Biotemas, 35 (2): 1-15, junho de 2022
ISSNe 2175-7925

http://dx.doi.org/10.5007/2175-7925.2021.e84470

Comparing beach seine and gillnet sampling methods in fish assemblages from Southern Brazilian shallow coastal lakes

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Submetido em 20/10/2021
Aceito para publicação em 13/05/2022

Resumo

Comparando os métodos de amostragem de rede de arrasto de praia e rede de emalhe em assembleias de peixes de lagos costeiros rasos do sul do Brasil. O objetivo do estudo foi comparar a riqueza, composição, dominância e tamanho dos peixes capturados com rede de arrasto de praia e redes de emalhe nas assembleias de peixes de lagos rasos costeiros do sistema do rio Tramandaí, sul do Brasil. Amostragens foram realizadas na zona litoral dos lagos Itapeva, Quadros, Malvas, Fortaleza, Rondinha e Barros. Análises de similaridade e dominância mostraram diferenças em riqueza, composição e abundância numérica entre os métodos. Onze espécies foram dominantes, mas apenas uma (*Psalidodon* aff. *fasciatus*) foi dominante em ambos os métodos. A rede de arrasto de praia capturou indivíduos com comprimento total entre 20 e 80 mm, enquanto as redes de emalhe indivíduos acima de 100 mm. Uma assembleia de maior riqueza em espécies e dominada por pequenos peixes foi encontrada nas margens. Ao contrário, uma assembleia de menor riqueza e peixes de maior tamanho foi encontrada nas áreas internas da zona litoral. Os métodos são complementares na avaliação da riqueza de espécies, visto que cada um tem sua seletividade. Concluímos que para programas de monitoramento de longo prazo a rede de arrasto é uma alternativa melhor, visto a confiabilidade dos dados, as facilidades no manuseio e o baixo custo de operação.

Palavras-chave: Desenho amostral; Padrões de dominância; Rio Tramandaí; Riqueza de espécies; Seletividade

Abstract

The aim of this study was to compare littoral zone fish assemblage richness, composition, dominance and size patterns between beach seine and gillnets sampling methods in coastal lakes at Tramandaí river, Southern Brazil. Monthly samples were taken in the littoral zones of six coastal shallow lakes (Itapeva, Quadros, Malvas, Fortaleza, Rondinha and Barros). Dominance and similarity analyses showed differences in species composition, numerical abundance and biomass among the sampling methods. Eleven species were dominant, but only one

(*Psalidodon* aff. *fasciatus*) was dominant to both sampling methods. Beach seines sampled individuals with a total length ranging from 20 to 80 mm, while gillnets sampled individuals with a total length over 100 mm. An assemblage with high species richness, dominated by small fishes was found in the lake's margins. In contrast, an assemblage with lower species richness comprised of larger fishes was found in inner areas. The methods are complementary in accessing species richness. Beach seine is a better alternative for monitoring programs as it provides reliable data at lower cost. These results may be useful in the sample design of future research or in the monitoring of ichthyofauna.

Key words: Dominance patterns; Sampling design; Selectivity; Species richness; Tramandaí river

Introduction

A frequent issue in sampling design is the choice for the better sampling method suitable to each approach of fish assemblages or target species (RADINGER et al., 2019; FRENCH et al., 2021; MERZ et al., 2021). Fish assemblages sampling methods may be biased by size range, mobility and fish behavior (e.g., solitary or schooling and littoral or pelagic species) (ERŐS et al., 2009; OLIN et al., 2009; PRCHALOVÁ et al., 2009). All sampling methods which estimate abundance, distribution and length are biased, which influences results, and any conclusions must take it into account (MENEZES et al., 2012; ACHLEITNER et al., 2014; FRENCH et al., 2021). Furthermore, the distribution and abundance of fishes in lakes may be influenced by a range of abiotic (e.g., lake area, depth, temperature and habitat heterogeneity) and biotic (e.g., competition, predator avoidance and trophic state) factors and these may be variable among species in different spatial and temporal scales (GRAY et al., 2009; MENEZES et al., 2012). Different sampling methods may be biased when the environment-species relationship is depicted. Relative importance of different environmental variables in explaining abundance and biomass of fishes may differ between methods and species (MENEZES et al., 2012).

Gillnets are the preferred method for lake monitoring in Europe (DECELIERE-VERGÈS et al., 2009; MENEZES et al., 2012). Although widely used as a research tool for sampling fish populations, they are very selective and tend to underestimate species with small appendages or hard structures, those exhibiting a more sedentary lifestyle, and the smallest individuals of a given species (HUBERT et al., 2012; MENEZES et al., 2012). In this sense the reliability of data obtained from passive methods can be improved with the addition of data obtained through active methods (OLIN et al., 2009; EGGLETON et al., 2010). The knowledge of the sampling method, the required effort and its selectivity for the target species, improves catch efficiency, saving time and money (HUBERT et al., 2012). Also, there is consensus that a fish species inventory from a given environment must be made through the use of multiple sampling gears, once every method has its selectivity and may miss species that other method catch (MENEZES et al., 2012).

Fish are essential biological component in lakes, playing a major role in the food chain (SCHINDLER; SCHEUERELL, 2002; VANDER ZANDEN; VADEBONCOEUR, 2002). In this sense, knowledge of functional patterns of fish assemblages may help the development of appropriate policies to prevent eutrophication or support restoration projects (JEPPESEN et al., 2005; RAO et al., 2015). Fish represent an important component of the biodiversity of shallow coastal lakes in subtropical regions of South America, which have a high diversity (KRUK et al., 2009; TEIXEIRA DE MELLO et al., 2009; GUIMARÃES et al., 2014). Many shallow lakes are experiencing adverse effects from climate change, eutrophication and pollution, which can lead to biodiversity loss (QUINTELA et al., 2019; REID et al., 2019; ALBERT, et al., 2021).

Little attention has been given to differences among sampling methods in the subtropical region when compared to the temperate region. Distinct patterns of composition, richness, dominance, and size structure of fishes captured with beach seine and gillnets has been verified in Southern Brazilian lakes at Patos Lagoon system. A more diverse assemblage with smaller fishes was found in shallow margins and the opposite in the inner littoral zone (GARCIA et al., 2006; ARTIOLI et al., 2009). Also, in Patos Lagoon system, the fishes captured at Mirim lake by two different beach seines showed low faunal similarity and numerical abundance (CENI; VIEIRA, 2013).

