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Diel and seasonal changes in the distribution of fish on a southeast Brazil sandy beach

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Abstract The effect of diel and seasonal changes in the distribution of fishes on a subtropical sandy beach on the southeastern coast of Brazil were studied. Seine netting was carried out on both seasonal and diel scales between July 1998 and June 1999. A total of 46 fish species was recorded, six being numerically dominant: *Anchoa tricolor*, *Gerres aprion*, *Harengula clupeola*, *Atherinella brasiliensis*, *Mugil liza* and *Diapterus rhombeus*. Seasonal changes in abundance of dominant species were detected. Species dominant in winter were *Anchoa tricolor, H. clupeola* and *Atherinella brasiliensis*; in spring, *Anchoa tricolor* and *G. aprion*; in summer *G. aprion* and *D. rhombeus*; and in autumn *M. liza* and *H. clupeola*. Overall, diel patterns did not reveal any significant trends; however, if we consider each season separately, an increase in *A. tricolor* abundance was recorded during the day in winter/spring, being replaced at night by *H. clupeola* in winter, and by *G. aprion* in spring. Increases in number of individuals and biomass at sunset, and decreases during the night were recorded. The winter/spring inshore/offshore movements at diel scale performed by the three most abundant species demonstrate that diel fluctuation acts more at a species-specific level than at a structural one; in summer there was no evidence of diel movements due to a heavy influx of *G. aprion* and *D. rhombeus*, which use the area throughout day and night, increasing overall abundance. Seasonal movements seems to be related to ontogenetic change in species, while diel movements in the fish assemblage seem to be more related to physiological requirements, such feeding activity of each particular species, than to physico-chemical conditions.

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Introduction

Sandy beaches are considered physically dynamic and changeable environments, which are used by juvenile fishes as nursery areas in spite of their relatively low habitat complexity (Ayvazian and Hyndes 1995). Such beaches are inhabited by a large number of species, which use the available food; these species also benefit from turbidity, which protects them from predators, thanks to the high turbulence of the water (Lasiak 1986).

Shifts in population densities depend on fluctuations in environmental condition, or may be inherent in the physiological characteristics of each population (Ricklefs 1996). In sandy beaches, which are highly dynamic and productive areas, temporal changes in composition and abundance of the assemblages are expected (Methven et al. 2001). Such variations are mainly shown on seasonal and diel scales.

Seasonal fluctuation in abundance of fishes throughout the year commonly results from recruitment peaks (Mariani 2001), or from species interacting with environmental variations (Ayvazian and Hyndes 1995; Potter et al. 2001). Migrations or movements inshore/offshore that are dictated by ontogenetic changes also can be the cause of such variations (Gibson et al. 1993). On the other hand, diel variations in fish assemblages are reported as being associated with feeding activity and predator avoidance, and these changes are modulated by tidal cycles and photoperiod (Gibson et al. 1996; Morrisson et al. 2002).

Such investigations are essential for knowledge of the life cycles of species that use the shallows areas in bays. Understanding shifts in composition and structure in juvenile fish assemblages at beaches is an important issue in fish ecology, since it is part of the strategy developed by species to reduce mortality during their early lives.

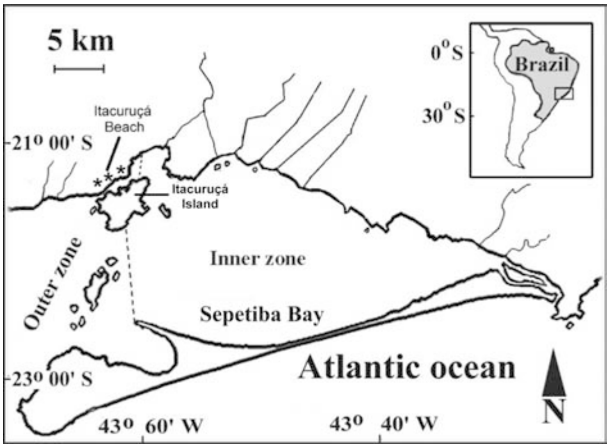


Fig. 1 Study area, Itacuruçá Beach, Sepetiba Bay, Brazil. *Asterisks* indicate the sampling sites

The Itacuruçá beach (Fig. 1), located in an outer zone of the Sepetiba Bay (22°54′–23°04′ S, 43°34′–44°10′ W), is one of several subtropical sandy beaches in southeastern Brazil. It receives influence from oceanic waters and is situated in a protected area due the proximity of Itacuruçá Island, only 1 km away from the coastline. Waters are saline (ca 31 ppt) and transparent; the bottom is mainly muddy (Araújo et al. 1997; Pessanha et al. 2000) due to the relatively calm waters. Mean tidal ranges are 1.3 m on springs and 0.5 m on neaps. This work aims to describe the composition and structure of fish assemblage at Itacuruçá sandy beach and to analyse changes in fish distributions on seasonal and diel scales.

