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# Temporal dynamics of a fish community in the lower portion of a tidal creek, Pando sub-estuarine system, Uruguay

Rodrigo Gurdek & Alicia Acuña-Plavan

Departamento de Oceanografía y Ecología Marina, Instituto de Ecología y Ciencias Ambientales,
Facultad de Ciencias, Universidad de la República, Iguá 4225, CP 11400 Montevideo, Uruguay. (rgurdek@gmail.com; acuplavan@gmail.com)

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**ABSTRACT.** Estuaries are highly dynamic ecosystems subjected to variability of their fish communities over different time scales. The nearshore fish community of the lower Pando estuary, a temperate sub-system of the Río de la Plata estuary, was sampled from May 2002 to June 2003. A total of 2,165 fishes, represented by 16 species were caught by seine netting. Captures were dominated by juveniles (>90%), as well as by the sciaenid *Micropogonias furnieri* (Desmarest, 1823) (82.8%). The fish community showed high seasonal variability, with the greatest diversity and biomass in summer and spring and the highest species richness during summer. Lowest values of all community parameters occurred in winter and autumn, seasons that presented the highest similarity in fish composition. Number of species was correlated with water temperature and salinity. The ichthyofaunal composition showed significant diel differences in summer and spring. Diel changes were observed in the density of *M. furnieri* and *Odontesthes argentinensis* (Valenciennes, 1835), occurring mainly during the day, and of *Mugil liza* Valenciennes, 1836, *Parapimelodus valenciennis* (Lütken, 1874) and *Brevoortia aurea* (Spix & Agassiz, 1829), caught mostly during the night. Temporal variability was attributed to environmental fluctuations, life cycle of species as well as to feeding patterns and small-scale displacements. Presented findings in the Pando sub-estuary denote similar juvenile use and seasonal patterns to those found in estuaries. Further studies in the nursery function and juvenile dynamics over the year are recommended in order to better understand the ecological role of sub-estuaries.

**KEYWORDS.** Ichthyofauna, community parameters, seasonal variability, diel variability, sub-estuary.

**RESUMO.** **Dinâmica temporal de uma comunidade de peixes na parte baixa de um arroio costeiro, sistema subestuarino Pando, Uruguai.** Os estuários são ecossistemas dinâmicos que apresentam variabilidade nas suas comunidades de peixes em diferentes escalas de tempo. A comunidade de peixes costeiros do baixo estuário do Pando, um subsistema temperado do estuário do Río de la Plata, foi amostrada entre maio de 2002 e junho de 2003. Um total de 2.165 peixes, representados por 16 espécies, foi documentado com a pesca de arrasto. As capturas foram dominadas pelos jovens (>90%), assim como pelo sciaenídeo *Micropogonias furnieri* (Desmarest, 1823) (82,8%). A comunidade de peixes apresentou uma grande mudança sazonal, com a máxima diversidade e biomassa no verão e primavera, e a máxima riqueza de espécies durante o verão. Os menores valores de todos os parâmetros comunitários ocorreram no inverno e outono, estações com a maior similaridade na composição da ictiofauna. O número de espécies foi correlacionado com a temperatura de água e salinidade. A composição da ictiofauna apresentou mudanças significativas diárias no verão e primavera. Verificou-se uma variabilidade diária na densidade da *M. furnieri* e *Odontesthes argentinensis* (Valenciennes, 1835), ocorrendo principalmente durante o dia, e de *Mugil liza* Valenciennes, 1836, *Parapimelodus valenciennis* (Lütken, 1874) e *Brevoortia aurea* (Spix & Agassiz, 1829), observadas principalmente durante à noite. A variabilidade temporal foi atribuída a interação com o ambiente, ciclo de vida das espécies assim como a atividade alimentar e movimentos de pequena escala. Resultados no subestuário Pando denotam um uso de juvenis e padrões sazonais semelhante aos dos estuários. Mais pesquisas no papel das áreas de berçário e dinâmicas juvenis ao longo do ano são recomendadas para compreender melhor o papel ecológico dos subestuários.

**PALAVRAS-CHAVE.** Ictiofauna, parâmetros da comunidade, variabilidade sazonal, variabilidade diária, subestuário.

Estuaries have been widely recognized as essential ecosystems for the development of key functions in the life cycle of fish species. Estuaries are highly productive environments, acting as nursery areas, feeding grounds and temporal habitats for a wide range of fish species (Day *et al*., 2013). Due to high dynamism, estuarine waters have been subjected to many studies quantifying the temporal variability of biotic and abiotic parameters (Akin *et al*., 2005; Barletta *et al*., 2008). Therefore, a number of temporal scales, including seasonal and diel scales, have been suggested (Hoeksema & Potter, 2006).

In the seasonal cycle, recruitment, migration and bio-environmental interaction are some examples of biological processes taking place in estuaries (Idelberger & Greenwood, 2005; Barletta *et al*., 2008). Changes in density, biomass and number of species of the estuarine fish assemblages in temperate estuaries are often reported (Hagan & Able, 2003; Barletta *et al*., 2008). Environmental variability such as salinity and temperature fluctuations, and timing of both reproduction and life history characteristics, have been the most commonly invoked drivers of the observed patterns (Hagan & Able, 2003; Simier *et al*., 2006).

