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SPATIAL AND TEMPORAL CHANGES OF THE MALACOFAUNA FROM A SANDY SHORE IN THE RÍO DE LA PLATA, ARGENTINA

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ABSTRACT

The aim of this work is to analyze the composition, structure and distribution of the malacofauna present in the sandy shore of the Río de la Plata estuary, Argentina, related to temporal and spatial variables. On the basis of six seasonal samplings, biocenotic parameters (abundance, density, dominance and frequency) and structural parameters (Shannon-Weaver diversity, species number, evenness and mean density) were calculated. Two kinds of surfaces were considered: vegetation and sediment.

A total of 22 macroinvertebrate taxa was collected in 218 samples (mean organism density: 18,256.6 individuals/m^2). Three groups were dominant: molluscs, hirudines (leeches) and isopods. Molluscs were represented by six gastropod species (*Asolene platae, Biomphalaria straminea, Chilina fluminea, Gundlachia concentrica, Heleobia pisicium, Pomacea insularum*) and four bivalve species (*Corbicula fluminea, C. largillierti, Erodona mactroides, Pisidium sterkianum*). The gastropod *Heleobia piscium* (Orbigny) had the highest density (D = 13,850 individuals/m^2). Another dominant species was the bivalve *Corbicula fluminea* Müller, which was recorded in 100% of the samplings.

No changes were observed related to the temporal variable. But, when the spatial variable was considered, a close relationship was shown between both kinds of substrata and a clear littoral zonation. During low tides, two zones were determined, one parallel to the coast that extended 150-200 m, and another of the same size, with a predominance of sands and lesser organic content adjacent to the coast. Molluscs were present in both zones, although the highest density and richness were attained in the first zone, in which hirudines were also found. The other zone yielded isopods, species of the bivalve *Corbicula* (almost exclusively) and a very low gastropod density.

Key words: ecology, benthos, Gastropoda, *Asolene platae, Biomphalaria straminea, Chilina fluminea, Gundlachia concentrica, Heleobia piscium, Pomacea insularum*, Bivalvia, *Corbicula fluminea, C. largillierti, Erodona mactroides, Pisidium sterkianum*, Argentina.

INTRODUCTION

Littoral zones are transitional environments between aquatic and terrestrial conditions (Wetzel, 1981; Margalef, 1983). They are characterized as dynamic zones bearing a fauna adapted to the typical gradients of an intertidal area (Clarke Guerra & Peña Monardez, 1988).

Changes in the structure of benthic communities are diagnostic features that can detect alterations caused by human activity (Prat & Ward, 1994).

In Argentina, studies of sandy shore benthos deal mainly with the sea shore. Studies on freshwater environments are focused mostly on deep benthos. Researches involving the littoral benthos of continental waters are scarce. The following works refer specifically to the Río de La Plata shore: Scarabino *et al.*, 1975; Roccatagliata, 1981; Darrigran, 1991, 1992a, 1993, 1994, 1995, 1999; Darrigran & Rioja, 1988; Darrigran & Pastorino, 1995; Gullo & Darrigran, 1991.

The Río de la Plata estuary, with its colossal size (35,000 km^2) and great water flow (16,000-28,000 m^3/s) producing its own depuration by dispersion and dilition of the waste, is highly influenced by human activity (Colombo *et al.*, 1990), which exerts a very harmful effect on the coast. The Río de la Plata Argentine shore comprises two kinds of natural substrata: (1) hard "caliche," and (2) soft, sandy or sandy-silty.

It is important to know the specific composition, abundance and distribution of the benthic fauna of the Río de la Plata intertidal area in order to evaluate the environmental impact caused by humans in this multiple-use environment (industrial and urban use, sportive and comercial fishing, water sports, etc).

The purpose of this work was to study the composition, distribution and structure of the malacofauna of a sandy shore, Punta Blanca, in the Río de la Plata (34°56'38" S lat.; 57°40'55" W long.), in relation to the malacofauna's spatial, temporal and trophic components. The Punta Blanca shore has a high percentage of sandy substrate and a low percentage of silty substrate (Darrigran, 1991, 1992a; Wells & Daborn, 1998).

ENVIRONMENTAL SETTING

The climate of the area is warm-temperate. The littoral sediments are composed of sandy-silts and silts (Fig. 1).

The Río de la Plata shore is influenced by an inconstant and rather unpredictable hy-

FIG. 1. Río de la Plata Map. Geographic location of the sampling stations, Punta Blanca. Coarse shading = silt, silty-sand sedimentary facies; fine shading = silty clay facies. Zone A, concentration saline (C.S.) = 0.5‰; Zone B, C.S. = 0.5 to 25‰; Zone C, C.S. = 25 to 35‰.

drologic regime owing to the action of daily tides of unequal levels. Also, aeolian action causes significant disturbances in daily tides (Balay, 1961). During low tides, the Punta Blanca shore provides a large sandy beach about 500 m in width from the coast to the low tide level. Two sectors, I and II, were considered in the area studied. Each sector displayed a series of sub-environments or "strata" parallel to the coast (Fig. 2) which were defined by biotic peculiarities (presence or absence of hydrophytes) and abiotic ones (water retention and air exposure time).

Sector I was divided into four strata: A, B, C and D.

