

Comparing sampling strategies for surf-zone fish communities

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Abstract. Beach seining is used for capturing surf-zone fishes for scientific or fishery purposes. Sampling gear and different sampling approaches pose difficulties for comparative analyses. We compared parallel tows (PT) and beach hauls (BH) using the same beach seine, observing differences in species number (SPUA = number of species m^{-2}), total and relative abundance (CPUA = number of individuals m^{-2}) and average size. ANOVA and PERMANOVA showed that both the number of species and abundance were significantly different between sampling approaches and seasons, with higher values for BH. Most abundant *Umbrina coroides* showed significant interactions with higher CPUA for PT in summer and *Diplodus argenteus* for BH from winter to summer. *Harengula clupei* and *Trachinotus carolinus* showed significant differences between sampling strategy with BH capturing more individuals. *Trachinotus carolinus* and *Sardinella brasiliensis* both showed differences between seasons with higher CPUA in the summer and autumn respectively. Results suggest that catch structure and composition differ between sampling strategies, but a seasonal component associated with recruitment of one or more species also influenced the catch. The PT appears to be more effective but time consuming. The BH may be an alternative method, but results may not be comparable.

Additional keywords: biomonitoring, littoral zone.

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Introduction

Beach seining is a well established method for sampling surf-zone fishes (e.g. Dahlberg 1972; Monteiro-Neto *et al.* 2003; Gaelzer and Zalmon 2008) and shallow-water sandy beach habitats (Spach *et al.* 2006; Jurajda *et al.* 2009). Some advantages of this technique include its simplicity and ability to sample large areas (Pierce *et al.* 1990). Beach seines are usually towed parallel to shore at a certain depth, pulled by one person on each side of the seine (Godefroid *et al.* 1997, 1998; Monteiro-Neto *et al.* 2003; Gaelzer and Zalmon 2008). Although this is probably the usual procedure for sampling surf-zone fish communities, seines of different lengths, heights and mesh sizes were used by several authors limiting possible faunal comparisons between large geographical areas (Dahlberg 1972; Peters and Nelson 1987; Ross *et al.* 1987). Monteiro-Neto and Musick (1994) suggested that comparisons between datasets collected with beach seines of different lengths and similar mesh sizes are feasible but limited.

Small-scale fishers also use beach seines to harvest fish stocks in coastal waters (Lima and Pereira 1997; McClanahan and Mangi 2004; Tubino *et al.* 2007) and estuaries (Stokesbury *et al.* 1999; Gray and Kennelly 2003; Butcher *et al.* 2005; Gray *et al.* 2005). Fishers set their beach seines from small boats, in a

semi-circular path, hauling it back towards the shore, either by hand (Lima and Pereira 1997) or small winches (Gray and Kennelly 2003). Fishes do not usually enter the cod-end until just before the cessation of seining, when the net is landed in shallow water.

Fishers at the fishing village of Itaipu, Niterói, RJ, Brazil, have a long tradition of harvesting local fish stocks, using the previously mentioned semi-circular haul strategy. Their local knowledge passes across generations through personal experience and oral history for more than 200 years (Lima and Pereira 1997), and may be regarded as fisher's traditional ecological knowledge (TEK). While observing our 'scientific' method of sampling surf-zone fishes, local fishers raised the question of whether towing the seine parallel to shore would provide a similar catch composition to their fishing strategy. The fishers' expectations were that our method would catch less fishes and provide a biased estimate of abundance and diversity of near-shore fishes.

In order to test this hypothesis, we compared the two beach seine towing strategies (parallel tow – PT and semi-circular beach haul – BH) using the same fishing gear to assess species composition, abundance and average size of captured individuals. We also tested whether such changes would vary on a

seasonal basis since seasonal variation in surf-zone fish assemblages has been reported.

Material and methods

We conducted our experiment at three sites along Itaipu beach, Niterói, RJ, South-eastern Brazil, a sandy beach partially protected from incoming swells due to the presence of three islands in the path of predominant waves (Fig. 1). Artisanal fisheries, including beach seining and gill-netting are the main fishing activities present in the area (Tubino *et al.* 2007).