Throughout diel temporal scales, fish dynamics are closely related to feeding patterns, avoidance of potential predators or adverse physicochemical conditions and use of shelter habitats (OLIVEIRA-NETO *et al*., 2008; CASTILLO-RIVERA *et al*., 2010; BECKER *et al*., 2011). Among the proposed factors controlling these interactions, photoperiod has been suggested as one of the most important (GAELZER & ZALMON, 2008). Light levels provide an easily quantifiable assessment of risk from predators, linking diel movements to feeding ecology and predator avoidance of fish species. Thus, species can respond to diel variation by timing activity levels with the diel period (CLARK *et al*., 2003).

The Río de la Plata (RdlP) system constitutes one of the largest estuaries in the world. The marginal Uruguayan coast of the RdlP has been suggested as a nursery fish habitat (RETTA *et al*., 2006). Along this coast a series of sub-estuarine creeks flow into the RdlP, among which is located the Pando sub-estuarine system. Previous studies conducted in this system described the temporal distribution of fish species, highlighting the ecological role of the Pando sub-estuary as a nursery ground for juvenile fish, mainly for the species *Micropogonias furnieri* (Desmarest, 1823) (ACUÑA *et al*., 2010). ACUÑA *et al*. (2010) suggested a correlation between the fish abundance and temperature, as well as advised on the role of salinity over the functional structure and juvenile use of the area.

To date, little is known about the temporal dynamics of fish communities in sub-estuaries apart from the general trend found in estuaries. In this sense, the purpose of the present study was to compliment the seasonal analysis undertaken by ACUÑA *et al*. (2010), and to determine the diel variability of the fish community in the Pando sub-estuary. Therefore, the aim was to determine the seasonal and diel composition of the fish community, analyse the seasonal and diel variability and relate these patters to the environmental fluctuations. No-differences in the fish composition, abundance, species richness or diversity were proposed between seasons or diel periods.

## MATERIALS AND METHODS

The Pando tidal creek system (34°47'S, 55°52'W) is a small temperate sub-estuary influenced by tidal waters of the RdlP (ACHA *et al*., 2008) (Fig. 1). No data exist on astronomical tides for Pando estuary, but the adjacent area of the RdlP presents small tidal amplitude (0.3 m) (MTOP-PNUD, 1979). The Pando estuary covers a drainage basin of 973 km² and has an average flow of 10.9 m³/s (CAYSSIALS *et al*., 2000).

The study was carried out between May 2002 and June 2003 (except in May 2003), during the afternoon. Once a month fish was collected at three replicate sites in nearshore waters by seine net (12 m long, 2 m high, 12 mm knot-to-knot), with two 25 m long ropes joined to each end of the net. The net was laid parallel to the shore and then hauled onto the beach, in order to sample fish to a depth of 1.5 m (swept area of 300 m$^2$). Additionally, during August 2002 (winter), December 2002 (spring), February 2003 (summer) and June 2003 (autumn), sampling was designed to obtain fish data throughout one 24-hour period, with 18 hauls divided between light and dark hours. Simultaneously, the water temperature and salinity were measured using a multi-parameter device.

Fish were identified to species according to RINGUELET *et al*., 1967; FIGUEIREDO & MENEZES (1978; 1980), MENEZES & FIGUEIREDO (1980), MENNI *et al*. (1984), MENEZES & FIGUEIREDO (1985), FIGUEIREDO & MENEZES (2000) and DYER (2006), counted, measured to the nearest 1 mm and weighed to the nearest 0.1 g.

Fish community parameters (number of fish, species richness, diversity, through Shannon-Wiener index, and biomass) were compared between seasons and day periods (day and night). Assumptions of normality and homogeneity of variance were analysed by Shapiro Wilk's test (SHAPIRO & WILK, 1965) and Levene's test (based on the averages),

