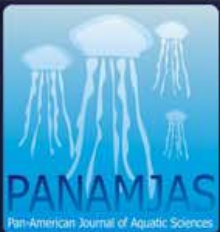


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Cover photo of this issue: *Lytechinus variegatus* (Lamarck, 1816) (Echinodermata, Echinoidea, Toxopneustidae) *in situ* at the Ponta do Seixas beach, Paraíba State, Brazil. Picture taken on November 2007 by Ana Cecília Giacometti Mai.



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Length-weight relationships for 11 fish species from the Gulf of Tunis (SW Mediterranean Sea, Tunisia)

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Abstract. In this study, length–weight relationships of 11 commercial fish species from the Gulf of Tunis: *Mullus barbatus*, *Scomber scombrus*, *Sparus aurata*, *Boops boops*, *Spicara maena*, *Diplodus annularis*, *Merluccius merluccius*, *Trachurus trachurus*, *Trachurus mediterraneus*, *Pagellus erythrinus* and *Lithognathus mormyrus* were presented. The values of the slope *b* in the length - weight relationship ranged from 2.674 to 3.368 and intercepts between 0.0021 and 0.0515.

Key words: Fishery resources, fish morphometry, ichthyofauna of the Mediterranean Sea.

Resumo. Relações comprimento-peso para 11 espécies de peixes do Golfo de Tunes (Mar Mediterrâneo Sudocidental, Tunisia). No presente estudo, as relações comprimento-peso para 11 espécies comerciais de peixes do Golfo de Tunis: *Mullus barbatus*, *Scomber scombrus*, *Sparus aurata*, *Boops boops*, *Spicara maena*, *Diplodus annularis*, *Merluccius merluccius*, *Trachurus trachurus*, *Trachurus mediterraneus*, *Pagellus erythrinus* e *Lithognathus mormyrus* foram apresentadas. O valor do coeficiente angular *b* nas relações comprimento – peso variou entre 2.674 e 3.368 e o valor de interseção da reta no eixo Y variou entre 0.0021 e 0.0515.

Palavras-chave: Recursos pesqueiros, morfometria de peixes, ictiofauna do mar mediterrânea.

The Gulf of Tunis provides a significant proportion of the overall marine fish production in Tunisia and is considered one of the most important fishery grounds of the Tunisian coast (Azouz 1973, Gharbi 1980, Zarrad *et al.*, 2001). The Gulf of Tunis is also known as an important spawning and nursery ground for several fish species (Hattour 1991, Zarrad *et al.*, 2003).

Length and weight data are a useful and standard result of fish sampling programs. These data are needed to estimate growth rates, length and age structures, and other components of fish population dynamics (Kolher *et al.*, 1995). Length-weight relationships allow fisheries scientists to convert growth-in-length equations to growth-in-weight in stock assessment models (Dulčić & Kraljević 1996, Gonçalves *et al.*, 1997, Morato *et al.*, 2001, Stergiou & Moutopoulos 2001, Özaydin *et al.*, 2007), estimate biomass from length frequency distributions (Anderson & Gutreuter 1983, Petrakis

& Stergiou 1995, Dulčić & Kraljević 1996), and calculate fish condition (Petrakis & Stergiou 1995). Length-weight relationships are also useful for comparing life history and morphological aspects of populations inhabiting different regions (Gonçalves *et al.*, 1997, Stergiou & Moutopoulos 2001). Despite the utility of length-weight relationship in fisheries science and the importance of the Gulf of Tunis for Tunisian fisheries, information about the length-weight relationships of fish species in Tunis Gulf is scarce and incomplete.

The present study presents estimates of the length weight relationships for 11 species of the families Carangidae, Mullidae, Scombridae, Sparidae and Merlucciidae.

Data were collected during twelve monthly trawl surveys conducted in February 2003 to January 2004 in the gulf of Tunis (Fig 1). Twelve hauls were operated monthly, based on a random sampling method, covering an area of 570 km²

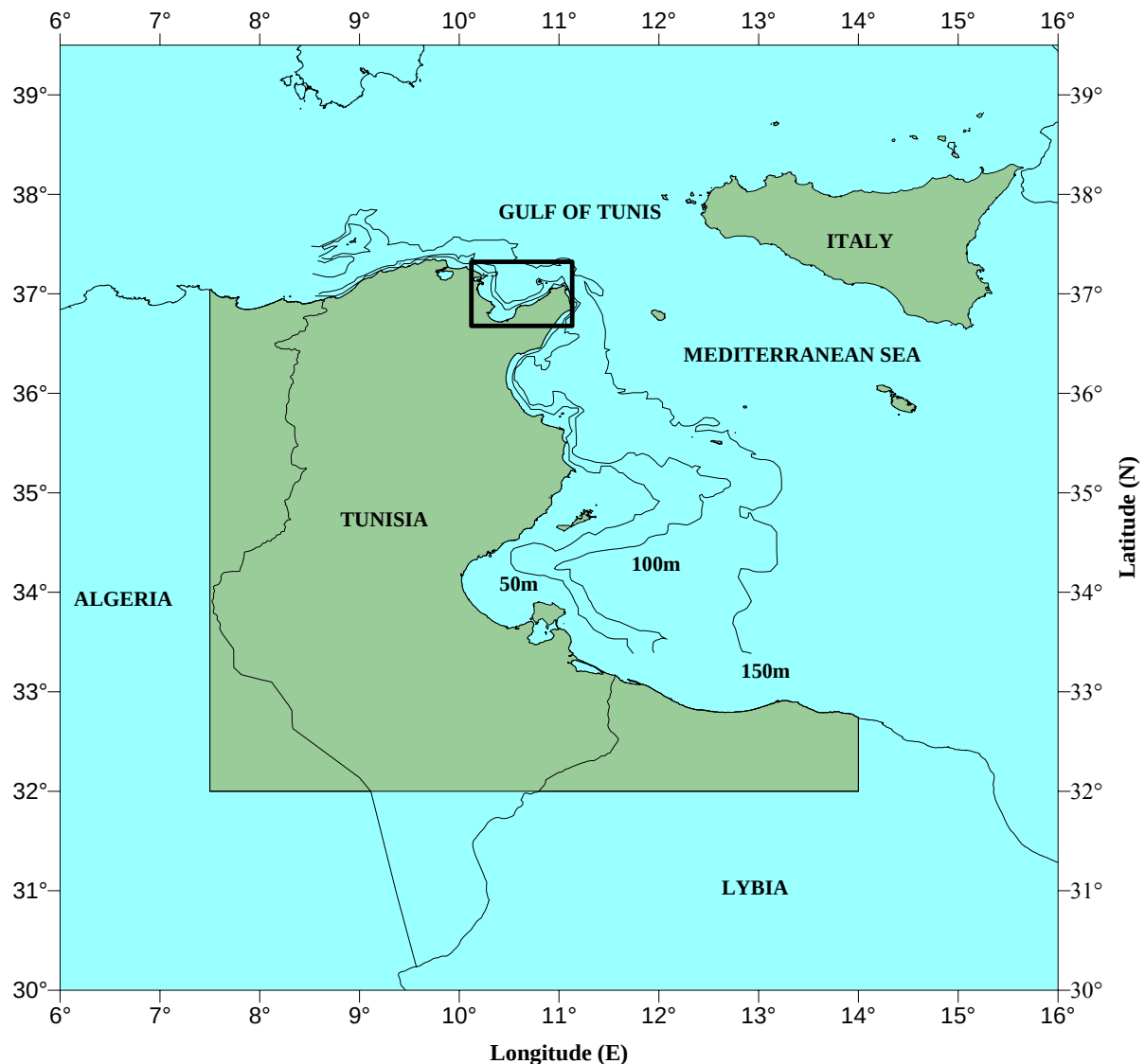


Figure 1. Map of Gulf of Tunis

between 40 and 100 m of depth, on professional boats. These experimental surveys were operated monthly on professional boats, covering an area of 570 km² between 40 and 100 m of depth. The vessel used was equipped with a Tunisian shrimp's trawl (modified Gulf of Mexico trawl) with 52 mm stretched mesh in the wing and 40 mm in the cod-end. Each haul lasted 120 min at an average speed of 3 knots.

In the laboratory specimens were sorted by sex, measured to the nearest 1 mm (total length, TL) and weighed to the nearest 0.1 g (weight, W). The relationship between the length and weight of a fish is usually expressed by the equation $W=aL^b$ (Ricker 1973) where W is body weight (g), L is total length (cm), a is the intercept and b is the slope (fish growth rate) (Beverton & Holt 1996). The parameters a and b of the length-weight relationships were estimated by the least-square method based on the predictive or Type I linear

regression model (Sokal & Rohlf 1981), using W as the dependent variable and L as the independent variable, the data analysis has given that for each specie, the number of outliers is far less than 10% of total data and thus the least square model is satisfactory for each set of data (Chen & Jackson 2000). The degree of adjustment of the model studied was assessed by the correlation coefficient (r). Student's t-test was applied to verify whether the declivity of regression (constant "b") presented a significant difference of 3.0, indicating the type of growth: isometric ($b=3.0$), positive allometric ($b>3.0$) or negative allometric ($b<3.0$) (Spiegel 1991). In all cases a statistic significance of 5% was adopted.

A total of 5533 individual fish length and weight observations were recorded for the 11 fish species analyzed in this study. The estimated parameters and length characteristics of the length-weight relationship are given in Table I.

Table I. Descriptive statistics and estimated parameters of the length-weight relationship for 11 fish species from the Gulf of Tunis. min, minimum; max, maximum; S.E, standard error; n, the sample size; *a*, the intercept of the relationship; *b*, the slope of the relationship; *r*, coefficient of correlation.

Species	Sex	n	Length characteristics (cm)				Parameters				
			mean	SE	min	max	<i>a</i>	<i>b</i>	SE (<i>b</i>)	<i>r</i>	t-test
<i>Mullus barbatus</i> (Linnaeus, 1758)	males	664	12,8	0,12	6,3	21	0,004	3,28	0.0314	0,99	4,237*
	females	1099	16,4	0,07	9,7	25	0,007	3,12	0.0521	0,97	5,073*
	both	1763	14,9	0,07	6,3	25	0,005	3,23	0.0072	0,99	3,291*
<i>Sparus aurata</i> (Linnaeus, 1758)	males	124	19	0,1	16	22	0,052	2,8	0.0651	0,92	3,096*
	females	271	17	0,06	17	23	0,014	2,72	0.0398	0,93	3,566*
	both	395	19,2	0,05	16	23	0,03	2,67	0.0152	0,91	4,381*
<i>Diplodus annularis</i> (Linnaeus, 1758)	males	183	13,2	0,09	9,6	17	0,033	2,72	0.0557	0,92	3,022*
	females	287	13,1	0,07	10	17	0,01	2,86	0.0723	0,92	2,873*
	both	470	13	0,52	9,6	17	0,012	2,9	0.0752	0,93	2,895*
<i>Pagellus erythrinus</i> (Linnaeus, 1758)	males	285	19,1	0,16	11	29	0,01	2,84	0.0358	0,97	2,012*
	females	613	16,8	0,08	11	25	0,018	2,84	0.0637	0,97	2,395*
	both	898	17,2	0,84	7,4	29	0,017	2,85	0.0239	0,98	2,208*
<i>Spicara maena</i> (Linnaeus, 1758)	males	121	16	0,17	9,9	19	0,03	2,82	0.0448	0,97	1,708ns
	females	209	14,9	0,11	11	19	0,012	2,94	0.0333	0,96	1,695ns
	both	330	15,4	0,09	9,5	20	0,014	2,87	0.0328	0,96	1,493ns
<i>Merluccius merluccius</i> (Linnaeus, 1758)	males	187	22,4	0,35	16	43	0,004	3,17	0.0354	0,98	3,511*
	females	340	26,1	0,24	17	41	0,005	3,11	0.0284	0,98	2,996*
	both	527	24,8	0,21	16	43	0,004	3,13	0.0232	0,98	4,147*
<i>Boops boops</i> (Linnaeus, 1758)	males	71	18,2	0,24	15	23	0,003	3,01	0.0827	0,97	0,245ns
	females	172	19,5	0,19	12	26	0,009	2,98	0.0458	0,97	0,232ns
	both	243	18,5	0,14	12	26	0,007	3,06	0.0278	0,98	0,255ns
<i>Trachurus trachurus</i> (Linnaeus, 1758)	males	85	19,3	0,32	13	32	0,007	3,00	0.0242	0,98	0,553ns
	females	144	19,1	0,17	15	25	0,007	2,98	0.0168	0,97	0,287ns
	both	229	17,5	0,17	9	32	0,007	2,98	0.0279	0,99	0,749ns
<i>Trachurus mediterraneus</i> (Steindachner, 1863)	males	182	18,9	0,28	8,8	30	0,007	2,99	0.0206	0,98	0,201ns
	females	280	19,6	0,18	12	28	0,009	2,9	0.0135	0,96	0,231ns
	both	462	17,9	0,2	8,8	30	0,007	3,01	0.0236	0,99	0,166ns
<i>Lithognathus mormyrus</i> (Linnaeus, 1758)	males	28	18,5	0,28	15	21	0,005	2,92	0.0457	0,96	0,854ns
	females	89	18,8	0,15	15	22	0,01	2,98	0.0398	0,98	0,778ns
	both	117	18,7	0,13	15	22	0,009	2,84	0.0291	0,98	0,852ns
<i>Scomber scombrus</i> (Linnaeus, 1758)	males	44	24,4	0,49	17	32	0,002	3,35	0.0385	0,98	3,177*
	females	55	26,1	0,31	18	32	0,006	3,18	0.0429	0,99	2,386*
	both	99	25,2	0,21	17	32	0,002	3,37	0.1658	0,99	3,557*

*: $p < 0.05$; ns: $p > 0.05$

The sample size ranged from 99 individuals for *Scomber scombrus* to 1763 for *Mullus barbatus*. The r values ranged from 0.82 for *Sparus aurata* to 0.99 for *Trachurus trachurus*, and all regressions were highly significant. Values of b ranged from 2.674 for *Sparus aurata* to 3.368 for *Scomber scombrus*. A high degree of positive correlation between total length and total weight of all 11 fish species is indicated by high values of correlation coefficient r . The estimated values of b were close to 3.0 ($p > 0.05$) showing isometric growth for *Lithognathus mormyrus*, *Boops boops*, *Spicara maena*, *Trachurus trachurus* and *Trachurus mediterraneus*.

The values of the exponent b for males, females and combined sexes were significantly ($p < 0.05$) higher than 3.0 exhibited a positive allometric growth for *Mullus barbatus*, *Merluccius merluccius*, and *Scomber scombrus*. The slopes for male, female and both sexes for *Sparus aurata*, *Diplodus annularis* and *Pagellus erythrinus* showed a significant difference ($p < 0.05$) lower than 3.0 reflecting a negative allometric growth.

Even though the change of b values depends primarily on the shape and fatness of the species, various factors may be responsible for the differences in parameters of the length/weight relationships among seasons and years, such as temperature, salinity, food (quantity, quality and size), sex, time of year and stage of maturity (Pauly 1984, Sparre 1992). According to Bagenal & Tesch (1978), Gonçalves *et al.*, (1997), Taskavak & Bilecenoglu (2001) and Özeydin *et al.*, (2007), the parameter b , unlike the parameter a , may vary seasonally, and even daily, and between habitats. Thus, the length-weight relationship in fish is affected by a number of factors including gonad maturity, sex, diet, stomach fullness, health, and preservation techniques as well as season and habitat, none of which were taken into consideration in the present study.

The information gained in the present survey can enable fish biologists to derive weight estimates for the Gulf of Tunis fishes that are measured but not weighed. The length-weight parameters hereby reported may be of considerable use in ongoing studies of catches in Tunisian commercial fisheries.

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Lysosomal Membrane Stability of the brown mussel *Perna perna* (Linnaeus) (Mollusca, Bivalvia) exposed to the anionic surfactant Linear Alkylbenzene Sulphonate (LAS)

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Abstract. The effects of the Linear Alkylbenzene Sulphonate (LAS) were evaluated on the mussel *Perna perna* (Linnaeus, 1758), using a cellular level biomarker. The Neutral Red Retention Time (NRRT) assay was used to estimate effects at cellular levels. Significant effects were observed for the NRRT assay, even in low concentrations. The effects at cellular level were progressive, suggesting that the organisms are not capable to recover of such increasing effects. Additionally, the results show that the levels of LAS observed for Brazilian coastal waters may chronically affect the biota.

Keywords: Ecotoxicology; Biomarkers; Detergent; Effect; Marine Pollution; Mussel.

Resumo. Estabilidade de membranas de lisossomos de mexilhões *Perna perna* (Linnaeus) (Mollusca, Bivalvia) expostos ao surfactante Alquilbenzeno Sulfonato de Sódio Linear. Os efeitos do Alquilbenzeno Sulfonato de Sódio Linear sobre o mexilhão *Perna perna* (Linnaeus, 1758) foram avaliados por meio do uso de um biomarcador celular, o ensaio do tempo de retenção do vermelho neutro (NRRT). Efeitos significativos foram observados para o ensaio do NRRT, mesmo em baixas concentrações. Os efeitos ao nível celular foram progressivos, sugerindo que os organismos não conseguem se recuperar dos efeitos crescentes da exposição. Os resultados ainda mostram que níveis de LAS presentes na costa brasileira podem afetar cronicamente a biota.

Palavras-chave: Ecotoxicologia; Biomarcadores; Detergente; Efeito; Poluição Marinha; Mexilhão.

Detergents are often present in industrial and domestic effluents, due to their multiple uses. Such compounds are used worldwide as cleaning agents, participating also in the production of oil and textile products, in mineral extraction and exploration and being used as dispersants during oil spill episodes (Lewis 1991). These substances have surfactant properties, i.e. the molecules present a polar and a non polar regions, which allow them to reduce the surficial tension of any solution, to concentrate onto surfaces and to form ions aggregates and micelles (Abel 1974).

In the last 25 years, the anionic surfactant Linear Alkylbenzene Sulphonate (LAS) has been the most used in the composition of domestic detergents (Larson & Woltering 1995). This compound started to be produced during the 1960's decade,

substituting the Alquilbenzene sulfonates (ABS) (Holman & Macek 1980). The LAS is nowadays widely spread in many different aquatic environments, where it has an important pollutant potential (Ainsworth 1992). Since the 1970's decade, investigations on the toxic effects of the LAS have been conducted with aquatic organisms, as fish (Swedmark *et al.* 1971, Barbieri *et al.* 2002, Rocha *et al.* 2007), crustaceans (Swedmark *et al.* 1971, Lewis & Suprenant 1983, Singh *et al.* 2002) and mollusks (Swedmark *et al.* 1971, Marin *et al.* 1994, Da Ros *et al.* 1995, Hansen *et al.* 1997), especially in Europe and North America.

The main effects already appointed as a result from the exposure of aquatic organisms to anionic detergents are cellular, histological and physiological damages, which comprise alterations

in the fish gill tissues (Swedmark *et al.* 1971, Abel 1974, Supriyono *et al.* 1998), lysosomal disturbances and enzymatic inhibition or stimulation (Drewa 1988, Da Ros *et al.* 1995), growth reduction (Hansen *et al.* 1997) and alteration of the cardiac activity (Swedmark *et al.* 1971).

The aim of this study was to evaluate the LAS effects on the brown mussel *Perna perna* (Linnaeus, 1758), by using a biomarker at cellular level, in order to contribute to the comprehension of its toxic mode of action and to the management of the LAS environmental levels. To achieve that, the neutral red retention time assay (NRRT) was used.

Adult healthy individuals of *P. perna* (41.2 – 77.3 mm shell length) were collected from a mussel farm, located at Cocanha Beach, Caraguatatuba, North Shore of São Paulo, Brazil. According to the State Environmental Agency, this site is considered clean and its waters present good quality (CETESB 2007). After collection, the animals were acclimated to laboratory conditions for 24 hours, in tanks containing filtered seawater, and kept under intense and continuous aeration, constant temperature ($25 \pm 2^\circ \text{C}$) and natural conditions of light.