The **A stratum** is the closest to the coast and is ± 10 m wide. It matches the beginning of a ground depression that is parallel to the coast. Hydrophytes, empty shells and anchoring structures of the marshy vegetation lie on the substratum. Marshy vegetation is present throughout the year and consists of *Scirpus californicus* (C.A. Mey) Stend, *Gymnocoronis spilanthoides* (Don) DC., *Echinodorus grandiflorus* (Cham. et Schlech) Micheli, and *Eryngium pandanifolium* Chan. et Schlecht.

The **B stratum** is the continuation and the deepest part of the A stratum (0.25 to 0.30 deep). It is 15 m wide. The amount of empty shells and anchoring structures for vegeta-

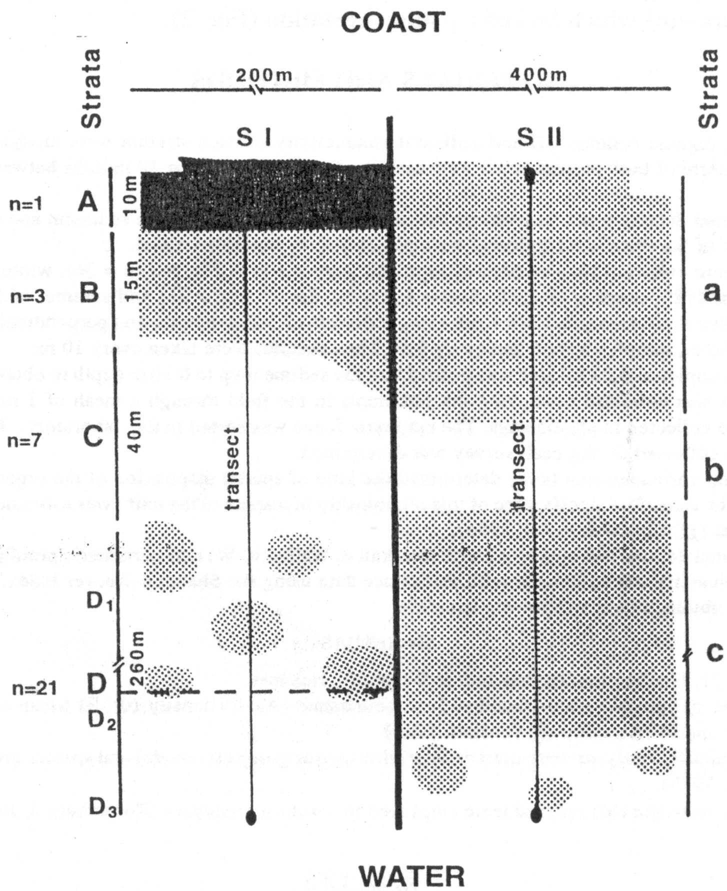

FIG. 2. Diagram of the sampling zone on the Punta Blanca shore. Shading = Rushland (*Scirpus californicus*); solid black = other marshy hydrophytes. **S.I** = sector I. **S.II** = sector II. **N** = minimal number of samples.

tion is smaller. *Scirpus californicus* is representative of the marshy vegetation.

The **C stratum** is 40 m wide and corresponds to another depression (± 0.50 m deep). Both B and C strata never dry out, even during low tides. This C stratum had no hydrophytes throughout the year, except during the 1985 summer, when a dense proliferation of *Elodea* Rich and, in lesser density, species of the genus *Potamogeton* Linnaeus could be observed. A filamentous chlorophytic algae of the genus *Rhizoclonium* was also found. This dense vegetation comprised the whole B and C strata and the first 25% of D stratum. Since February 1985, the filamentous algae were absent. At the beginning of the fall of 1985, the remaining vegetation had completely disappeared.

Although this vegetation is generally recurrent during summers (Darrigran, 1991), it did not develop from the summer of 1985 through the summer of 1987.

The **D stratum** is the last and most extensive of the substrata (± 250 m wide). It consists of isolated depressions and sand mounds, and has a slight slope. Small groups of scattered *Scirpus californicus* represent the hydrophytes.

Sector II had smoother sediments than did Sector I. *Scirpus californicus* prevailed among the hydrophytes, forming a broad rushland divided into two strata by a wide depression (B stratum) which lacked aquatic vegetation (Fig. 2).

MATERIALS AND METHODS

Granulometry, organic content, pH and sediment conductivity of each stratum were analyzed. Water and sediment temperature of both sectors strata were measured every 30 days for 10 months between 1 pm and 2 pm.

The malacofaunal density was measured by the amount of mollusks present in sediment and on *Elodea* sp., so the dry weight of the vegetation collected during each survey was determined.

Six samples were collected (n = number of samples): summer (n = 43), fall (n = 36), winter (n = 36) and spring (n = 36) of 1985; summer of 1986 (Sector I, n = 34; Sector II, n = 36) and summer of 1987 (n = 31). Samples were taken during maximal low tides along transects of 300 m length, and perpendicular to the coast line. In the first 60 m, samples were taken every 5 m. Then samples were taken every 10 m.

A cylindrical sampler of 0.07 m^2 area was pushed into the sediment up to 0.10 m depth to obtain the samples. The malacofauna was collected by sieving the sediments in the field through a mesh of 1 mm. Immersed hydrophytes were collected in plastic bags. The epiphytic fauna was sorted in the laboratory. The dry weight of the vegetation collected during each survey was determined.

The relationship variance/mean (s^2/x) determined the kind of spatial disposition of the organisms sampled (Elliott, 1983). The statistical significance of this relationship in respect to the unity was estimated by means of the chi square test (χ^2) (Sokal & Rohlf, 1984).

The malacofaunal density was compared with Kruskall & Wallis (K-W) non-parametric proof (Siegel, 1974).

