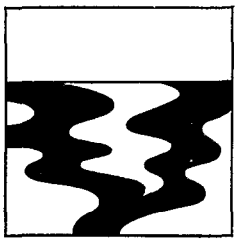

Evaluation of density and biomass of a bivalve population (Diplodon delodontus expansus) (Küster, 1856) in a small tropical reservoir

Raoul Henry (1) and Claudete Aparecida Simão (1)

Summary

Density and biomass of D. delodontus expansus (Küster, *1856*) *(Mollusca, Bivalvia) were estimated in the Reservoir of the Rio Pardo (Botucatu, São Paulo, Brazil), in December, 1982. The average population density of the bivalves in the reservoir was 36.62 specimens.m*$^{-2}$*, at 98 sampling stations. Total density in the reservoir was estimated at 5.8 million individuals. Average biomass was 347.27 g.m*$^{-2}$ *(alcohol weight); 225.00 g.m*$^{-2}$ *(shells dry weight) and 10.92 g.m*$^{-2}$ *(bodies dry weight). Total biomass in the reservoir was estimated at 55.0 tons (alcohol weight), 35.6 tons (shells dry weight) and 1.7 tons (bodies dry weight). The granulometric analysis of the sediment showed that silt presented greater correlation with biomass and density (r = 0.16), though unsignificant. The other fractions of sediment (sand and clay) showed lower correlation coefficients with density and biomass of the bivalves. The granulometric composition of the sediment was not related with density and biomass of the animals. A revision of other ecological factors showed that there are no limiting factors on the distribution and abundance of bivalves in the reservoir. This explains probably the high values of density and biomass.*

Key words : Density — Biomass — Bivalve — Tropical reservoir — Brazil.

Résumé

Évaluation de la densité et de la biomasse du peuplement de bivalves *(Diplodon delodontus expansus)* (Küster, 1856) dans un petit réservoir tropical

La densité et la biomasse de D. delodontus expansus (Küster, *1856*) *(Mollusca, Bivalvia) ont été estimées dans le réservoir du Rio Pardo (Botucatu, São Paulo, Brésil) en décembre 1982. La densité moyenne du peuplement de bivalves a été estimée à 36,62 individus.m*$^{-2}$ *pour les 98 stations de prélèvement, et le stock total dans le réservoir à 5,8 millions d'individus. La biomasse moyenne était de 347,27 g.m*$^{-2}$ *(poids alcoolique); 225,00 g.m*$^{-2}$ *(poids sec des coquilles) et 10,92 g.m*$^{-2}$ *(poids sec du corps). La biomasse totale dans le réservoir a été estimée à 55,0 tonnes (poids alcoolique), 35,6 tonnes (poids sec des coquilles) et 1,7 tonnes (poids sec des corps). L'analyse granulométrique du sédiment a révélé que le limon a une plus grande corrélation avec la densité et la biomasse des animaux en relation aux fractions du sédiment, mais n'est pas significative (r = 0,16). Les autres fractions du sédiment (sable et argile) ont des corrélations plus basses avec la densité et la biomasse des bivalves. La composition granulométrique du sédiment n'a pas de relation évidente avec la densité et la biomasse des animaux. Une révision des autres facteurs écologiques a pu montrer qu'il n'existe aucun facteur limitant la distribution et l'abondance des bivalves dans le réservoir. Cela est probablement l'explication des grandes valeurs de densité et biomasse obtenues.*

Mots-clés : Densité — Biomasse — Bivalve — Réservoir tropical — Brésil.

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1. INTRODUCTION

In tropical regions, the benthic fauna has been studied less profoundly that zooplankton or phytoplankton. The works conducted in Africa, in Lake Chad (DEJOUX *et al.*, 1969; LÉVÊQUE, 1971, 1972; LÉVÊQUE *et al.*, 1983), in Lake Chilwa (MCLACHLAN & MCLACHLAN, 1969), in Lake George (BURGIS *et al.*, 1969) and Lake Kariba (MCLACHLAN & MCLACHLAN, 1971) showed that the benthic biomass was not low and had a very important role in the productivity of the ecosystem. Particularly in Lake Chad and probably in Lake Chilwa, the benthic mollusks are very abundant and constitute the major part of the benthic biomass.

