

Applying multi-mesh gillnet to monitor fish communities in neotropical rivers

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Neotropical fish diversity has been declining, driven by increasing human pressures. This accelerating loss underscores the urgent need for standardized methods capable of reliably monitoring these communities. Here, we evaluated the effectiveness of nordic multi-mesh gillnets for sampling fish communities in the Uruguay River. Species were captured from small to large mesh sizes (5–55 mm, knot to knot). Model performance varied among species, with clear evidence of size-selectivity. Size bias was observed primarily for the smallest length classes of Siluriformes species trapped in larger meshes. Nordic multi-mesh gillnets were efficient at catching small-bodied species, while their efficiency decreased for large-bodied species. These findings indicate that nordic multi-mesh gillnets are useful for monitoring Neotropical fish communities but require size-bias correction, particularly for Siluriformes. Although our study supports the use of these nordic multi-mesh gillnets, it demonstrates that they should be complemented with larger mesh sizes if large-bodied fish need to be sampled in Neotropical rivers.

Keywords: Biodiversity, Characiformes, Neotropics, River ecosystem, Siluriformes.

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La diversidad de peces neotropicales ha disminuido en las últimas décadas, impulsada por el aumento de las presiones humanas. Esta pérdida acelerada destaca la urgente necesidad de métodos estandarizados para monitorear estas comunidades de manera confiable. En este estudio, evaluamos la eficacia de las redes agalleras tipo nórdicas, de malla múltiple, para el muestreo de comunidades de peces en el Río Uruguay. Las especies fueron capturadas en todos los tipos de mallas, las más pequeñas hasta las más grandes (5–55 mm, de nudo a nudo). El desempeño del modelo varió entre especies, con clara evidencia de selectividad por talla. Se observó un sesgo de tamaño, principalmente en las clases de longitud más pequeñas de especies de Siluriformes atrapadas en las mallas grandes. Las redes nórdicas de malla múltiple fueron eficientes para capturar especies de tamaño corporal pequeño, mientras que su eficiencia disminuyó para especies de grandes. Estos hallazgos indican que este tipo de redes son útiles para monitorear comunidades de peces en la región Neotropical, pero requieren correcciones por sesgo de tamaño, particularmente para los Siluriformes. Aunque este estudio respalda el uso de estas redes, demuestra que deberían complementarse con mallas de mayor tamaño si se requiere muestrear peces de mayores dimensiones en ríos neotropicales.

Palabras clave: Biodiversidad, Characiformes, Ecosistema fluvial, Neotrópico, Siluriformes.

INTRODUCTION

Neotropical freshwater fish are increasingly threatened by anthropogenic pressures, including pollution, biological invasions and overfishing (Shantz *et al.*, 2020; Pelicice *et al.*, 2021; Moi *et al.*, 2025). Hence, standardized long-term monitoring of neotropical freshwater fish is essential (Magurran *et al.*, 2010). In this context, multi-mesh gillnets are among the most widely used standardized sampling tools in certain regions, such as Europe (Millar, Holst, 1997; Carol, García-Berthou, 2007). This method allows simultaneous fishing with multiple mesh sizes, thereby capturing a broad range of body sizes. Although the use of multi-mesh gillnets has been standardized across Europe (Appelberg *et al.*, 1995), no equivalent method exists in the Neotropical region.

Neotropical freshwaters harbor more than 4,200 fish species (Tonella *et al.*, 2023). Neotropical fish assemblages are highly diverse and are dominated by Characiformes and Siluriformes, which exhibit a broad range of body sizes and morphological traits (Albert *et al.*, 2020). Given this highly diverse taxonomic and functional structure, combined with the intensification of anthropogenic pressures, it is necessary to establish standardized gillnet-based methods capable of assessing catch-length distributions, population size structure, and species abundance in Neotropical fish assemblages, while also enabling evaluations of anthropogenic impacts (Moi *et al.*, 2024, 2025). Although multi-mesh gillnets have been adopted in recent Neotropical studies (*e.g.*, González-Bergonzoni *et al.*, 2019, 2020; López-Rodríguez *et al.*, 2019; Moi *et al.*, 2024), their selectivity for these diverse fish communities remains untested.

Gillnets are highly selective and passive fishing gears, and their efficiency is directly related to the probability that fish will encounter them (Millar, Holst, 1997). Therefore, gillnets are ineffective for catching sedentary fish, and seasonal differences in individual movement can alter the encounter probability (Neumann, Willis, 1995). The probability of capture also depends on the fish being successfully entangled in the net. Considering that when a fish is entangled in a net, it involves several parts of its body, such as the operculum, spines, maxilla, and teeth, the probability of capture increases when the organism has more external structures (Shoup, Ryswyk, 2016). Hence, mesh size is a key factor influencing the size of individuals caught in gillnets (Hubert *et al.*, 2012; Tesfaye *et al.*, 2016). It is also strongly size-selective, because the length of an individual caught in a given mesh size usually differs by less than 20% of the length most efficiently retained by the mesh (Hamely, 1975, 1980).