Six samples (three for parallel tow and three for beach haul) were collected in the morning period, once or twice (August, October) a month, between July 2002 and July 2003, totalling 45 samples for each sampling strategy. Collected fishes were placed in plastic bags (one sample) and preserved on ice. In the laboratory, fishes were identified to species level, measured and weighed.

The net used was 16-m long and 2.5-m high with mesh size of 10 mm. The sampling strategies were as follows:

- (1) Parallel tow (PT) – one pole of 2.5 m was tied to each side of the net. The net was then dragged parallel to the shore line for 100 m at a maximum depth of 1.6 m. To calculate the area swept by the net, we measured the distance between poles during tows (three measurements during one tow per month) and calculated the average opening of 14.10 m. We then estimated that the average area covered per sample was 1410 m². Each parallel tow took approximately 7 min to be completed.
- (2) Beach haul (BH) – one rope of ~30 m was tied to each side of the net, and the net set at ~28 m from the shore, with the aid of a floating device. The net was then hauled back to shore pulling both ropes at the same time. The swept area was calculated by measuring the mouth of the net at the beginning and at the end of the haul. The average opening at the beginning was 14.0 m and at the end, 1.0 m. Using the trapeze formula for calculating the area, we estimated that an average area of 210 m² was sampled. Semi-circular hauls took about 4 min to be completed.

Species richness per unit area (SPUA = number of species m⁻²), catch per unit area (CPUA = number of individuals m⁻²) for the total catch and the five most abundant species per sample were calculated. A two-way ANOVA was used to test for significant differences between sampling strategies (PT, BH), seasons (winter – June to August; spring – September to November; summer – December to February; autumn – March to May) and their interactions, for the number of individuals, number of species, SPUA, total CPUA and CPUA of the five most abundant species. Variables were tested for normality (Kolmogorov–Smirnov test) and homogeneity of variances (Cochran tests), and transformed ($\log_{10}(x+1)$) to meet ANOVA assumptions. Analyses were performed in STATISTICA 7 software (StatSoft, Tulsa, OK, USA).

Two-way Permutational Multivariate Analysis of Variance (PERMANOVA – Anderson 2005) was used for testing differences in fish abundance (number of individuals), CPUA and average size composition per species between sampling strategies, seasons and their interactions. We used the Bray–Curtis

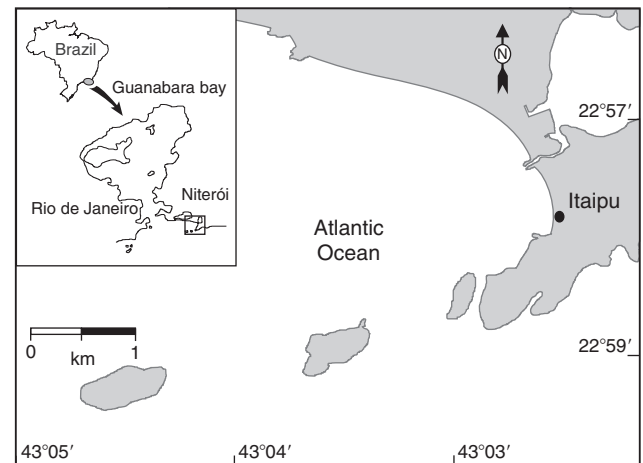


Fig. 1. Research area at Itaipu beach, Niterói, south-eastern Brazil.

similarity measure and 9999 permutations (Clarke 1993). This test performs an ANOVA experimental design on the basis of any distance measure, using a Monte Carlo Permutation method (Anderson 2005). Pairwise post hoc tests were performed to further investigate differences between seasonal groups.

A Bray–Curtis similarity matrix, calculated from the original catch data, was used in Similarity Percentages (SIMPER) analysis to determine which species were most responsible for the dissimilarity between the two strategies (Clarke 1993). Both PERMANOVA and SIMPER analysis were performed in PRIMER 6 + PERMANOVA software (Clarke and Gorley 2006).