In Brazil, the investigations on the benthic fauna in reservoirs are yet scarce and concern mainly the study on density and spatial distribution of the Chironomidae (STRIXINO & STRIXINO, 1980, 1982) and Oligochaeta (Có, 1979). Some observations were also conducted on a bivalve mollusk *(Diplodon beckeanus)* in the littoral zone of Lake Juturnaiba (ALVARENGA *et al.*, 1979).

The rupture of the dam of Rio Pardo in December 1982 appeared to be an opportunity to carry out the first evaluation of biomass of *Diplodon delodontus expansus* (Mollusca, Bivalvia) in a brazilian reservoir. This bivalve species is well known in rivers of the State of Rio Grande do Sul (Brazil). However, they are more frequently found in the River Tietê, State of São Paulo (PARODIZ, 1973). Some biological aspects of the species, such as studies on hermaphroditism, seasonal histological variations of the gonads, sex ratio and histochemistry of the polysaccharides in the podal glands of the species are also known (CURIAL & LANGE, 1974a, b; 1975; MOLFI & CURIAL, 1977).

2. THE ENVIRONMENT

The Reservoir of the Rio Pardo (Botucatu, SP) is situated at 22°59′ S and 48°25′ W. It is a small reservoir (maximum lenght 600 m; maximum width: 5.25 m; maximum depth: 4.0 m; average depth: 2.0 m) (HENRY, 1981). The Rio Pardo is a side arm of the Rio Paranapanema which crosses the State of São Paulo from the east to the west and finally flows into the Rio Paraná (Fig. 1). The most common vegetation in this region is the "cerrado" type, with mainly "Botucatu" type soil, consisting of sandstone. More abundant vegetation (forest) or cultivated soils may be found in basalt areas (JIM, 1970).

The ecology of the Reservoir of the Rio Pardo was studied since 1975: hydrology and climate (HENRY & CURI, 1981a), physical and chemical parameters (HENRY, 1981), primary production (HENRY *et al.*, 1978), ecology of *Escherichia coli* and coliforms (HENRY & LOPES, 1978), fish and some aspects of the biology of *Hoplias malabaricus* (PELLEGRINI-CARAMASCHI, 1979; PELLEGRINI-CARAMASCHI *et al.*, 1982).

As a result of this studies, the Reservoir of the Rio Pardo show ecological characteristics which are more similar to those of rivers than of lacustrine systems (HENRY & SOUSA, 1984).

In December 1982, as a consequence of heavy rains, the dam broke and the Reservoir was emptied. The water inflow of the Rio Pardo was then kept in its older riverbed (Fig. 2). A fairly high density of the bivalve *D. delodontus expansus* was observed on exondated zones and we took this opportunity to study distribution and biomass of that species in the Reservoir.

3. METHODOLOGY

Sampling Methods

The bivalves were manually collected two days after drainage of the Reservoir at 28 samplings sites (Fig. 2). On each site, an area of 1 m² was investigated down to a depth of 10 cm in order to collect also animals which probably were buried in the sediment. All species were fixed in alcohol. An additional sampling was conducted between December the 13th and 28th, 1982, at 70 stations sites. At that time, bivalves were dead and shells only were collected. Sediment samples (approximately 500 g) were also collected at almost all stations.

Granulometric Analysis of the Sediment

The sediment samples were dried in the open air and in the shadow of the laboratory. Next, they were filtered in the Granutest screen (netting 2 mm) to separate the coarse fraction (detritus, roots, etc.). Pipettes method, according to KILMER & ALEXANDER (1949), were used to determine the percentage of silt and clay (fraction < 0.05 mm). The different sand fractions (very coarse: 2.000-1.000 mm; coarse sand: 1.000-0.5000 mm; medium sand: 0.500-0.250 mm; fine sand: 0.250-0.100 mm; very fine sand: 0.100-0.050 mm) were determined through screening of a sediment sample (10 g), previously dried in oven at 110 °C, for 24 hours.

