Brazilian Journal of Biology®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Original Article

Influence of urbanization on size and biomass of a small-sized characid fish (*Diapoma alburnum*) in a subtropical river basin of southern Brazil

Influência da urbanização no tamanho e biomassa de um peixe caracídeo de pequeno porte (*Diapoma alburnum*) em uma bacia hidrográfica subtropical do sul do Brasil

Otávio Gutierrez e Silva[a]* , Taís de Fátima Ramos Guimarães[a] , Fernando Gertum Becker[a] , Sandra Maria Hartz[a]
[a]Universidade Federal do Rio Grande do Sul – UFRGS, Instituto de Biociências – IB, Departamento de Ecologia, Porto Alegre, RS, Brasil

Abstract
The coastal lagoons of the Tramandaí River basin are dynamic ecosystems characterized by high biodiversity. They provide important ecosystem services, such as water supply for human consumption, industry, agriculture, animal husbandry, leisure activities, tourism and fishing. Constant increases in the human population and the use and occupation of the land around the lagoons has brought growing demands for their resources, resulting in increased pressure that compromises these ecosystems. Understanding how biological populations respond to these anthropogenic pressures is essential. This study examined whether the degree of urbanization around 23 lagoons in the Tramandaí River basin influences the size and biomass of the characid fish species *Diapoma alburnum*. Specimens were collected between 2009 and 2012 using standardized drag nets. All specimens were measured for standard length to determine average length (size) per lagoon, while all fish collected per lagoon were weighed together to determine average biomass per lagoon by dividing by the number of specimens. Urbanization around the lagoons was measured using satellite images representing artificial nocturnal light as a proxy for urbanization. Nocturnal light intensity was measured within 1 km, 3 km, and 5 km buffers around each lagoon. The resulting urbanization index ranged 6 – 44% for the 5 km buffer, from 3 – 55% for the 3 km buffer and 1 – 65% for the 1 km buffer. Regression analyses showed a significant positive relationship with increasing urbanization around lagoons for *D. alburnum* average biomass in the 3 km and 5 km buffers and for *D. alburnum* average length in the 3 km buffer. Although urbanization around the lagoons is not fully established, the results indicate its impact on the size and biomass of *D. alburnum*.

Keywords: characidae, characiformes, coastal lagoons, Rio Grande do Sul.

Resumo
As lagoas costeiras da bacia do Rio Tramandaí são ecossistemas dinâmicos que apresentam uma alta biodiversidade e fornecem importantes serviços ecossistêmicos como água para consumo humano, para indústrias, agricultura, criação animal, áreas para lazer, turismo e pesca. Com o constante aumento populacional e o uso e ocupação do solo ao entorno das lagoas, crescem as demandas por seus recursos, pressionando e comprometendo cada vez mais esses ecossistemas. Desta forma, faz-se necessário compreender como as populações biológicas respondem a essas pressões antropogênicas. Esse estudo tem por objetivo avaliar se diferenças no grau de urbanização ao entorno das lagoas afetam a biomassa e comprimento de uma espécie de Characidae (*Diapoma alburnum*) presente em 23 lagoas da bacia do rio Tramandaí. Exemplares foram coletados entre os anos de 2009 e 2012, utilizando redes de arrasto. Para a coleta e análise de dados foi medido o comprimento padrão dos indivíduos, e para biomassa foi feita a pesagem de todos os peixes, dividido pelo número de indivíduos coletados por lagoa. Para mensurar a urbanização ao entorno das lagoas, utilizou-se imagem de satélite representando luz noturna como proxy de urbanização e extraiu-se a intensidade de luz noturna em buffers de 1 km, 3 km e 5 km ao redor de cada lagoa. O índice de urbanização variou entre 6% e 44% para o buffer de 5 km, de 3% a 55% para o buffer de 3 km e 1% a 65% para o buffer de 1 km ao redor dessas lagoas. Os resultados de análises de regressões mostraram que *D. alburnum* apresentou relação significativa positiva para biomassa nos buffers de 3 km e 5 km, e uma relação significativa positiva no comprimento médio para o buffer de 3 km, conforme aumenta a urbanização ao entorno das lagoas costeiras. Evidenciamos neste estudo, que apesar da urbanização ao entorno das lagoas ainda não está totalmente consolidada, é possível ver impactos em tamanho e biomassa em populações de *D. alburnum*, e por ser mais tolerante a fatores de pressão antrópica, a espécie pode ser usada como bioindicador.

Palavras-chave: characidae, characiformes, lagoas costeiras, Rio Grande do Sul.

*e-mail: otaagutierrez@gmail.com
Received: April 10, 2024 – Accepted: July 5, 2024

This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

1. Introduction

Coastal lagoons are generally shallow, lentic bodies of water distributed along the coasts of continents where their development is due to constant interaction with the marine and terrestrial environments. They are representative and valuable ecosystems for humanity, as they have high biodiversity and are used for fishing and leisure activities and as water supply for human and other animal consumption and agriculture (Esteves et al., 2008). Such lagoons are also destinations of human effluent discharges, which can compromise water quality (Merten and Minella, 2002).

