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Temporal and spatial patterns of annelid populations in intertidal sediments of the Quequén Grande estuary (Argentina)

J. López Gappa, A. Tablado, M. C. Fonalleras & M. L. Adami
Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Av. Angel Gallardo 470, Buenos Aires C1405DJR, Argentina
E-mail: lgappa@mail.retina.ar

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Abstract

Temporal and spatial patterns of polychaete and oligochaete populations inhabiting intertidal sediments of the Quequén Grande estuary (Buenos Aires Province, Argentina) were analysed monthly during a yearly period. Local sediments are poorly selected, very fine sands, with a high percentage of mud. Two sites, located at both banks of the estuary were studied: (1) Site N, with a comparatively steep slope and percentage of mud increasing with sediment depth; (2) Site Q, with a gentle slope and percentage of mud increasing towards the sediment surface. The assemblage of annelids was characterised by a very low specific richness, being composed just by 4 species: the polychaetes *Laeonereis acuta*, *Boccardiella ligerica* and *Capitella* sp., and the tubificid oligochaete *Ilyodrilus* cf. *frantzi*. Density of the nereid *L. acuta* reached a peak in late summer and a minimum in spring. The population of *Capitella* sp. also showed maximum densities in summer, but collapsed during early fall, disappearing completely from the study area. Densities of *I.* cf. *frantzi* were highly variable in time and space. Three of the 4 species showed maximum densities at site Q, where mud content was highest at the sediment surface. At this sampling site, most of the *L. acuta* population occurred within the upper 8 cm of the substrate. On the contrary, at site N, where mud and organic matter content increased with depth, this species was more abundant at subsurface layers (8–16 cm) than at the sediment surface.

Introduction

Polychaetes are usually the most abundant organisms in macroinfaunal communities of estuarine environments (e.g. Ambrogi, 1990; Ieno et al., 1998), playing a major role in energy transfer through the benthic-demersal food web. Polychaetes feed mainly upon plant detritus (Fauchald & Jumars, 1979), which is transformed in animal biomass available to predators that frequently visit the estuarine benthos to feed, such as fish (Bemvenuti, 1987, 1988; Lasta, 1995) and birds (Ieno et al., 1998; Ieno & Bastida, 1998). In addition, trophic activities and movements of many polychaete species and other macrobenthic organisms greatly contribute to sediment reworking and oxidation (Rhoads, 1974). The analysis of biodiversity and the spatial and temporal patterns of estuarine infaunal communities is, therefore, a necessary step to understand processes that regulate these ecosystems.

The infauna of estuarine areas in southern Brazil shows remarkable biogeographic affinities with that of northern Argentina. In Brazil, particularly in Paranaguá Bay and Patos coastal lagoon, macrobenthic fauna has been the subject of several studies (Capítoli et al., 1978; Bemvenuti et al., 1978, 1992; Capítoli & Bemvenuti, 1982; Bemvenuti, 1994; Lana et al., 1997; Netto & Lana, 1997, among others).

The ecology of some macrobenthic polychaetes of the Río de la Plata estuary has been studied by Cachés (1980), Ieno et al. (1997, 1998) and Ieno & Bastida (1998). Ecological observations on polychaetes inhabiting Mar Chiquita coastal lagoon, one of the best known mixohaline environments in Argentina, may be found in Olivier et al. (1972 a, b), Ieno & Elías

(1995) and Schwindt & Iribarne (1998). Polychaete assemblages from littoral habitats near Blanca Bay have been studied by Elías (1991, 1992), Elías & Ieno (1993) and Elías & Bremec (1994).

No information is yet available on the ecology of soft bottom communities of the Quequén Grande estuary, except for its foraminiferan and thecamoebian fauna (Boltovskoy & Boltovskoy, 1968; Wright, 1968). A few records of estuarine polychaetes for the study area can be found in the taxonomic bibliography (Orensanz & Estivariz, 1971). Therefore, the aim of this study is to describe the structure of polychaete and oligochaete populations inhabiting intertidal soft sediments in the Quequén Grande estuary, analysing their horizontal and vertical distribution, and seasonal changes.

