperatura, do pH, da condutividade elétrica e da concentração de oxigênio dissolvido foram realizadas em 90 pontos amostrais distribuídos randomicamente na represa. A represa de Ponte Nova é um reservatório monomictico, quente, com temperatura variando entre 16.9°C e 29.0 °C e hipolimnion anóxico (> 8 metros de profundidade) em janeiro. A comunidade bentônica foi composta por 36 taxa, sendo Chironomidae o grupo com maior riqueza, com 21 taxa. Chaoboridae (Chaoborus) foi o táxon dominante, representando cerca de 70% do benthos total, e a maior densidade da fauna bentônica, 851 ind.m<sup>-2</sup>, foi registrada em julho. Batimetricamente, as maiores densidades foram usualmente registradas nas áreas mais profundas da represa (> 8 metros) devido à maior abundância de Chaoborus. Chironomidae e Oligochaeta ocorreram em baixa densidade e habitaram preferencialmente as regiões mais rasas. Por outro lado, os valores dos índices de diversidade (Shannon-Wiener e de Margalef) diminuíram com o aumento da profundidade. A regressão múltipla "Stepwise" apontou como variáveis significativas, a profundidade ( $b = -0.39$ ,  $p < 0.001$  para Chaoborus;  $b = -0.404$ ,  $p < 0.001$  para quironomídeos;  $b = -0.236$ ,  $p < 0.001$  para oligoquetos); a temperatura ( $b = -0.172$ ,  $p = 0.001$  para Chaoborus;  $b = -0.262$ ,  $p < 0.001$  para oligoquetos), fração fina do sedimento ( $b = 0.218$ ,  $p = 0.038$  para oligoquetos), as concentrações de matéria orgânica ( $b = -0.229$ ,  $p <$

0.001 para Chaoborus;  $b = -0.342$ ,  $p < 0.001$  para oligoquetos) e oxigênio dissolvido ( $b = 0.156$ ,  $p < 0.007$  para Chaoborus;  $b = -0.170$ ,  $p = 0.031$  para quironomídeos) como os principais preditores na distribuição dos organismos bentônicos. A represa de Ponte Nova possui uma comunidade de invertebrados bentônicos diversificada; com alta riqueza de táxons e baixas densidades populacionais.

**Palavras-chave:** Bentos, composição de macroinvertebrados, distribuição por profundidade, Chironomidae, represa tropical.

---

## Introduction

The number of reservoirs has increased all over the world (Tundisi, 1993), and in Brazil this scenario is not different. Much limnological information about these ecosystems has been accumulated for decades and, although there is less information on the structure of benthic communities in Brazilian reservoirs (Pamplin et al., 2006), the number of studies on this community has increased (Santos, 1995; Soriano, 1997; Corbi & Trivinho-Strixino, 2002; Moretto et al., 2003, and others) in the last years.

In most lentic freshwaters, the benthic community is mainly composed of chironomids larvae and oligochaetes, but other groups, less rich and abundant, can also be present. Those organisms are crucial to the aquatic ecosystems, since they play a role in the energy transfer and nutrient cycling (Covich, 1999).

Many abiotic and biotic factors (e.g., substrate type, food availability, oxygen concentration, and predation) have been pointed out as significant to the abundance and distribution of these organisms (Bechara, 1996; Jónasson 1996). Many authors, such as Petridis & Sinis (1993, 1995), Giovanni et al. (1996), and Baudo et al. (2001), have demonstrated that depth is a key factor in the distribution of benthos in lentic ecosystems. Limnological studies (e.g., Goldman & Horne, 1983, Wetzel, 1993, Esteves, 1998) have identified three different zones (littoral, sublittoral and profundal) in which benthic organisms can live and which are frequently defined by a gradient of physical and morphological features, such as habitat complexity, light penetration, macrophytes occurrence, among others. Comparatively, littoral zones are more diverse than the profundal ones; however, the latter have recently aroused the interest of many researchers (Esteves, 1998).

The aim of the current study was to investigate the structure (composition and abundance) of the benthic fauna in the Ponte Nova Reservoir by analyzing the

temporal and bathymetric distribution patterns as well as the factors contributing to these patterns.

---

## Material and Methods

### Study Area

Ponte Nova Reservoir (23°33'S and 45°50'W) is located in the upper basin of the Tietê River, in the southern region of São Paulo state (Fig. 1). Its construction was completed in 1972 and was aimed at controlling water level and, sometimes, supplying the metropolitan area of São Paulo city with water.

The reservoir covers an area of about 28 km<sup>2</sup> and has a mean volume of 296x10<sup>6</sup> m<sup>3</sup>. Maximum and mean depths are 18.5 and 10.5 meters, respectively (Takino & Maier, 1981). Mean outflow is 9.9 m<sup>3</sup>.s<sup>-1</sup> and the residence time is around 346 days. Drainage area is 320 km<sup>2</sup> and the main tributaries are Tietê River and Claro River.

Ponte Nova Reservoir is the unique reservoir before the metropolitan region of São Paulo city. Its surroundings are characterized by pasture and agricultural areas, and remnants of Atlantic forest. The climate in the region is classified as mesothermal, with rainy summers and dry winters (Cwb type in Köppen classification), and the average temperature of 17.5 °C. Peaks of precipitation are observed between December and March, ranging from 157.7 mm to 231.6 mm, and the mean annual rainfall is about 1.357 mm (SIGRH, 2002).

### Sampling and laboratorial analyses

Samplings were carried out in January, April, July and November of 2001. A total of 90 sites were established in the reservoir. At each sampling site, one sample was collected using a Van Veen grab (area: 378 cm<sup>2</sup>), totalizing 360 samples during the study. Material was sieved through a 210 μm mesh net and fixed in 10% formalin.

At the laboratory, the organisms were hand-sorted, and then identified and counted. Identification (at genus or species level) of invertebrates was performed under optic microscope and stereomicroscope, using manuals and identification keys (Brinkhurst & Marchese, 1991; Trivinho-Strixino & Strixino, 1995; Epler, 2001). Chironomids larvae and oligochaetes were mounted in semi-permanent slides with Hoyer solution to evidence important morphological features.

Density, relative abundance and occurrence frequency were estimated as structure parameters of macroinvertebrates community. Shannon-Wiener diversity and Margalef richness indexes were calculated

according to Margurran (2003).

Abiotic variables (pH, conductivity, dissolved oxygen and temperature) were measured in a site near the reservoir bottom by using a multiprobe HORIBA<sup>®</sup> U-10 model. The profiles of these variables were determined between 8:00 to 9:00 a.m. in a central site, as indicated in Fig. 1. In April, dissolved oxygen concentration was not measured due to technical troubles with the multiprobe sensor apparatus. Organic matter (peroxide digestion method) in sediment and the granulometric composition (Suguio, 1973) were determined in samples obtained with a core sampler (area: 33.2 cm<sup>2</sup>).

