# APPENDICULARIAN DISTRIBUTION IN THE RÍO DE LA PLATA ESTUARY AND ADJACENT NERITIC AREAS

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## INTRODUCTION

The hydrology of the Río de la Plata estuarine system is extremely complex, being characterized by pronounced horizontal and vertical stratification of physical and chemical properties. The river outflow into coastal shelf waters is associated with strong temporal fluctuations, resulting in a variable thermohaline structure. This estuarine ecosystem exhibits high biological productivity due to the high nutrient input from the Río de la Plata (Carreto & Benavides, 1982; Carreto *et al.*, 1986; Negri *et al.*, 1988) and also is characterized by the penetration and dominance of euryhaline marine species which live in brackish waters, either permanently or temporarily (Boschi, 1988). The zooplankton of the estuarine system and surrounding neritic waters has been studied by Fernández Aráoz *et al.* (1991, 1994) and Ramírez & Santos (1994), who analyzed the distribution and abundance of copepod, amphipod and euphausiid species.

The main goal of the present contribution was to study the variability of appendicularian distribution in an environment of great regional relevance. After a faunistic survey, pronounced size differences among individuals of the same species and maturity degree from different localities were observed. Therefore, as an additional goal, individuals coming from different selected subareas were compared, in order to analyze possible morphometrical differences related to environmental factors.

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## MATERIALS AND METHODS

The study area ranged from 34° to 41°S latitude, from the Río de la Plata estuary to the southern end of Buenos Aires Province, covering mainly coastal and inner shelf waters cruised by the BIP "Capitán Oca Balda" in October 1993 (Fig. 1). One hundred and forty-eight plankton samples were collected using a 200-μm mesh Pairovet net, 0.50 m in mouth diameter. Vertical tows from bottom to surface were taken with a CTD sensor attached to the net.

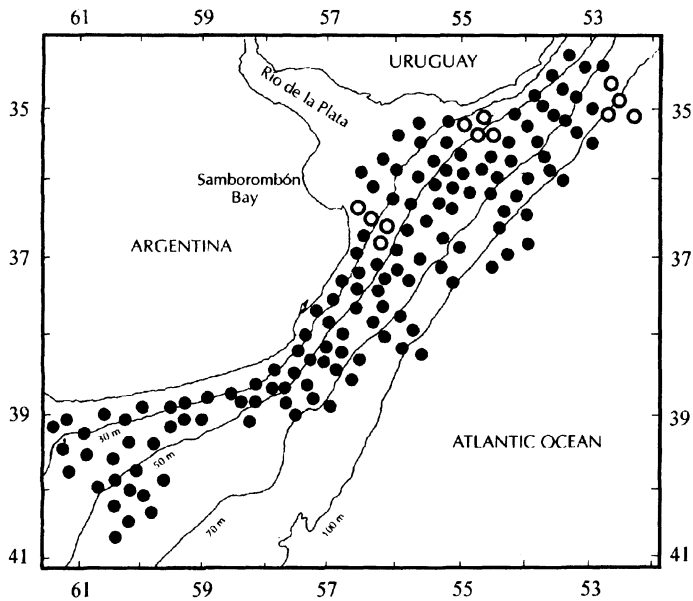


Fig. 1
Geographic position of the stations sampled by the cruise of the BIP "Capitán Oca Balda" in the Río de la Plata estuary and adjacent neritic areas. Blank circles indicate the stations selected in each of the three areas chosen for the comparative study of specimen's size.

Species density was calculated in terms of the number of specimens per cubic meter. In order to compare appendicularian size, three areas, with four randomly chosen stations each, were chosen: two areas in the northern estuarine region -inshore and offshore Uruguayan shelf waters- and the third one in the southern coastal area of Samborombón Bay (Fig. 1). These three areas were selected because of their contrasting hydrological features. The stations within each area were selected taking into account the simultaneous presence of the studied species. Because of their greater abundance, only the species of the genus *Oikopleura* were considered for the morphometric comparison. Trunk lengths of all individuals were measured and classified into two size

categories selected according to the maximum body size of the studied species: < 0.55 mm and 0.56-0.95 mm for *O. dioica* and < 0.75 mm and 0.76-1.35 mm for *O. fusiformis*. The densities of each size interval were compared by a three-way mixed ANOVA model. The factors considered were: area (Uruguayan coast, offshore Uruguayan area, and southern coastal area), station in area (nested factor) and size (small and large animals). A Tukey-Kramer multiple comparison method was used to compare mean densities of small and large specimens among the three areas (Sokal & Rohlf, 1981).