Study area

The Quequén Grande River (Fig. 1) has a mean flow of 11.3 $m^3\ s^{-1}$, draining a basin of around 7800 km^2 (Sala, 1975). It is originated in the Tandilia system, flowing through a rich agricultural plain and opening in the Atlantic Ocean. The estuary is located between the cities of Necochea and Quequén. It has a width of 150–200 m, reaching 400 m near its mouth, where an important harbour is to be found. Mean depth reaches 2–3 m in the central, non-dredged zone of the estuary (Piccolo & Perillo, 1997). Sediments at the mouth of the estuary consist of fine sands, becoming gradually finer upstream, with increasing proportions of very fine sands and mud (Wright, 1968). Local tides are characterised by diurnal inequalities, with a mean and maximum amplitude of 1.08 m and 1.76 m, respectively.

Salinity shows remarkable fluctuations within the estuary, mainly due to the tidal cycle, but also related to freshwater inflow, which is affected by the amount of rainfall in the basin. The most complete surveys of salinity fluctuations in the Quequén Grande estuary were carried out by Boltovskoy & Boltovskoy (1968) and Wright (1968). They measured the salinity of 75 samples collected at the bottom of the estuary during 1966–1967. Their most extreme values were 0.48‰ and 33.75‰, but the extension surveyed by these authors was much greater than the area covered during the present study. Their salinity measurements fluctuated between 6.6‰ and 26.7‰ at the area that we call site Q in the present study, and between 8.4‰ and 15.6‰ at the area that we call site N (see below). As an example of the remarkable fluctuations of the estuary, in only one salinity station located approximately 1 km upstream of our site N (see Fig. 1), they recorded values between 27.7‰ and 4.7‰ during a 5 h period.

Table 1. Grouping of samples for ANOVA in three intertidal height levels at sites N and Q. Heights are measured in cm below the beginning of terrestrial vegetation (see also Fig. 4)

Level	Site N		Site Q	
	Height (cm)	No. of samples	Height (cm)	No. of samples
High	20.9–55.8	4	66.5–91.4	4
Middle	55.9–90.8	2	91.5–116.4	6
Low	90.9–125.8	4	116.5–141.5	4

Material and methods

Two intertidal sampling sites were selected, one on each bank of the Quequén Grande estuary (Fig. 1): (a) Site Q, located on the east bank, 100 m upstream from a bridge connecting the cities of Necochea and Quequén, at a distance of 8–10 m from the beginning of terrestrial vegetation; (b) Site N, located on the west bank, 20 m downstream from the remains of a former bridge, and approximately 800 m upstream from site Q, at a distance of 8–10 m from the beginning of terrestrial vegetation.

From October 1997 to October 1998, 6 replicated samples separated by distances of 20–40 cm, were collected at each site per month. Samples (length: 25 cm, diameter: 4.5 cm) were taken using a cylindrical acrylic core, filtered *in situ* using a conical net with a mesh size of 250 μm to wash off most of the sediment, fixed in 7% formalin, and later transported to the laboratory for analysis. Infaunal organisms were separated, and annelid species were identified and counted under stereomicroscope.

Horizontal changes in annelid populations were assessed on February 1998 during a lowest low tide by a transect perpendicular to the shoreline at each site. Three samples (2 replications for fauna plus 1 sample for sediment particle analysis) were collected every 5 m, beginning at the uppermost area where the sediment allowed the introduction of the corer, and ending at the water level. Transects at sites Q and N consisted of 7 and 5 sampling points, respectively. The lowest sediment sample of site Q (39 m) was lost. Their relative heights were measured with a sighting level.