The specific diversity was calculated with abundance data using the Shannon-Weaver Index.

Evenness was obtained by the following equation:

$$Ev=(e^{H-1})/(S-1)$$

where e=2.71; H=Shannon-Weaver Index; S=specific richness.

Five biocenotic parameters were considered: 1) abundance (A), 2) density (d), 3) Mean density (D), 4) dominance (Dm) and 5) frequency (F) (Cornet, 1986).

Taxonomic similarity analyses were used to determine census groups (Q mode) and species groups (R mode) (Sneath & Sokal, 1973).

Jaccard (J) and Morisita (M) indexes were employed in similarity analyses (Rosemberg & Resh, 1993).

RESULTS

Environmental data

Granulometric Composition. A sand fraction prevailed in Sector I. C stratum and the first part of D stratum tended towards a greater concentration of silts, and, to a lesser extent, towards clay (Fig. 3).

The sand fraction percentage decreased in Sector II in relation to Sector I, and therefore the silt and clay fractions increased (Fig. 3). The C stratum of sector II showed these features up to its first half, the rest being as D stratum of Sector I.

The trends observed for each sector and stratum, were kept throughout the year.

Sediment Chemical Composition. Sector I had low percentages of organic content, decreasing progressively from the coast towards the river. Therefore A, B and C strata were those of greatest organic concentration (Fig. 4). Sector II had a greater organic concentration than did Sector I.

The pH of Sector I was almost neutral, while in Sector II, it tended to acidify (Fig. 4).

Temperature. There were seasonal water temperature changes which varied from a maximum of 33°-35°C during the summer to a minimum of 14°-15°C in winter. There

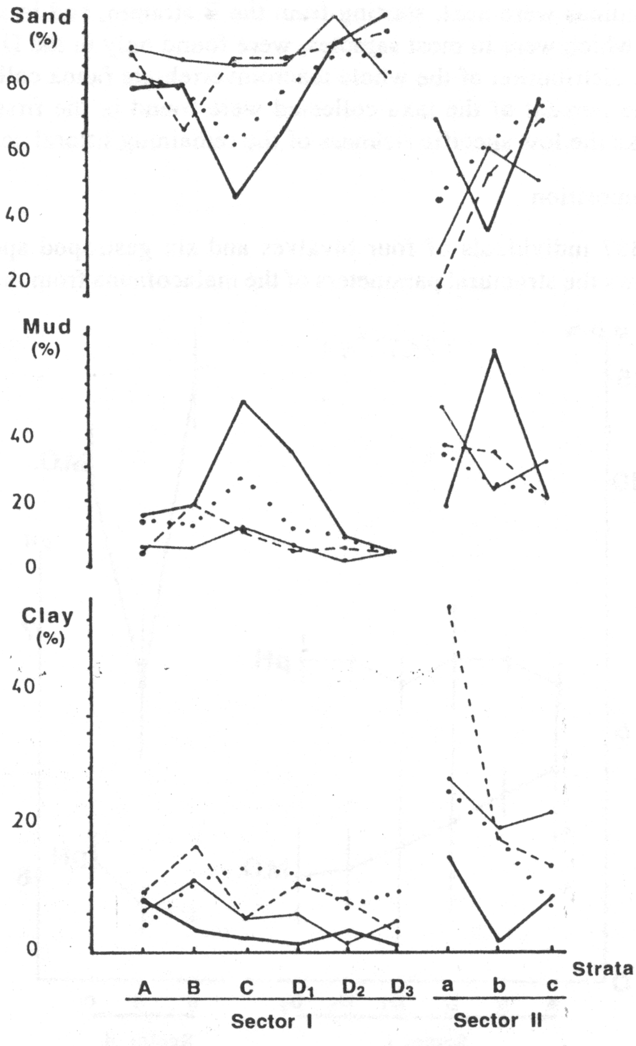

FIG. 3. Seasonal variation in amounts of sand, mud and clay in the Punta Blanca shore. .... = summer; ———— = winter; – – – – – = autumn; ——— = spring.

were differences of 1°C between the water-sediment phases (higher in the liquid medium). No thermal differences were observed between the two sectors.

Composition of the littoral macrobenthos

Two hundred and 18 samples were taken, comprising a total of 278.596 specimens belonging to 22 taxa (mean density = 18,256.6 individuals/m²). Fig. 5 represents the specific richness (S) and the total number of specimens of the most important macroinvertebrates collected and shows the predominance of the malacofauna over the other groups (arthropods-isopods and annelids-hirudines).

The composition of the littoral macrofauna displayed some differences in diversity and density of taxa in each season and in each stratum. Molluscs were the most stable group, both in density and in specific richness, when considering spatial and temporal variables. The hirudines were next, starting from the B stratum, and in all seasons. Finally the isopods, which were in most samples, were found only in the D stratum.

Fig. 6 shows the distribution of the whole macroinvertebrate fauna collected in Punta Blanca. Ninety-one percent of the taxa collected were found in the first 150 m of the transect. This marks the low specific richness of the remaining littoral zone sampled.