Materials and methods

Beach seine netting was performed over 24-h periods during July (winter) and December (spring) 1998, and March (summer) and June (autumn) 1999. Samples were taken every 3 h, at 0800, 1100, 1400, 1700 hours during the day, and 2000, 2300, 0200 and 0500 hours through the night. This procedure was replicated three times on each sampling occasion. This schedule allows the separation of diel and seasonal effects. The apparatus used was a 7-mm stretched-mesh beach-seine, 10 m×2 m. The net was laid parallel to the shore in water approximately 1.5 m deep, and was hauled by two persons, one on each end of the net, covering an extension of approximately 30 m. Total area sampled was taken as the distance the net was laid offshore multiplied by the mean width of the haul.

All fish collected were identified to species, measured to the nearest 1 mm total length (TL) and weighed to the nearest 0.1 g. Numbers of fish in each haul were estimated by calculating the number of individuals in each species. Relative abundance was determined based on total number of fish caught per unit effort (CPUE). Length–frequency distributions were determined for the dominant species at size class interval of 5 mm. For comparative purposes, it was necessary to transform all catch data into density or biomass (number or weight of fish per sample). Diel and seasonal averages in fish abundance and biomass were compared by a non-parametric Kruskall-Wallis test since data did not fit the assumptions of parametric analysis of variance. The a posteriori Man-Whitney (U) test, at 95% confidence level ($P < 0.05$) was used each time the null hypothesis was rejected (Zar 1982). Percentage of similarity (Krebs 1989) was used to assess patterns of species composition according to season, and a detrended correspondence analysis (DCA) was used on fish abundance transformed via the $\log(x+1)$ function.

Results

Species collected

A total of 25,338 fish from 46 species representing 23 families was collected in 96 beach seine hauls made at Itacuruçá beach during the four excursions, from July 1998 to June 1999 (Table 1). The five most numerous species were *Anchoa tricolor*, *Gerres aprion*, *Harengula clupeola*, *Atherinella brasiliensis*, *Mugil liza* and *Diapterus rhombeus,* which accounted for 89% of the total number of fishes. *G. aprion*, *H. clupeola*, *Anchoa tricolor*, *Atherinella brasiliensis*, *Citharichthys spilopterus* and *Sphoeroides testudineus*, in decreasing order, accounted for 77% of the total weight (Table 1).

Seasonal changes

The number of individuals was higher in winter, due to the high contribution of the most abundant species *Anchoa tricolor* and *H. clupeola*; the number was lower in autumn. Biomass, on the other hand, peaked in summer, due to the high contribution of the Atherinopsidae *Atherinella brasiliensis*, the Gerreidae *G. aprion* and *D. rhombeus*, the Paralichthyidae *C. spilopterus* and *C. arenaceus, and the* Tetraodontidae *S. testudineus* and *S. greeley*. The number of species varied between seasons, due to changes in the occurrence of rare species, being higher in summer and lower in autumn (Table 1). Significant differences in the number of individuals, biomass and number of species occurred between seasons (Table 2).

The most numerous species changed in abundance according to season. *Anchoa tricolor* and *H. clupeola* predominated in winter, *A. tricolor* and *G. aprion* in spring, *G. aprion* and *D. rhombeus* in summer and *M. liza* and *H. clupeola* in autumn (Table 1).

The similarity coefficient of fish abundances between seasons indicates highest similarity between winter and spring. On the other hand, summer and winter, and spring and autumn showed the lowest similarity, indicating changes in fish composition between winter/spring and summer/autumn. (Table 3).

The ordination diagram of the two first axes of DCA of fish abundance explained 84% of the total variance (Table 4) and showed a well-defined seasonal pattern. Axis I explained 50% of the total variance and showed higher loads for *M. liza*, *Synodus foetens*, *Citharichthys arenaceus*, *Diapterus rhombeus*, *M. platanus*, *Trachinotus falcatus* and *Oligoplites saurus*, and lower loads for *Harengula clupeola*, *Gobionellus boleosoma* and *Anchoa tricolor*. Axis II explained 34% of total variance and showed higher loads for *H. clupeola* and *Atherinella brasiliensis*, and lower loads for *Fistularia petimba*,

Table 1 Numerical abundance and biomass of fish species at Itacuruçá Beach, Brazil, in 1998 and 1999