In order to compare high, middle and low intertidal levels, samples were grouped in 3 levels of equal

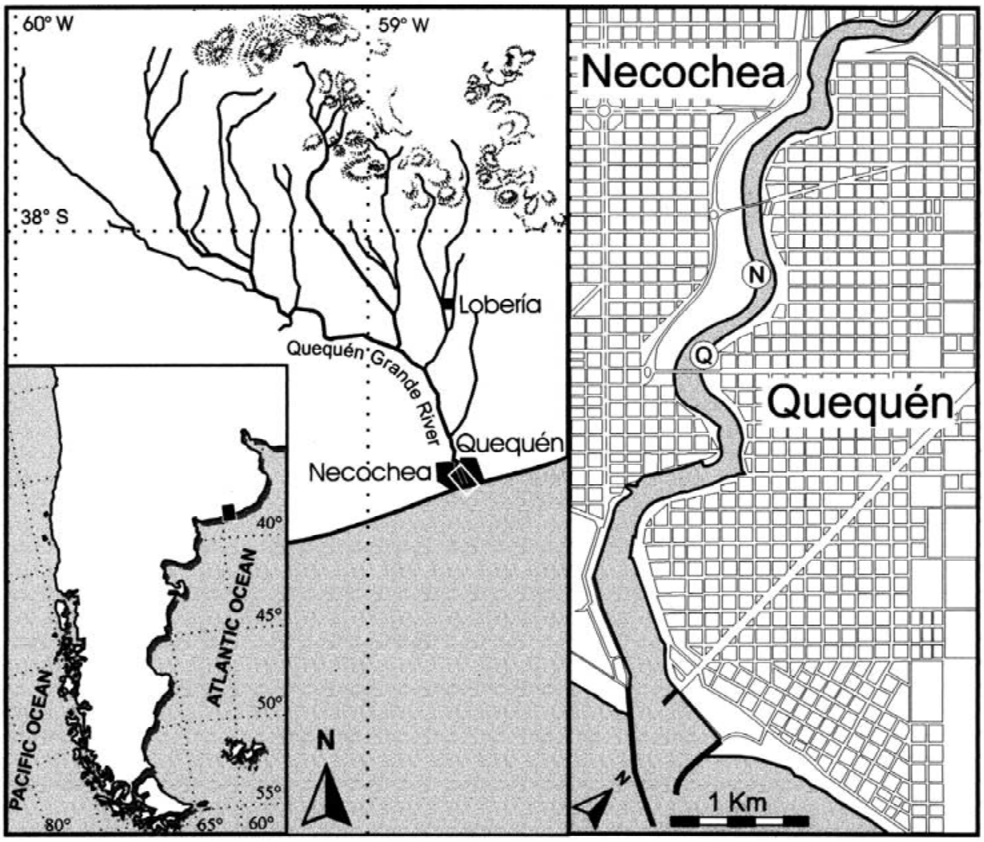

Figure 1. Map showing the Quequén Grande basin and estuary, its harbour, and the cities of Necochea and Quequén. N and Q: sampling sites.

vertical height at each site, spanning vertical intervals of 25 or 35 cm (Table 1). Variations in density of annelid populations found at different levels of the intertidal zone were analysed by one-way ANOVA. Homogeneity of variances was accomplished using the logarithmic transformation [$x' = \ln(x + 1)$], and was verified using Cochran's C test. In the only case in which this requisite could not be met, the significant result was confirmed by a non-parametric Kruskal–Wallis test. After a significant result in an ANOVA, differences among levels were analysed with an *a posteriori* LSD (least significant difference) test (Sokal & Rohlf, 1981).

In order to estimate the maximum depth at which annelids can be found within the sediment, we obtained four 32 cm cores (and one further sample for sediment particle analysis) at each sampling site, on October 21, 1998. Sediment cores were cut in four 8 cm intervals, and organisms were identified and counted in each fraction. The null hypothesis of independence between sampling sites and depth at which annelids can live within the sediment was analysed by means of the Chi square test (Sokal & Rohlf, 1981). Water temperature was recorded near the surface within Quequén Harbour, by taking 4–9 measurements per month, from October 1997 to October 1998.

On October 22, 1998, salinity was measured at both sampling sites with a conductivity meter, during a 12 h tidal cycle (7.00–19.00 h) with an expected amplitude of 1.20 m.

