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Scientific Note

COMPARING THE USE OF BEACH SEINE AND CAST NET AT CHARACTERIZING INTERTIDAL FISH FAUNA STRUCTURE OF A SUBTROPICAL BAY*

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ABSTRACT

Although beach seines and cast nets are widely used to sample fishes in coastal marginal habitats, a comparison between such gears at determining fish fauna structure of tidal flats during high water is lacking. Here we compared the effectiveness of a multifilament beach seine and a monofilament cast net for sampling the intertidal fish assemblage structure of a subtropical bay in Brazil. We found an overall best performance for beach seine. In comparison to cast net, the beach seine sampled (I) a substantially greater density for the local dominant species, *Atherinella brasiliensis*; (II) a slightly greater density for juveniles of other conspicuous species, i.e. *Mugil curema*, *Eucinostomus argenteus*, *Harengula clupeola*, and *Oligoplites saurus*; (III) a higher total and mean richness; and (IV) higher the number and abundance of benthivores and higher the abundance of omnivores. The cast net better sampled the small planktivores, especially *Sardinella brasiliensis* juveniles. Such outcomes could support a future local fish-monitoring program and emphasize the great importance of evaluating the gear performance before starting fish sampling operations.

Key words: ecological monitoring; Araçá bay; neotropical fauna; marine biodiversity.

COMPARANDO O USO DA PICARÉ E TARRAFA NA CARACTERIZAÇÃO DA ESTRUTURA DA ICTIOFAUNA DO ENTREMARÉS DE UMA BAÍA SUBTROPICAL

RESUMO

Embora redes-de-arrasto-de-praia (picarés) e tarrafas sejam amplamente utilizadas para amostragem de peixes em habitats marginais costeiros, ainda não há uma comparação entre tais petrechos para a determinação da estrutura da ictiofauna de planícies de maré durante a maré alta. Neste estudo, comparamos a efetividade de uma picaré de multifilamento com a efetividade de uma tarrafa de monofilamento para amostrar a estrutura da ictiofauna do entre-marés de uma baía subtropical do Brasil. A picaré apresentou um melhor desempenho geral. Em comparação com a tarrafa, a picaré amostrou (I) densidade substancialmente maior da espécie localmente dominante, *Atherinella brasiliensis*; (II) uma média densidade relativamente maior para juvenis das demais espécies localmente conspícuas, i.e., *Mugil curema*, *Eucinostomus argenteus*, *Harengula clupeola* e *Oligoplites saurus* (III); maiores valores da riqueza média e total; e (IV) melhor tanto a abundância de onívoros, quanto o número e a abundância de bentívoros. A tarrafa amostrou melhor os pequenos planctívoros, especialmente juvenis de *Sardinella brasiliensis*. Tais resultados poderão dar suporte a um futuro programa de monitoramento da ictiofauna local e enfatizam a grande importância da avaliação do desempenho de amostradores da ictiofauna antes de se iniciar quaisquer atividades de amostragem.

Palavras-chave: monitoramento ecológico; baía do Araçá; fauna neotropical; biodiversidade marinha.

INTRODUCTION

Tropical and subtropical coastal fish species show remarkable diversity in behavior, morphology, and size. Such features, coupled with a typically high local richness, make the use of multiple sampling-fish gears indispensable to achieve robust characterizations of ecological patterns. Such use is based on the assumption that one gear should overcome the sampling biases from another, improving the representation of the fish assemblage structure, i.e. species composition and abundance (ROZAS and MINELLO 1997; ROTHERHAM *et al*., 2012).

Beach seine (BS) and cast net (CN) are widely used to sample small-sized fish faunas in coastal marginal habitats (e.g. CONTENTE *et al*., 2011; STEIN III *et al*., 2014). Several studies have compared the performance of such gears with others for sampling the fish fauna (ROZAS and MINELLO, 1997; GUEST *et al*., 2003; BAKER and MINELLO, 2011). For example, in Australia's seagrass banks, BS was more accurate than the beam trawl for sampling the species composition and estimating the density of most local species (GUEST *et al*., 2003). In marsh habitats of the Gulf of Mexico, BAKER and MINELLO (2011) found that the CN undersampled the densities of small benthic species in comparison to the drop sampler and benthic sled, but the CN estimated the highest density for larger and mobile fishes. Comparisons of efficiency between CN and BS at sampling fish faunas are few. In coastal ditches in Florida, STEVENS (2006) found that CN and BS sampled similar species compositions, but the density sampled by CN was lower that sampled by BS for most species. To our knowledge, to date, there is no comparison of the structure of fish assemblage sampled by CN with that sampled by BS in non-vegetated, shallow, tidal flats habitats, during the high tide. The objective of this study was to compare the performance of the BS and CN at sampling the fish assemblage structure of a subtropical tidal flat, the Araçá Bay (southeastern Brazil).