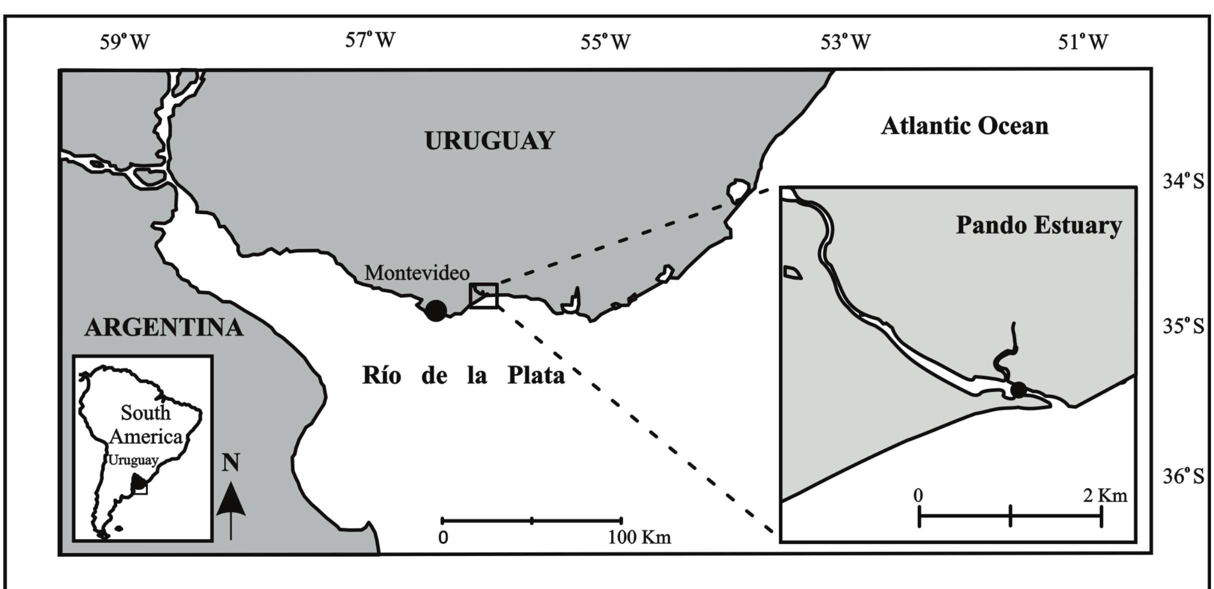


Fig. 1. Study area in the lower Pando sub-estuary, Uruguay. Sampling location is indicated by a black circle.

respectively. When necessary, data were transformed to Log (n) or Log (n+1). Parametric analysis of variance (ANOVA) or non-parametric Kruskal-Wallis was used depending on the fulfilment of the assumptions. A post hoc Tukey's Test or Mann-Whitney was used to test for multiple comparisons. To test whether the ichthyofaunal composition differed significantly between seasons or day period, a similarity matrix was subjected to one-way analysis of similarity (ANOSIM) (Clarke, 1993) using the PRIMER 6 multivariate statistics package. The Bray Curtis similarity matrix was constructed employing log transformed (n+1) densities of fish species. The R-statistic values determined by ANOSIM for significant comparisons were used to ascertain the degree to which a priori groups of samples were dissimilar (Clarke, 1993). R-statistic values approaching unity demonstrate that the compositions of the samples in each group are very different, while those close to zero show that they are very similar. To analyse the temporal contribution of each species to its annual total catch, the percentage contribution of the main fish species in each season was plotted. Spearman rank correlation coefficients ($\rho$) were used to determine the extent to which fish distributions were correlated with abiotic variables. A significance level of $\alpha = 0.05$ was established (Sokal & Rohlf, 1969).

## RESULTS

Mean seasonal water temperature and salinity values ranged from 11.1° C to 24.4° C and from 2.4 to 10.9, respectively (Tab. I). Significant differences were found between seasons for both variables (Kruskal-Wallis, $p < 0.001$). Maximum temperature and salinity values were registered during summer, while minimum temperature and salinity values occurred during autumn and winter, respectively (Tab. I). Diel variability only showed significant differences in summer, with the highest salinity values occurring during day (ANOVA, $p < 0.05$) (Tab. I).

Tab. I. Environmental data measured from May 2002 to June 2003 in the lower Pando sub-estuary, Uruguay. Data is expressed as mean value ± standard deviation. * = no data register.

| Temperature (°C) | Winter | Spring | Summer | Autumn |
|---|---|---|---|---|
| Season | 15 ± 0.6 | 24 ± 0.4 | 24.4 ± 1.1 | 11.1 ± 1.9 |
| Day | 15.1 ± 0.8 | 24 ± 0.4 | 24.3 ± 1.7 | 12 ± 1 |
| Night | 15 ± 0.6 | * | 24.6 ± 0.4 | 9.7 ± 2.5 |
| Salinity | | | | |
| Season | 2.4 ± 0.2 | 4 ± 0.4 | 10.9 ± 5.2 | 3.5 ± 1 |
| Day | 2.5 ± 0.2 | 4 ± 0.4 | 15.1 ± 3.8 | 3.3 ± 1.1 |
| Night | 2.4 ± 0.1 | * | 6.8 ± 1.2 | 4 ± 0.5 |

A total of 2,165 individuals, belonging to 16 species and eleven families and weighing 53.39 kg were caught by seine netting during monthly and diel sampling (Tab. II). Captured fish were predominately juveniles (>90%). *Micropogonias furnieri* was the most abundant species, both in number of individuals (82.8%) and biomass (38.1%), caught in all sampling periods and represented by more than 99% of juveniles. Other representative species in terms of number of individuals were *Mugil liza* Valenciennes, 1836 (7.6%) and *Odontesthes argentinensis* (Valenciennes, 1835) (2%). *Cyprinus carpio* Linnaeus, 1758 (25.7%) and *Paralichthys orbignyanus* (Valenciennes, 1839) (15.9%) were also abundant in terms of biomass, representing the largest individuals in the fish community (Tab. II). In terms of the seasonal variability of the most abundant species, *M. furnieri* was the only species with a constant occurrence throughout the year (Fig. 2). *Mugil liza*, *Parapimelodus valenciennis* (Lütken, 1874) and *P. orbignyanus* were most abundant

Tab. II. Taxonomic, abundance and morphometric data of fish community caught by seine netting from May 2002 to June 2003 in the lower Pando sub-estuary, Uruguay (R, rankings by abundance; N, numbers; g, grams; %, percentage contributions to total catch; LR, length range; ML, mean length; % OF, percentage of occurrence frequency).