Species	Winter		Spring		Summer		Autumn		Percentage of total	
	N[a]	W[b]	N[a]	W[b]	N[a]	W[b]	N[a]	W[b]	N[a]	W[b]
Clupeidae										
Harengula clupeola	2,006	1,317	2	2.1	11	26	262	140.9	9.14	12.67
Engraulidae										
Anchoa tricolor	11,103	863.4	4,572	330.4	–	–	46	17.8	63.01	10.33
Anchoa januaria	17	31.8	232	87.5	–	–	–	–	0.99	1.01
Anchoa lyolepis	2	5.0	20	3.2					0.08	0.06
Cetengraulis edentulus	–	–	–	–	–	–	1	0.2	< 0.01	< 0.01
Synodontidae										
Synodus foetens	9	16.6	–	–	5	11.9	19	52.0	0.13	0.68
Belonidae										
Strongylura timucu	2	16.9	–	–	2	10.0	–	–	0.01	0.23
Atherinopsidae										
Atherinella brasiliensis	321	197.5	125	156.8	259	804.0	5	6.0	2.84	9.93
Fistulariidae										
Fistularia tabacaria	–	–	–	–	1	36.0	–	–	< 0.01	0.30
Fistularia petimba	–	–	7	55.5	3	23.9	1	4.1	0.04	0.71
Triglidae										
Prionotus punctatus	5	24.3	2	16.2	3	37.0	5	180.7	0.06	2.20
Syngnathidae										
Syngnathus folletti	–	–	4	4.2	1	2.7	–	–	0.02	0.05
Serranidae										
Diplectrum radiale	1	13.9	–	–	–	–	1	15.9	< 0.01	0.25
Acanthistius brasilianus	1	2.5	–	–	–	–	–	–	< 0.01	0.02
Carangidae										
Trachinotus carolinus	–	–	10	3.0	–	–	–	–	0.04	0.02
Trachinotus falcatus	–	–	–	–	10	26.1	–	–	0.04	0.22
Oligoplites saurus	1	3.4	–	–	14	21.2	–	–	0.06	0.21
Oligoplites palometa	–	–	–	–	1	0.5	–	–	< 0.01	< 0.01
Chloroscombrus chrysurus	–	–	2	0.1	–	–	–	–	< 0.01	< 0.01
Lutjanidae										
Lutjanus synagris	–	–	–	–	5	10.0	–	–	0.02	0.08
Gerreidae										
Gerres aprion	619	297.3	1,811	178.8	1,402	2,802.4	9	55.9	15.39	28.35
Gerres gula	1	19.4	1	7.4	3	19.0	–	–	0.02	0.39
Gerres melanopterus	–	–	–	–	3	2.3	–	–	0.01	0.01
Gerres lefroyi	2	0.4	–	–	–	–	–	–	< 0.01	< 0.01
Diapterus rhombeus	–	–	–	–	500	502.6	–	–	2.00	4.28
Haemulidae										
Haemulon steindachneri	–	–	–	–	–	–	2	35.5	< 0.01	0.30
Orthopristis ruber	–	–	–	–	2	30.6	–	–	< 0.01	0.26
Sciaenidae										
Menticirrhus littoralis	–	–	1	0.5	–	–	–	–	< 0.01	< 0.01
Ephippididae										
Chaetodipterus faber	–	–	2	2.2	6	16.7	–	–	0.03	0.16
Mugilidae										
Mugil liza	32	4.6	7	1.5	49	289.9	441	32	2.12	3.30
Mugil platanus	–	–	–	–	16	128.8	–	–	0.06	1.09
Dactyloscopidae										
Dactyloscopus crossotus	–	–	–	–	–	–	1	0.1	< 0.01	< 0.01
Gobiidae										
Gobionellus boleosoma	14	2.6	–	–	1	0.2	–	–	0.06	0.02
Gobionellus stigmaticus	1	0.2	–	–	1	0.3	–	–	< 0.01	< 0.01
Bathygobius soporator	–	–	1	4.4	5	56.3	–	–	0.02	0.51
Paralichthyidae										
Citharichthys spilopterus	81	128.7	28	63.2	89	615.3	59	154.5	1.03	8.02
Citharichthys arenaceus	3	39.1	7	13.6	18	111.9	18	45.6	0.18	1.79
Etropus crossotus	1	15.9	–	–	–	–	–	–	< 0.01	0.13
Syacium papillosum	1	0.1	–	–	–	–	–	–	< 0.01	< 0.01
Paralichthys brasiliensis	–	–	1	12.5	–	–	1	0.1	< 0.01	0.10
Paralichthys orbignyanus	–	–	1	6.5	–	–	–	–	< 0.01	0.05
Achiridae										
Achirus lineatus	–	–	2	0.4	10	19.4	–	–	0.04	0.16
Cynoglossidae										
Symphurus tessellatus	1	2.6	–	–	–	–	1	34.1	< 0.01	0.31

Table 1 (Contd.)

Species	Winter		Spring		Summer		Autumn		Percentage of total	
	N[a]	W[b]	N[a]	W[b]	N[a]	W[b]	N[a]	W[b]	N[a]	W[b]
Monacanthidae										
Monacanthus ciliatus	10	1.5	47	43.7	31	23.6	43	42.9	0.52	0.95
Tetraodontidae										
Sphoeroides testudineus	6	3.2	66	164.5	235	678.7	1	7.2	1.23	7.28
Sphoeroides greeley	–	–	48	47.3	104	296.5	2	19.4	0.61	3.09
Total	14,240	3,007.8	6,999	1,205.4	2,790	6,603.9	918	904.23		
Number of species	24		24		29		19			

[a]Numerical abundance
[b]Biomass

Table 2 Results of Kruskall-Wallis and a posteriori Mann-Whitney tests for comparisons of catch per unit effort (CPUE), number of species and biomass between seasons and diel at Itacuruçá Beach in 1998 and1999

Parameter	Seasons[a]		Diel	
	χ^2	Mann-Whitney	χ^2	Mann-Whitney
CPUE	17.46*	W > S > Su > A	5.04**	Day > night
Number of species	23.86*	Su > S > W > A	1.56	–
Biomass (g)	27.00*	Su > W > S > A	1.50	–

[a]*W* winter, *S* spring, *Su* summer, *A* autumn
*$P < 0.01$
**$P < 0.05$

Achirus lineatus and *Bathygobius soporator* (Table 4; Fig. 2).