METHODS

The study was performed at a selected, mud-bottom intertidal area of the Araçá Bay, São Paulo state. The bay is limited in the north by the Port of São Sebastião (Figure 1). The area is subjected to a semidiurnal, microtidal regime (mean tidal range ~ 1.0 m). For more details on environmental characteristics of this ecosystem, see AMARAL *et al*. (2016).

Sampling was performed during the first days of the neap tide in high water [depth (mean ± standard deviation) = 0.73 ± 0.25 m] and at night (after 6:30 pm). Five surveys were performed: spring–1 (October 2012), autumn (March 2013), winter (June 2013), spring–2 (October 2013), and summer (January 2014). In each survey, one night was required to sample with each gear. In the first two surveys, we randomly chose the sampling nights. After such surveys, the local fishermen requested us to minimize the interference of our sampling operations on their gill-net fishery that also frequently took place in the beginning of the neap tide in the bay. Thus, for the succeeding surveys, we used the CN in the first sampling nights, since this gear causes a lesser habitat perturbation than that caused by the BS.

The CN was 6.6 m in diameter and had a 10-mm monofilament mesh (between knots). The area sampled by this gear was assumed to be round (= 34.73 m^2). The CN was deployed by a well-trained local fisherman by using a non-motorized canoe. In total five points were randomly chosen in the selected area (Figure 1) and one deployment was made in each point. Points were at least 30 m apart from one another. The BS was 20-m wide and 3-m high with a 15-m long bag. This net was made of a 5-mm square-shaped multifilament mesh (between knots). In total five replicate tows, at least 25 m distant from each other, were obtained. Tows started from and ended in the sandy beach reaching the deeper limit of the selected area (Figure 1). Because of technical problems, we obtained only four replicates in autumn. The order and location of tows were randomly selected within the area. One person holding a GPS device (± 3 m) followed the tow in order to trace

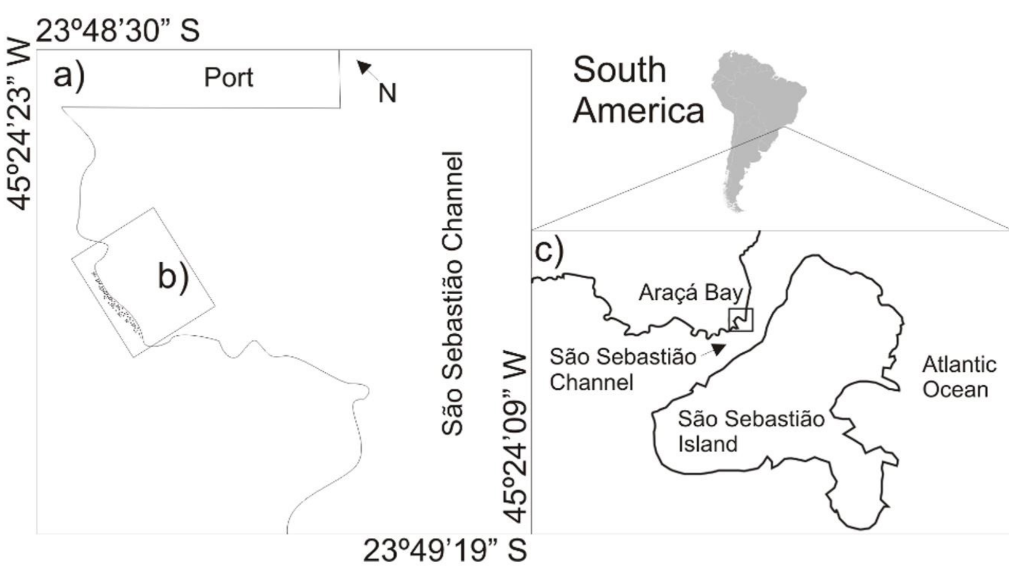

Figure 1. The Araçá Bay (a) located on the São Sebastião Channel (c), southeastern coast of Brazil, and the selected area of the intertidal habitat of the bay (b) where gears were operated. In (b), dots on the shoreline represent a sand beach and "Port", the Port of São Sebastião.

the swept area that was estimated using Google Earth. The mean sampled area was 378 ± 153 m^2.