Around seventy freshwater fish species are recorded in the coastal lakes of the Tramandaí river system (MALABARBA et al., 2013), which corresponds to 68% of the species described for the whole basin (102 species according to BERTACO et al., 2016). In the Tramandaí river system fish studies usually aim the biology of one (or a few) species, or the composition and dominance patterns of a single lake (revised in MALABARBA et al., 2013). There is no data on freshwater fish composition, size and dominance patterns, that takes into account the differences among sampling methods from the coastal plain lakes of the Tramandaí river basin. In a paper, the fish species richness of 31 shallow costal lakes in the Tramandaí river basin were studied, focusing on the connectivity of the lakes and their functional fish communities (GUIMARÃES et al., 2014). According to the results, 55 fish species were captured through gillnets, including 36 freshwater fish species. Connectivity was the most important factor in predicting the richness of estuarine fish species, but not in predicting the richness of freshwater species (GUIMARÃES et al., 2014). In the estuarine zone of the Tramandaí river system and the adjacent seacoast, long-term spatiotemporal variation of juvenile fish assemblage was studied through use of standardized beach seine. Species richness and composition were different between these zones (VIEIRA et al., 2019).

In the present work our objectives are: (1) compare littoral zone fish assemblage richness, composition, dominance and size patterns between beach seine and gillnets, (2) assess the similarity of littoral zone fish assemblage structure as depicted by the two sampling methods. We applied multivariate statistical analyses to highlight these differences and provide information to guide fish management and increase efficiency in future research.

Materials and Methods

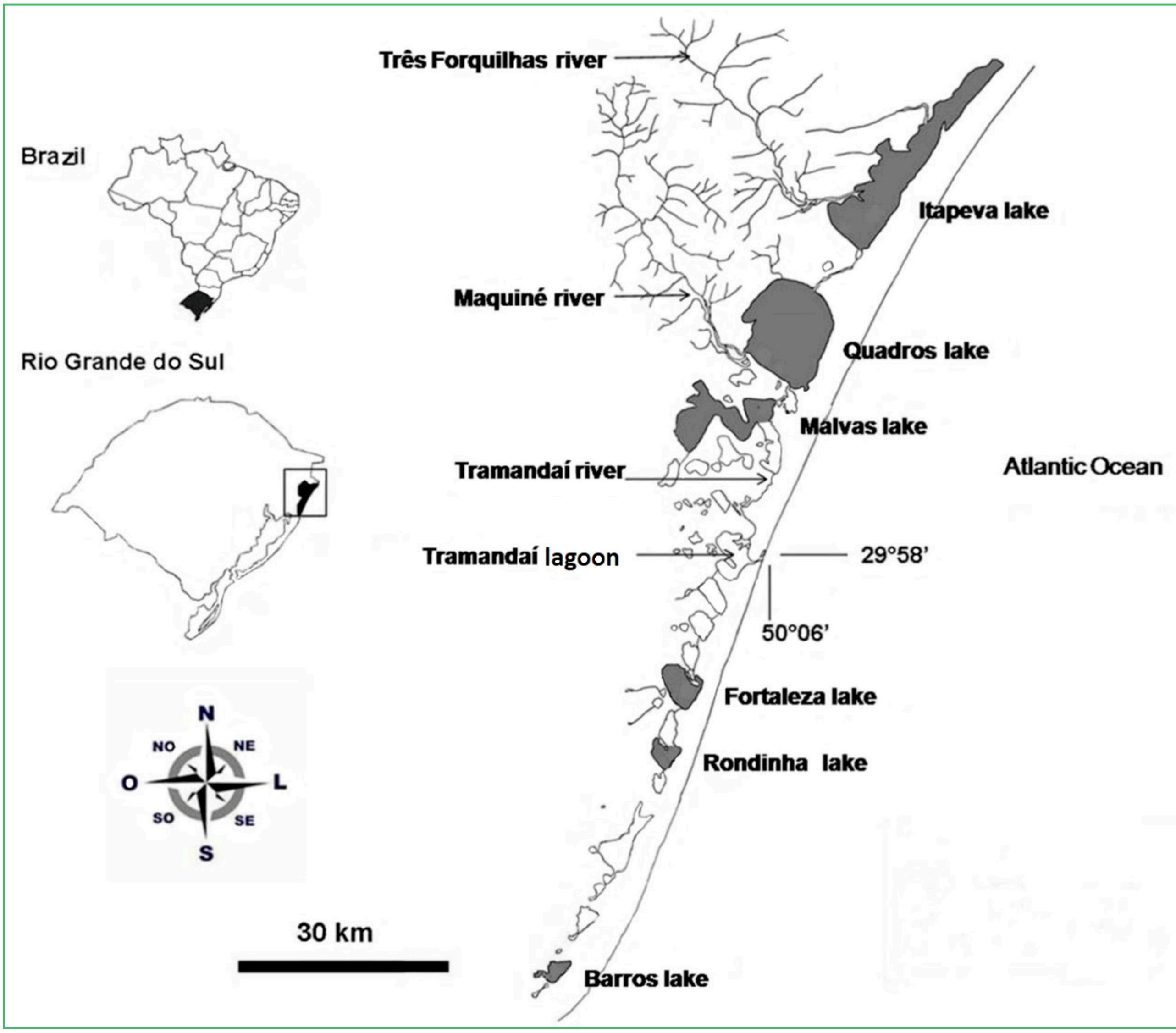
Study area

The Tramandaí river basin is located on the northern coastal plain of Rio Grande do Sul (29°17’ to 30°18’S and 49°44’ to 50°24’W) (Figure 1), encompassing a total area of 2,540 km^2 and containing approximately 450 km^2 of surface water (LOPARDO, 2002). The Tramandaí river basin is formed by three sub-basins: the Tramandaí river system, Maquiné river and Três Forquilhas river. The Maquiné and Três Forquilhas rivers flow from the slopes of the Serra Geral Mountain formation at the Quadros and Itapeva lakes on the coastal plain. These lakes are, in turn, interconnected with a series of other lakes until they reach the Atlantic Ocean via the mouth of the Tramandaí lagoon. This lower portion of the Tramandaí river basin has a total area of about 1,800 km^2, encompassing several isolated and/or interconnected shallow coastal lakes whose origin dates back to ancient sea level oscillations and wind action (TOMAZELLI; VILLWOCK, 2005). This area is named Tramandaí river system. This area is subdivided into two parts: the northern part, encompassing the lakes located north of the Tramandaí lagoon, and the southern part, composed of the lakes that lie south of the Tramandaí lagoon. No lakes in the system had a salinity record of over 30 ppt (WÜRDIG, 1987). Freshwaters and slightly brackish waters can be found in the same lake at different times, depending on the recent wind direction and sea level. Only the Tramandaí lagoon contains saline waters (salinity < 30 ppt).

These environments usually present sandy or muddy bottom, with submerged, emergent, and floating aquatic plants close to its margins. The terrestrial vegetation includes swamp forests from Itapeva State Park, in the municipality of Torres, to the West margins of Barros Lake, in the municipality of Mostardas. Fish fauna includes small sized species associated to swamps, small lakes and streams, and larger, commercially important species, in deeper areas of lakes and channels (MALABARBA et al., 2013).