The use and occupation of environments combined with climate change is placing freshwater ecosystems in a biodiversity crisis, where they are under greater pressure than any other ecosystem (Reid et al., 2019). Freshwater biodiversity is declining at an accelerated rate, two times faster than in terrestrial and marine environments (Tickner et al., 2020). In the face of these abrupt changes in biodiversity loss, it is important to conduct studies that pay attention to freshwater ecosystems and discuss measures that contribute to conservation and help tackle the freshwater biodiversity crisis (Albert et al., 2021; Ottoni et al., 2023).

As urbanization increases around lagoons, so does anthropogenic activity and the pollution load in these ecosystems. This, in turn, decreases microhabitat heterogeneity on the shore and alters the amount of aquatic macrophytes available (Bryan and Scarnecchia, 1992) and the amount and type of substrate (Jennings et al., 1996). The availability of these elements is fundamental for various organisms, especially fish, which use these resources for foraging, reproduction, and shelter. It is therefore important to monitor these environments in relation to land use and occupation to determine the effects of these factors.

The advance of urbanization can be measured using geographic information systems (GIS) (Weng, 2001), as they allow the visualization of land use, making them a highly relevant tool for biodiversity monitoring and conservation studies (Salem, 2003). Satellite images of artificial night light represent one useful tool of GIS because they are good indicators of human pressure, verifying human occupations at different spatial scales (Guetté et al., 2018) and working as a good proxy for urbanization, especially for population density (Mellander et al., 2015), being able to capture and measure artificial light emitted at night from urban settlements connected to the electricity grid. In addition, since more urbanized locations emit more nighttime light than less urbanized locations, the degree of nocturnal luminosity around water bodies can be used to quantify the degree of urbanization.

The human population of the north coast of the state of Rio Grande do Sul has been increasing constantly (Moura et al., 2015; Strohaecker et al., 2006). Linked to this is an increase in anthropogenic impacts on ecosystems, such as the emission of effluents which, due to their high load of organic compounds and nutrients, affect the quality of water bodies (Merten and Minella, 2002). Differences in the concentrations of limnological factors, such as phosphorus and nitrogen compounds, caused by anthropogenic activities can decrease species richness and contribute to accelerated growth of aquatic macrophytes and algae (Bicudo et al., 2017), which harms the water quality of the region's ecosystems.

Studies of freshwater fish assemblages in regions affected by urbanization show negative effects on the integrity of these ecosystems. The greater the degree of urbanization in the surroundings of aquatic ecosystems, the lower the fish species richness and the greater the predominance of generalist species that are tolerant of anthropogenic impacts (Reash and Berra, 1987; Cunico et al., 2006; Ferreira et al., 2021). Furthermore, fish species that are more tolerant of anthropogenic impacts can take advantage of a greater availability of food and/or unoccupied niches, which is reflected in increased size and weight (Morado et al., 2017).

Due to human population growth and the constant process of urbanization (Moura et al., 2015), which put increasing pressure on these ecosystems, combined with a scarcity of studies on how urbanization affects fish assemblages in aquatic coastal basins in southern Brazil, a better understanding of how organisms respond to these pressures is needed.

The present study aimed to assess whether the degree of urbanization around lagoons affects the size and biomass of fish by determining for each lagoon the average length (size) and average biomass of the characid species *Diapoma alburnum* (Hensel, 1870), a very frequent and abundant fish in the coastal lagoons of the Tramandaí River basin. We hypothesized that *D. alburnum* will have greater size and biomass in lagoons with higher urbanization since, being an abundant species, it is likely to be more resilient and better adapt to the effects.

2. Material and Methods

2.1. Study area

The Tramandaí River basin is located on the coastal plain of the northern coast of Rio Grande do Sul State, southern Brazil. It has a drainage area of approximately 2,978.11 km^2 (Castro, 2019a) and encompasses 41 coastal lagoons with varying degrees of connectedness (Guimarães et al., 2014) (see Figure 1). The lagoons are rich in fish (Bertaco et al., 2016) and aquatic macrophyte (Irgang and Gastal Junior, 1996) species. The climate of the region is classified as humid subtropical Cfa, characterized by hot summers and no dry season (Hasenack and Ferraro, 1989).

The lagoons are used for rice farming, effluent emission, public and industrial supply, fishing, and animal husbandry, with the greatest demand for water being in the months of November to February (Castro, 2019b). These activities drive the local economy and are essential for the people of the region (Dobrovolski and Laydner, 2000). Nonetheless, these activities harm the quality of water bodies, generating environmental and social damage. The amount of domestic effluent discharged into the lagoons is very high, with less than 18% of the urban settlements in the basin having adequate sewage treatment (Castro, 2019b).