Fishes caught were stored on ice and identified [according to FIGUEIREDO (1977), FIGUEIREDO and MENEZES (1980, 2000), MENEZES and FIGUEIREDO (1980, 1985), and CARPENTER (2002a, 2002b, 2002c)], and measured (standard length, SL; nearest ±1.0 mm) in the laboratory. Species included in the federal red list of endangered species were identified, measured, weighed, and immediately returned to the water. The species' vouchers are deposited at the Zoological Museum of the University of São Paulo (LAMAS *et al*., 2016).

Due to ecologically different patterns between juveniles and adults, and the great abundance in the bay, the Silver mojarra *Eucinostomus argenteus* (Gerreidae) and the Caitipa mojarra *Diapterus rhombeus* (Gerreidae) were separated into juvenile and adult groups and treated as distinct descriptors in the analyses. To take into account the gear effect on functional attributes of the assemblage, we also classified species into functional groups, defined on the basis of body size, coarse-scale vertical habitat use, and trophic pattern (Table 1; ERÖS *et al*., 2009). Information of such traits was obtained from literature.

A two-way design was used for testing the effect of the gear (fixed factor) and survey (random factor) on the mean richness

Table 1. Frequency of occurrence (how many times the species occurred in all replicates – FO%), the functional group (FG), and length range (standard length – SL) of the species caught using cast net (CN) and beach seine (BS) in Araçá Bay (southeastern Brazilian coast). The FG codes mean the combination of abbreviations of trophic categories, size, and habitat use pattern. Only species with FO > 4% are shown. Total of deployments per gear = 25.

Species	Family	FG	FO%		SL (mm)	
			BS	CN	min	max
Eucinostomus melanopterus J	Gerreidae	Bent.LD	21		42	88
Ctenogobius boleosoma	Gobiidae	Bent.SD	54		16	48
Trachinotus falcatus	Carangidae	Bent.SD	46		14	52
Citharichthys spilopterus	Paralichthyidae	Bent.SD	25		37	119
Umbrina coroides	Sciaenidae	Bent.SD	13		56	136
Chilomycterus spinosus	Diodontidae	Bent.SD	8		15	
Hemiramphus brasiliensis	Hemiramphidae	Herb.LP	13		102	175
Centropomus undecimalis	Centropomidae	Phyp.LP	21		123	175
Strongylura marina	Belonidae	Phyp.LP	13		168	300
Hyporhamphus roberti	Hemiramphidae	Plank.LP	8		116	136
Hyporhamphus unifasciatus	Hemiramphidae	Plank.LP	8		104	246
Anchoa tricolor	Engraulidae	Plank.SP	67		28	79
Opisthonema oglinum	Clupeidae	Plank.SP	8		66	66
Diapterus rhombeus A	Gerreidae	Bent.LD		8	118	158
Eucinostomus argenteus A	Gerreidae	Bent.LD	8	8	88	100
Eucinostomus argenteus J	Gerreidae	Bent.SD	71	68	16	89
Diapterus rhombeus J	Gerreidae	Bent.SD	50	24	15	187
Sphoeroides greeleyi	Tetraodontidae	Bent.SD	33	8	35	102
Trachinotus carolinus	Carangidae	Bent.SD	29	4	22	74
Eucinostomus gula	Gerreidae	Bent.SD	17	12	56	110
Haemulopsis corvinaeformis	Haemulidae	Bent.SD	8	20	37	128
Bathygobius soporator	Gobiidae	Bent.SD	21	4	32	116
Etropus crossotus	Paralichthyidae	Bent.SD	13	8	25	77
Prionotus punctatus	Triglidae	Bent.SD	13	8	51	70
Albula vulpes	Albulidae	Bent.SD	13	4	29	125
Orthopristis ruber	Haemulidae	Bent.SD	4	4	47	70
Mugil curema	Mugilidae	Detr.SP	75	60	19	252
Atherinella brasiliensis	Atherinopsidae	Omni.SP	96	4	20	128
Harengula clupeola	Clupeidae	Plank.SP	33	48	28	81
Sardinella brasiliensis	Clupeidae	Plank.SP	17	30	35	104
Oligoplites saurus	Carangidae	Zhyp.SP	71	28	17	114