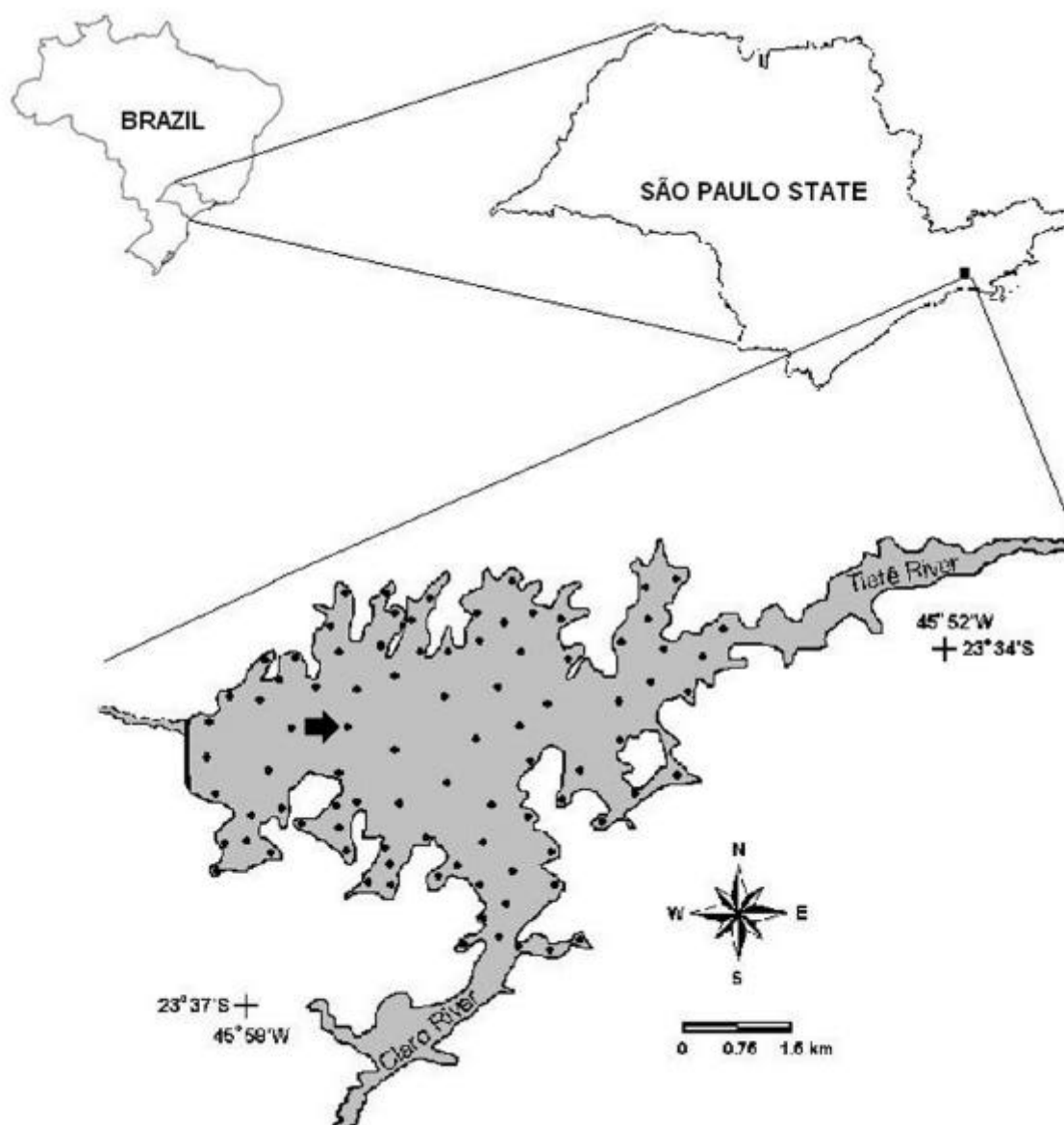


Figure 1: Map of Ponte Nova Reservoir and sampling stations. The arrow indicate the station where profiles of pH, conductivity, temperature and dissolved oxygen concentration were measured.

## Data analysis

One-way ANOVA test was used to determine differences between the seasonal samplings for the macroinvertebrates and environmental data. A Stepwise Multiple Regression (forward method) was performed in order to identify the main variables controlling benthic distribution. Detrended Correspondence Analysis ordination (DCA) was used to evidence the importance of depth on benthos distribution. Taxa with relative abundance superior to 1% were considered in this last method. To minimize discrepancy values, only macroinvertebrate data were previously Ln(x+1) transformation.. All statistical analyses were performed using Statistica (StatSoft 2001) and Instat (GraphPad Instat 2000).

## Results

### Environmental variables

Tab. I summarizes the range, mean and

standard deviations of some limnological variables of sediment of the Ponte Nova Reservoir. Only temperature, dissolved oxygen, pH and conductivity were significantly different ( $p < 0.0001$ ) among the sampling periods. The pH near the bottom ranged from 5.07 to 7.83, and the conductivity varied between 22  $\text{mS}\cdot\text{cm}^{-1}$  and 50  $\text{mS}\cdot\text{cm}^{-1}$ , with major values registered in November. As regards the oxygen concentrations, the smallest mean value was recorded in January, due to the anoxia in some parts of the reservoir. In the last two samplings, this condition was not documented and the mean oxygen concentration was around 11.0  $\text{mg}\cdot\text{L}^{-1}$ .

Sediment of the Ponte Nova Reservoir was enough heterogeneous in relation to granulometric composition, with high values of sand (up to 97.52%) in some areas, and of clay (up to 85.08%) in others (Tab. 1). Percentage of organic matter in the sediment ranged from 0.43% to 28.85% in the whole period (ANOVA  $F = 0.577$ ;  $p = 0.630$ ).

Table I: Maximum, minimum and mean  $\pm$  S.D. (standard deviation) values of limnological variables measured at the surface of Ponte Nova Reservoir in 2001 and results of ANOVA.

Variables	January	April	July	November	ANOVA	
					F	p
pH	5.07 - 7.83 (6.65 $\pm$ 0.46)	5.14 - 7.38 (5.95 $\pm$ 0.38)	5.60 - 7.58 (6.71 $\pm$ 0.36)	5.50 - 6.88 (6.33 $\pm$ 0.26)	80.917	<0.0001
Conductivity ( $\text{mS}\cdot\text{cm}^{-1}$ )	23.00 - 46.00 (28.34 $\pm$ 7.09)	22.00 - 36.00 (23.08 $\pm$ 1.54)	30.00 - 40.00 (36.33 $\pm$ 4.85)	40.00 - 50.00 (40.33 $\pm$ 2.07)	273.38	<0.0001
Dissolved oxygen ( $\text{mg}\cdot\text{L}^{-1}$ )	0.00 - 9.00 (5.09 $\pm$ 3.69)	-	8.20 - 15.80 (12.03 $\pm$ 1.27)	7.40 - 12.70 (10.14 $\pm$ 0.99)	214.98	<0.0001
Temperature ( $^{\circ}\text{C}$ )	19.70 - 29.00 (24.42 $\pm$ 2.51)	22.70 - 26.20 (24.68 $\pm$ 0.52)	16.90 - 24.90 (18.74 $\pm$ 1.38)	22.10 - 29.00 (23.80 $\pm$ 1.55)	260.11	<0.0001
Organic Matter (%)	0.73 - 22.94 (8.22 $\pm$ 5.41)	0.43 - 22.70 (7.54 $\pm$ 5.51)	0.60 - 24.34 (7.18 $\pm$ 5.49)	0.49 - 28.85 (7.70 $\pm$ 5.34)	0.577	0.630
Sand (%)	0.49 - 96.30 (50.21 $\pm$ 33.34)	0.60 - 95.98 (50.44 $\pm$ 32.72)	0.37 - 95.91 (51.44 $\pm$ 36.01)	0.60 - 97.52 (47.24 $\pm$ 34.33)	0.242	0.867
Clay (%)	3.70 - 85.08 (37.26 $\pm$ 26.50)	4.04 - 81.65 (35.47 $\pm$ 23.87)	4.08 - 81.68 (35.16 $\pm$ 25.86)	2.48 - 82.64 (37.57 $\pm$ 24.73)	0.210	0.889
Silt (%)	0.00 - 37.31 (12.52 $\pm$ 9.55)	0.00 - 35.11 (14.72 $\pm$ 10.50)	0.00 - 42.74 (13.41 $\pm$ 11.77)	0.00 - 39.49 (15.20 $\pm$ 10.97)	1.159	0.325

Thermal structure in the Ponte Nova Reservoir was well established with an evident stratification in January, when temperature decreased progressively, around 5.5°C, from 7.5 meters to near the bottom; while in the others periods, a nearly complete isotherm was present (Fig. 2). As regards the dissolved oxygen, water column was well oxygenated with concentrations around 8.44 mg.L<sup>-1</sup>; except in January, when an anoxic hypolimnetic layer was defined in depths over 10.5 meters. Values of pH were more discrepant

in January and April, when they ranged roughly 1.60, while in other two samplings, the difference was not more than 0.52. In January, pH showed patterns similar to temperature and dissolved oxygen, with values varying between 6.62 and 7.04 above 9.5 meters and from 5.55 to 5.82 in depths lower than 11.5 meters (Fig. 2). For electrical conductivity, concentrations in the water column were the same in July and November, while in January and April an increase near to the bottom was observed.