Results

In total, 48 species and 15 611 individuals, belonging to 28 families, were captured. The five most abundant species (*Umbrina coroides*, *Harengula clupeiola*, *Diplodus argenteus*, *Trachinotus carolinus* and *Sardinella brasiliensis*) represented 88.4% of the catch in numbers (Table 1). Individuals ranged in size between 10 and 200 mm of total length (TL).

The parallel tow (PT) caught 46 species and 12 245 individuals. The most abundant species sampled using this method were *U. coroides*, *D. argenteus* and *T. carolinus*, comprising 67.6% of the total number caught. The beach haul (BH) yielded 34 species and 3366 individuals. *H. clupeiola*, *S. brasiliensis* and *T. carolinus* were the most abundant species and represented 72.5% of the numerical abundance (Table 1).

Two-way ANOVA for number of species, species richness per unit area (SPUA), total fish abundance and catch per unit area (CPUA) were significantly different for both factors but not for the interaction term (Table 2). The PT captured more species ($\bar{x} = 7.5$ spp. sample⁻¹) in absolute numbers than the BH ($\bar{x} = 5.2$ spp. sample⁻¹). Corrected by the swept area (SPUA), the BH was more efficient at capturing more species per area ($\bar{x} = 0.5$ spp. m⁻²) than the PT ($\bar{x} = 2.5$ spp. m⁻²). Despite seasonal differences in both number of species and SPUA, Student–Newman–Keuls (SNK) post hoc tests were unable to determine which groups differed.

Table 1. Percentage abundance (A) and frequency of occurrence (FO) of species collected through parallel tow and beach haul strategies at Itaipu, RJ, Brazil

Species were ordered by decreasing total catch. At the bottom of the table, the total number of individuals, species and samples are indicated. 0.0 = less than 0.1%

Species	Parallel tow		Beach haul		Total catch (%)
	A (%)	FO (%)	A (%)	FO (%)	
<i>Umbrina coroides</i>	34.2	82.2	5.94	33.3	28.1
<i>Harengula clupeiola</i>	11.7	71.1	47.6	62.2	19.5
<i>Diplodus argenteus</i>	20.9	57.8	8.9	42.2	18.3
<i>Trachinotus carolinus</i>	12.5	71.1	9.8	77.8	11.9
<i>Sardinella brasiliensis</i>	9.4	37.8	15.0	33.3	10.6
<i>Menticirrhus littoralis</i>	3.6	75.6	2.8	40.0	3.4
<i>Polydactylus oligodon</i>	2.0	13.3	0.1	4.4	1.6
<i>Eucinostomus argenteus</i>	0.9	37.8	1.9	44.4	1.1
<i>Atherinella brasiliensis</i>	0.1	11.1	2.8	28.9	0.7
<i>Pomatomus saltatrix</i>	0.3	15.6	2.5	24.4	0.7
<i>Anchoviella lepidentostole</i>	0.6	6.7	0.1	4.4	0.5
<i>Menticirrhus americanus</i>	0.6	33.3	0.4	17.8	0.5
<i>Astroscopus y-graecum</i>	0.4	15.6	0.4	13.3	0.4
<i>Polydactylus virginicus</i>	0.5	17.8	0.3	13.3	0.4
<i>Dactylopterus volitans</i>	0.4	6.7	0.0	2.2	0.3
<i>Trachinotus falcatus</i>	0.4	15.6	0.1	4.4	0.3
<i>Prionotus punctatus</i>	0.2	17.8	0.0	2.2	0.2
<i>Anchoa lyolepis</i>	0.1	4.4	0.3	2.2	0.1
<i>Bothus robinsi</i>	0.2	11.1	0.1	6.7	0.1
<i>Chaetodipterus faber</i>	0.2	15.6			0.1
<i>Fistularia petimba</i>	0.1	17.8	0.1	4.4	0.1
<i>Mugil liza</i>	0.1	4.4	0.1	4.4	0.1
<i>Orthopristis ruber</i>	0.1	13.3			0.1
<i>Selar crumenophthalmus</i>	0.0	2.2			0.1
<i>Selene vomer</i>	0.1	6.7			0.1
<i>Tylosurus acus</i>			0.0	2.2	0.1
<i>Albula vulpes</i>	0.0	8.9	0.0	2.2	0.0
<i>Boridia grossidens</i>	0.0	6.7			0.0
<i>Bothus ocellatus</i>	0.0	4.4	0.1	6.7	0.0
<i>Caranx hippos</i>	0.0	2.2	0.0	2.2	0.0
<i>Centropomus undecimalis</i>	0.0	2.2			0.0
<i>Cetengraulis edentulus</i>	0.0	2.2			0.0
<i>Chloroscombrus chrysurus</i>	0.0	2.2			0.0
<i>Citharichthys macrops</i>	0.0	4.4	0.1	6.7	0.0
<i>Etropus crossotus</i>	0.0	4.4	0.1	8.9	0.0
<i>Eucinostomus gula</i>	0.0	2.2	0.0	2.2	0.0
<i>Genidens genidens</i>	0.1	4.4			0.0
<i>Lagocephalus laevigatus</i>	0.0	8.9			0.0
<i>Oligoplites saurus</i>			0.0	2.2	0.0
<i>Scomber japonicus</i>	0.0	2.2	0.0	2.2	0.0
<i>Scorpaena isthmensis</i>	0.0	2.2			0.0
<i>Sphoeroides spengleri</i>	0.0	2.2	0.0	2.2	0.0
<i>Sphyræna tome</i>	0.0	4.4			0.0
<i>Stephanolepis hispidus</i>	0.0	6.7			0.0
<i>Synodus foetens</i>	0.1	6.7	0.0	2.2	0.0
<i>Trachinocephalus myops</i>	0.0	2.2	0.1	8.9	0.0
<i>Trachinotus marginatus</i>	0.0	2.2	0.1	2.2	0.0
<i>Upeneus parvus</i>	0.0	4.4			0.0
Total individuals	12 245		3366		15 611
Total species	46		34		48
Total samples		45		45	90