Trophic categories: Bent = Benthivores; Detr = Detritivores; Plank = Planktivores; Omni = Omnivores; Phyp = Piscivores-hyperbenthivores; Herb = Herbivores; Zhyp = Zooplanktivores-hyperbenthivores; Size: S = Small (≤ 100 mm SL, Standard Length); L = Large (> 100 mm SL); Coarse-scale vertical habitat use: D = demersal and benthic species; P = pelagic species; A = adult and J = juvenile for *E. argenteus* and *D. rhombeus*.

(is a univariate variable, corresponding to the number of species by each gear operation) and species assemblage structure (multivariate variable = species composition and density). Density was calculated for each species and gear operation dividing the number of captured individuals by the covered area by the gear. For richness, ANOVA was run on PERMANOVA algorithm based on Euclidean distance matrices. We performed the ANOVA with PERMANOVA, because the test statistics for PERMANOVA is equivalent to F and it allows the calculation of p-values without assuming a normal distribution of errors (i.e., a calculation with permutations) (ANDERSON *et al*., 2008), a distribution not fit to our data. Before the analyses, the data were root-square transformed to reduce the heterogeneity of variances. Levene's F test for equality of variances was used to test the assumption of homogeneity of variance. Since this assumption was not met for the "gear" term in all cases, we set at 1% (UNDERWOOD, 1981).

For multivariate variable, a PERMANOVA test was based on the Bray–Curtis similarity index with root-square transformed density data. Since PERMANOVA is sensitive to differences in within-group dispersions, a permutational analysis of multivariate homogeneity of dispersions (PERMDISP) was applied to test such effects (ANDERSON *et al*. 2008), and they were found to be non-significant (spring–1, $P = 0.51$; autumn, $P = 0.30$; winter, $P = 0.06$; spring–2, $P = 0.42$; summer, $P = 0.55$) and thus, irrelevant for the PERMANOVA results. Post-hoc permutational t-tests were applied to verify significant faunal differences between the pairs of gears. SIMPER procedure was applied to 90% cumulative contribution cut-off level to determine the species that contributed to the faunal differences between gears. Determinations of p-values for tests were based on 9,999 permutations. PERMANOVA was performed using PRIMER 6 v. 6.1.11 + PERMANOVA v. 1.0.1 (ANDERSON *et al*., 2008; CLARKE and GORLEY, 2006).

RESULTS

A total of 47 species was captured using both gears. BS sampled greater richness (n = 41) than CN (24). A total of 23 and 6 species were exclusively captured using BS and CN, respectively. BS sampled greater number of functional groups (n = 12) than CN (8). None functional group was exclusively recorded by CN. Half of the large-sized (> 100 mm SL) functional groups captured by BS were absent in the CN catches (Table 1).

ANOVA results revealed that gear, survey and survey–gear interaction significantly affected the mean richness (Table 2). The significant result for the interaction implies that the gear effect was inconsistent throughout the survey. In fact, the richness differed significantly according to gear in all pair-wise comparisons of the post-hoc tests (t-test: autumn, $P = 0.004$; winter, $P = 0.007$; spring-2, $P < 0.001$; summer, $P < 0.001$), except in one case (spring-1, $P = 0.99$). In all cases of the significant post-hoc tests, the mean richness was greater using BS than using CN (mean richness: autumn BS = 12.5, CN = 4; winter BS = 11.4, CN = 3.8; spring-2 BS = 9.4, CN = 4; summer BS = 7.4, CN = 2.6). Most part of the total variance in the mean richness was attributable to gear differences (Table 2).

PERMANOVA results revealed that, while the main effect of gear showed a clear tendency to significance, the gear effect was significantly dependent on the survey (Table 2). The assemblage of species differed significantly according to gear in all pair-wise comparisons of the post-hoc tests (t-test: spring-1, $P = 0.0063$; autumn, $P = 0.0138$; winter, $P = 0.0072$; spring-2, $P = 0.0090$; summer, $P = 0.0100$). Gear-survey interaction and gear were responsible for 27% and 20% of total variability, respectively (Table 2).