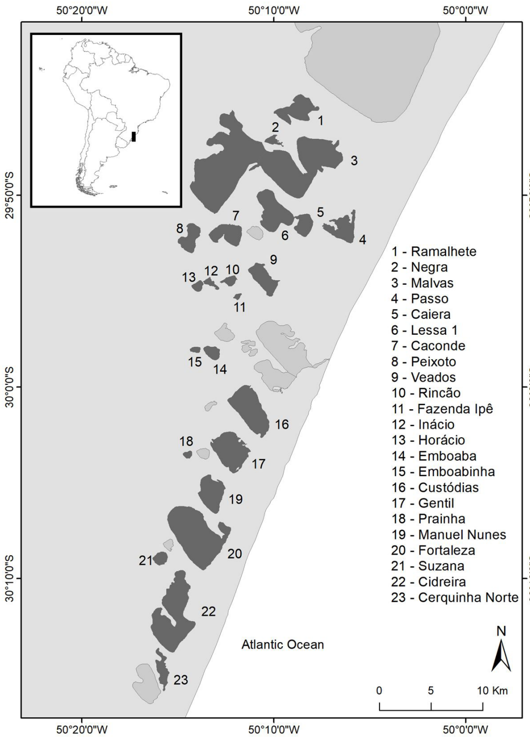


Figure 1. Map of lagoons of the Tramandaí River basin, southern Brazil. Showing the 23 lagoons studied highlighted in dark gray. These lagoons were analyzed for *Diapoma alburnum* biomass and length data.

2.2. Fish data

The fish used in this study were sampled in a standardized way during 22 expeditions conducted in 23 lagoons of the Tramandaí River basin between April 2009 and September 2012 (Figure 1). Specimens were sampled in each lagoon during both warm months (October to April) and cold months (May to September). Samplings were conducted using standardized drag nets (10 m x 1.5 m, 15 mm mesh) and a sampling effort of three trawls per lagoon.

The most representative species, both in frequency and number of specimens, of the samples was determined in the laboratory to be *Diapoma alburnum*. Length data were obtained using stratified random sampling because it is a reliable and sufficient method and does not require the measurement of all specimens in a sample (Froese, 2006). For this, fish of a sample were separated into size groups of small, medium, and large, from which 10 specimens each were randomly selected. The 30 specimens were then measured for standard length (tip of snout to the last caudal peduncle) using a digital caliper. If a sample contained less than 30 specimens, all specimens were measured. The specimen standard lengths were then averaged to obtain the average specimen length in each lagoon. They were four scientific lots (UFRGS29781, UFRGS29782, UFRGS29783 e UFRGS29784) from 4 different lagoons deposited in the collection of the Department of Zoology at Universidade Federal do Rio Grande do Sul (UFRGS), because the species is very abundant in the Tramandaí River basin (Malabarba et al., 2013) and has many specimens in the collection.

Biomass data were obtained by weighing (g) all specimens in a sample on a digital scale. The sum of the biomass for each lagoon was then divided by the number of specimens weighed from the respective lagoon to obtain the average specimens biomass per lagoon.

2.3. Land cover data

A satellite image containing the annual average of artificial nocturnal illumination for the year 2012 (National Oceanic and Atmospheric Administration www.noaa.gov) was used to measure the degree of urbanization around each lagoon and to obtain an indirect measure of population density and land use and occupation by urbanization. The image was superimposed on a map of land cover and lagoons in the study area obtained from Hasenack and Weber (2010) continuous vector map of the state of Rio Grande do Sul (scale of 1:50,000), which shows the state's entire water network. This overlay was performed using the ArcGis 10.4 program (Esri, 2014), which was also used to create coverage areas/ buffers of 1 km, 3 km and 5 km around each lagoon.

Nocturnal light was calculated for each lagoon by dividing the sum of the light pixel values in a buffer by the number of pixels in the same buffer. The image used discounts the values of clouds, fires and lunar illumination in the calculation of the annual average and shows variation in the intensity of artificial nocturnal light, ranging from 0 to 63 for each pixel with 63 being the maximum value of artificial nocturnal light that the satellite captures and 0 being the absence of light. These values were then standardized with the pixel value of 63 being considered 100% urbanization. The obtained light intensity values determine indirect values for urbanization around each lagoon. This method was also used by Guimarães et al. (2021) to relate fish beta diversity to the proportion of artificial nocturnal light, as it is possible to have an accurate response to human presence both in rural areas connected to the electricity grid and in large urban centers around the lagoons in order to measure how much each lagoon is impacted.

2.4. Data analysis

Average length and weight data fish per lagoon were related to luminosity values using linear models and R software version 4.0.2 (R Core Team, 2023). Length and weight values for *Diapoma alburnum* were obtained for each lagoon, combining all the data collected during the sampling period. Average specimen length, average specimen biomass and nocturnal light data for the 1 km buffer were converted to the natural logarithmic scale, while the nocturnal light data for the 5 km and 3 km buffers were transformed into log(x+1). Relationships with $P<0.05$ were considered significant.