Sediment particle size was analysed by measuring total dry weight of the sample, sieving through a column of 6 sieves of decreasing mesh size (2000/1000/500/250/125/ 62.5 μm) under a continuous water flow, and finally drying and weighing each fraction. Means and standard deviations (phi units) were calculated graphically, according to methods proposed by Folk & Ward (1957). Mud percentage was compared between sampling sites using the non-parametric Mann–Whitney's U test (Sokal & Rohlf, 1981). Organic matter content was analysed by com-

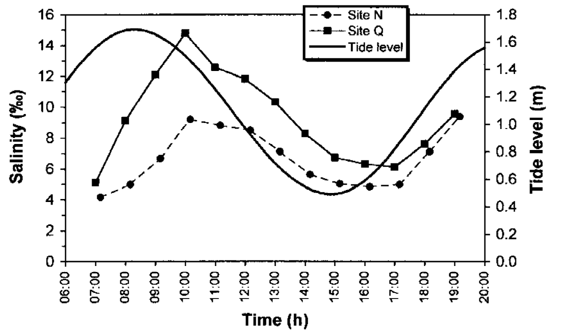

Figure 2. Salinity and tidal height in the Quequén Grande estuary, during a 12 h tidal cycle at sites N and Q.

busting a sediment subsample at 480 °C during 5 h (Byers et al., 1978).

Results

Temperature and salinity

Mean water temperature of the estuary was 15.9 °C during the study period, with an annual range of 12.6 °C. Highest temperature (23.4 °C) was recorded in February 1998, and lowest (10.8 °C) in August 1998.

Salinity ranged between 4.2 and 9.4‰ (average 6.6‰) at site N, and between 5.1 and 14.8‰ (average 9.3‰) at site Q, during a 12 h tidal cycle (Fig. 2). Salinity fluctuations were parallel at both sites, but the maxima were remarkably different in spite of their proximity. Highest and lowest salinity values occurred almost 2 h after the high and low tide, respectively.

Seasonal changes

L. acuta densities were high during late summer (March) and lower in spring (October 1997 and 1998) (Fig. 3). Densities were higher at site Q than at site N (maxima: almost 32 000 vs. 15 000 ind m^{-2}, respectively), but fluctuations were parallel at both sampling sites.

Seasonal fluctuations in population density of *Capitella* sp. were also similar at both sites (Fig. 3). This species was twice more abundant at site Q than at site N (maxima: 15 000 vs. 6000 ind m^{-2}, respectively). *Capitella* sp. density decreased from spring 1997 to early summer 1998, and then increased during late summer, reaching a peak in March. The population suffered a sudden collapse at both sites in early autumn 1998 (April) and did not recover again during the study period.