The total percentages of sand, clay and silt observed in each sample were presented in the form of a triangular diagram (KENITIRO, 1973), in which the texture of the sediment was classified according to the classification of U.S.D.A. (1951), modified by the Brazilian Society of Soil Sciences (LEMOS & SANTOS, 1976).

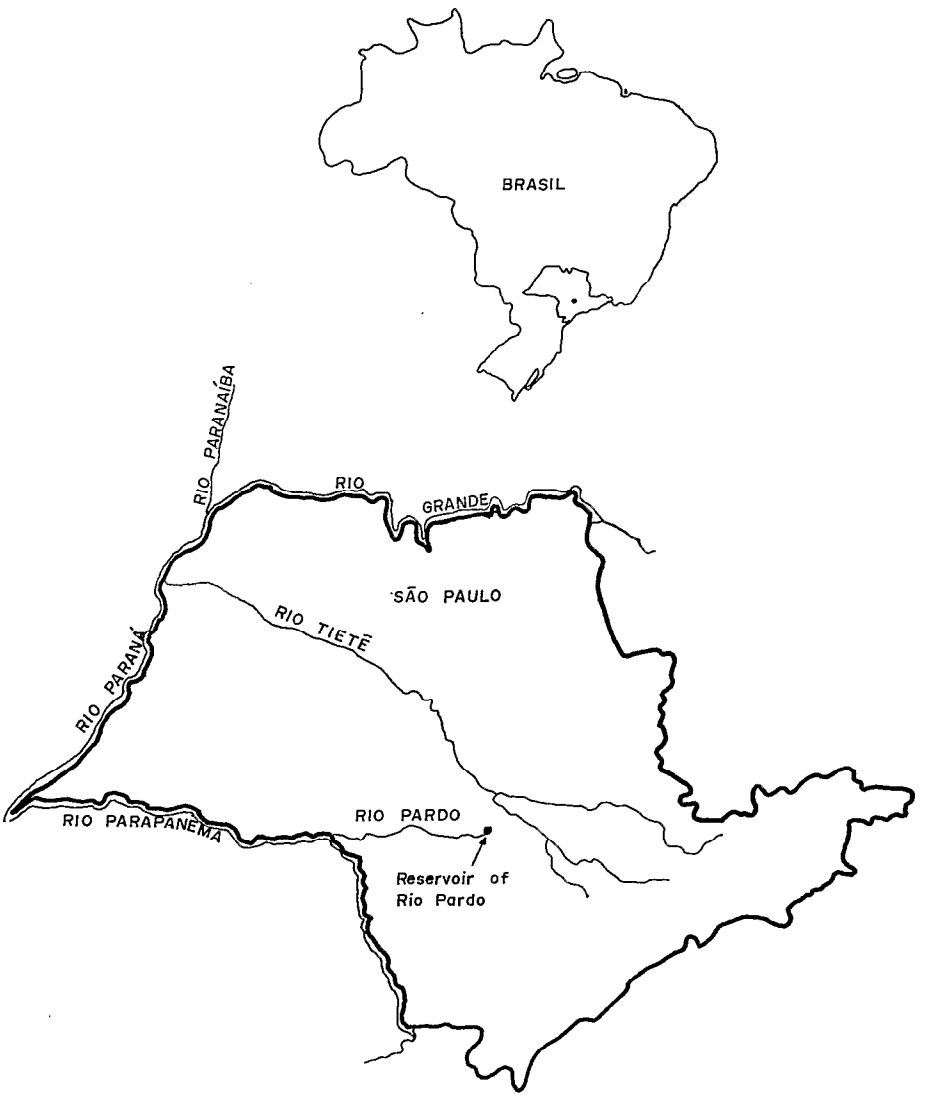

FIG. 1. — Situation of the Reservoir of the Rio Pardo (Botucatu) in the State of São Paulo and in Brazil

Relationships Between Size and Individual Weight

Length of bivalves were measured using a pachymeter. For eleven size classes, alcohol weight, shell dry weight and body dry weight were estimated. For dry weights, bodies and shells were dried in oven at 60 °C, for 48 hours.