Plotting sample scores from DCA coded by seasons produced a marked clustering of the temporal series (Fig. 2). An anti-clockwise temporal pattern was shown beginning with samples collected during winter in the upper left corner, moving to spring in the lower left. The circle is continued through the center lower area for summer and then completed moving to the extreme right in autumn. This distinctive sequential distribution corresponds to the seasonal changes in the relative abundance of the 21 species. Axis I provides the main distinction between the winter and summer/autumn while axis II shows differences in summer and winter fish composition. The most abundant species in winter were *Anchoa tricolor* and *H. clupeola* (upper left) and, in spring, *A. tricolor* and *G. aprion* (left and center). In summer, the most abundant species were *D. rhombeus* and *Sphoeroides* spp, while in autumn, *M. liza* was most abundant (right).

Table 3 Pairs of similarity coefficient for fish abundance between pairs of seasons at Itacuruçá Beach in 1998 and 1999

Seasons	Similarity (%)
Winter/spring	72.28
Winter/summer	8.09
Winter/autumn	21.79
Spring/summer	30.83
Spring/autumn	8.31
Summer/autumn	9.34

Diel changes

Overall, only few fish species changed in abundance between day and night. On the other hand, if we consider each season separately, diel variation seems to occur in two ways, depending on season: in winter, *A. tricolor* occurred in high abundance during the day, being replaced by *H. clupeola* during the night, but in spring, *A tricolor*, which also occurred in highest abundance during the day, was replaced by *G. aprion* during the night. Overall, most number of individuals and species occurred during the day, with some species being exclusive to either day or night. Species which were found exclusively during the day were *Strongylura timucu*, *Trachinotus carolinus*, *Menticirrhus littoralis*, *Paralichthys orbigniana*, *Gerres melanopterus*, *Trachinotus falcatus*, *Oligoplites palometa*, *Fistularia tabacaria*, *Paralichthys brasiliensis* and *Cetengraulis edentulus,* while exclusively at night were *Acanthistius brasilianus*, *Syacium papillosum*, *Symphurus tessellatus*, *Chloroscombrus chrysurus*, *Orthopristis ruber*, *Haemulon steindachneri* and *Dactyloscopus crossotus*. Overall, species representing the highest weight occurred during the night.

In relation to diel CPUE changes, the highest number of individuals was caught during the day. Highest CPUE values were recorded at sunset (1700 hours), followed by a decreased number of individuals during the night. At sunrise (0500 hours) the number of individuals increased again (Fig. 3). The number of species did not change between day and night, although a slight increase in

Table 4 Component loads of species abundance on the first two axes from detrended correspondence analysis at Itacuruçá beach from August 1998 to June 1999

Species	Species code	Axis 1	Axis 2
Synodus foetens	Synfoe	294	210
Atherinella brasiliensis	Athbra	149	325
Gobionellus boleosoma	Gobbol	46	209
Citharichthys spilopterus	Citspi	193	222
Prionotus punctatus	Pripun	191	204
Gerres aprion	Gerapr	100	94
Oligoplites saurus	Olisau	276	36
Sphoeroides testudineus	Sphtes	207	50
Harengula clupeola	Harclu	21	302
Monacanthus ciliatus	Moncil	157	0
Mugil liza	Mugliz	330	172
Citharichthys arenaceus	Citare	288	258
Sphoeroides greeley	Sphgre	202	22
Fistularia petimba	Fispet	82	−92
Achirus lineatus	Achlin	149	−96
Chaetodipterus faber	Caefab	156	92
Bathygobius soporator	Batsop	172	−42
Diapterus rhombeus	Diarho	238	49
Mugil platanus	Mugpla	301	81
Trachinotus falcatus	Trafal	264	81
Anchoa tricolor	Anctri	0	143
Eigenvalues		0.77	0.52
Percentage variance		50	34

number of species was recorded at sunset (1700 hours) and during the early night (2000 hours) (Fig. 3). After this period the number of species decreased and, at sunrise, it increased again. Biomass was higher at night than during the day. A peak in biomass was recorded early at night (2000 hours), then a decrease from 2300 to 0200 hours, and an increase at sunrise (0500 hours) (Fig. 3).