The LAS used in this investigation consisted in molecules containing linear 12 carbon chain (according to the information provided by the producer). A 1000 mg.L^{-1} LAS stock solution was prepared by the addition of pure LAS salts (Merck, PA) in distilled water. The LAS test-solutions were prepared by diluting a stock solution (50 mg.L^{-1} LAS) in filtered sea water. The following LAS concentrations were prepared: 0.50; 0.25; 0.13; 0.06 and 0.03 mg.L^{-1} . Filtered ($100 \mu\text{m}$ acetate membrane) sea water was used as control.

The experiments consisted in exposing the animals for 24h to the LAS dilutions, and the further observation of sub-lethal effects. The physical-chemical characteristics of the different tested solutions were monitored in all the experiments.

The Neutral Red Retention Time (NRRT) assay followed the method described by Lowe *et al.* (1995), using the blood of ten animals of each treatment. The neutral red retention time was obtained by estimations of the proportion of haemocytes which released the neutral red dye to the citosol and/or by anomalies in the size and color of lysosomes and the cells shape. When 50% or more cells exhibited alterations, the time interval was recorded. The mean retention time was calculated for each concentration and the comparison to the control was made by analysis of variance (ANOVA) followed by the Dunnett test (Zar 1984).

In the experiment, the physical-chemical characteristics of the tested dilutions showed very small variations: salinities ranged between 33 and 35 ‰, temperatures ranged from 23 to 25°C and pH ranged between 7.60 and 8.08.

The mean NRRT was significantly lower ($p < 0.05$), in comparison to the control, for the organisms exposed to 0.5; 0.25; 0.13 and 0.06 mg.L^{-1} LAS (Fig. 1). The decreasing of the dye retention time was directly related to the increasing of the LAS concentration, indicating that this compound damages the membranes. For the smaller concentration (0.03 mg.L^{-1}), the NRRT was not significantly different from that observed in the control.

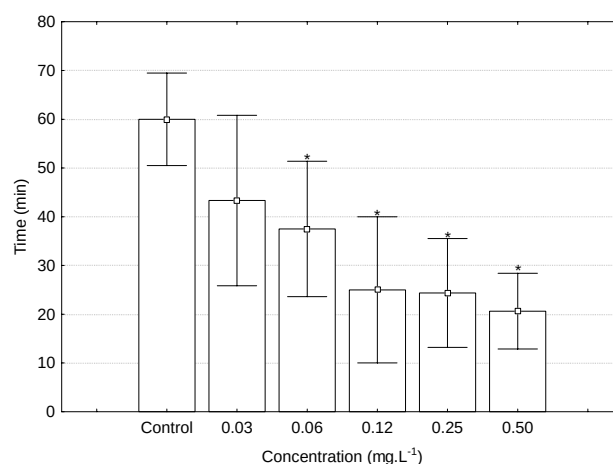


Figure 1. Mean NRRT (minutes) in haemocytes lysosomes of the mussel *P. perna* (Error bars indicate standard deviations and * indicates significant differences, $p \leq 0.05$).

The fragility of lysosomal membranes is quantitatively related to the level of stress induced by the xenobiotics, once the lysosomes are involved in many essential cellular processes, representing the main organelle responsible to remove toxic compounds from the citosol (Moore 1982, 1985). In mollusks, lysosomes play a key role in the process of mediating enzymes for the catabolism of endogenous and exogenous material, and in the regulation of the cell homeostasis, by fagocytosis, digestion, depuration and excretion of xenobiotics (Moore 1985, Viarengo *et al.* 1987, McVeigh *et al.* 2006). As consequence of the accumulation of contaminants in the lysosomes, alterations and damages in the lysosomal membranes may occur, releasing thus the digestive enzymes to the citosol and producing increased autolytic activity (Moore 1985, McVeigh *et al.* 2006).

Due to the tensoactive properties of detergents, the biological membranes can be considered main targets of such compounds; becoming thus useful models to evaluate the sub-

lethal effects of this kind of substance, in special if the membrane stability is considered.

The results obtained in the present study may be explained, at least partially, by the incorporation and accumulation of the detergent into the lysosomes (Bragadin *et al.* 1996). As consequence of the depuration process, free species of oxygen can be produced; consequently, alteration in the concentration of antioxidant enzymes may occur, as observed by Da Ros *et al.* (1995) in mussels exposed to LAS. The resulting lipoperoxidation may affect the stability of the biological membranes (Torres *et al.* 2002, Gorinstein *et al.* 2003), as observed in the present study.

Another factor which could be involved in the fragilization of the cell membranes is the structural modification of their proteins and phospholipids, caused by the anionic surfactant. The detergent is a molecule capable to bind to lipids and form micelles, thus it can bind to the phospholipids and destabilize and/or break the biological membranes. This process is known as *binding membranes* (Cserháti *et al.* 2002).

However, the increasing responses as result of LAS exposure are not always observed. Marin *et al.* (1994), in a study on the effects of LAS contaminated sediments on the mussel *Mytilus galloprovincialis* (Lamarck, 1819), observed a not significant increase in the respiratory rate of the exposed organism, whereas other studies with fishes evidenced the occurrence of effects in the animals exposed to low LAS concentrations (Barbieri *et al.* 2000, Barbieri *et al.* 2002). Depledge & Andersen (1990) and Depledge *et al.* (1995) mentioned the capability of marine organisms to compensate, temporarily or partially, the effects of contaminants by physiological mechanisms. However, if the alterations in biochemical, cellular and histological levels keep growing or remain constant for longer periods, the animals frequently cannot maintain such compensatory mechanisms, and then the physiological effects become apparent (Drewa 1988, Hofer *et al.* 1995, Swedmark *et al.* 1973).

In Brazil, minor importance has been given to the presence and discharges of detergents in the aquatic environment, although the use of such compounds is increasing all along the country. The lacking of information on their toxic effects on the biological communities represents a problem to the establishment of regulations and to the determination of maximum concentrations for the effluents discharged into the environment.

The results obtained in the present study showed that the significant LAS effects on mussels

occurred in concentrations lower than those found by Mastroti *et al.* (2001) for sea urchin embryos; in that study, significant effects were observed from 0.2 mg L⁻¹ LAS. Mastroti *et al.* (1998) reported that the levels of LAS in estuarine and marine waters of São Paulo ranged between 0.03 and 2.08 mg L⁻¹ with exceptional values reaching 8.47 mg L⁻¹, thus many already found values exceed the concentrations capable to produce significant effects, according to data obtained in the present study. Therefore, more attention must be given to the presence of surfactants in the environment, especially in marine and estuarine waters, once these compounds are toxic, present low degradation in salt waters (Mastroti *et al.* 1998) and are widely discharged into the coastal waters. The maximum permitted concentration of LAS in salt waters should be at least 0.03 mg.L⁻¹ (or lower), in order to avoid sub-lethal effects and long-term ecological disturbances. However, further studies with more species are needed to establish legal standards for LAS in marine and estuarine Brazilian waters.

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Dados sobre a alimentação de jovens de tubarão-tigre, *Galeocerdo cuvier* (Péron & Lesueur) (Elasmobranchii, Carcharhinidae), do sul do Brasil

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Abstract. Data on the food of juveniles Tiger Shark, *Galeocerdo cuvier* (Péron & Lesueur) (Elasmobranchii, Carcharhinidae), from southern Brazil. Three fishing communities in two regions of the southern Brazilian coast were studied in different periods between 2001 and 2007; Barra do Saí (SC) and Brejatuba (PR), bordering the littoral region of the Santa Catarina and Paraná States, and Ipanema, located in the central portion of the Paraná State. Two newborns and 16 young individuals of *Galeocerdo cuvier* were observed, with total lengths between 70 and 195 cm. Of the 18 specimens caught, 61.1% had some stomach content. Analyzes food of young of *G. cuvier*, according to the IRI%, showed predominance of Teleostei fish (98.2%), with emphasis on the families Balistidae and Monacanthidae. However, the participation of Birds, Crustaceans, Cephalopods and Polychaetes in their feeding is also recorded.

Key words: Tiger shark, diet, Paraná, Santa Catarina.

Resumo. Três comunidades em duas regiões litorâneas do sul do Brasil foram acompanhadas em diferentes períodos entre 2001 e 2007: Barra do Saí (SC) e Brejatuba (PR), localizadas na região limítrofe dos Estados do Paraná e Santa Catarina, e Ipanema, localizada na porção central do Estado do Paraná. Durante todo o estudo foram observados 16 exemplares jovens e dois neonatos, com comprimentos totais variando entre 70 e 195 cm. As capturas foram registradas apenas em redes de emalhe de fundo, principalmente nas malhas 16, 18 e 45 cm. Dos 18 exemplares capturados, 61,1% apresentavam algum conteúdo estomacal. As análises alimentares de jovens de *G. cuvier*, de acordo com o IRI%, mostraram predominância de peixes teleosteos (98,28%), com destaque para as famílias Balistidae e Monacanthidae. Porém, a participação de Aves, Crustáceos, Cefalópodes e Poliquetas na sua alimentação também são registradas.

Palavras-chave: Cação tintureira, dieta, Paraná, Santa Catarina.

O tubarão-tigre, *Galeocerdo cuvier* (Péron & Lesueur, 1822) (Elasmobranchii, Carcharhinidae), é conhecido principalmente na faixa tropical e subtropical de todos os oceanos e exibe padrão de distribuição vertical no qual grandes exemplares preferem águas mais profundas e indivíduos jovens são freqüentemente capturados em águas rasas (Randall 1992, Simpfendorfer 1992, Gadig 2001). No Brasil sua distribuição é conhecida ao longo de toda a costa, mas aparentemente é mais abundante no Norte e Nordeste (Gadig, 2001). São poucos os trabalhos publicados específicos sobre esta espécie

no Brasil (e.g. Alves, 1977, Gadig & Sazima 2003, Shibuya *et al.* 2005). O presente estudo tem como objetivo contribuir com o conhecimento da biologia desta espécie no litoral brasileiro, com base em dados sobre alimentação de juvenis capturados da pesca artesanal do litoral sul do Brasil.

As amostragens foram conduzidas em diferentes áreas: entre julho de 2001 e junho de 2003 em Brejatuba (25°53' S 48°33' W), município de Guaratuba (PR) e na comunidade de Barra do Saí (26°00' S, 48°36' W), município de Itapoá (SC); entre abril de 2004 e março de 2006, na Barra do

Saí; e entre junho de 2006 e abril de 2007, em Ipanema (25°38' S, 48°25' W), município de Pontal do Paraná (PR). Nas pescarias foram utilizadas redes de emalhe de fundo com malhas 16 e 45 cm (entre nós opostos esticados), colocadas em profundidade máxima de cerca de 20 m, a uma distância máxima de 13 milhas náuticas (Robert & Chaves 2006).

Para cada exemplar foram registrados o comprimento total (cm), o sexo e o estágio de maturidade sexual, de acordo com Motta *et al.* (2007). Os estômagos também foram removidos e fixados em solução de formol a 4%. No laboratório os conteúdos estomacais foram examinados e identificados até o menor nível taxonômico possível. Foi calculado o Índice de Importância Relativa (IRI%) (Pinkas *et al.* 1971): $IRI\% = (V\% + N\%) * F.O.\%$; onde, em relação a cada item alimentar, "V" refere-se ao volume; "N", ao número, e "F.O.", à frequência de ocorrência. Apenas os estômagos que não estavam vazios ou evertidos foram utilizados no cálculo. Não foram considerados os bicos de cefalópodes para valores volumétricos no intuito de evitar subestimativas.

De 272 desembarques observados, apenas 18 exemplares de *G. cuvier* foram registrados. Este resultado mostra que se trata de uma espécie ocasional na região estudada. Dos exemplares capturados dois eram neonatos e 16 jovens. O comprimento total médio foi de 130,5 cm (desvio padrão $\pm 35,44$; variação: 70-195 cm).

Sete espécimes (38,9%) estavam com o estômago vazio ou evertido e 11 (61,1%) apresentaram algum conteúdo. Foram identificadas oito famílias de peixes teleósteos; uma espécie de Ave; um gênero de cefalópodes; uma ordem de artrópodes (Crustácea, Decapoda); e uma classe de anelídeos (Polychaeta) - Tabela I.

Devido à impossibilidade de identificar todos os itens alimentares até o menor nível taxonômico possível, os mesmos foram agrupados em grandes taxa, conforme Tabela II. A análise do Índice de Importância Relativa, realizada a partir de 11 estômagos, revelou dieta composta predominantemente por peixes teleósteos da Classe Actinopterygii. Apesar dos outros itens - cefalópodes, crustáceos e aves - terem sido encontrados de 9,09 a 18,18% dos estômagos, representaram menos de 0,2% do Índice de Importância Relativa.

Segundo a literatura, *Galeocerdo cuvier* preda considerável diversidade de organismos, como peixes ósseos, elasmobrânquios, répteis marinhos, cetáceos e invertebrados (Lowe *et al.* 1996, Simpfendorfer *et al.* 2001, Heithaus 2001, Shibuya *et al.* 2005). A baixa diversidade registrada no presente estudo provavelmente é derivada do pequeno número de estômagos analisados, mas o pequeno tamanho dos exemplares (<195 cm) possivelmente interfere na possibilidade de consumo de itens de maior tamanho, como tartarugas, elasmobrânquios e cetáceos. Simpfendorfer *et al.* (2001), na Austrália e Lowe *et al.* (1996), no Havaí, constataram que indivíduos menores que 200 cm de comprimento, consumiam mais frequentemente teleósteos e/ou serpentes marinhas. Lowe *et al.* (1996) registrou tartarugas, elasmobrânquios e cetáceos em indivíduos acima de 210 cm de comprimento. Shibuya *et al.* (2005) registram em um único exemplar de 226 cm, peixes teleósteos e um elasmobrânquio.

Na área de estudo, teleósteos das famílias Sciaenidae e Clupeidae estão entre os numericamente mais abundantes nas capturas com redes de malhas de 7 a 16 cm (Robert 2004).

Tabela I. Itens alimentares encontrados em 11 indivíduos de *Galeocerdo cuvier*.

Filo	Classe	Ordem	Família: espécie
Chordata	Actinopterygii (Teleostei)	Tetraodontiformes	Balistidae: <i>Balistes</i> sp. (descritor)
			Monacanthidae: <i>Stephanolepis hispidus</i> (Linnaeus, 1766)
		Clupeiformes	Tetraodontidae: <i>Sphoeroides testudineus</i> (Linnaeus, 1758)
			Clupeidae: <i>Harengula clupeola</i> (Cuvier, 1829)
		Perciformes	Ephippidae: <i>Chaetodipterus faber</i> (Broussonet, 1782)
			Haemulidae: <i>Haemulon</i> sp. Cuvier, 1829
			Sciaenidae: não identificado
			Gerreidae: <i>Eucinostomus gula</i> (Quoy and Gaimard, 1824)
			<i>Sula leucogaster</i> (Boddaert, 1783)
			Loliginidae: <i>Loligo</i> sp. Lamarck, 1798
Mollusca	Cephalopoda	Teuthoidea	não identificado
Artropoda	Crustacea	Decapoda	não identificado
Annelida	Polychaeta		não identificado

Tabela II. Composição alimentar de 11 estômagos de *Galeocерdo cuvier* expresso em valores percentuais dos métodos numéricos (N), volumétricos (V), frequência de ocorrência (F.O.) e Índice de Importância Relativa (IRI%).

Itens alimentares	%N	%V	%F.O.	IRI%
Actinopterygii (Teleostei)				98,28
Monacanthidae + Balistidae	18,52	25,48	36,36	15,75
Haemulidae – <i>Haemulon</i> sp.	5,55	1,27	9,09	0,61
Ephippidae - <i>Chaetodipterus faber</i>	1,85	0,6	9,09	0,22
Gerreidae - <i>Eucinostomus gula</i>	1,85	1,57	9,09	0,31
Clupeidae	14,81	11,55	18,18	4,72
Tetraodontidae – <i>Sphoeroides testudineus</i>	1,85	0,18	9,09	0,18
Sciaenidae	5,55	9,61	18,18	2,71
Não identificados	38,89	36,06	100	73,78
Cephalopoda - <i>Loligo</i> sp.	5,55	--	18,18	--
Crustacea	1,85	0,03	9,09	0,17
Polychaeta	1,85	0,06	9,09	0,17
Aves	1,85	13,6	9,09	1,38

Porém, Monacanthidae e Balistidae representaram uma pequena parcela dos indivíduos capturados nestas redes. Tais fatos sugerem que *G. cuvier* aproveita-se de itens mais disponíveis no meio, ao consumir Sciaenidae e Clupeidae, mas que é seletivo ao consumir Monacanthidae e Balistidae (itens, que somados, representaram maior IRI%). Os indivíduos destas duas famílias são peixes comuns em ambientes de substratos consolidados (Brito 2003, Floeter *et al.* 2007). De fato, a maioria dos tubarões analisados que consumiram Monacanthidae e/ou Balistidae foram capturados por redes armadas próximas as Ilhas Currais ou Itacolomis (Paraná), onde o substrato é predominantemente rochoso. Comparativamente, a densidade de muitas espécies de peixes teleosteos é maior em ambientes de substrato consolidado (Ferreira *et al.* 2001, Ferreira *et al.* 2004, Floeter *et al.* 2007).

Um exemplar aqui analisado, medindo 195 cm, tinha penas e ossos de *Sula leucoaster* no estômago e foi capturado próximo Ilha de Currais, que é utilizada como área de alimentação e nidificação de *Sula leucogaster* e *Larus dominicanus* (Krull 2004). Os fatos expostos sugerem fortemente que *G. cuvier* faça incursões ocasionais em ambientes de substratos consolidados com finalidade alimentar, o que converge com os dados de Gadig (2001), Heithaus (2001) e Simpfendorfer *et al.* (2001), os quais indicam que esta espécie é oportunista.

Levando em consideração a frequência de ocorrência de lulas, *Loligo* sp., nos tratos digestórios de *G. cuvier* e a abundância deste gênero na região sul do Brasil (Haimovici & Perez 1991), é possível que estes cefalópodes representem um importante

item da dieta de *G. cuvier*, como representaram para jovens de *Sphyrna zygaena* na mesma região (Bornatowski *et al.* 2007).

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***Squalonchocotyle squali* MacCallum (Monogenoidea, Hexabothriidae) on *Squalus acanthias* Linnaeus (Elasmobranchii, Squalidae) from the Atlantic coast of Argentina**

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Abstract. The presence of *Squalonchocotyle squali* MacCallum 1931 parasite of *Squalus acanthias* Linnaeus, 1758, is reported for the first time in the Atlantic coast of Argentina, previous descriptions by MacCallum (1931), Price (1942) y Dillon & Hargis (1968) were compared. The possibility of the monogenoidean parasite of *S. acanthias*, from the Falkland Islands, collected by Kuznetsova (1975) and cited as *Squalonchocotyle* sp being representative of *S. squali* is discussed. The geographical range of distribution of *S. squali* is increased, and it's presence on the Southeast of the Atlantic Ocean is confirmed.

Key words: Monogenoidean, gill parasites, sharks, South Atlantic, San Jorge Gulf.

Resumen. *Squalonchocotyle squali* MacCallum (Monogenoidea, Hexabothriidae) en *Squalus acanthias* Linnaeus (Elasmobranchii, Squalidae) de la costa Atlántica Argentina. Se cita por primera vez para la costa Atlántica Argentina la presencia de *Squalonchocotyle. squali* MacCallum 1931 parásito de *Squalus. acanthias* Linnaeus, 1758. Se comparan descripciones previas realizadas por MacCallum (1931), Price (1942) y Dillon & Hargis (1968). Se discute la posibilidad de que el monogeneo parásitos de *S. acanthias*, provenientes de las Falkland Islands, colectados por Kuznetsova (1975) y citado como *Squalonchocotyle* sp. sea representantes de *S. squali*. Se amplía el rango de distribución geográfica de *S. squali* y se confirma su presencia en el sudeste del Océano Atlántico.

Palabras clave: Monogeneos, parasitos branquiales, tiburones, Atlántico Sur, Golfo de San Jorge.

