



Utilization patterns of surf zone inhabiting fish from beaches in Southern Brazil

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Abstract. The ecological role of sand beaches as nursery ground for fish, by providing refuge, food and protection, was sustained in this work given the dominant presence of juvenile fish, which corresponded to 98% of total capture. These habitats could be considered accessory areas for transient fish fauna such as anchovies (*Anchoa lyolepis* and *Anchoa tricolor*) and herrings (*Sardinella brasiliensis*) from close by estuarine regions. These species presented an increase in size during the study period, which indicates the nursery function of the area. Other species, such as juveniles of *Trachinotus carolinus* and *Menticirrhus littoralis* displayed evidence of strong site-fidelity, and remained in the surf zones the entire year. *Harengula clupeiola* showed the most defined growing pattern, and apparently, bigger individuals move offshore to reproduce in January, while they are recruited back in February. The abundant food supply provided by the many small-size species also attracts the visit of predators such as *Pomatomus saltatrix*, which doubled its size during the present study. In conclusion, the evolutionary patterns of recruitment and reproduction established in accordance with seasonal fluctuations have made sand beaches important spatial resources for many fish species, which comprise the lower levels of marine food webs, and are consequently essential for the environmental health.

Key words: Sand beaches, ichthyofauna, nursery, recruitment, reproduction, Pontal do Sul.

Resumo. Padrões de utilização de peixes da zona de arrebentação de praias no sul do Brasil.

A importância ecológica de praias arenosas como locais de criação para peixes provendo refúgio, alimento e proteção é sustentada neste trabalho devido a presença quase exclusiva de juvenis que corresponderam a 98% da captura total. Esses habitats podem ser considerados áreas acessórias às espécies transientes como as manjubas (*Anchoa lyolepis* e *Anchoa tricolor*) e sardinhas (*Sardinella brasiliensis*) as quais apresentaram incremento no tamanho durante o período deste estudo, indicando a função de berçário. De forma oposta juvenis de *Trachinotus carolinus* e *Menticirrhus littoralis* parecem apresentar fidelidade local às zonas de arrebentação que são extensivamente utilizadas por juvenis durante todo o ano. *Harengula clupeiola* apresentou o mais definido padrão de crescimento no qual em janeiro indivíduos maiores aparentemente se movem para fora da costa para se reproduzirem, com os recrutas retornando em fevereiro. A grande abundância de alimento provida por espécies de pequeno porte também atraem predadores como *Pomatomus saltatrix* que dobrou de tamanho durante este estudo. Como conclusão os padrões evolutivos de recrutamento e reprodução estabelecidos em sincronia com flutuações sazonais tornaram as praias importantes recursos espaciais para muitas espécies de peixes que compõe estágios iniciais da cadeia alimentar marinha e conseqüentemente essenciais à saúde ecossistêmica.

Palavras-chave: Praias arenosas, ictiofauna, berçário, recrutamento, reprodução, Pontal do Sul.

Introduction

It is academically accepted that fish assemblages of surf zones are numerically dominated by few species (McFarland 1963, Modde & Ross 1981) made up largely of juveniles with small body size (Robertson & Lenanton 1984, Lasiak 1986, Reina-Hervas & Serrano 1987, Gibson *et al.* 1996, Clark 1997). These characteristics are usually found in sheltered estuarine areas where the nursery function has been well established (Gibson 1973, Ruple 1984, Lasiak 1984, Ross *et al.* 1987). The high dynamics of surf zones may act as sheltered habitats and offer the same advantages of protection against predators and abundant food supply (McLachlan 1983, Ross 1983, Lasiak 1986, Bennet 1989) to marine fish. These features are provided by a continued wave action above the sandy floor, making nutrients available to marine food web (McLachlan 1980) and diminishing visibility due to increased turbidity (Gibson 1973).

In general, highest diversities and abundances are found in warmer months (Fox & Mack 1968, Naughton & Saloman 1978, Modde & Ross 1981, Ross 1983, Lasiak 1984), while small abundances are observed during winter months. Conversely, Godefroid (1996) and Monteiro-Neto *et al.* (1990), who worked on sandy beaches in Southern Brazil, found that smallest abundances of fish occurred in spring. Many authors attributed the seasonal fluctuation of abundance to temperature, salinity, turbidity and wind velocity, with the latter factor being considered less important during long-period fluctuations and more determinant only in short-time changes (Modde & Ross 1981, Allen 1982, Ross *et al.* 1987, Lamberth *et al.* 1995). Seasonal cycles in fish abundance and diversity at beach surf zones can not be ascribed to changes in physical conditions, but rather to the reflex of recruitment patterns determined by reproductive activity and coastal circulation (Ross *et al.* 1987, Gibson *et al.* 1993, Lamberth *et al.* 1995), which occur either by adult emigration or temporary exploration of adjacent high productivity areas (Allen 1982).

The present study aimed to provide detailed biological information on size characterization and temporal utilization of fish inhabiting shallow habitats such as sand beaches, and the particularities within each species.

Materials and methods

Study site

The study took place at Pontal do Parana, Parana State, Southern Brazil. The sampled area is approximately 3 km long and is geographically protected by prevailing East-Southeastern winds because of the presence of two islands (Mel Island and Galheta) and submerged sand bars built by the tidal regime of Paranagua bay estuarine complex (Fig. 1). According to Godefroid (1996), the studied area is classified as dissipative with sediment grain size diminishing from the entrance of Paranagua bay southwards. The beaches are microtidal (tidal range < 1.5 m) with two ebb tides per day. Local weather is classified as humid subtropical climate with warm summer and undefined dry season (Bigarella 1978, Angulo 1992). Precipitation reaches 1998 mm per year and summer is the rainy season.

Fish assemblages were sampled using a beach seine net, 15 m long and 2.6 m height with a stretched mesh size of 5 mm, at 3 locations. Samples were collected during daylight hours, between 6.00 and 10.00h from June 2004 to May 2005. Five hauls, each covering 30 m in distance, were made per site. Hauls were separated by 5m to minimize the influence between them, and all samples were collected at low water spring tides. The hauls were conducted by two people, one on each end of the net. The net was taken towards the surf zone by one of them to a depth of 1.5 m, approximately between 10 and 30 m into the sea. Both sides were pulled simultaneously parallel to the beach face up to 30 m, when the deeper end of the net was pulled towards the other net end.

All fish collected were identified to species level following Figueiredo & Menezes, 1978, Figueiredo & Menezes, 1980, Menezes & Figueiredo, 1980, Menezes & Figueiredo, 1985, Barletta & Correa, 1992, Figueiredo & Menezes, 2000. Specimens were weighted (g) and measured to the nearest 1 mm (total length and standard length), except when samples were very large. In such cases, measurements were restricted to a sub sample of 30 individuals per species. The remainder was weighted, counted and incorporated as weight and number counts. In addition, sex (male, female or non identified) and maturity stage were documented for the sub sample through direct observation, according to the macroscopic scale of gonadal maturation of Vazzoler (1981).