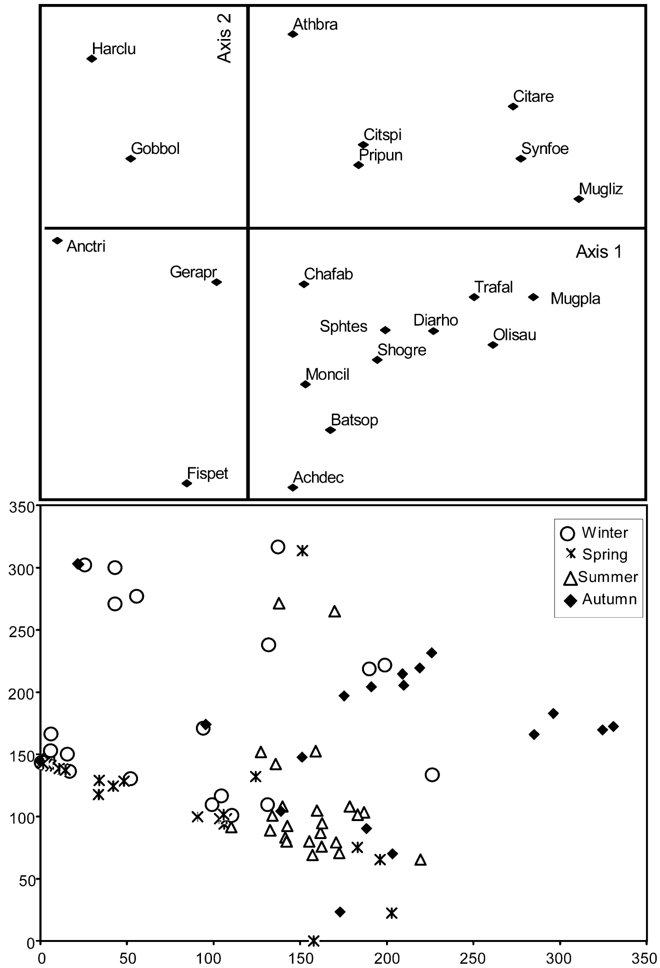


Fig. 2 The two main axes from detrended correspondence analysis on the 21 most abundant fish species in Itacuruçá beach, from August 1998 to June 1999. *Species codes* are as given in Table 4

Relative abundance

Changes in fish assemblages are mainly caused by changes in occurrence of dominant species. Dominant species were arbitrarily defined as those that contributed to more than 2% of the total number of caught fish. According to this definition, six dominant species were found, as follows: *Anchoa tricolor*, *Gerres aprion*, *Harengula clupeola*, *Atherinella brasiliensis*, *Mugil liza* and *Diapterus rhombeus*.

The six dominant species change their abundance and occurrence seasonally ($P < 0.01$). *Anchoa tricolor*, *H. clupeola* and *Atherinella brasiliensis* were more abundant in winter; *Anchoa tricolor* and *G. aprion* in spring; *G. aprion* and *D. rhombeus* in summer; and *M. liza* in autumn. *D. rhombeus* occurred only during summer (Table 5).

The dominant species did not present any evident diel change pattern (Table 5). However, some species did change daily in abundance. *A. tricolor* and *M. liza* showed higher abundance during daylight hours, while the remain dominant species were found during darkness.

Higher *A. tricolor* abundance occurred during the day, peaking at sunset (1700 hours) (Fig. 4); *G. aprion* was caught during all of the 24-h period, but higher values occurred during the night, peaking at 2000 and 0500 hours (Fig. 4); peaks of abundance for *H. clupeola* were recorded at sunset (1700 hours) continuing throughout the night, when the highest abundances were recorded (Fig. 4); *Atherinella brasiliensis* was caught throughout the 24-h period, being more abundant during darkness, and peaking at 1400, 2000 and 0500 hours (Fig. 4); *M. liza* showed highest abundances during the day, peaking at 0800 and 2000 hours (Fig. 4); *D. rhombeus* showed high abundance during all of the 24-h period, but highest records occurred at night, peaking at 2000 and 0200 hours (Fig. 4).

Size

Dominant fish species showed sizes ranging from 10 to 110 mm, being predominantly young-of-the-year and juveniles in the first years of life. *Anchoa tricolor* ranged from 25 to 40 mm TL, with largest sizes being recorded during spring (Fig. 5). *G. aprion* showed smaller size in winter and spring when compared to individuals

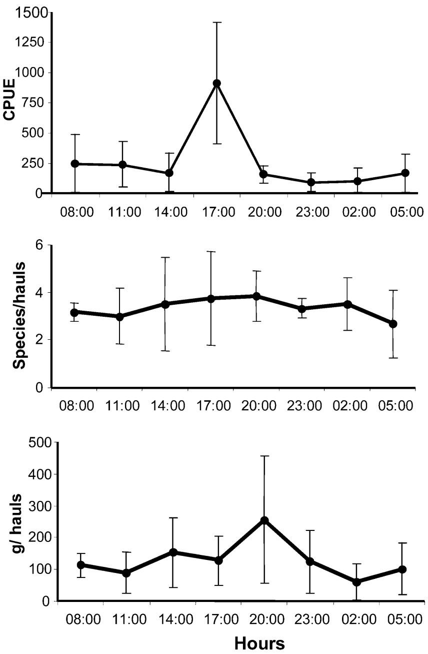


Fig. 3 Diel changes in catch per unit effort (CPUE), number of species and biomass at Itacuruçá beach, from August 1998 to June 1999

caught in summer and autumn, suggesting an influx of recruits in the first period from reproduction areas and the use of the beach as a nursery area. In winter/spring *G. aprion* showed modal groups measuring 15–25 mm TL, reaching their largest size at 50 mm TL in summer/autumn (Fig. 5).