3. Results

Data were collected for 7758 specimens of *Diapoma alburnum* (see Table S1). Percentage of urban coverage varied among buffers of each lagoon and among lagoons, ranging from 6% to 44% for 5 km buffers, 4% to 55% for 3 km buffers, and 1% to 65% for 1 km buffers (see Figure 2).

Linear models of average length and average biomass of *Diapoma alburnum* per lagoon and nocturnal light intensity in buffers around lagoons showed significant positive relationships for average biomass and nocturnal light intensity for the 3 km buffer (P = 0.008) and average biomass and nocturnal light intensity for the 5 km buffer (P = 0.024; Figure 3B and C). They also showed a significant positive relationship for average length and nocturnal light intensity for the 3 km buffer (Figure 3E).

4. Discussion

The present study used artificial nocturnal light emission around lagoons as a proxy measure for degree of urbanization. Although measuring water quality variables at the sampling points at the same time that fish were sampled would have been the ideal method for determining the degree of eutrophication suffered by the lagoons as a result of urbanization (and by the fish), it was not possible due to logistical problems.

Nonetheless, several studies have already investigated the water quality of the coastal lagoons of the Tramandaí River basin and have highlighted the impacts of urbanization on these bodies (Pedrozo and Rocha, 2007; Bohnenberger et al., 2018; Castro and Rocha, 2016; Cabezudo et al., 2020, among others). The present study performed Spearman correlation tests between nocturnal light data and the limnological water data of Bohnenberger et al. (2018) and found significant correlations between pH and the 1 km, 3 km and 5 km buffers (P = 0.01, 0.01 and 0.02 respectively). Thus, greater urbanization may be altering the landscape around lagoons, creating connections with saline waters (Guimarães et al., 2022), and consequently affecting pH.

The highest nocturnal light intensities were for Custódias lagoon, which is closer to the municipality of Tramandaí, and Peixoto lagoon, which is closer to Osório municipality. Osório has a long history of discharging its untreated domestic effluent directly into Marcelino lagoon (Pedrozo and Rocha 2007; Castro, 2019a), which is very close to Peixoto lagoon, so the organisms in Peixoto lagoon could be impacted by the anthropogenic effects more severely. The lowest nocturnal light intensities were for Manuel Nunes and Ramalhete lagoons.

Studies have shown that species that are more tolerant to anthropogenic impacts around water bodies may have an advantage over less tolerant species (Reash and Berra, 1987; Cunico et al., 2006; Morado et al., 2017; Ferreira et al., 2021). Since *Diapoma alburnum* was the most frequent and abundant species in the lagoon samples of the present study, it could be presumed to be more tolerant to anthropogenic effects, which would favor it over less frequent and abundant species. Nevertheless, the level of urbanization around the lagoons does not seem severe enough for this advantage to be stronger in *D. alburnum*.

The results indicated that the size and biomass of *Diapoma alburnum* increased as urbanization around the coastal lagoons increased for the 3 and 5 km buffers, but not for the 1 km buffer. The significant result for average length in these buffers may be due to the specific physical