To verify the environmental influence on the faunal composition and structure at each site, surf zone water temperature (C), salinity (Practical

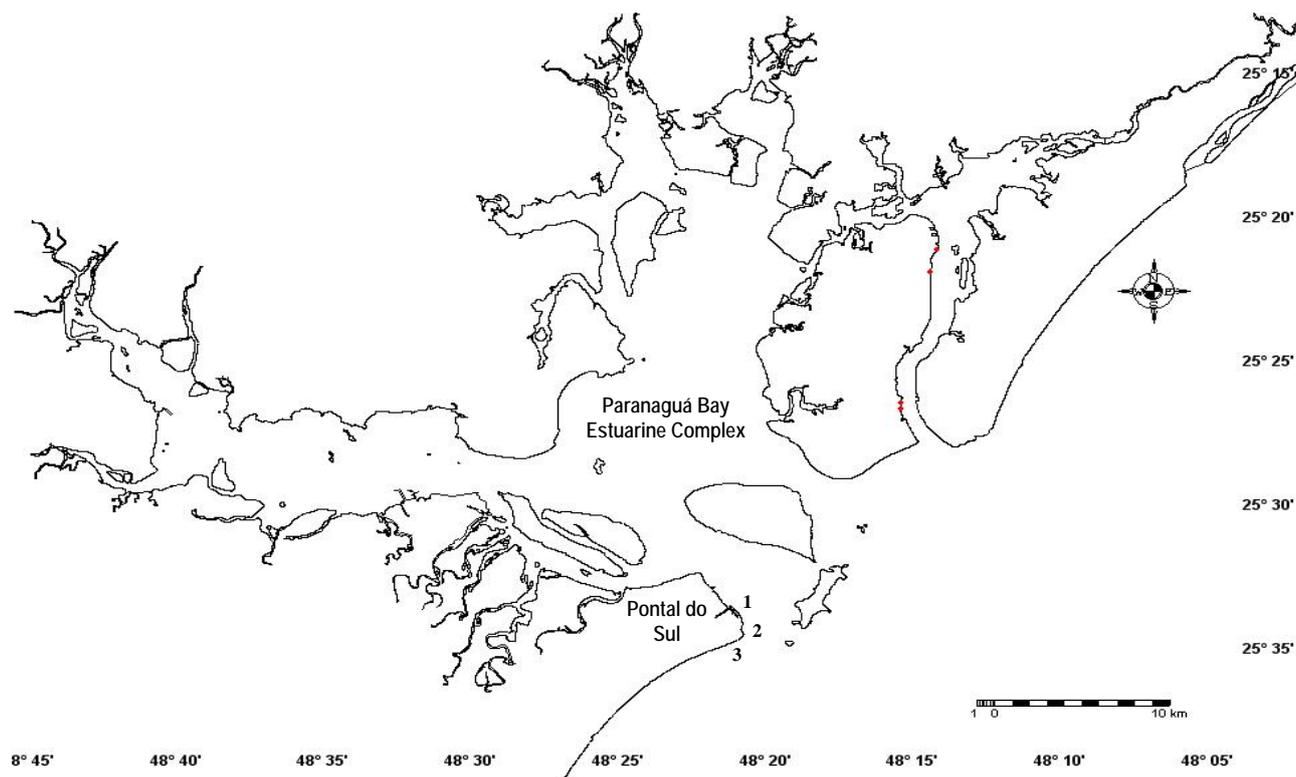


Figure 1. Map showing the studied area in Pontal do Sul, Brazil (1-3).

Salinity Scale – PSS), wave height (m) and period (s) were measured monthly, as no differences between successive hauls were observed. Wave height was taken with a 2 m ruler as the metric difference between crest and sea level of the largest waves breaking on the surf zone. Wave period was measured from the duration (in seconds) of 11 successive breaking waves and divided by 10 to calculate the period of a single wave. This procedure was repeated twice to obtain an average.

Data analyses

Fish collected from all seine hauls were pooled to provide monthly means, since the same dominant species have occurred and were abundant in the three studied areas. Homogeneity and normality of abiotic and biotic monthly means were tested using Bartlett Chi-square and Kolmogorov-Smirnov tests, respectively (Sokal & Rohlf 1995). To meet the assumptions of ANOVA, number of individuals and biomass were log-transformed while richness was square-root transformed. One-way ANOVA was used to test differences amongst monthly means for the biotic and abiotic data. Monthly averages of standard length were tested with ANOVA to verify the existence of differential utilization patterns of the surf zone habitat by the most abundant species. Moreover, monthly relative

frequencies of gonadal maturation stages, according Vazzoler (1981) scale, were used to assess the false herring *Harengula clupeola* (Cuvier 1829) reproductive activity *in situ*.

For operational purposes, some abbreviations were adopted to distinguish between two different species: *Mugil* sp.1 is one species of *Mugil* genus that can not be identified since scales were absent on the analyzed individuals; *Mugil* sp. 2 is the code to mullet *Mugil gaimardianus* Desmarest 1831, species that no longer exists (Menezes *et al.* 2003) and *S. brasiliensis* 1 is the Brazilian sardine *Sardinella brasiliensis* (Steindachner 1879) to distinguish it from the abbreviation of the serra spanish mackerel *Scomberomorus brasiliensis* Collette, Russo & Zavala-Camin 1978 (ICZN 2000).

Results

Environmental parameters

Amongst the environmental parameters, only temperature differed significantly, mainly in the comparisons between winter and summer months, which varied from 19 °C in June to 28 °C in January. Salinity ranged from 25 (January) to 36 (July); the shortest wave height was 5 cm (June and September) while the highest was 70 cm (May), and the wave period varied from 4.2 s (October) to 11.5 s (April) (Fig. 2).