The relationships between size and weight were used for biomass estimates of samples:

— alcohol weight = — 12.13+4.14 length (r = 0.936)
— dry shell weight = — 8.21+2.75 length (r = 0.923)
— dry body weight = — 0.38+0.13 length (r = 0.885)

4 RESULTS

4.1. Probable effects of ecological factors on the distribution and abundance of bivalves

RELATIONSHIP BETWEEN GRANULOMETRY AND DENSITY OF MOLLUSKS

Considering that the nature of bottom may have an effect on the benthic distribution and abundance, the granulometric study was carried out in the majority of sampling stations (Fig. 2). Half of the sediment samples were classified as silt loam and clay (Fig. 3). The contribution of sand in the granulo-

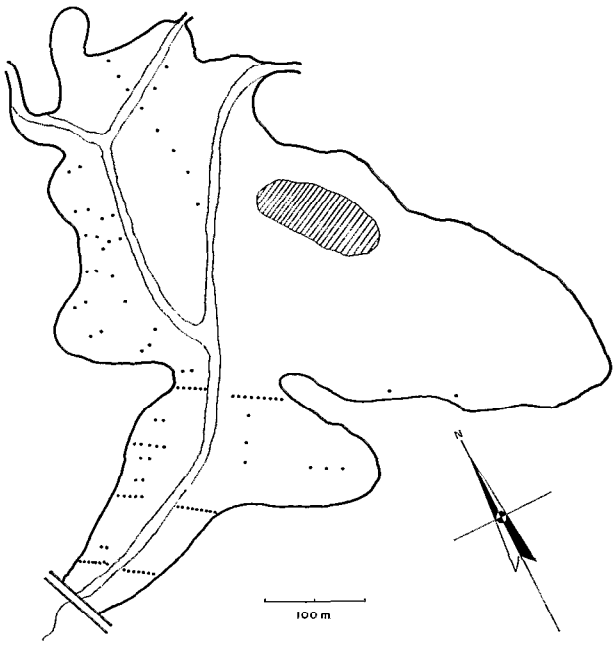

FIG. 2. — Sampling sites of the organisms and sediment in the Reservoir of the Rio Pardo (Botucatu, SP)

metric composition of bottom of the reservoir was reduced to approximately 10 % of the samples. The result of suspended particles sedimentation, from the flowing waters, is the cause of low amount of sand in all the samples.

The estimate of correlation coefficients between the main fractions of sediment and density of bivalves shows no significant relation between the sediment granulometric composition and abundance of mollusks (Tabl. I). Therefore, *Diplodon delodontus expansus* appear to have no striking preference for a sediment type in the Reservoir of Rio Pardo, at least between the different types of sediment from the samples of the environment.

OTHER FACTORS

The water content and the pH of sediment were also studied and correlated with the benthic fauna in the Reservoir. The pH of sediment was clearly acid (variation amplitude 3.8 to 6.0) and the sediment presented a water loss of 2.64 to 37.78 % after drying the samples in oven (105 °C, 24 hours).

The estimate of correlation coefficients between these characteristics and the density of bivalves showed no significant relation between the abundance of mollusks and pH and water content.

The low depth of the Reservoir (average depth: 2.5 m) appears not to be a limiting factor on the distribution of bivalves (HENRY & SIMÃO, 1984). In fact, previous studies (HENRY, 1981; HENRY & CURI, 1981a) showed that the water is well oxygenated near the bottom during the year and therefore, the mollusks can live in all the regions of the Reservoir. The conductivity of water is low (< 25 $\mu S.cm^{-1}$) (HENRY, 1981) and, therefore, don't affect the distribution of mollusks.

The Reservoir of Rio Pardo had a mean retention time of 6.3 days during the year (variation amplitude 3.4 to 12 days) and the ecological characteristics are more similar to those of rivers than of lacustrine systems (HENRY & SOUSA, 1984). The water flow, measured in the Rio Pardo and Córrego Água da Madalena (other tributary of the Reservoir) was in both the lotic systems higher than 0.3 $m.s^{-1}$ during the year (HENRY & SOUSA, 1984). These hydrological characteristics allow a continuous renewal of a water in the Reservoir and therefore affect positively on the distribution of bivalves in the environment.