To minimize size bias in fish sampling, gillnets with multiple mesh sizes are deployed simultaneously. Although this approach minimizes bias, it does not eliminate selectivity entirely. The length–frequency distributions obtained from gillnet catches may not accurately reflect the true proportions of each species in the environment (Shoup, Ryswyk, 2016). Previous studies have quantified the gillnet selectivity and proposed correction methods for length–frequency data (*e.g.*, Shoup, Ryswyk, 2016; Smith *et al.*, 2017; Klein *et al.*, 2019). However, these corrections have been developed primarily for the Holarctic region, and no analogous corrections exist for Neotropical systems. Regional differences are important, as fish communities vary markedly across biogeographic realms. For example, in the Holarctic, orders such as Cypriniformes, Perciformes, and Salmoniformes predominate. These fish typically lack prominent external structures such as pectoral spines, and plates being mostly wrapped around their opercles and fins. In Neotropical fish communities, Siluriformes and Characiformes are highly diverse and abundant. In particular, the family Loricariidae (“armored catfish”) can reach high richness and abundance in these rivers (Albert *et al.*, 2020). This family includes several fish with large pectoral and dorsal fin spines, often time serrated, bony plates along the body and even ossified barbels, all of them being structures easily wrapped in gillnets. Consequently, gillnet selectivity may differ substantially between regions dominated by morphologically distinct taxa.

Gillnet selectivity may be analyzed directly or indirectly (Millar, Fryer, 1999). The direct method is implemented if fish lengths distributions are known, but as this knowledge is rare, this method is generally not feasible in practice (Millar, Holst, 1997). As such, gillnet selectivities are evaluated by the indirect methods, in which different mesh sizes are employed at the same time, and size-specific selectivities are assessed through comparison of the capture of each individual length class between the meshes (Millar, Holst, 1997; Vandergoot *et al.*, 2011). The indirect method is quantified with selectivity curves where the probability of capture for each fish length class by each mesh size is calculated as a proportion of the total catch of the length class across all mesh sizes (Shoup, Ryswyk, 2016).

The probability of capture indicates how efficiently that mesh size catches fish of the optimum length. Millar, Holst (1997) provide a statistical approach for indirectly estimating gillnet retention curves through generalized linear modelling (the SELECT method). This method offers a critical approach to size selectivity analysis and has been used in gillnet selectivity studies (*e.g.*, Rodríguez-Climent *et al.*, 2012; Radomski *et*

al., 2020). Despite its importance, the indirect method presents a weakness because it evaluates gillnet selectivity only for fish that are collected by the net and not for the overall fish population (Shoup, Ryswyk, 2016). This results in gillnet size bias being related to the morphology of the retained fish, rather than to differences in size-specific encounter rates (Booth, Potts, 2006). To correct the size bias of the indirect method, Shoup, Ryswyk (2016) developed a correction factor derived from the selectivity curves, which allows for an accurate examination of the contact selectivity of the fish population sampled.

In this study, we monitored the fish community in a neotropical river (the Río Uruguay) over seven years. We used benthic nordic multi-mesh gillnet (Appelberg *et al.*, 1995; Olin *et al.*, 2004). This multi-mesh gillnet has proven useful for managers in European countries, as it provides comprehensive estimates of fish size distributions (Appelberg *et al.*, 1995). The use of this multi-mesh net could also be useful for managers in the neotropical region. To our knowledge, no study has assessed the selectivity of the nordic multi-mesh gillnet for Neotropical fish, which could inform the implementation of this method in these hyperdiverse rivers. Hence, we aimed to identify the best-fit selectivity model for gillnet catches in the Río Uruguay.

MATERIAL AND METHODS

Study area. The study was performed in the Río Uruguay, which has an approximate length of 1,838 km and a drainage area of 365,000 km². In this river, the flood pulse is driven mainly by precipitation in the upper portion of its catchment, which increases during El Niño events, producing irregular flood peaks approximately every 3.5–6 years (Krepper *et al.*, 2003). We sampled fish communities at three sites distributed along a 40-km stretch of the lower Río Uruguay, from upstream to downstream, respectively: i) Nuevo Berlín, ii) Fray Bentos, and iii) Las Cañas (Fig. 1).

Fish sampling. The fish community was sampled twice a year in April (fall) and December (spring) at the three river sites mentioned above. We used standard nordic multi-mesh gillnets, consisting of 30 m-long nets with 12 mesh panels of varying sizes, with measures knot to knot of: 5, 6.25, 8, 10, 12.5, 15.5, 19.5, 24, 29, 33, 43, and 55 mm, respectively. To provide a comprehensive spatial monitoring assessment, fish samples were collected at the exact same locations in autumn and spring. In total, we used eight individual nordic multi-mesh gillnets, joining two nets together at each location, hence, resulting in four sets composed by two nordic multi-mesh gillnet each one. Thus, each set measured a total length of 60 m length and 1.5 m height, resulting in an area of 90 m². We positioned two of these 60 m-long sets parallel to each other in the littoral zone, at a maximum distance of 100 m from the coast, with 300 m between them and a depth of 1–2 m. The other two multi-mesh gillnet sets were located at 500 m from the coast in line with the littoral ones, with 300 m between them and at a depth of 2–5 m. Nordic multi-mesh gillnets were deployed from 7 p.m. to 7 a.m., covering approximately 12 h during the twilight and night period. For this study, fish caught in 46 nordic multi-mesh gillnets were analyzed. This number corresponds to selecting one Nordic multi-mesh gillnet per sampling event. During the 8-year monitoring period (2009–2016), 48 sampling events were planned (two per year at

