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LONGITUDINAL DISTRIBUTION OF MOLLUSCAN COMMUNITIES IN THE RIO DE LA PLATA ESTUARY AS INDICATORS OF ENVIRONMENTAL CONDITIONS

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ABSTRACT

Samples were taken from sixteen localities situated along the Argentine littoral of the Río de la Plata, from the 34°29'S 58°28'W to the 35°27'S 57°08'W. The following parameters were considered: Shannon-Weaver diversity index; evenness; species richness; average density and frequency. The Jaccard coefficient was used to analyse the qualitative similarity between samples.

In the Río de la Plata Argentine littoral 21 species of molluscs were found, eight of which were pelecypods and thirteen were gastropods (four pulmonate species and nine mesogasteropod prosobranchs. According to the distribution pattern of the malacofauna sampled, the Argentine littoral of the Río de la Plata can be divided in two zones: (1) Zone I: from 34°29'S 58°28'W to 34°54'S 57°47'W. The first section of this zone is characterized by a high density of few species, whereas in the second section there is a great fluctuation in the density and species reachness of the malacofauna. These values tend to "normality" in relatively low polluted areas. (2) Zone II: from the end of Zone I to 35°27'S 57°08'W, with a lower degree of pollution due to natural purification. In this zone, the main limiting factor of the malacofauna distribution pattern is salinity. *Corbicula fluminea* (Müller 1774) and *Limnoperna fortunei* (Dunker 1857) are proposed as good pollution bioindicator-bioacumulators and should be the aim of future research.

Key words: Littoral molluscs, Río de le Plata, distribution, environment, pollution.

INTRODUCTION

The Río de la Plata is one of the most important water bodies of South America. It receives the urban and industrial residues of large cities like Buenos Aires and Montevideo, and also the runoff water from one of the most important farming areas in South America. There are large ports (Buenos Aires and La Plata) in this environment. This estuary is also used for recreation purposes and as a water resource for industrial and human consumption. These uses, often incompatible with each other, produce an environmental impact which is difficult to evaluate in the Río de la Plata estuary due to a deficient knowledge about 1) the ecosystem and 2) the benthos of this environment. The study of the composition, abundance and distribution of the benthic fauna in intertidal areas is crucial to detect and evaluate the alterations caused by human action (Clarke Guerra & Peña Monardez, 1988). There are few papers on the benthic fauna of the Río de la Plata. As for the deep benthos of this environment, there are the works of Boltovskoy (1957a, 1958) and Boltovskoy & Lena (1974b) concerning foraminifers, and the researches of Boltovskoy (1957b) and Boltovskoy & Lena (1974a) on the tecamebas. The studies of Darrigran & Rioja (1988), Darrigran (1991, 1994), and Gullo & Darrigran (1991) on the distribution of the isopod, molluscan and hirudinean fauna, respectively, are related to some taxocenosis of the macrobenthos of the Río de la Plata Argentine coast. Scarabino *et al.* (1975) carried out a study on benthic communities in the littoral system of the Montevideo Department. Sprechmann (1978) referred to the distribution of the Neogene and Quaternary malacofauna on that coast.

The purpose of this paper is to establish the relationship between the littoral malacofauna distribution and the environmental features of the Río de la Plata because: 1) In the Parano-Platense system, the molluscan fauna is one of the most important benthic taxocenosis (Bonetto & Tassara, 1987/8), 2) The malacofauna is a group commonly employed in biomonitoring environmental pollution (Weber, 1973; Harman, 1974; Mouthon, 1981; Branco, 1984; Nott & Nicolaidou, 1989; Rainbow & Phillipis, 1993), and 3) the concentration of different contaminants is, in general, low in the main channel of the streams and high on the coast (Comisión Administradora del Río de la Plata, 1989; Osn, Agosba, Sihn, 1992).

MATERIALS AND METHODS

Sixteen sampling stations (EM 1-16) were selected (Fig. 1). Table 1 shows, together with collection dates and sample numbers, the relationship between these sampling stations and the zonation of the Río de la Plata proposed by Urien *fide* Boltovskoy & Lena (1974a, 1974b).

Samples were taken during the warm season according to Mouthon (1980) and Elliott (1983), and they were classified by the different substratum types of the Río de la Plata shore ("soft" substratum: sand beaches; "hard" substratum: "caliche" – tight sandy silt – beaches, stones and aquatic vegetation).