| Species | Number of fish | | | Biomass of fish | | | Total length (mm) | | % OF |
|---|---|---|---|---|---|---|---|---|---|
| | R | N | % | R | g | % | LR | ML | |
| *Micropogonias furnieri* (Desmarest, 1823) | 1 | 1,792 | 82.8 | 1 | 20,359 | 38.1 | 27-250 | 99 | 100 |
| *Mugil liza* Valenciennes, 1836 | 2 | 165 | 7.6 | 4 | 6,124.7 | 11.5 | 29-365 | 120 | 82.4 |
| *Odontesthes argentinensis* (Valenciennes, 1835) | 3 | 43 | 2 | 5 | 2,282.7 | 4.3 | 32-307 | 181 | 47.1 |
| *Parapimelodus valenciennis* (Lütken, 1874) | 4 | 38 | 1.8 | 7 | 631.8 | 1.2 | 76-147 | 119 | 29.4 |
| *Paralichthys orbignyanus* (Valenciennes, 1839) | 5 | 37 | 1.7 | 3 | 8,465.2 | 15.9 | 83-624 | 262 | 76.5 |
| *Brevoortia aurea* (Spix & Agassiz, 1829) | 6 | 28 | 1.3 | 9 | 207 | 0.4 | 30-168 | 79 | 41.2 |
| *Platanichthys platana* (Regan, 1917) | 7 | 21 | 1 | 12 | 62.2 | 0.1 | 51-95 | 68 | 23.5 |
| *Genidens barbus* (Lacepède, 1803) | 8 | 15 | 0.7 | 8 | 571.4 | 1.1 | 85-205 | 155 | 35.3 |
| *Lycengraulis grossidens* (Spix & Agassiz, 1829) | 9 | 11 | 0.5 | 10 | 147.4 | 0.3 | 59-165 | 116 | 23.5 |
| *Pomatomus saltatrix* (Linnaeus, 1766) | 10 | 4 | 0.2 | 11 | 73 | 0.1 | 89-149 | 126 | 11.8 |
| *Menticirrhus americanus* (Linnaeus, 1758) | 11 | 3 | 0.1 | 13 | 61.6 | 0.1 | 105-163 | 134 | 11.8 |
| *Cyprinus carpio* Linnaeus, 1758 | 12 | 3 | 0.1 | 2 | 13,693 | 25.7 | 605-744 | 667 | 11.8 |
| *Macrodon ancylodon* (Bloch & Schneider, 1801) | 13 | 2 | < 0.1 | 6 | 640 | 1.2 | 310-340 | 325 | 5.9 |
| *Pogonias cromis* (Linnaeus, 1766) | 14 | 1 | < 0.1 | 14 | 29 | < 0.1 | 145 | 145 | 5.9 |
| *Urophycis brasiliensis* (Kaup, 1858) | 15 | 1 | < 0.1 | 15 | 21.6 | < 0.1 | 150 | 150 | 5.9 |
| *Luciopimelodus pati* (Valenciennes, 1835) | 16 | 1 | < 0.1 | 16 | 17.6 | < 0.1 | 154 | 154 | 5.9 |
| Species richness | 16 | | | | | | | | |
| Total number | | 2,165 | | | | | | | |
| Total biomass | | | | | 53,387.2 | | | | |