Malacological composition

A total of 262,357 individuals of four bivalves and six gastropod species was collected. Table 1 shows the structural parameters of the malacofauna from the Punta Blanca

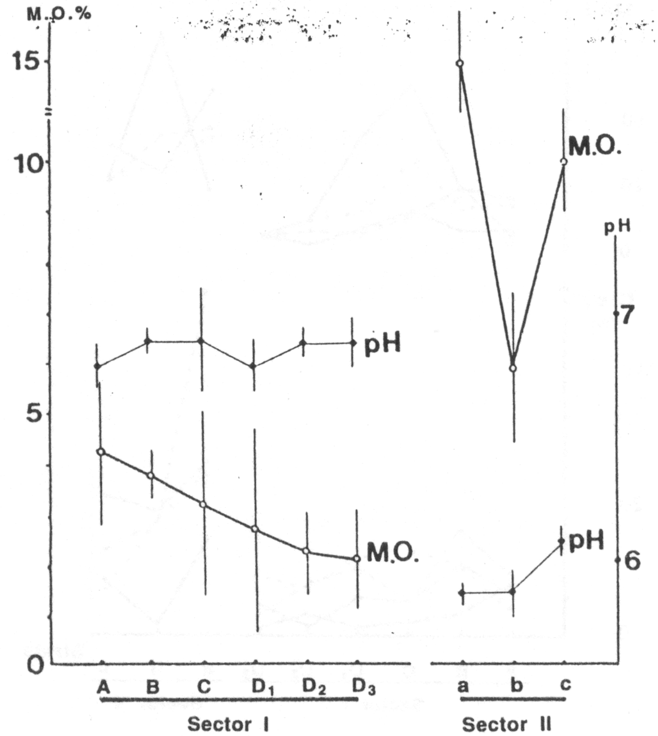

FIG. 4. Organic content (M.O.) and pH of the sampling area on Punta Blanca shore. Bars at each point represent 95% confidence intervals.

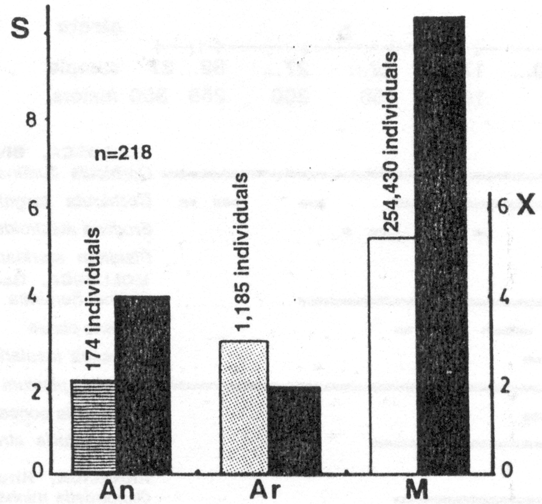

FIG. 5. Dominant benthic macroinvertebrates on the Punta Blanca shore. Comparison of the specimens number of each group in Punta Blanca. X = total number of specimens in log; S = specific richness; N = samples; **An** = Annelida (hirudines, *i.e.*, leeches); **Ar** = Arthropoda (isopods); **M** = Mollusca (Gastropoda and Bivalvia).

shore, including mean density, dominance, frequency and faunistic features of each population in the six samples. The highest density corresponds to the gastropod *Heleobia piscium* (Orbigny) (13,850 ind./m^2), *i.e.*, 92.8% of the species collected. The two other dominant species were the pelecypod *Corbicula fluminea* Müller (constance frequency = 100%) and the gastropod *Biomphalaria straminea* (Dunker) (rare frequency = 20.7%). Two important littoral populations were those of the bivalve *Corbicula largillierti* Philippi (constance frequency = 68.5%; density = 172 ind./m^2), and the gastropod *Chilina fluminea* (Maton) (common frequency = 34.5; density = 20 ind./m^2). The remaining species were rare on the Punta Blanca sandy shore.

This shore displays two kinds of spatial disposition of molluscs: aggregate and random. The latter was not frequent and could be due to a spurious sampling effect.

Molluscan populations which are common or constant have the same numerical importance in both sectors of the Punta Blanca sandy shore (Fig. 7). The total densities and the density of each species did not show significant differences in both sectors.

During the 1985 summer, detritivores and periphyton-grazing molluscs occurred in the immersed hydrophyte stratum. The mean density of the molluscan populations in this substratum was 23,703 specimens for every 10 g of *Elodea* sp. *Heleobia piscium*, *Biomphalaria straminea* and *Chilina fluminea* were found in decreasing order of density; *Pomacea insularum* d'Orbigny and *Gundlachia concentrica* (d'Orbigny) had lower values.

Fig. 8 shows the vegetation dry weight (in grams) per sample along the transect, and the abundance of associated malacofauna. Along the hydrophyte substratum, the population number is homogeneous and independent of the abundance or the substratum thickness. Density values of the malacofauna present in the aquatic vegetation did not show significant differences ($X^2_{(1;0.05)}$ = 3.84; K-W = 0.82). When the hydrophitic substrate disappeared (at the beginning of the fall season of 1985), *Biomphalaria straminea* was no longer found and *Heleobia piscium* decreased to one-tenth of its mean density.