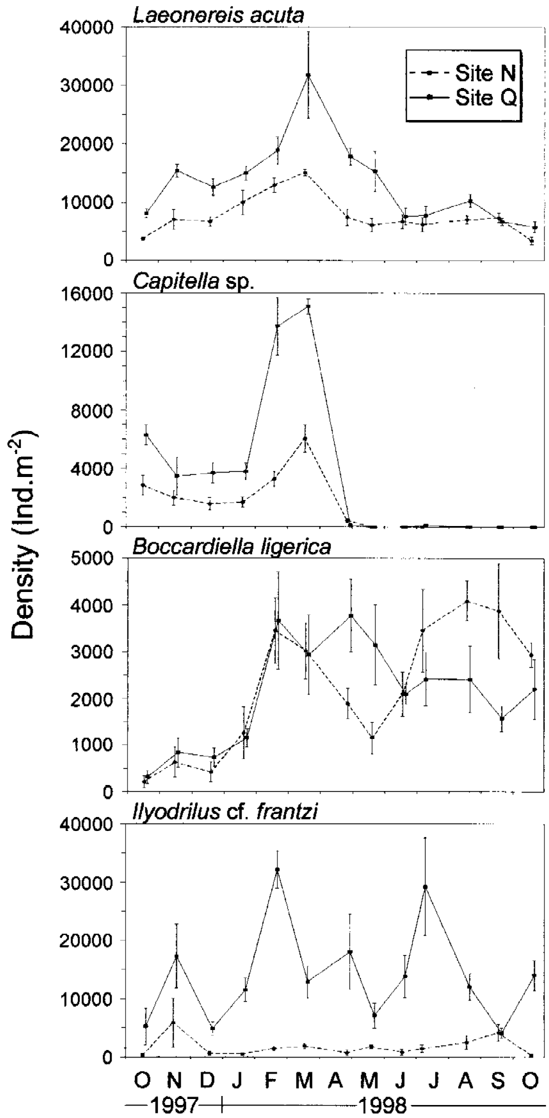

Figure 3. Seasonal changes in the density of *Laeonereis acuta, Capitella* sp, *Boccardiella ligerica* and *Ilyodrilus* cf. *frantzi* at sites N and Q.

Density values of *B. ligerica* were similar at both sampling sites, but showed different seasonal trends (Fig. 3). Low densities were found from October 1997 to January 1998 at both sites. At site Q, densities of *B. ligerica* increased remarkably and reached peak values between February and April 1998, and then remained at intermediate levels since winter. On the contrary, at site N, *B. ligerica* showed high density values in February 1998, but the maximum was attained during winter (August 1998).

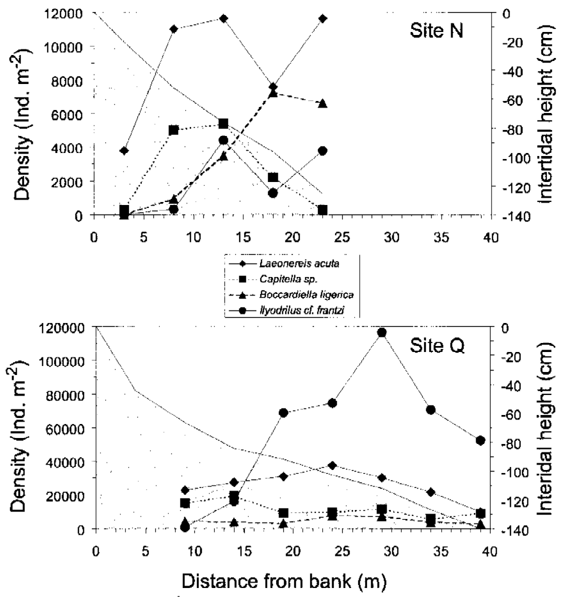

Figure 4. Density changes of four annelid species and substrate slope (shadowed area) in the intertidal zone at sites N and Q. Note that the ordinate scale is one order of magnitude higher at site Q than at site N.

Table 2. Particle size and organic matter content along two transects perpendicular to the shoreline in the Quequén Grande estuary. S.D.: standard deviation

	Gravel (%)	Sand (%)	Mud (%)	Phi	S.D.	Organic matter (%)
Site N						
3 m	1.3	23.0	75.7	5.1	1.47	4.00
8 m	0.2	32.1	67.7	4.8	1.45	4.17
13 m	0.5	44.7	54.8	4.4	1.45	2.91
18 m	0.4	46.3	53.3	4.3	1.51	4.34
23 m	1.6	38.8	59.6	4.4	1.58	4.64
Site Q						
9 m	0.9	57.1	42.0	4.2	1.24	2.78
14 m	3.8	44.5	51.7	4.4	1.61	4.29
19 m	0.5	42.5	57.0	4.6	1.28	3.81
24 m	0.9	40.2	58.9	4.6	1.26	3.95
29 m	3.0	55.9	41.1	4.1	1.50	2.99
34 m	1.0	55.1	43.9	4.2	1.24	3.35

The oligochaete *I.* cf. *frantzi* was more abundant at site Q than at site N (maxima: around 32 000 vs. almost 6000 ind m^{-2}, respectively) (Fig. 3). This species showed no clear seasonal trends. Its density was extremely variable at scales of 20–40 cm (distance among replications within the same sampling site).