The studied lakes are: Itapeva (95.16 km^2), Quadros (119 km^2) and Malvas (55.08 km^2) in the northern part;

FIGURE 1: Map showing the geographical position of the Tramandaí river basin and the coastal lakes sampled (in grey).



and Fortaleza (18.54 km^2), Rondinha (8.92 km^2) and Barros (9.2 km^2) in the southern part. The lakes in the northern part are larger (> 20 km^2) and have low (< 3 m) to intermediary depths (3 to 5 m). The lakes in the southern part are smaller (< 10 km^2) or intermediary (10 to 20 km^2) in size and have lower depths (< 3 m). The Barros Lake has different characteristics from all the others as it is part of a series of asymmetric lakes, which tend to be deeper (> 5 m), clearer and have a low trophic level (SCHWARZBOLD; SCHÄFER, 1984; SCHÄFER, 1988; SCHÄFER et al., 2009). All lakes have emergent macrophytes along their margins, with *Schoenoplectus californicus* (Reed) being the most common species (PRADO, 2009).

The annual average temperature is 19°C and the annual precipitation ranges from 1,121 to 1,654 mm. In spring and summer prevail winds from the east and northeast while winds from the south and southwest prevail in autumn and winter (FERRARO; HASENACK, 2009).

Sampling design

Monthly field trips were conducted from November 2008 to April 2010, totaling eleven sampling sites in each lake's littoral zone. Two sampling methods were used: 1) A set of nine gillnets (nylon monofilament; 1.5 m high; 30 m long) were placed in inner areas of the littoral zone in the afternoon. The nine different mesh sizes were: 15, 20, 25, 30, 35, 40, 50, 60, 70 mm between adjacent knots, totaling 270 m. The nets were placed close to emergent reed vegetation banks around 30 m from the margin, at depths of up to 3 m. Nets were removed the next day. Sampling effort comprised an average of 18 h/month in each lake and a total sampling area of 405 m^2. 2) Beach seine (10 m long; 2 m high; 5 mm mesh size) were used in marginal areas. These areas are comprised of shallow sandy beaches with reed stands along their edges, with a depth of up to 1 m at the edges of the reed banks. Sampling effort in each site (except for the Malvas lake in which a beach seine was not used) consisted of five hauls, each used perpendicular to the lake margin and covering an area of about 100 m^2, totaling 500 m^2. Fish were anesthetized with clove oil, fixed in a 10% formalin solution and then preserved in 70% ethanol.

Data analysis

Fish were identified, counted, measured (each individual's total length T_L, to the nearest 0.01 mm) and weighed (total weight T_W, to the nearest 0.001 g of all fish of each species in each sampling method) in the laboratory. Fish species names and habitat use were updated according to Eschmeyer and Fricke (2021). Representative specimens were cataloged in the fish collection of the Zoology Department, at the Federal University of Rio Grande do Sul, Brazil. Juveniles whose species could not be determined were named with the epithet "spp." and were not considered in the overall species count in each method.

Each sampling unit was defined as one beach seine haul (100 m^2) and gillnet mesh (45 m^2) in each lake (n = 433; n = 844, respectively). The number of individuals was transformed into catch per unit effort (CPUE). Each species CPUE is defined as the number of specimens by square meter (ind/m^2) for beach seine, and number of specimens by square meter by hour (ind/m^2/h) for gillnets. Then, numerical percentage (NP) was calculated based on each species' CPUE using the formula: NP = (CPUEi/∑CPUEi)*100, where CPUEi is the catch per unit effort of species i, and the frequency of occurrence (FO) using the formula: FO = (n/N)*100, where n is the number of samples in which each species was recorded and N the total number of samples. Then the FO of each species was transformed in relative frequency of occurrence (FO%) using the formula: FO% = (FOi/∑FOi)*100, where FOi is the frequency of occurrence of species i.

In order to assess the dominance patterns of fish species captured by each sampling gear, the values of numerical percentage (NP) and the relative frequency of occurrence (FO%) for each species and sampling method was compared to each sampling method average (100/S where S = the total number of species captured in each sampling gear) and species were classified as follows: abundant and frequent (NP ≥ the average NP and FO% ≥ the average FO%); only abundant (NP ≥ the average NP and FO% < the average FO%); only frequent (NP < the average NP and FO% ≥ the average FO%); present (NP < the average NP and FO% < the average FO%). Abundant and frequent species were then considered to be dominant (ARTIOLI et al., 2009).

In order to assess the similarity of fish species collected by each sampling gear, data matrices were made and each sampling unit was defined by survey, lake and gear (n = 122). The Malvas and Barros lakes were not included. This was made to equalize the number of samples between methods. A one-way ANOSIM (with 9999 permutations) was applied to identify differences between species (variables) presence/absence values, numerical abundance (CPUEn) and biomass (CPUEb) between the sampling methods (factors). To highlight the main species responsible for the formation of each outlined group a similarity percentage (SIMPER) was applied. An exploratory ordination analysis of "non-metric multidimensional scaling" (nMDS) was performed to evaluate the samples distribution in a three-dimensional plane. The attributes were calculated through the Bray-Curtis coefficient. These analyses were performed using the software PAST version 4.08 (HAMMER et al., 2001). The CPUE data was transformed using the expression x' = log (x+1).

For the size structure analysis, 50 total length (T_L) classes (each class representing a 10 mm range) were defined. The variation in numerical abundance of the dominant species by T_L classes was based on the catch per unit effort by total length CPUE-T_L (VIEIRA, 2006) and transformed into CPUE-T_L percentage (%). The CPUE-T_L (%) of each species in each T_L class was estimated as the ratio between the sum of the ponderation factor (PF = N/n; where N is the number of individuals in a sample and n is the number of measured individuals) of each species in each T_L class, and the total sum PF for all length classes (PF-T_L/∑FP * 100).