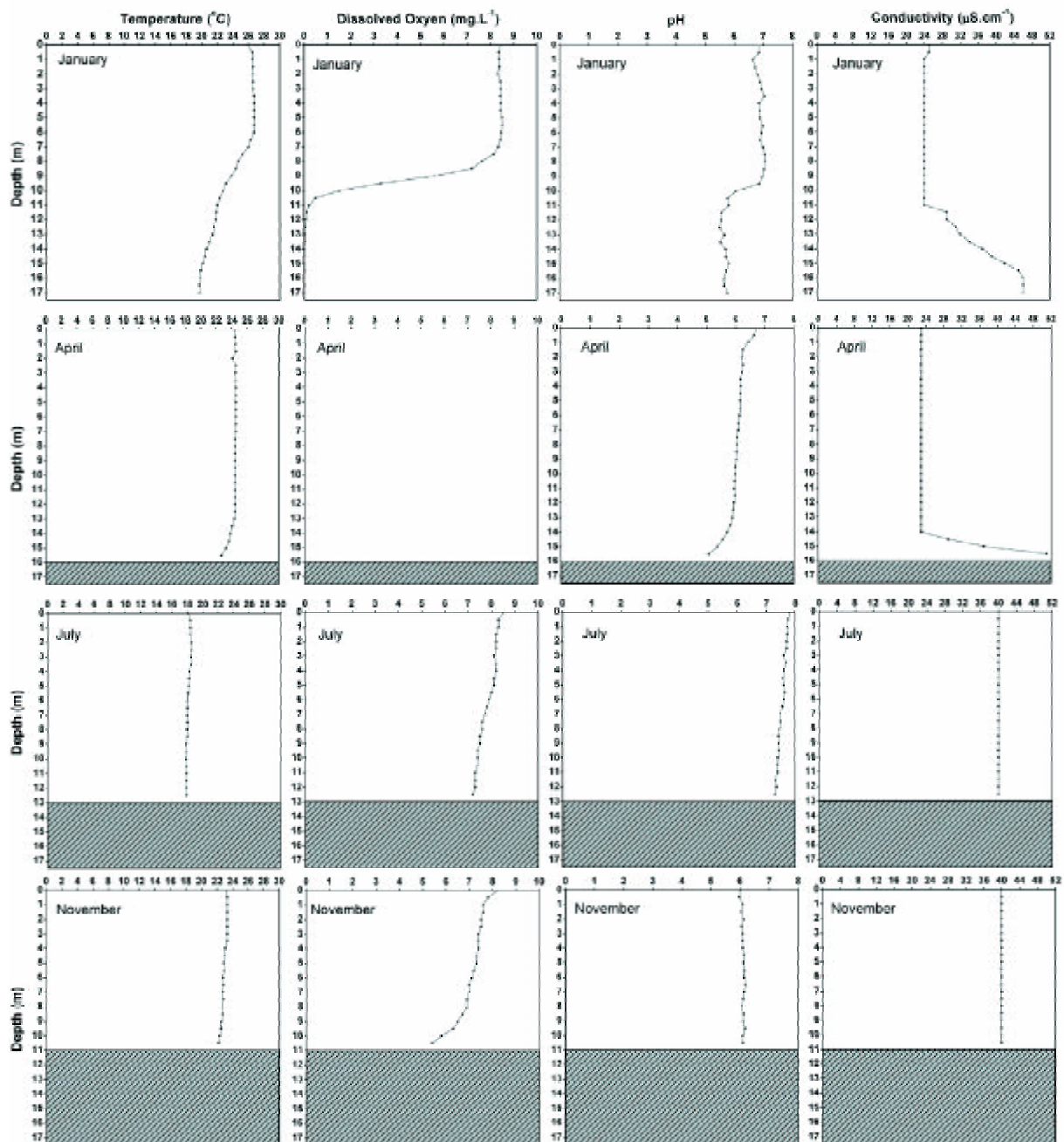


Figure 2: Vertical variation of temperature, dissolved oxygen, pH and conductivity in Ponte Nov Reservoir. Gray areas indicate the bottom of the reservoir.

## Composition and distribution of benthos

A total of 8,934 specimens belonging to 36 taxa were collected in the Ponte Nova Reservoir (Tab. II). Chironomidae was the richest group, with 21 taxa, followed by Oligochaeta, with 10 species. Odonata, Trichoptera, Chaoboridae and Ceratopogonidae (both families of Diptera) were also present, each one represented by a taxon. In the reservoir, most taxa were rare, with relative abundance lesser than 1% and occurrence in up to 2.0% of the total samples collected. On the other hand, Chaoborus (Lichtenstein, 1800) was the most important taxon, comprising 59.1% of all organisms collected and being present in 69.1% of the samples collected. Chironomidae and Oligochaeta comprised

approximately 32.7% and 7.7% of the total abundance, respectively. Among the chironomids, Polypedilum (Kieffer, 1912) was prevalent, with 7.9% of abundance and occurring in 37.3% of the total samples, followed by Caladomyia (Kieffer, 1921), with 5.2% and 34.0%, respectively. About oligochaetes, Branchiura sowerbyi (Beddard, 1892) was the dominant species, both in the relative abundance (4.1%) and in the frequency of occurrence (40.4%).

Mean densities of the four periods were significantly different (ANOVA:  $F = 3.213$ ;  $p = 0.0231$ ), mainly due to Chaoboridae and Chironomidae densities (ANOVA:  $F = 20.256$ ;  $p < 0.0001$  for Chaoboridae and  $F = 27.904$ ;  $p < 0.0001$  for Chironomidae). The highest mean density was registered in July, 851

Table II: Taxonomic composition and relative abundance of benthic collected in Ponte Nova Reservoir in 2001.

Taxons	Number of organisms				Relative Abundance (%)	Occurrence (%) out of 360 samples
	January	April	July	November		
<b>OLIGOCHAETA</b>						
Alluroididae						
Brinkhurstia americanus (Brinkhurst, 1964)	-	6	13	-	0.2	1.7
Naididae						
Allonais lairdi (Naidu, 1965)	4	3	2	-	0.1	1.1
Dero ( <u>Dero</u> ) multibranchiata (Steiren, 1892)	-	-	2	-	< 0.1	0.6
Pristina americana (Cernosvitov, 1937)	-	1	-	-	< 0.1	0.3
Slavinia evelinae (Marcus, 1942)	1	-	-	1	< 0.1	0.6
Opistocystidae						
Opistocysta funiculus (Cordeiro, 1948)	5	1	1	-	< 0.1	1.1
Tubificidae						
Bothrioneurum americanum (Stolc, 1886)	-	-	13	9	0.2	2.2
Branchiura sowerbyi (Beddard, 1892)	65	76	83	145	4.1	40.4
Limnodrilus hoffmeisteri (Claperede, 1892)	71	17	84	87	2.9	18.7
Limnodrilus udekemianus (Claperede, 1892)	-	-	2	-	< 0.1	0.6
<b>HIRUDINEA</b>						
Glossiphonidae	2	-	2	3	< 0.1	1.9

Table II: Cont.