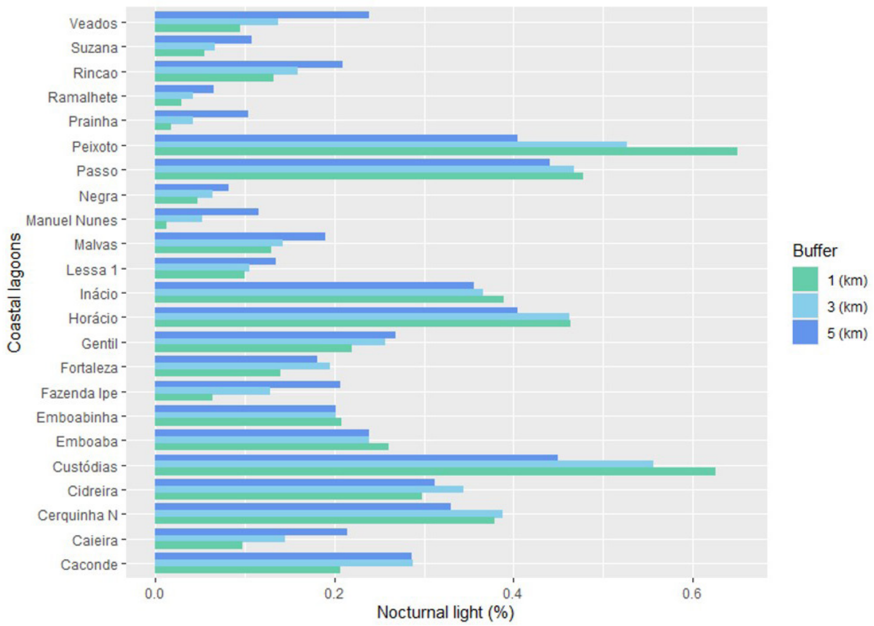
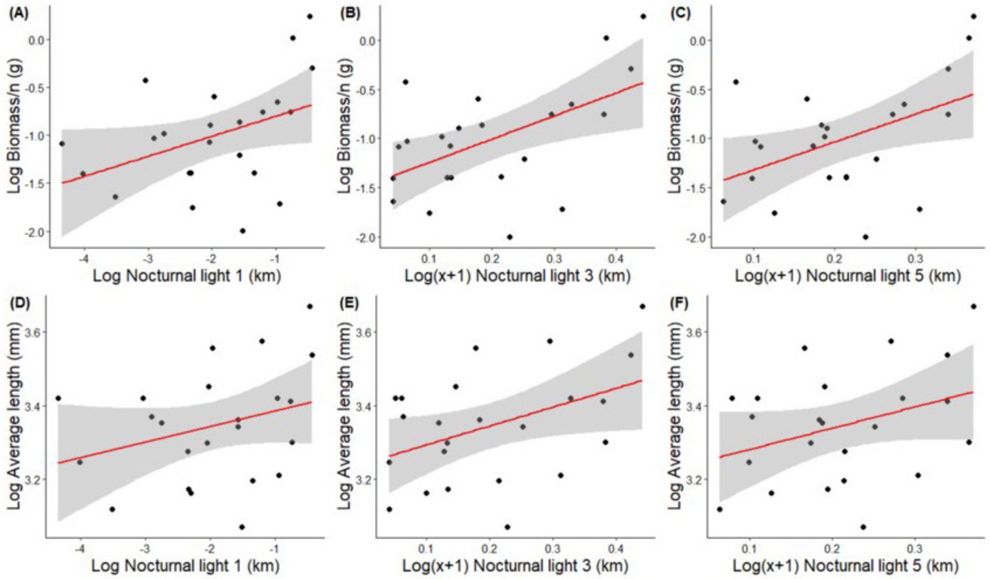


Figure 2. Average annual night light intensity in 2012 for buffers of 1 km, 3 km, and 5 km around each of the 23 studied coastal lagoons in the Tramandaí River basin, southern Brazil. Nocturnal light intensity is used as a proxy for urbanization, with higher values indicating greater urbanization.



	R^2	F-statistic	P-value
Biomass/n			
(A)	0.165	4.158	0.054
(B)	0.286	8.424	**0.008**
(C)	0.218	5.866	**0.024**
Average length			
(D)	0.0907	2.096	0.162
(E)	0.1806	4.631	**0.043**
(F)	0.120	2.865	0.105

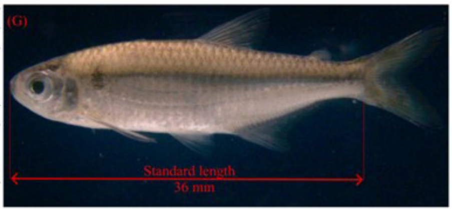


Figure 3. Linear models showing the relationship between (A) average biomass of *Diapoma alburnum* and nocturnal light intensity in the 1 km buffer, (B) average biomass and nocturnal light intensity in the 3 km buffer, (C) average biomass and nocturnal light intensity in the 5 km buffer, (D) average length of *Diapoma alburnum* and nocturnal light intensity in the 1 km buffer, (E) average length and nocturnal light intensity in the 3 km buffer, and (F) average length and nocturnal light intensity in the 5 km buffer. Significant relationships are indicated, showing that biomass and average length increase with urbanization as measured by nocturnal light intensity. (G) Photo of a specimen of *Diapoma alburnum* (UFRGS 29783), with standard length, by Taís Guimarães.

characteristics of each location and to the arrangement of urbanization in the landscape. The results for average biomass showed an increase as urbanization increased for the 3 km and 5 km buffers, probably due to the increase in organic matter released into these water bodies from increased surrounding anthropogenic activity. It makes sense that primary production biomass, such as macrophytes and phytoplankton, would increase in lagoons with more anthropogenic activities nearby due to increased pollutant load and connections with other water bodies (with more nutrients). As a consequence, the biomass of higher trophic groups would increase, ultimately leading to an increase in fish biomass. *Diapoma alburnum* is found in water bodies near the coastal region of the state of Rio Grande do Sul and Uruguay (Malabarba et al., 2013). It is considered an insectivorous and zooplanktivorous species, primarily feeding on Amphipoda, Copepoda, Collembola, and Diptera (Vilella et al., 2002). However, *D. alburnum* exhibits dietary plasticity (Rodrigues and Hartz, 2001), feeding on other available food resources such as macrophytes and Cladocera (Rodrigues and Hartz, 2001; Hartz, 1997). Being a typical species in the littoral zone of coastal lagoons, it can search for food items throughout the water column, foraging on invertebrates associated with the benthos as well as those found near the roots and leaves of macrophytes, such as *Eichornia* spp., which are close to the surface (Vilella et al., 2002). Nevertheless, the impacts of habitat fragmentation are not limited to areas with higher levels of artificial nocturnal light; anthropogenic disturbance can occur in regions where there is no emission of nocturnal light (Guetté et al., 2018). Therefore, even though *D. alburnum* did not show any significant relationships with the 1 km buffer, it is likely that the limited urbanization in these regions may still be affecting biodiversity in some way.