The samples was made during the low tide, at a constant distance (generally every 10 m) along transects perpendicular to the coast line. The transect length and sample numbers are in an inverse ratio to the heights of the tides. This uniform sampling method allows the estimation of littoral environmental changes and increases the probabilities of counting those species considered rare or not frequent within the environment (Laborda, 1986).

In sand beaches, the sampler used was a 0.30 m diameter cylinder (0.07 m^2 area). The sediment

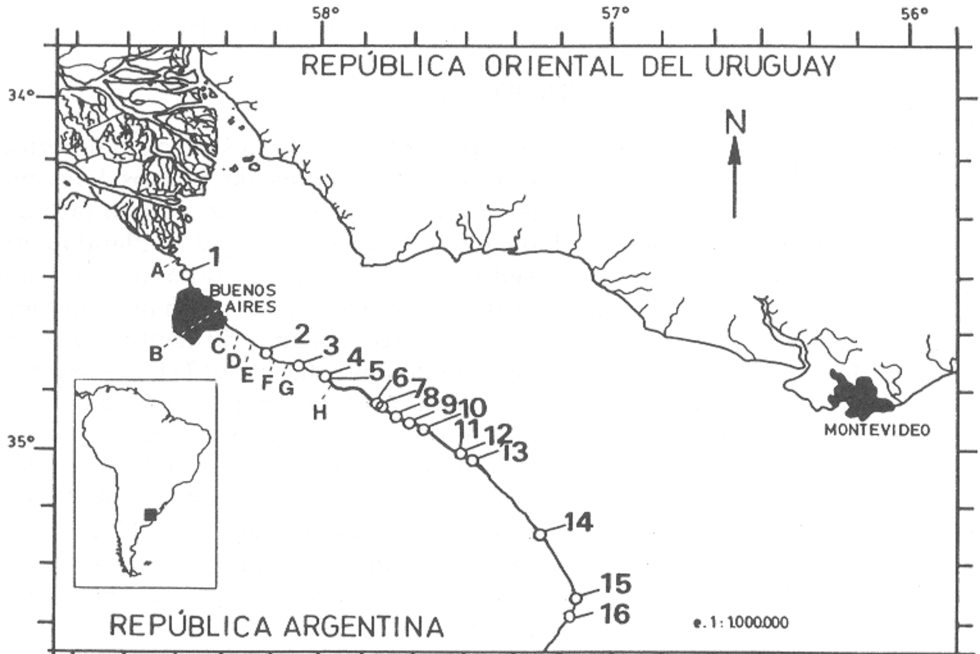


FIG. 1. Location of the sampling stations on the Argentine Río de la Plata shore. 1 = Anchorena beach; 2 = Quilmes beach; 3 = Hudson beach; 4 = Punta Lara I beach; 5 = Punta Lara II beach; 6 = La Plata city sewer outlet; 7 = Bagliardi beach; 8 = Municipal beach; 9 = La Balandra beach; 10 = Punta Blanca; 11 = Atalaya I beach; 12 = Atalaya II beach; 13 = Magdalena beach; 14 = Punta Indio beach; 15 = Punta Piedras I beach; 16 = Punta Piedras II beach. A = San Isidro; B = Palermo; C = Riachuelo; D = Santo Domingo; E = Bernal; F = Berazategui; G = Punta Colorada; H = water pumping.

TABLE 1. Sampled sites on the Argentine Río de la Plata shore. n - number of samples; (+) - environments where a sampling technique was applied.

Sampling Stations	Date	n	Substrata
Anchorena beach	10/12/87	16	Caliche (+)
Quilmes beach	10/02/87	20	Sand (+); stones
Hudson beach	10/12/89	15	Sand (+)
Punta Lara I beach	09/03/88	20	Sand (+)
Punta Lara II beach	09/03/88	20	Sand (+)
Sewage spill-out	29/03/88	15	Sand (+); stones
Bagliardi beach	20/03/88	20	Sand (+); stone; tru??
Municipal beach	08/02/88	20	Sand (+); stones
Balanda beach	08/02/88	20	Sand (+); stones
Punta Blanca beach	30/01/87	31	Sand (+)
Atalaya I beach	17/04/88	20	Sand (+); stones
Atalaya II beach	01/11/87	17	Sand (+)
Magdalena beach	10/02/87	20	Sand (+)
Punta Indio beach	24/01/87	45	Sand (+)
Punto Piedras I	27/01/87	20	Caliche (+) clay/muddy
Punta Piedras II	02/12/89	05	Caliche (+) clay/muddy