Hexabotrids monogenoidean have been reported in chondrichthyans with over 60 species described up to date. (Whittington & Chisholm 2003). These authors mentioned that for the total of polyopisthocotylean reported for chondrichthyans, 86.5 % were Hexabothriidae. Inside this family, *Squalonchocotyle* Cerfontaine 1899 was reported on sharks belonging to four different families (Squalidae, Lamnidae, Dalatiidae and Centrophoridae). *Squalonchocotyle squali* MacCallum (1931) was first described on the Piked dogfish *Squalus acanthias* Linnaeus, 1758 from Woods Hole, Massachusetts (mid-Atlantic Ocean), and later on the gills of *Squalus lebruni* (Vaillant) Berg, 1895 at South Island (South Pacific Ocean) by Dillon & Hargis (1968).

On the South Atlantic Ocean, Kuznetsova

(1975) reported *Squalonchocotyle* sp found on the gills of *S. acanthias* proceeding from the coast of the Falkland Islands (South Atlantic Ocean in front of the Argentinean coast).

During a parasitological study on marine fish from Argentina, infections with hexabotrids monogenoidean were observed, the primary objective of this study was to report the presence of *S. squali* on the gills of *S. acanthias* and to compare it with previous reports of this specie.

Fifty specimens of *S. acanthias* caught by a research vessel of the National Institute of Fisheries Research (INIDEP, EH02/01) at San Jorge Gulf (48°S-55°W; 100-200 m depth) were examined. The fish were frozen at - 20° C and once landed they were immediately transported to the laboratory. Gills were examined under a stereoscopic microscope for

monogenoidean. Parasites were fixed in AFA, stained in hydrochloric carmine, dehydrated in a series of alcohols, cleared with creosote and mounted in Canada balsam. Drawings were made by the aid of a drawing tube. All measurements were taken with an ocular micrometer and were reported in micrometres followed by the ranges in parenthesis (unless otherwise stated). Three relations among different structures were also used for morphological comparison with another report of this species: BL/HL: body length/ haptoral length; BL/HHL: body length/ haptoral hooks length; and HL/HAL: haptor length/ haptoral appendix length. The generic classifications follow Boeger & Kritsky (1989) and the key given by Bullard & Dippennar 2003. Host classification follows Compagno (1984, 1999).

Taxonomic summary

Squalonchocotyle squali MacCallum, 1931 (Figs. 1-4)

Host: *Squalus acanthias* Linnaeus, 1758

Locality: San Jorge Gulf, coastal region (38° 80' S 57° 33' W; 100-200 m depth), Argentina ,South western Atlantic Ocean)

Site of infections: gills

Prevalence, Mean intensity: 11.1%, 0.2

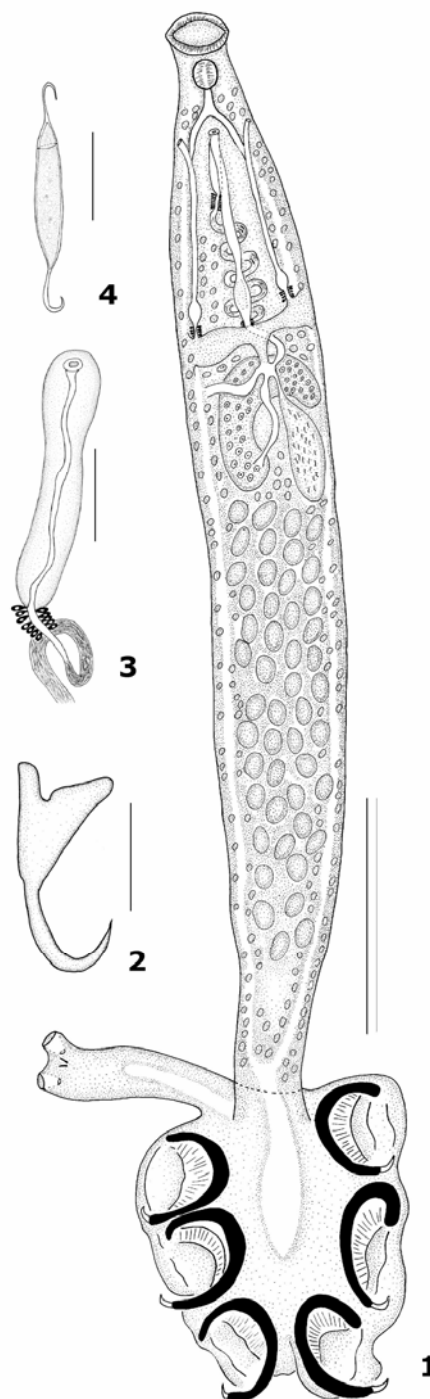
Voucher specimens: deposited in the Museo de La Plata Helminthological Collection (MPHC) (La Plata, Argentina) under the number: 5525

Descriptions: (based on 17 mounted specimens and 1 specimen in serial transversal sections, measurements taken on 11 specimens).

With the characters of *Squalonchocotyle* (*sensu* Boeger & Kritsky 1989). Body elongate 5.80 (4.76 -6.96) mm. long (excluding haptor) by 69 (62-87) wide (maximum) (fig 1). Haptor symmetrical of *Squalonchocotyle* type (Boeger & Kritsky 1989) 1.20 (1.12-1.26) mm. long by 1.00 (0.83-1.25) mm. wide, with six armed suckers; BL/HL 4.8:1 (4.2:1-5.5:1); appendix: 1.27 (0.94-1.35) mm. long by 190 (100-210) mm wide, bearing one pair of terminal suckers and single pair of anchors; suckers of the appendix 100 (90-110) in diameter; HL/HAL 4.5:1 (5:1-5.1:1); anchors: 58 (50-70) long with V shaped root, outer root length 16 (14-18) ; inner root length 13 (12-14); point length 20 (17-23) (fig. 2). Haptoral suckers 35 (30-37) in diameter; sucker sclerites similar in shape and size, total length 74 (57-91); point length 90 (70-12) and maximum width 100 (80-120); BL/HHL 7.6:1(3:1-7.8:1). Oral sucker terminal 230 (190-270) in diameter; pharynx 70 (50-120) in diameter; intestinal branches with lateral diverticula, joining the testes posteriorly, and with a

single branch penetrating into the haptor and the appendix.

Testes 45 (30-69) in number, located in the intercaecal area, posteriorly to the ovary and not reaching back to the union of intestinal branches. Vasa efferentia with thin wall. Vas deferens, dorsal to the uterus, thin walled, reaching a cirrus sac and opening in a common genital pore.



Figures 1-4. *Squalonchocotyle squali* MacCallum, 1931. Fig 1: Whole mount (ventral view) scale bar = 1mm. Fig. 2: Anchors scale bar = 0.05 mm. Fig.3: Detail of the terminal male genitalia scale bar = 0.05 mm. Fig.4: Egg, scale bar = 0.2 mm

Cirrus sac elongated 90 (75-100) long by 45 (40-50) wide and surrounded in its posterior end by glandular clusters. This sac was congruent with the "elongated cirral bulb type" described by Boeger & Kritsky (1989) (Fig. 3). Genital pore mid ventral, posterior to the pharynx 10 (8-12) in diameter, and located 50-60 posteriorly to intestinal bifurcation. Ovary folded into itself, placed on the pre-equatorial region; oviduct receiving the ducts of the seminal receptacle and the median vitelline duct. Seminal receptacle sac shape 500 (400-550) long, by 120 (100-150) wide; ootype fusiform with 7-10 internal ribs; uterus reaches the genital pore. Vaginal pores latero-ventral, located at each side of the median longitudinal line, at the level of the genital atrium; vaginal ducts straight, parallel, with basal glands, terminal portion non-muscular, and ending in the corresponding transverse vitellary duct. Vitellaria follicular, extending from the level of the pharynx to join the testes posteriorly without penetrating in the haptor neither in the appendix. Vitelline reservoirs Y shaped with each arm join with vaginal ducts. Eggs oval, operculated, 283 (250-350) long by 100 (80-130) wide, with a short curve filament 50-60 long at each pole (fig 4).

By the presence of a symmetrical haptor, sucker sclerites equals, haptoral appendix marginal with anchors, egg with two filaments, vaginae differentiated with parallel duct and non-muscular terminal portion, ovary proximal branched, seminal receptacle present, male copulatory organ with distal portion, and by the absence of dilated vas efferentia with glandular wall, the monogenoidean described now could be included in *Squalonchocotyle*. Present specimens of *Squalonchocotyle* are similar in their morphological features (body measurements, haptor length, pharynx and mouth diameter, haptoral hooks and anchors measurements, and the ratios (BL/HL, BL/HAL, BL/HHL) to *S. squali* described by Price (1942) based on the Mac Callum's (1931) material. On the other hand BL/HAL and BL/HHL relationships in *S. squali* parasite of *S. lebruni* described by Dillon & Hargis (1968) are bigger than those stated in the description by Price (1942) and than those described here; besides, the egg size are smaller. The sharks *S. acanthias* and *S. lebruni* are cogenetic, represent different species and come from different latitudes and regions (mid Atlantic Ocean and South Pacific Ocean respectively). Therefore it would be interesting to restudy the monogenoidean described by Dillon & Hargis (1968).

Squalonchocotyle sp studied by Kuznetsova (1975) on the same host that the monogenoidean reported now, could be representative of *S. squali*,

thus confirming the presence of this specie in the South Atlantic

At moment, in Argentina, Hexabothriidae family is represented by four species: *Callorynchocotyle marplatensis* Suriano & Incorvaia, 1982; *Erpocotyle schmitti* Suriano & Labriola, 1998, *E. microstoma* (Brooks, 1934) Yamaguti, 1963, and *S. squali*, present study. *E. microstoma* was reported as unconfirmed in the revision of Boeger & Kritsky (1989) but in same year of these publications it was reported and confirmed for *Sphyrna (Platysqualus) tudes* (Valenciennes, 1822) by Suriano & Labriola (1989).

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ARTIGO DE OPINIÃO

Re-pensando o estudo e o manejo da pesca no Brasil

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Está sendo criada a sociedade científica da pesca do Brasil, e há grande expectativa de que essa sociedade contribuirá significativamente para a conservação da pesca. Mas conservar a pesca brasileira é possível somente através de uma abordagem ao estudo e o manejo pesqueiro diferente daquela usada até hoje. Nas linhas abaixo, eu sugiro que é necessário resolver dois problemas relacionados com a falta de consideração do fator humano e das características da pesca brasileira.

Talvez, o problema mais importante é que a maioria da ciência pesqueira é, na verdade, biologia pesqueira. A ciência pesqueira que nos ensinaram, e que hoje em dia ensinamos nas salas de aula, não dá suficiente atenção ao papel do elemento humano. A ciência pesqueira reduziu o elemento humano a conceitos simplistas como, por exemplo, ‘esforço’ de pesca, entre outros. Dessa forma, os processos sociais que crescentemente ameaçam as populações de peixes foram quase que completamente marginalizados do estudo da pesca. Uma evidência disso é que os três livros mais citados na ciência pesqueira (Walters 1986, Hilborn & Walters 1992, Wootton 1998) enfocam-se quase que exclusivamente na biologia e ecologia dos peixes e em estratégias de pesca. Mas agora é claro que somente o entendimento sobre a biologia e ecologia das populações de peixes não é suficiente para determinar estratégias de exploração pesqueira que sejam sustentáveis. Uma das razões pela qual cerca de 25% dos estoques pesqueiros do mundo estão sobre-explorados e depletados (FAO 2005) é que pouca atenção foi dada aos processos humanos que afetam a pesca. A maioria das causas de sobre-exploração da pesca em todo o mundo está

diretamente relacionada a aspectos intrinsecamente humanos, como por exemplo a sobre-capitalização, os subsídios (Pauly *et al.* 2002), e o crescimento populacional humano.

Outro problema é que a abordagem convencional ao manejo pesqueiro é inadequada para a pesca no Brasil assim como na maioria dos países tropicais (Castello *et al.* 2007). A abordagem convencional é aquela onde os pesquisadores estudam a biologia e a dinâmica populacional do recurso pesqueiro, passam a informação à agência de manejo, e a agência determina regras de manejo que, às vezes, são implementadas na prática. A abordagem convencional é assim porque ela foi inventada na Europa e na América do Norte onde existem recursos humanos e financeiros suficientes (ou pelo menos em abundância) para que ela funcione da maneira como foi idealizada, embora nem sempre bem sucedida. Mas no Brasil não existem recursos humanos e financeiros em quantidades suficientes para que a abordagem convencional funcione com um mínimo de eficácia, pondo por água abaixo qualquer esperança de sustentabilidade. Uma prova disso é que mais da metade dos estoques pesqueiros mais produtivos do Brasil, os quais são “manejados” através da abordagem convencional, estão sobre-explorados (Paiva 1997).

Alguns de meus colegas podem argumentar que existem avanços na ciência pesqueira que prometem resolver ou amenizar o problema da sobre-pesca. Dois desses avanços são o uso de áreas protegidas e de modelos da cadeia trófica para reduzir esforço de pesca e aprimorar nosso entendimento dos sistemas aquáticos, respectivamente (Pauly *et al.* 2002). Mas as áreas protegidas e os modelos da cadeia trófica têm utilidade limitada

porquê até hoje nem as agências de manejo com mais recursos do mundo foram capazes de assegurar o cumprimento de regras simples de manejo, tais como cotas de captura (Pauly & Maclean 2003). No Brasil, muitas regras de manejo existem somente no papel, mesmo no caso de pescarias importantes tais como da lagosta no nordeste ou da sardinha-verdadeira na bacia sudeste (Paiva 1997, Isaac *et al.* 2006).

O manejo participativo (e suas variantes: co-manejo, manejo comunitário, etc) é outro avanço na ciência pesqueira, e este aparenta poder promover a conservação da pesca no Brasil através da integração do elemento humano no manejo pesqueiro (veja Berkes *et al.* 2001). Experimentos de manejo participativo estão ocorrendo em todo o país. Nos pampas do Rio Grande do Sul, por exemplo, o manejo participativo feito por pescadores artesanais e autoridades governamentais tem resultado na implementação de importantes medidas tais como a determinação de áreas pesca (Reis & D’Incao 2000, Kalikoski *et al.* 2002). Já nas florestas alagadas da Amazônia (Viana *et al.* 2007), a participação dos pescadores na avaliação dos estoques do pirarucu (*Arapaima gigas*), a determinação de cotas de pesca, até a fiscalização das regras de manejo ajudou em muito a reverter um estado de sobre-exploração da espécie (Viana *et al.* 2007). Apesar desses resultados positivos, no entanto, questões de participação e gestão pesqueira no Brasil continuam recebendo pouca atenção quando comparados as questões biológicas e ecológicas dos estoques pesqueiros. Por exemplo, uma coleção recente de artigos científicos, segundo os editores, considerou a pesca e o ecossistema no Brasil (Velasco *et al.* 2007), mas nenhum desses artigos considerou os processos sociais.

Como o leitor pode ver, o estudo o manejo da pesca no Brasil deixam muito a desejar mesmo quando consideramos os avanços recentes. A ciência pesqueira no Brasil e na maioria do mundo pode ser comparada com a estória das dez pessoas que estavam com seus olhos fechados, tocando um elefante grande, e tentando descobrir o que tocavam. Cada pessoa concluía coisas diferentes porquê cada uma delas tocava partes diferentes do elefante, e, assim, ninguém conseguia reconhecer o animal. Essa ciência inadequada se reflete no manejo da pior maneira possível: recursos pesqueiros sobre-explorados e agências de manejo incapazes de assegurar sua conservação (veja quadro).

Algo precisa ser feito para que a futura sociedade científica da pesca do Brasil possa ajudar a reverter o estado triste da pesca brasileira, e eu acredito que ainda estamos longe de saber exatamente o que. É por isso que o título deste ensaio inclui a palavra ‘re-pensando...’.

Todos nós sabemos que o primeiro passo para resolução de um problema é o seu reconhecimento, e parte desse reconhecimento já existe há algum tempo. Muito do que foi apresentado nas linhas acima foi inspirado no trabalho de muitos profissionais envolvidos em projetos de estudo e manejo pesqueiro no Brasil (McGrath *et al.* 1993, Diegues 1999, Reis & D’Incao 2000, Seixas & Berkes 2003, Viana *et al.* 2007). Em todo o Brasil, existem profissionais que possuem uma visão ampla e integrada da pesca—exatamente do tipo que é necessário para a conservação da pesca. O estudo de Isaac *et al.* (2006) é evidência disso. No entanto, eu tenho a impressão que os esforços desses profissionais ainda são irrisórios quando comparados com o tamanho do Brasil. Ainda é preciso consolidar a nível nacional um novo tipo de estudo e manejo pesqueiro.

A criação da sociedade científica da pesca do Brasil é um momento oportuno para engajar profissionais das áreas biológicas, sociais, e administrativas do país inteiro em uma processo de análise crítica sobre o estudo e o manejo da pesca. Somente assim, creio eu, seria possível produzir resultados positivos e suficientemente importantes para que possamos re-direcionar o curso atual do manejo pesqueiro no Brasil. Em um primeiro momento, seria interessante determinar lições aprendidas sobre manejo pesqueiro. Em um segundo momento, seria importante desenvolver abordagens alternativas ao manejo pesqueiro e avaliar junto a órgãos governamentais a viabilidade de implementá-las na prática. Seria fundamental implementar essas abordagens de manejo na forma de experimentos acompanhados de monitoramento, avaliação, e intervenção se necessário. Nossos colegas na Argentina, Chile, Mexico, e Uruguai têm feito algo parecido, embora em uma escala menor, e assim contribuído significativamente para o entendimento e a conservação da pesca nos seus países. Os estudos de Castilla & Defeo (2001) e Orensanz *et al.* (2005), por exemplo, analisam abordagens de manejo eficazes que foram desenvolvidas com base na realidade social e ecológica de algumas pescarias e implementadas

de forma adaptativa.

Promover a conservação da pesca brasileira é muito importante porquê o Brasil tem uma rede hidrográfica densa e uma linha costeira imensa—mas é difícil também porquê os livros que usamos para aprender *biologia* pesqueira não servirão de ajuda. Nesse sentido, eu convido meus colegas a re-pensar o estudo e o manejo da pesca brasileira, e a considerar cinco medidas de ação:

- Estudar a pesca como ela realmente é: um sistema integrado formado pela interação dos sistemas sociais e ícticos.
- Aprender de um processo lento mas significativo que está ocorrendo em todo o mundo de desenvolvimento de abordagens alternativas ao manejo pesqueiro para países tropicais e subdesenvolvidos (Pauly *et al.* 1989, Berkes *et al.* 2001, Castilla & Defeo 2001, Orensanz *et al.* 2005, Castello *et al.* 2007).
- Desenvolver abordagens ao manejo da

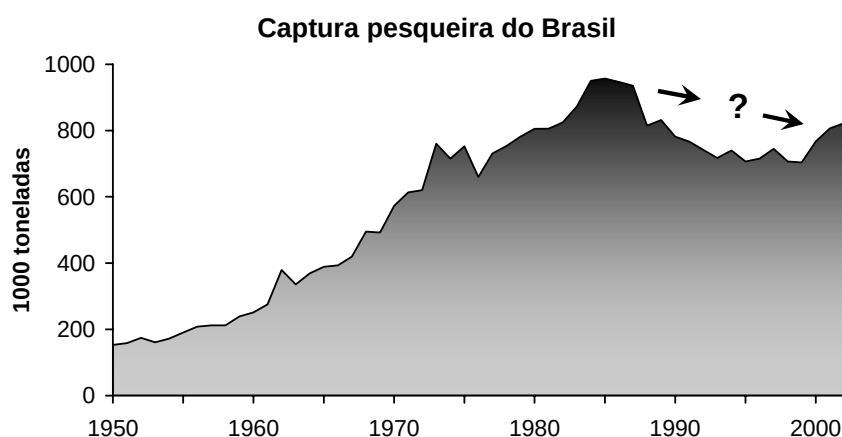
pesca do Brasil que sejam, digamos, “verde-e-amarelo”, autenticamente brasileiras. Abordagens eficazes de manejo pesqueiro requerem que os aspectos biológicos e ecológicos dos peixes sejam integrados com os aspectos econômicos, políticos e institucionais, das sociedades que os exploram.