Table 3. ANOVA of the density of four annelid species at different intertidal levels, along two transects perpendicular to the shoreline (sites N and Q) in the Quequén Grande estuary. H: high level, M: middle level, L: low level. *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$. $^{(1)}$: Heterogeneous variances, Cochran's C test, $P = 0.004$, Kruskal–Wallis test, $H = 8.61$, $P = 0.014$

Species	*F*	*P*	LSD test
Site N			
Laeonereis acuta	0.967	0.426	-
Ilyodrilus cf. *frantzi*	6.388	0.026*	M=L>H
Capitella sp.	1.457	0.296	-
Boccardiella ligerica	10.471	0.008**	L=M, M=H, L>H
Site Q			
Laeonereis acuta	5.053	0.028*	M=H, H=L, M>L
Ilyodrilus cf. *frantzi*	16.567$^{(1)}$	0.0005***	M=L>H
Capitella sp.	6.058	0.017*	H>M=L
Boccardiella ligerica	1.012	0.395	-

Intertidal zonation

Substrate slope was steeper at site N (5.5%) than at site Q (2.7%) (Fig. 4). Gravel percentages were very low in all samples of both sites. This fraction consisted mainly of small fragments of bivalve (*Tagelus plebeius*) and gastropod (*Heleobia australis*) shells. The sediment was poorly selected in all cases. High standard deviation values in some samples were directly related to the occurrence of shell fragments in the gravel fraction (Table 2).

Sediment characteristics were compared between sites using all sediment samples of each transect (Table 2). Mud percentage was significantly higher at the innermost sampling site (Site N: Mean = 62.6%, $n = 5$, Site Q: Mean = 49.1%, $n = 6$, Mann–Whitney's U test, $p = 0.045$). Mean phi values and organic matter content were also slightly higher at site N than at site Q, although differences were not significant.

At site Q, mud percentage and mean phi values increased from the upper- to the mid-intertidal, but then decreased towards lower levels. The opposite trend can be seen at site N, where mud percentage and mean phi values first decreased and then remained fairly stable (Table 2).

Intertidal zonation of the 4 annelid species was very variable at both sampling sites (Fig. 4, Table 3). *L. acuta* reached maximum density values at intermediate levels of both sites, but only at site Q these were significantly higher than those at lower levels. *Capitella* sp. was significantly more abundant than elsewhere only at high levels of site Q. On the other

Table 4. Particle size and percentage of organic matter at different depths within the sediment. S.D.: standard deviation

Depth	Gravel (%)	Sand (%)	Mud (%)	Phi	S.D.	Organic matter (%)
Site N						
0–8 cm	0.1	23.9	76.0	5.0	1.42	5.05
8–16 cm	0.0	20.3	79.7	5.2	1.35	6.06
16–24 cm	0.0	18.2	81.8	5.3	1.33	6.88
24–32 cm	0.3	13.1	86.6	5.5	1.31	8.08
Site Q						
0–8 cm	0.2	42.8	57.0	4.6	1.20	3.74
8–16 cm	0.9	56.6	42.5	4.2	1.23	2.93
16–24 cm	1.1	51.7	47.2	4.3	1.30	3.16
24–32 cm	8.6	53.3	38.1	3.8	1.94	2.85

hand, *B. ligerica* density clearly increased toward low intertidal levels only at site N. *I.* cf. *frantzi,* had significantly lower densities at high intertidal levels of both sites.

Vertical distribution

Mud and organic matter content, as well as mean phi values, were significantly higher at site N than at site Q for all strata taken together (Table 4, Mann–Whitney's *U* test, $p = 0.021$ for all sediment variables).

The vertical profile of sediment particle size was different at both sampling sites. Mud and organic matter content, and mean phi values, increased with depth at site N, but were highest at the sediment surface at site Q (Table 4).

All species were absent below 16 cm depth (Fig. 5). Whereas *B. ligerica* was found only at the sediment surface, both *L. acuta* and *I.* cf. *frantzi* were also recorded between 8 and 16 cm. *L. acuta* was the most abundant species at the subsurface layer of the sediment. Only 7% of *I.* cf. *frantzi* individuals were found between 8 and 16 cm, while around 30% of *L. acuta* specimens were found at this depth. Densities of *I.* cf. *frantzi* were highly variable, particularly at site N (Fig. 5).