was recovered manually and deposited in a sieve of 1 mm mesh, to be sieved in the field. In caliche beaches, the sampler was a frame of 0.40 x 0.40 m subdivided in 16 equal parts so that the epifauna present in this heterogeneous substratum could be also sampled.

The calculated parameters were as follows: 1) Specific diversity was calculated with abundance data using the Shannon-Weaver index, which can be expressed as H = -pi.In.pi, where pi is the number of individuals of each species as a function of the total number of individuals; 2) Evenness; $Ev = (e^{H-1})/(S-1)$, where e = 2.72, H = Shannon- Weaver index, and S = number of species; 3) Mean density (D) is mean number of individuals per square meter, in logarithm: D = □(ni/a)/M, where M = total number sampled, ni = number of individuals per sample, and a = sampler surface; 4) Frequency (F) = number of samples where it appeared that the species under consideration (m) were related to the total number of samples (M), expressed as percentages: F = m/M.100.

In addition, the Jaccard coefficient (J) was calculated (after Saiz, 1980) in order to compare the malacofauna of both extreme sampling stations of the shore with the rest of the stations, so as to obtain a view of the census disposition should there be an environmental gradient (Contreras *et al.*, 1985).

RESULTS

During this research, 348 samples were taken in sixteen samplings, from which 29,643 specimens were collected (D = 249 individuals/m^2). Twenty-one molluscan species were found (Table 2), eight of which were bivalves and 13 were gastropods.

Fig. 2A shows the variation of the species number (S) and the mean density (D) of the collected malacofauna in each sample. The highest values of S and D correspond to Balneario Anchorena (EM1; S=12) and Balneario Quilmes (EM2; D=9.469), respectively. Values of S and D in every sampling station allow the determination of two zones along the littoral: **Zone I**, comprising stations EM1 to EM8. The curves start from the highest S and D values of the littoral zone, and decrease rapidly towards EM6 (the outlet of the main sewer of La Plata city; S = 0, D = 0). S and D values at La Bagliardi and Balneario Municipality remain low and have little stability (EM7: S = 5 and D = 89, and EM8: S = 1 and D = 31). **Zone**

TABLE 2. Mollusc species found in all samplings on the Argentine Río de la Plata shore. For 1 to 16 see "sampling stations" in Table 1.

	Sampling Stations															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
GASTROPODA																
PROSOBRANCHIA																
Hydrobiidae																
Heleobia piscium d'Orbigny, 1835	+	+	+	-	-	-	+	-	-	+	+	+	+	+	-	-
H. australis (d'Orbigny, 1835)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Potamolithus orbigny Pilsbry, 1911	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
P. agapetus Pilsbry, 1911	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
P. petitianus (d'Orbigny, 1840)	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
P. lapidum (d'Orbigny, 1835)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. buschii (Frauenfeld, 1865)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pilidae																
Asolene platae (Maton, 1809)	-	-	-	-	-	-	-	-	-	+	+	-	+	-	-	-
Pomacea insularum d'Orbigny, 1835	-	-	+	-	-	-	+	-	+	+	-	-	+	-	-	-
PULMONATA																
Chilinidae																
Chilina fluminea (Maton, 1809)	+	+	-	-	+	-	+	-	-	+	+	+	-	-	+	-
Ancylidae																
Gundlachia concentrica (d'Orbigny, 1835)	+	+	-	-	-	-	+	-	-	+	+	+	+	-	-	-
Physidae																
Stenophysa marmorata Martens, 1898	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planorbidae																
Biomphalaria straminea (Dunker, 1848)	+	+	+	-	-	-	-	-	-	+	-	-	-	-	-	-
BIVALVIA																
Corbiculidae																
Corbicula fluminea (Müller, 1774)	+	-	+	+	+	-	+	+	+	+	+	+	+	+	-	-
C. largillierti (Philippi, 1844)	-	-	+	-	-	-	-	-	+	+	+	+	+	-	-	-
Aloididae																
Erodona mactroides Daudin in Beso 1802	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	-
Mycetopodidae																
Anodontites tenebricosus (Lea, 1834)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hyriidae																
Diplodon paranensis (Lea, 1860)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mytilidae																
Mytella charruana d'Orbigny, 1842	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Sphaeridae																
Musculium argentinum (d'Orbigny, 1842)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Pisidium sterkianum Pilsbry, 1897	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Mytilidae																
Limnoperna fortunei (Dunker, 1857)	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+