Results

A total of 45,856 specimens were sampled, belonging to eight orders, 21 families and 55 species (49 freshwater fish species, two freshwater/brackish species, sardine *Platanichthys platana* and anchovy *Lycengraulis grossidens* and four brackish/marine species, mullet - *Mugil liza*, sea catfish – *Genidens barbus*, *Genidens genidens* and sea bass – *Centropomus parallelus*) (ESCHMEYER; FRICKE, 2021). A total biomass of 548.2 kg was recorded. Characiformes represented 80% of the total number of individuals, presenting the highest species richness in both sampling methods (47.7% for beach seine and 36% for gillnets). They represented 87% of the total number of individuals and 77% of the total biomass of beach seine samples. Samples taken with beach seines contained 44 species (80%), while 39 species (71%) were caught with the gillnets. A total of 28 species (51%) were common to both methods, while 16 species were exclusive to the beach seine method and 12 were exclusive to the gillnets. The fish species caught exclusively by beach seines were: *Diapoma alburnum*, *Jenynsia lineata*, *Cheirodon ibicuhiensis*, *Cheirodon interruptus*, *Hyphessobrycon igneus*, *Ctenogobius shufeldti*, *Characidium zebra*, *Astyanax* sp. 1, *Homodiaetus anisitsi*, *Pseudocorynopoma doriae*, *Phalloceros caudimaculatus*, *Cynopoecilus fulgens*, *Cichlasoma portalegrense*, *Aphyocharax anisitsi*, *Microglanis cottoides*, *Brachyhypopomus draco*, and unidentified *Oligosarcus* spp. and *Rineloricaria* spp. juveniles. Those caught exclusively by gillnets were: *Odontesthes ledae*, *Trachelyopterus lucenai*, *Odontesthes bonariensis*, *Acestrorhynchus pantaneiro*, *Odontesthes piquava*, *Hoplosternum littorale*, *Hypostomus commersoni*, *Cyphocharax saladensis*, *Gymnotus carapo*, *Genidens genidens*, *Genidens barbus* and *Centropomus parallelus*.

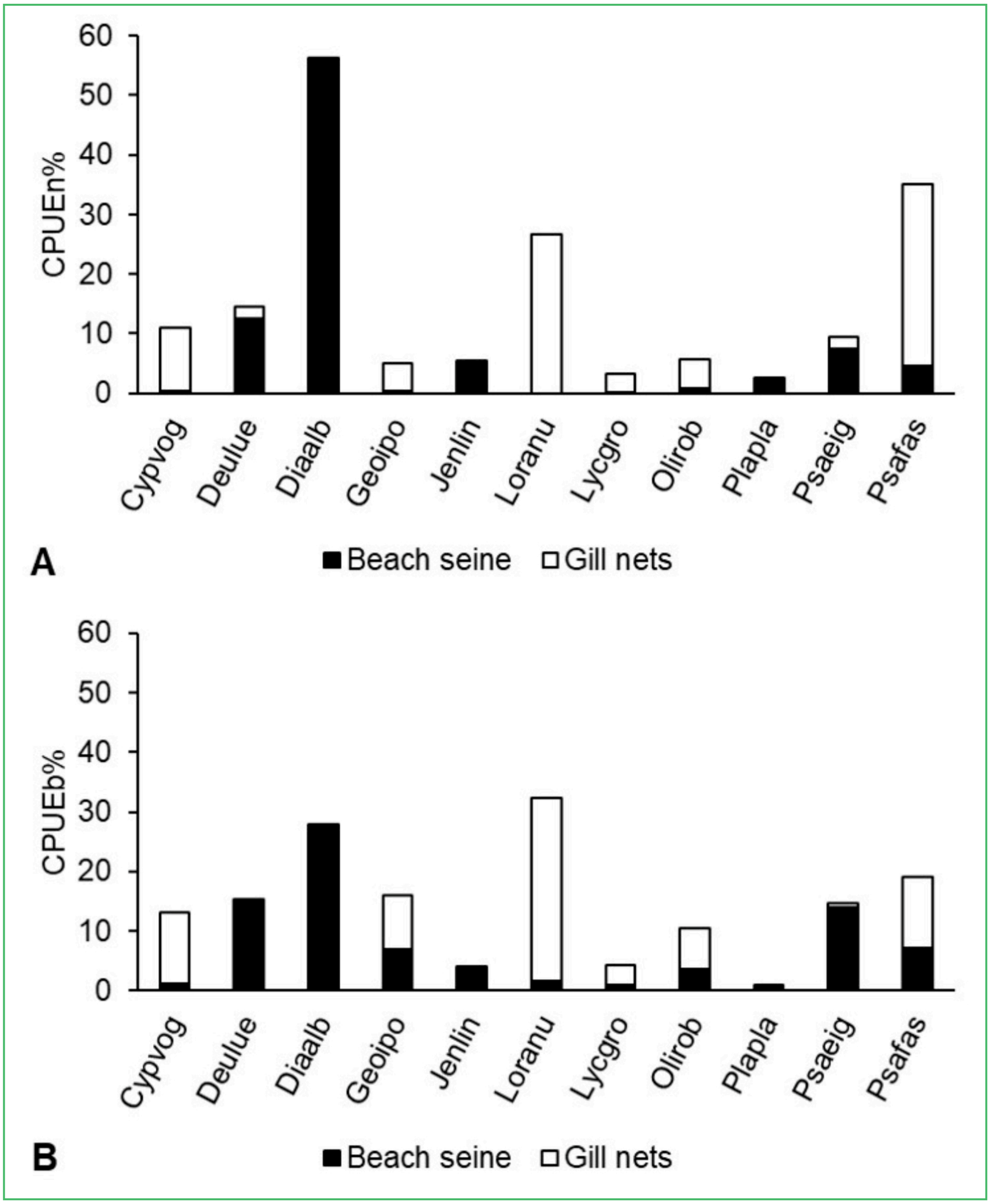
The ANOSIM showed significant differences in species composition (R = 0.720; $p < 0.05$), while the SIMPER showed a dissimilarity of 75.51% among the samples. The characids *D. alburnum*, *Deuterodon luetkenii* and *Psalidodon eigenmanniorum*, the one-sided livebearer *J. lineata*, the loricariid catfish *Loricariichthys anus*, the curimatid *Cyphocharax voga*, the cichlid *Geophagus iporangensis*, the trahira *Hoplias malabaricus* and silversides *Odonthestes* spp., contributed to 41.2% of the dissimilarity between methods.

Dominance patterns revealed that 11 species were dominant (%CPUE> average %CPUE) and frequent (%FO> average %FO) across all lakes and sampling methods. The dominant species in the beach seine samples were the characids *D. alburnum*, *D. luetkenii*, *P. eigenmanniorum* and *Psalidodon* aff. *fasciatus*, the one-sided livebearer *J. lineata* and the sardine *Platanichthys platana*. Together these species made up 88.6% of the total abundance (CPUEn) and 69% of the total biomass (CPUEb) captured by beach seines.

The dominant species in the gillnet samples were the characids *Oligosarcus robustus* and *P.* aff. *fasciatus* (the only species found in common with the beach seine samples), the loricariid catfish *L. anus*, the curimatid *C. voga*, the cichlid *G. iporangensis* and the Atlantic sabretooth anchovy *Lycengraulis grossidens*. These species made up 80.5% of the total abundance (CPUEn) and 74% of the total biomass (CPUEb) of the gillnet samples. The biomass data shares the same general pattern as the total abundance data (described above), but three species (the trahira *Hoplias malabaricus* in gillnets, and *O. robustus* and *G. iporangensis* in beach seines) were only dominant when weight was considered (Figure 2; Table 1).