Taxons	Number of organisms				Relative Abundance (%)	Occurrence (%) out of 360 samples
	January	April	July	November		
DIPTERA (Chironomidae)						
Tanypodinae						
Ablabesmyia (Johannsen, 1905)	23	24	206	93	3.9	29.2
Coelotanypus (Kieffer, 1913)	9	3	24	12	0.5	9.7
Djalmabatista (Fittkau, 1968)	9	13	134	79	2.6	15.9
Labrundinia (Fittkau, 1962)	-	2	2	2	< 0.1	1.7
Procladius (Skuse, 1889)	18	15	36	26	1.1	14.5
Chironominae						
Axarus (Roback, 1980)	-	1	-	-	< 0.1	0.3
Caladomyia	112	91	196	72	5.3	34.0
Chironomus (Meigen, 1803)	38	17	51	100	2.3	17.0
Cladopelma (Kieffer, 1921)	6	19	52	18	1.1	15.3
Cryptochironomus (Kieffer, 1918)	2	1	12	44	0.7	10.3
Dicrotendipes (Kieffer, 1913)	-	-	-	3	< 0.1	0.3
Fissimentum dessicatum (Cranston & Nolte, 1996)	13	43	145	38	2.7	21.2
Fissimentum sp2 (Roback, 1966)	1	-	4	4	0.1	2.2
Goeldichironomus (Fittkau, 1965)	6	1	5	8	0.2	3.1
Harnischia (Kieffer, 1921)	9	44	70	89	2.4	27.0
Nilothauma (Kieffer, 1921)	-	-	11	2	< 0.1	2.5
Polypedilum (Kieffer, 1912)	28	91	473	117	7.9	37.3
Polypedilum (Asheum) (Sublette & Sublette, 1983)	-	1	-	-	< 0.1	0.3
Saetheria (Jackson, 1977)	-	-	-	2	< 0.1	0.6
Zavreliella (v. d. Wulp, 1874)	1	-	1	-	< 0.1	0.6
Caladomyia (Kieffer, 1921)	112	91	196	72	5.3	34.0
Tanytarsus (Kieffer, 1920)	4	21	46	79	1.7	11.4
OTHERS DIPTERANS						
Chaoborus (Lichtenstein, 1800)	1485	1590	1209	1000	59.1	69.1
Bezzia (Kieffer, 1899)	-	-	13	10	0.3	3.3
ODONATA						
Phyllocycla (Calvert, 1948)	-	-	-	1	< 0.1	0.3
TRICHOPTERA						
Cymellus (Banks, 1913)	1	1	3	-	< 0.1	1.1
Total	1913	2082	2895	2044		
Richness (S)	23	24	29	26		

ind.m<sup>-2</sup>; while in the other samplings, densities were very similar, ranging from 562 ind.m<sup>-2</sup> to 601 ind.m<sup>-2</sup> (Fig. 3). Chaoboridae was the main component of benthic community in first two samplings, with about 77% of the total in each period; while the relative abundance of Chironomidae was around 16%. In the

samplings conducted in July and November, a decrease in the relative abundance of Chaoboridae (around 45%) and a correspondent increase in the relative abundance of Chironomidae (up to 50%) were observed. In the Ponte Nova Reservoir, oligochaetes had low relative abundance, ranging from 5% in April to 12% in November.

Other invertebrates accounted up to 0.7% of total benthos in July and November (Fig. 3).

Fig. 4 shows the mean values of Shannon-Wiener and Margalef indexes in the Ponte Nova Reservoir. ANOVA test pointed out a significant difference between the periods ( $F = 11.564$ ;  $p < 0.0001$  and  $F = 8.651$ ;

$p < 0.0001$  for Shannon-Wiener and Margalef indexes, respectively). In the first two samplings, lower values were registered for both indexes (around 0.68 for Shannon-Wiener and 0.88 for Margalef index); while in July and November, the values were 1.05 and 1.31, respectively.

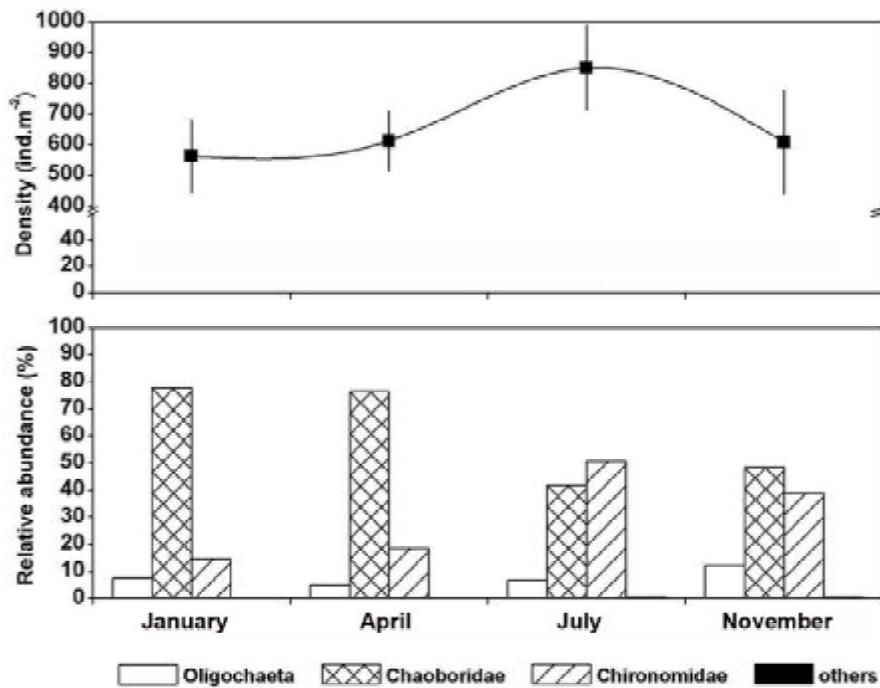


Figure 3: Mean density of total benthos and relative abundance of the main invertebrate groups in Ponte Nova Reservoir in 2001. Vertical bars in the density refer to the confidence interval ( $\alpha = 0.05$ ).

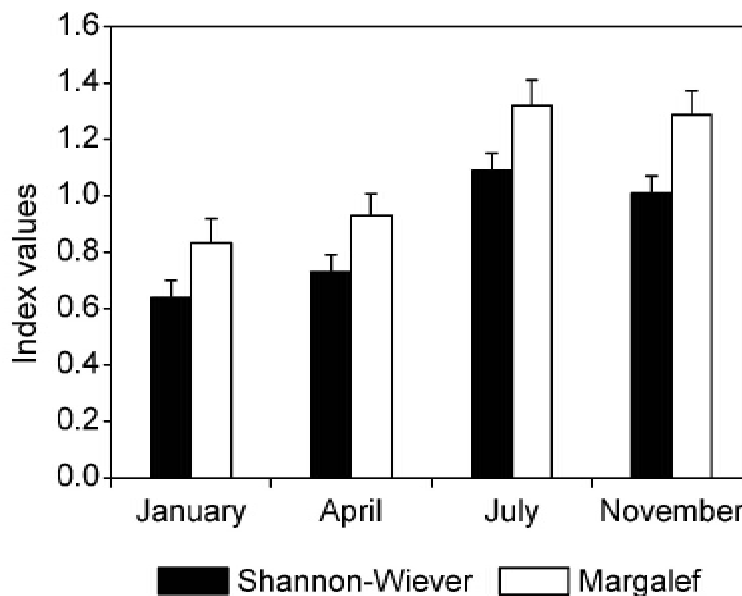


Figure 4: Values of Shannon-Wiener and Margalef diversity indexes for the samplings periods at Ponte Nova Reservoir in 2001.