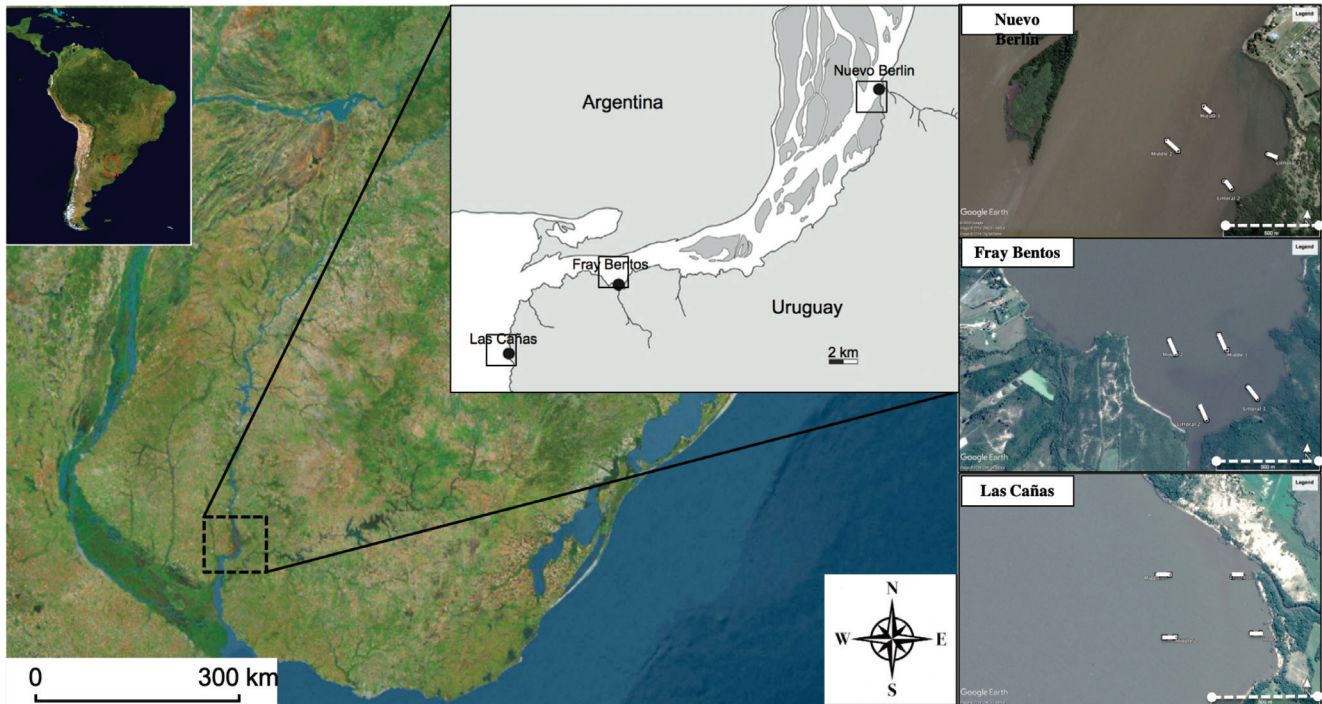


FIGURE 1 | Map of the Uruguay River, highlighting the three distinct sites within the river that have been monitored from 2009 to 2016. The dots at each site indicate the locations where the fish collection nordic multi-mesh gillnets were deployed. The rectangles represent the exact sites where the full set of two nordic multi-mesh gillnets was deployed, totaling eight Nordic multi-mesh gillnets.

three sites), with one Nordic multi-mesh gillnet randomly selected in each event for the selectivity analysis. Two events were lost, resulting in 46 gillnets, which together represent a total sampled gillnet area of 2,070 m² across autumn and spring campaigns. Fish were identified based on the twelve different mesh sizes in which the fish were caught. The collected fish were identified at the species level, counted, and measured (standard length, cm). All fish vouchers are in the fish collections of the Facultad de Ciencias, Universidad de la República, Montevideo (ZVCP) and Centro Universitario Regional del Este (CURE-Ict).

Data analysis. We selected species with more than 60 individuals caught during monitoring for the gillnet selectivity analysis (Tab. S1). A total of 14 species matched this criterion: *Apareiodon affinis*, *Psalidodon* spp., *Piabarchus stramineus*, *Cynopotamus argenteus*, *Cyphocharax platanus*, *Iheringichthys labrosus*, *Megaleporinus obtusidens*, *Loricariichthys melanocheilus*, *Pachyurus bonariensis*, *Parapimelodus valenciennis*, *Pimelodella gracilis*, *Pimelodus maculatus*, *Prochilodus lineatus* and *Ricola macrops* (see Tab. S1).

We estimated gillnet selectivity for 14 species using Millar's (1992) SELECT approach, implemented in the R package TropFishR (Mildenberger *et al.*, 2017). The SELECT uses a generalized linear model, assuming Poisson distribution of the gillnet catch data to fit them to a specified model using Maximum Likelihood (Millar, Holst, 1997). The selectivity's curves are fitted as the relative probability of a fish of a given length to be captured when contacting a mesh of a determinate size (Millar, Holst, 1997). We tested four selectivity models, Normal location, Normal scale, Lognormal, and Gamma (Fig. 2), which correspond to different types of statistical distributions used

to describe the probability of capture across fish lengths. The Normal scale, Gamma, and Lognormal models follow the principle of geometric similarity, meaning that both the mean and the standard deviation of the retention curve shift proportionally with mesh size (Millar, Holst, 1997). In contrast, the Normal location model assumes a proportional increase of the mean with mesh size but a fixed standard deviation, so all gillnet variants have the same variability (Millar, Holst, 1997). The Normal location and Normal scale models assume a symmetric (Gaussian) distribution, whereas the Gamma and Log-normal models assume a skewed distribution (Millar, Holst, 1997). The choice of these distribution affects the shape of the selectivity curve and how well it fits the observed catch data. Catch rates were summarized into 42 length classes ranging from 30 to 439 mm, with all classes spanning 10 mm to cover the full-size range of the sampled fish. The best-fit model for each species was determined based on the lowest model deviance and most randomly distributed residuals (Millar, Holst, 1997). We also used overdispersion to determine the best model as suggested by Holst *et al.* (1998). The dispersion parameter is estimated by the ratio of deviations *vs.* degrees of freedom. Specifically, a dispersion parameter > 1 indicates excessive dispersion.