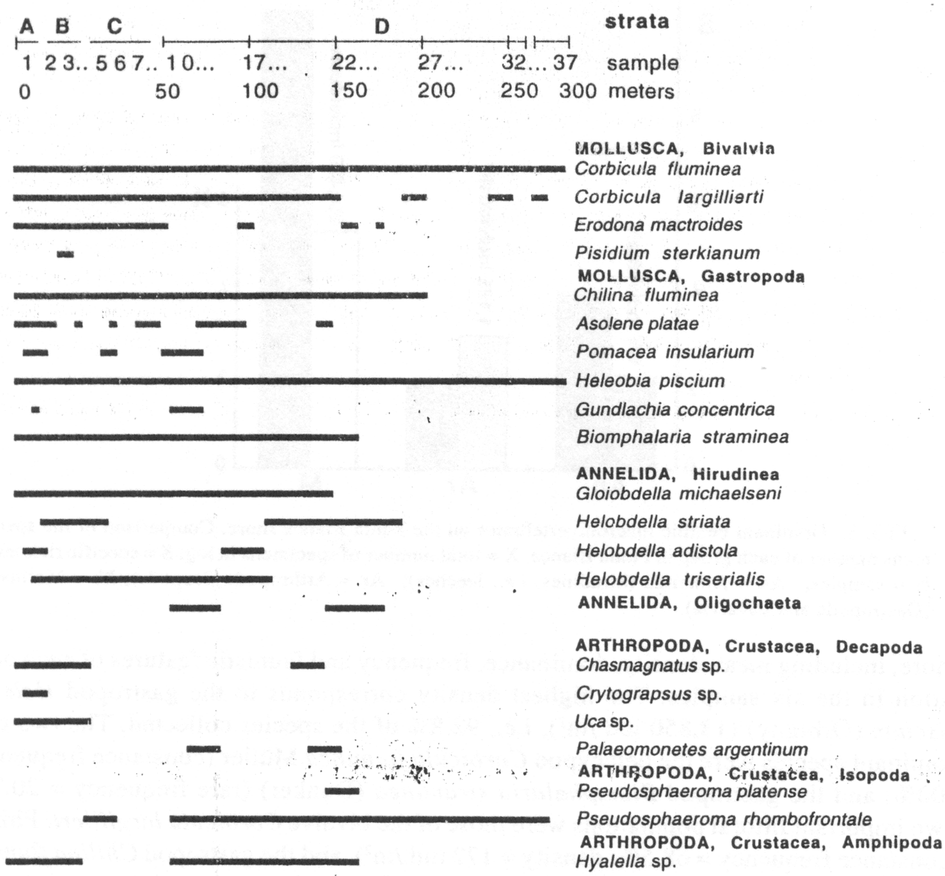

FIG. 6. Faunistic composition of the littoral macrobenthos of Punta Blanca. Bold line = presence.

The greatest molluscan richness and density were found in the first half of the transect. However, bivalves were well represented, both in the first stratum (50% of the total density) and in the other three. Gastropods, to the contrary, had 70% of their total density in the first stratum, with less than 10% of their density being in the D stratum.

Taxocenosis structure

The structural parameters of the Punta Blanca molluscan taxocenosis can be seen in Table 1. The specific richness did not show marked differences through the seasons of the year, although it decreased in the last two samplings. The diversity index values were low (less than 1) and, as to evenness, they tended to increase in the last samples.

Cluster analysis

Fig. 9 shows the dendrogram resulting from the cluster analysis of the sample unities of each sampling made in the 1985 summer in relation to the qualitative composition of its malacofauna (Q mode). Two groups of samples segregate clearly over 50% of similarity: the first comprises all the samples collected from the sediment (group I); the second encloses those taken from the demersed aquatic vegetation during that summer (group II).

Fig. 10 represents a dendrogram of the quantitative analysis of the species in each

TABLE 1. Parameters of the malacofauna from Punta Blanca sandy shore: **A**, Quantitative parameters.

A

SPECIES	D	Dm	F	F.C.
C. fluminea Müller	791	5.30	100.00	c d di
C. largillierti Philippi	81	0.50	68.52	c di
E. mactroides Daudin	3	0.02	12.35	r
Ch. fluminea (Maton)	20	0.13	34.46	co
A. platae (Maton)	1	0.006	6.37	r
P. insularum Orbigny	2	0.02	6.37	r
H. piscium (Orbigny)	13,850	92.80	96.41	c d e
B. straminea (Dunker)	167	1.21	20.72	d r di
G. concentrica (Orbigny)	1	0.01	1.59	r
P. sterkianum Pilsbry	0.2	0.001	0.39	r

B

	1	2	3	4	5	6	TOTAL
H	0.38	0.31	0.27	0.71	0.44	0.94	0.45
Ev	0.07	0.05	0.04	0.15	0.11	0.31	0.06
D	29,488	17,077	15,102	9,32	11,256	3,382	14,257
X_t	116,115	41,362	31,714	21,964	29,154	7,893	247,484
S	8	8	8	8	6	6	10

Dm = dominance; F = frequency; D = density; x = specimens number; F.C. = faunal features (d = dominant; c = constant; di = diffuse; r = rare; e = expansive; co = common). **B**, Structural parameters. 1 = summer/1985; 2 = fall/1985; 3 = winter/1985; 4 = spring/1985; 5 = summer 1986; 6 = summer/1987. H = specific diversity; ev = evenness; S = specific richness; D = mean density; X_t = total number of molluscs.

sampled substratum (R mode). Two groups segregate at a low similarity level. Group I comprises *Heleobia piscium*, *Corbicula fluminea* and *C. largillierti*, and group II comprises the remaining species. *Heleobia piscium* is, within group I, isolated from the other two species. *Heleobia piscium* is one of the most frequent species along the transect and the one reaching the highest density.

DISCUSSION AND CONCLUSIONS

In this paper, the strong influence of the stratum on the malacofaunal distribution can be seen. In the area studied, the substratum consists of hydrophytes and sediments. Hydrophytes are, by themselves, a definite habitat for most freshwater gastropods (Mouthon, 1980; Rondelaud *et al.*, 1985).