- Re-formular os currículos universitários de ensino do manejo pesqueiro. A biologia pesqueira deve necessariamente ser ensinada junto com as questões sociais que afetam a pesca. Professores em todo o país precisam de um livro texto adequado.

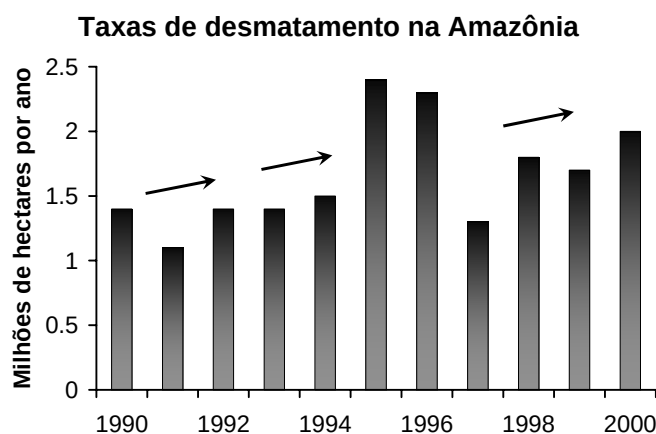
- Vencer o obstáculo da falta de comunicação da ciência pesqueira no Brasil. Por exemplo, Castello (2007) questionou a possibilidade de manejar sustentavelmente os recursos pesqueiros no Brasil, mas até hoje ninguém se manifestou a respeito. Avanços científicos requerem comunicação, e não existe um jornal científico dedicado a pesca brasileira.

Quadro: Qual é o futuro dos recursos pesqueiros Brasileiros?

A captura pesqueira no Brasil tem caído já há mais de uma década devido a sobre-exploração dos estoques pesqueiros, embora tenha havido uma leve recuperação nos últimos anos.



No entanto, um programa nacional implementado em 2003 visa renovar a frota pesqueira e aumentar em 50% as capturas pesqueiras (SEAP/PR 2003). Esse plano pode piorar as tendências atuais de sobre-exploração pesqueira no Brasil (Fonte de dados: FishStat 2004)



A Amazônia possui uma diversidade íctica enorme, e a maioria das espécies de peixe consumidas pelas populações amazônicas depende da floresta para viver. Mas o desmatamento põe em risco essa diversidade íctica assim como o abastecimento de pescado para a população local. As taxas de desmatamento atuais vão aumentar drasticamente com a implementação do plano federal chamado ‘Avança Brasil’ para desenvolver a Amazônia (fonte de dados: Laurance *et al.* 2002).

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Composition of the aquatic invertebrate fauna associated to the mangrove vegetation of a coastal river, analyzed through a manipulative experiment

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Abstract. The present study analyzed the composition of the aquatic fauna associated to the mangrove forest in a southeastern Brazilian river. The composition of the macrofauna in the roots of the marginal vegetation located at three different salinity stretches was analyzed by sampling pieces of the submerged branches of the vegetation (natural substrate) and pieces of “sisal” rope (artificial substrate), installed close to the natural vegetation and sampled after a period of 14 colonization days. In both types of substrate, twelve taxonomic groups were sampled, representing three phyla (Cnidaria, Annelida and Arthropoda). The crustaceans, corresponding to the most diversified group, were represented by Copepoda, Tanaidacea, Isopoda, Amphipoda and Decapoda. The highest salinity stretch showed the highest abundance, with a progressive decrease from high to low salinity for both substrates. Copepoda and Tanaidacea predominated on both substrates, although the artificial substrate exhibited the highest total abundance and species richness. Considering the relative abundance of the taxonomic groups on both substrates, the majority of groups predominated in the highest salinity range. Significant differences on the longitudinal distribution of abundance were associated to the variation on salinity and with the complexity of the substrate.

Key words: Artificial substrate, colonization, macroinvertebrates, natural substrate, salinity stretches.

Resumo. Composição da fauna de invertebrados aquáticos associados à vegetação de manguezal de um rio costeiro, analisada através de um experimento de manipulação. No presente estudo foi analisada a composição da fauna aquática associada a um rio em um manguezal do sudeste do Brasil. A composição da macrofauna presente nas raízes da vegetação marginal foi estudada pela amostragem de pedaços dos galhos submersos da vegetação (substrato natural) e pedaços de corda de sisal (substrato artificial), instalados em três trechos de diferente salinidade, perto da vegetação natural e retirados depois de um período de 14 dias de colonização. Em ambos os tipos de substrato, foram amostrados um total de 12 grupos taxonômicos, representando três filos (Cnidaria, Annelida e Arthropoda). Os crustáceos, grupo mais diversificado, foram representados por Copepoda, Tanaidacea, Isopoda, Amphipoda e Decapoda. A região de salinidade alta apresentou maior abundância, com uma diminuição progressiva da abundância da salinidade alta para a baixa em ambos os substratos. Copepoda e Tanaidacea predominaram em ambos os substratos, embora o substrato artificial exibisse a maior abundância e riqueza destes dois grupos. Considerando a abundância relativa dos grupos taxonômicos nos dois substratos, a maioria dos grupos predominou no trecho de salinidade mais alta. As diferenças significativas de abundância na distribuição longitudinal foram associadas à variação na salinidade e na complexidade do substrato.

Palabras clave: substrato artificial, colonização, macroinvertebrados, substrato natural, trechos de salinidade

Introduction

Coastal ecosystem is traditionally known as an important nursery area for both estuarine-resident and temporary-resident species (Chaves & Bouchereau 1999). Nursery area for Penaeidae juveniles in this ecosystem have been associated with food availability and shelter from predators, supplied by physical structures, such as substratum and turbidity, in combination with the agonistic behavior of shrimps (Primavera 1997). Due to the contrasting environmental conditions of the coastal ecosystem, the geometric complexity of the substratum can increase the colonization rates by protecting the organisms from environmental constraints and increasing the area available for the fauna establishment (Jacobi & Langevin 1996).

The study of the associated aquatic fauna on mangrove forest becomes a complex task because of the high richness and because of the great influence of tides on salinity variation and on the colonization process. An appropriated methodology for these studies is the utilization of experimental structures that allows habitat simplification and enables control of environmental variations upon sampling areas (Brower & Zar 1984; Uieda 1999). According to Deutsch (1980), seasonal experimentation of short or long substrate exposition are useful for studies on macroinvertebrates colonization rate, allowing the determination of how, where and when the colonization occur.

Few experimental studies were developed in coastal regions. Some of the available papers deserve attention like as Hulberg & Oliver (1980) in rocky shores, Heck & Thoman (1981) in muddy habitats and Fitzhugh & Fleeger (1985) in estuary.

The preservation of mangroves is very important for the maintenance of the biodiversity of this important link between the continental waters and the sea. Mangroves are susceptible to high environmental impact (Grasso 1998), which may have strong negative effect upon the local fishery. Mangroves are found in Brazil from 04°30'N to 28°30'S, under a wide range of environmental conditions (Schaeffer-Novelli *et al.* 1990). Unfortunately, despite its importance as feeding, growth and reproduction areas for a diversified fish fauna, the knowledge of the ichthyofauna on intertidal environment is still very restricted (Paiva Filho & Toscano 1987; Barletta-Bergan *et al.* 2002; Felix *et al.* 2006; Corrêa & Uieda 2007).

The aims of the current study were: to analyze the diversity of the macroinvertebrate fauna associated to the roots of the mangrove vegetation,

to analyze the variation in the composition of this fauna in function of salinity variation, and, at the same time, to test the efficiency of an artificial substratum through an experimental manipulation. This work intends to analyze two predictions: 1) The artificial substratum allows a colonization process similar to the one in natural vegetation, 2) The community composition changes in function of differences in salinity.

Material & Methods

Study site

The study was carried out in the mangrove of the Rio da Fazenda (23°31' to 23°34'S, 45°02' to 45°05'W), located in the Serra do Mar State Park, Picinguaba Unit (Núcleo Picinguaba). The Picinguaba Unit is situated in the State of São Paulo, and preserves all the environments that compose the coastal ecosystem complex: beach, rocky shore, "restinga" (coastal dune forest), mangroves, coastal plain forest and hillside forest. Rio da Fazenda is a coastal river, aprox. 6 km long. Its headwaters are on the slopes of the Serra do Mar, and its mouth at Fazenda Beach; its course is entirely contained within the boundaries of the Picinguaba Unit (Fig. 1).

In order to determine the variation of the fauna composition in relation to the variation on salinity, common in mangroves, the study was conducted in stretches with different ranges of salinity. Three stretches were selected to conduct the work: a downstream stretch with the highest salinity (6.4 ± 2.0 ; 23°22'24"S, 44°50'62"W), an upstream stretch with the lowest salinity (0.9 ± 0.8 ; 23°21'11"S, 44°50'83"W), and a median stretch with intermediate values of salinity (2.0 ± 0.9 ; 23°21'15"S, 44°50'78"W). Although these stretches differed in salinity, they showed similar values of some abiotic characteristics measured during the study period, like dissolved oxygen (7.0, 7.9 and 7.8 mgO₂L⁻¹, respectively for each stretch) and water temperature (27.6, 24.9 and 25.6°C). The mangrove vegetation is composed mainly by *Hibiscus pernambucensis* Arruda (Malvaceae), *Laguncularia racemosa* (L.) C. F. Gaertn. (Combretaceae) and *Eugenia* sp Linnaeus (Myrtaceae).

Data collection and analyses

The fauna composition was sampled directly from the roots of the mangrove vegetation (Fig. 1) and also from the artificial substrata installed in the same area. In this way, we could use the results not only for a fauna characterization, but also to test the efficiency of colonization on artificial substratum.

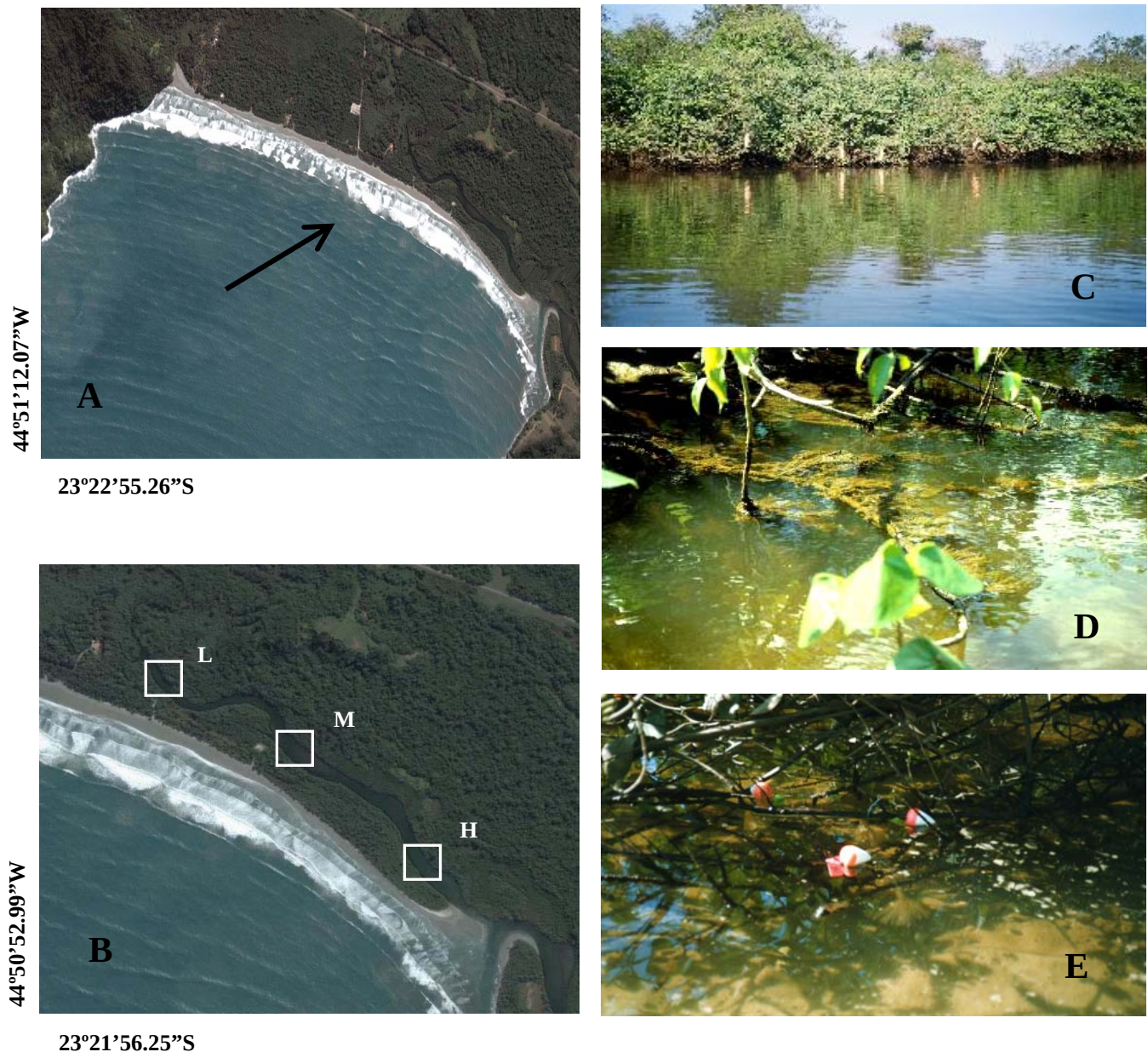


Figure 1. Study area at the Rio da Fazenda mangrove. Satellite photo (earth.google.com) of the Fazenda Beach (arrow in A) and of the Rio da Fazenda mangrove with the position of the three stretches of salinity (H- high, M- median, L- low, in B). Detail of the mangrove marginal vegetation (median stretch in C) and of the natural (branches with algae and organic matter adhered to the roots, in D) and artificial substrata (colored buoys supporting a piece of sisal rope, in E).

The use of artificial substratum has a great advantage upon the use of natural one by allowing the standardization of the colonization time and of the sampling area (Lambert & Resh 1985; Uieda 1999; Carvalho & Uieda 2004).

The macroinvertebrates were sampled during the 2003 rainy season (February). On each selected stretch of salinity, ten replicates of artificial substrata were installed. The artificial substratum was composed by a piece of sisal rope (7.5 cm), attached to a weight for its maintenance under the water (Fig. 2) and tied to the branches of the mangrove vegetation. The natural substratum

consisted on a branch piece with roots and adhered algae.

Fourteen days after the installation of the artificial substrata, ten replicates of the natural substrata and ten of the artificial substrata were removed and packed in flasks with formaldehyde 5%. In the laboratory, the substratum was washed in the formaldehyde to dislodge the adhered animals. The liquid was poured under three granulometric sieves (meshes of 1.0, 0.5 and 0.25 mm). The sieves were inspected under stereomicroscope and the macroinvertebrates were sorted, identified and counted (the taxonomic level depends on the group).

Because Copepoda occurred in a great number of individuals and because they passed through the small sieve mesh, their abundance was analyzed by sub samples. The liquid that passed through the sieves was agitated and ten replicates were separated and analyzed under stereomicroscope in Sedgwick-Rafter chamber.

Relative abundance curves of species, or species importance curve, were constructed by plotting the $\log(x+1)$ of absolute abundance of each animal group against the corresponding rank, in decreasing order of abundance (Brower & Zar 1984). After testing for normality (Shapiro-Wilks; $\alpha\lambda\phi\alpha = 0.05$) and homocedasticity (Levene; $\alpha\lambda\phi\alpha = 0.05$), an analysis of variance (ANOVA one-way) followed by a multiple comparison test (Tuckey) was used in order to evaluate significant differences between salinity (three stretches) and substrata (two types).

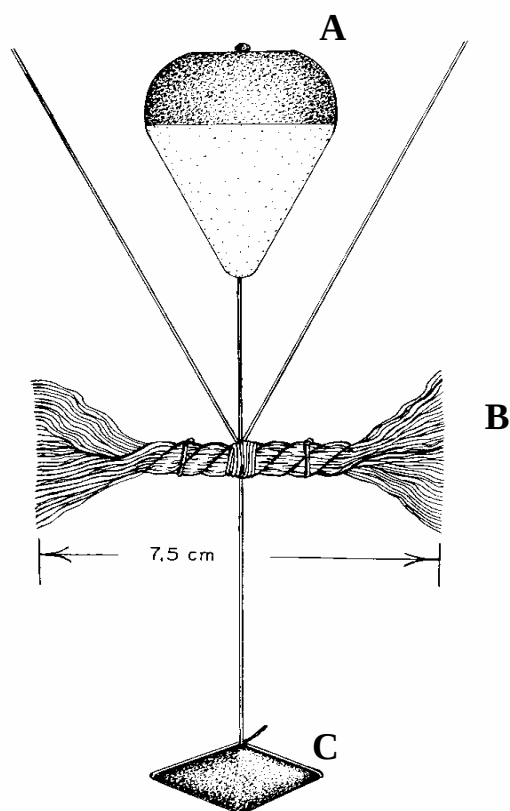


Figure 2. Schematic design of artificial substratum: A- colored buoy; B- sisal rope of 7.5 cm length; C- weight.

Results

The taxonomic groups identified included macroinvertebrates of three phyla: Cnidaria (Hydrozoa), Annelida (Polychaeta) and Arthropoda (Arachnida, Insecta and Crustacea). The insects were represented only by Diptera (Chironomidae) and Ephemeroptera, with the predominance of the first

one. Crustaceans, the most diversified group, were represented by Copepoda (Harpacticoida and Cyclopoida), Tanaidacea (Tanaidae), Isopoda (Sphaeromatidae and Munnidae), Amphipoda (Gammaridea) and Decapoda (Caridea and Brachyura).

Copepoda and Tanaidacea predominated on both substrata, although the artificial substratum exhibited the greatest abundance and species richness (Table I). When compared by the dominance curve, the similarities between the natural and artificial substrata were evident, with the dominance of Copepoda (rank 1) and Tanaidacea (rank 2) found on both substrata (Fig. 3). However, the groups intermediate in abundance that prevailed on the natural substratum were Isopoda and Diptera and on the artificial substrata were Diptera and Polychaeta (Table I).

Apparently the differences between substrata were related to the dominance of Copepoda at all salinity ranges on the artificial substratum (Table I). This result was confirmed by the ANOVA, with a significant difference between substrata when all groups were considered ($p = 0.002$, $F = 9.970$, $df = 1$), but not when the abundance of Copepoda was excluded from the analysis ($p = 0.792$, $F = 3.191$, $df = 1$).

The spatial variation on abundance was significant when considered the sum of both substrata, with the low salinity stretch presenting the lowest abundance in the two situations, including and excluding Copepoda (Fig. 4). The longitudinal variation on macrofauna abundance was also confirmed when the two substrata were analyzed separately (Fig. 5). The significant difference between salinities for natural substratum is related to the dominance of Copepoda on the high and median salinity stretches and the dominance of Isopoda and Tanaidacea on the low salinity stretch (Table I). The significant difference between salinities for

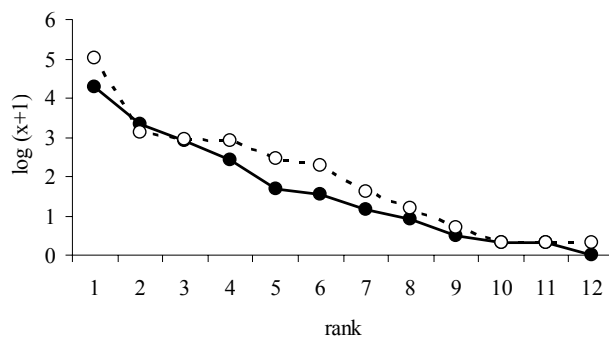


Figure 3. Relative abundance curves of the taxonomic groups sampled on the natural (black points) and artificial (white points) substrata (sum of the three stretches of different salinity). The absolute abundance [$\log(x+1)$] was plotted against the corresponding rank, presented in decreasing order of abundance.