All specimens measured were classified into three maturity stages according to the descriptions made by Fenaux (1976), Esnal & Castro (1977) and Esnal *et al.* (1985) in the case of *O. dioica* and by Bückmann (1972) and Capitanio & Esnal (1996) in the case of *O. fusiformis*. For *O. dioica*, the only species of Appendicularia with separate sexes, specimens were considered mature when the gonad was granular and turgid and its height exceeded that of mid-trunk. Only in mature individuals could sex differentiation be observed, since there is a clear difference in gonad texture between females and males, *viz.* both ovary and testis look granular but whereas the ovary has larger spherical cells, the testis shows a fine-grained texture. For *O. fusiformis*, a specimen was considered to be mature when the testes extended laterally, surrounding the stomach and the postcardial caecum, the latter being observed by transparency. Gonad cross sections of specimens from the different areas, which were classified as mature under the stereoscopic microscope, were stained with haematoxylin-eosin. Comparative observations were made on the histological structure of the ovary.

## RESULTS

The stations south of Samborombón Bay were strongly influenced by the river discharge (Fig. 2). Surface brackish waters in this area had salinity values of 25 to 28 ‰ and a temperature of 15 °C, whereas the deeper layers had salinities comparable to the coastal shelf waters of the northern sector. Figure 3a shows temperature and salinity variation against depth in one station south of Samborombón Bay. In this profile a pronounced vertical stratification of both parameters is evident. The influence of the river outflow on the Uruguayan coast was much weaker, especially offshore where waters of subantarctic origin prevailed in the deeper layers. Uruguayan inshore waters had salinity values around 31 to 33 ‰ and temperatures between 12 and 13 °C, showing vertical mixing of the whole water column sampled (0-30 m) (Fig. 3b). The offshore area had salinity values between 33.5 to 34 ‰, and a temperature of about 8 °C in the deeper layers (Fig. 3c).

Three appendicularian species were recorded in 64 stations, including *Fritillaria borealis*, *Oikopleura dioica* and *O. fusiformis*. The distribution and abundance of these species are indicated in Fig. 4. *O. dioica* was found in higher abundances at the inshore stations south of Samborombón Bay, associated with low-salinity waters. Off Uruguay

this species appeared in most stations, but usually in lower densities, especially in the outer shelf. No individuals of *O. dioica* were found in the offshore stations located between 38 and 41° S, which were influenced by subantarctic waters in most of the water column sampled (0-50 m). *F. borealis* appeared in very low densities in the inshore stations south of Samborombón Bay, generally associated with *O. dioica*. *O. fusiformis* was the dominant species off Uruguay, showing a pronounced preference for outer-shelf waters with 33.5 ‰ salinity. The southernmost stations, with salinities between 25 and 27 ‰, exhibited lower appendicularian densities. No appendicularians were found in stations located at the mouth of the estuary. This brackishwater area (salinities between 0.5 and 30 ‰) is characterized by higher concentrations of suspended material (mean value of 50 mg/l; Bazán & Arraga, 1993).

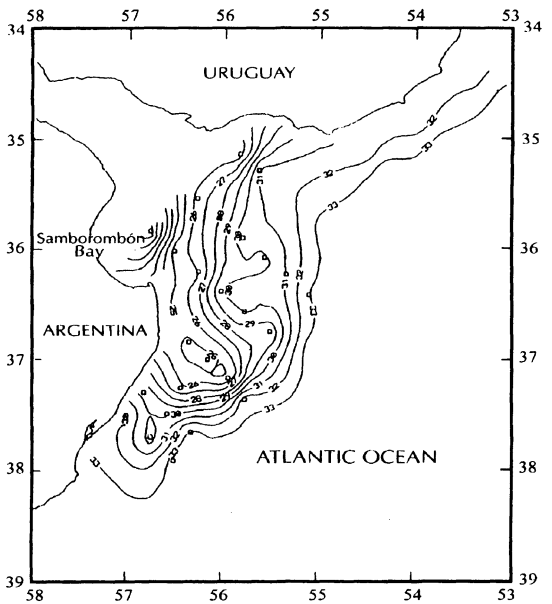


Fig. 2
Surface salinity (‰) in the Rio de la Plata estuary and adjacent neritic areas.