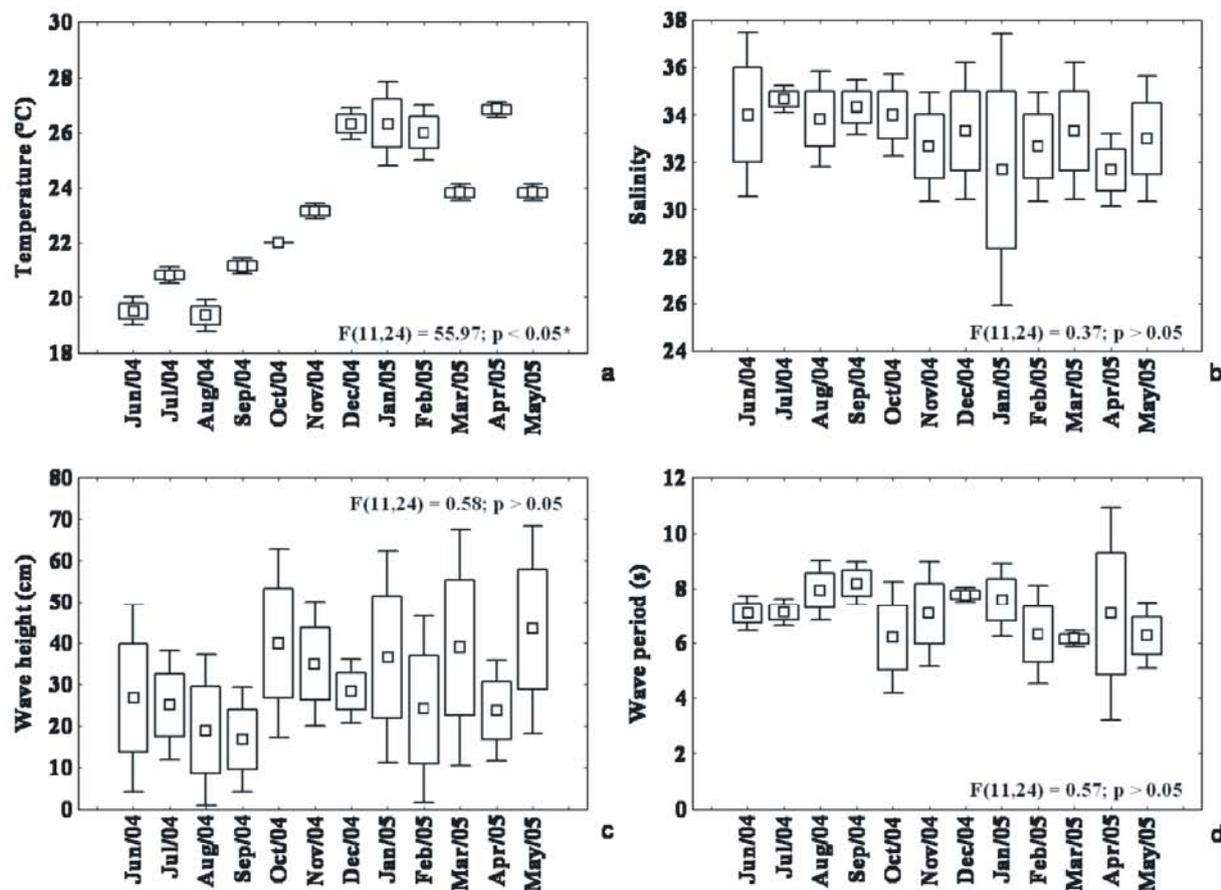


Figure 2. ANOVA test for temporal variation of monthly average of (a) temperature, (b) salinity, (c) wave height and (d) wave period between June/04 and May/05 in surf zone habitats in Pontal do Paraná, Brazil. (□ Mean, □ S.E. and ⊥ S.D.; * Significance level < 0.01).

Fish composition

A total of 26,865 individuals, corresponding to 84,838 Kg in weight, were caught during the one-year sampling period. They represented 63 taxa in 28 families, (Table I). Numerically, *H. clupeiola* (42.10 %), *S. brasiliensis* 1 (14.52 %), florida pompano *Trachinotus carolinus* (Linnaeus 1766) (11.76 %), shortfinger anchovy *Anchoa lyolepis* (Evermann & Marsh 1900) (10.85 %) and pejerrey *Odontesthes bonariensis* (Valenciennes 1835) (8.47 %) were dominant and accounted for 87.7 % of the total capture. These species were also important in terms of biomass and *H. clupeiola* (41 %), *T. carolinus* (7 %) and *O. bonariensis* (6.5 %) altogether contributed to more than 54 % of the catch (Table I).

Planktophagous fish were more abundant, representing 19 % of total species, whilst benthophagous fish were well distributed among the species with a prevalence of 34 % of all species captured. Most species were demersal (67 %) and 63 % occurred in marine-estuarine habitats (Table I).

Temporal variation

All variables were statistically significant at 0.05 p-level. Highest captures were obtained in the course of autumn and winter months, and the lowest ones in spring (Table I and Fig. 3 a). Biomass variation followed that of fish number, with similar trends in monthly variation of mean values (Fig. 3 b). Richness decreased from June to September, when the minimum value was recorded, and subsequently, an increase occurred from January to March (Fig. 3 c). Diversity fluctuated without any seasonal pattern, and while the richest month was the most diverse, the lowest diversity mean value was found in July (Fig. 3 d). Species were heterogeneously distributed, causing a reduction in the evenness index in June and July. Conversely, the lowest species catch and the highest mean value of evenness were observed in September (Fig. 3 e).

Most fish caught were between 30-50 mm standard length (SL) and almost all were immature (98 %). This result showed a high proportion of juvenile stage in the catches (Table I), and to

Table I. Species composition, total catch, length, occurrence and developmental stages for fish caught in surf zone habitats in Pontal do Paraná, Brazil. (J – juvenile, A – adult and M – marine, ME – marine-estuarine, E – estuarine).

Family	Species	Seasons				Total catch		Standard length (mm)			Developmental stage	Estuary association	Reference*
		Winter	Spring	Summer	Autumn	N	% total	Mean ± SD	Min	Max			
Albulidae	<i>Albula vulpes</i>	0	7	8	1	16	0.06	61.18 ± 24.57	23	128	J,A	ME	1,7
Atherinopsidae	<i>Odontesthes bonariensis</i>	2261	3	4	9	2277	8.48	59.36 ± 11.88	42	153	J,A	M	1,7
Belonidae	<i>Strongylura marina</i>	0	6	14	7	27	0.10	320.92 ± 46.51	202	437	J,A	ME	1,7
	<i>Strongylura</i> sp.	0	0	0	1	1	0.00	57	57	57	J	—	—
	<i>Strongylura timucu</i>	10	0	4	0	14	0.05	290.07 ± 59.02	162	395	J,A	ME	1,7
Carangidae	<i>Chloroscombrus chrysurus</i>	3	0	0	5	8	0.03	36.5 ± 18.24	15	70	J	ME	3,6
	<i>Oligoplites saliens</i>	12	3	6	136	157	0.58	107.86 ± 41.56	13	385	J	ME	3,6
	<i>Selene vomer</i>	2	0	0	0	2	0.01	32 ± 2.83	30	34	J	ME	3,6,7
	<i>Trachinotus carolinus</i>	442	142	1125	1453	3162	11.77	37.11 ± 12.99	11	106	J	ME	3,7
	<i>Trachinotus falcatus</i>	15	0	4	30	49	0.18	25.57 ± 7.25	15	43	J	ME	3,7
	<i>Trachinotus goodei</i>	57	1	24	90	172	0.64	48.72 ± 16.95	22	104	J	M	3,7
	<i>Trachinotus marginatus</i>	1	2	0	0	3	0.01	63.33 ± 26.39	33	81	J	M	3,7
	<i>Trachinotus</i> sp.	0	0	2	1	3	0.01	14 ± 1.00	13	15	J	—	—
Centropomidae	<i>Centropomus parallelus</i>	0	0	0	1	1	0.00	198	198	198	A	ME	2,7
Clupeidae	Clupeidae juveniles	0	0	1	3	4	0.02	20.75 ± 1.5	19	22	J	—	—
	<i>Harengula clupeola</i>	4437	764	502	5610	11313	42.11	56.93 ± 11.15	32	131	J,A	ME	1,6
	<i>Ophistonema oglinum</i>	3	0	0	83	86	0.32	60.09 ± 8.25	37	76	J	M	1,7
	<i>Platanichthys platana</i>	0	0	4	0	4	0.02	26 ± 1.41	24	27	J	E	1,6
	<i>Sardinella brasiliensis</i>	2	0	7	3893	3902	14.52	64.94 ± 14.53	25	108	J	M	1,6,7
Dactylopteridae	<i>Dactylopterus volitans</i>	0	1	0	0	1	0.00	166	166	166	A	ME	2,7
Diodontidae	<i>Cylichthys spinosus</i>	0	0	0	1	1	0.00	12	12	12	J,A	ME	5,7
Engraulidae	<i>Anchoa parva</i>	54	17	2	26	99	0.37	48.50 ± 8.04	31	67	J,A	ME	1,6
	<i>Anchoa lyolepis</i>	1	2	1	2913	2917	10.86	42.99 ± 6.25	34	70	J,A	ME	1,6
	<i>Anchoa tricolor</i>	2	13	74	58	147	0.55	48.16 ± 14.99	31	103	J,A	ME	1,6
	<i>Cetengraulis edentulus</i>	13	2	0	0	15	0.06	71.26 ± 6.17	57	84	J	ME	1,7
	Engraulidae juveniles	0	374	20	21	415	1.52	23.22 ± 3.17	14	41	J	—	—
	<i>Lycengraulis grossidens</i>	1	0	0	0	1	0.00	49	49	49	J	ME	1,6
Ephippidae	<i>Chaetodipterus faber</i>	0	0	0	6	6	0.02	31.33 ± 7.87	23	43	J	ME	5,6
Gerreidae	<i>Diapterus rhombeus</i>	0	3	0	0	3	0.01	106.66 ± 5.51	101	112	A	ME	3,7
	<i>Eucinostomus argenteus</i>	0	1	0	11	12	0.05	69.5 ± 11.36	58	97	J,A	ME	3,6
	<i>Eucinostomus lefroyi</i>	0	0	105	549	654	2.43	14.05 ± 3.53	8	56	J	M	3,7
	<i>Eucinostomus melanopterus</i>	0	0	1	0	1	0.00	127	127	127	A	ME	3,7

Table I. Continued from previous page.