II, consists of the rest of the sampling stations. In this zone, both curves tend to be more stable. Starting from La Balandra (EM9), S and D values increase, reaching the highest values at Punta Blanca (EM10: S = 9 and D = 3.289). Then they decrease gradually towards Punta Piedras II station (EM16: S = 2 and D = 37).

Fig. 2B shows the diversity (H) and evenness (Ev) curves for all sampling stations (EM1 to EM16). H values remain low along the littoral. Balneario Anchorena (EM1: H = 0.6) is the station of highest diversity. The eveness has its highest value at La Bagliardi station (EM7: Ev = 1). Both H and Ev curves reflect two littoral zones, defined by the following stations: **Zone I.** EM1 to EM8. The values of these curves shift as a whole, displaying peaks and valleys one after the other.

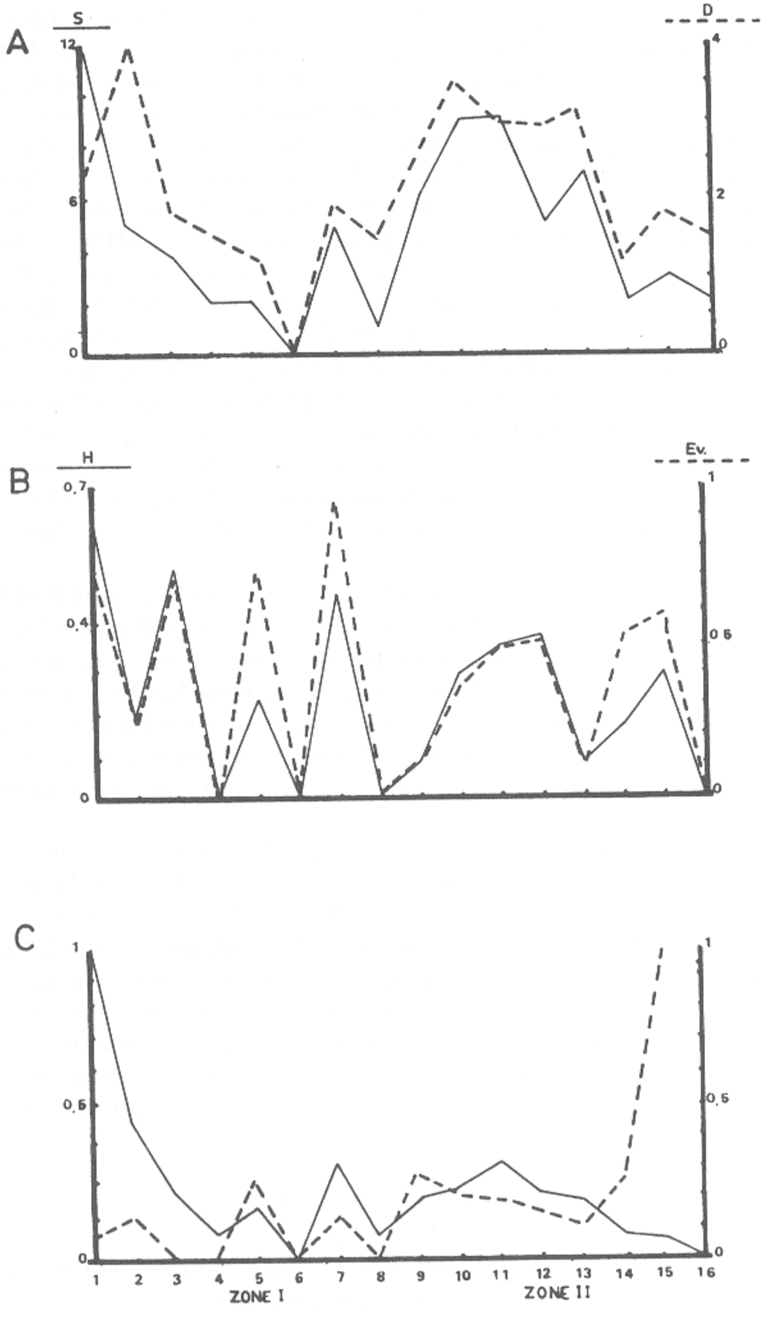


FIG. 2. Relationships between the different sampling stations. A, Comparison of the specific richness (S, solid line) and mean density, in logarithm (D, dashed line). B, Comparison of the diversity index (H, solid line) and the evenness (Ev, dashed line). C, Comparison of the Jaccard coefficient values resulting from the first sampling station compared with the rest (solid line) and the values resulting from the last station compared with the rest (dashed line). From 1 to 16, same references as Fig. 1.

In general, the highest and lowest H and Ev values of the sampled littoral appear in this zone. **Zone II.** Comprising the rest of the sampling stations. Both curves display only one valley, in Magdalena station (EM13). In general, H and Ev show values near 0.4-0.5, decreasing to 0 in Punta Piedras II station (EM16).

Fig. 2C shows the comparison curves using the Jaccard coefficient (J) between the species composition of the samples of the stations placed on the furthest end of the littoral, with the rest of the samples. Punta Piedras II station (EM16) displays no similarity with any other station but Punta Piedras I (EM15), so that it was taken as one end of the J index. In this figure it can be observed that 1) The furthest samples are very different one another; 2) A broad intermediate sector is delimited between the furthest samples (EM2 to EM14), which does not show much similarity with the latter (J<0.5); 3) The intermediate sector is in its turn divided into two zones: **Zone I.