Previous assessments have found bias in gillnet selectivity's to certain fish length classes, leading to underestimating selectivity to some fish length classes (Hansen *et al.*, 1997; Shoup, Ryswyk, 2016). To minimize bias, we used the method of Shoup and Ryswyk (2016) to estimate the magnitude of the size bias and to correct the length frequency of individuals that contacted the net. The method uses selectivity curves to adjust the length-frequency distributions of each fish species (Hansen *et al.*, 1997). Selectivity-adjusted data are compared with unadjusted (Shoup, Ryswyk, 2016). The relative selectivity values (*S*) for employed nordic multi-mesh gillnets, *i.e.*, normalizing selectivity across the mesh sizes, were calculated as:

Normal scale (K_1, k_2)	→	$\exp\left(-\frac{(L-k_j \times m_j)^2}{2k_2^2 \times m_j^2}\right)$
Normal location (k, σ)	→	$\exp\left(-\frac{(L-k \times m_j)^2}{2\sigma^2}\right)$
Gamma (α, k)	→	$\left(\frac{L}{(\alpha-1) \times k \times m_j}\right)^{\alpha-1} \exp\left(\alpha - 1 - \frac{L}{k \times m_j}\right)$
Lognormal (μ, σ)	→	$\frac{m_j}{L \times m_1} \exp\left(\mu - \frac{\sigma^2}{2} - \frac{\left(\log(L) - \mu - \log\left(\frac{m_j}{m_1}\right)\right)^2}{2\sigma^2}\right)$

FIGURE 2 | Equations and parameters for the four SELECT models. Equations are related to the mesh size j (m_j) with number of fish of length L captured in that mesh size. Other symbols used in equations are constant in models. Fitted constants describing contact selectivity for the fish community in Uruguay. We fitted models for all 14 species (occurrence > 60 individuals). Models were fitted with Normal scale, Normal location, Gamma e Lognormal distributions.

$$S_l = \sum_j (S_j(l) / \max_j)$$

Where $s_j(l)$ is the selectivity of size class l in mesh size j , and \max_j is the maximum selectivity value $[s_j(l)]$ observed among all length classes (Shoup, Ryswyk, 2016). We adjusted the abundance of each length class (*i.e.*, adjusted fish length–frequency) by dividing the total number of fish captured in a given length class (catch from all mesh sizes) by the overall net selectivity value (S_l) for that length class (Shoup, Ryswyk, 2016). We then compared the unadjusted and S_l -adjusted length–frequency data for each species using a variance analysis (ANOVA). Our data met the assumptions of normality and equal variance, as indicated by the graphical analysis of residuals.

RESULTS

We caught 75 fish species represented by 4,458 individuals, where 1,170 individuals belonged to the Characiformes and 2,008 individuals to the Siluriformes (Tab. S1). These were the two orders most commonly caught, accounting for 85% of fish captured. The overall catches decreased with the increase in mesh sizes, where smaller mesh caught more fish than larger mesh (Fig. 3). All mesh sizes caught a wide size range of several fish species. Nevertheless, the mean standard deviation in length of sampled fish for all 14 species increased with mesh size (Tab. S2).

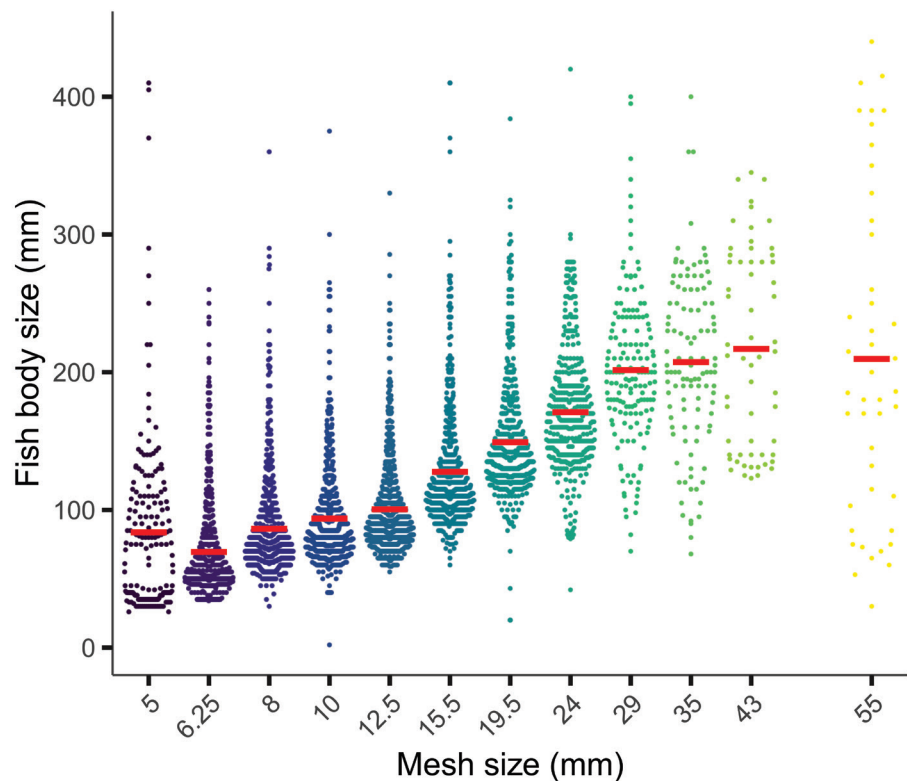


FIGURE 3 | Length class of fish (mm) caught in each mesh size (5, 6.25, 8, 10, 12.5, 15.5, 19.5, 24, 29, 35, 43, and 55 mm) used by “nordic multimesh gillnet”. The horizontal red line represents the average body size of fish caught in each mesh size.