Table 2. Two-way ANOVAs with interaction for total fish abundance, catch per unit area (CPUA), species number, species richness per unit area (SPUA) and CPUA of the five most abundant species, with sampling strategy and season as main factors
d.f. = degrees of freedom; F = test value. * = $P < 0.05$; ** = $P < 0.01$; ns = not significant

Source of variation	Sampling strategy			Season			Interaction		
	d.f.	F	P	d.f.	F	P	d.f.	F	P
Number of species	1	9.25	0.00**	3	3.05	0.03*	3	0.40	0.75ns
SPUA	1	171.12	0.00**	3	2.94	0.04*	3	0.48	0.70ns
Total fish abundance	1	28.12	0.00**	3	4.73	0.00**	3	0.66	0.58ns
CPUA	1	4.96	0.03*	3	4.72	0.00**	3	0.66	0.58ns
<i>U. coroides</i>	1	16.53	0.00**	3	2.25	0.09ns	3	3.67	0.02*
<i>H. clupeiola</i>	1	4.55	0.04*	3	1.60	0.19ns	3	0.27	0.85ns
<i>D. argenteus</i>	1	1.61	0.21ns	3	36.52	0.00**	3	3.61	0.02*
<i>T. carolinus</i>	1	4.37	0.04*	3	12.89	0.00**	3	0.19	0.91ns
<i>S. brasiliensis</i>	1	0.73	0.39ns	3	6.29	0.00**	3	0.47	0.71ns

Table 3. Two-way PERMANOVA with interaction for fish abundance, catch per unit area (CPUA), and average size composition per species with sampling strategy and season as main factors

d.f. = degrees of freedom; F = test value; $P_{(MC)}$ = Monte Carlo asymptotic P -values. * = $P < 0.05$; ** = $P < 0.01$; ns = not significant

Source of variation	Sampling strategy			Season			Interaction		
	d.f.	F	$P_{(MC)}$	d.f.	F	$P_{(MC)}$	d.f.	F	$P_{(MC)}$
Fish abundance	1	6.78	0.00**	3	4.11	0.00**	3	1.36	0.08ns
CPUA	1	4.49	0.00**	3	4.58	0.00**	3	0.91	0.63ns
Size composition	1	4.29	0.00**	3	3.97	0.00**	3	0.98	0.51ns

More individuals were captured with the PT ($\bar{x}_n = 272.1$) than with the BH ($\bar{x}_n = 74.8$), but correcting by the swept area the BH showed an increased abundance ($\bar{x}_{CPUA} = 35.6 \text{ ind. m}^{-2}$) compared with the PT ($\bar{x}_{CPUA} = 19.3 \text{ ind. m}^{-2}$). Again, SNK post hoc tests were unable to determine which groups differed.