** Stations EM2 to EM8, characterized by a significant fluctuation of the similitude coefficient values, *i.e.*, these sampling stations have little similarity among them in relation to their malacological composition; **Zone II.** Includes the rest of the sampling stations (EM9 to EM14) that have more homogeneous resemblance values, *i.e.*, the species composition among these sampling stations is more similar.

The species frequency (F) of bivalves (Fig. 3A) is lower in Zone I (EM1 to EM8) than in Zone II (EM9 to EM16). Likewise, the presence of the bivalve *Corbicula fluminea* Müller in Zone I is greater than the rest of the bivalve species as a whole in that zone. In contrast, in Zone II, although *C. fluminea* has the same frequency value as in the previous zone (F=50%), it is less frequent than the rest of the bivalve species. In Zone I, the species frequency of pulmonate gastropods is greater than that of the prosobranch mesogastropods; in Zone II the species frequency is just the reverse (Fig. 3B).

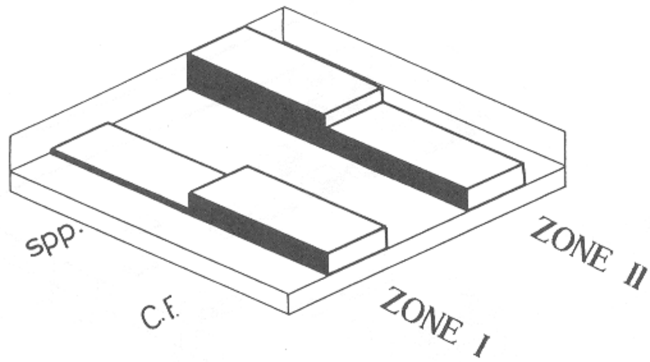
On the basis of a comparative analysis of the densities of the more frequent gastropods and bivalves (Fig. 4), it was observed that in the Zone I there is a low number of species, and low densities of mesogastropods. This condition is inverted when pulmonate gastropods are considered. To the contrary, in Zone II the density and abundance of pulmonate species decrease, while those of the megagastropods increase and overtake those of pulmonates. Bivalves are present in Zone I with only one species, *Corbicula fluminea*, in considerable density, whereas in Zone II this species increases in density. In addition, the other two bivalves (*Erodona mactroides* Daudin and *C. largillierti* Philippi), both more frequent in the littoral, appear in this zone.