The nested-ANOVA for *O. dioica* and *O. fusiformis* (Tab. 1) showed a significant interaction between size and area ($P<0.01$). The mean densities of small and large specimens were compared among the three areas, indicating that size-class distribution was significantly different ($P<0.01$) in the southern area in relation to the northern sector (Tab. 2). All stations of both Uruguayan areas (coastal and outer-shelf) were characterized by the predominance of large individuals. In contrast, the area south of

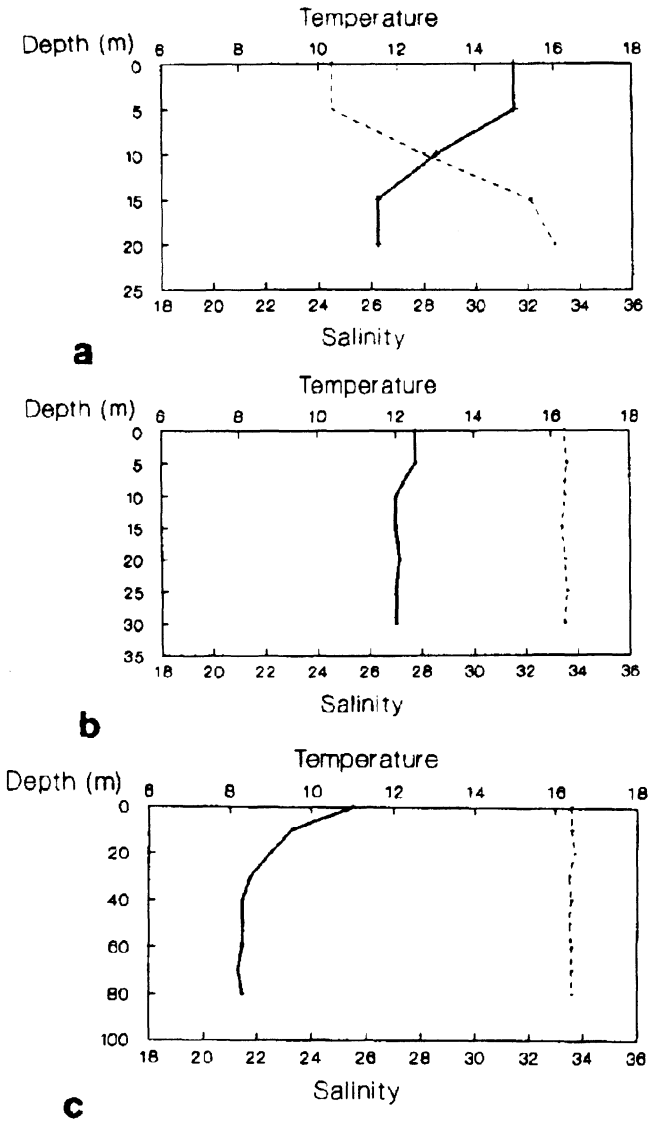


Fig. 3
Profiles of temperature (°C) and salinity (‰) in one station of the three selected areas used for the morphometric comparison. a: station of the southern coastal area at Samborombón Bay, b: station of the nearshore area of the northen region of the estuary and c: station of the offshore area

Samborombón Bay was characterized by the predominance of small individuals. In the northern areas, the mean sizes of the three maturity stages assigned to *O. dioica* and *O. fusiformis* were considerably larger than those in the southern area. This difference is more striking when comparing fully-mature individuals. On average, mature individuals of *O. dioica* were 0.75 mm long in the northern area against 0.45 mm in the southern area, whereas for *O. fusiformis* the figures were 0.99 mm in the north against 0.65 mm in the south. Ovary cross sections (Fig. 5) of *O. dioica* and *O. fusiformis* (showing a very turgid appearance) exhibited similar maturity degrees in both areas.

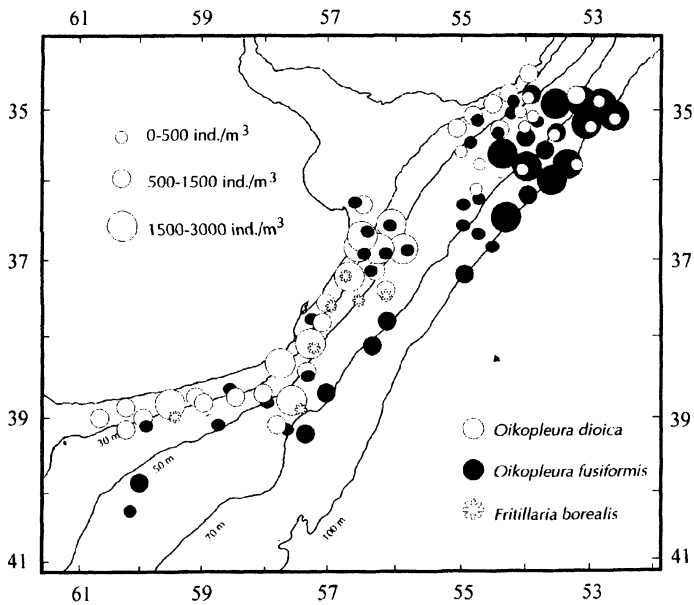


Fig. 4
Distribution and abundance of *Oikopleura dioica*, *O. fusiformis* and *Fritillaria borealis* in the study area.