Harengula clupeola showed modal size groups ranging from 35 to 45 mm TL, during winter and autumn (Fig. 5). *Atherinella brasiliensis* showed different size groups according to season, with smaller size recorded during winter, and largest in summer (Fig. 5).

M. liza ranged in size from 20 to 35 mm TL, though in summer, larger individuals with a mean size of 85 mm were recorded (Fig. 5). *D. rhombeus* was recorded only during summer, with individuals ranging from 25 to 80 mm TL (Fig. 5).

Discussion

Ichthyofauna at Itacuruçá beach showed relatively high richness and was dominated by a few abundant species, which use the area during early life. Several works have reported the use of beaches and other shallow environments by juvenile fishes all over the world (Romer 1990; Layman 2000; Methven et al. 2001); most of them consider such environments as rearing, feeding and protection grounds for juvenile fishes.

Seasonal segregation in occurrence of the most abundant fish was detected by DCA, and two main groups were found: one characterized by samples from the summer, and the other by those found during the winter. Spring samples were placed near to summer, while autumn samples appeared near to winter in the ordination diagram. This suggests that spring presented fish assemblage slightly similar to summer, while autumn's assemblages were more similar to those of winter. A higher diversity due to rare species was shown for the samples in summer. Species presenting peak abundance in different season were also reported by Potter et al. (2001), who attributed this mainly to differences in their life cycle.

Fishes inhabiting the protected areas of beaches and shallows change abundances seasonally (McFarland 1963) mostly due to young-of-the-year movements into and out of such areas. Such seasonal changes are due to the abundances of juveniles, which use these zones for recruitment and better larval survival (Potter et al. 2001). Romer (1990) reported the physical instability associated with water quality that characterizes the dynamics of fish assemblages, with different species interacting both daily and seasonally.

Seasonal variations at Itacuruçá beach were related to changes in abundance of dominant species, reflecting the dynamics of the community. Some species occur all through the year, peaking at certain periods: *Anchoa tricolor*, *Harengula clupeola* and *Atherinella brasiliensis* peak in winter; *Anchoa tricolor* and *Gerres aprion* in spring; *G. aprion* and *Diapterus rhombeus*, in summer; and *Mugil liza* in autumn. Different periods of recruitment could be associated with such a pattern. Recruitment has been described for some species in the Sepetiba bay; anchovies recruit mainly in late winter and spring (Silva and Araújo 1999), and Gerridae and Atherinidae in late summer and autumn (Araújo and Santos 1999; Pessanha and Araújo 2001). Recruitment variation can significantly influence both population size and community structure in marine system (Danilowicz 1997) and this situation matches the findings of the present work.

Table 5 Results of Kruskall-Wallis and a posteriori Mann-Whitney tests for comparisons of abundance of dominant species by diel and seasons at Itacuruçá beach from August 1998 to June 1999

Species	Seasons[a]		Diel	
	χ^2	Mann-Whitney	χ^2	Mann-Whitney
Anchoa tricolor	36.62*	W > S > A > Su	4.44	–
Gerres aprion	45.00*	S > Su > W > A	0.66	–
Harengula clupeola	15.00*	W > A > Su > S	1.20	–
Atherinella brasiliensis	13.41*	W > Su > S > A	4.35	–
Mugil liza	3.63**	A > Su > W > S	0.80	–
Diapterus rhombeus	75.78*	Su > W, S, A	0.25	–