Family	Species	Seasons				Total catch		Standard length (mm)			Development stage	Estuary association	Reference*
		Winter	Spring	Summer	Autumn	N	% total	Mean ± SD	Min	Max			
Haemulidae	<i>Conodon nobilis</i>	8	0	0	0	8	0.03	35.62 ± 4.21	26	39	J	ME	3,6
	<i>Pomadasys corvinaeformis</i>	0	1	10	10	21	0.08	49.38 ± 11.95	34	76	J	ME	3,7
Hemiramphidae	<i>Hyporhamphus unifasciatus</i>	16	29	0	40	85	0.32	133.4 ± 20.06	94	222	J,A	ME	1,5
Monacanthidae	<i>Stephanolepis hispidus</i>	1	3	0	0	4	0.02	29.75 ± 6.70	20	35	J,A	M	5,7
Mugilidae	<i>Mugil</i> sp. 1	82	62	16	42	202	0.75	22.84 ± 2.65	10	29	J	—	—
	<i>Mugil</i> sp. 2	1	0	0	5	6	0.02	97.5 ± 9.89	80	108	J	—	—
Paralichthyidae	<i>Citharichthys arenaceus</i>	1	7	1	7	16	0.06	73.56 ± 17.91	45	117	J	ME	5,7
	<i>Citharichthys macrops</i>	0	0	0	1	1	0.00	57	57	57	J	M	5,7
	<i>Etropus crossotus</i>	5	2	22	11	40	0.15	50.9 ± 13.16	24	92	J	ME	5,7
	<i>Scyacia papillosum</i>	1	0	0	0	1	0.00	183	183	183	A	M	5,7
Pleuronectidae	<i>Oncopterus darwinii</i>	0	1	0	0	1	0.00	25	25	25	J	M	5,7
Polynemidae	<i>Polydactylus virginicus</i>	17	0	69	35	121	0.45	45.95 ± 19.45	17	103	J	ME	4,7
Pomatomidae	<i>Pomatomus saltatrix</i>	10	16	70	10	106	0.40	82.49 ± 14.90	52	133	J	ME	2,7
Sciaenidae	<i>Ctenosciaena gracilicirrhus</i>	0	5	0	0	5	0.02	19.4 ± 2.51	15	21	J	ME	3,7
	<i>Larimus breviceps</i>	0	2	0	1	3	0.01	33.66 ± 31.56	13	70	J	ME	3,7
	<i>Menticirrhus americanus</i>	11	1	1	1	14	0.05	38.5 ± 15.91	21	73	J	ME	3,6
	<i>Menticirrhus littoralis</i>	186	175	157	93	611	2.27	45.08 ± 23.44	12	160	J	M	3,6
	<i>Micropogonias furnieri</i>	7	0	0	0	7	0.03	23.71 ± 2.29	21	27	J	ME	3,6
	<i>Ophioscion punctatissimus</i>	2	0	0	0	2	0.01	35.5 ± 2.12	34	37	J	M	3,7
	<i>Paralonchurus brasiliensis</i>	1	0	0	0	1	0.00	39	39	39	J	M	3,6
	<i>Steliffer rastrifer</i>	0	0	0	3	3	0.01	30.66 ± 7.02	24	38	J	M	3,6
	<i>Umbrina coroides</i>	0	22	2	3	27	0.10	33.48 ± 4.43	22	46	J	ME	3,7
	Scomberidae	<i>Scomberomorus brasiliensis</i>	0	0	0	1	1	0.00	156	156	156	J	M
Sphyraenidae	<i>Sphyraena tome</i>	0	1	0	0	1	0.00	73	73	73	J	M	4,7
Syngnathidae	<i>Syngnathus folletti</i>	3	3	0	1	7	0.03	123.71 ± 21.63	85	147	J	M	2,7
Synodontidae	<i>Synodus foetens</i>	12	4	38	9	63	0.24	68.53 ± 17.32	42	133	J	M	1,6,7
Tetraodontidae	<i>Sphoeroides testudineus</i>	0	3	4	0	7	0.03	116.85 ± 18.04	89	150	A	E	6,7
Trichiuridae	<i>Trichiurus lepturus</i>	0	0	0	1	1	0.00	99	99	99	A	ME	6,7
Triglidae	<i>Prionotus nudigula</i>	10	0	0	3	13	0.05	45.61 ± 9.11	34	64	J	M	2,7
	<i>Prionotus punctatus</i>	4	0	0	2	6	0.02	53.83 ± 10.57	43	72	J	ME	2,6
Uranoscopidae	<i>Astrocospus y-graecum</i>	7	1	0	0	8	0.03	43.25 ± 12.66	30	70	J	ME	4,7
Total (N)		7701	1679	2298	15187	26865	1.00						

* Bibliography used: 1 = Figueiredo & Menezes (1978); 2 = Figueiredo & Menezes (1980); 3 = Menezes & Figueiredo (1980); 4 = Menezes & Figueiredo (1985); 5 = Figueiredo & Menezes (2000); 6 = Corrêa (1987) and 7 = Fishbase (Froese & Pauly, 2005).

describe pattern of species utilization, mean body length of most abundant species were analyzed by month (Fig. 4).

The Clupeiforms, except *H. clupeiola*, showed low monthly catches that occurred mainly during the warmer months (February to May) (Fig. 4 b-d). Monthly mean SL of *S. brasiliensis* 1 increased from 40 to 80 mm between February and April (Fig. 4 b), but no other species showed this increase in SL. *O. bonariensis* occurred during most sampling months, but the highest frequencies were observed during June and July (winter months), when small animals (ca. 60 mm) were caught in high numbers. The mean size of

these individuals, however, increased in successive samples until ca. 120 mm (Fig. 4 e). The palometa *Trachinotus goodei* Jordan & Evermann 1896 was not sampled during spring or early summer (Fig. 4 h). The bluefish *Pomatomus saltatrix* (Linnaeus 1766) was absent at the end of autumn, nevertheless, its size doubled (from ca. 60 to 120 mm) during the entire period (Fig. 4 i). *H. clupeiola*, *T. carolinus* and the Gulf kingcroaker *Menticirrhus littoralis* (Holbrook 1847) were present in most samples (Fig. 4 a, f e g), but, *H. clupeiola* was the only species to show a clear pattern of growing average until late January (ca. 50 to 80 mm) (Fig. 4 a).