Pressures on water bodies are severe (Reid et al., 2019, Tickner et al., 2020), generating serious concern to discuss measures to help conserve these ecosystems (Albert et al., 2021; Ottoni et al., 2023). The positive trend of increased size and biomass with urbanization found for *Diapoma alburnum* suggests it is less sensitive and more tolerant to organic pollution, and even experiences benefit for length and weight. Thus, *D. alburnum* has the potential to be a good bioindicator of trophic conditions for coastal lagoons, so it could help promote the conservation of lagoons with future work.

5. Conclusion

Although anthropogenic impacts generated by urbanization are known to affect entire ecosystems, the present study showed that urbanization can have a clear influence on the size and biomass of fish species living in the coastal lagoons. *Diapoma alburnum* had a larger size for the 3 km buffer and greater biomass for all three buffers of lagoons with greater urban impact. This finding may be positive for the conservation of these ecosystems. Additionally, the 3 km buffer showed a better response of size and biomass to urbanization, making more suitable for environmental impact assessments of coastal lagoons.

Acknowledgements

We would like to Lucas de Fries, Camila Both, Ng Haig They and Felipe Ottoni for their comments and suggestions; to Erik Wild for the english text; to CNPq for the undergraduate scholarship. SMH received a CNPq research grant (305549/2018-9).

References

ALBERT, J.S., DESTOUNI, G., DUKE-SYLVESTER, S.M., MAGURRAN, A.E., OBERDORFF, T., REIS, R.E., WINEMILLER, K.O. and RIPPLE, W.J., 2021. Scientists' warning to humanity on the freshwater biodiversity crisis. *Ambio*, vol. 50, no. 1, pp. 85-94. http://doi.org/10.1007/s13280-020-01318-8 PMid:32040746.

BERTACO, V., FERRER, J., CARVALHO, F.R. and MALABARBA, L.R., 2016. Inventory of the freshwater fishes from a densely collected area in South America: a case study of the current knowledge of Neotropical fish diversity. *Zootaxa*, vol. 4138, no. 3, pp. 401-440. http://doi.org/10.11646/zootaxa.4138.3.1 PMid:27470773.

BICUDO, C.E.M., TUNDISI, J.G. and SCHEUENSTUHL, M.C.B., 2017. *Waters of Brazil strategic analysis*. 1st ed. Cham: Springer. 191 p. http://doi.org/10.1007/978-3-319-41372-3.

BOHNENBERGER, J.E., SCHNECK, F., CROSSETTI, L.O., LIMA, M.S. and MOTTA-MARQUES, D.D., 2018. Taxonomic and functional nestedness patterns of phytoplankton communities among coastal shallow lakes in southern Brazil. *Journal of Plankton Research*, vol. 40, no. 5, pp. 555-567. http://doi.org/10.1093/plankt/fby032.

BRYAN, M.D. and SCARNECCHIA, D.L., 1992. Species richness, composition, and abundance of fish larvae and juveniles inhabiting natural and developed shorelines of a glacial Iowa lake. *Environmental Biology of Fishes*, vol. 35, no. 4, pp. 329-341. http://doi.org/10.1007/BF00004984.

CABEZUDO, M.M., RIBEIRO, K.F., SCHNECK, F., WERNER, V.R., LIMA, M.S., BOHNENBERGER, J.E. and CROSSETTI, L.O., 2020. Ecological factors shaping cyanobacterial assemblages in a coastal lake system. *Hydrobiologia*, vol. 847, no. 10, pp. 2225-2239. http://doi.org/10.1007/s10750-020-04250-w.

CASTRO, D. and ROCHA, C.M., 2016. *Qualidade das águas na bacia hidrográfica do rio Tramandaí*. Porto Alegre: Via Sapiens. 172 p.

CASTRO, D., 2019a. *Ciclo das águas na bacia do Rio Tramandaí*. Porto Alegre: Via Sapiens. A bacia do Rio Tramandaí, pp. 20-45.

CASTRO, D., 2019b. *Ciclo das águas na bacia do Rio Tramandaí*. Porto Alegre: Via Sapiens. Os usos da água na bacia, pp. 102-110.

CUNICO, A.M., AGOSTINHO, A.A. and LATINI, J.D., 2006. Influência da urbanização sobre as assembléias de peixes em três córregos de Maringá, Paraná. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 23, no. 4, pp. 1101-1110. http://doi.org/10.1590/S0101-81752006000400018.