The best-fitting model estimated using the SELECT method, varied considerably among the 14 species (Tab. 1). Assuming equal fishing power for all meshes, the normal scale model had the lowest deviance value for the *A. affinis*, *Psalidodon* spp., *P. stramineus*, and *P. gracilis* (Fig. 4). The normal location model had the lowest deviance value for *C. platanus*, *P. lineatus*, *Pimelodus* sp., and *R. macrops* (Fig. 4). The lognormal model had the lowest deviance value for *C. argenteus*, *M. obtusidens*, *I. labrosus*, *L. melanocheilus*, *P. valenciennis* and *P. bonariensis* (Fig. 4). We found that small mesh sizes had the highest selectivity for smaller length classes, whereas the large mesh size had the highest selectivity for the largest length classes. In addition, the smallest mesh sizes (*i.e.*, 5, 6.25, 8 and 10 mm) showed very similar selectivity curves for the length of the fish caught (Fig. 4), especially for the Siluriformes species, which suggests that these mesh sizes overlap.

TABLE 1 | Model parameters, residual deviance, degrees of freedom (df), for four gillnet selectivity models (*i.e.*, Normal scale, Normal location, Log-normal, and Gamma) estimate using SELECT method. Parameters 1 and 2 are k and σ for normal location model; k_1 and k_2 for normal scale model (spread proportional to mesh size); α and k for gamma model; μ_1 and σ for lognormal model. The model with lowest deviance for each of 14 species is indicated in bold text. Abundance is the number of individuals of each species that were included in the analyses.

Fish model	Abundance	Model	Fishing power relative mesh size			
			Par. 1	Par. 2	Deviance	df
<i>Apareiodon affinis</i>	264	Normal location	4.79	7461.93	850.21	419
		Normal scale	41.42	13.39	389.76	419
		Gamma	5.31	1.72	745.512	419
		Lognormal	3.91	0.35	806.51	419
<i>Psalidodon</i> spp.	526	Normal location	5.93	158.66	502.08	262
		Normal scale	6.25	0.83	258.16	262
		Gamma	45.58	0.13	381.41	262
		Lognormal	3.43	0.02	363.01	262
<i>Piabarchus stramineus</i>	296	Normal location	0.33	53.71	485.02	60
		Normal scale	7.53	0.82	55.63	60
		Gamma	48.60	0.15	116.12	60
		Lognormal	3.64	0.02	155.21	60
<i>Cynopotamus argenteus</i>	79	Normal location	6.87	2507.78	160.81	264
		Normal scale	9.41	33.67	203.71	264
		Gamma	6.90	1.44	171.69	264
		Lognormal	3.81	0.13	157.21	264
<i>Cyphocharax platanus</i>	254	Normal location	6.16	485.59	187.52	198
		Normal scale	7.53	6.80	615.45	198
		Gamma	16.12	0.44	446.63	198
		Lognormal	3.53	0.04	376.15	198
<i>Iheringichthys labrosus</i>	955	Normal location	8.27	49.28	483.34	364
		Normal scale	12.57	25.36	634.12	364
		Gamma	5.94	2.10	378.01	364
		Lognormal	4.07	0.21	319.52	364
<i>Megaleporinus obtusidens</i>	157	Normal location	6.75	30.84	341.58	360
		Normal scale	8.95	10.03	352.34	360
		Gamma	9.38	0.96	328.23	360
		Lognormal	3.75	0.11	319.68	360



TABLE 1 | (Continued)

Fish model	Abundance	Model	Fishing power relative mesh size			
			Par. 1	Par. 2	Deviance	df
<i>Loricariichthys melanocheilus</i>	168	Normal location	11.35	60.17	220.03	324
		Normal scale	17.04	55.94	297.54	324
		Gamma	6.72	2.48	235.83	324
		Lognormal	4.34	0.15	216.23	324
<i>Pachyurus bonariensis</i>	260	Normal location	6.31	870.35	366.24	220
		Normal scale	7.44	3.57	254.73	220
		Gamma	17.10	0.42	270.57	220
		Lognormal	3.56	0.06	214.41	220
<i>Parapimelodus valenciennis</i>	300	Normal location	7.50	193.61	355.23	276
		Normal scale	9.43	10.56	440.23	276
		Gamma	11.62	0.77	285.10	276
		Lognormal	3.75	0.08	251.36	276
<i>Pimelodella gracilis</i>	146	Normal location	9.51	366.65	182.54	276
		Normal scale	8.89	3.03	122.44	276
		Gamma	18.10	0.50	150.52	276
		Lognormal	3.81	0.07	176.09	276
<i>Pimelodus</i> sp.	105	Normal location	7.34	144.46	112.19	324
		Normal scale	10.59	16.23	180.29	324
		Gamma	8.02	1.29	147.43	324
		Lognormal	3.87	0.12	134.06	324
<i>Prochilodus lineatus</i>	63	Normal location	4.95	1159.48	130.01	324
		Normal scale	5.77	2.90	164.80	324
		Gamma	17.66	0.33	145.41	324
		Lognormal	3.34	0.05	137.23	324
<i>Ricola macrops</i>	107	Normal location	10.29	82.65	152.83	288
		Normal scale	20.33	138.16	199.91	288
		Gamma	3.95	5.29	175.02	288
		Lognormal	4.54	0.31	163.81	288

We also found some degree of size bias for all 14 fish species monitored. Through overall selectivity curves, we identified length-specific relative selectivity values (Rel S_l) for each length class, which typically corrected these biases. For most species (*A. affinis*, *Psalidodon* spp., *C. argenteus*, *C. platanus*, *M. obtusidens*, *I. labrosus*, *P. valenciennis*, *P. gracilis*, *L. melanocheilus*, *R. macrops*, and *P. bonariensis*), the highest Rel S_l was observed at intermediate length classes (100–300 mm), whereas the smallest classes had the lowest Rel S_l values (Tabs. S3, S4). In contrast, for *P. stramineus*, *P. lineatus* and *Pimelodus* sp. the peak selectivity occurred in smaller length classes (< 150 mm) (Tab. S2). No fish species had peak selectivity in larger length class (> 400 mm).