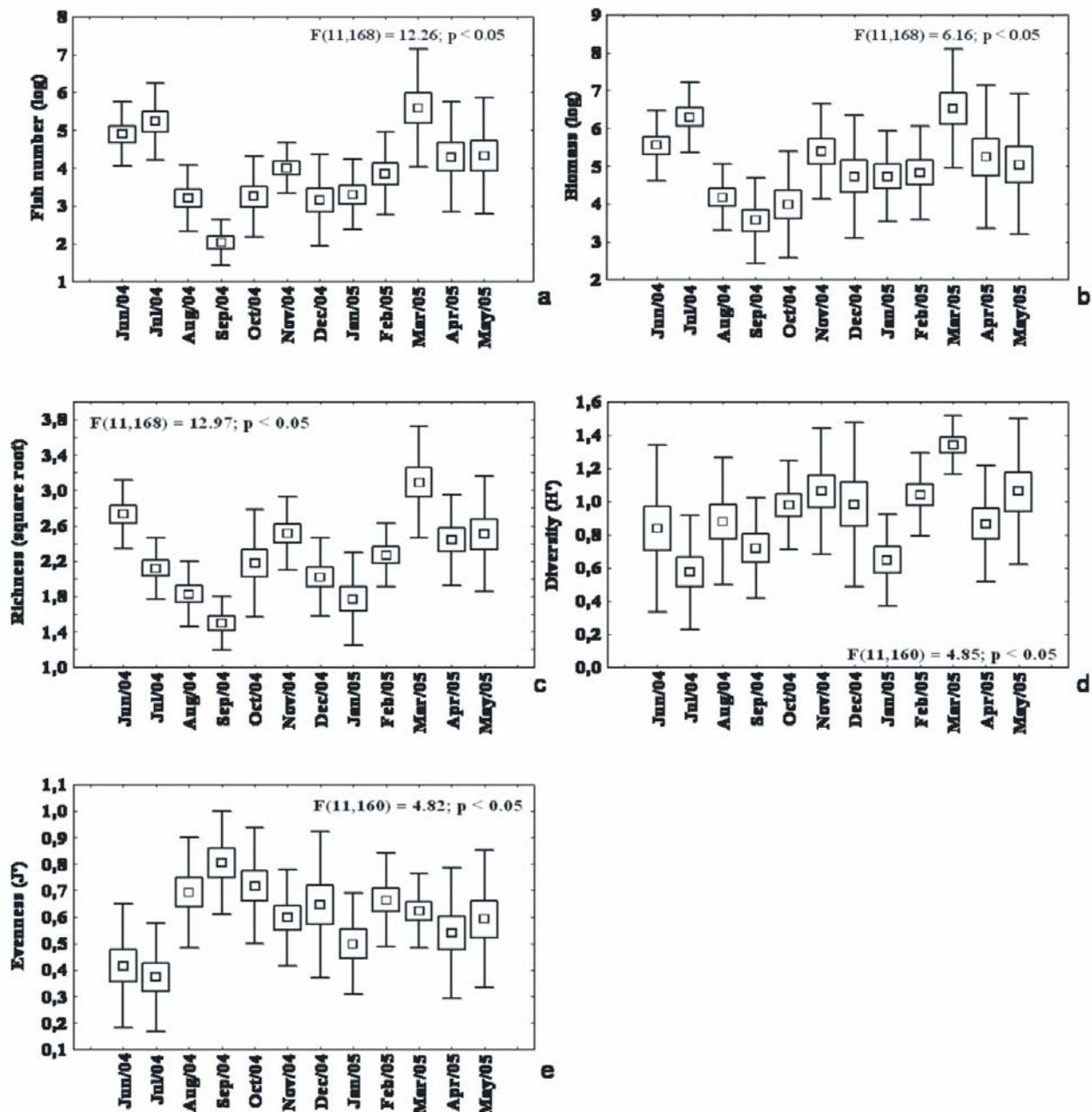


Figure 3. ANOVA test for temporal variation of (a) fish number and (b) biomass, (c) richness, (d) Shannon-Wiener diversity and (e) Pielou evenness from Jun/04 to May/05 in surf zone habitats in Pontal do Paraná, Brazil. (□ Mean, □ S.E. and | S.D.).

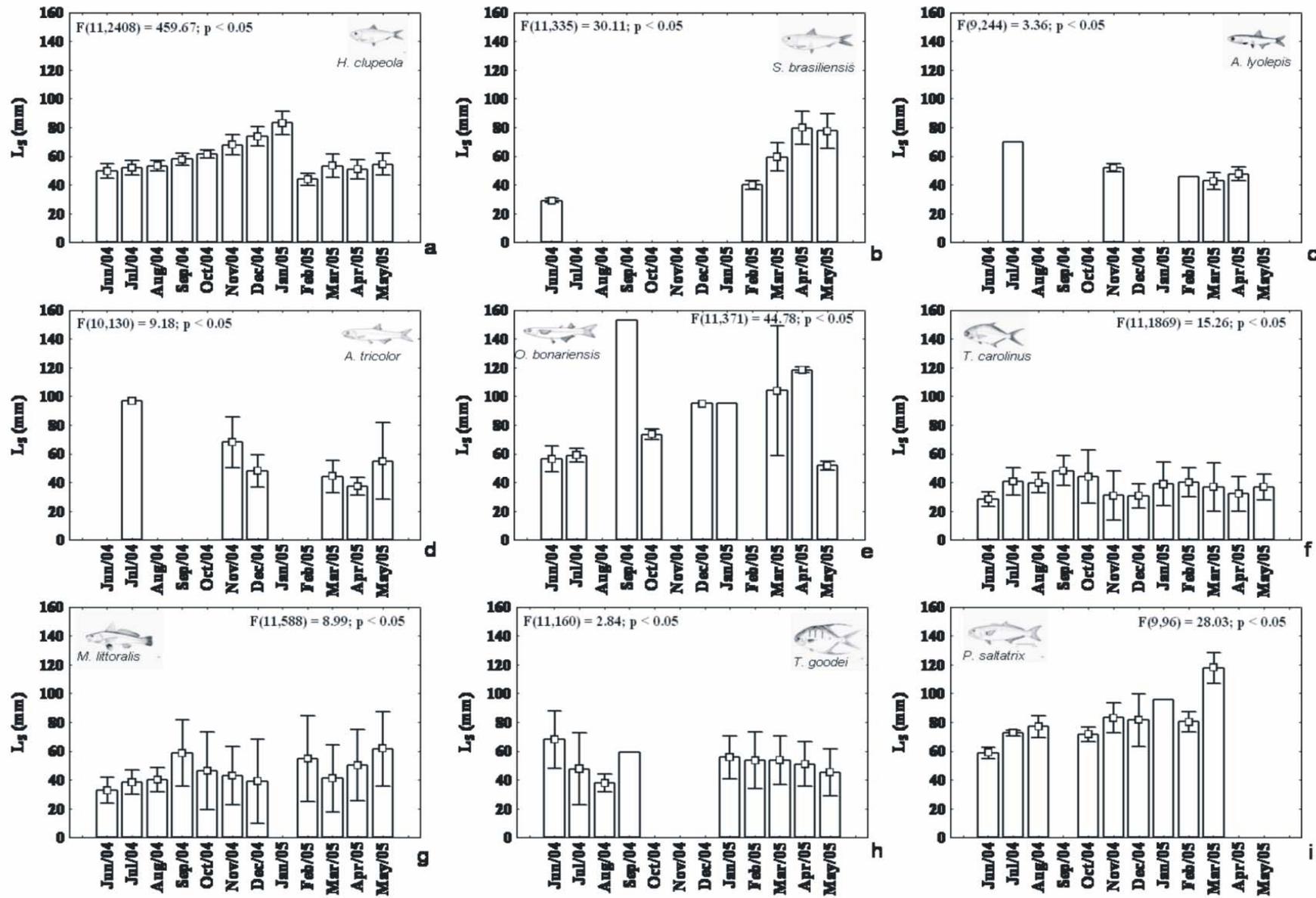


Figure 4. Monthly mean (\square) and standard deviation (\perp) of standard length (L_s) of frequent and abundant species collected between June/04 and May/05 in surf zone habitat in Pontal do Paraná, Brazil.