Sediment is the main factor of distribution of the deep benthos malacofauna in freshwater bodies (Harman, 1972; Bonetto *et al.*, 1973). Deep benthos occurs in a more stable environment than the littoral benthos (Claassen, 1987). Potential factors acting on the distribution of deep benthic organisms (temperature, salinity, air exposure, etc.) provide low variability. However, littoral environments are more unstable since they are the interface between the area of land drainage and the open water (Wetzel, 1981). Other factors besides the kind of substratum noteably affect the benthos distribution in a littoral environment. In the area studied, these factors are:

1. Water energy, which acts in two different ways:
   a. Indirectly, related to the kind of sediment; particles are arranged by size accord-

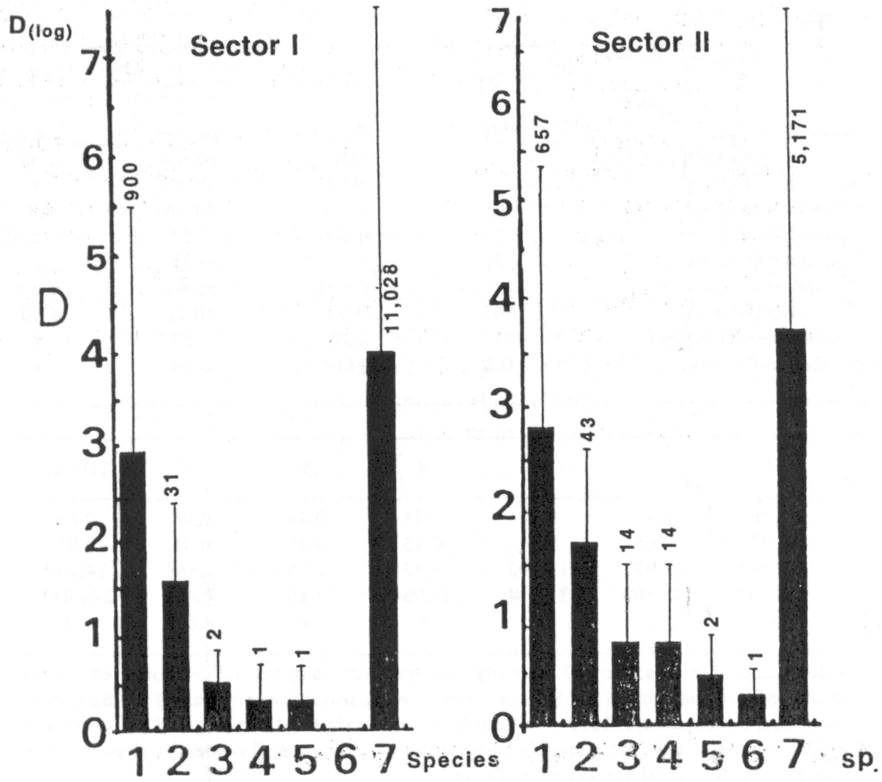

FIG. 7. Comparison of molluscan population densities on the Punta Blanca shore during summer 1986. Malacofaunal density (in $\log_{10}$ (x+1). 95% confidence intervals. **I** and **II** = sector I and sector II. **1** = *Corbicula fluminea*; **2** = *Corbicula largillierti*; **3** = *Erodona mactroides*; **4** = *Chilina fluminea*; **5** = *Asolene platae*; **6** = *Pomacea insularum*; **7** = *Heleobia piscium*.

ing to the water movement velocity (Parker *et al.*, 1985).

b. Directly over the specimens: in the case of molluscs with indirect reproduction, it affects the settling larval and dispersion (Mouthon, 1980; Gallardo, 1989). Likewise, it affects the disposition of the infaunal mollusc populations, and also the wear on shells (Bonetto *et al.*, 1975; Ituarte, 1981, 1982).

2. Air exposure. Littoral organisms must be adapted to this factor, as they depend on tidal rhythms. Changes of temperature, salinity and desiccation are quite marked during exposure to air. The hydrologic regime of the Río de la Plata shore is also influenced by winds and changing tidal cycles and, therefore, exposure periods become in-constant.

3. Organic content of sediments. This affects the number of specimens in molluscan populations according to the kind of trophic ethology to which they belong (Bonetto *et al.*, 1973; Levington, 1974; Reise, 1985). In the substratum available at the Punta Blanca shore, the total density of gastropods (deposit feeders) is higher than 70% in the environment formed by A, B and C strata, *i.e.*, where the greatest silt and organic concentration is found; the rest of their total density is found in D stratum. Bivalves (suspensivores) are most frequent in D stratum (F = 50%) where silt and organic concentration decrease and, therefore, there are lower probabilities for the filling up the bivalves' filter branchiae (Levington, 1979).