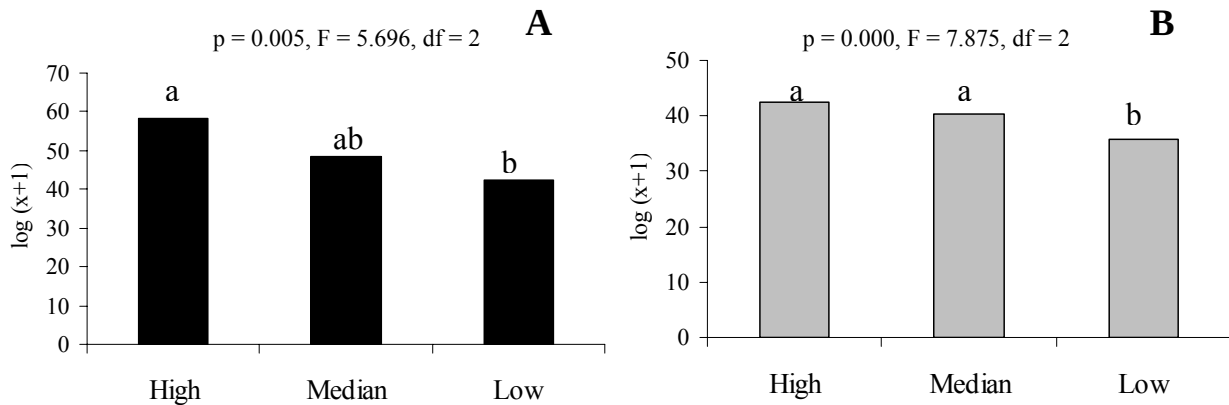


Figure 4. Abundance [log (x+1)] of macroinvertebrates sampled on High, Median and Low salinity stretches (sum of natural and artificial substrata), including (A) and excluding (B) Copepoda values, and the results of Tuckey test (different letters indicate significant differences, $\alpha = 0.05$).

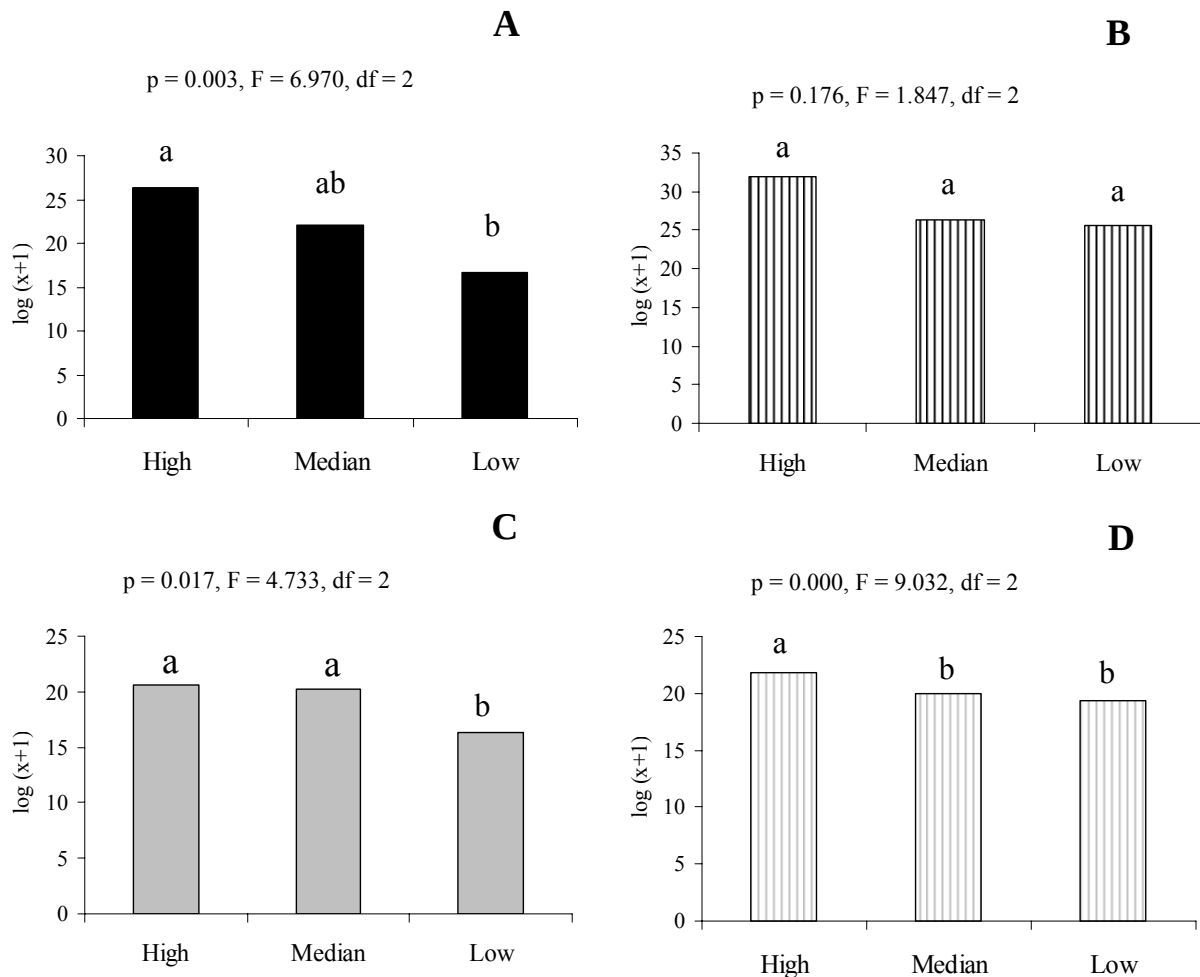


Figure 5. Abundance [log (x+1)] of macroinvertebrates sampled on High, Median and Low salinity stretches of the natural (A and C) and artificial substrata (B and D), including (A and B) and excluding (C and D) Copepoda values, and the results of Tuckey test (different letters indicate significant differences, $\alpha = 0.05$).

artificial substratum, when Copepoda abundance was removed, is related to the dominance of Tanaidacea and Polychaeta at high salinity, of Tanaidacea, Polychaeta and Diptera at median salinity, and of Diptera and Tanaidacea at low salinity.

The analysis of the relative abundance by salinity stretch of the taxonomic groups presented in

the natural and artificial substrata (Table I, Fig. 6) showed that the majority of groups were found in the three stretches. However, if considered only the six most abundant groups (Polychaeta, Diptera, Copepoda, Tanaidacea, Isopoda, and Amphipoda; Table I), the majority was predominant in the higher salinity on both substrates, except for Diptera and Isopoda.

Table I. Absolute (total number of individuals) and relative abundance (%) of macroinvertebrates sampled on the natural and artificial substrata installed in three stretches of different salinity (high, median and low) during the colonization experiment realized in February/2003 on the mangrove of Fazenda River.

Taxonomic groups	Natural Substratum								Artificial Substratum							
	High		Median		Low		TOTAL		High		Median		Low		TOTAL	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Hydrozoa	-	-	-	-	1	0.1	1	<0.0	2	<0.0	12	0.1	-	-	14	<0.0
Polychaeta	30	0.2	16	0.4	-	-	46	0.2	254	0.3	235	1.2	77	0.6	886	0.8
Arachnida	-	-	-	-	1	0.1	1	<0.0	-	-	-	-	1	<0.0	1	<0.0
Diptera	48	0.3	111	2.5	97	14.6	256	1.1	62	<0.0	229	1.1	498	3.8	789	0.7
Ephemeroptera	-	-	1	<0.0	1	0.1	2	<0.0	-	-	-	-	1	<0.0	1	<0.0
Copepoda	16,161	91.3	3,242	72.3	48	7.2	19,451	58.1	75,50	98.0	19,00	94.6	12,12	93.2	106,63	96.8
Tanaidacea	1,39	7.9	643	14.3	194	29.2	2,227	9.7	588	0.8	461	2.3	230	1.8	1,279	1.2
Isopoda	49	0.3	452	10.1	316	47.5	817	3.6	107	0.1	115	0.6	73	0.6	295	0.3
Amphipoda	21	0.1	11	0.3	1	0.1	33	0.1	190	0.2	3	<0.0	1	<0.0	194	0.2
Caridea	6	<0.0	4	<0.0	3	0.5	13	<0.0	14	<0.0	23	0.1	3	<0.0	40	<0.0
Brachyura-crabs	1	<0.0	3	<0.0	3	0.5	7	<0.0	1	<0.0	-	-	3	<0.0	4	<0.0
Brachyura-larvae	-	-	-	-	-	-	-	-	1	<0.0	-	-	-	-	1	<0.0
TOTAL	11,706	77.5	4,483	19.6	665	2.9	22,854	16.0	77,04	70.0	20,08	18.2	13,01	11.8	111,13	84.0

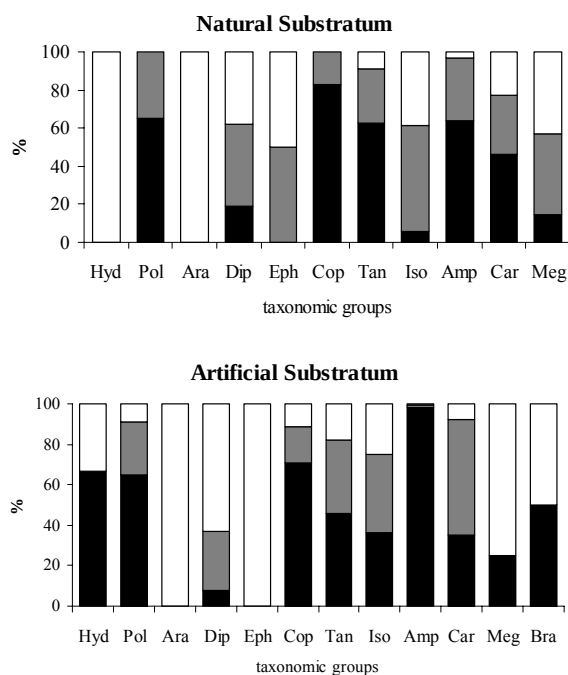


Figure 6. Relative abundance (%) of macroinvertebrates on natural and on artificial substrata sampled on the three stretches (high , median and low salinity ranges). Hyd-Hydrozoa, Dip- Diptera, Tan- Tanaidacea, Car- Caridea, Pol- Polychaeta, Eph- Ephemeroptera, Iso- Isopoda, Meg- Megalopa, Ara- Arachnida, Cop- Copepoda, Amp- Amphipoda, Bra- Brachyura.

Discussion

Nowadays Copepoda is the most studied crustacean taxa in Brazil, although plankton studies are still scarce (Amaral & Jablowski 2005). Species that carry their eggs, like Cyclopoida species, are more abundant in estuaries, where the depth is small and fish predation is not as common as in open sea (Vuorinen *et al.* 1983). The use of vegetation as shelter is supposed to be related to the high mortality of Copepoda in the plankton (Bell & Westoby 1986).

Although we sampled only on February, based on the literature (Bell 1980) we can speculated that the great abundance of Copepoda found in the Fazenda River mangrove, mainly in the high salinity stretch, may be related to its reproductive peak during summer months. In a South Carolina salt marsh, about 80% of Copepoda occurred on summer and only less than 5% represented the whole community on other seasons (Bell 1980).

For Tanaidacea, the second most abundant macroinvertebrate taxa sampled on the Fazenda River, little can be discussed here due to the scarcity of literature data. In a review of Tanaidacea on the coastal region of two Brazilian States (Rio de Janeiro and Santa Catarina), Gutu (1996) stressed the low occurrence in the Brazilian coast and the

limitation of biological data. In Brazil, 28 species are known, 17 belonging to the Suborder Apseudomorpha and 11 to the Suborder Tanaidomorpha (Gutu 1996). The family Tanaidae, the one found in the Fazenda River mangrove, belongs to the second Suborder.

Isopoda, the third most abundant crustacean taxa sampled on the Fazenda River, is cited by Pires (1982) as an important group with occurrence on intertidal regions, associated with algae coverage and represented mostly by the family Sphaeromatidae. This group can live in a great variety of habitats and can tolerate a broad range of environmental conditions (Pires 1982).

A number of chironomid species are tolerant of a wide range of salinities and this insect group may be a major component of the fauna of brackish waters (Pinder 1995). According to Pinder (1995), species of Chironomidae adapted to life in the intertidal zone have been recorded from coasts all over the world and they are taxonomically diverse in this habitat. Nevertheless, the taxonomic and ecological knowledge of this group in Brazil is restricted, mainly at mangrove habitats (Trivinho-Strixino & Strixino 1995).

Manipulative experiments of natural communities has been growing and generating important contributions for the comprehension of the colonization, maintenance and persistence of communities (Hulberg & Oliver 1980). In colonization experiments, it is important to evaluate the efficiency of the artificial substratum. The great advantage of the artificial substratum is to allow a sampling standardization, regarding the sampled area and the recording of the initial time of colonization process, difficult when using natural substratum (Carvalho & Uieda 2004). In the present experiment, the artificial substratum proved to be appropriated making ease the installation and allowing the sampling standardization.

In experimental studies it is also important to analyze if the artificial substratum provides the same conditions of the natural one, like protection and shelter against predators and good foraging conditions. In the present work, the existence of these conditions on the artificial substratum was indirectly evaluated by the analysis of the community structure at the end of the experiment. At the three studied stretches, the natural vegetation, composed by submerged branches covered with algae, was well reproduced by the artificial substrate, which allowed the colonization of algae and macrofauna similar to the one colonizing the roots of the mangrove vegetation.

The significant difference between the

artificial and the natural substrata, associated here with the spatial variation (salinity ranges) of Copepoda abundance in the natural substratum, may be related to the structure of this substratum. At the end of the field work it was observed that the natural vegetation of the median salinity stretch showed large quantities of branches, algae, and organic matter, the low salinity stretch showed high quantities of branches and algae, and the high salinity stretch showed few branches and algae. Spatial differences in the structure of the natural substratum probably provided different conditions for macroinvertebrates colonization, with strong effect on Copepoda. On the other hand, no differences for the artificial substratum structure between stretches were recorded, even at the end of the 14 colonization days. The structural complexity of habitat seems to affect the abundance and diversity of animal communities, with more structurally complex algae species allowing a higher richness and diversity (Hull *et al.* 2001). The complexity of habitat can not only increase the number of available niches for colonization, but can also provide refuge against predation (Coull & Wells 1983), or even reduce predation effects for changing the efficiency of forage. Some authors, such as Heck & Thoman (1981) and Underwood *et al.* (2000), suggested that predation intensity is lower in habitats with more vegetation than in habitats without vegetation, what can be related to the highest density of animals in this substratum.

Besides the structural complexity of the natural substratum, the sampling area can influence the colonization process. For example, in a colonization experiment conducted at two shallow subtidal sites in North Carolina, Eggleston *et al.* (1999) compared the abundance of macroinvertebrates colonizing small (0.25m²) and large patches (1m²) of artificial plants. They found that the density of Decapoda, Amphipoda and Isopoda was larger in small patches than in large patches, probably related to an increase in foraging rates, since estuarine macrofauna is influenced by the heterogeneity of habitat in a small spatial scale (Eggleston *et al.* 1999). In the Fazenda River experiment the influence of the substratum area was controlled as the artificial and the natural substrata had similar areas.

Thus, the significant spatial difference on abundance of macroinvertebrates associated to the mangrove vegetation found in the Rio da Fazenda emphasized the salinity as an important environmental factor affecting the distribution of the aquatic fauna associated to the mangrove vegetation. This vegetation can provide shelter and a place for

foraging not only for a diversified and abundant macroinvertebrate fauna, but also for a great variety of fish species. In the same area, Corrêa & Uieda (2007) observed many fish species exploring the submerged branches of the mangrove vegetation as shelter and feeding on the macroinvertebrate fauna that colonizes this vegetation (2007).

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Observations on the ecology of the hermit crabs *Propagurus gaudichaudii* Milne-Edwards (Decapoda: Paguridae) and *Dardanus insignis* Saussure (Decapoda: Diogenidae) in the outer Uruguayan shelf

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Abstract. *Dardanus insignis* occurs in the northernmost portion of the Uruguayan shelf, whereas *Propagurus gaudichaudii* characterized the southern area. This can be associated with inter-specific differences in the patterns of shell utilization.

Key words: benthic communities, gastropods, shell use, continental shelf, Uruguay.

Resumen. Observaciones sobre la ecología de los cangrejos ermitaños *Propagurus gaudichaudii* (Decapoda: Paguridae) y *Dardanus insignis* (Decapoda: Diogenidae) en la plataforma continental externa uruguaya. *Dardanus insignis* se encontró al norte del área de la plataforma continental uruguaya, mientras que *Propagurus gaudichaudii* caracterizó la porción sur. Esto puede estar asociado con diferencias en el uso de caparazones entre especies.

Palabras clave: comunidades bentónicas, gasterópodos, uso de caparazones, plataforma continental, Uruguay.

Introduction

In the Uruguayan shelf, the hermit crabs *Propagurus gaudichaudii* Milne-Edwards, 1836 and *Dardanus insignis* (Saussure, 1858) commonly occur as by-catch in the trawl fisheries (F. Scarabino, pers. obs). *Propagurus gaudichaudii* is an endemic hermit crab from the coast of South America, extending its Atlantic distribution from Uruguay to Magallanes strait, from the subtidal to a depth of 150 m (Scelzo 1973, Boschi & Gavio 2005, Vinuesa 2005). In contrast, *D. insignis* occurs from the eastern United States, Gulf of Mexico, Antilles, Brazil, Uruguay and Argentina south to Chubut (43°S) in depths from 1.5 to 500 m¹ (Scelzo 1973, Spivak 1997). Thus, both species overlaps its distribution ranges from 36°S to 43°S. The biology of these species is poorly known, the latter being

somewhat better studied. Fernandes-Góes (1997) investigated the spatial and temporal distribution of *D. insignis* in Ubatuba Bay (São Paulo State, Brazil) while population biology and growth were examined by Branco *et al.* (2002). Available data for *P. gaudichaudii* for the study area are restricted to species description and distribution (Forest & de Saint Laurent 1968).

In this vein, this study aimed to advance knowledge on the spatial distribution and patterns of shell use of *D. insignis* and *P. gaudichaudii* at the Uruguayan continental shelf; a key area where the presence of contrasting water masses over the outer shelf determines a biogeographic boundary for the benthic fauna (e.g. Carranza *et al.* 2007, Carranza *et al.* 2008). This work report observations carried onboard research vessel “Aldebarán” of the DINARA (National Direction of Aquatic Resources), during an experimental cruise during July 2006 directed to the evaluation of the stock and by-catch of *Merluccius hubbsii* Marini, 1933. The fishing gear used for the evaluation consisted in an

¹ The depth mentioned by Scelzo (1973) for R/V “Walther Herwigh” station N° 246, 36°48’S-54°03’W seems to be incorrect based on the faunal composition of the sample provided in Olivier & Scarabino (1972), e.g. presence of the shallow water species *Mytilus edulis*.

Engel type bottom trawl net with a 24 m horizontal opening and a 100 mm stretched mesh in the cod ends. A total of 36 stations were allocated based on a stratified design based on the biological features of the target species between 59 and 233 m depth (Figure 1). In each station, 30 minutes tows were performed, depth was noticed and a CTD cast (SBE-19) profiled the water column for temperature and conductivity from the surface to the bottom. The exact location of the stations was determined by Global Positioning System (GPS).

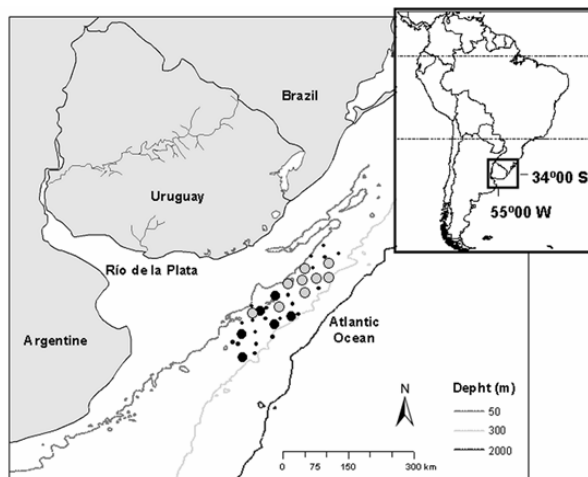


Figure 1. Distribution of the surveyed stations (●) and collection sites for the species of hermit crabs *Propagurus gaudichaudii* (●) and *Dardanus insignis* (●) at the Uruguayan shelf. Both species were never collected in the same trawl.