Comparing species abundance, there was a difference in the species abundance between the two methods of capture (R = 0.881; $p < 0.05$) (Figure 3). However, when considering the species biomass, this difference was not found (R = 0.001; $p = 0.331$). In turn,

FIGURE 2: Dominant species percent abundance based on (A) capture per unit effort in number of individuals (CPUEn) and (B) biomass (CPUEb) of the samples from beach seine and gillnets. Species code see Table 1. Fish collected in the Tramandaí basin Southern Brazil, between 2008 and 2010.



SIMPER showed an average sample dissimilarity of 96.12% in CPUEn and 78.51% in CPUEb. The characids *D. alburnum*, *D. luetkenii*, *P. eigenmanniorum* and the one-sided livebearer *J. lineata* contributed to 61.9% of the CPUEn dissimilarity among sampling methods (Table 2). Overall, a larger quantity of individuals of these species were recorded by the beach seine method. In biomass (CPUEb) the loricariid catfish *L. anus*, the characids *D. alburnum*, *D. luetkenii*, *P.* aff. *fasciatus* and *P. eigenmanniorum*, the trahira *H. malabaricus*, the curimatid *C. voga* and the cichlid *G. iporangensis* contributed to 58.9% of the dissimilarity between the sampling methods (Table 3). Here, the larger size of the captured individuals in the gillnets contributed to a higher biomass for the gillnets.

There were differences in the average size of fishes sampled using beach seines compared to those sampled using gillnets. Beach seine samples consisted of fish between 10 to 70 mm (Figure 4A), while gillnet samples consisted of fish that were larger than 100 mm (Figure 4B). The average TL of dominant species in beach seine samples ranged from 30.8 to 51.8 mm, whereas the average of dominant species in gillnet samples ranged from 120.7 to 235.5 mm. The only common dominant species in both sampling methods was the characid *P.* aff. *fasciatus*. In comparison with the previous results, characid *P.* aff. *fasciatus* individuals from beach seine samples had a lower average size (~51 mm) than those from gillnets (120.7 mm). A similar trend was observed for other species recorded in both gillnets and beach seine samples: their average size was lower in beach seine samples and higher in gillnets (Table 1).

TABLE 1: Comparative list of numerical capture per unit effort (sum of the CPUEn), structure size (minimum, maximum total length (Min. Max.) and total length mean (Mean)) and the relative importance (based on the CPUEn% and FO%), where: (black) abundant and frequent, (brown) only abundant, (dark grey) only frequent, (light grey) present species and (colorless) absent species, caught with distinct methods. Total number of individuals of each species (N) and endemic species (*). The fishes identified with “spp.” were not counted for species richness. Fish collected in the Tramandaí basin Southern Brazil, between 2008 and 2010.

Species	Code	Beach seine				Gill nets				N
		CPUEn	Total Length (mm)			CPUEn	Total Length (mm)			
			Mean±SD	Min.	Max.		Mean±SD	Min.	Max.	
Diapoma alburnum (Hensel 1870)	*Diaalb*	**199.55**	38.2±12	13	147					19,955
Psalidodon aff. *fasciatus* (Cuvier 1819)	*Psafas*	**15.90**	50.9±14	9	133	**3.744**	121.2±31	14	115	4,845
Deuterodon luetkenii (Boulenger 1887)	*Deulue*	**44.59**	43.6±12	17	378	0.239	87.7±9	70	137	4,708
Psalidodon eigenmanniorum (Cope 1894)	*Psaeig*	**26.71**	51.8±12	20	117	0.246	102.9±18	67	171	2,846
Loricariichthys anus (Valenciennes 1835)	*Loranu*	0.13	189.4±106	36	330	**3.251**	235.5±46	102	400	2,688
Jenynsia lineata (Jenyns 1842)	*Jenlin*	**19.09**	36.1±11	15	92					1,909
Cyphocharax voga (Hensel 1870)	*Cypvog*	1.16	61.1±19	25	185	**1.294**	152.7±33	92	341	1,173
Platanichthys platana (Regan 1917)	*Plapla*	**8.40**	30.8±12	16	75	0.028	97.4±3	92	105	864
Oligosarcus robustus Menezes 1969	*Olirob*	2.76	81.2±23	37	205	**0.608**	189.8±40	115	353	829
Odontesthes spp.	*Odospp*	6.04	40.5±22	13	136	0.049	156.4±15	139	216	651
Geophagus iporangensis Haseman 1911	*Geoipo*	1.37	83.2±66	13	667	**0.552**	161.6±33	80	266	585
Astyanax lacustris (Lütken 1875)	*Astlac*	3.72	63.4±19	37	130	0.109	113.0±18	78	146	458
Cheirodon ibicuhiensis Eigenmann 1915	*Cheibi*	4.36	39.3±7	18	60					436
Cheirodon interruptus (Jenyns 1842)	*Cheint*	4.02	38.0±9	19	137					402
Oligosarcus jenynsii (Günther 1864)	*Olijen*	2.11	59.9±21	17	188	0.209	176.8±38	111	319	396
Lycengraulis grossidens (Spix & Agassiz 1829)	*Lycgro*	0.69	79.4±60	22	425	**0.379**	191.1±37	84	288	371
Odontesthes ledae Malabarba & Dyer 2002*	*Odoled*					**0.357**	175.8±22	140	280	358
Corydoras paleatus (Jenyns 1842)	*Corpal*	3.07	36.4±8	22	70	0.011	75.1±5	66	80	315
Rineloricaria quadrensis Reis 1983*	*Rinqua*	0.83	78.5±30	27	201	0.106	144.6±8	129	165	178
Hoplias malabaricus (Bloch 1794)	*Hopmal*	0.12	104.4±74	26	255	0.197	283.0±62	126	515	176
Hyphessobrycon igneus Miquelarena, Menni, López & Casciotta 1980	*Hypign*	1.70	30.0±9	15	55					170
Ctenogobius shufeldti (Jordan & Eigenmann 1887)	*Cteshu*	1.56	35.1±7	20	56					156
Trachelyopterus lucenai Bertoletti, da Silva & Pereira 1995	*Traluc*					0.162	168.0±19	106	256	137
Crenicichla lepidota Heckel 1840	*Crelep*	1.23	38.2±18	28	147	0.016	182.2±41	116	250	136