A complementary pattern of size distribution was observed through the monthly gonadal maturation stages of *H. clupeiola*. Individuals of initial maturity stage (B) began to appear in the surf zone in November and continued until January, when first maturity (C) fish occurred and initial maturity stage individuals increased to 70%. Subsequently, only immature individuals were caught, a similar pattern to those observed on the initial months (June to October) (Fig. 5).

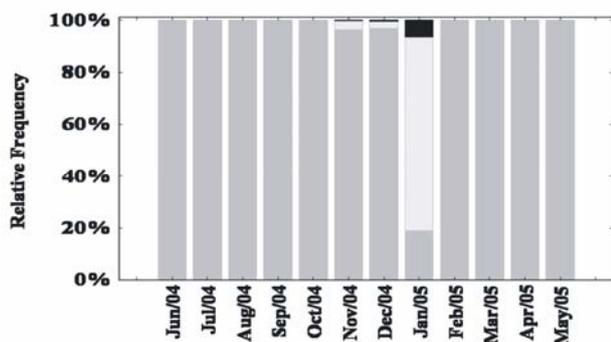


Figure 5. *Harengula clupeiola*. Occurrence of gonadal maturation stages occurrence between Jun/04 and May/05 for in surf zone habitats in Pontal do Paran, Brazil. (■ immature individuals - A, ■ individuals in maturation - B and ■ mature individuals - C).

Discussion

An inherent characteristic of sand beach ichthyofauna is the dominance of the assemblages by a few species (McFarland 1963, Modde & Ross 1981). Such a pattern could be viewed from the evolutionary perspective of the occupation of this environment, where only a few species succeeded to reproduce and to remain in a turbulent and mutable habitat. Great quantities of clupeiforms inhabiting surf zones were found by several authors (McFarland 1963, Beckley 1984, Lopes *et al.* 1993), indicating the massive utilization of this habitat by a typical transient fauna between estuarine and open sea environments (Strydom 2003).

In addition to clupeids and engraulids, carangids and sciaenids, such as *T. carolinus* and *M. littoralis* respectively, are common in the surf zone, and are widely documented along beaches around the world (Ross 1983, Modde & Ross 1983, Nelson 1986, Ross & Lancaster 2002). These species are zooplanktophagous and their juveniles find abundant food supply, protection against predators and shelter in low visibility shallow water habitats of oceanic and estuarine beaches (Clark *et al.* 1994, Nash & Santos 1998).

Despite net selectivity, juvenile is the most frequently found stage in sand beaches (Robertson &

Lenanton 1984, Lasiak 1986, Reina-Hervas & Serrano 1987, Clark 1997), and thus, this environment has been recognized as nursery by many studies (Gunter 1938, Gibson 1973, Ruple 1984, Ross *et al.* 1987, Bennet 1989, Whitfield 1989, Godefroid 1996). The beaches studied in the present investigation are considered accessory nursery areas, since they are near the Paranagu estuarine complex and are used by most species during at least part of their life cycle.

In general, most species are characterized as seasonal or sporadic migrants, with few species considered as truly resident (McLachlan 1983). According to Day (1951), estuarine resident species are those that spend their entire life cycle within the estuary. This definition of resident species can be applied to species that are represented by all maturity stages and are constant throughout the year in beach environments. Modde (1980) appointed *T. carolinus*, scaled herring *Harengula jaguana* Poey 1865, *M. littoralis* and other three species as residents on Gulf of Mexico beaches. However, in the present study, none could be considered as resident, because no species were captured in all gonadal maturation stages according to Vazzoler (1981) macroscopic scale.

Recruitment patterns are the result of seasonal changes in abundance and diversity on surf zone fish, which could be determined by reproductive activity and coastal circulation (Ross *et al.* 1987) or either by emigration or exploration of high productive areas by adults (Allen 1982). High diversity and abundance are found in warmer months while colder months show low values (Fox & Mack 1968, Naughton & Saloman 1978, Modde & Ross 1981, Ross 1983, Lasiak 1984). In addition, Godefroid (1996) and Monteiro-Neto *et al.* (1990) found the lowest numbers of fish during spring at Southern Brazil beaches, which are results similar to those observed in the present study. The peak value of evenness occurred during September, when equal species contribution was related to low number of species and individuals, as shown by Nash & Santos (1998). On the other hand, large aggregates of *O. bonariensis* and *H. clupeiola* occurred in June and July, which consequently decreased the evenness index.

Taking into consideration several investigations conducted near the studied area (Godefroid 1996, Rocha *et al.* 2002, Godefroid *et al.* 2004, Spach *et al.* 2004), we suggest that most fish concentrate their reproductive effort over spring and summer. During this period, high temperatures favour phytoplankton production and consequently,

the zooplankton, which will raise the survival chances for larval and juvenile individuals. Estuaries are the principal feeding and growing area for early stages of several marine species and few species displace themselves toward estuaries in order to spawn. Conversely, many species spawn on the continental shelf (Chaves & Bouchereau 2000). During processes of habitat shifts, an aggregation phase of many species may occur near estuary mouths, particularly in beach environments, which could be considered an additional recruitment area essential for their life cycle.

This hypothesis can be supported by the occasional occurrence of many engraulids such as *Anchoa lyolepis*, tungao *A. tricolor* (Spix & Agassiz 1829) and the clupeid *S. brasiliensis* 1. The recruitment of these species appears to occur during late summer or early autumn (Godefroid 1996), when many shoals approach shallow waters and leave soon after. This behaviour, according to McFarland (1963), may indicate a reproductive pattern or a simple population aggregation, the purpose of which is still unknown. Mean SL of *S. brasiliensis* 1 increased continuously from February (40 mm) to May (80 mm) and the same occurred in relation to *A. lyolepis*, although in a smaller proportion (42–48 mm). As reproduction data for these two species were absent, and capture were restricted to few months, it could be assumed that the studied area is inserted in a migratory route, acting as a temporary refuge or an orientation site, as concluded by Modde (1980).

Harengula clupeola and *T. carolinus* seem to recruit all year round, as previously described by Godefroid (1996), but *M. littoralis* also presented this pattern, since they are numerous and their presence is constant in all seasons. *H. clupeola* showed a clear growing pattern in the studied area. Mean SL value increased from 50 to 80 mm until January and a new body-size class entry was observed in the subsequent month. January was the only month when mature individuals were captured (C stage), although juveniles (A stage) were observed only in February. This coincides exactly with the cohort entrance and is an indication of the recruitment. Modde (1980) found for congener *H. jaguana* two annual peaks of recruitment, one in early spring and another in late summer, with few individuals exceeding 50 mm. He attributed this lack of larger individuals to both reduced catchability and movement outward from the beach. In the present study, individuals larger than 80 mm were not caught perhaps due to the large mesh-size of the seine net or to their absence of the study area. The most acceptable hypothesis is the latter, since

H. clupeola is a small body-sized species with maximum length of 170 mm (Figueiredo & Menezes 1978) and not capturing this species would be improbable, since much bigger individuals such as the common halfbeak *Hyporhamphus unifasciatus* (Ranzani 1842) (133.4 mm) or timucu *Strongylura timucu* (Walbaum 1792) (290.07 mm) have been caught.