4.2. **Abundance and biomass of mollusks**

The Figure 4 shows the length of all the specimens ($n = 913$) collected two days after drainage of Reservoir. The majority of bivalves was found in the length classes 5.10 to 5.65 cm ($n = 323$). No small specimens (1.80 cm) were collected in the Reservoir during our study. The mean weights for each length classes are given in Table II. Density is lower than 30 $ind.m^{-2}$ for half of the sampling sites (Fig. 5), but can reach much higher values in a few ones.

On an average for the 98 stations, density and biomass are rather high (Tab. III). If we consider such values as means for the Reservoirs, and assuming an area of 15.82 ha, the mollusk stock is therefore 5.79×10^6 individuals, and the biomass 55 tons alcohol weight, 35.6 tons dry shells, 1.7 tons dry organic matter.

5. DISCUSSION

According to ALVARENGA & RICCI (1981), Unionidea are more frequently observed in muddy bottom. However, they can also be found in sandy bottom. For MANSUR (1972, 1973), *Castalia undosa martensi* (Bivalvia, Hyriidae) give preference to habitats located near rushes in soils consisting mainly of fine sand, and *Diplodon* species are mainly observed in fine sand areas. *D. charruanus* and *D. pilsbryi* prefer bottom consisting of coarse sand and current water and muddy bottoms with calm waters (MANSUR & ANFLOR, 1981). VEITENHEIMER & MANSUR (1978) pointed out that *Mycetopoda legumen* is mainly found in compact fine sand areas. *Anodontites trapezeus*, *A. trapezialis* and *Diplodon*

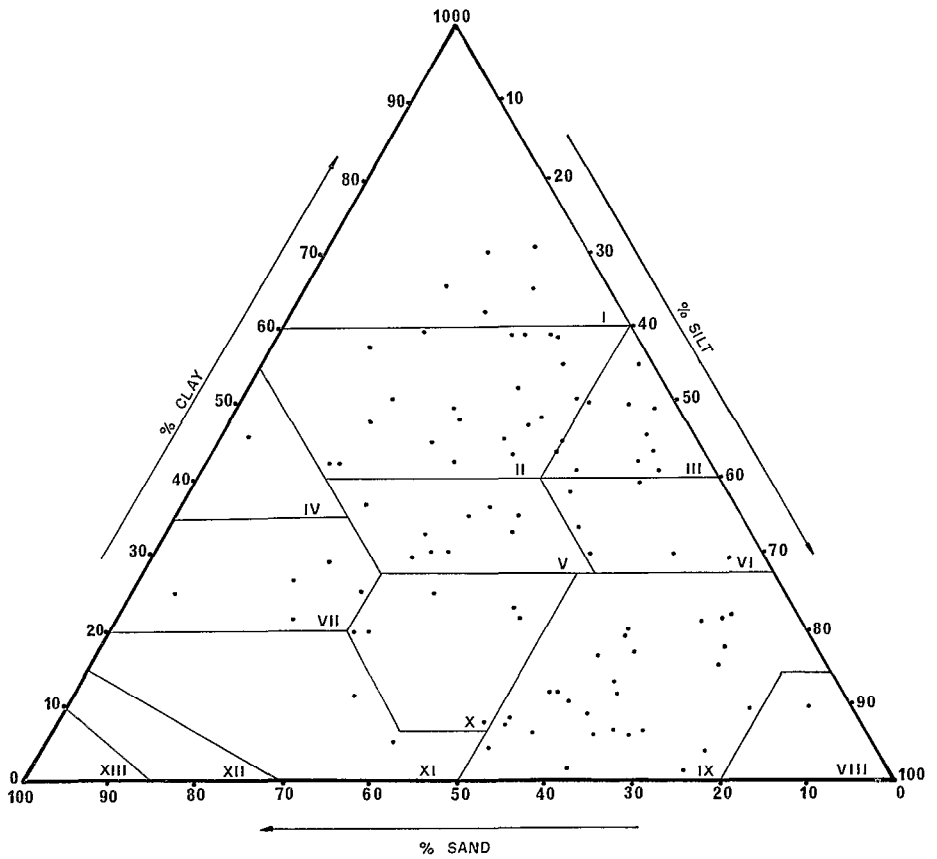

FIG. 3. — Dispersion of the sediment samples in the Reservoir of the Rio Pardo (Botucatu, SP) in relation to the total sand, clay and silt fractions (%). (Texture classes: I. Clayey clay; II. Clay; III. Silt clay; IV. Sandy clay; V. Clay loam; VI. Silty clay loam; VII. Sandy clay loam; VIII. Silt; IX. Silt loam; X. Loam; XI, Sandy loam; XII. Loamy sand; XIII. Sand)