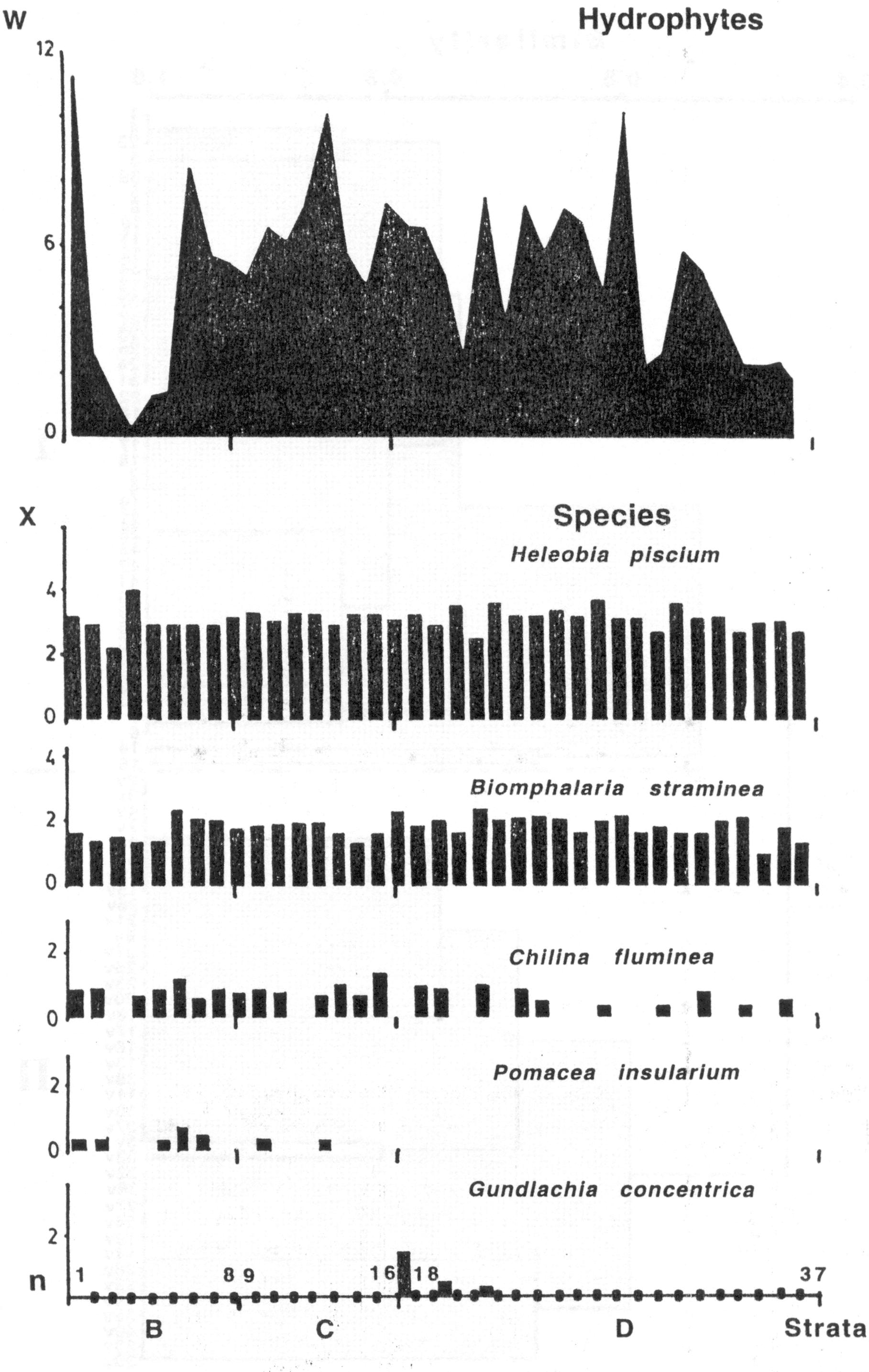

FIG. 8. Comparison between the abundance (number of specimens in each sample) of molluscan populations associated with the *Elodea* sp. stratum and *Elodea* sp. abundance (weight of the vegetation in each sample). Sampling of summer 1985. **X** = abundance in $\log_{10}(x+1)$; **W** = abundance in grams; **1 – 37** = samples.