Depth at which annelids can live within the sediment was not independent of sampling site: 15.7% and 33.3% of the individuals were found below 8 cm at sites Q and N, respectively (Chi square test: $X^2 = 439.8$, $p << 0.001$). At site N, where mud and organic matter content increased with depth, *L. acuta* was more abundant in the subsurface layer (8–16 cm), than at the sediment surface (0–8 cm) (Fig. 5).

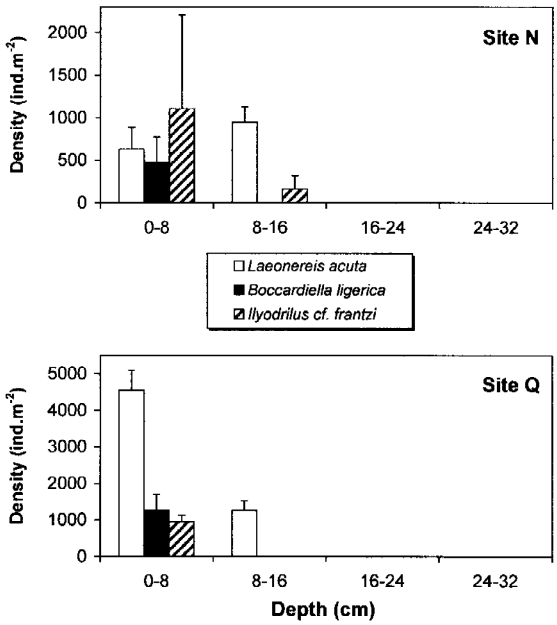

Figure 5. Density of *Laeonereis acuta*, *Boccardiella ligerica* and *Ilyodrilus* cf. *frantzi* at different sediment depths. *Capitella* sp. was absent when this part of the study was carried out. Vertical bars indicate one standard error.

Discussion

The infaunal macrobenthic community of intertidal sediments had a very low specific richness, being mainly composed of 4 annelid species: the nereid *Laeonereis acuta*, the spionid *Boccardiella ligerica* (=*Boccardia hamata* sensu Orensanz & Estivariz, 1971; see Blake, 1983), the tubificid *Ilyodrilus* cf. *frantzi*, and a species of *Capitella* belonging to the *C. capitata* complex (Grassle & Grassle, 1976). The remaining members of this community, such as leeches, amphipods and nemerteans were extremely rare, and bivalves were completely absent. Ostracods were abundant only at the sediment surface, their shells being a major component of the sediment fraction between 0.5 and 1.0 mm. The low biodiversity of this region has been already emphasised for other brackish water environments of Buenos Aires Province (Ieno & Bastida, 1998). It is a characteristic feature of this geographic area, since there are just 3 infaunal polychaete species in the Quequén Grande estuary (this study), 4 in Samborombón Bay (Ieno & Bastida, 1998) and 5 in Mar Chiquita coastal lagoon (Olivier et al., 1972a). Polychaete species richness is not much higher at the mixohaline zone of Patos coastal lagoon (southern Brazil), where up to 7 species have been found (Bemvenuti et al., 1992). Low species richness in this region is undoubtedly related to complex oceanographic processes occurring offshore, such as the subtropical shelf front and the Río de la Plata plume (Piola et al., 2000). A detailed biogeographic study on this phenomenon is still lacking.

Pollution is another well-known cause of low specific richness (Pearson & Rosemberg, 1978). The infaunal benthic communities within Quequén Harbour area show clear symptoms of organic enrichment. Our sampling sites, however, were located more than 2 km upstream, and may be regarded as affected by relatively lower levels of environmental stress.