TABLE I

Correlation coefficients between the granulometric fractions (Vcs = very coarse sand; Cs = coarse sand; Ms = medium sand; Fs = fine sand; Vfs = very fine sand; silt and clay) and biomass (Aw = alcohol weight; Dw = dry weight) and density of *Diplodon delodontus expansus*

VARIABLE / VARIABLE	Vcs	Cs	Ms	Fs	Vfs	Silt	Clay	Aw	Dw	Density
Vcs	1.000	0.330	0.439	0.358	0.044	-0.239	-0.106	-0.182	-0.180	-0.185
Cs	-	1.000	0.596	0.124	0.089	-0,087	-0.286	-0.113	-0.111	-0.103
Ms	-	-	1.000	0.757	0.472	-0.340	-0.348	-0.046	-0.044	-0.030
Fs	-	-	-	1.000	0.639	-0.394	-0.348	-0.074	-0.072	-0.053
Vfs	-	-	-	-	1.000	-0.374	-0.223	-0.132	-0.129	-0.135
Silt	-	-	-	-	-	1.000	-0.650	0.159	0.161	0.154
Clay	-	-	-	-	-	-	1.000	-0.006	-0.009	-0.017
Aw	-	-	-	-	-	-	-	1.000	0.999*	0.981*
Dw	-	-	-	-	-	-	-	-	1.000	0.980*
Density	-	-	-	-	-	-	-	-	-	1.000

*$p < 0.05$

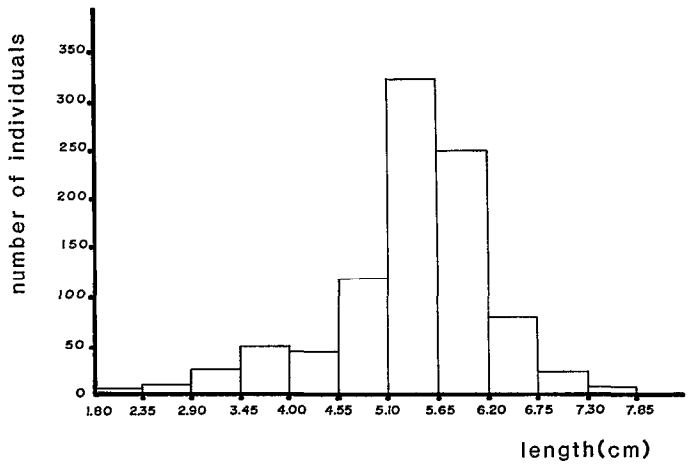

Fig. 4. — Distribution of the *Diplodon delodontus expansus* specimens in function of length

TABLE II

Means (x) and standard deviations (s) of lenght and biomass (alcohol and dry weights of the shell and body) of *Diplodon delodontus expansus*

SIZE CLASSES (cm)	ALCOHOL WEIGHT (g)		SHELL DRY WEIGHT (g)		BODY DRY WEIGHT (g)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
1.80 - 2.35	0.670	0.138	0.420	0.066	0.023	0.006
2.35 - 2.90	1.230	0.237	0.785	0.101	0.040	0.014
2.90 - 3.45	1.934	0.512	1.222	0.303	0.062	0.017
3.45 - 4.00	2.998	0.710	1.889	0.531	0.089	0.027
4.00 - 4.55	4.687	0.789	3.026	1.026	0.161	0.023
4.55 - 5.10	6.558	1.312	4.409	0.746	0.235	0.058
5.10 - 5.65	9.252	1.526	5.794	1.172	0.274	0.060
5.65 - 6.20	11.544	1.824	7.243	1.071	0.347	0.076
6.20 - 6.75	15.746	1.772	10.453	1.619	0.475	0.110
6.75 - 7.30	19.237	2.567	12.874	1.816	0.662	0.188
7.30 - 7.85	22.046	2.789	14.886	1.836	0.690	0.085