Comparing the corrected length frequencies (*i.e.*, adjusted by Rel S_l ; Tabs. S3, S4) with unadjusted data, we found similar values for *A. affinis*, *Psalidodon* spp., *P. stramineus*, *C. argenteus*, *C. platanus*, *M. obtusidens*, and *P. bonariensis*, implying no significant biases for these species (Fig. 5). In contrast, we found significant differences between adjusted and unadjusted data for siluriform species, including *I. labrosus*, *L. melanocheilus*, *P. valenciennis*, *P. gracilis*, *Pimelodus* sp., and *R. macrops* (Fig. 5). For Siluriformes species biases occurred primarily in the smallest length classes, particularly those below 100 mm, where the adjusted data were substantially higher than the unadjusted values (Fig. 5).

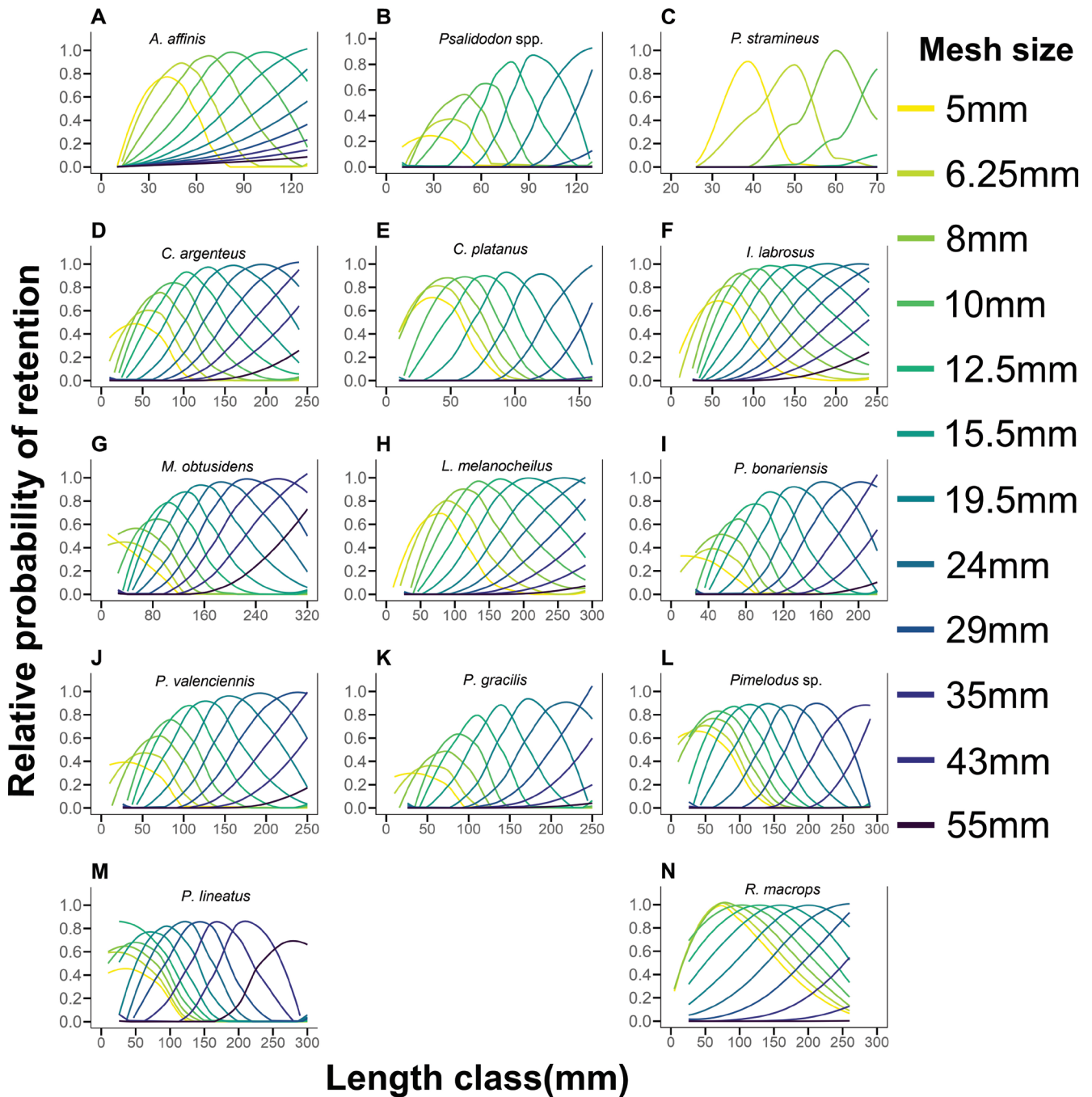


FIGURE 4 | Selectivity curves of “Nordic Gillnet multimesh” fitted for 14 species, sampled in Uruguay River, during six years. The retention curves from left to right correspond to 5, 6.25, 8, 10, 12.5, 15.5, 19.5, 24, 29, 35, 43, and 55-mm mesh, respectively.