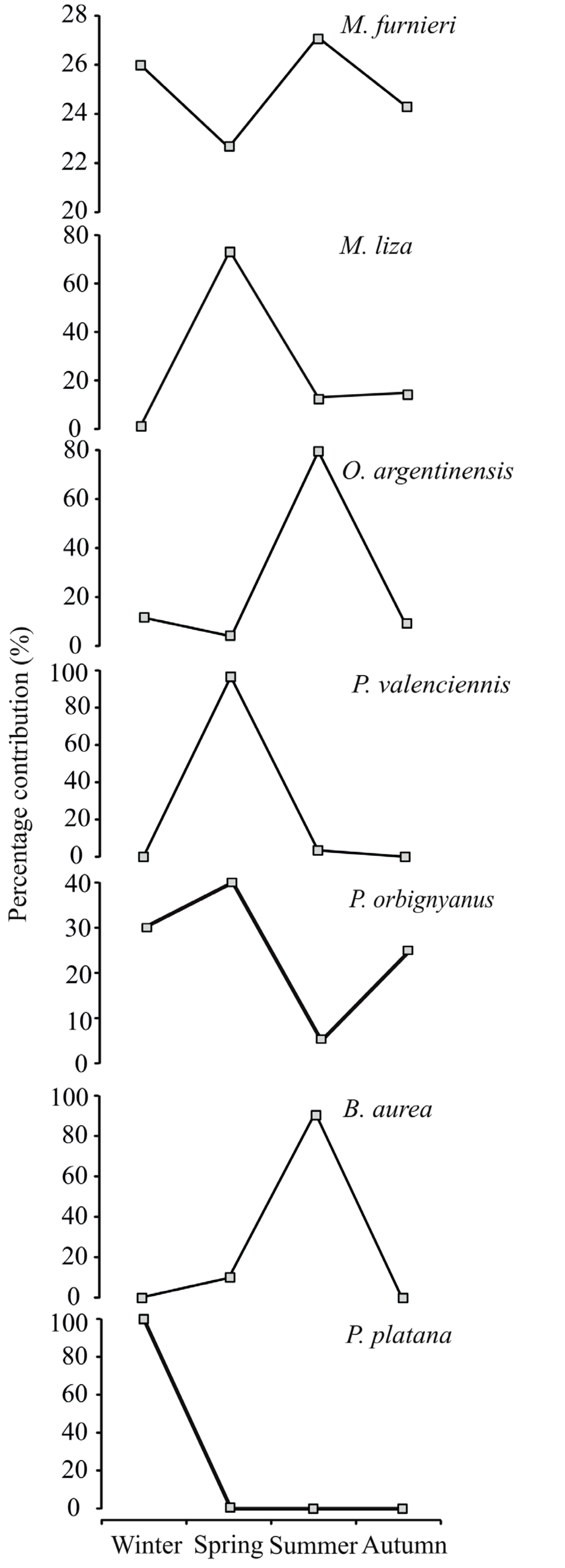


Fig. 2. Seasonal changes in percentage contribution of the most abundant species caught by seine netting from May 2002 to June 2003 in the lower Pando sub-estuary, Uruguay.

during spring, *O. argentinensis* and *Brevoortia aurea* (Spix & Agassiz, 1829) during summer and *Platanichthys platana* (Regan, 1917) during winter (Fig. 2).

Seasonal differences were detected in biomass, species richness, diversity and fish composition of the community (Kruskal-Wallis, $p < 0.001$; ANOSIM, $p = 0.001$, except for winter and autumn with $p < 0.05$), except for the number of individuals (Kruskal-Wallis, $p > 0.05$). According to comparisons of the community parameters, summer and spring could be classified as periods with the greatest diversity and biomass of the fish community, compared to winter and autumn (Fig. 3; Tab. III). Maximum average values of fish species richness (4/300 $m^2$) and diversity (0.72/300 $m^2$) were found during summer, while highest average values of biomass occurred in spring (4.53 kg/1000 $m^2$) (Fig. 3). All parameters presented minimum average values during winter and autumn (Fig. 3). Highest similarity in fish composition were found between winter-autumn (ANOSIM, $R = 0.098$), followed by summer-autumn (ANOSIM, $R = 0.312$), summer-winter (ANOSIM, $R = 0.389$) and summer-spring (ANOSIM, $R = 0.432$). A significant correlation was detected between number of species and both water temperature (Spearman, $\rho = 0.54$, $p < 0.05$) and salinity (Spearman, $\rho = 0.51$, $p = 0.05$).

Analysis of diel variability performed seasonally only showed significant differences in density and biomass during winter (ANOVA, $p < 0.05$), with highest average values during the day (86 individuals/1000 $m^2$; 1,008.6 g/1000 $m^2$) (Fig. 4). Ichthyofaunal composition differed significantly between day and night in summer and spring (ANOSIM, $p < 0.01$). Diel patterns in the fish composition were largely attributed to *M. furnieri*, *M. liza*, *O. argentinensis*, *P. valenciennis* and *B. aurea*, as well as to the occurrence of occasional species (Tab. IV). *Micropogonias furnieri* showed greater average density (77 individuals/1000 $m^2$) (Kruskal-Wallis, $p < 0.05$) and biomass (436.5 g/1000 $m^2$) (Kruskal-Wallis, $p < 0.001$) during the day in winter (Tab. IV). *Mugil liza*, *P. valenciennis* and *B. aurea* were mainly caught at night, during autumn (five individuals/1000$m^2$) (Kruskal-Wallis, $p < 0.05$), spring (nine individuals/ 1000 $m^2$) (Kruskal-Wallis, $p < 0.01$) and summer (six individuals/ 1000 $m^2$) (Kruskal-Wallis, $p < 0.01$), respectively (Tab. IV). *Odontesthes argentinensis* was more abundant in the day (eight individuals/ 1000 $m^2$) (Kruskal-Wallis, $p < 0.05$) in summer (Tab. IV). The higher density of *O. argentinensis* during the day was correlated with the salinity values (Spearman, $\rho = 1$, $p < 0.05$) (Fig. 5).

## DISCUSSION

Over the study period the lower portion of the Pando sub-estuary presented a low number of fish species, compared to tropical estuaries (ARCEO-CARRANZA & VEGA-CENDEJAS, 2009; ZÁRATE-HERNÁNDEZ *et al.*, 2012). The species richness and fish composition was consistent with what has been found in adjacent sub-estuarine systems along the Uruguayan coast (GURDEK *et al.*, 2016; ACUÑA *et al.*, in press). Similar results were found in temperate estuarine systems by JAMES *et al.* (2008), LOEBMANN *et al.* (2008), CARDOSO *et al.* (2011)