DISCUSSION AND CONCLUSIONS

In the Argentine littoral zone of the Río de la Plata, 21 species of molluscs were found, eight of them were bivalves and 13 were gastropods (four pulmonate species and nine mesogastropod prosobranchs).

As was observed in the analysis of the density, species richness, evenness and diversity curves, and in the analysis of Jaccard coefficient values (Fig. 2), the Argentine littoral of the Río de la Plata is divided into two zones: **Zone I** includes sampling stations EM1 to EM8. This is the area of greatest contamination (Table 3) of this body of water (Ringuelet, 1967; Gariboglio *et al.*, 1977; Jorquera, *et al.*,

A. Bivalvia



B. Gastropoda

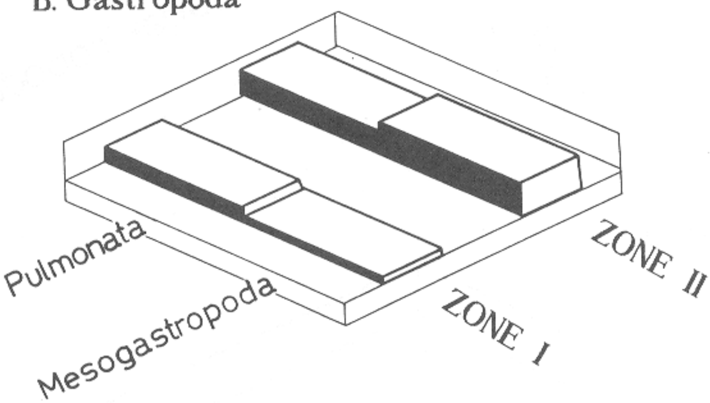
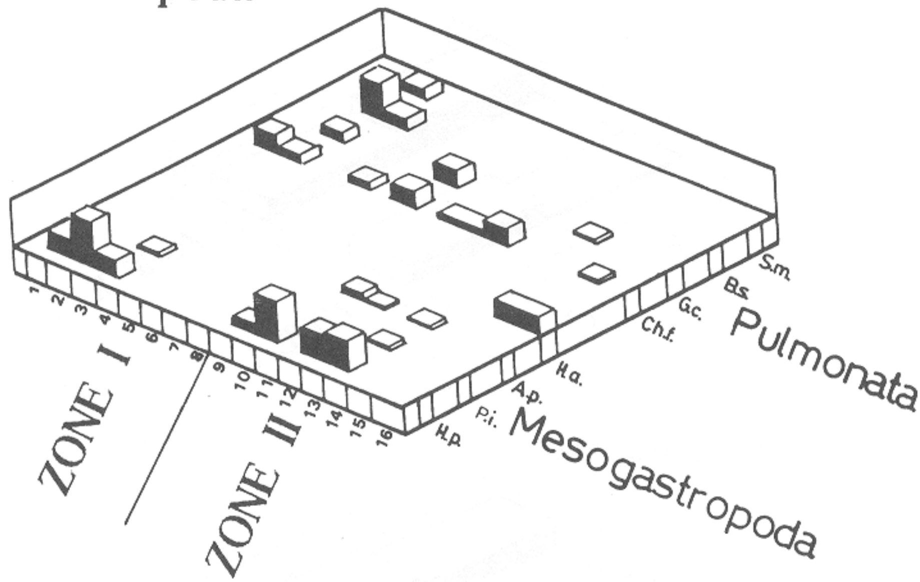


FIG. 3. Comparison of the frequencies of bivalves (A) and gastropods (B) present in both contaminant zones proposed for the Argentine Río de la Plata shore. C.f. = *Corbicula fluminea;* spp. = the rest of the clam species.

1978; Mariñelarena, 1989; Cattoggio, 1989; Bazün & Arraga, 1989). There are two ports, Buenos Aires and La Plata, in this zone, so there are important industrial centers and the outlet of two main sewers in this zone, *viz.*, that of the Gran Buenos Aires (between EM2 and EM3 stations) and that of La Plata city (EM6). **Zone II** comprises a fringe from the end of Zone I up to the political limit of the Río de la Plata. In this zone, there are different grades of water self-depuration. For example, the waters of the fluvio-marine zone have lower fecal bacteria contents than the former zone (Monticelle & Costagliola, 1986). This fact would imply an interaction of some other factors on the distribution of the malacofauna, *e.g.*, variations in the water salinity. According to Pearson & Rosemberg (*fide* Elías, 1987), the population density and specifies richness curves allow the estimation of succesive stages in an environmental gradient caused by contamination, such as 1) the opportunists stage (EO), with a great abundance of a few benthic species; 2) the ecotone (E), where the abundance is low and the evenness and diversity increase; and 3) the transition zone (T), in which, after large initial fluctuations of