Two-way ANOVA for the five most abundant species showed significant interactions between factors for *U. coroides* and *D. argenteus*. *U. coroides* showed higher CPUA for PT in the summer ($\bar{x}_{CPUA} = 20.1 \text{ ind. m}^{-2}$), whereas *D. argenteus* had higher CPUA for BH from winter to summer ($\bar{x}_{CPUA} = 23.5 \text{ ind. m}^{-2}$, 14.8 ind. m^{-2} and 23.1 ind. m^{-2} respectively). *H. clupeiola* and *T. carolinus* showed significant differences between sampling strategy with BH capturing more individuals than the PT for both species. Also, *T. carolinus* and *S. brasiliensis* showed differences between seasons with higher CPUA in the summer and autumn respectively.

PERMANOVA indicated that fish abundance, CPUA and average size composition per species were significantly higher for BH ($\bar{x}_{score} = 59.1$, 59.1 and 52.7 respectively) than for PT ($\bar{x}_{score} = 56.9$, 56.8 and 46.8 respectively). Significant seasonal differences were also found, but post hoc pairwise comparisons could not detect where those differences occurred between seasons. The interaction between sampling strategies and seasons was not significant (Table 3).

SIMPER analysis revealed within group similarity of 16.8% for BH and 19.6% for PT, and between group dissimilarity of 84.8%. The five most abundant species were responsible for 79.7% of the dissimilarity between sampling strategies.

Discussion

The selection of the appropriate method to sample fish in a given environment is essential for obtaining unbiased estimates of species diversity and abundance within the community under study (Bayley and Herendeen 2000; Gray *et al.* 2005; Rotherham *et al.* 2008). Several authors have addressed the issue of how different gears effectively sample fish communities in several environments, including rivers (Clavero *et al.* 2006; Wanner *et al.* 2010), lakes (Hayes 1989), estuaries (Stokesbury *et al.* 1999; Butcher *et al.* 2005; Gray *et al.* 2005) and the surf zone (Monteiro-Neto and Musick 1994). In general, studies have shown that different gears may be more suitable to sample specific habitats (Guest *et al.* 2003), species (Clavero *et al.* 2006) or size classes of one or more species (Shoup *et al.* 2003).

Despite the fact that beach seining is the most efficient way to sample fish in shallow waters of sandy beaches, the variability of beach seine dimensions and mesh sizes hinders comparisons among studies (Monteiro-Neto and Musick 1994). As previously noted, beach seining is usually conducted parallel to shore (Monteiro-Neto and Musick 1994; Monteiro-Neto *et al.* 2003; Gaelzer and Zalmon 2008), but the questions of how sampling is conducted and how it may affect catches within the same habitat have not been addressed. Thus, the questioning of our sampling by Itaipu fishers was pertinent and important.

The results obtained in this study showed that catch structure and composition differed between sampling strategies, suggesting that beach seine catches vary whether the seine is towed or

hauled. Monteiro-Neto and Musick (1994) observed that sampling the surf zone with nets of similar mesh sizes yielded comparable results in a relative scale but not in absolute values, and that species composition would not vary significantly. Gray *et al.* (2005) compared multi-mesh gill-nets and trammel nets, but did not observe significant differences in the number of individuals, species composition and catch per unit effort (CPUE). Maintaining gear and mesh size constant, our results contradicted these findings, indicating that the way we sampled the fish fauna in the surf zone strongly affected species abundance, richness, size of individuals and species-specific CPUE. Therefore, once a sampling gear is chosen to study the fish fauna in a certain habitat, it is also important to select the gear operation, as different sampling strategies may result in distinct catch assemblages.