Observations on by-catch of benthic species were registered. In this sense, all hermit crabs and its gastropod shell hosts were collected and determined onboard. Voucher material for each crab and associated gastropod shells is deposited at the National Museum of Natural History, Montevideo (MNHNM). Environmental conditions associated with the records of each species were described in terms of the range and standard deviation for all the measured environmental parameters, and a Student's t-test was then used to evaluate the statistical significance of the observed differences using species as the grouping variable. Frequencies of occurrence (as total occurrences/number of stations) and by-catch per unit effort (BPUE, as individuals/30') were calculated for both species. The species of gastropods utilized as refuges by the hermit crabs were identified *in situ*, registering also measures of its shells (Shell length, SL, from apex to distal end) to the nearest 0.1 cm.

A total of 36 hermit crabs and their respective shell hosts were examined. Hermit crabs were observed on the 78% of the 36 stations surveyed. From these, *D. insignis* was numerically

dominant, adding to the 80% of the collected specimens. Differences on latitudinal distribution were also observed, being *D. insignis* observed between 35°08'S and 36°03'S, whereas *P. gaudichaudii* occurred from 35°41' to 36°57'S, at depths ranging from 60 to 206 m and 63 to 147 m respectively. BPUE of *D. insignis* ranged from 0 to 10 specimens, averaging 0.78 ± 1.86 (ind/30' $\pm$ SE) while *P. gaudichaudii* averaged 0.22 ± 0.6 . Species did not differ statistically in mean depth of occurrence (Student's t-test; $t=0.24$, $p=0.69$) or salinity ($t=1.06$, $p=0.29$). In contrast, there were differences in mean sea bottom temperatures ($t=2.56$, $p<0.05$), being *P. gaudichaudii* associated with cooler waters. *Dardanus insignis* was found occupying shells of the gastropods *Tonna galea* (Linnaeus, 1758; Tonnidae), *Trophon patagonicus* (d'orbigny, 1839; Muricidae), *Odontocymbiola magellanica* (Gmelin, 1791), *Adelomelon ancilla* (Solander in Lightfoot, 1786) and *Zidona dufresnei* (Donovan 1823; Volutidae) whereas shells of *Fusitriton magellanicus* (Röding, 1798; Ranellidae), *A. ancilla* and *O. magellanica* were utilized by *P. gaudichaudii* (Table I).

Findings show that at the Uruguayan continental shelf, there is a spatial segregation of both species, with *D. insignis* occurring in the northernmost portion of the study area, whereas *P. gaudichaudii* characterized the southern area (below 36°00'S). This is coincident with the idea of the study area as biogeographic limit for decapod crustaceans: Holthuis (1952) already recognized the mouth of the Río de la Plata as the northern boundary of the antiboreal zone in the Atlantic (see references in Gorny 1999). At this area, there is little noticeable effect of the freshwater discharge in the benthic environment, which affects mainly coastal, shallower areas (Ortega & Martínez 2007). Some other environmental factors like the amount of organic matter and texture of sediment may also affect the spatial and seasonal distribution of hermit crabs (Mantelatto *et al.* 2004; Meireles *et al.* 2006) especially at local spatial scales. Although there is a remarkably lack of fine-grained data on sediment features, sandy-muddy bottoms seems to be evenly distributed in the trawlable bottoms of Uruguayan shelf here analysed (Correia *et al.* 1996), and are thus presumably of lesser importance on the distribution patterns of the species here studied at this geographic scale.

Recently, Riestra *et al.* (2006) mentioned *P. gaudichaudii* occurring as by catch in the *Z. dufresnei* fishery at the Uruguayan shelf, between 34° 20'S- 35° 22'S, but these records are probably

Table I. Observed shell host species and number of observations categorized by hermit crab. Mean ($\pm$ standard deviation, cm) shell length (SL) are provided for each shell species.

SHELL HOSTS	<i>Dardanus insignis</i> n (Mean $\pm$ SD)	<i>Propagurus gaudichaudii</i> n (Mean $\pm$ SD)
<i>Tonna galea</i>	20 (12.35 $\pm$ 1.02)	-
<i>Trophon patagonicus</i>	4 (4.50 $\pm$ 3.14)	-
<i>Adelomelon ancilla</i>	2 (13 $\pm$ 5.65)	2 (17.50 $\pm$ 0.07)
<i>Odontocymbiola magellanica</i>	1(11)	5 (16.3 $\pm$ 0.57)
<i>Zidona dufresnei</i>	1(15.00)	-
<i>Fusitriton magellanicus</i>	-	1 (7.00)

based on misidentifications, as mentioned therein, and should be assigned to *D. insignis*. Most likely, this species is restricted to coastal, shallower waters south of Río de la Plata, while *P. gaudichaudii* is restricted to deeper waters at this latitude, following subantarctic waters until reaching its range endpoint near 36°S, a phenomenon already documented for bathyal gastropods (Carranza *et al.* 2007). Conversely, *D. insignis* inhabits deeper waters northward, and has been reported from off Arroyo Chuy, (34° 40'S) in 350 m depth (Rieger 1997), thus reinforcing this idea.

Between 35° 42'S and 36° 04'S, both hermit crab species coexists, thus overlapping in the shell hosts: at this latitudinal range, *D. insignis* was found in *O. magellanica*, *A. ancilla* and *T. varians*. These gastropod species are reported for the first time as host of *D. insignis*, in addition to *Pachycymbiola brasiliensis* (Lamarck, 1811), *Buccinanops gradatus* (Deshayes, 1844) [= *cochlidium* (Dillwyn, 1817)] and *Olivancillaria urceus* (Röding, 1798) (Rieger 1997). Within this latitudinal range, both species also overlapped in its bathymetric distribution, coexisting at the 60-90 m fringe.

However, both species were never found in the same trawl, suggesting that biological interactions (i.e. competence for shell or other resources) may be affecting the observed distribution patterns. It is necessary to take into consideration, nevertheless, the relatively low fishing effort and the lack of replicates as putative factors affecting the observed pattern. Differences in hermit crab distribution may also be explained by differences in the physical habitat, since sea bottom temperature was in average lower at the stations where *P. gaudichaudii* was registered. Thus, the mechanism generating the pattern may involve both resource and habitat partitioning (Vance 1972). However, the low BPUE observed may be due either to a low population density or to low efficiency of the fishing gear. In summary, findings show shelf areas with different shell-availability, leading to different patterns of

shell utilization not suggesting shell limitation, but some kind of negative biological interaction operating at a limited geographical range. This suggests that species boundaries for these species may be reflecting both responses to biotic and abiotic environmental features. Further studies are encouraged to analyse the consistency of the patterns here depicted and explore the causal mechanisms.

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The effect of natural antioxidant (*Thymus vulgaris* Linnaeus) on flesh quality of tuna (*Thunnus thynnus* (Linnaeus)) during chilled storage

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Abstract. Tuna *Thunnus thynnus* flesh was treated with dried thyme *Thymus vulgaris*, vacuum-packed and then stored at 0 °C for 18 days. Proximate composition, thiobarbituric acid reactive substance (TBARS), total volatiles bases, trimethylamine, pH and fatty acids composition were determined throughout the period of storage. No significant differences ($p > 0.05$) between moisture, ash, protein and lipid were found between lots. The antioxidant effect of thyme was shown by the lower TBARS levels and the unaffected fatty acids composition found in thyme-treated lot. Significant differences ($p < 0.05$) were observed in fatty acid profiles of control lot before and after storage, whereas no significant differences were recorded for treated lot in any class of fatty acids after 15 days of storage. In control samples, saturated and monounsaturated fatty acids percents increased from 30.66 to 34.16 and from 20.33 to 21.32 respectively, whereas the polyenes percent decreased from 41.32 to 38.64%.

Key words: Tuna, Thyme, Antioxidant, Chilling, Oxidation, TBARS, Fatty acids.

Resumo. O efeito de antioxidantes naturais (*Thymus vulgaris* Linnaeus) na qualidade da carne de atum (*Thunnus thynnus* Linnaeus) durante o armazenamento refrigerado. A carne do atum *Thunnus thynnus* foi tratada com tomilho seco *Thymus vulgaris*, embalada a vácuo e, em seguida, armazenado a 0°C durante 18 dias. Composição centesimal, substâncias reativas ao ácido tiobarbitúrico (TBA), bases voláteis totais, trimetilamina, pH e a composição de ácidos graxos foram determinados durante todo o período de armazenamento. Nenhuma diferença significativa ($p > 0,05$) entre a umidade, cinza, proteína e lipídio foram encontrados entre os lotes. O efeito antioxidante do tomilho foi demonstrado pelo menor nível de TBA e os níveis inalterados da composição de ácidos graxos composição foram encontrados no lote tratado com tomilho. Diferenças significativas ($p < 0,05$) foram observadas nos perfis de ácidos graxos do lote controle antes e após o armazenamento, enquanto que nenhuma diferença significativa foi registrada para o lote tratado em qualquer classe de ácidos graxos após 15 dias de armazenamento. Nas amostras controle, os percentuais de ácidos graxos saturados e monoinsaturados aumentaram de 30,66 para 34,16 e de 20,33 para 21,32, respectivamente, enquanto que o percentual de polienos diminuiu de 41,32 para 38,64%.

Palavras-chave: Atum, tomilho, antioxidante, resfriamento, oxidação, TBA, ácidos graxos.

Introduction

Tuna is an important fish species with high economic value as a result of its growing demand in international markets. It is generally consumed fresh, canned and frozen. Fish lipids are known to be rich in polyunsaturated fatty acids (PUFAs), especially the n-3 PUFAs family including eicosapentaenoic acid (EPA or 20:5 n-3), docosapentaenoic acid

(DPA or 22:5 n-3) and docosahexaenoic acid (DHA or 22:6 n-3) which may readily be oxidised to form lipid hydroperoxides (Osman *et al.* 2001, Boran *et al.* 2006). Oxidation of lipids that occurs in raw material during storage, processing, heat treatment, and in the final products during subsequent storage, is one of the basic processes causing rancidity in

food products (Donelli & Robinson 1995). Such oxidative deterioration may affect the organoleptic characteristics, including taste and aroma making the final product unacceptable for consumption. Therefore, several investigations have been undertaken with the aim to enhance the shelf-life extension, the stability of lipid-containing products and food quality. Application of antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) in the food industry is one of the most technically and commonly used procedures to reduce the oxidation process (Frankel 1993, Karpinska *et al.* 2001). However, such substances are volatile and easily decompose at high processing temperatures. The possible toxicity of synthetic chemicals used as antioxidants has been the subject of several studies (Powell *et al.* 1986, Thompson & Trush 1986) and recently, the food industry and nutritional institutes (Food Science Australia, Riverside Life Science Centre, Australia; Bioanalytical Laboratory, Pharmaceutical Product Development Inc., Middleton, Wisconsin, USA ; Institute of Organic Chemistry, Bulgarian Academy of Sciences, Sofia, Bulgaria...) focused investigations on the use of natural antioxidants (spices, herbs, and vegetable extracts) due to their antioxidant properties and phenolic contents (Akhtar *et al.* 1998). For instance, the antioxidative effect of thyme is based essentially on polyphenolic compounds as flavonoids (Luteolin), while thymol and carvacrol have low activity (Hollman *et al.* 1996, Lacroix *et al.* 1997, Justesen & Knuthsen 2001).

Despite the numerous cited studies on the antibacterial and antioxidant activity of herbs and vegetable extracts (Chaieb *et al.* 2007) and subsequent effect on the shelf life of foods, few data exist on the effect of *Thymus vulgaris* on the shelf-life of refrigerated fish and fish products. The objective of the present work was to study the combined effect of vacuum-packaging and antioxidant activity of *Thymus vulgaris* on the shelf-life and quality indicators of tuna fillets during 18 days of chilled storage.

Material and Methods

Fish sampling and processing

Tuna *Thunnus thynnus* was caught in April 2006 in the Northern area of the Tunisian Sea. The fishes were transported on ice to the laboratory of Department Marine Biodiversity and Biochemistry, INSTM, (La Goulette, Tunisia) where they were eviscerated, headed and filleted. Thyme *Thymus vulgaris* from Tunisia was dried, powdered and sterilised by a dose of 25 kGy

of gamma irradiation in the National Centre of Nuclear Sciences and Technology (Sidi Thabet, Tunisia). Tuna fillets (150 ±10g, each) were separated into two lots: one was left as a control lot and the second was sprinkled (0.1%) with powdered thyme. All lots were then vacuum-packed in polyethylene bags and stored at 0 °C for 18 days.

Tissue sampling was performed on days 0, 3, 6, 9, 12, 15, 18. At each time, samples were rapidly stored at -80 °C until analysis. Frozen period was no longer than 3 weeks. Prior to analysis, tuna flesh was thawed and homogenized on ice for 3 min using an Ultra-turrax blender. Sample homogenates were immediately subjected to analysis.

Biochemical analysis

Moisture

Moisture of the tuna samples was determined according to the AOAC (1990) method by drying in an oven at 105 °C (n = 6). Results were expressed as percentage of wet weight.

Ash

Ash content was determined by heating sample for 6 h in an oven at 525 °C (n = 6) according to the AOAC (1995) method. Results were expressed as percentage of wet weight.

Protein

Total protein content in the homogenized samples was determined using the method described by Lowry *et al.* (1951). This colorimetric method uses the fact that the Folin-Ciocalteu reagent in presence of protein, was reduced in a blue complex which the intensity was directly proportional to the protein content, and showing a maximum of absorbance to 750 nm. Results were expressed as g per 100 g of fresh sample.

Carbohydrate

The carbohydrate content was determined according to the method of Dubois *et al.* (1956). Simple sugars, oligosaccharides, polysaccharides, and their derivatives give an orange-yellow color when treated with phenol and concentrated sulphuric acids. Results were expressed as mg per 100 g of fresh sample.

Lipids extraction

Total lipids were extracted according to the method of Folch *et al.* (1957) by chloroform/methanol (2/1). The aliquot of the chloroform layer extract was evaporated to dryness and lipids were quantified gravimetrically.

Fatty acids analysis

Fatty acids Methyl Esters (FAMES) were obtained by the method described by Metcalfe *et al.* (1966). A fraction of the lipid extract was saponified with 0.5 mol/L NaOH in methanol followed by a methylation in 12% boron trifluoride in methanol (BF₃/MeOH). The methylated sample was then extracted with n-hexane. All of these reactions were performed in quadruplicate for each sample. The resulting methyl esters were analysed by gas chromatography (GC) using an Agilent Technologies chromatograph 6890N (Agilent Technologies, Palo Alto, CA, USA) equipped with a flame ionization detector (FID), a splitless injector and a polar INNOWAX 30 M silica capillary column (0.25 mm i.d. & 0.25 µm film thickness). The temperature of the injector and detector were 220 °C and 275 °C, respectively. Helium was used as a carrier gas with a flow rate of 1.5 ml/min. Peaks were identified by comparison of their retention times with FAMES standards (SUPELCO). The sequences of fatty acids were ranged according to their chromatographic retention times and the values are given as percentages of the total fatty acids methyl esters.

Thiobarbituric acid reactive substance (TBARS)

The TBARS was determined according to the AOCS (1998) method. This procedure allows the direct determination of TBARS in oils and fats without preliminary isolation of secondary oxidation products; it is applicable to animal and vegetable fats and oils. Oil sample (50 to 200mg) dissolved in 1-butanol mixed with 0.2% TBA in 1-butanol were incubated 2 hours in a 95 °C water bath and cooled for 10 min under tap water (TBARS reaction). The absorbance was measured at 532 nm against a corresponding blank (a reaction with all the reagents and treatments except the oil extract). The standard curve was determined by the TBARS reaction of a series of aliquots (0.1 to 1 ml) of 0.2 mM TMP (1,1,3,3-tetramethoxypropane) prepared in 1-butanol. The results were expressed as mg malonaldehyde/kg of oil.

Total volatile bases (TVB-N)

The TVB-N was determined by flow injection analysis (Ruiz-Capillas & Horner 1999).

Trimethylamine (TMA-N)

The TMA-N was determined by flow injection analysis (Sadok *et al.* 1996).

pH

The pH was measured using a pH-meter at

room temperature on homogenates in water in a ratio 1:10 (w/v) (AOAC 1995).

Antioxidant activity of thyme

The Antioxidant activity was conducted as described by (Osawa & Namiki 1985). A sample of powdered thyme (1.3 mg) was dissolved in 10 ml of 50 mM phosphate buffer (pH=7), and was added to a solution of 0.13 ml of linoleic acid and 10 ml of 99.5 % ethanol. The total volume was then adjusted to 25 ml with distilled water. The mixture was incubated in a 50 ml assay tube with a screw cap at 40 ± 1° C in a dark room and the degree of oxidation was evaluated by measuring the ferric thiocyanate values according to the method of Mitsuta *et al.* (1966). A total of 100 µl of the oxidised linoleic acid solution was added to 4.7ml of 75 % ethanol, 0.1 ml of 30 % ammonium thiocyanate, and 0.1 ml of 0.02 M ferrous chloride solution in 3.5 % HCl. After 3 min stirring, the absorbance was measured at 500 nm. α-Tocopherol was used as reference and distilled water as control. The antioxidative capacity of inhibiting the peroxide formation in linoleic acid system was expressed as follows:

$$\text{Inhibition (\%)} = [1 - (\text{Absorbance of sample} / \text{Absorbance of control})] \times 100$$

DPPH assay I (%)

The free radical-scavenging activity was determined by the DPPH test using the method of Tepe *et al.* (2005). This test aims to measure the capacity of the extracts to scavenge the stable radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) formed in solution by donation of hydrogen atom or an electron. If the extracts have the capacity to scavenge the DPPH free radical the initial blue/purple solution will change to a yellow colour due to the formation of diphenylpicrylhydrazine. This reaction is used as a measure of the ability of the extracts, or any other antioxidant, such as BHT, to scavenge any free radical.

To 5 ml of a methanol solution of 2,2'-diphenylpicrylhydrazyl (DPPH) 0.002% in methanol, 50 µl of essential oil or extract solutions were added and the mixture was incubated at room temperature for 30 min. The absorbance was measured at 517 nm against a corresponding blank.

Inhibition percentage of free radical DPPH was calculated in the following way:

$$I (\%) = (A_{\text{blanc}} - A_{\text{sample}} / A_{\text{blanc}}) \times 100$$

where A_{blank} is the absorbance of the control reaction (a reaction with all the reagents except the test extract), and A_{sample} is the absorbance of the test extract. Tests were carried out in quadruplet and the extract concentration providing 50% inhibition (IC_{50}) was obtained by plotting extract solution concentration versus inhibition percentage.

Statistical analysis

Statistical analysis was performed using SPSS software, version 10.0.5. The comparison of flesh quality indicators during storage were tested using Duncan's test (95% confidence interval) with one-way ANOVA. Data are expressed as mean $\pm$ standard error; n values are shown in each table and figure.

Results and Discussion

Biochemical analysis

Table I shows the changes of proximate composition of both tuna fillets lots during storage. The lipid and protein contents found in this study in fresh tuna were 10.49 and 16.21 g/100g, respectively. Mourente *et al.* (2001) reported for Atlantic female northern bluefin tuna (*Thunnus thynnus thynnus* L.) a low fat content ranging from 0.82 to 1.55 g/100g fresh white muscle. Lower lipid levels, have been reported also for *Thunnus alalunga* (0.88 ± 0.64 g lipid /100g fresh muscle) and *Euthynnus lineatus* (1 ± 0.3 g lipid /100g fresh muscle) (Ben-Gigirey *et al.* 1999, Manzano *et al.* 2000). The high tuna lipid level found in this study may be related to season. Generally, lipid content varies within species (1.46 to 5.77 g/100g) and is affected by the catching season (1.2 to 18.4 g/100g) (Bandarra *et al.* 1997, Osman *et al.* 2001).