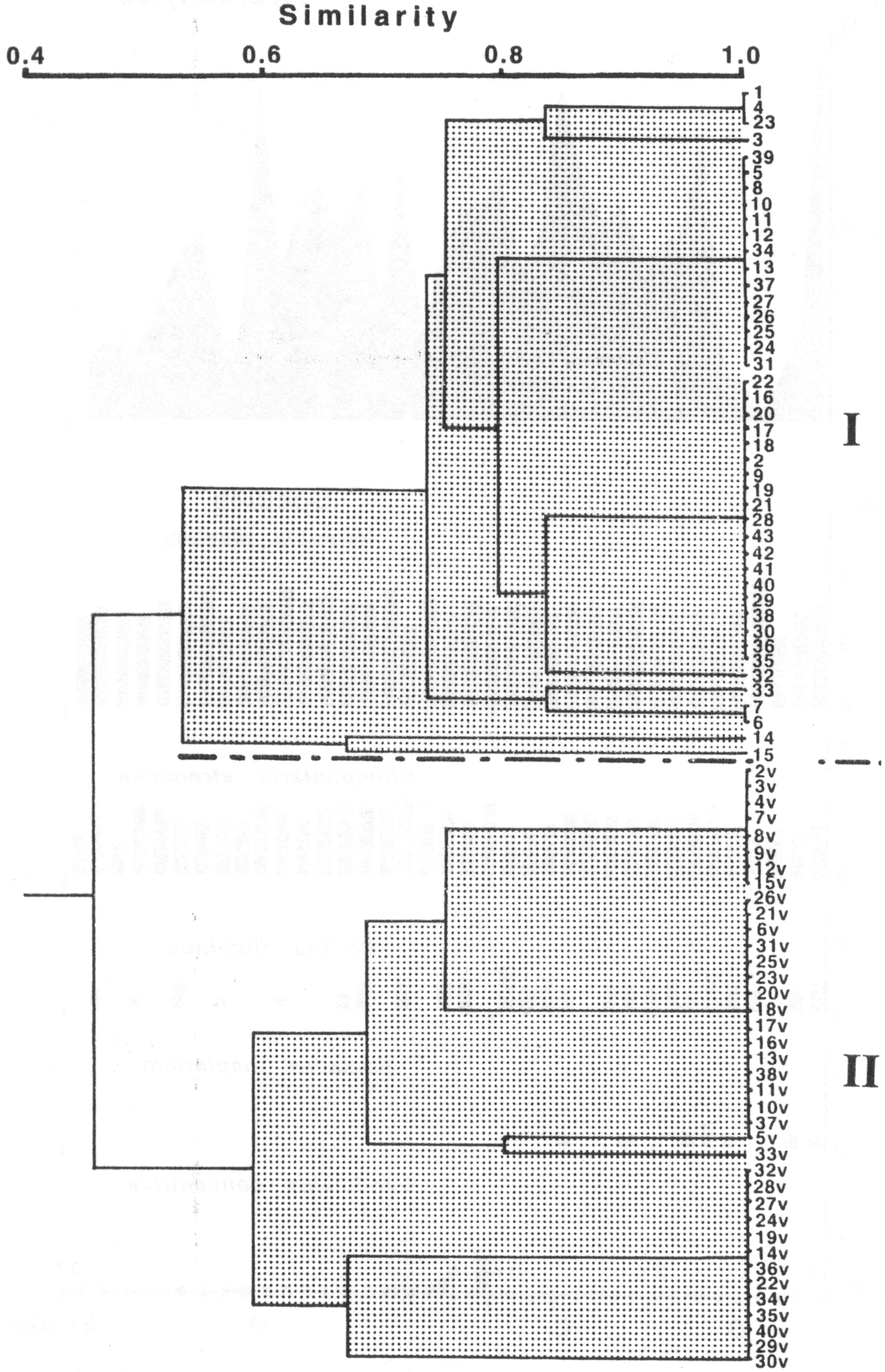

FIG. 9. Qualitative composition of the malacofauna from the Punta Blanca shore during the summer of 1985. Similarity coefficient: Jaccard. Cophenetic correlation coefficient = 0.92. **I**, 1-43 = samples collected from the sediment; **II**, 2v-40v = samples taken from the aquatic vegetation.

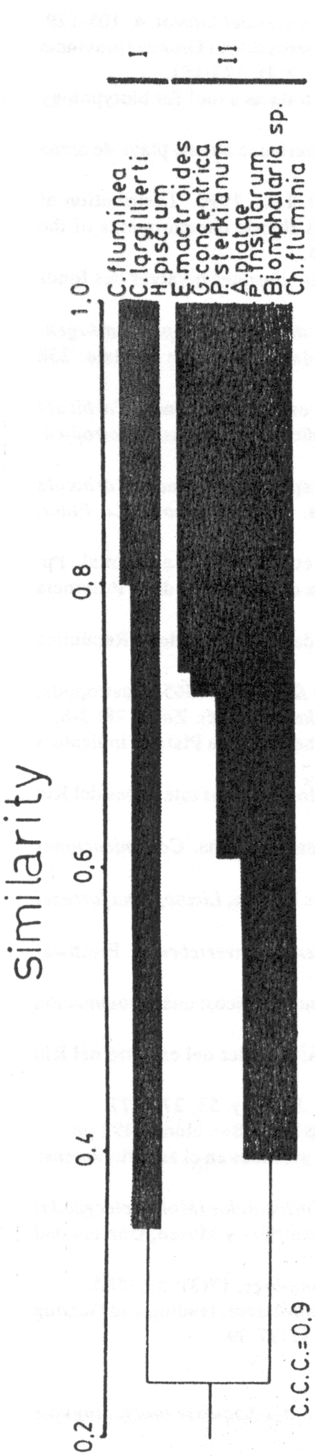

FIG. 10. Quantitative analysis of the molluscan species collected in Punta Blanca shore. Similarity coefficient: Morisita. C.C.C. = cophenetic correlation coefficient.

Three macroinvertebrate groups prevail in this sandy shore: molluscs, hirudines and isopods. According to their distributions, the beach can be divided into two parallel strips. One of the strips, 150 to 200 m wide and adjacent to the coast, is where the hirudines occur. The second strip, of the same size and adjacent to the water, is where the isopods occur. The malacofauna occurs in both strips and is the dominant group of the littoral benthos, in both species richness and species abundance.

In the sandy shore of Punta Blanca, 10 species of molluscs were collected, five of which are rare or contingent in this environment *(Pomacea insularum*, *Asolene platae*, *Gundlachia concentrica*, *Erdona mactroides* and *Pisidium sterkianum*). The rest of the species have a high dominance *(Heleobia piscium*, *Corbicula fluminea* and *Biomphalaria straminea*) or high frequency on the shore *(Corbicula largillierti* and *Chilina Fluminea*).

Seasonal analysis of the malacofaunal structural parameters show low specific richness and evenness, and a progressively decreasing density of most populations. The Shannon-Weaver index shows low values; however, it tends to increase in the last samples. Although this index is the least influenced by population densities (Pielou, 1969; Hutchinson, 1981; Margalef, 1986), it depends on the specimen number per sample (density) and on the common species of the community (Wolda, 1983). When it is taken into account that one of the dominant species (*Biomphalaria straminea*) is no longer found on the shore, and another species (*Heleobia piscium*) decreased ten times in its mean density, the slight rise of the diversity curve can be understood.

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