Species	Code	Beach seine				Gill nets				N
		CPUEn	Total Length (mm)			CPUEn	Total Length (mm)			
			Mean±SD	Min.	Max.		Mean±SD	Min.	Max.	
Hisonotus leucofrenatus (Miranda Ribeiro 1908)	*Hisleu*	1.29	35.6±10	17	63	0.001	60.0±0	60	60	130
Gymnogeophagus gymnogenys (Hensel 1870)	*Gymgym*	0.47	85.4±47	6	143	0.104	121.5±20	83	187	127
Gymnogeophagus lacustris Reis & Malabarba 1988*	*Gymlac*	0.16	113.4±53	32	190	0.107	130.4±25	77	180	99
Charax stenopterus (Cope 1894)	*Chaste*	0.10	62.9±16	23	80	0.080	113.3±10	91	134	85
Oligosarcus spp.	*Olispp*	0.85	66.4±18	27	114					85
Crenicichla maculata Kullander & Lucena 2006	*Cremac*	0.05	113.0±47	37	160	0.091	189.2±43	135	320	80
Characidium zebra Eigenmann 1909	*Chazeb*	0.64	41.5±8	30	61					64
Pimelodella australis Eigenmann 1917	*Pimaus*	0.32	93.1±19	67	135	0.033	126.7±15	107	186	58
Odontesthes bonariensis (Valenciennes 1835)	*Odobon*					0.063	185.6±37	139	363	51
*Astyanax sp.*1	*Astsp1*	0.41	30.2±7	20	61					41
Homodiaetus anisitsi Eigenmann & Ward 1907	*Homani*	0.38	31.0±6	17	43					38
Pseudocorynopoma doriae Perugia 1891	*Psedor*	0.37	48.5±8	40	78					37
Astyanax sp.	*Astssp*	0.03	55.7±9	44	65	0.044	138.3±10	109	156	35
Acestrorhynchus pantaneiro Menezes 1992	*Acepan*					0.018	198.7±23	155	231	19
Australoheros acaroides (Hensel 1870)	*Ausaca*	0.11	59.4±39	14	135	0.007	120.8±24	77	156	17
Odontesthes piquava Malabarba & Dyer 2002*	*Odopiq*					0.019	152.3±8	138	165	16
Hoplosternum littorale (Hancock 1828)	*Hoplit*					0.018	188.8±31	97	215	15
Genidens genidens (Cuvier 1829)	*Gengen*					0.016	281.2±29	225	340	13
Gymnogeophagus spp.	*Gymspp*	0.11	31.5±7	16	40	0.002	166.0±3	163	169	13
Phalloceros caudimaculatus (Hensel 1868)	*Phacau*	0.13	27.7±6	17	37					13
Centropomus parallelus Poey 1860	*Cenpar*					0.015	320.2±68	206	445	12
Cynopoecilus fulgens Costa 2002	*Cynful*	0.12	20.7±3	17	27					12
Hyphessobrycon togoi Miquelarena & López 2006	*Hyptog*	0.09	62.9±17	33	86	0.003	86.7±2	84	90	12
Rhamdia quelen (Quoy & Gaimard 1824)	*Rhaque*	0.02	109.0±26	83	135	0.010	330.1±67	259	505	11
Rineloricaria spp.	*Rinspp*	0.07	35.6±6	27	45					7
Cichlasoma portalegrense (Hensel 1870)	*Cicpor*	0.05	98.6±40	20	128					5
Aphyocharax anisitsi Eigenmann & Kennedy 1903	*Aphani*	0.03	40.7±0	40	41					3
Gymnogeophagus rhabdotus (Hensel 1870)	*Gymrha*	0.02	47.5±26	22	73	0.001	149.0±0	149	149	3
Hypostomus commersoni Valenciennes 1836	*Hypcom*					0.004	505.0±115	385	660	3
Mugil liza Valenciennes 1836	*Mugliz*	0.02	157.0±123	34	280	0.001	283.0±0	283	283	3
Microglanis cottoides (Boulenger 1891)	*Miccot*	0.02	40.0±3	37	43					2
Genidens barbus (Lacepède 1803)	*Genbar*					0.003	305.0±3	302	308	2
Brachyhypopomus draco Giora, Malabarba & Crampton 2008	*Bradra*	0.01	80.0±0	80	80					1
Cyphocharax saladensis (Meinken 1933)	*Cypsal*					0.001	105.0±0	105	105	1
Gymnotus carapo Linnaeus 1758	*Gymcar*					0.001	270.0±0	270	270	1
Total of individuals		35498				10358				45856
Total of species		44				39				55

FIGURE 3: Two-dimensional nMDS ordination plots showing the relationships among assemblages of fish sampled with gillnets and beach seine for presence/absence data (A) and CPUEn data (B). Species code see Table 1. Fish collected in the Tramandaí basin Southern Brazil, between 2008 and 2010.