## DISCUSSION

Individual sizes of *O. dioica* and *O. fusiformis* in the northern areas of the Río de la Plata estuary were larger than those in the southern area, even if specimens with the same maturity degree (as shown by the histological structure of the ovary) were compared. These size differences could be assigned to the more oceanic characteristics of the northern stations and not to the distance to the shore, since population sizes of both species, from inshore and offshore northern areas were not significantly different.

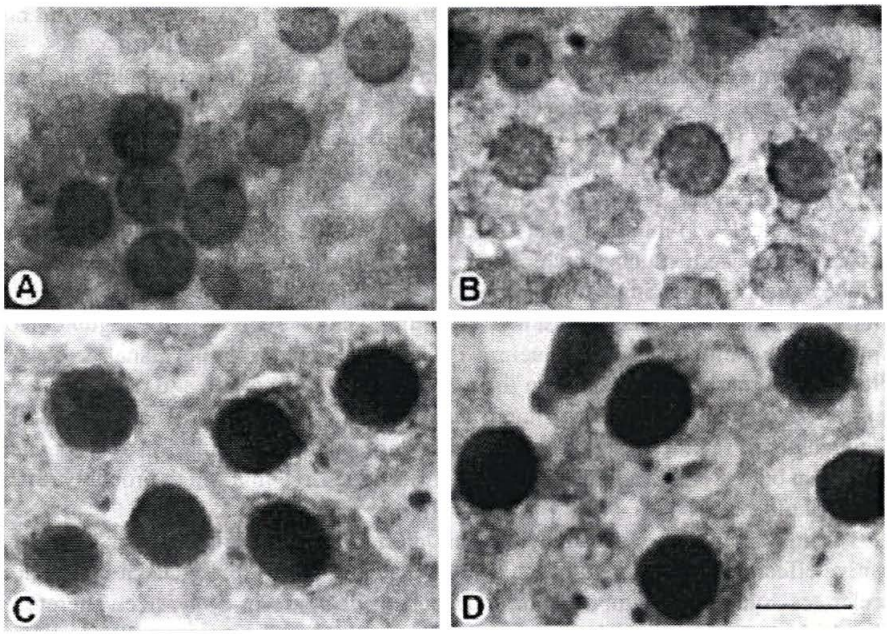


Fig. 5
Photographs of stained ovary cross sections of mature specimens of *O. dioica* and *O. fusiformis* from the different areas. A: *O. dioica* from Samborombón Bay, B: *O. dioica* from the northen areas, C: *O. fusiformis* from Samborombón Bay and D: *O. fusiformis* from the northern areas. Scale: 0,01 mm.

A somewhat generalized phenomenon among planktonic organisms is that when a species is able to tolerate a wide range of salinities, brackish-water forms tend to be smaller than those living at higher salinities. According to Tokioka (1979) populations from inshore waters are frequently represented by individuals smaller than those of the same species occurring in surrounding open neritic waters. This would indicate a faster maturation and a shorter generation time in coastal animals. Physiologically, these organisms tend to be more eurythermal and euryhaline than oceanic zooplankters. Tokioka (1979) mentions several examples illustrating this phenomenon, including chaetognaths, copepods and the appendicularian *O. dioica*. In the case of *O. dioica*, the author mentions that although the species is a cosmopolitan member of the neritic fauna, individuals which occasionally occur in oceanic waters are larger than those from inshore waters. This is attributed to a retarded maturation phenomenon. Oceanic specimens would take longer to reach sexual maturity, thus preventing population densities as high as those in coastal areas. The paucity of food and the absence of water currents favourable for the accumulation of animals in vast oceanic areas seem to be responsible for the absence of any self-supporting oceanic population of this species.

This hypothesis agrees with the pattern observed in our study, since *O. dioica* did not reach high densities in the outer-shelf waters of Uruguay.