DOBROVOLSKI, R.L. and LAYDNER, C.P., 2000. *Diretrizes para o desenvolvimento dos Municípios do Litoral Norte*. Porto Alegre: FEPAM, 90 p.

ESRI, 2014. *ArcGis Desktop v.10.3*. Redlands: ESRI.

ESTEVES, F.A., CALIMAN, A., SANTANGELO, J.M., GUARIENTO, R.D., FARJALLA, V.F. and BOZELLI, R.L., 2008. Neotropical coastal lagoons: an appraisal of their biodiversity, functioning, threats and conservation management. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 68, no. 4, pp. 967-637. http://doi.org/10.1590/S1519-69842008000500006. PMid:19197469.

FERREIRA, F.S., SOLÓRZANO, J.C.J. and SÚAREZ, Y.R., 2021. Influence of urbanization on stream fish assemblages in three microbasins in the Upper Paraná River Basin. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 83, pp.1-10. http://doi.org/10.1590/1519-6984.247384. PMid:34190764.

FROESE, R., 2006. Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. *Journal of Applied Ichthyology*, vol. 22, no. 4, pp. 241-253. http://doi.org/10.1111/j.1439-0426.2006.00805.x.

GUETTÉ, A., GODET, L., JUIGNER, M. and ROBIN, M., 2018. Worldwide increase in artificial light at night around protected areas and within biodiversity hotspots. *Biological Conservation*, vol. 223, pp. 97-103. http://doi.org/10.1016/j.biocon.2018.04.018.

GUIMARÃES, T.D.F.R., HARTZ, S.M. and BECKER, F.G., 2014. Lake connectivity and fish species richness in southern Brazilian coastal lakes. *Hydrobiologia*, vol. 740, no. 1, pp. 207-217. http://doi.org/10.1007/s10750-014-1954-x.

GUIMARÃES, T.D.F.R., PETRY, A.C., BECKER, F.G. and HARTZ, S.M., 2022. Relations between land use and fish species richness in Neotropical coastal lagoons. *Hydrobiologia*, vol. 849, no. 17-18, pp. 4087-4099. http://doi.org/10.1007/s10750-022-04845-5.

GUIMARÃES, T.D.F.R., PETRY, A.C., HARTZ, S.M. and BECKER, F.G., 2021. Influence of past and current factors on the beta diversity of coastal lagoon fish communities in South America. *Journal of Biogeography*, vol. 48, no. 3, pp. 639-649. http://doi.org/10.1111/jbi.14029.

HARTZ, M.S., 1997. *Alimentação e estrutura da comunidade de peixes da lagoa Caconde, litoral norte do estado do RS, Brasil*. São Carlos: Universidade Federal de São Carlos, 288 p. Tese de Doutorado em Ecologia e Recursos Naturais.

HASENACK, H. and FERRARO, L., 1989. Considerações sobre o clima da região de Tramandaí, RS. *Pesquisas Em Geociências*, vol. 22, no. 22, pp. 53-70. http://doi.org/10.22456/1807-9806.21456.

HASENACK, H. and WEBER, E., 2010. *Base cartográfica vetorial contínua do Rio Grande do Sul - escala 1:50.000*. Porto Alegre: UFRGS Centro de Ecologia.

IRGANG, B.E. and GASTAL JUNIOR, C.V.S., 1996. *Plantas aquáticas da planície costeira do Rio Grande do Sul*. Porto Alegre: Ed. dos Autores, 290 p.

JENNINGS, M., JOHNSON, K. and STAGGS, M. 1996. *Shoreline protection study: a report to the Wisconsin state legislature*. Madison: Wisconsin Department of Natural Resources, 137 p.

MALABARBA, L.R., NETO, P.C., BERTACO, V.A., CARVALHO, T.P., SANTOS, J.F. and ARITOLI, L.G.S., 2013. *Guia de Identificação dos Peixes da Bacia do Rio Tramandaí*. Porto Alegre: Via Sapiens, 140 p.

MELLANDER, C., LOBO, J., STOLARICK, K. and MATHESON, Z., 2015. Night-Time Light Data: A Good Proxy Measure for Economic Activity? *PLoS One*, vol. 10, no. 10, pp.1-18. http://doi.org/10.1371/journal.pone.0139779 PMid:26496428.

MERTEN, G.H. and MINELLA, J.P., 2002. *Qualidade da água em bacias hidrográficas rurais: um desafio atual para a sobrevivência futura. Agroecologia e Desenvolvimento e Desenvolvimento Rural Sustentável*, vol. 3, no. 4, pp. 33-38.

MORADO, C., ARAÚJO, F. and GOMES, I., 2017. The use of biomarkers for assessing effects of pollutant stress on fish species from a tropical river in Southeastern Brazil. *Acta Scientiarum. Biological Sciences*, vol. 39, no. 4, pp. 431-439. http://doi.org/10.4025/actascibiolsci.v39i4.34293.