According to Duncan's test, no significant differences ($p > 0.05$) were found for moisture, ash, protein and lipid between all fillets lots during the storage period. Similarly, carbohydrate content decreased slightly at the end of storage but remained no-significant for $p > 0.01$. These findings are in accordance with those reported by Chomnawang *et al.* (2007).

Fatty acids

Fatty acids composition of control and treated tuna fillets during refrigerated storage are presented in Tables II and III. Polyunsaturated fatty acids (PUFAs) constitute the majority of the fatty acids pool, followed by saturated (SFAs) and monounsaturated fatty acids (MUFAs). Within these groups, the major fatty acids were palmitic

acid (16:0), stearic acid (18:0) and oleic acid 18:1 (n-9 & n-7). The total polyenes content was 41.32%, with eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) being the prominent polyunsaturated fatty acids.

Significant differences ($p < 0.05$) in fatty acid profiles (SFAs, MUFAs and PUFAs) were observed in control lot before and after storage. SFAs and MUFAs percents increased from 30.66 to 34.16 and from 20.33 to 21.32 respectively, PUFAs levels remain unchanged during the three first days (from 41.32 % to 41.28 %), thereafter, a significant decrease ($p < 0.05$) was showed in day 6 (39.89 %) and in day 12 (38.74 %).

In treated lot, PUFAs levels remain significantly constant from day 0 (41.32 %) to day 15 (41.05 %), thereafter, a significant decrease was showed at the end of storage (day 18) to reach 39.38 % (Fig. 1). The decrease of PUFAs percentage may indicate the oxidation of these unsaturated fatty acids during storage. Such changes were not observed in thyme treated lot. The uses of natural antioxidant in fish fillets has induced the stability of fatty acids profiles without altering their composition and minimize such auto-oxidation. These results are in accordance with those reported by Serdaroglu & Felekoglu (2005).

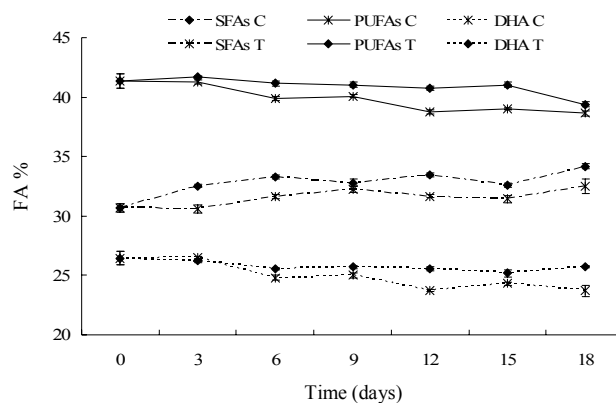


Figure 1. Changes in PUFAs, SFAs and DHA values of control and thyme treated tuna fillets during chilled storage. Bars indicate standard deviations from quadruplicate determinations. FA: fatty acid; PUFAs: polyunsaturated fatty acids; SFAs: saturated fatty acids; DHA: docosahexaenoic acid; C: control lot; T: treated lot.

Due to their high degree of unsaturation, EPA and DHA are readily oxidized. Such characteristic has suggested the use of the polyene index $[(EPA + DHA)/16:0]$ and PUFAs/SFAs to evaluate oxidative deterioration of polyunsaturated fatty acid in fish lipids (Wada & Fang 1992). In this study, the polyene index and PUFAs/SFAs values in control samples decreased from 1.70 % to 1.52 % and from 1.35 % to 1.20 % following 15 days of

storage, respectively. No changes were observed in polyene index and PUFAs/SFAs values for thyme treated lot. It has been reported that sardines treated with rosemary extract and onion juice, retained ratio of [EPA + DHA/16:0] statically constant during storage (Serdaroglu & Felekoglu 2005).

TBARS

Several studies showed that TBARS values may be used as indicator of seafood lipid quality, whether fish was ice stored, chilled or frozen (Vareltzis *et al.* 1988). In this study, fresh tuna TBARS level was 0.34 mg malonaldehyde/kg (Fig. 2), such levels remained constant up to 6 days of chilled storage, with no significant differences between control and thyme treated lots. The observed stability of the product to lipid oxidation could be attributed to the chilling condition and to the O₂ barrier properties of the polyethylene bags used in the packages. Thereafter a significant increase was observed in both lots with higher levels in control lot ($p < 0.05$) toward the end of the storage (> 9 days of storage). The increase in TBARS indicated formation of secondary lipid oxidation products such as aldehydes and others volatiles compounds (Kolakowska 2002).

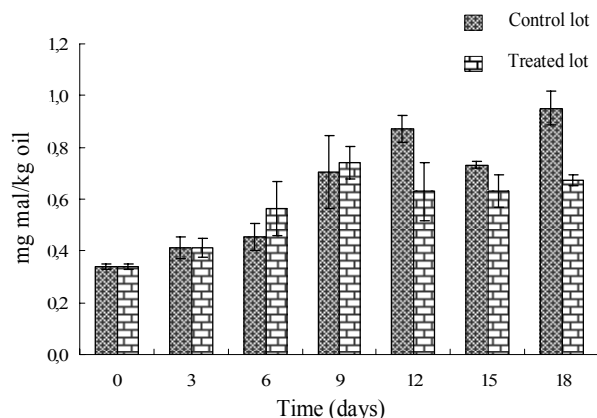


Figure 2. Changes in TBARS values of control and thyme treated tuna fillets during chilled storage. Bars indicate standard deviations from quadruplicate determinations. mal: malonaldehyde; TBARS: thiobarbituric acid reactive substance.

These findings are in accordance with the antioxidative effect of thyme *Thymus vulgaris* observed by others authors (Justesen & Knuthsen 2001, Sachetti *et al.* 2005).

Mazorra-Manzano *et al.* (2000) reported for black-skipjack (*Euthynnus lineatus*) muscle an increase ($p < 0.05$) in TBARS values from an initial value of 10 mg malonaldehyde/kg sample to a final value of 52 mg malonaldehyde/kg after 24 days of iced storage. Ryder *et al.* (1984) reported for

mackerel (*Trachurus novaezelandie*) 8.3 mg malonaldehyde/100g after 7 days of ice storage and correlated this TBA level with off-odors and flavours for cooked fish as well as rancidity odors in gills. Chaijan *et al.* (2006) reported also that after 15 days of iced storage, TBARS value in sardine muscle increased by 97% (620 mg malonaldehyde/kg sample) when compared with that found in fresh muscle. In this study, TBARS of all examined tuna samples did not exceed 1 mg malonaldehyde/kg oil with a measured maximum value in control tuna sample at 18 days of chilled storage.

Antioxydant activity

Many naturals antioxidants are plant phenolics found in every part of the plant, including the fruit, seeds and leaves (Kim *et al.* 1997, Shahidi 2000, Sachetti *et al.* 2005). The major constituent of Thyme *Thymus vulgaris* is Luteolin, to wich are attributed many of the antioxidant properties (Justesen & Knuthsen 2001). The antioxidant activity may occur via various mechanisms such as the inhibitory effect on lipid peroxidation and by scavenging the radicals.

In our data, the ethanol thyme extract exhibit good radical scavenging activities ($IC_{50} = 18.6 \pm 0.5 \mu\text{g/ml}$) and it was significantly higher ($p < 0.05$) to that of standard butylatedhydroxytoluene. Differently, Mata *et al.* (2007) have reported a low radical scavenging activities for wild thyme *Thymus serpyllum* ($IC_{50} = 13.2 \pm 0.3 \mu\text{g/ml}$) and a high radical scavenging for *Mentha spicata* and *Rosmarinus officinalis* ($IC_{50} = 65.2 \pm 0.1 \mu\text{g/ml}$ and $36 \pm 0.1 \mu\text{g/ml}$ respectively).

The relative antioxidant inhibition for the powdered thyme was calculated against that of α -Tocopherol. The inhibition level of thyme was 78.07% and it is significantly ($p < 0.05$) lower than α -Tocopherol (83.58%). Plant extracts are complex mixtures and reports of antioxidant activities evaluated by different tests are not always concordant (Trouilla *et al.* 2003, Sachetti *et al.* 2005, Tepe *et al.* 2005, Mata *et al.* 2007).

TVB-N and TMA-N

Table IV shows the results of chemical analysis of control and thyme treated tuna fillets during chilled storage. The initial TVB-N level was 11.69 mg/100g, which is noticeably lower than levels found in other fresh tuna such as *Euthynnus lineatus* and *Thunnus alalunga* (25.5 and 22.89 mg/100g TVB-N respectively) (Ben-Gigirey *et al.*

Table I. Proximate composition of control and thyme treated tuna fillets during chilled storage. Means (n = 4) with the same letter within columns are not significantly different (p > 0.05).

Storage time (days)	Control lot					Thyme treated lot				
	Moisture (g/100g)	Ash (g/100g)	Lipids (g/100g)	Carbohydrates (mg/100g)	Proteins (g/100g)	Moisture (g/100g)	Ash (g/100g)	Lipids (g/100g)	Carbohydrates (mg/100g)	Proteins (g/100g)
0	70.60 ± 0.85a	1.22 ± 0.06a	10.49 ± 0.87a	80.45 ± 2.82ab	16.21 ± 0.89 a	70.60 ± 1.71a	1.26 ± 0.05a	10.49 ± 0.87a	80.45 ± 2.82ab	16.21 ± 0.89a
3	70.07 ± 0.58a	1.28 ± 0.09a	9.93 ± 0.53a	81.84 ± 2.74ab	15.35 ± 1.37a	69.26 ± 1.48a	1.21 ± 0.08a	11.16 ± 0.55a	67.06 ± 12.06a	14.84 ± 1.17a
6	69.10 ± 0.40a	1.36 ± 0.09a	10.39 ± 0.53a	80.76 ± 7.29ab	16.29 ± 1.21a	68.85 ± 0.34a	1.29 ± 0.08a	11.07 ± 0.63a	72.26 ± 7.40ab	15.74 ± 0.96a
9	69.48 ± 1.30a	1.27 ± 0.05a	9.85 ± 0.45a	82.92 ± 2.94ab	16.74 ± 0.94a	68.95 ± 0.13a	1.26 ± 0.07a	10.71 ± 1.18a	73.13 ± 7.49ab	16.06 ± 1.28a
12	69.80 ± 0.40a	1.30 ± 0.09a	10.38 ± 1.57a	80.52 ± 5.22ab	14.73 ± 1.16a	68.76 ± 0.13a	1.25 ± 0.08a	11.12 ± 0.74a	74.38 ± 5.84ab	15.46 ± 0.85a
15	69.58 ± 0.42a	1.26 ± 0.07a	10.94 ± 1.75a	82.60 ± 1.98a	15.43 ± 1.28a	70.64 ± 0.31a	1.34 ± 0.06a	11.14 ± 1.55a	84.09 ± 2.49b	16.83 ± 1.31a
18	69.43 ± 0.35a	1.20 ± 0.08a	10.59 ± 1.46a	75.39 ± 9.94b	15.49 ± 1.25a	69.66 ± 0.04a	1.26 ± 0.09a	11.94 ± 1.38a	74.42 ± 7.01ab	15.82 ± 0.69a

Table II. Change in fatty acids composition of control tuna fillet during chilled storage. Means (n = 4) with the same letter within rows are not significantly different (p > 0.05). The values do not represent 100% because minor fatty acids are not reported. Others SFAs: 15:0 ; 17:0 ; 20:0. Others MUFAs: 14:1 ; 15:1 ; 17:1 ; 20:1 n-9. Others PUFAs: 16:2; 20:2; 20:3.

Control	0 days	3 days	6 days	9 days	12 days	15 days	18 days
Fatty acids							
14:00	3.24 ± 0.12a	3.35 ± 0.03ab	3.68 ± 0.03d	3.60 ± 0.07cd	3.79 ± 0.02d	3.48 ± 0.05d	3.79 ± 0.05bc
16:00	19.94 ± 0.20a	20.93 ± 0.09bc	21.44 ± 0.13d	21.09 ± 0.20bcd	21.36 ± 0.13cd	21.56 ± 0.14b	20.68 ± 0.13d
18:00	5.60 ± 0.04a	6.28 ± 0.04e	6.11 ± 0.04cd	6.04 ± 0.01bc	6.16 ± 0.02d	7.00 ± 0.02b	6.01 ± 0.02f
others SFAs	1.89	1.98	2.06	2.05	2.12	2.11	2.08
SFAs	30.66 ± 0.36a	32.54 ± 0.13b	33.29 ± 0.19cd	32.78 ± 0.29bcd	33.44 ± 0.17d	32.58 ± 0.19bc	34.16 ± 0.22e
16:1 n-7	3.75 ± 0.12a	3.72 ± 0.02a	4.06 ± 0.04bcd	4.01 ± 0.05bc	4.20 ± 0.03d	3.94 ± 0.03cd	4.16 ± 0.03b
18:1 n-9	12.66 ± 0.26a	12.63 ± 0.04a	12.84 ± 0.11ab	12.95 ± 0.03ab	13.32 ± 0.06c	13.13 ± 0.07bc	13.13 ± 0.06bc
18:1 n-7	2.17 ± 0.05a	2.18 ± 0.00a	2.25 ± 0.02b	2.27 ± 0.00bc	2.32 ± 0.01c	2.31 ± 0.01bc	2.29 ± 0.01bc
others MUFAs	1.75	1.99	1.83	1.82	1.81	1.94	1.81
MUFAs	20.33 ± 0.37a	20.52 ± 0.06ab	20.98 ± 0.12bc	21.05 ± 0.08c	21.74 ± 0.09d	21.38 ± 0.09cd	21.32 ± 0.11cd
18:2 n-6	1.60 ± 0.04a	1.63 ± 0.01a	1.68 ± 0.01b	1.68 ± 0.00b	1.72 ± 0.01b	1.69 ± 0.01b	1.73 ± 0.01b
18:3 n-3	1.56 ± 0.05a	1.58 ± 0.00a	1.70 ± 0.01bc	1.69 ± 0.01b	1.73 ± 0.01bc	1.58 ± 0.01c	1.76 ± 0.01a
20:4 n-3	1.17 ± 0.03a	1.17 ± 0.02a	1.24 ± 0.01bc	1.21 ± 0.00b	1.23 ± 0.00bc	1.15 ± 0.00c	1.26 ± 0.01a
20:5 n-3	7.52 ± 0.11a	7.56 ± 0.03a	7.67 ± 0.03ab	7.68 ± 0.01ab	7.61 ± 0.03ab	7.14 ± 0.02b	7.76 ± 0.06c
22:5 n-3	1.48 ± 0.06a	1.26 ± 0.02b	1.26 ± 0.02b	1.31 ± 0.01b	1.28 ± 0.00b	1.26 ± 0.01b	1.33 ± 0.01b
22:6 n-3	26.45 ± 0.55a	26.50 ± 0.08a	24.81 ± 0.19b	25.02 ± 0.21b	23.73 ± 0.10c	24.30 ± 0.17c	23.70 ± 0.46bc
others PUFAs	1.54	1.59	1.53	1.48	1.44	1.53	1.48
PUFAs	41.32 ± 0.60a	41.28 ± 0.07a	39.89 ± 0.21bc	40.08 ± 0.21b	38.74 ± 0.14d	39.03 ± 0.18d	38.64 ± 0.20d
EPA/DHA	0.28 ± 0.00a	0.29 ± 0.00a	0.31 ± 0.00b	0.31 ± 0.00b	0.32 ± 0.00c	0.33 ± 0.00c	0.29 ± 0.00d
PUFAs/SFAs	1.35 ± 0.01a	1.27 ± 0.00b	1.20 ± 0.01c	1.22 ± 0.02c	1.16 ± 0.01d	1.20 ± 0.01c	1.13 ± 0.01d

Table III. Change in fatty acids composition of thyme treated tuna fillet during chilled storage. Means (n = 4) with the same letter within rows are not significantly different ($p > 0.05$). The values do not represent 100% because minor fatty acids are not reported. Others SFAs: 15:0 ; 17:0 ; 20:0. Others MUFAs: 14:1 ; 15:1 ; 17:1 ; 20:1 n-9. Others PUFAs: 16:2; 20:2; 20:3.

Thyme treated lot	0 days	3 days	6 days	9 days	12 days	15 days	18 days
Fatty acids							
14:00	3.24 ± 0.12ab	3.37 ± 0.08abc	3.54 ± 0.03bc	3.46 ± 0.05bc	3.39 ± 0.01abc	3.18 ± 0.13a	3.28 ± 0.06abc
16:00	19.94 ± 0.20ab	19.55 ± 0.24a	20.24 ± 0.10abc	20.58 ± 0.14bc	20.19 ± 0.08abc	20.80 ± 0.42c	20.19 ± 0.17abc
18:00	5.60 ± 0.04a	5.85 ± 0.02ab	5.87 ± 0.03ab	6.20 ± 0.03bc	6.07 ± 0.03b	6.51 ± 0.29c	6.11 ± 0.02b
others SFAs	1.89	1.81	2	2.02	2.01	1.99	1.83
SFAs	30.66 ± 0.36ab	30.57 ± 0.37a	31.65 ± 0.15bc	32.24 ± 0.23c	31.65 ± 0.12bc	31.42 ± 0.28c	32.49 ± 0.58abc
16:1 n-7	3.75 ± 0.12a	3.83 ± 0.04ab	4.00 ± 0.02b	3.94 ± 0.04ab	3.94 ± 0.01ab	3.79 ± 0.14ab	3.90 ± 0.03ab
18:1 n-9	12.66 ± 0.26a	12.86 ± 0.03a	12.81 ± 0.04a	12.92 ± 0.05a	12.93 ± 0.04a	12.88 ± 0.25a	12.79 ± 0.04a
18:1 n-7	2.17 ± 0.05a	2.25 ± 0.01ab	2.26 ± 0.01ab	2.26 ± 0.01ab	2.29 ± 0.01b	2.20 ± 0.06ab	2.25 ± 0.00ab
others MUFAs	1.75	1.78	1.78	1.72	1.86	2.14	1.88
MUFAs	20.33 ± 0.37a	20.71 ± 0.04ab	20.85 ± 0.05ab	20.94 ± 0.09ab	21.03 ± 0.07b	20.81 ± 0.07b	21.02 ± 0.35ab
18:2 n-6	1.60 ± 0.04a	1.69 ± 0.01bc	1.72 ± 0.01c	1.70 ± 0.01bc	1.68 ± 0.00abc	1.62 ± 0.06ab	1.68 ± 0.01abc
18:3 n-3	1.56 ± 0.05a	1.72 ± 0.00c	1.77 ± 0.00c	1.69 ± 0.01bc	1.68 ± 0.01abc	1.58 ± 0.09ab	1.68 ± 0.01abc
20:4 n-3	1.17 ± 0.03a	1.27 ± 0.01a	1.29 ± 0.01a	1.23 ± 0.01a	1.24 ± 0.01a	0.88 ± 0.24b	1.25 ± 0.01a
20:5 n-3	7.52 ± 0.11ab	7.88 ± 0.04c	8.01 ± 0.03c	7.82 ± 0.03bc	7.80 ± 0.03bc	5.73 ± 1.51a	7.79 ± 0.04bc
22:5 n-3	1.48 ± 0.06a	1.42 ± 0.01ab	1.39 ± 0.02ab	1.36 ± 0.02bc	1.34 ± 0.01bc	1.25 ± 0.07c	1.37 ± 0.02ab
22:6 n-3	26.45 ± 0.55a	26.23 ± 0.14ab	25.54 ± 0.10bc	25.70 ± 0.11abc	25.54 ± 0.17bc	25.20 ± 0.31c	25.76 ± 0.09abc
others PUFAs	1.54	1.5	1.44	1.55	1.54	1.63	1.51
PUFAs	41.32 ± 0.60a	41.73 ± 0.16a	41.15 ± 0.15a	41.04 ± 0.12a	40.74 ± 0.19a	41.05 ± 0.08a	39.38 ± 0.24b
EPA/DHA	0.28 ± 0.00a	0.30 ± 0.00b	0.31 ± 0.00b	0.30 ± 0.00b	0.31 ± 0.00b	0.30 ± 0.00a	0.29 ± 0.01b
PUFAs/SFAs	1.35 ± 0.01ab	1.37 ± 0.02a	1.30 ± 0.01bc	1.27 ± 0.01c	1.29 ± 0.01c	1.31 ± 0.01d	1.21 ± 0.03bc

Table IV. Change in total volatile bases, trimethylamine and pH of control and thyme treated tuna fillets during chilled storage. Means (n = 4) with the same letter within columns are not significantly different ($p > 0.05$).