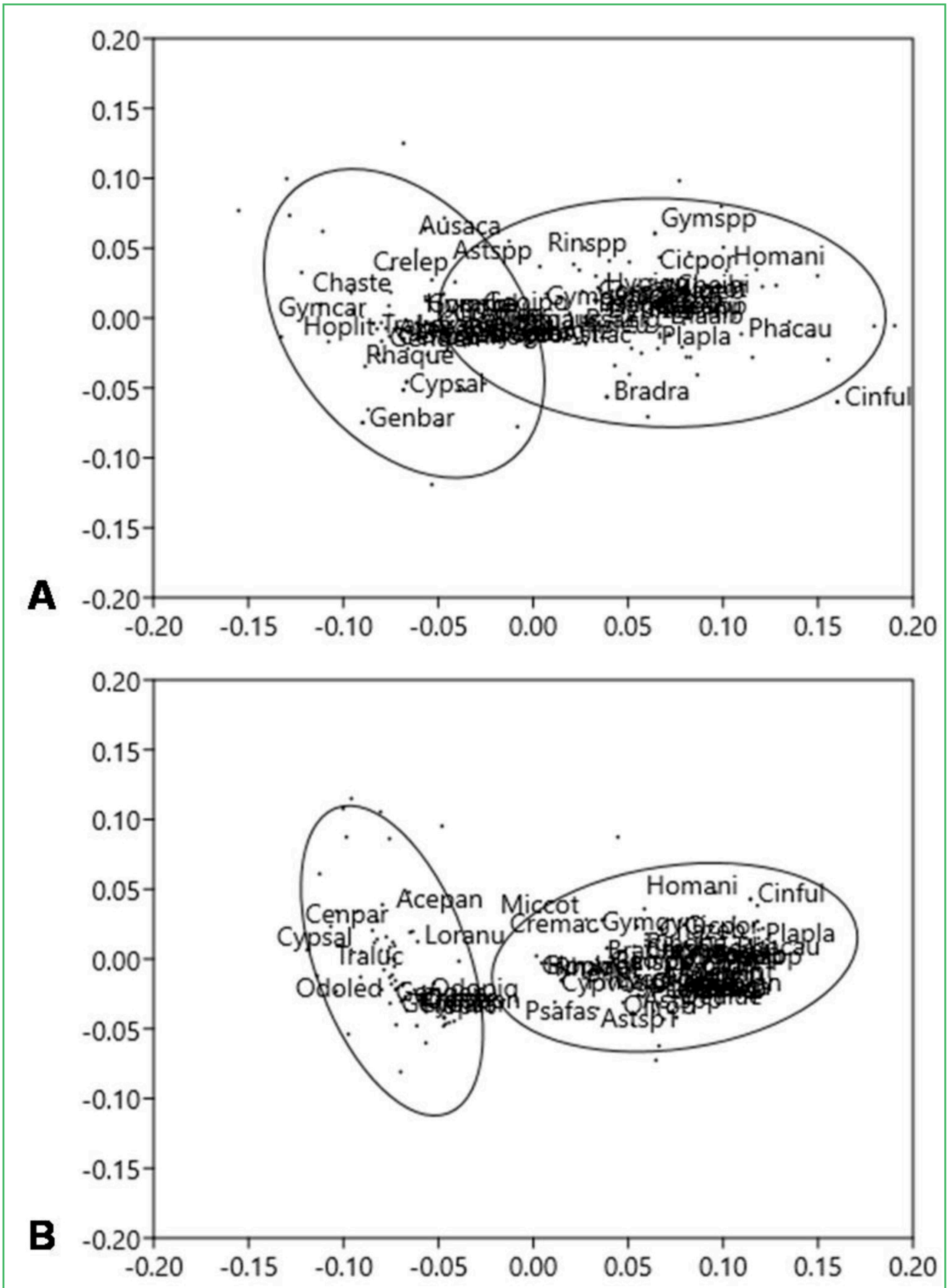


TABLE 2: SIMPER analysis showing the percent contribution of the major species for the dissimilarity in CPUEn between samples (factor = net). Fish collected in the Tramandaí basin Southern Brazil, between 2008 and 2010.

Species	**Average abundance**[a]		**Average dissimilarity**[b]	**Contribution**[c] **(%)**
	Beach Seine	**Gill Nets**		
Diapoma alburnum	11.09	0.00	31.04 ± 2.71	33.47
Deuterodon luetkenii	2.48	0.01	10.66 ± 1.60	11.49
Psalidodon eigenmanniorum	1.48	0.01	8.15 ± 1.56	8.79
Jenynsia lineata	1.06	0.00	7.53 ± 1.86	8.12
Psalidodon aff. *fasciatus*	0.88	0.21	4.26 ± 1.13	4.59
Odontesthes spp.	0.33	0.00	4.11 ± 1.25	4.43
Platanichthys platana	0.47	0.00	3.70 ± 0.71	3.99
Cheirodon ibicuhiensis	0.24	0.00	3.22 ± 1.39	3.47

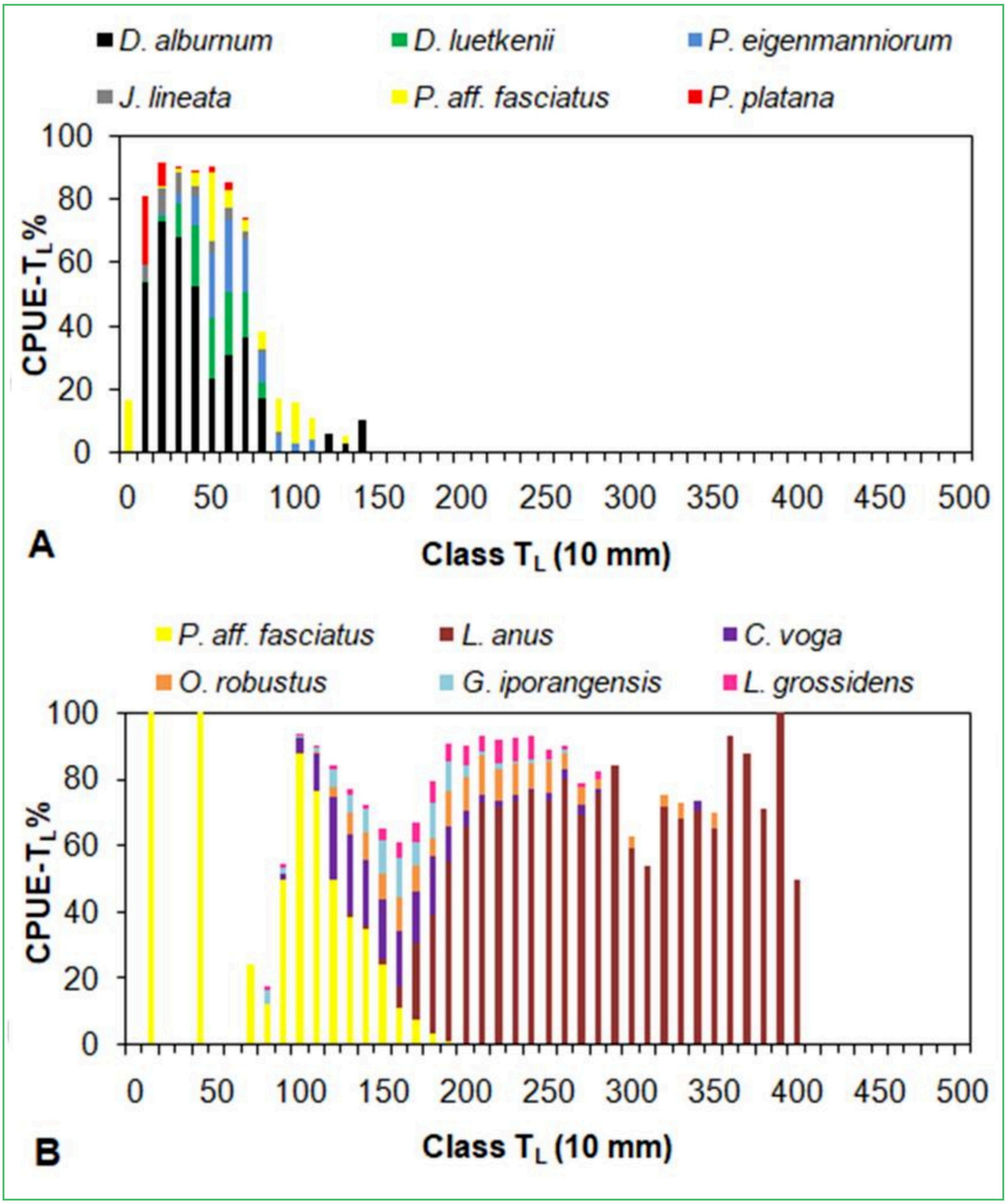
[a] Contribution of each species to the average dissimilarity between groups. [b] Average dissimilarity between groups ± standard deviation. [c] Percent contribution of each species (> 3,0%) for the dissimilarity between groups.

TABLE 3: SIMPER analysis showing the percent contribution of the major species for the dissimilarity in CPUEb between samples (factor = net). Fish collected in the Tramandaí basin Southern Brazil, between 2008 and 2010.