[a] *W* Winter, *S* spring, *Su* summer, *A* autumn
*$P < 0.01$ **$P < 0.05$

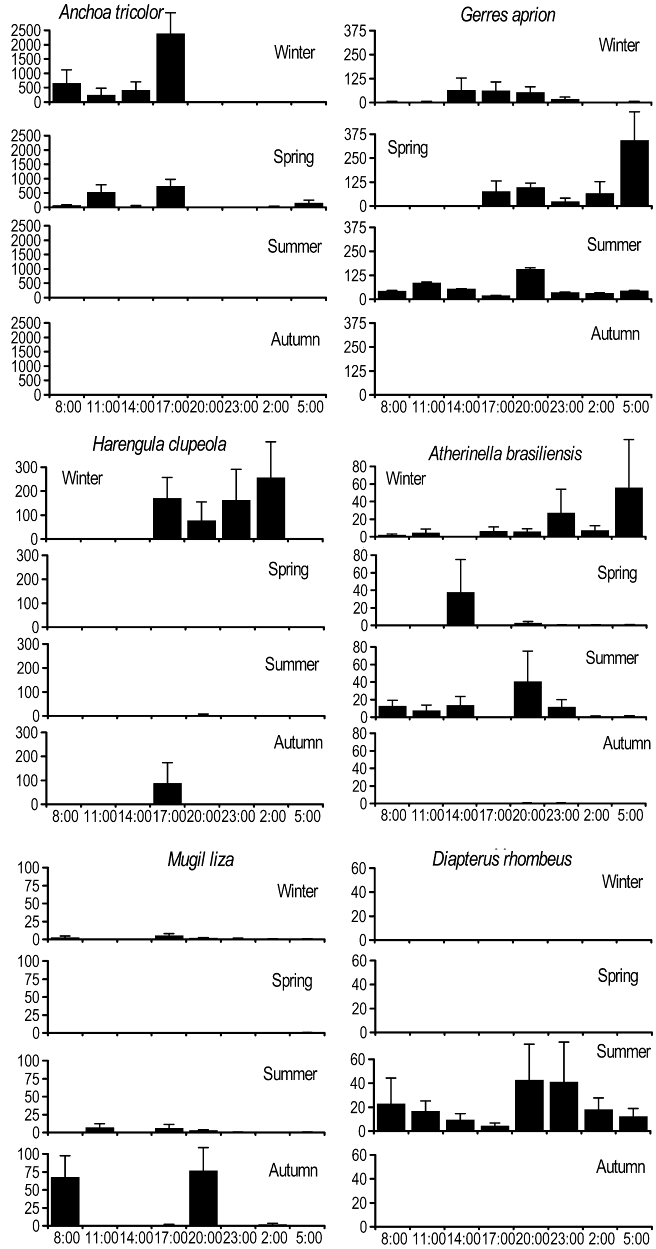


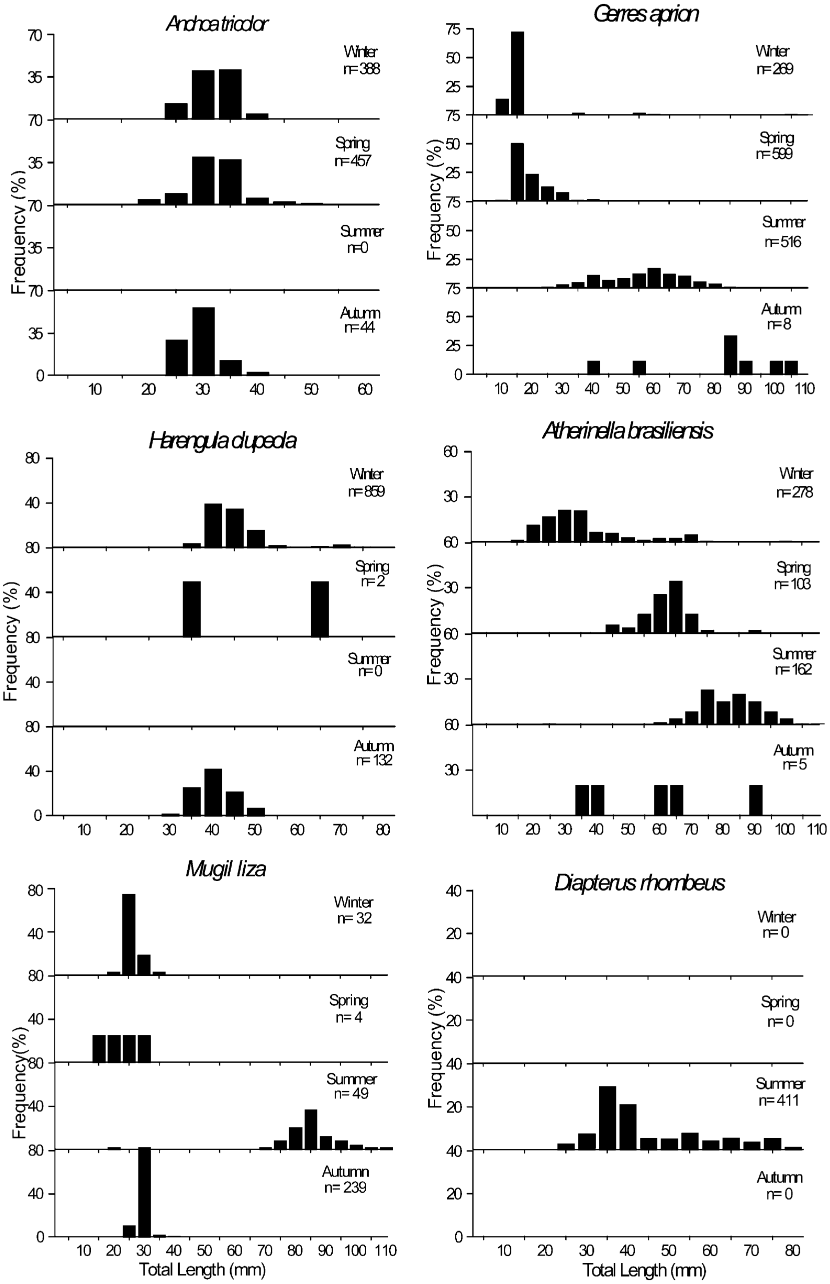
Fig. 4 Diel and seasonal variations in CPUE for *Anchoa tricolor*, *Gerres aprion*, *Harengula clupeola*, *Atherinella brasiliensis*, *Mugil liza* and *Diapterus rhombeus*, from August 1998 to June 1999