Considering the depth distribution in the Ponte Nova Reservoir, densities were usually higher in the deepest areas (Fig. 5). In January, densities around 268 ind.m<sup>-2</sup> were found up to 6 meters, followed by a progressive increase until 14 meters, where a density of 1063 ind.m<sup>-2</sup> was registered (735-1361 ind.m<sup>-2</sup>, 95% confidence intervals), and up to that depth mean density declined around 682 ind.m<sup>-2</sup>. Densities in April varied between 377 ind.m<sup>-2</sup> (226-529 ind.m<sup>-2</sup>, 95% confidence intervals) and 441 ind.m<sup>-2</sup> (268-615 ind.m<sup>-2</sup>, 95% confidence

intervals) until 8 meters of depth, and in the superior depth density improved to 1084 ind.m<sup>-2</sup> (mean density: 910 ind.m<sup>-2</sup>). In July, peaks of high densities were observed in depth above 4 meters with mean density equal 1131 ind.m<sup>-2</sup>. During November, the highest densities occurred between 8 and 12 meters depth, with mean density of 1297 ind.m<sup>-2</sup>. Inversely, both Shannon-Wiener and Margalef diversity indexes decreased in the highest depth (especially after 6 meters), as shown in Fig. 6.

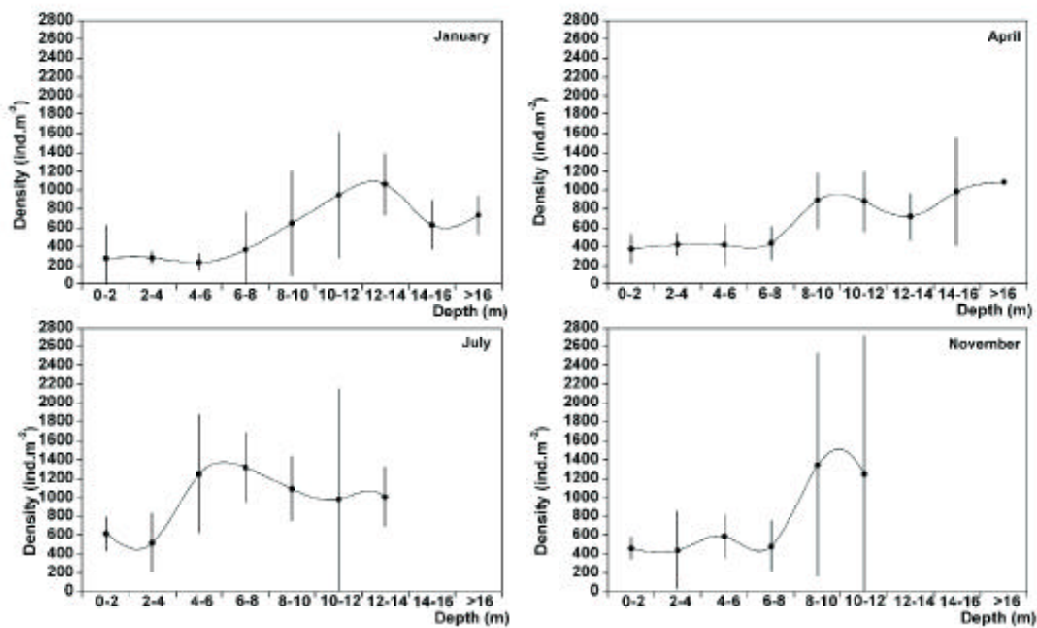


Figure 5: Depth variation of total density of benthos in Ponte Nova Reservoir in 2001. Vertical bars in density refer to the confidence interval ( $\alpha = 0.05$ ).

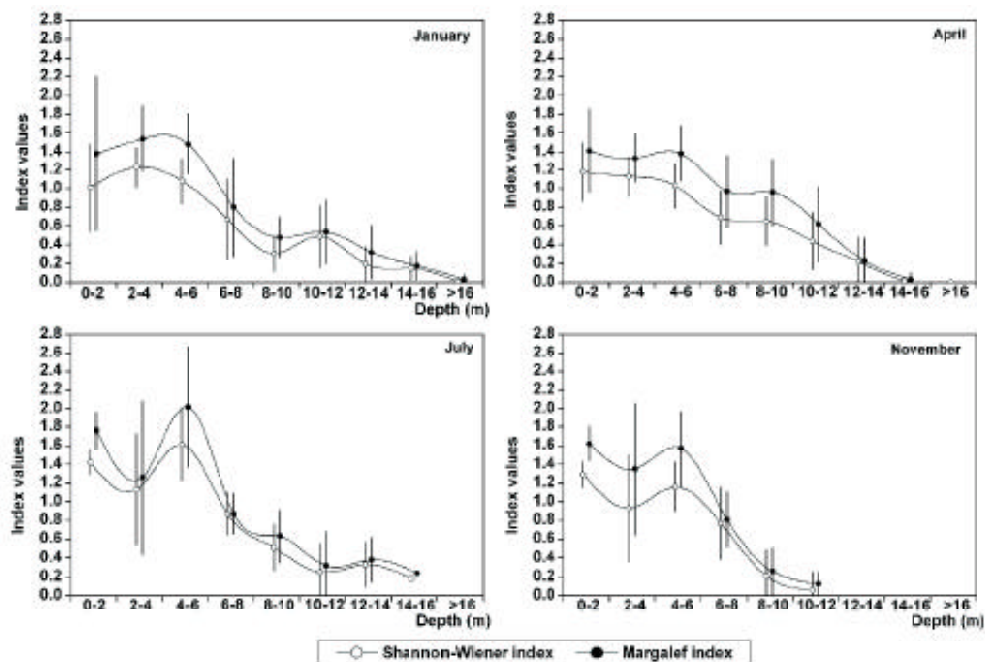


Figure 6: Depth variation of Shannon-Wiener and Margalef diversity indexes in Ponte Nova Reservoir in 2001. Vertical bars in density refer to the confidence interval ( $\alpha = 0.05$ ).

High densities in deeper areas (over 8 meters) were due to the presence of Chaoboridae, which preferentially inhabited these areas with relative abundance usually above 70% (Fig. 7). In April, Chaoboridae and Chironomidae had similar abundance ranging between 39% and 49% until 4 meters, and,

in November, the former was dominant in depths above 4 meters. On the other hand, Chironomidae and Oligochaeta continuously decreased with increased depth. Up to 6 meters of depth, relative abundance of the former was in general above 38%; while to the latter, it was not above 15%.