Species	Average abundance[a]		Average dissimilarity[b]	Contribution[c] (%)
	Beach Seine	Gill Nets		
Loricariichthys anus	0.38	10.34	9.52 ± 2.20	12.31
Diapoma alburnum	6.14	0.00	8.42 ± 2.50	10.89
Hoplias malabaricus	0.20	3.35	5.69 ± 1.80	7.36
Cyphocharax voga	0.27	4.03	5.08 ± 1.45	6.56
Psalidodon eigenmanniorum	3.08	0.21	4.3 3± 1.55	5.60
Deuterodon luetkenii	3.30	0.13	4.31 ± 1.38	5.57
Psalidodon aff. *fasciatus*	1.57	4.03	4.12 ± 1.37	5.33
Geophagus iporangensis	1.52	3.09	4.09 ± 1.35	5.29
Oligosarcus robustus	0.78	2.38	3.5 6± 1.27	4.61
Jenynsia lineata	0.89	0.00	2.47 ± 1.73	3.20

[a] Contribution of each species to the average dissimilarity between groups. [b] Average dissimilarity between groups ± standard deviation. [c] Percent contribution of each species (> 3,0%) for the dissimilarity between groups.

FIGURE 4: Dominant species relative abundance based on capture per unit effort by size classes of total length (CPUE-TL) in the beach seine (A) and gillnets (B). Fish collected in the Tramandaí basin Southern Brazil, between 2008 and 2010.



Discussion

Using beach seine in shallow marginal areas and gillnets in inner areas of littoral zones resulted in contrasting fish species assemblage composition, dominance and size patterns. The more protected and vegetated shallow lake margins were characterized by a more diverse (regarding of species richness) assemblage and dominated by small fishes (< 50 mm), such as the characids *P. eigenmanniorum*, *P.* aff. *fasciatus*, *D. alburnum* and *D. luetkenii*, the livebearer *J. lineata* and the freshwater sardine *P. platana*. In contrast, inner waters were dominated by an assemblage with a lower species richness comprised of larger fishes (> 100 mm), such as the catfish *L. anus*, the larger characids *O. robustus* and *P.* aff. *fasciatus*, the curimatid *C. voga*, the cichlid *G. iporangensis* and the anchovy *L. grossidens*. Gillnets were inefficient at sampling small fish, such as characids, livebearers, freshwater goby and juveniles, while beach seine were inefficient at sampling adult silversides *O.ledae*, *O. bonariensis*, *O. piquava*, allochthonous species, black catfish *T. lucenai* and dog fish *A. pantaneiro*, and the estuarine species *G. genidens*, *G. barbus* and *C. parallelus*.

Our results corroborate the results found for other studies in shallow lakes from Southern Brazilian coastal plains (GARCIA et al., 2006; ARTIOLI et al., 2009), being partially supported by studies in similar aquatic ecosystems on other continents. A study comparing gillnets and electrofishing in 56 shallow lakes from Denmark, showed that lakes diversity is better assessed through littoral zone sampling and with electrofishing (MENEZES et al., 2012). In 14 Austrian alpine lakes, gillnets, electrofishing, and hydro acoustics has differed in fish species richness, composition, and abundance between these three sampling techniques. The gillnets sampled around 70% of the species found in this study, which is similar to our findings. In lakes margins (2 m deep, at most), electrofishing sampled around 60% of all species of the study. While electrofishing has sampled individuals between 20-60 mm, gillnets samples included individuals between 60-80 mm (ACHLEITNER et al., 2014). A comparative study between five sampling methods in shallow marine habitats from Western Australia, has shown that highest richness for fish assemblages was obtained through seine nets. The combination of methods which included seine nets was distinct from other method combinations based on highest diversity. Fish size in seine net samples on this study was higher (50-150 mm, L_T) (FRENCH et al., 2021) than what we found in our study. In a North American eutrophic reservoir, fish species richness, relative abundance, and fish size, assessed through two sampling methods (beach and open water seines), were compared to those obtained from a mobile platform, which can sample both habitats (nearshore and open water). The CPUE was always higher nearshore regardless the sampling method. Average fish species richness per sample was higher in nearshore habitats compared to open waters, and also when platform and seine nets used in both habitats were compared (MERZ et al., 2021).

All studies share the common outcome that a combination of sampling methods is the best way to fully assess the fish species diversity. Our study, however, cannot precisely define which is the best method combination to assess fish diversity, once many other methods could be applied in other non-explored habitats (e.g. densely vegetated margins). Further studies, using different sampling techniques (e.g. electrofishing), and exploring other habitats (e.g. pelagic and deep zones), could establish what is the best combination of sampling effort and methods to obtain the best fish assemblage representation in shallow subtropical lakes. Defining the best sampling methods for different habitats, target species, fish size, or specific goals is crucial for sampling design in ichthyofauna research (OLIVEIRA et al., 2014; RADINGER et al., 2019). We admit that only a sampling design with controlled experiments, which imply in conducting selectivity experiments for each of the target species using the different methods, can really establish the catch differences between gillnets and beach seines. Although we understand that there are substantial differences between both sampling methods used in the present study, we conclude that distinct patterns of fish species composition and dominance between marginal and inner areas can be found in the littoral zone of coastal lakes of Tramandaí river system, as found in other lentic ecosystems (MENEZES et al., 2012; ACHLEITNER et al., 2014).

Our results point out that a combination of both sampling methods is needed to assess more complete information on fish assemblage diversity in the littoral zones of the studied lakes. When assessed individually, however, beach seines are more effective, demanding lesser efforts than gillnets. Sampling with beach seines require a few hours to be performed while gillnets need long hours of exposure (eventually the whole night), frequently requiring at least two revisions. Removing the fish from the net is also an issue, given it frequently harm them and lead them to death. Our results point that using beach seines may provide reliable information about changes in fish species richness and composition in shallow coastal lakes, since standardized in time and space and operated by the same people, being a good sampling device for low-cost monitoring projects. (VIEIRA, 2006; CENI; VIEIRA, 2013; VIEIRA et al., 2019).

Finally, we conclude that the fishing gears (gillnets and beach seine) provide different results regarding fish species richness, composition, and dominance when used in the littoral zones of the coastal shallow lakes sampled in our study. Beach seine, however, was more effective in assessing abundance and richness, the basis for many diversity metrics. Within this context, the beach seine can be used as a reliable, low budget alternative when the study goal includes monitoring the fish species diversity from the littoral zones of these lakes. When other goals are considered, such as looking for a specific fish size, or population assessment, using exclusively gillnets or combining with beach seine might be more appropriated. We believe that our results might be useful for the effective assessment of fish assemblage structure in subtropical shallow coastal lakes in monitoring programs development.

Acknowledgments

To Centro de Estudos Costeiros Limnológicos e Marinhos (CECLIMAR) and Ministério da Agricultura e Pesca for logistical and financial support. To Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) for sampling permit (#18439-1). L.G.S.A is grateful to CAPES for a doctoral fellowship.

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