Itacuruçá beach plays an important role in the early life history of several fish species, mainly the dominant species that use the beach in early life. Length–frequency distributions showed that some species are present on beaches all year round, following their developmental stages in their life cycle. *A. tricolor* was caught during its larvae stage, while *H. clupeola* and *M. liza* were represented by early juvenile stages, remaining in the area until reaching a larger size, then moving to deeper areas in the bay. *G. aprion* and *Atherinella brasiliensis*, considered resident species (Araújo and Santos 1999; Pessanha and Araújo 2001), were represented by smaller juveniles in winter and remained on the beach until summer, when they presented larger sizes, then migrated offshore. Small species spend the whole of their life cycles in these environments, e.g. members of the Atherinidae; larger species, such as Mugilidae, Clupeidae and Engraulidae, use these waters seasonally, predominantly as nursery areas (Schafer et al. 2002). The use of Itacuruçá beach by juvenile fishes is associated with calm and protective waters with ample diversity of microhabitats, due to the proximity of the rocky Itacuruçá Island, and this environment offers shelter and food diversity for fishes. This habitat diversity suggests that the fish assemblage can use different mechanisms to control the community, mainly through resource partition (Ross 1986).

Evidence for a distinct diurnal or nocturnal fish community at Itacuruçá beach was not detected in this work, although the greatest number of species and individuals was caught at sunset and early night. The most remarkable changes in fish assemblages were caused by changes in the most abundant species, or by the presence or absence of rare species. Rare species were found only during the day or only during the night, with none occurring in both periods. Gibson et al. (1996) also found similar results for a beach on the west coast of Scotland. Daily changes at Itacuruçá are associated with large catches of *Anchoa tricolor* during the day and the remaining abundant species during the night. Overall, pelagic species tend to present daylight activity and this matches observations of *A. tricolor* at Itacuruçá, but not *H. clupeola*. Movements toward the beach at night by herring were observed by Manteifel et al. (1978) who attributed them to feeding activities. On the other hand, the higher abundance of *G. aprion* at night in spring could be related to their activity pattern that may respond to local circumstances of prey availability, predation risk and biotic conditions (Gibson et al. 1996). Demersal species tend to move regularly in the water column during darkness to seek food, which consists mainly of pelagic crustaceans (Maes et al. 1999). The gradual decrease in light intensity at dusk and its increase in the early morning hours serve as signals of change in biotic environmental conditions, reflected in the behavior of fishes from different ecological groups, and belonging to different links of the food chain of the water body (Manteifel et al. 1978).

Several species in Itacuruçá presented increased abundance at sunset (1700 hours) and during early night hours; this pattern has been described for different tropical and subtropical beaches (Lasiak 1984; Gibson et al. 1996; Godefroid et al. 1998). This occurs mainly for the following reasons: (1) during daylight most species aggregate in deeper waters, moving to shallow areas at night (Metheven et al. 2001); (2) movements toward shallow water are due to increased number of predators which prey mainly at the bottom in deeper areas (Gibson et al. 1996); and (3) visual stimulus and capacity to escape from nets could affect catches during daylight (Casey and Myers 1998). Diurnal and nocturnal fish activities were also reported by Hobson (1965), who

Fig. 5 Length–frequency distribution for *Anchoa tricolor*, *Gerres aprion*, *Harengula clupeola*, *Atherinella brasiliensis*, *Mugil liza* and *Diapterus rhombeus* at Itacuruçá beach, from August 1998 to June 1999



indicated that diurnal species were associated with herbivorous or omnivorous habits, while nocturnal species were predators.

High dominance of a small number of species in beach and other shallow areas may be due to individuals that are exploring abundant food resources, because of their evolutionary adaptation to explore these particular environmental conditions in such systems. When the physical dynamics and nutrients determine the rates of primary and secondary productivity, the most-adapted fish species take advantage of the trophic availability of the environment (Abookire et al. 2000). There are areas where planktophages, invertevores or omnivores predominate, and use the availability of plankton (mainly zooplanktivores) and the invertebrate availability in both infauna and epifauna (Miller and Dunn 1980). Dominant species at Itacuruçá beach showed varied trophic structure; *Anchoa tricolor* and *Harengula clupeola* are planktivores, while *Gerres aprion*, *Diapterus rhombeus*, *Atherinella brasiliensis* and *Mugil liza* are omnivores, detritivorous or benthic invertevores. Such trophic classifications were based on work on the feeding habits of several systems of the Brazilian Coast (Bemvenuti 1990; Júnior 1995; Santos and Araújo 1997).

The results of this study point to an evident temporal shifts in fish community composition and abundance, mainly in the most numerous species. Overall, the seasonal and diel pattern of use of the beach by juvenile fish could be a strategy of temporal segregation developed through their evolutionary history to take advantage of the food availability and generally favorable conditions in this area.

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