Additionally, *T. carolinus* and *M. littoralis* did not present any indication of mean size increment and they were represented only by immature individuals, which could be an indication of continuous spawning activity. This resulted in simultaneously entrance and consequent mixture of many cohorts in beach environments (Modde 1980) that also prevented the visualization of defined cohort patterns. The dominance of immature individuals leads to the assumption that either bigger fish were not caught by the sampling gear or they left the area after reaching some particular size. Fields (1962) and Modde (1980) proposed that *T. carolinus* of sizes of 60–70 mm and 80 mm, respectively, move offshore to deeper waters. Also Bellinger & Avault (1970) verified that fish up to 100 mm SL class remain in the surf zone. In the present study, mean value of 37.71 mm SL were found for *T. carolinus*, and the biggest fish captured was 106 mm SL. However, Godefroid (1996), working with a 18 m seine net with smaller mesh-size, caught fish measuring 70–80 mm and only one specimen 90–100 mm size class. Perhaps the same pattern found by Bellinger & Avault (1970) could be applied to beaches at Pontal do Sul, but more samples with different fishing gears are necessary to reach a conclusion about this issue.

Growth patterns could not be identified for the congener *T. goodei*, which was caught only as juveniles. This result can be explained by the same hypothesis presented for *T. carolinus* and *M. littoralis*, however, further studies also need to be conducted to clarify this matter. *O. bonariensis* is a cold water species that usually migrate from Southern Brazil to warmer waters during winter. High occurrence of this species took place in June and July, appearing sporadically in the other months. Even with few individuals captured during the rest of the year, an increasing size trend could be observed towards summer months, but it could not be considered conclusive because of the low incidence of individuals. Similarly, *P. saltatrix*, a piscivorous fish, seems to utilize the area for feeding and growth, where it doubled its size (60 to 120 mm). *P. saltatrix* probably took advantage of the abundant food resource provided by many shoals of clupeiforms.

It could be concluded that reproductive patterns for the studied species are linked to seasonal fluctuation, but when the species data were analyzed altogether in a community context, these trends were not evident and such information could have been lost. This is the fundamental reason why in this study much attention was paid to species utilization in respect to seasonal fluctuation in the surf zone environment. In summary, it is clear that shallow habitats such as sandy beaches represent a significant spatial resource to early life stages of many fish in Pontal do Sul, which becomes most important during summer and autumn months when many immigrant species occur in these habitats in search of shelter and abundant food supply. For this reason, efforts must be made to preserve these habitats (mainly estuarine and adjacent regions) by improving surveillance and control on any-activity that could adversely affect the environmental health. The creation of connected and functional Marine Protected Areas could contribute to fish stocks sustainability, maintenance of food web relationships and environmental balance.

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References

- Allen, L. G. 1982. Seasonal abundance, composition and productivity of the littoral fish assemblage in upper Newport Bay California. **Fishery Bulletin**, 80 (4): 769-789.
- Angulo, R. J. 1992. Geologia da planície costeira do estado do Paraná. **PhD. Thesis**. Instituto de Geologia - Universidade de São Paulo, São Paulo, Brasil, 334 p.
- Barletta, M. & Corrêa, M. F. M. 1992. **Guia para identificação de peixes da costa do Brasil**. UFPR, Curitiba, 131pp.
- Beckley, L. E. 1984. The ichthyofauna of the Sundays Estuary, South Africa, with particular reference to the juvenile marine component. **Estuaries**, 7 (3): 248-258.
- Bellinger, J. W. & Avault-Jr, J. W. 1970. Seasonal occurrence, growth, and length-weight relationship of juvenile pompano, *Trachinotus carolinus*, in Louisiana. **Transactions of the American Fishery Society**, 100: 353-358.
- Bennet, B. A. 1989. The fish community of a moderately exposed beach on the southern Cape Coast of South Africa and an assessment of this habitat as nursery for juvenile fish. **Estuarine, Coastal and Shelf Science**, 28: 293-305.
- Bigarella, J. J., Becker, R. D., Matos, D. J. & Werner, A. 1978. **A serra do mar e a porção oriental do Estado do Paraná – Um Problema de Segurança Ambiental e Nacional**. Curitiba: Secretaria do Estado do Planejamento - Associação de Defesa e Educação Ambiental. 249 p.
- Chaves, P. T. & Bouchereau, J. L. 2000. Use of mangrove habitat for reproductive activity by the fish assemblage in the Guaratuba bay, Brazil. **Oceanologica Acta**, 23 (3): 273-280.
- Clark, B. M. 1997. Variation in surf-zone fish community structure across a wave exposure gradient. **Estuarine, Coastal and Shelf Science**, 44: 659-674.
- Clark, B. M., Bennet, B. A & Lamberth, S. J. 1994. A comparison of the ichthyofauna of two estuaries and their adjacent surf zones, with as assessment of the effects of beach-seining on the nursery function on estuaries for fish. **South African Journal of Marine Science**, 14: 121-131.
- Corrêa, M. F. M. 1987. Ictiofauna da Baía de Paranaguá e adjacências (litoral do estado do Paraná, Brasil). Levantamento e produtividade. **MSc. Thesis**. Departamento de Zoologia - Universidade Federal do Paraná, Paraná, Brasil, 406 p.
- Day, J. H. 1951. The ecology of South African estuaries. Part 1. A review on estuarine conditions in general. **Transactions of the Royal Society of South Africa**, 33: 53.
- Fields, H. M. 1962. Pompanos (*Trachinotus* spp.) of South Atlantic coast of the United States. **Fishery Bulletin**, 62: 189-222.
- Figueiredo, J. L. & Menezes, N. 1978. **Manual de peixes marinhos do sudeste do Brasil. II. Teleostei (1)**. Museu de Zoologia da USP, São Paulo, 110 pp.
- Figueiredo, J. L. & Menezes, N. 1980. **Manual de peixes marinhos do sudeste do Brasil. III. Teleostei (2)**. Museu de Zoologia da USP, São Paulo, 90pp.
- Figueiredo, J. L. & Menezes, N. 2000. **Manual de peixes marinhos do sudeste do Brasil. VI. Teleostei (5)**. Museu de Zoologia da USP, São Paulo, 116 pp.