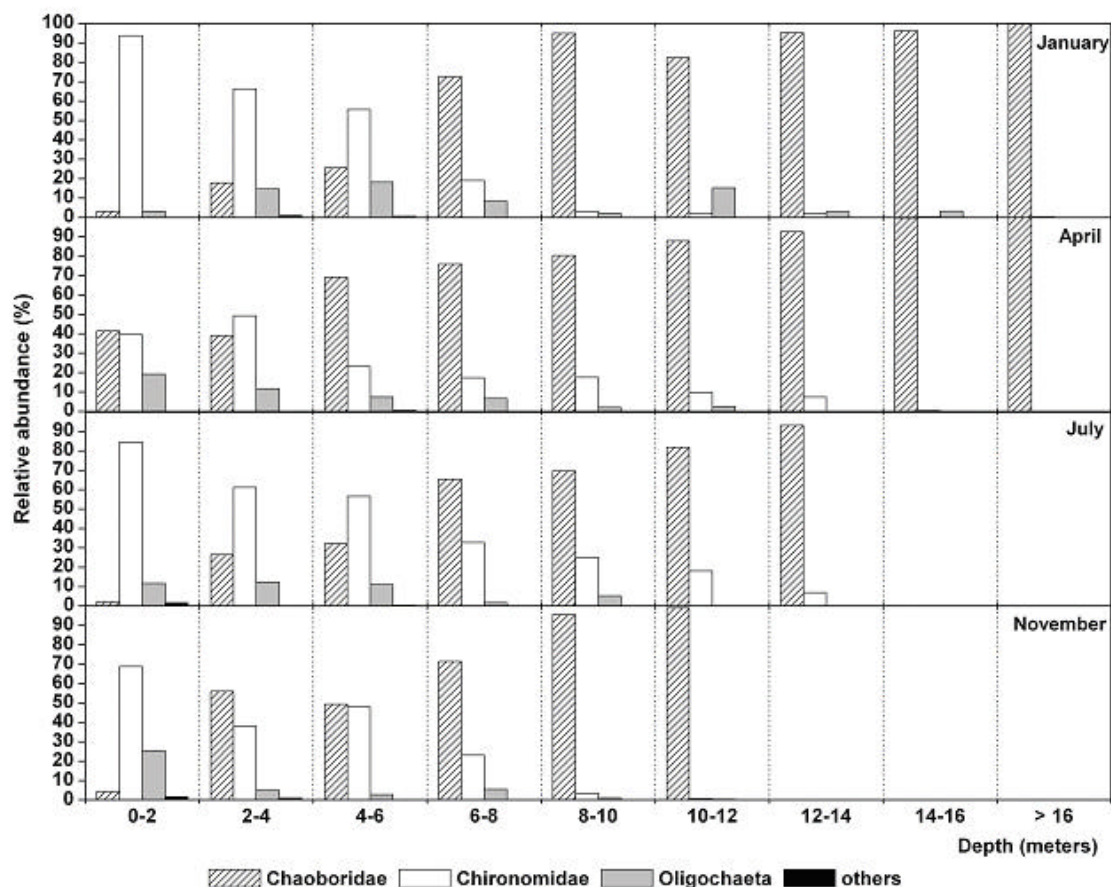


Figure 7: Relative abundance of the main benthic groups in relation to depth in Ponte Nova Reservoir in 2001.

Table III: Stepwise multiple regression analysis, considering the main groups of benthos as dependent variables and environmental features as independent variables. Variables included in the model with  $p < 0.01$ .

Groups	F	R	R <sup>2</sup>	Adj. R <sup>2</sup>	p	Indep. vars.	Beta in	P
Chaoboridae	54.517	0.713	0.509	0.499	<0.0001	Depth	-0.395	<0.0001
						Temperature	-0.172	0.001
						Organic matter	-0.292	<0.0001
						Oxygen	0.186	0.007
Chironomidae	15.005	0.381	0.145	0.135	<0.0001	Depth	-0.404	<0.0001
						Oxygen	-0.170	0.03
						Organic matter	-0.121	0.05
Oligochaeta	13.369	0.450	0.203	0.187	<0.0001	Temperature	-0.262	<0.0001
						Depth	0.236	<0.001
						Organic matter	-0.342	<0.001
						Fine grain (clay+silt)	0.218	0.03

Results of Stepwise Multiple Regression are shown in Tab. III and are concerned with distribution of Chaoboridae, depth ( $b = -0.395$ ;  $p < 0.001$ ), temperature ( $b = -0.172$ ;  $p = 0.001$ ), organic matter ( $b = -0.229$ ;  $p < 0.001$ ) and dissolved oxygen ( $b = 0.156$ ;  $p < 0.007$ ). These variables were selected as predictors and the regression model was significant ( $\text{adj. } R^2 = 0.499$ ;  $p < 0.001$ ). For Chironomidae, regression model ( $\text{adj. } R^2 = 0.381$ ;  $p < 0.001$ ) was defined by depth ( $b = -0.404$ ;  $p < 0.001$ ) and dissolved oxygen ( $b = -0.170$ ;  $p = 0.031$ ); whereas for oligochaetes, temperature ( $b = -0.262$ ;  $p < 0.001$ ), depth ( $b = -0.236$ ;  $p < 0.001$ ), organic matter ( $b = -0.342$ ;  $p < 0.001$ ) and fine sediment ( $b = 0.218$ ;  $p = 0.038$ ) were the predictors to the regression ( $\text{adj. } R^2 = 0.187$ ;  $p < 0.001$ ).

Eigenvalues scores of Detrended Correspondence Analyses (DCA) were 0.74 (axis 1) and 0.38 (axis 2), as shown in Fig. 8. In the first axis of DCA, taxa

were separated into two groups according to depth. Group I was formed by *Djalmabatista* (Fittkau, 1968), *Ablabesmyia* (Johannsen, 1905), *Fissimentum dessicatum* (Roback, 1966), *Tanytarsus* (v. d. Wulp, 1874), and *Caladomyia*, found with high relative abundance (exceeding 95%) in the shallow region (up to 6 meters) of the reservoir. Group II comprised taxa, such as chironomids *Chironomus* (Meigen, 1803), *Harnischia* (Kieffer, 1921), *Polypedilum* (Kieffer, 1912), *Procladius* (Skuse, 1889) and *Cladoplema* (Kieffer, 1921), and oligochaetes *Limnodrilus hoffmeisteri* (Claparede, 1862) and *Branchiura sowerbyi*, which had generally 50% of abundance until 6 meters, but also had high abundance between 6 and 14 meters. *Chaoborus* had high abundance (around 86% of total density) in deep areas (more than 8 meters), and is showed separated of both groups, I and II.

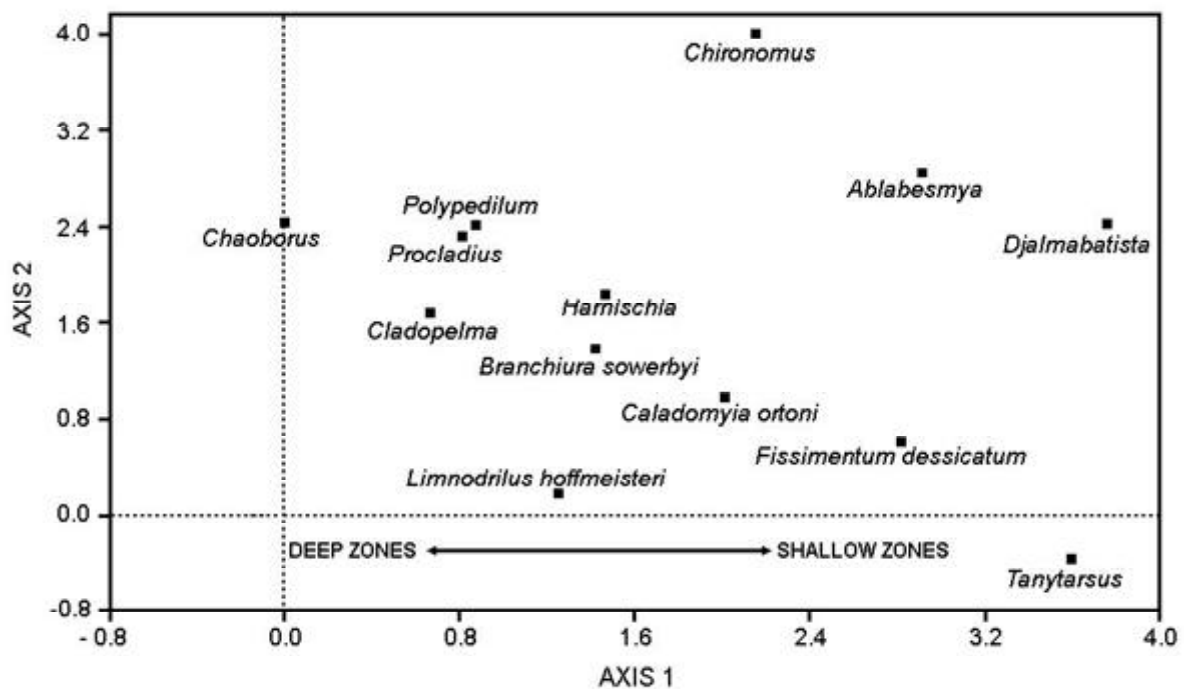


Figure 8: Detrended Correspondence Analyses of main benthic taxa in Ponte Nova Reservoir in 2001.