In our study, the total number of species and individuals was higher in the PT, with more efficient catch of demersal and bottom oriented fish species (*U. coroides*, *M. littoralis*). The beach haul (BH) appeared to be more efficient for catching shoaling pelagic fishes (*H. clupei*, *S. brasiliensis*). Gear efficiency and selectivity may be attributed to fish escape (Bayley and Herendeen 2000; Butcher *et al.* 2005) or avoidance behaviour (Guest *et al.* 2003; Shoup *et al.* 2003). Butcher *et al.* (2005) observed that mullets escaped the net by jumping over the surface line. Furthermore, patchy distribution of individuals of one or more species could influence catch efficiency and affect comparative results between gears and fishing methods (Guest *et al.* 2003).

Van Den Avyle *et al.* (1995) observed that the preferred sampling method for a given study will depend on the fish size-range and habitat being sampled. Butcher *et al.* (2005) pointed out that at least one out of four fishing gears tested in their experiment showed differences in the capture efficiency for one of the target species (*Sillago ciliata*). Similar results were obtained by Clavero *et al.* (2006) comparing fish traps, suggesting that population estimates based on single-gear catches may lead to biased estimates of length–frequency or abundances in some species. Moreover, Shoup *et al.* (2003) highlighted that distinct net types caught different species and presented particular species-specific CPUE and length distributions. The authors indicated that using several gears and sampling strategies would provide a more complete picture of the abundance and size structure of the fishery than using only one net type. Although the CPUE for the BH was higher than the PT in absolute values, the BH captured fewer fish species. Accordingly, the number of replicate samples should be increased when applying this strategy in order to avoid underestimating species richness of a certain surf-zone habitat.

Since the PT takes longer, with the seine being dragged as far as 100 m, it may provide enough time for fast-swimming pelagic species to avoid the net, while capturing slow-moving bottom oriented species. On the other hand, the BH requires less time and takes shoaling pelagic fishes by surprise, rapidly hauling them to shore. Nevertheless, the amount of ground covered by this strategy is small, providing less chance to catch bottom-oriented species.

A consistent seasonal component appeared in the catches influencing SPUA and CPUA. Several authors have pointed out the nursery role of the surf-zone habitat (e.g. Vieira 1991;

Giannini and Paiva-Filho 1995; Monteiro-Neto *et al.* 2003; Strydom and d'Hotman 2005) for several fish species. Seasonal variations may be attributable to recruitment patterns of young of the year in the surf zone, causing seasonal changes in species composition and numbers of individuals. Many of these species are either surf-zone residents (*censu* Monteiro-Neto *et al.* 2003) or estuarine-dependent species that use the surf-zone habitat as a transition zone between offshore spawning areas and estuarine nurseries (Monteiro-Neto *et al.* 1990; Vieira 1991; Strydom and d'Hotman 2005). Nevertheless, our analysis indicated that both sampling strategy and seasons were independent factors, not interacting with each other most of the time.

The beach seine fishery carried out by Itaipu fishers is a well established and efficient method for capturing shoaling coastal species (Lima and Pereira 1997; Seckendorff and Azevedo 2007). The seine is often set in deeper waters, several hundred metres from the shore, using a boat. It is not surprising that fishers considered our sampling procedure a very unorthodox method to catch fish, since towing their net in the same manner seemed to be an impossible task. Our experiment demonstrated that both sampling strategies, PT and BH, worked well within the surf zone under 1.2-m deep, but results differed between them. In absolute values, the PT caught more fish and species than the BH, even though pelagic fishes were less represented in these catches. Regarding the sampling area, the BH appeared to be more productive, although its small sampled area could be a problem for obtaining unbiased estimates of the surf-zone fish fauna. The PT appears to be more effective for capturing surf-zone fishes, but is also more time consuming. The BH may be an alternative method for obtaining more replicate samples, but results from this strategy may not be comparable with others due to the differences found. We suggest that further studies should acknowledge both the BH and PT as complementary strategies to sample surf-zone fishes. Nevertheless, the choice of strategy may depend on the objectives of the study.

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