The results from SIMPER analysis revealed that (I) such gear-survey interaction (Table 2) was mainly due to the seasonal variability in abundance of the most abundant and frequent species (the "main species", i.e. present in at least ≥ 30% of replicates of each gear and totaled cumulatively 95% of the total density of each gear); (II) the main species also accounted for most of the faunal dissimilarity between gears across the surveys (SIMPER results: mean percentage dissimilarity = 81.8%, ranging from 74.3% to 90.0%); and (III) despite the seasonal faunal variability, the pattern of differences in abundance of the main species between the gears was relatively persistent across the surveys. Due to such reasons, and for the sake of simplicity, rather

Table 2. PERMANOVA results of the test of the null hypothesis of no gear and survey effect on the intertidal assemblage. Significant values ($P < 0.05$) are in bold.

Source	d.f.	SS	MS	Pseudo–F	*P*	*Var (%)*
Fish species richness						
Gear (G)	1	7.5	7.5	15.2	**0.017**	42.9
Survey (S)	4	1.0	0.2	2.7	**0.038**	10.1
GxS	4	2.0	0.5	5.5	**0.001**	23.0
Residuals	39	3.5	0.1			24.0
Fish assemblage structure						
Gear (G)	1	6137.3	6137.3	2.9	0.0564	19.0
Survey (S)	4	9334.6	2333.7	4.3	**0.0001**	20.1
GxS	4	8469.9	2117.5	3.9	**0.0001**	26.6
Residuals	39	20904	535.9			34.3

SS = Sum of Squares; d.f. = degrees of freedom; MS = Mean of Square; Var = percentage variance (how much of total variance is attributable to each term).

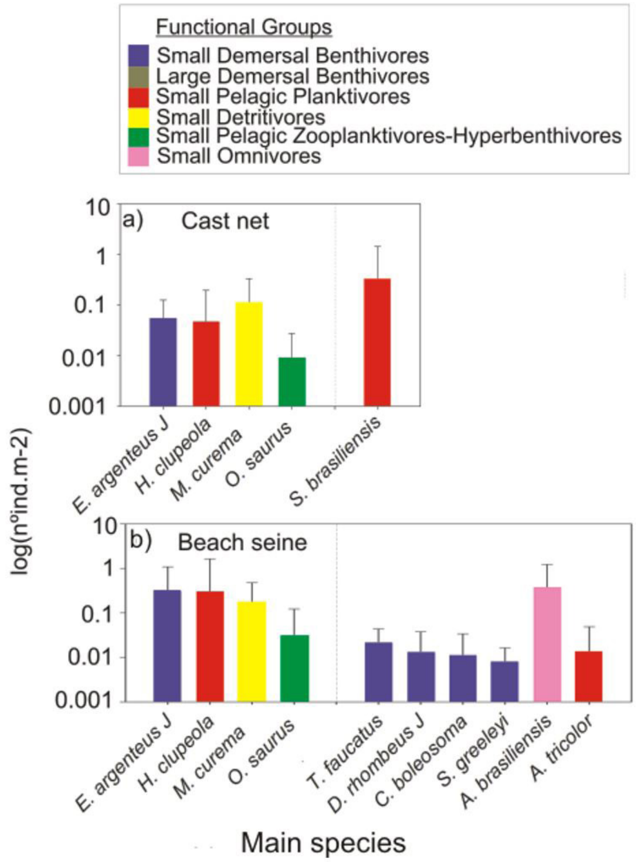

Figure 2. The mean density of the main species (present in at least ≥ 30% of replicates and totaled cumulatively 95% of the total density of each gear) of the cast net a) and beach seine b). The functional group of each species is also shown. Main species shared by both gears are shown on the left side of the dotted line of the graphs; those classified as main species in only one gear are shown on the right side. Density is in log10-scale. Bars represent ± standard deviation. After the name of some species, “J” = juvenile.

than showing the full SIMPER results, we showed graphically the abundance of the main species responsible for the between-gear faunal differences, averaged across the surveys (Figure 2).