The same phenomenon was observed in other appendicularian populations from different areas of the ocean. Shiga (1976) compared trunk lengths of *O. labradoriensis* from two bays (Funka Bay and Oshoro Bay) with those of outer neritic waters of the Bering Sea. He found that in the latter area, individual trunk lengths of all maturity stages were considerably larger as compared to specimens collected closer to the coast. Zoppi de Roa (1971) mentions that *O. rufescens* and *O. dioica* populations from the Cariacco Gulf were much smaller than those from the outer neritic areas of the Caribbean Sea. Contrasting with *O. dioica*, neither *O. rufescens* nor *O. fusiformis* have strictly neritic habits, so there must be some other factors involved in the regulation of population dynamics and size-structure in that case. For example, Esnal & Castro (1985) found marked differences in the tail dimensions of coastal and oceanic specimens of *O. longicauda* from Brazilian waters, which were generally smaller in coastal specimens. This feature was attributed to differences in the concentration of suspended particles in both areas, producing differential filtration rhythms, which probably affect tail morphology.

Temperature also plays a key role in determining the life-cycle span, having a positive effect on gonadal maturation time (Fenaux, 1976). Rapid gonadal maturation decelerates somatic growth, with the consequent decrease in body size. Therefore, individuals mature faster and attain smaller sizes at higher temperatures (Paffenhöfer, 1973, 1975; Fenaux, 1976; 1985). Several laboratory experiments, made by these authors on *O. dioica*, demonstrate temperature influence: at 14 °C the generation time was 11 days, at 22 °C it was reduced to 4 days, while at 7 °C it was extended to 24 days. Similar results were obtained on *Fritillaria borealis* (Paffenhöfer, 1975). No similar studies have been carried out on other appendicularian species, but the above-mentioned results may also apply to *O. fusiformis*.

Plankton organisms occurring south of Samborombón Bay can be expected to concentrate in the surface layers owing to the shallow depths and the high concentrations of suspended material all around the bay, so *O. dioica* and *O. fusiformis* populations probably occur at higher temperatures than those from the Uruguayan areas (the observed differences were 4 °C with respect to the outer Uruguayan shelf and about 3 °C with respect to the coastal area). This may partially explain the smaller individual size of mature animals in the southern bay as compared to the northern area.

The general distributional pattern of the species agrees with previous investigations (Forneris, 1965; Fenaux, 1966, 1967, 1968; Esnal, 1972, 1973; Tokioka, 1979; Esnal *et al.*, 1985). *Oikopleura dioica* dominates in coastal and estuarine environments (Fenaux, 1966, 1967, 1968). *Fritillaria borealis* is considered a cosmopolitan species that frequently appears in subantarctic and temperate waters (Esnal *et al.*, 1996), but its absence in the majority of the stations could be explained by a plankton-net selectivity effect as it is a very small species. *Oikopleura fusiformis* shows a wide distributional

range, that includes neritic and oceanic environments, although its preference for the latter has been mentioned (Esnal, 1972, 1973; Esnal & Castro, 1977).

The absence of appendicularians at the mouth of the estuary cannot be explained only by low salinities, since Esnal (1972) has already reported *O. dioica* and *F. borealis* from brackish waters (19.4 ‰ salinity), whereas salinity values in the stations herein considered exceeded 25 ‰. Esnal *et al.* (1985) also found *O. dioica* in the mouth of the River Potengi (North Brazil), reaching a density of 244 individuals per cubic meter. The distribution limits of these species in the Río de la Plata estuary might be also due to the influence of a turbidity front. The highest concentrations of suspended sediments (200-250 mg/l) have been recorded between the middle and the outer part of the estuary, decreasing to mean surface values of 15 mg/l at the mouth of the estuary (Bazán & Arraga, 1993). However, *O. dioica* populations seem to be able to develop in areas with high concentration of suspended particles. Dagg *et al.* (1996) described a population of this species in the plume of the Mississippi River which removes a significant fraction of small suspended lithogenic particles. Appendicularian faecal pellets contained large amounts of fine-grained lithogenic material, mostly 2 μm in size. Therefore, the distributional pattern of *O. dioica* at the mouth of the Río de la Plata estuary is probably regulated by a combination of factors which only a more detailed periodic sampling may reveal.