## Discussion

The Ponte Nova Reservoir has been previously studied with respect to some limnological features (phytoplankton: Xavier et al., 1985; zooplankton: Sendacz et al., 1985; nutrients and chlorophyll a: Maier & Takino, 1985; water circulation and

stratification: Maier, 1985, and others); however, there are no studies regarding the structure of benthos community in the reservoir. Immature stages of insects, mainly Diptera, were the main component of benthos in the reservoir, being the major group contributing to the benthic taxon

richness. Among the Diptera, organisms belonging to the Chironomidae family were the major contributors to the taxon richness. This corroborates what is already established in the literature that these organisms are usually the main component of benthic communities (Petridis & Sinis, 1993; Di Giovanni et al., 1996; Strixino & Trivinho-Strixino, 1998; Roque et al., 2004).

Valenti & Froehlich (1988), analyzing the densities of benthic populations in ten reservoirs in São Paulo State, recorded mean values higher than 2,000 ind.m<sup>2</sup>, and even 40,000 ind.m<sup>2</sup> in some places. In the Ponte Nova Reservoir, benthic densities were much lower in all sampling periods. This can be related to the fact that this reservoir is the first one in the Tietê River, close to the headwaters and oligotrophic conditions (Sendacz et al., 2006). Another possible reason is the fact that, compared with other reservoirs of this basin, the Ponte Nova reservoir has only two main tributaries, Tietê and Claro Rivers, thus receiving small contributions from its basin.

Comparing the four samplings performed along different seasonal periods of the year, the results obtained of this study showed that there was significant seasonal variation in the mean densities of benthic populations ( $p = 0,023$ ), with an increase during drought.

Chaoborus (the phantom midge) was undoubtedly the main component of benthic community, corresponding to almost 70% of the total number of organisms. This dipteran larvae is a voracious predator of invertebrates, both benthic and planktonic inhabitants (Kajak & Ranke-Rybicka, 1970), and have great migratory capacity in the water column (Liljendahl-Nurminen et al., 2002), thus inhabiting deep layers. According to Hare (1995), they also use this capacity to avoid being predated, particularly by fishes, resulting in high densities in the sediment during the day and high densities in the water column during the night. In the Ponte Nova Reservoir, the phantom midge seems to follow this pattern, preferably occupying the deeper zones at the samplings, possibly as a refuge from predators.

Many environmental factors (e.g. depth, oxygen concentration, availability food, substrate type, and others) have been pointed out as regulators of benthic community structure in reservoirs (Kajak, 1988; Prat et al., 1992; Bechara, 1996;

Jonasson, 1996). In the Ponte Nova reservoir, the results obtained through Stepwise Multiple Regression technique indicated that depth, temperature, dissolved oxygen and organic matter are the major factors related to abundance and distribution of benthos. As pointed out by Petridis and Sinis (1993), and Bazzanti et al. (1994), the effect of depth is indirect, being associated with changes in important physical and chemical variables, such as temperature and dissolved oxygen. In Brazil, Corbi & Trivinho-Strixino (2002), and Moretto et al. (2003), studying benthos of Anhumas and Corumbá reservoirs, respectively, evidenced the importance of depth on benthos distribution.

As regards the effect of depth variation on the reservoir, Chaoboridae inhabited preferentially the deepest regions, even in the presence of anoxia, while Chironomidae and Oligochaeta had greater densities in shallow areas. The preference of Chaoboridae for deeper zones in the reservoirs has been thoroughly documented (Rabette & Lair, 1998; Corbi & Trivinho-Strixino, 2002), being regarded as a result of the ability of this group to survive under low oxygen concentrations and of the advantage of avoiding predators by remaining in deep waters (Jaeger & Walz, 2002).

In spite of the high organic matter content in the sediment of the Ponte Nova Reservoir, it appears that there are non-point sources of organic effluents or major contributions via non-point sources. This is possibly the reason why low densities were recorded for benthic organisms, especially for Oligochaeta. For this group, temperature and organic matter were negatively correlated with its distribution and abundance, while depth and fine sediment fraction (silt and clay) were positively correlated. According to Real & Prat (1992), Oligochaeta densities are usually positively correlated with higher amounts of fine particles in the sediment and higher concentrations of organic matter.

Another important factor affecting communities living in the littoral zone of reservoirs is the variation in the water level, usually determined by the seasonal pattern of rainfall or by the imposed operational regime on water discharge (Mastrantuono, 1987). Prus et al. (1999) observed that the small fluctuation in the water level (less than 2 meters) in the Myczkowce Dam allowed the maintenance of species richness in the

bottom invertebrate community at the littoral region, whereas in the Solina Dam, subjected to a variation of more than 10 meters in the water level, the littoral environment was disrupted and the community was impoverished. During this study, it was registered a decreased around 3.3 meters and 5.5 meters in July and November, respectively, in the water level in the Ponte Nova Reservoir if compared with the first sampling period. The changes were mainly determined by the rainfall pattern in the year 2000 and most of 2001, with a pronounced drought resulting in a precipitation deficit of around 250. This drop in the water level is probably related to the increased abundance of the benthic community as a whole, particularly in chironomids.

This work evidenced that the Ponte Nova Reservoir has a diversified community of benthic invertebrates, is rich in taxa, but shows low population densities. Such characteristics are consistent with its meso-oligotrophic condition. Considering that almost all the other reservoirs in the Tiete River basin are ongoing an accelerated process of eutrophication, efforts to conserve water quality and community diversity are recommended.

---

## Acknowledgements

We thank Mrs. Mercedes R. Marchese (Instituto Nacional de Limnologia, Argentina) for helping with oligochaetes taxonomical identification and for suggesting this paper. The first author had financial support from FAPESP (Proc n. 99/12393-8).