BS and CN performed similarly for representing the top four most abundant, main species, i.e., White mullet *Mugil curema* (Mugilidae), juveniles of *E. argenteus*, False herring *Harengula clupeola* (Clupeidae), and the Leatherjacket *Oligoplites saurus* (Figure 2). This determined that both gears were relatively similar at collecting small detritivores (exclusively represented by *M. curema*) and small zooplanktivores and hyperbenthivores. However, compared to CN, BS sampled (I) slightly greater density for the most abundant, main species that were common to both gears; (II) a higher number of main species (6 versus 1), and (III) the higher mean density of the Brazilian silverside *Atherinella brasiliensis* (Atherinopsidae) (Figure 2). These outcomes also meant that the BS sampled better the number and abundance of benthivorous fish species and the abundance of omnivores (exclusively represented by *A. brasiliensis*) than CN. CN best sampled only the juveniles of the Brazilian sardinella, *Sardinella brasiliensis* (Clupeidae). This fact and the high CN catches of *H. clupeola* indicate that CN sampled better the diversity of small planktivores (Figure 2).

DISCUSSION

The overall best performance of the BS for sampling the structure of the Araçá Bay intertidal fish assemblage might be because, besides the smaller mesh size of the BS, the relative catchability and mean area sampled were greater for BS than for CN, resulting in a higher capacity of confining fish per sample unit (NÉDÉLEC and PRADO, 1990; GUEST *et al*., 2003; STEVENS, 2006; COLWELL, 2009). Despite not efficient for benthic fishes, the CN was efficient for capturing small pelagic fishes, especially *S. brasiliensis* juveniles. This performance might be related to the operation characteristics of the CN. When the area confined by this net after casting is gradually enclosed, fishes that remain close to, or buried in the substrate might escape beneath the lead line, whereas small pelagic fishes remain in the water column and are effectively enclosed in the bag or entangled on the net body (BAKER and MINELLO, 2011). Moreover, the aggregated dispersion, typical of shoaling pelagic fishes, may have contributed for the higher performance of the CN on these fishes (MONTEIRO-NETO and PRESTRELO, 2013).

Although there are differences in mesh size, type of wire, and dimensions among our gears and those of previous studies, similarities emerged when comparing our results with previous ones. The BS was also more efficient than the CN for estimating the density of main species in a non-vegetated ditches of Florida (STEVENS, 2006) and in creeks of Australia (JOHNSTON and SHEAVES, 2008). The mean fish richness and abundance were better sampled using BS than using CN in an artificial freshwater reservoir in the northeastern Brazil (MEDEIROS *et al*., 2010). The low CN performance for sampling richness and benthic species was also found when comparing the CN with the centipede net (WANG *et al*., 2009), drop sampler, and benthic sled (BAKER and MINELLO, 2011), gears that are specifically designed for capturing benthic fishes (ROZAS and MINELLO, 1997).

We had expected that our BS was effective for capturing small midwater and bottom-dwelling species (BUTCHER *et al*., 2005; DEMBKOWSKI *et al*., 2012), but not for capturing larger (>100 mm SL) species because of its relatively low operating speed (BAYLEY and HERENDEEN, 2000) and multifilament line that minimizes entangling (COLLINS, 1979). Due to these limitations, we had included the CN for sampling species larger than those captured by BS, because the speed for confining the targeted area, the type of line (monofilament), and the larger mesh size of the CN benefit containment and entangling of larger and faster species (COLLINS, 1979; STEIN III *et al*., 2014). Contrary to our expectations, the large-sized fishes were better sampled by BS than by CN. This might be because both the coverage area and relative catchability of the BS were greater and could compensate the limited efficiency of BS for entangling larger fishes owing to the net’s small-mesh size and multifilament wire (COLLINS, 1979), a hypothesis to be assessed in the future.

CONCLUSION

Successful ichthyological studies are underpinned by a previous sampling gear selection process, which is generally neglected in the context of the Neotropical fish fauna. Our results highlight the importance of this step and could support the gear selection in fish-monitoring programs in similar tidal flats from elsewhere and in Araçá Bay, where a monitoring will be essential if the planned expansion of the Port of São Sebastião over the bay occurs. For Araçá Bay, a better monitoring of the intertidal fish assemblage structure will be achieved using beach seine; while a better monitoring of small pelagic fishes, especially *S. brasiliensis* juveniles (one region's most important fisheries resource), will be reached using cast net. Replication of our gear comparison in other tidal flats was logistically impossible and was the drawback of the study. Such replications should be performed in the future in order to verify the generalizations of our conclusions.

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