rotundus gratus are found in a muddy or a muddy-sand bottom (HEBLING, 1976; HEBLING & PENTEADO, 1974). LEWANDOWSKI & STANCZYKOWSKA (1975) comparing the density of *Unio tumidus* at three stations with different granulometric characteristics, found a higher number of individuals in areas consisting of sandy bottoms covered with a fine layer of silt and a considerable amount of decayed vegetal matter whereas the distribution of *Anodonta piscinalis* was approximately identical at the three stations. HARMAN (1972) studied the distribution of mollusks in the State of New York (USA) and found four different associations according to the nature of the bottom.

In Lake Chad, the nature of sediment has a significant influence on distribution and density of the benthic fauna (DEJOUX *et al.*, 1971).

In the Reservoir of the Rio Pardo, the results of granulometric analysis showed that silt was the most frequent fraction observed. Althought the correlation-coefficients obtained between silt and density and silt and biomass were the higher correlations, they were not significant. Therefore, this granulometric fraction was not directly related to biomass and density of the species. According to HEBLING & PENTEADO (1974), water content is very important for the vertical distribution of bivalves in the sediment. They reported that *Diplodon*

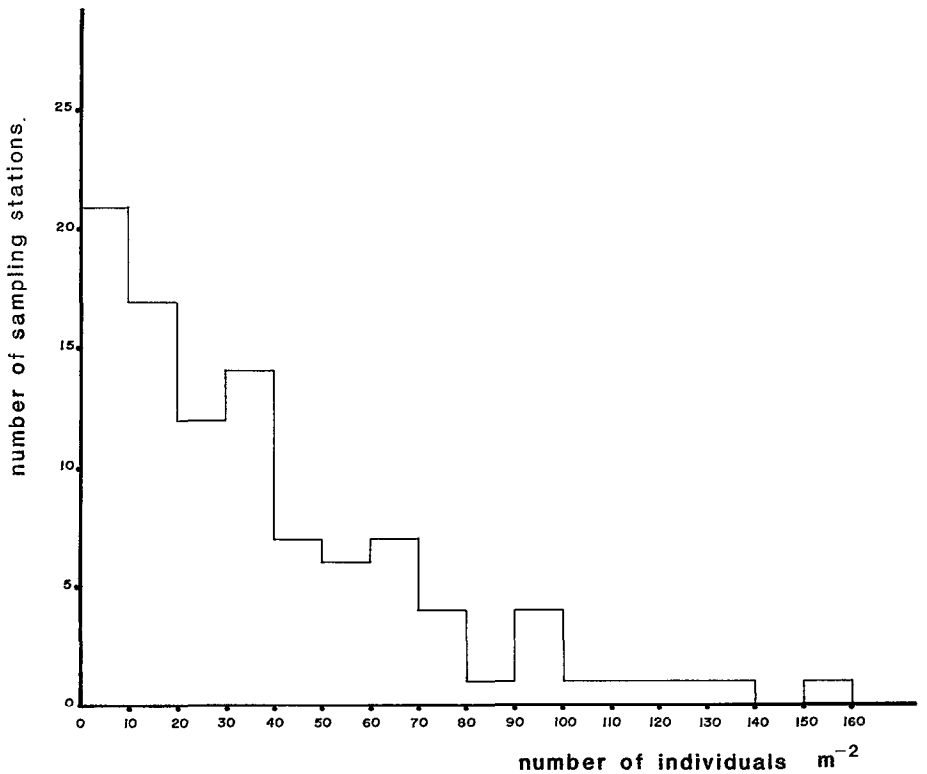

FIG. 5. — Sampling frequence in function of population density (specimens.m^{-2}), for the 98 sampling stations in the Reservoir of Rio Pardo

TABLE III

Means ($\bar{x}$) and standard deviations (s) of biomass (g.m^{-2}) and density (individuals.m^{-2}) of *Diplodon delodontus expansus* in 98 sampling stations

VARIABLE	STATISTICS	
	$\bar{x}$	s
Alcohol weight	341.27	293.97
Shell dry weight	225.00	191.07
Body dry weight	10.92	9.30
Density	36.62	32.31

rotundus gratus occurs in substrata with high contents of silt and clay and water content. In the Reservoir of the Rio Pardo, the majority of sediment consisted of silt, but water content appear to have no effect on the abundance of bivalves.