A. Gastropoda



B. Bivalvia

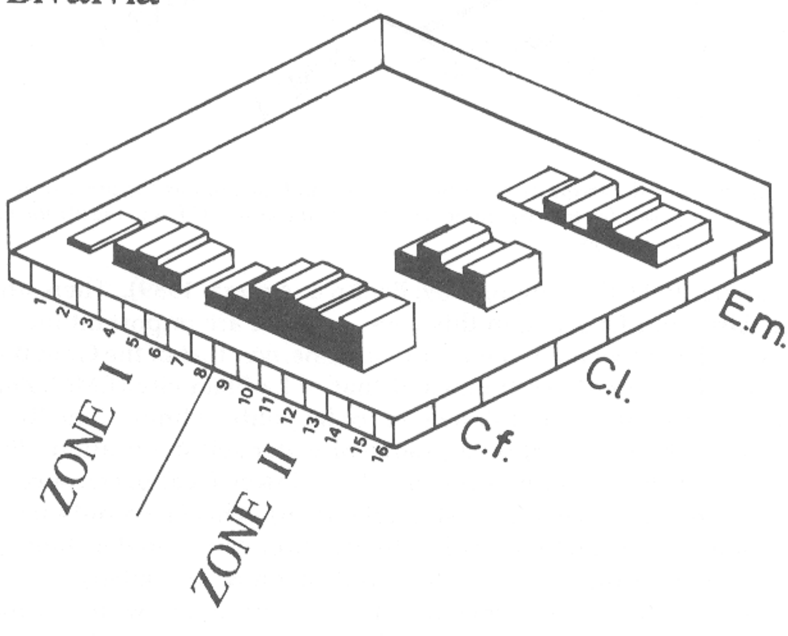


FIG. 4. Comparison of the more frequent gastropod (A) and bivalve (B) densities in both zones. C.f. = *Corbicula fluminea;* C.l. = *C. largillirti;* E.m. = *Erodona mactroides;* H.p. = *Heleobia piscium;* H.a. = *H. australis;* P.i. = *Pomacea insularum;* A.p. = *Asolene platae;* Ch.f. = *Chilina fluminea;* G.c. = *Gundlachia concentrica;* B.s. = *Biomphalaria straminea;* S.m. = *Stenophysa marmorata.* From 1 to 16, same references as Fig. 1.

TABLE 3. Parameters of water (taken from Darrigran & Pastorino, 1995). DO = dissolved oxygen, mg/L; BDO = biological oxygen demand, mg/L; COD = chemical oxygen demand, mg/L; C = chlorides, mg/L; S = sulfates, mg/L; SM = suspension material, mg/L; T = turbidity, NTU; Na, Pb, K, mg/L; As, µg/L.

Localities	DO	BDO	COD	C	S	SM	T	Na	Pb	As	K	
San Isidro	3.4	1.3	14.2	16	18	145	28	15.8	6	6.4	2.6	34°28′S 58°28′W
Palermo	3.2	3.5	4.2	19	15	87.9	50	19.8	18	6.4	3.7	34°34′S 58°25′W
Riachuelo	0.0	3.9	16.9	46	–	27.6	49	46.7	10	10.4	4.2	34°38′S 58°21′W
Santo Domingo	2.5	3.3	22.0	29	22	70.8	24	32.5	13	7.5	32.5	34°39′S 58°18′W
Bernal	4.5	10.4	17.0	48	–	43.4	–	52.3	15	10.4	4.2	34°43′S 58°01′W
Berazategui	3.1	11.1	30.0	40	27	2.4	28	41.9	8	9.6	3.8	34°48′S 58°11′W
Punta Colorada	0.2	11.6	30.0	36	20	35.8	35	37.8	13	8.6	4.2	34°46′S 58°08′W
Punta Lara	1.7	0.5	11.7	31	20	35.4	39	31.6	3	6.8	3.7	34°48′S 57°59′W
Water pumping	4.7	5.3	11.7	31	20	35.4	39	31.6	3	6.8	3.7	34°04′S 57°55′W
Sewage spill-out	4.7	4.1	21.7	27	20	80.4	37	27.7	15	6.4	3.3	34°52′S 57°49′W

the population, the community approaches its “normal” state.