Table 1 : Three-way mixed ANOVA factors for *Oikopleura dioica* and *O. fusiformis*. The values marked with an asterisk are significant at 1%. D.F.: degrees of freedom, MS: mean square, F: statistic value, P: probability. The degrees of freedom of the error were calculated by subtracting 14 degrees of freedom to the total degrees of freedom in both cases (N-1=498 for *O. fusiformis* and N-1=143 for *O. dioica*).

| Species | Factors | DF | MS | F |
|---|---|---|---|---|
| | area | 2 | 0.2770 | 102.59 (P<0.01)* |
| | station within area | 9 | 0.0027 | — |
| | size | 1 | 2.1360 | 577.29 (P<0.01)* |
| *O. dioica* | size x area | 2 | 0.0190 | 5.13 (P<0.01)* |
| | error | 129 | 0.0037 | — |
| | area | 2 | 1.3740 | 353.21 (P<0.01) |
| *O. fusiformis* | station within area | 9 | 0.0039 | — |
| | size | 1 | 6.4460 | 537.17 (P<0.01) |
| | size x area | 2 | 0.1230 | 10.25 (P<0.01) |
| | error | 484 | 0.0120 | — |

Table 2: Comparison between mean densities (ind./m3) of small and large specimens of *Oikopleura dioica* and *O. fusiformis* from the three selected areas, using the Tukey-Kramer method. A: coastal area and B: outer area of the northern region of the Río de la Plata estuary; C: southern coastal area at Samborombón Bay. The underlined means were not significantly different at P=0.01.

| Species | Size intervals | A | B | C |
|---|---|---|---|---|
| *O. dioica* | < 0.55 mm | 520 | 418 | 2520 |
| | 0.56-0.95 mm | 1320 | 1215 | 308 |
| *O. fusiformis* | <0.75 mm | 258 | 271 | 980 |
| | 0.76-1.35 mm | 2050 | 2325 | 150 |

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## ABSTRACT

Appendicularians from the Río de la Plata estuary and southern coastal areas from 34° to 41°S, Argentina were studied. Three species were found: *Oikopleura fusiformis*, *O. dioica*, and *Fritillaria borealis*. *O. fusiformis* showed a pronounced preference for outer shelf waters (33.5 ‰ salinity), being dominant at the Uruguayan coast. *O. dioica* was mainly found at coastal stations and its abundance was higher in waters with salinities between 25 and 27 ‰. *F. borealis* appeared at very low densities, generally associated with *O. dioica*. No appendicularians were found at the mouth of the estuary with high concentrations of suspended sediments. Trunk lengths of individuals of each species from three areas with very different hydrological features, were compared to analyze size differences among animals showing the same maturity degree. The northern part of the estuary was characterized by the predominance of large individuals, forming a significantly different group from that of the southern area. Small individuals were predominant at the southern area, which showed marked stratifications of temperature and salinity. Histological sections of gonads of small animals with mature appearance from the southern area showed the same maturity degree as the larger mature specimens from the northern areas. The relationship between size differences and environmental factors is discussed.

Key-words: Appendicularia, distribution, maturity stage size, Río de la Plata estuary.

## RESUMO

Apendiculárias do estuário do "Rio da Prata" e áreas costeiras entre 34° e 41°S, Argentina, foram estudadas. Três espécies foram coletadas: *Oikopleura fusiformis*, *O. dioica* e *Fritillaria borealis*. *O. fusiformis* foi dominante na costa do Uruguai especialmente nas águas externas da plataforma (salinidade 33.5‰). *O. dioica* foi achada sobretudo nas estações costeiras e foi mais abundante nas águas com salinidades entre 25 e 27 ‰. *F. borealis* teve densidades muito baixas, ocorrendo geralmente associada com *O. dioica*. Na boca do estuário, caracterizada por uma grande concentração de sedimentos em suspensão, não foram encontradas apendiculárias. O comprimento do corpo dos indivíduos de cada espécie, procedentes de três áreas com diferentes características hidrológicas, foi comparado para analisar diferenças nos tamanhos de animais com igual grau de maturação. As duas áreas situadas ao norte do estuário foram significativamente diferentes da outra localizada no sul, visto que todas as estações ao norte foram caracterizadas pela dominância de indivíduos de maior tamanho. Na área sul, com uma marcada estratificação de temperatura e salinidade, os organismos de pequeno tamanho foram predominantes. Secções histológicas de gônadas de indivíduos pequenos da área sul do estuário, com aparência matura, mostraram o mesmo grau de maduração das gônadas dos indivíduos maduros de maior tamanho da área norte. A relação entre as diferenças de tamanho e os fatores ambientais é discutida.


Palavras-chave: Appendicularia, distribuição, tamanho dos estádios de maturação, estuário do Rio da Prata.

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