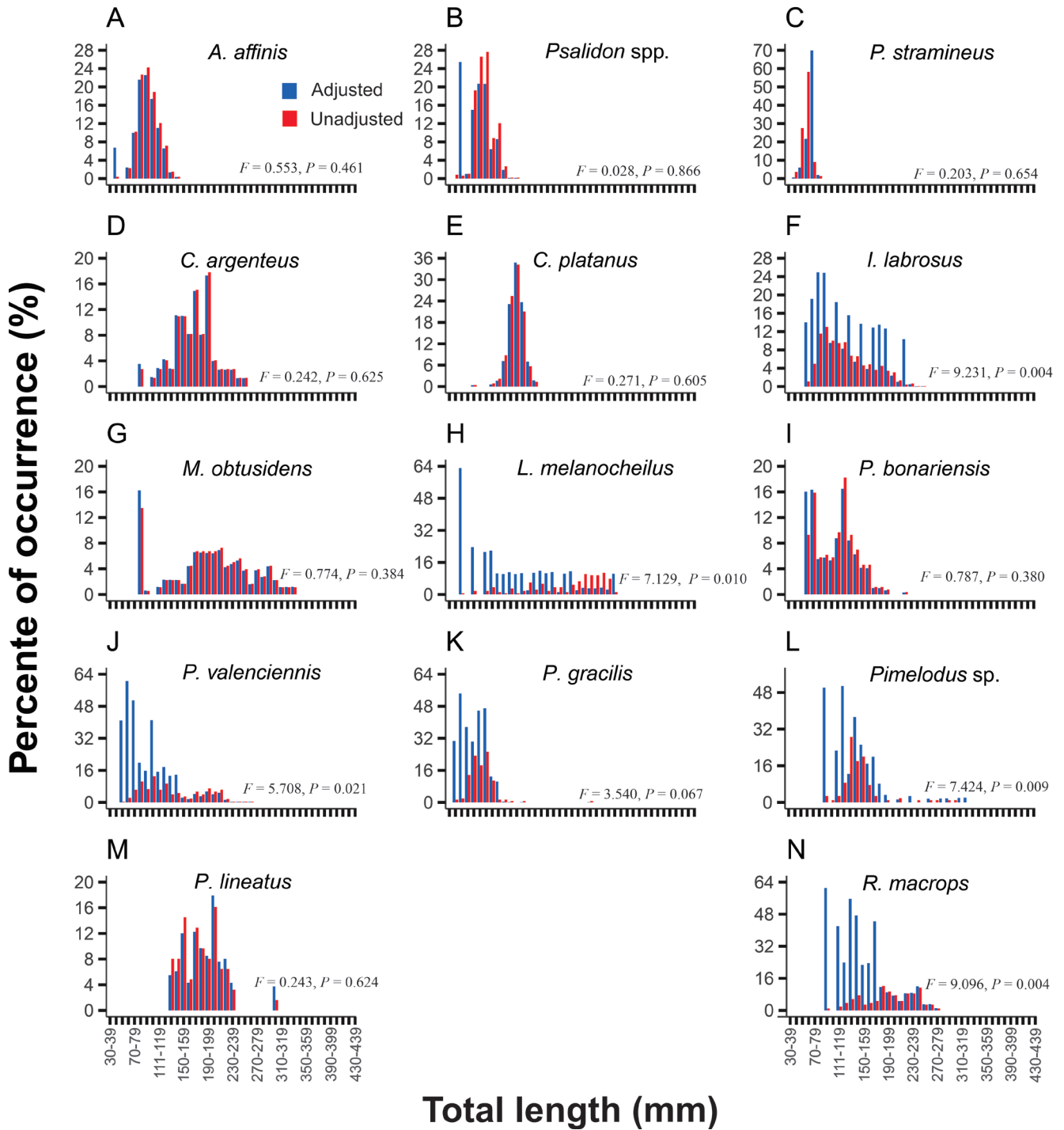


FIGURE 5 | Percent occurrence of 14 fish species per length class across three sites in the Río Uruguay, sampled during seven years using nordic multimesh gillnet. Catch rates were summarized into 42 length classes ranging from 30 to 439 mm, with all classes spanning 10 mm to cover the entire size range of the sampled fish. Blue bars indicate adjusted data for contact selectivity and red bars indicate data unadjusted. The differences between the adjusted and unadjusted data were calculated using analysis of variance (ANOVA). F and P values are shown within each graph, where $P < 0.05$ indicates significant differences.

DISCUSSION

Based on monitoring data, this study evaluated the selectivity of the “nordic multi-mesh gillnet” for 14 fish species along the Río Uruguay. We found that Siluriformes and Characiformes were the most commonly captured orders, matching their high abundance in Neotropical fish assemblages (Albert *et al.*, 2020; Tonella *et al.*, 2023). In general, fish length increased with mesh size (Fig. 3), highlighting the size selectivity of the nordic multi-mesh gillnet. Different selectivity models were more suitable for different species, indicating that model performance is species-specific (Millar, Fryer, 1999; Carol, García-Berthou, 2007; Tesfay *et al.*, 2016). Several Siluriformes species showed evidence of size bias, which was corrected using overall selectivity curves (adjusted by Rel SI) following Shoup and Ryswyk (2016). These findings indicate that the nordic multi-mesh gillnet may be effectively used for monitoring fish stocks in Neotropical rivers, although size biases may occur for Siluriformes.