Depth had no limiting effect on the occurrence of bivalves in the Reservoir of the Rio Pardo (HENRY & SIMÃO, 1984). Others chemical parameters (dissolved oxygen, conductivity) had no direct effect on density of *D. delodontus expansus*. The apparent absence of limiting factors explains the high density of bivalves in the Reservoir.

Density and biomass of *D. delodontus expansus* in the Reservoir of the Rio Pardo were high when compared to the data on the other species in the temperate and tropical lakes (Tab. IV). Comparison of these data in temperate (Lake Mikolajskie, Poland) and tropical (Reservoir of the Rio Pardo, Brazil) regions showed that the population density of Unionidae (5 species) in Lake Mikolajskie was 0.6 specimens.m^{-2}, extremely low when compared to the Reservoir of the Rio Pardo (36.62 specimens.m^{-2}). The same was observed for biomass. In Amazonian Lakes, the percentage composition of Bivalvia *(Pisidium sterkanium)* to benthic biomass ranges from 0 to 22 % in seven lakes and the absence of mollusks and other groups (Hirudinea, Oligochaeta, Chironomidae and Ephemeroptera) in some lakes, was due to low oxygen content, chemical factors and to water level fluctuations during the year (FITTKAU *et al.*, 1975).

The results in the Reservoir of Rio Pardo are the first step to better knowledge of benthic fauna of

TABLE IV

Comparison of density and biomass of aquatic shells in temperate and tropical environments

LAKES OR RESERVOIRS	SPECIES	DENSITY (ind.m^{-2})	BIOMASS ALCOHOL WEIGHT (g.m^{-2})	BIOMASS SHELL DRY WEIGHT (g.m^{-2})	BIOMASS BODY DRY WEIGHT (g.m^{-2})	REFERENCES
Mikolajskie (littoral zone)	Anodonta piscinalis Anodonta cygnea Anodonta complanata Unio tumidus Unio pictorum	0.60	10.965	2.632	0.184	Lewandowski & Stanczykowska (1975)
Juturnaíba	Diplodon besckeanus	12.48	-	-	-	Alvarenga et al. (1977)
Chad (1968)	Corbicula africana	42.43	-	-	-	Lévêque (1972)
	Caelatura aegyptiana	4.37	-	-	-	
	Pisidium pirothi	7.86	-	-	-	
	Byssanodonta parasitica	10.13	-	-	-	
Chad (1970)	Corbicula africana	43.42	10.091	-	-	Lévêque (1972)
	Caelatura aegyptiana	6.70	10.527	-	-	
	Pisidium pirothi	3.54	0.018	-	-	
	Byssanodonta parasitica	3.61	0.027	-	-	
Reservoir Rio Pardo	Diplodon delodontus expansus	36.62	347.27	225.00	10.92	This work

brazilian reservoirs and to their role in the functionning of these reservoirs. The bivalves are filterers and can contribute for a decrease of suspended particles in the water column. A previous study (HENRY & CURI, 1983) showed that the suspended matter is, in water surface, smaller in lower than in upper reservoir. *D. delodontus expansus* is surely an important component for decreasing of the suspended particles through filtration, beyond of seston sedimentation. The filtration rate can vary from 0.3 l.h^{-1} for Unionidae in Lake Mikolajskie, Poland (LEWANDOWSKI & STANCZYKOWSKA, 1975) to 3.6 l.h^{-1} for *Unio pictorum* (ELLIS, 1978). If these filtration rates are applied for *D. delodontus expansus* and considering the population density in the Reservoir of the Rio Pardo, all the volume of Reservoir (406,411 m^3) could be filtered in approximately 10 days to less than one day, respectively.

These considerations show that a study of aquatic ecosystem should take into account the benthic fauna for a better understanding of their structure, dynamics and productivity.

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