---

## References

- Baudo, R., Occhipinti, A., Nocentini, A.M. & Sabolla, M. 2001. Benthos of lake Orta in the year 1996. *J. Limnol.*, 60:241-248.
- Bazzanti, M., Seminara, M. & Tamori, C. 1994. Depth distribution and relationships to the trophic state of sublittoral and profundal macrobenthos in Lake Vico (Central Italy). *Limnologica*, 24:13-21.
- Bechara, J.A. 1996. The relative importance of water quality, sediment composition and floating vegetation in explaining the macrobenthic community structure of floodplain lakes (Paraná River, Argentina). *Hydrobiologia*, 333:95-109.
- Brinkhurst, R.O. & Marchese, M.R. 1991. Guia para la identificación de oligoquetos acuáticos continentales de Sud y Centroamérica. Asociación de Ciencias Naturales del Litoral, Santo Tomé. 207p.
- Corbi, J.J. & Trivinho-Strixino, S. 2002. Spatial and bathymetric distribution of the macrobenthic fauna of the ribeirão das Anhumas Reservoir (Américo Brasiliense -SP, Brazil). *Acta Limnol. Bras.*, 14:35-42.
- Covich, A.P., Palmer, M. & Crowl, T.A. 1999. The role of benthic invertebrate species in freshwater ecosystems. Zoobenthic species influence energy flows and nutrient cycling. *Bioscience*, 49:119-127.
- Di Giovanni, M.V.D., Goretti, E. & Tamanti, V. 1996. Macrobenthos in Montedoglio Reservoir, central Italy. *Hydrobiologia*, 321:17-28.
- Epler, J.H. 2001. Identification manual for the larval Chironomidae (Diptera) of North and South Carolina. North Carolina Department of Environmental and Natural Resources, Division of Water Quality, North Carolina. 526p.
- Goldman, C.R. & Horne, A.J. 1983. *Limnology*. McGraw-Hill, New York. 464p.
- GraphPad Software, Inc. 2000. GraphPad InStat version 3.00 for Windows 95. www.graphpad.com.
- Hare, L. 1995. Sediment colonization by littoral and profundal insects. *J. North Am. Benthol. Soc.*, 14:315-323.
- Jaeger, I.S. & Walz, N. 2002. *Chaoborus flavicans* (Diptera) is an oxy-regulator. *Arch. Hydrobiol.*, 155:401-411.
- Jonasson, P.M. 1996. Limits for life in the lake ecosystem. *Verh. Int. Verein. Theor. Limnol.*, 26:1-33.
- Kajak, Z. & Ranke-Rybicka, B. 1970. Feeding and production efficiency of *Chaoborus flavicans* Meigen (Diptera, Culicidae) larvae in eutrophic and dystrophic lake. *Pol. Arch. Hydrobiol.*, 17:225-232.
- Kajak, Z. 1988. Considerations on benthos abundance in freshwaters, its factors and mechanisms. *Int. Rev. Gesamten Hydrobiol.*, 73:5-19.
- Liljendahl-Nurminen, A., Horppila, J., Eloranta, P., Malinen, T. & Uusitalo, L. 2002. The seasonal dynamics and distribution of *Chaoborus flavicans* larvae in adjacent lake basins of different morphometry and degree of eutrophication. *Freshwater Biol.*, 47:1283-1295.
- Maier, M.H. 1985. *Limnologia de reservatórios do Sudeste do Estado de São Paulo*,

- Brasil. II - Circulação e estratificação da água. Bol. Inst. Pesca, 12:11-43.
- Maier, M.H. & Takino, M. 1985. Limnologia de reservatórios do Sudeste do Estado de São Paulo. IV - Nutrientes e clorofila a. Bol. Inst. Pesca, 12:75-102.
- Margurran, A.E. 2003. Measuring biological diversity. Blackwell Publishing, Maden. 260p.
- Mastrantuono, L. 1987. Invertebrate community in the littoral-regulated area of a hydroelectric lake-reservoir (Lake Campotosto, central Italy). Riv. Idrobiol., 26:17-32.
- Moretto, Y., Higuti, J. & Takeda, A.M. 2003. Spatial variation of the benthic community in the Corumbá reservoir, Goiás, Brazil. Acta Sci. Biol. Sci., 25:23-30.
- Pamplin, P.A.Z., Almeida, T.C.M. & Rocha, O. 2006. Composition and distribution of benthic macroinvertebrates in Americana Reservoir (SP, Brazil). Acta Limnol. Bras., 18:121-132.
- Petridis, D. & Sinis, A. 1993. Benthic macrofauna of Tavropos Reservoir (central Greece). Hydrobiologia, 202:1-12.
- Petridis, D. & Sinis, A. 1995. Benthos of Lake Mikri Prespa (North Greece). Hydrobiologia, 304:185-196.
- Prat, N., Real, M. & Rieradevall, M. 1992. Benthos of Spanish lakes and reservoirs. Limnetica, 8:221-229.
- Prus, T., Prus, M. & Bijou, P. 1999. Diversity of invertebrate fauna in littoral of shallow Myczkowce dam reservoir in comparison with a deep Solina dam reservoir. Hydrobiologia, 408/409:203-210.
- Rabette, C. & Lair, N. 1999. Spatial and temporal distribution of benthic stages of *Cyclops vicinus* and *Chaoborus flavicans* in relation to abiotic factors and benthic fauna. Hydrobiologia, 390:61-72.
- Real, M. & Prat, N. 1992. Factors influencing the distribution of chironomids and oligochaetes in profundal areas of Spanish reservoirs. Neth. J. Aquat. Ecol., 26:405-410.
- Roque, F.O., Correia, L.C.S., Trivinho-Strixino, S. & Strixino, G. 2004. A review of Chironomidae studies in lentic systems in the State of São Paulo, Brazil. Biota Neotrop., 4:1-19.
- Santos, C.M. 1995. Distribuição espacial e temporal da fauna mesobentônica da represa de Jurumirim (Rio Paranapanema - SP). São Carlos, USP, 147p (Dissertação).
- Sendacz, S., Kubo, E. & Cestarolli, M.A. 1985. Limnologia de reservatórios do Sudeste do Estado de São Paulo. VII - zooplâncton. Bol. Inst. Pesca, 12:187-207.
- Sendacz, S., Caleffi, S. & Santos-Soares, J. 2006. Zooplankton biomass of reservoirs in different trophic conditions in the State of São Paulo, Brazil. Braz. J. Biol. 66:337-350.
- Sistema Integrado de Gerenciamento de Recursos Hídricos de São Paulo - SIGRH. Banco de dados. <http://sigrh.sp.gov.br/sigrh/bsecon/bancomedados/plu/plu.htm>.
- Soriano, A.J.S. 1997. Distribuição espacial e temporal de invertebrados bentônicos da represa de Barra Bonita (SP). São Carlos, UFSCar, 149p (Dissertação).
- StatSoft, Inc. 2001 Statistica: data analysis software system, version 6. [www.statsoft.com](http://www.statsoft.com).
- Strixino, G. & Trivinho-Strixino S. 1998. Povoamentos de Chironomidae (Diptera) em lagos artificiais. In: Nessimian, J.L. & Carvalho, A.L. (eds.) Ecologia de insetos aquáticos. Universidade do Rio de Janeiro, Rio de Janeiro. p.141-154.
- Suguio, K. 1973. Introdução à sedimentologia. Edgard Blücher/EDUSP, São Paulo. 317p.
- Takino, M. & Maier, M.H. 1981. Hydrology of reservoirs in the São Paulo State, Brazil. Verh. Int. Verein. Limnol., 21:1060-1065.
- Trivinho-Strixino, S. & Strixino, G. 1995. Larvas de Chironomidae (Diptera) do Estado de São Paulo: guia de identificação e diagnose dos gêneros. PPGERN-UFSCar, São Carlos. 229p.
- Valenti, W.C. & Froehlich, O.O. 1988. Estudo da macrofauna bentônica de dez reservatórios do Estado de São Paulo. Cienc. Zootec., 3:1-3.
- Xavier, M.B., Monteiro-Junior, A.J. & Fujiara, L.P. 1985. Limnologia de reservatórios do Sudeste do Estado de São Paulo. VII - fitoplâncton. Bol. Inst. Pesca, 12:145-186.
- Wetzel, R.G. 1993. Limnologia. Fundação Calouste, Lisboa. 1010p.

**Received:** 08 March 2007

**Accepted:** 18 January 2008