- Froese, R. & D. Pauly (Eds.). 2005. FishBase. World Electronic Database accessible at <http://www.fishbase.org>. (Accessed 20/09/2005).
- Fox, L. S. & Mack, W. R. Jr. 1968. Seasonal occurrence of fishes in two shore habitats in Barataria Bay, Louisiana. **Proceedings of Louisiana Academy of Science**, 31: 43-53.
- Gibson, R. N. 1973. The intertidal movements and distribution of young fish on sandy beach with special reference to the plaice (*Pleuronectes platessa* L.). **Journal of Experimental Marine Biology and Ecology**, 12: 79-102.
- Gibson, R. N., Ansell, A. D. & Robb, L. 1993. Seasonal and annual variations in abundance and species composition of fish and macrocrustacean communities on a Scottish sandy beach. **Marine Ecology Progress Series**, 98: 89-105.
- Gibson, R. N., Robb, L., Burows, M. T. & Ansell, A. D. 1996. Tidal, diel and long term changes in the distribution of fishes on a Scottish sandy beach. **Marine Ecology Progress Series**, 130: 1-17.
- Godefroid, R. S. 1996. Estrutura da comunidade de peixes da zona de arrebentação da praia de Pontal do Sul, Paraná, Brasil. **MSc. Thesis**. Departamento de Zoologia – Universidade Federal do Paraná, PR, Brasil, 129 p.
- Godefroid, R. S., Spach, H. L., Santos, C., MacLaren, G. N. Q. & Schwarz Jr, R. 2004. Mudanças temporais na abundância e diversidade da fauna de peixes do infralitoral raso de ma praia, sul do Brasil. **Iheringia – Serie Zoologia**, 94 (1): 95-104.
- Gunter, G. 1938. Seasonal variations in abundance of certain estuarine and marine fishes in Louisiana with particular reference to life histories. **Ecological Monographs**, 8 (3): 313 – 346.
- ICZN. 2000. **International code of Zoological Nomenclature**. Article 16, Recommendation 16.1. Accessible at <http://www.iczn.org/iczn/index.jsp>
- Lamberth, S. J., Clark, B. M. & Bennett, B. A. 1995. Seasonality of beach seine catches in false bay, South Africa, and implications for management. **South African Journal of Marine Science**, 15: 157-167.
- Lasiak, T. A. 1984. Structural aspects of the surf zone fish assemblage at King's Beach, Algoa Bay, South Africa: Short - term fluctuations. **Estuarine, Coastal and Shelf Science**, 18: 347-360.
- Lasiak, T. A. 1986. Juveniles, food, and the surf zone habitat: implications for the teleost nursery areas. **South African Journal of Zoology**, 21: 51- 55.
- Lopes, R. G., Rodrigues, E. S., Puzzi, A., Pita, J. B., Coelho, J. A. P. & Freitas, M. L. 1993. Levantamento ictiofaunístico em um ponto fixo na Baía de Santos, estado de São Paulo, Brasil. **Boletim do Instituto de Pesca**, 20: 7-20.
- McFarland, W. N. 1963. Seasonal change in the number and the biomass of fishes from the surf at Mustang Island, Texas. **Publications of the Institute of Marine Science**, 9: 91-105.
- McLachlan, A. 1980. Exposed sandy beaches as semi-closed ecosystems. **Marine Environmental Research**, 4: 59 – 63.
- McLachlan, A. 1983. Sandy beaches ecology - A review. Pp 321 – 380 *In*: McLachlan, A. & Erasmus, T., (Eds.). **Sandy beaches as ecosystems**. The Hague, Dr. Junk Publishers, 766 p.
- Menezes, N. & Figueiredo, J. L. 1980. **Manual de peixes marinhos do sudeste do Brasil. IV. Teleostei (3)**. Museu de Zoologia da USP, São Paulo, 90pp.
- Menezes, N. & Figueiredo, J. L. 1985. **Manual de peixes marinhos do sudeste do Brasil. V. Teleostei (4)**. Museu de Zoologia da USP, São Paulo, 90 p.
- Menezes, N. A., Backup, P. A., Figueiredo, J. L. & Moura, R. L. 2003. **Catálogo de peixes marinhos do Brasil**. Vol. 1. 1ed. Museu de Zoologia da USP, São Paulo, 159p.
- Modde, T. & Ross, S. T. 1981. Seasonality of fishes occupying a surf zone habitat in the northern Gulf of Mexico. **Fishery Bulletin**, 78 (4): 911-921.
- Modde, T. & Ross, S. T. 1983. Trophic relationships of fishes occurring within a surf zone habitat n the northern gulf of Mexico. **Northeast Gulf Science**, 6 (2): 109 -120.
- Modde, T. 1980. Growth and residency of juveniles fishes within a surf zone habitat in the Gulf of Mexico. **Gulf Research Reports**, 6 (4): 377-385.
- Monteiro-Neto, C., Blacher, C., Laurent, A. A. S., Snisck, F. N., Canozzi, M. B. & Tabajara, L. L. C. de A. 1990. Estrutura da comunidade de peixes em águas rasas na região de Laguna, SC, Brasil. **Atlântica**, 12 (2): 53 – 69.

- Nash, R. D. M. & Santos, R. S. 1998. Seasonality in diel catch rate of small fishes in a shallow-water fish assemblage at Porto Pim Bay, Faial, Azores. **Estuarine, Coastal and Shelf Science**, 47: 319 – 328.
- Naughton, S. P. & Saloman, C. H. 1978. Fishes of the nearshore zone of St. Andrew Bay, Florida, and adjacent coast. **Northeast Gulf Science**, 2 (1): 43 – 55.
- Nelson, W. O. 1986. Predation and prey population variation in a high energy sand beach macrofaunal community. **Ophelia**, 26: 305 – 316.
- Reina-Hervas, J. A. & Serrano, P. 1987. Structural and seasonal variations of inshore fish populations in Málaga Bay, Southeastern Spain. **Marine Biology**, 95: 501-508.
- Robertson, A. I. & Lenanton, R. C. 1984. Fish community structure and food chain dynamics in the surf zone of sandy beaches: the role of aquatic macrophyte detritus. **Journal of Experimental Marine Biology and Ecology**, 84: 265-283.
- Rocha, C., Favaro, L. F. & Spach, H. L. 2002. Biologia reprodutiva de *Sphoeroides testudineus* (Linnaeus) (Pisces, Osteichthyes, Tetraodontidae) da gamboa do Bagaçu, Baía de Paranaguá, Paraná, Brasil. **Revista Brasileira de Zoologia**, 19 (1): 57-63.
- Ross, S. T. 1983. A review of surf zone ichthyofaunas in the Gulf of Mexico. Pp. 25-34 *In*: Shabica, S. V., Cofer, N. B. & Cake, Jr., E. W. (Eds.) **Proceedings of the Northern Gulf of Mexico Estuaries and Barrier Islands Research Conference**. Atlanta, GA, U.S. Department of the Interior, National Park Service, Southeast Regional Office, June 13-14. 191 p.
- Ross, S. W. & Lancaster, J. E. 2002. Movements and site fidelity of two juvenile fish species using surf zone nursery habitats along the southern North Carolina coast. **Environmental Biology of Fishes**, 63: 161-172.
- Ross, S. W., McMichael, R. H. Jr & Ruple, D. L. 1987. Seasonal and diel variation in the standing crop of fishes and macroinvertebrates from a Gulf of Mexico surf zone. **Estuarine, Coastal and Shelf Science**, 25: 391 – 412.
- Ruple, D. L. 1984. Occurrence of larval fish in the surf zone of a Northern Gulf of Mexico barrier island. **Estuarine, Coastal and Shelf Science**, 18: 191 – 208.
- Sokal, R. R. & Rohlf, F. J. 1995. **Biometry**. W. H. Freeman and Company, 859 p.
- Spach, H. L., Godefroid, R. S., Santos, C., Schwarz-Jr, R. & Queiroz, G. M. L. N. 2004. Temporal variation in fish assemblage composition on a tidal flat. **Brazilian Journal of Oceanography**, 52 (1): 47 – 58.
- Strydom, N. A. 2003. Occurrence of larval and early juvenile fishes in the surf zone adjacent to two intermittently open estuaries, South Africa. **Environmental Biology**, 66: 349-359.
- Vazzoler, A. E. A. M. 1981. Manual de métodos para estudos biológicos de populações de peixes - reprodução e crescimento. Brasília: CNPq, 108 p.
- Whitfield, A. K. 1989. Ichthyoplankton in a southern African surf zones: nursery area for the postlarvae of estuarine associated fish species? **Estuarine, Coastal and Shelf Science**, 29: 533 – 547.

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