Laeonereis acuta is one of the most frequent and abundant polychaetes in mixohaline environments of the Atlantic coast of South America. The occurrence of this species has been described in the estuaries of the rivers Sergipe and Piauí (Couto & Fernandes, 1998), Saco da Ribeira (Amaral, 1979), Paranaguá Bay (Netto & Lana, 1997), Patos Lagoon (Capítoli et al., 1978; Bemvenuti et al., 1978), Samborombón Bay (Ieno & Bastida, 1998), Mar Chiquita coastal lagoon (Olivier et al., 1972a, b), Blanca Bay (Elías & Ieno, 1993), San Antonio Bay (Escofet et al., 1978) and Puerto Madryn (Escofet, 1983).

The abundance and feeding habits of *L. acuta* make this organism a key prey species in the estuarine food web, where it is predated by crabs, polychaetes and fishes (Orensanz & Estivariz, 1971), and also by several wading birds (Ieno et al., 1998). Its seasonal cycle showed a clear peak of abundance during the summer months (February or March) and very low densities in spring at several localities where it was studied (Escofet, 1983; Omena & Amaral, 1998).

The *Capitella capitata* species complex (see Grassle & Grassle, 1976) was first recorded in Argentina in sandy beaches of Nuevo Gulf, Patagonia (Escofet, 1983). These species are regarded as opportunists and are often associated to organic enrichment processes (Pearson & Rosemberg, 1978), showing strong population fluctuations, and very high values of the production/biomass ratio (Martín & Grémare, 1997). At the Quequén Grande estuary, *Capitella* sp. also showed strong seasonal changes, with a higher density in summer (February–March), and disappearing since autumn. The seasonal cycle at the Quequén Grande estuary resembles the population fluctuations found at Nuevo Gulf, where higher densities were recorded between February and May, and a sharp decrease was then observed during winter (Escofet, 1983). In Patagonia, *Capitella* sp. is a major food item of demersal fishes such as *Eleginops maclovinus* (Escofet, 1983).

Although the dominance of *Laeonereis acuta* is a common feature in the benthos of all brackish water environments of Buenos Aires Province, the infaunal assemblage of the Quequén Grande estuary may be distinguished by the presence of *Capitella* sp. and the absence of *Heteromastus similis* (Ieno & Elías, 1995; Ieno & Bastida, 1998). Infaunal communities dominated by *L. acuta* and *C. capitata* have also been found in the estuaries of the Sergipe and Piauí rivers, in Northeast Brazil (Couto & Fernandes, 1998) and in non-vegetated environments of Paranaguá Bay (Netto & Lana, 1997).

The two sites studied, located at both banks of the estuary, are inhabited by the same assemblage of species. They show, however, clear differences in terms of abundance and vertical distribution, which are correlated with substrate characteristics. The relatively steep slope and the decrease of the mud fraction towards the surface, suggest that erosion predominates at the innermost sampling site (N). On the contrary, the gentle slope and the increase of the mud fraction towards the surface at the outermost site (Q), are indicative of an environment where sedimentation prevails. In other words, hydrodynamic factors may be determining the distribution of fine sediments, and therefore organic matter (Table 4), at different substrate depths. As a consequence, subsurface sediments may have a higher food value for infaunal organisms at site N than at site Q, which is reflected in the vertical distribution of some infaunal species. Indeed, at site N, the burrowing polychaete *Laeonereis acuta* was more abundant in the sediment layer between 8 and 16 cm (Fig. 5). In Mar Chiquita coastal lagoon, *L. acuta* can be found between depths of 0–15 cm, but 57% of the population is concentrated within the upper 5 cm of the sediment (Palomo & Iribarne, 1998).

Higher density values at site Q than at site N found in 3 of the 4 annelid species (*L. acuta*, *C. capitata* and *I.* cf. *frantzi*) throughout a yearly period (Fig. 3), may be related to deposition of fine sediments and organic matter. Feeding is strongly dependent on sediment characteristics in these detritivorous species. On the contrary, the spionid polychaete *Boccardiella ligerica* had a similar density at both sites (Fig. 3). This sedentary species lives exclusively on the sediment surface (Fig. 5), with its palps actively exploring the sediment–water interface.

Laboratory and field experiments will be necessary to study the major processes determining the observed patterns of abundance of infaunal organisms of the Quequén Grande estuary.

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