In the Río de la Plata’s Argentine littoral, the Balneario de Quilmes (EM2) corresponds to a similar stage as the so-called Opportunist (EO). This station has a low mollusc richness and a high population density of molluscs. Besides, four of the five molluscan species found are all pulmonate gastropods. The latter present the highest pollution tolerance, by comparison to the prosobranchs (Weber, 1973; Mouthon, 1980; Branco, 1984). Sampling stations EM3 to EM8 reflect the so-called transition stage (T). These stations are strongly influenced by two large urban residue sources: 1) the main sewers of the Gran Buenos Aires, which discharge 1,400 m away from the coast at Berazategui (Ringuelet, 1967; Osn, Agosba, Sihn, 1992), and 2) the outlet of the main sewers of La Plata city, whose residues are eliminated on the beach, causing a greater retention of sewer contaminants at the littoral level (Mariñelarena, 1989). As can be observed in Fig. 2A, the impact caused by both outlets is different. Although the sewers of the Gran Buenos Aires support the charge of a larger urban zone, there is a peak of opportunists next to it, with a high environmental stress zone that allows a few species to adapt and populate it intensely. To the contrary, the direct outlet of the La Plata sewer on the beach does not allow the settlement of any shore macrobenthos population. This fact, together with the absence in both sewers of previous water treatment, would provoke the fluctuations of molluscan populations in these sampling stations.

The species frequency and molluscan population density sampled in Zone I can also be related to the degree of areal organic contamination. Gastropods in Zone I present a greater species richness. The frequency of pulmonate species (generally considered to have greater contamination tolerance than the rest of the molluscs) is greater than that of the mesogastropods (usually considered sensitive to organic contaminants). Bivalves, which generally are intolerant or facultatively intolerant to contamination, are represented in this zone with a high frequency only by *Corbicula fluminea*. Therefore, *C. fluminea* may be considered to be pollution tolerant, while the rest of the bivalve species are found with only low frequencies. According to Harman (1974), *C. fluminea* has all the characteristics to be a good bioindicator, *i.e.,* they are 1) easy to recognize by non-specialists; 2) abundant along an extended geographical region; 3) tolerant to some particular phenomena, or may be indicative of some particular conditions; 4) relatively long lived; and 5) partially sessile or with little mobility, so they cannot migrate rapidly out of the zone temporarily affected by environmental stress. Further, there is broad knowledge about the reproductive biology and population dynamics of *C. fluminea* in the Río de la Plata (Ituarte, 1982, 1985; Darrigran & Maroñas, 1989; Darrigran, 1992), as well as studies carried out in the Holarctic Region about the ability of *C. fluminea* to concentrate heavy metals (McMahon, 1983) or biocides (Colombo *et al.*, 1990) in its tissues.

In the last six or seven decades, the environment studied here has been altered by human actions, which have caused a decrease in the number of species, in general, and of molluscs in particular, which were formerly common in the area, *e.g.*, Bivalvia: Mycetopodidae and Hyriidae (Ringuelet, 1981).

Also, enviromental change has been produced also by the introduction of invader species, such as *Corbicula fluminea* and *Limnoperna fortunei* (Dunker 1857). The Asiatic *C. fluminea* was introduced into the Río de la Plata by the 1970s (Ituarte, 1981). More recently there was a settlement of an invader mytilid, *Limnoperna fortunei*, also coming from southeastern Asia (Pastorino *et al.*, 1993). In the bottom of Table 2 the trend of this epifaunal species to have a frequencies like that of *C. fluminea* can be observed, which would indicate a significant tolerance to contamination, and, therefore it can be used as a contaminant bioacumulator, as have mytilid species of the Northern Hemisphere marine littoral.

The continuous urbanization of the surrounding areas of this water body will continue to produce an environmental impact, each time greater, that may be evaluated by means of research using the macrobenthos as bioindicators. The present paper begins such research on the Río de la Plata.

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