MOURA, N.S.V., MORAN, E.F., STROHAECKER, T.M. and KUNST, A.V., 2015. A urbanização na zona costeira: processos locais e regionais e as transformações ambientais - o caso do Litoral Norte do estado do Rio Grande do Sul, Brasil. *Ciência e Natura*, vol. 37, no. 3, pp. 594-612. http://doi.org/10.5902/2179460X18503.

OTTONI, F.P., SOUTH, J., AZEVEDO-SANTOS, V.M., HENSCHEL, E. and DE BRAGANÇA, P.H.N., 2023. Editorial: Freshwater biodiversity crisis: Multidisciplinary approaches as tools for conservation. *Frontiers in Environmental Science*, vol. 11, pp.1-4. http://doi.org/10.3389/fenvs.2023.1155608.

PEDROZO, C.D.S. and ROCHA, O., 2007. Environmental quality evaluation of lakes in the Rio Grande do Sul coastal plain. *Brazilian Archives of Biology and Technology*, vol. 50, no. 4, pp. 673-685. http://doi.org/10.1590/S1516-89132007000400013.

R CORE TEAM, 2023 [viewed 14 March 2024]. *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing. Available from: https://www.R-project.org/.

REASH, R.J. and BERRA, T.M., 1987. Comparison of fish communities in a clean-water stream and an adjacent polluted stream. *American Midland Naturalist*, vol. 118, no. 2, pp. 301-322. http://doi.org/10.2307/2425788.

REID, A.J., CARLSON, A.K., CREED, I.F., ELIASON, E.J., GELL, P.A., JOHNSON, P.T.J., KIDD, K.A., MACCORMACK, T.J., OLDEN, J.D., ORMEROD, S.J., SMOL, J.P., TAYLOR, W.W., TOCKNER, K., VERMAIRE, J.C., DUDGEON, D. and COOKE, S.J., 2019. Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews of the Cambridge Philosophical Society*, vol. 94, no. 3, pp. 849-873. http://doi.org/10.1111/brv.12480 PMid:30467930.

RODRIGUES, G.G. and HARTZ, M.S., 2001. Food dynamics of fish and the interaction with macroinvertebrates from a shallow lake in southern Brazil. *Journal SIL Proceedings, 1922-2010 Internationale Vereinigung für Theoretische und Angewandte Limnologie: Verhandlungen*, vol. 27, no. 6, pp. 3309-3314. https://doi.org/10.1080/03680770.1998.11902439.

SALEM, B.B., 2003. Application of GIS to biodiversity monitoring. *Journal of arid Environmensts*, vol. 54, no. 1, pp. 91-114. http://doi.org/10.1006/jare.2001.0887.

STROHAECKER, T.M., FUJIMOTO, N.S.V.M., FERREIRA, A.H. and KUNST, A.V., 2006. Caracterização do uso e ocupação do solo dos municípios do litoral norte do estado do Rio Grande do Sul. *Desenvolvimento e Meio Ambiente*, vol. 13, pp. 75-98. http://doi.org/10.5380/dma.v13i0.4624.

TICKNER, D., OPPERMAN, J.J., ABELL, R., ACREMAN, M., ARTHINGTON, A.H., BUNN, S.E., COOKE, S.J., DALTON, J., DARWALL, W., EDWARDS, G., HARRISON, I., HUGHES, K., JONES, T., LECLÈRE, D., LYNCH, A.J., LEONARD, P., MCCLAIN, M.E., MURUVEN, D., OLDEN, J.D., ORMEROD, S.J., ROBINSON, J., THARME, R.E., THIEME, M., TOCKNER, K., WRIGHT, M. and YOUNG, L., 2020. Bending the curve of global freshwater biodiversity loss: An Emergency Recovery Plan. *Bioscience*, vol. 70, no. 4, pp. 330-342. http://doi.org/10.1093/biosci/biaa002 PMid:32284631.

VILELLA, F.S., BECKER, F.G. and HARTZ, S.M., 2002. Diet of Astyanax species (Teleostei, Characidae) in an Atlantic forest river in Southern Brazil. *Brazilian Archives of Biology and Technology*, vol. 45, no. 2, pp. 223-232. http://doi.org/10.1590/S1516-89132002000200015.

WENG, Q., 2001. A Remote Sensing? GIS Evaluation of Urban Expansion and Its Impact on Surface Temperature in the Zhujiang Delta, China. *International Journal of Remote Sensing*, vol. 22, no. 3, pp. 1999-2014. http://doi.org/10.1080/713860788.

Supplementary Material

Supplementary material accompanies this paper.

Table S1 - Values of the total number of specimens for each logoon of the Tramandaí River basin, southern Brazil

This material is available as part of the online article from https://doi.org/10.1590/1519-6984.285436