Most of the fish species monitored in the Río Uruguay are small-bodied, usually reaching less than 200 mm at the adult stage (*e.g.*, *A. affinis*, *Psalidodon* spp., *P. stramineus*, *C. platamus*). For these species, we showed that the nordic multi-mesh gillnet was able to catch individuals of a full range of body sizes. However, some species (*e.g.*, *M. obtusidens* and *P. lineatus*) are large-bodied, reaching over 700 mm in adulthood. For these species, the nordic multi-mesh gillnets only caught individuals smaller than 300 mm, meaning that they failed to represent the full-size range of large-bodied fishes. This limitation arises not from the gillnet design itself, but from the fact that its mesh sizes were originally developed for European streams, with a maximum of 55 mm (Appelberg *et al.*, 1995). As such, using nordic multi-mesh gillnets for monitoring small-bodied fish is highly effective, whereas if the objective is to monitor large species, this gillnet should include segments with larger meshes. Importantly, the nordic design is based on a geometric progression of mesh sizes, with a fixed ratio of 1.25 between consecutive meshes (Appelberg *et al.*, 1995). Therefore, nordic multi-mesh gillnets could be adapted to catch large fish by increasing the mesh size following a geometric scale with a ratio of 1.25 (Olin *et al.*, 2004; Specziár *et al.*, 2009). By continuing this progression, the new mesh sizes would be: 70 mm, 90 mm, 115 mm, 145 mm, 185 mm, and 240 mm, which are consistent with those used to capture large-bodied fishes in other Neotropical rivers (Moi *et al.*, 2021; Santos *et al.*, 2022). We therefore suggest that further studies adapt the nordic multi-mesh gillnet to also target large-bodied individuals, which have high economic importance (Pelicice *et al.*, 2023).

Our results have important applicability, since researchers and managers may use the selectivity curves to adjust catch data when using the nordic multi-mesh gillnet. Data were adjusted (*i.e.*, corrected length-frequency) by dividing the number of fish captured within a given length class by the overall probability of retention (*SI* value) (Tab. S3) for that length class (Hansen *et al.*, 1997). In this method, for instance, if a given net captures ten individuals of *Apareidon affinis* within the 70–79 mm length class, where *SI* = 0.5 for that length class during one twilight, then the catch of *A. affinis* should be adjusted to 20 individuals per twilight. In the aforementioned example, we divide the number of individuals captured by the *SI* value (10/0.5) to adjust for the size bias against this length class. Perhaps more importantly, when we adjusted the number of

fish captured, we found twice as many fish as in the unadjusted data. This means that we should double the number of fish captured to account for fish that have contacted the net without being retained.

We showed that Siluriformes species were abundant in length classes with low selectivity. This implies that these species had an S_l value closer to 0 than to 1, which resulted in large adjusted values. By contrast, Characiformes were abundant in length classes with high selectivity; that is, these species showed an S_l closer to 1 than to 0, resulting in lower adjusted values. These results indicate that the selectivity curves produced strong adjustments in populations of Siluriformes but relatively minor differences in Characiformes. Therefore, the standard use of the nordic multi-mesh gillnet should be done cautiously, and relative selectivity should always be applied to correct the data, especially for catfish species.

This different selectivity patterns between orders (*e.g.*, Characiformes *vs.* Siluriformes) found are related to the species-specific morphologies. For instance, Siluriformes have larger pectoral and dorsal spines, in addition to the presence of barbels (*e.g.*, *I. labrosus*, *Pimelodus* sp.), and the Loricariidae have plates with a large number of structures that are very easily tangled in a mesh (*e.g.*, *R. macrops*) without actually penetrating the fishing gear. Therefore, these species can be considered incidental catches in an unsuitable mesh, which results in size-specific significant differences in the probability of retention. Indeed, we observed that many large-bodied Siluriformes individuals were tangled in small mesh sizes with their spines and barbels. This could explain the low selectivity and significant difference between adjusted and unadjusted length–frequency distributions for only catfish species. In contrast, we did not observe a significant difference between adjusted and unadjusted data for Characiformes species. This indicates that Nordic multi-mesh gillnets are highly selective for this order, probably because Characiformes species do not have many spines that tangle them in smaller meshes.

Neotropical fish stocks have been highly overexploited by human-induced pressures (Agostinho *et al.*, 2004; Link, Watson, 2019; Moi *et al.*, 2021). In several cases, the fish population's deterioration is not detectable until it is irreversible. Therefore, it is crucial to establish long-term monitoring and control of fish stocks in the Neotropical realm. This is the first study analyzing gillnet selectivity for the Río de la Plata basin, one of the largest estuaries on the planet. Specifically, we provide evidence that the nordic multi-mesh gillnet has a high length selectivity for Characiformes species. Despite this, an important bias for length-based population analyses was evident for Siluriformes species, which is minimized using selectivity corrections. We recommend that researchers and management agencies in Neotropical countries adopt the nordic multi-mesh gillnet for monitoring fish stocks. To increase gillnet accuracy, studies should incorporate adjustments for selectivity, preferably when monitoring Siluriformes species.

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Dieison André Moi: Conceptualization, Data curation, Formal analysis, Investigation, Validation, Visualization, Writing-original draft, Writing-review and editing.

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Franco Teixeira-de-Mello: Conceptualization, Funding acquisition, Investigation, Project administration, Resources, Supervision, Validation, Visualization, Writing-review and editing.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

AI STATEMENT

The authors did not use any AI-assisted technologies in the creation of this manuscript or its figures.

COMPETING INTERESTS

The authors declare no competing interests.

SUPPLEMENTARY MATERIAL

Supplementary Material File

PEER REVIEW

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