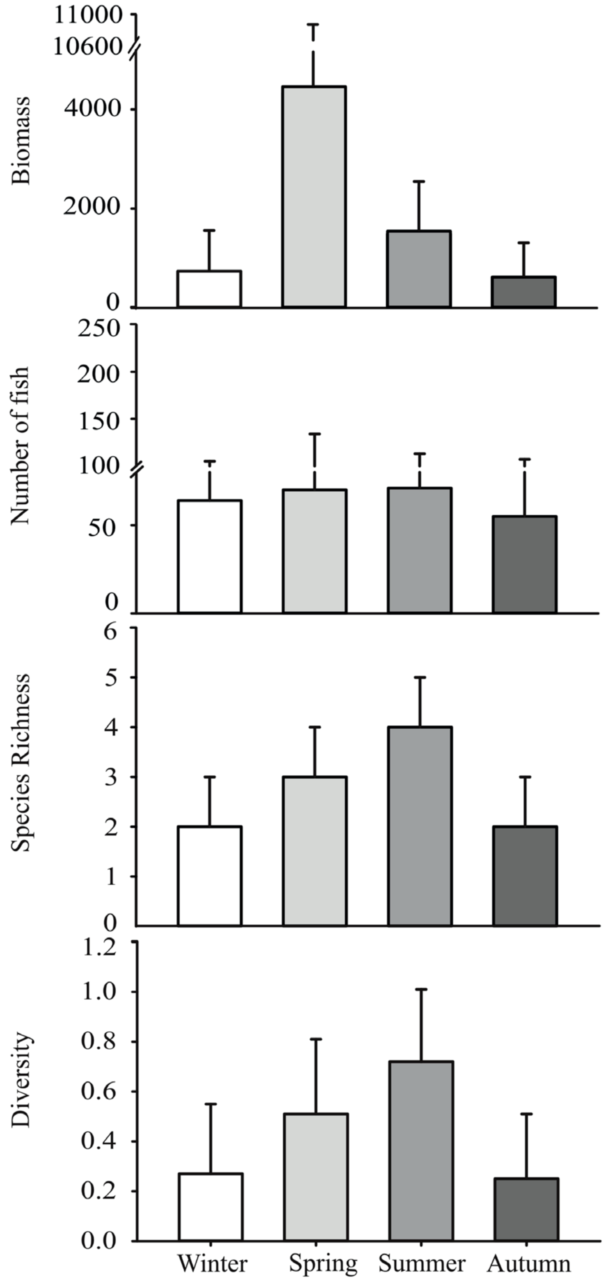


Fig. 3. Seasonal variability of fish catch data in terms of mean (± SD) biomass (biomass/ 1000 m²), number of fish (fish number/ 1000 m²), species richness (species/300 m²) and diversity (diversity value/300 m²) from May 2002 to June 2003 in the lower Pando sub-estuary, Uruguay.

and BRUNO *et al*. (2013). However, the collected number of species could be low in comparison to other temperate estuaries (POTTER *et al*., 1990). A relatively low number of species can be linked to properties such as latitude (*i.e.*, temperate latitude), estuary area (*i.e.*, small size) and diversity of habitats (*i.e.*, poor habitat diversity) (FRANCA *et al*., 2011; PASQUAUD *et al*., 2015). Also, low salinity values can mean a natural disturbance imposed in an estuary to the fish assemblage (ALBARET *et al*., 2004). During the sampling period the Pando waters were influenced by El Niño Southern

Tab. III. Significance levels (Mann-Whitney test) obtained from comparing fish community parameters between seasons of the year from May 2002 to June 2003 in the lower Pando sub-estuary, Uruguay (* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; ns, no significant difference).

| Parameter | Win-Spr | Win-Sum | Win-Aut | Spr-Sum | Spr-Aut | Sum-Aut |
|---|---|---|---|---|---|---|
| Species Richness | * | *** | ns | * | * | *** |
| Diversity | * | *** | ns | ns | * | *** |
| Biomass | ** | ** | ns | ns | *** | ** |
| Density | ns | ns | ns | ns | ns | ns |

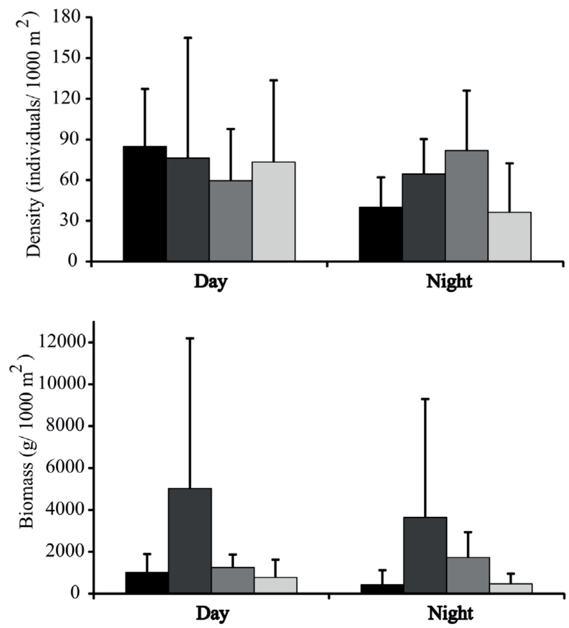


Fig. 4. Diel variability of the fish community in terms of density and biomass (mean value ± SD) in different seasons (from left to right: winter, spring, summer and autumn) in the lower Pando sub-estuary, Uruguay.

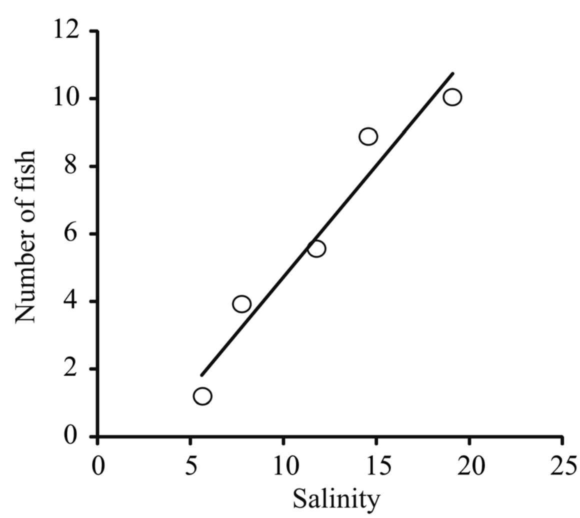


Fig. 5. Relationship between number of fish (mean fish number/1000 m²) of species *Odontesthes argentinensis* (Valenciennes, 1835) and salinity during summer in the lower Pando sub-estuary, Uruguay.

Tab. IV. Diel fish catch differences by season of the year caught by seine netting from May 2002 to June 2003 in the lower Pando sub-estuary, Uruguay (D, day; N, night). Data is expressed in mean density (N) (individuals/ 1000 m$^2$), mean biomass (g) (g/1000 m$^2$).

| Species | Winter | | | | Spring | | | | Summer | | | | Autumn | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D (N) | D (g) | N (N) | N (g) | D (N) | D (g) | N (N) | N (g) | D (N) | D (g) | N (N) | N (g) | D (N) | D (g) | N (N) | N (g) |
| *Micropogonias furnieri* | 77 | 436.5 | 35 | 140.8 | 43 | 1,632.5 | 52 | 960 | 44 | 607 | 68 | 854 | 70 | 539.1 | 31 | 254.7 |
| *Mugil liza* | | | < 1 | 28.4 | 29 | 349.3 | | | 2 | 116.2 | 3 | 528.3 | 1 | 8.6 | 5 | 212.5 |
| *Odontesthes argentinensis* | 2 | 16.8 | | | | | < 1 | 21.3 | 8 | 398.6 | 3 | 272.3 | 1 | 65.5 | | |
| *Parapimelodus valenciennis* | | | | | 1 | 6.4 | 9 | 117.6 | < 1 | 4.1 | | | | | | |
| *Paralichthys orbignyanus* | 2 | 546.6 | 1 | 242.7 | 1 | 119.6 | 2 | 696.1 | < 1 | 24.4 | | | 2 | 155.5 | < 1 | 3 |
| *Brevoortia aurea* | | | | | < 1 | 0.1 | < 1 | 0.3 | 2 | 7.4 | 6 | 23.2 | | | | |
| *Platanichthys platana* | 5 | 6.6 | 2 | 7.9 | | | | | | | | | | | | |
| *Genidens barbus* | | | | | 2 | 84.5 | < 1 | 5.9 | < 1 | 19.8 | 2 | 56.8 | | | | |
| *Lycengraulis grossidens* | < 1 | 2.1 | 2 | 12.9 | | | | | 2 | 36.4 | | | | | | |
| *Pomatomus saltatrix* | | | | | | | | | 1 | 14.9 | | | | | | |
| *Menticirrhus americanus* | | | | | | | | | < 1 | 2.8 | | | | | | |
| *Cyprinus carpio* | | | | | 1 | 3,233 | < 1 | 1,838 | | | | | | | | |
| *Luciopimelodus pati* | | | | | | | | | | | | | < 1 | 6.5 | | |

Oscillation (BIDEGAIN *et al*., 2005), which caused salinity values to decrease. Contrasting environmental conditions are expected to occur in the Pando compared to other estuaries, since the Pando sub-estuary is connected to an estuary (*i.e.*, RdlP) rather than to oceanic waters.

Fish assemblage of the study system was dominated by juvenile individuals, which is a common pattern found in estuaries around the world due to the ecological functions they provide, particularly for postlarvae and juveniles (POTTER & HYNDES, 1999; MCLUSKY & ELLIOTT, 2004). Another common feature observed was the dominance of a few fish species, mainly by the sciaenid *M. furnieri* in juvenile stages. *Micropogonias furnieri* is a widely distributed species along the western Atlantic coast, being the most abundant species in the estuarine RdlP (GARCÍA *et al*., 2010), where the species spawns (MACCHI *et al*., 1996). These findings denote the importance of the Pando sub-estuarine system as a nursery ground in the life cycle of fish species that use the RdlP as a spawning ground (ACUÑA *et al*., 2010).

On the other hand, largest individuals such as *P. orbignyanus* reached the maximum size of the species and were captured by the end of winter. Maximum size individuals of the species also occurred in an adjacent sub-estuarine system, Solís Grande, in the same period (Rodrigo Gurdek, pers. observ.). It is suggested a seasonal movement of the largest individuals of *P. orbignyanus* from the RdlP into the sub-estuaries, which could be related to the breeding season. On the other hand, the register of *C. carpio* in the lower sub-estuary denotes the extension of the distribution of this freshwater invasive species in the Pando system, possibly regulated by river discharge. As well, the same species was captured in the Solís Grande sub-estuary under minimum salinity values (around 0). Individuals of *C. carpio* were also registered in the Solís Grande in salinities values of around 20, suggesting a higher salinity tolerance range than expected (Rodrigo Gurdek, pers. observ.).

Environmental characteristics constitute a main factor in structuring fish associations (THIEL *et al*., 1995; WHITFIELD, 1999; SELLESLAGH & AMARA, 2008). In the Pando estuary, highest diversity and species richness values occurred when water temperature and salinity reached their maximums (*i.e.*, summer followed by spring). Additionally, fish composition was more similar during the cold seasons (*i.e.*, winter and autumn) than between summer and the rest of the seasons. Previous studies in the Pando estuary indicated the significant role of temperature and salinity in structuring the use of habitat by juveniles, suggesting a correlation between temperature and estuarine fish abundance, and between salinity and marine migrants abundance (ACUÑA *et al*., 2010). JAUREGUIZAR *et al*. (2004) suggested temperature as the abiotic parameter with the strongest influence on seasonal structure of fish assemblages in the RdlP. Seasonal and reproductive movements, and relative abundance of fish species within the fish assemblages in the RdlP populations could be the result of salinity and temperature fluctuations (JAUREGUIZAR *et al*., 2004). Similar results were found by HOEKSEMA & POTTER (2006) in a temperate Australian estuary, describing the maximum number and abundance of fish species during summer and the minimum during winter. These authors demonstrated that seasonal differences in fish composition were greater between opposite seasons, reinforcing the idea of considering both environmental variability and life cycles of fish species when addressing temporal variability in estuarine environments.

GREENWOOD *et al*. (2007) observed regular seasonal changes in the fish community structure in the lower portion of an estuary in the United States. Authors attributed those patterns to the biological cycle of transient species (*i.e.*, spawning and migration patterns). In the Pando sub-estuary, seasonal movements performed by the most numerous fish species (including reproduction pulses, since many individuals were juveniles in the first part of their life cycle), along with occurrence of rare species, are suggested as the main factors. On the other hand, the highest and constant occurrence over the year of the dominant species *M. furnieri* would explain the lack of differences in number of individuals between seasons.

The fish abundance, number of species and diversity did not differ substantially between day and night in any season, except for winter, with higher abundance values in the day. These results were consistent with those found by PESSANHA & ARAÚJO (2003) and RIBEIRO *et al*. (2006) in estuarine systems from Brazil and Portugal. PESSANHA & ARAÚJO (2003) stated that changes in assemblage structure were caused by shifts in abundance of particular species. In the present study, diel patterns in the fish community density and biomass were largely attributed to *M. furnieri* occurrence. CLARK *et al*. (2003) in a temperate sub-estuary from the United States found higher number of a related species, *Micropogonias undulatus* (Linnaeus, 1766), during the day. This variability was associated to feeding patterns of the species, which depended on the occurrence of its preys. In the Pando sub-estuary, an absence of a diel feeding cycle has been suggested for the species over the year, however diet analysis in winter determined that full stomachs were predominant during daytime (Ruben Canavese, pers. comm.).

In addition to *M. furnieri*, specific diel changes were registered for *M. liza*, *P. valenciennis* and *B. aurea* showing higher abundances at night, which could be related to feeding activity and predator avoidance (BECKER *et al*., 2011). At the diel scale, METHVEN *et al*. (2001) in a Newfoundland estuary observed both, species that showed no significant difference between day and night, and species caught primarily at night, suggesting an onshore movement of these species during night. Mugilids tended to be nocturnal in estuarine habitats of Brazil (PESSANHA & ARAÚJO, 2003; OLIVEIRA-NETO *et al*., 2004). Nocturnal habits of *P. valenciennis* could be attributed to its non-visual feeding mode (GELÓS *et al*., 2010), and like other Siluriformes, it could present a nocturnal behavior (FERNÁNDEZ *et al*., 2007). Salinity values were not registered during the night, however due to the freshwater ecology of the species, these could have been lower during the nocturnal period. Regarding the diel variability observed for *B. aurea*, results were consistent with those found by BARREIROS *et al*. (2005) in southern Brazil, who observed higher densities of a closely related species, *Brevoortia pectinata* (Jenyns, 1842), during nighttime. Also, the species *O. argentinensis* presented daily differences in the Pando estuary, which may be attributed to its preference towards higher salinity values (TOMBARI *et al*., 2005). GURDEK *et al*. (2011) showed that *Odontesthes* sp. decreased in number towards the evening-night time in the Solís Grande sub-estuary, considering the photoperiod as the main influencing factor.

Turbidity might have affected the fish assemblage daily patterns. Diel differences in the fish composition were less evident during winter and autumn (with the lowest salinity values), compared to summer and spring. A strong inverse relationship between turbidity and salinity values has been suggested in estuaries (CYRUS & BLABER, 1992). The same kind of relationship was observed in the Solís Grande sub-estuary (Rodrigo Gurdek, pers. observ.). In this sense, predation rates were reported to be highest in clear versus turbid waters because of visual cues, suggesting that of predation risk will be reduced in turbid aquatic ecosystems (UTNE-PALM, 2002; DE ROBERTIS *et al*., 2003).

This work appears to be one of the few attempts to describe temporal patterns of estuarine use and diel variability of fish communities in a sub-estuarine environment. Presented findings included temporal changes in the fish community regarding seasonal and diel scales. Evidence of an extensive use of the system by juveniles was provided, mainly for *M. furnieri*, suggesting the nursery use of fish estuarine populations. Results in the Pando sub-estuary were in accordance with those found in estuaries. Future studies in sub-estuaries should take into account the diel variability according to different size classes of fish within littoral zones, as well as include a more intense seasonal and diel sampling regime. Sampling in different weather conditions rather than El Niño is also recommended. Findings will help to better understand the species and community dynamics as well as the ecological use of species in the sub-estuaries.

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