Storage time (days)	Control lot			Thyme treated lot		
	TVB-N	TMA-N	pH	TVB-N	TMA-N	pH
0	11.69 ± 0.85a	0.56 ± 0.16a	6.27 ± 0.06a	11.69 ± 0.85a	0.56 ± 0.16a	6.27 ± 0.06a
3	12.76 ± 0.58a	0.58 ± 0.10a	6.21 ± 0.13a	12.95 ± 0.37a	0.68 ± 0.07a	6.25 ± 0.10a
6	12.37 ± 0.40a	0.47 ± 0.09a	6.19 ± 0.11a	12.79 ± 0.59a	0.72 ± 0.11a	6.22 ± 0.13a
9	11.85 ± 1.30a	0.47 ± 0.15a	6.24 ± 0.07a	13.04 ± 0.56a	0.66 ± 0.07a	6.17 ± 0.12a
12	12.11 ± 0.40a	0.49 ± 0.11a	6.31 ± 0.09a	13.29 ± 0.95a	0.61 ± 0.11a	6.32 ± 0.07a
15	12.24 ± 0.42a	0.65 ± 0.14a	6.34 ± 0.08a	15.08 ± 1.05b	0.74 ± 0.15a	6.26 ± 0.08a
18	12.78 ± 0.35a	0.55 ± 0.13a	6.26 ± 0.11a	15.50 ± 0.80b	0.74 ± 0.15a	6.29 ± 0.09a

1999, Manzano *et al.* 2000). The initial TVB-N levels found in this study indicated that the fish were of high quality. Throughout the refrigerated storage period, the TVB-N content in tuna-control lot showed no significant changes. In the thyme-treated lot, the TVB-N showed a slight increase towards the end of the storage period, although it was statistically significant. In all lots, TVB-N levels remained significantly lower than the current rejection limit of 30-35 mg/100g (EEC 1995).

The initial TMA-N level in tuna flesh was 0.56 mg/100g, showing no change ($p > 0.05$) with levels far below the limit of acceptability of 10-15 mgTMA/100g (Sikorski *et al.* 1989) in all lots during the period of storage. It appears from this study that TVB-N and TMA indices do not provide a good indication of tuna *T. thynnus* freshness or spoilage, as these volatile bases levels were quite constant throughout the storage period although TVB-N parameter is considered as a legal index.

pH

The initial pH value of flesh tuna fillets was 6.27. Such level remained statically constant ($p > 0.05$) in both lots during the period of storage (Table IV). These results are in disagreement with those reported by Ruiz-Capillas & Moral (2001), who found an increase in pH of black-skipjack *Euthynnus lineatus* muscle after 24 days of ice-storage. It is well known that pH changes during refrigerated storage differ according to fish species and other factors such as the degree of microorganism contamination and storage condition (Ben-Gigirey *et al.* 1999).

Conclusion

Post-mortem biochemical changes indicated that tuna could be stored up to 18 days of chilled storage at 0°C. Tuna lipids were susceptible to oxidation during chilled storage but thyme-treatment minimized such auto-oxidation. These observations were consistently confirmed by the TBARS and polyunsaturated fatty acids data. Moreover, powdered thyme *Thymus vulgaris* can be used as an easily accessible source of natural antioxidants in commercial food products as they have better consumer acceptance.

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Record of the St. Helena deepwater scorpionfish, *Pontinus nigropunctatus* (Günther) (Scorpaeniformes: Scorpaenidae), in the Saint Peter and Saint Paul Archipelago, Brazil

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Abstract. An individual of the scorpaenid St. Helena deepwater scorpionfish, *Pontinus nigropunctatus* (Günther, 1868) was caught by a fisherman close to the rocks of the Saint Peter and Saint Paul Archipelago, Brazil (0°55'N; 29°21'W). It is the first record of the species for the archipelago, early reported only as an endemic species of the St. Helena Island. The specimen measured 42.5 cm total length, weighed 1100 g, and was caught by hand line at night at 150 meters local depth.

Key words: Endemic species, new record, Atlantic archipelago, deepwater fish, bottom hand line.

Resumo. Registro do peixe-escorpião-de-água-profunda-de-Santa-Helena *Pontinus nigropunctatus* (Günther) (Scorpaeniformes: Scorpaenidae), no Arquipélago de São Pedro e São Paulo, Brasil. Um exemplar de peixe-escorpião, o peixe-escorpião de Santa Helena, *Pontinus nigropunctatus* (Günther, 1868), foi capturado por um pescador próximo ao Arquipélago de São Pedro e São Paulo, Brasil (0°55'N; 29°21'W). É o primeiro registro da espécie para o arquipélago, anteriormente reportado somente como espécie endêmica da Ilha de Santa Helena. O espécime mediu 42,5 cm de comprimento total, pesou 1100 g, e foi capturado com linha de mão durante a noite a 150 m de profundidade local.

Palavras chave: Espécies endêmicas, novo registro, arquipélago Atlântico, peixe de profundidade, pesca de mão de linha de fundo.

An individual of the scorpaenid St. Helena deepwater scorpionfish, *Pontinus nigropunctatus* (Günther, 1868) (Fig.1), was caught by a fisherman close to the rocks of the Saint Peter and Saint Paul Archipelago (SPSPA), Brazil (0°55'N; 29°21'W). It is the first record of the species for the SPSPA, early reported only as an endemic species of the St. Helena Island (Edwards & Glass, 1987; Trunov, 2006). The specimen was caught on 17 July 2007, at night (21:00 local time), during bottom hand line fishery, by a fisherman of a tuna boat that operate around the archipelago. The specimen measured 42.5 cm total length, weighed 1100 g, and was caught at 150 meters local depth with a chunk of flying fish (*Cheilopogon cyanopterus*) as bait. After

retrieved, the fish was stored frozen for posterior identification.

The SPSPA, a group of small rocky islands 1100 Km from extreme east Brazil (Fig. 2), is an important fishing ground particularly for tunas, wahoo, sharks and flying fishes. Recent information concerning SPSPA ichthyofauna was published by Vaske *et al.* (2005), where a total of 116 taxa were recorded, 100 at the species level, eight at the genus level, and eight at the family level. Fifty two species were considered reef fishes and 64 were pelagic species. Former records of scorpaenids for the SPSPA, indicate the presence of two species. *Scorpaenodes insularis* (Eschmeyer, 1971) is an endemic species of islands from Meso-Atlantic



Figure 1. Deepwater scorpionfish, *Pontinus nigropunctatus* from Saint Peter and Saint Paul Archipelago.

Ridge, SPSPA, Ascension and St. Helena Islands, who inhabit waters from 5 to 35 meters depth in the SPSPA (Lubbock & Edwards, 1981). Another report is *Scorpaena* sp. cited by Feitoza *et al.* (2003).

St. Helena lies in the South Atlantic Ocean, east of the mid-Atlantic Ridge, 1,913 km west of Angola and 3,284 km east to southeast of Brazil. The nearest island is Ascension, 1,296 km northwest. The coastal waters of St. Helena support 10 endemic fish species, a further 16 shared only with Ascension Island (Edwards & Glass, 1987). Oceanic sites experience extreme isolation and relatively small shallow water area, thus diminishing the chances of larval input from the continental margins as well as limiting the availability of suitable habitats for the adults (Floeter *et al.*, 2001). Only after the mid-1990s, a significant increase in sampling effort resulted in some knowledge of the Brazilian reef fish fauna (Floeter & Gasparini, 2000, 2001; Floeter *et al.*, 2001; Joyeux *et al.*, 2001, Luiz Jr. *et al.*, 2007; Rocha & Rosa, 2001; Feitoza *et al.*, 2003). Nevertheless, the Brazilian reef fish community beyond 30 m remains broadly unknown (Feitoza *et al.*, 2005). Cluster analysis of the zoogeographic affinities between the deep reefs off the hump of Brazil and other western Atlantic sites, pointed out the isolation of fish fauna of the SPSPA (Feitoza *et al.*, 2005). According Feitoza *et al.* (2003), SPSPA should be considered as an impoverished outpost of the Brazilian province. This fact is observed in the SPSPA, where representatives of some continental species also occur, like *Epinephelus itajara* and *Lutjanus purpureus* (Vaske-

Jr. *et al.*, 2006), and the new westward record of *P. nigropunctatus* in the present study, that is considered a Vulnerable (VU) species by IUCN (2004), and evidence the connection with isolated islands of the Mid-Atlantic Ridge.

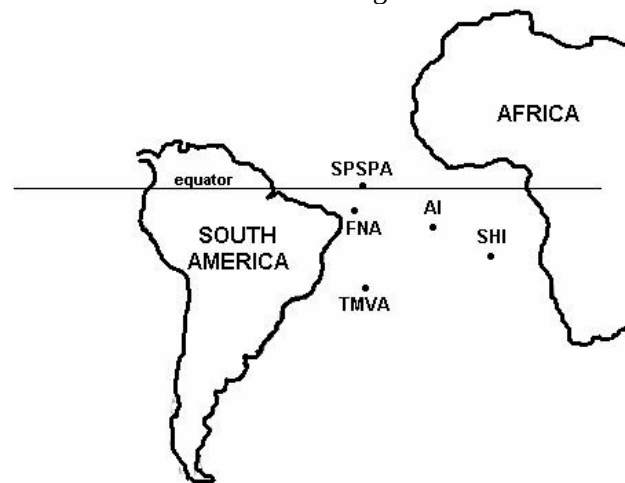


Figure 2. Main islands of central Atlantic. SPSPA – Saint Peter and Saint Paul Archipelago; AI – Ascension island; FNA – Fernando de Noronha Archipelago; SHI – Saint Helena Island; TMVA – Trindade and Martin Vaz Archipelago.

The Saint Peter and Saint Paul Archipelago is an important scientific ground for biodiversity and zoogeographic studies because it is situated in the path of the South Equatorial Atlantic current that flows westward, and the North Equatorial undercurrent that flow eastward, that may strongly influence in the species distribution, specially in the unexplored habitat at depths beyond 150 m, which may hide a greater number of unknown species.

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Changes in benthic assemblages of the Gulf of Batabanó (Cuba) - results from cruises undertaken during 1981-85 and 2003-04

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Abstract. Benthos samples in the Gulf of Batabanó (Cuba) were evaluated to explore if reported reduced lobster and finfish catches over the past two decades may be (at least partially) related to community changes and loss of benthic habitats of the gulf. Data was obtained from cruises carried out during the periods 1981-85 and 2003-04 covering the whole gulf area. Results suggest that adverse changes have occurred in the benthic assemblages in the areas of south of Pinar del Río and La Coloma with a great reduction in species diversity and seagrass coverage. Signs of disturbance of the benthic assemblage are also evident close to Peninsula Zapata and at the northeast of Isla de La Juventud. Further research in these four areas is strongly recommended to identify the sources of disturbances and to quantify impacts on the fishery.

Key words: Bottom community, habitat loss, lobster fishery.

Resumen. Cambios en las asambleas bénticas del Golfo de Batabanó (Cuba) - resultados de cruceros realizados durante 1981-85 y 2003-04. En este estudio se analizaron muestras de bentos obtenidas del Golfo de Batabanó con el fin de explorar si la reducción en las actuales capturas de langostas y peces del Golfo, durante las dos últimas décadas, estaría relacionada (al menos parcialmente) con cambios en la comunidad del bentos y pérdida de hábitat en el lugar. Los datos fueron obtenidos de cruceros, que abarcaron toda el área del Golfo, realizados durante los años 1981-85 y 2003-04. Los resultados muestran cambios drásticos en el bentos al sur de la zona denominada Pinar del Río y La Coloma con subsecuentes reducciones en la diversidad de especies y cobertura de pastos. Señales de disturbios en el bentos fueron también observadas en la Península de Zapata y al noreste de la Isla de La Juventud. Se recomienda intensificar los estudios en estas cuatro zonas del Golfo, con la finalidad de identificar las fuentes de disturbio y cuantificar los impactos a las pesquerías.

Palavras chave: Comunidades de fondo, pérdida de habitat, pesca de langosta.

Introduction

Benthic organisms are the most common targets in biological assessments of environmental quality (Rosenberg and Resh 1993, Southerland and Stribling, 1995). These organisms provide a primary food source for fish, birds and marine mammals and affect sediment stability (Jumars & Nowell 1984) and geochemistry (Pfannkuche & Lochte 2000). They also possess appropriate attributes for use as

cost-effective indicators of environmental change and water quality (Bilyard 1987, Fabricius & McCorry 2006), such as limited motility, deposit feeding and relative long life cycles (Rosenberg & Resh 1993, Thompson & Lowe, 2004). Other characteristics that make these organisms suitable as indicators are their presence in a variety of habitats, a widely described response to stressors, the

existence of well-developed standardised protocols for sampling and the availability of background data in many cases.

In Cuba, the importance of benthic communities as sources of food and habitat for important economic marine species has been recognized since the decade of the 1970s. Research on benthos diversity, population dynamics and changes caused by natural or anthropogenic sources was considered essential to achieve an optimal resource management (Gomez *et al.* 1980, Alcolado 1990). Thus, considerable research effort was directed to the study of benthic communities of the Gulf of Batabanó during this period, being the gulf one of the most important fishing grounds in the country. At least 60% of the landings of the spiny lobster (*Panulirus argus* Latreille 1804) fishery are obtained from Batabanó (Baisre 1985, Alcolado 1990, Puga *et al.* 1996). However, catches of lobster and other important commercial fish species have shown a declining trend over the last two decades, with as yet no sign of recovery despite the enforcement of fishery management policies in the area (Claro *et al.* 2001, Valle 2005).

Changes in the nutrient input during the last two decades with subsequent changes in the hydrochemical cycle of the Gulf have been suggested as being responsible for the present lower productivity (Claro *et al.* 1994, Puga 2005). However, there are as yet no reports of deterioration or habitat loss for lobster and fish communities, which may also be playing an important role in the decrease of the fishery landings. Pollution due to urbanization, fishing gear damage to benthic biotopes and non-anthropogenic factors, such as the

loss of seagrass coverage due to higher frequency of hurricanes passing through the area, are also likely causes of habitat loss in the Gulf and subsequent changes in lobster landings (Hernandez and Puga 1995).

The main purpose of this study was to analyse benthic assemblages of the Gulf of Batabanó as recorded during the period 1981-1985, when lobster catches peaked at mean annual catches of c.a. 12000 t (Claro *et al.* 2001), with data from twenty-five years later. During the nineties, lobster catches dropped to levels around 5000t and have remained low ever since (Baisre 2000). The comparison of bottom communities during both periods, will allow us to test our working hypothesis according to which lobster and fish catches in the area were negatively affected by general environmental deterioration or habitat loss.

Material and Methods

This research was carried out in the Gulf of Batabanó (21°N, 80°W), in southwest Cuba. The Gulf covers an area of c.a. 20,850 km² and has an average depth of 5-6 m. The area is fringed by mangrove stands along the northern and western shores and by coral reefs to the south, where it borders with the open ocean. During May 2003 and November 2004, two research cruises along the Gulf were carried out by the Cuban Oceanographic Institute (Instituto de Oceanología de Cuba) and benthic samples were taken from 24 and 21 sampling sites respectively (Figure 1). Samples were analysed and are presently preserved in the same research institute. For comparison, benthos data from the period 1981-1985 were obtained from the

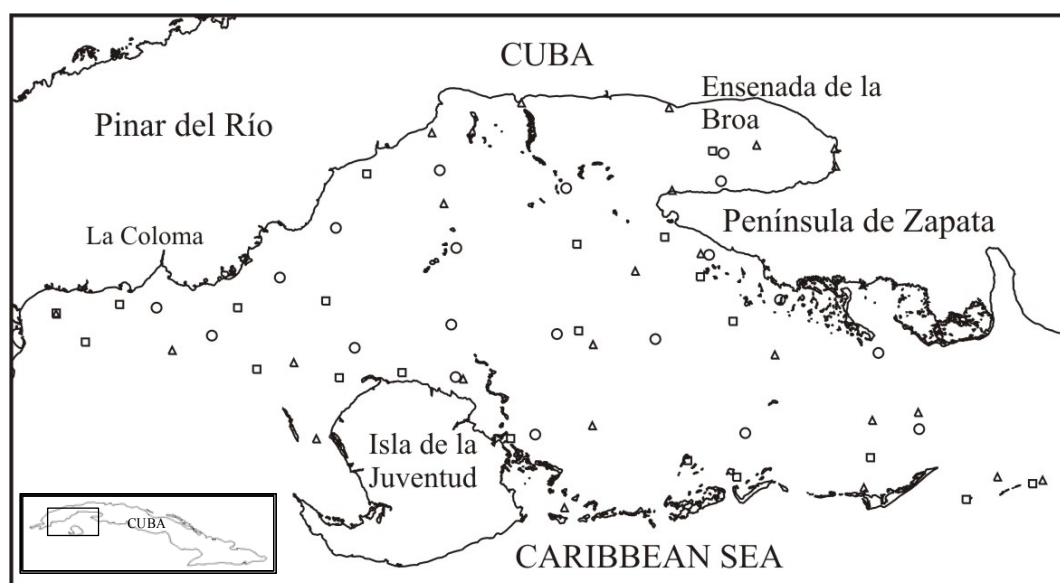


Figure 1. Map of the study area, Gulf of Batabanó, showing sampling sites for cruises during 1981-1985 (circles), 2003 (triangles) and 2004 (squares).

literature (Alcolado 1990). These data correspond to 7 research cruises carried out in the Gulf (sampling sites are also shown in Figure 1). During both periods, sampling techniques were fully comparable and in some cases samples were taken and analysed by the same scientific personnel.

Sampling

Sponges and echinoderms were collected using a 0.74 m long rake with a mesh size of 4 mm covered with a 2 cm mesh size net. At each sampling site, three hauls of 14 to 30 m were carried out and organisms were preserved in alcohol (70%).

At the same sampling sites, a corer with an internal diameter of 15 cm was used to collect seagrass and macroalgae. The corer was used four times at random (4 replicates) in an area of 10 m². These samples were washed out with seawater and preserved with 5% formaldehyde neutralised with sodium tetraborate. To estimate foliar biomass, samples were identified to species level, washed with 5% chlorhydric acid to eliminate epiphytes and then rinsed with tap water. Samples were dried in an oven until constant weight and then weighed using an electronic scale with 0.1 g precision.

For the meiofauna samples, a cylinder with an effective sampling area of 5 cm² and volume of 50 cm³ was employed using SCUBA diving. Samples were preserved in 4% formaldehyde neutralised with sodium tetraborate, and then sieved through a column with mesh sizes ranging from 500 to 45 micron using tap water. Macrozoobenthos was sampled using a frame-net-suction dredge system, collecting the sediment from an area of 0.1m²

submerged 10 cm into the substrate. The samples were subsequently preserved in neutralised 4% formaldehyde. Sediment was separated by decantation and organisms, which remain after using a sieve of 500 micron, were collected for identification.

Data analysis

Data between both periods were compared using number of species, species composition, percentages of occurrence and average biomass per habitat. These variables were applied to different taxonomic groups. For analysis and spatial comparison purposes, we also divided the Gulf into four areas as shown in Figure 2. Area I covered the northern portion of the gulf bordered to the south by an imaginary line between the westernmost portions of Zapata Peninsula and Punta Capitana (north of La Coloma). Area II covered the portion between the trajectories of a straight line passing through the middle of Isla de la Juventud until reaching Area I in the north. Area III enclosed the area between the western portion of Zapata Peninsula in the north and Cayos del Rosario in the south, parallel to Area II; and Area IV the area between the eastern portion of Cayos Diego Pérez and the eastern border of Cayo Largo. Bottom characteristics in each of the areas covered a range of sediment features, seagrass coverage and habitat diversity; however this division helped us to compare sub-areas sampled in both periods and to identify regions with different levels of habitat loss.

For the purpose of characterizing areas of a common benthic species assemblage for both study

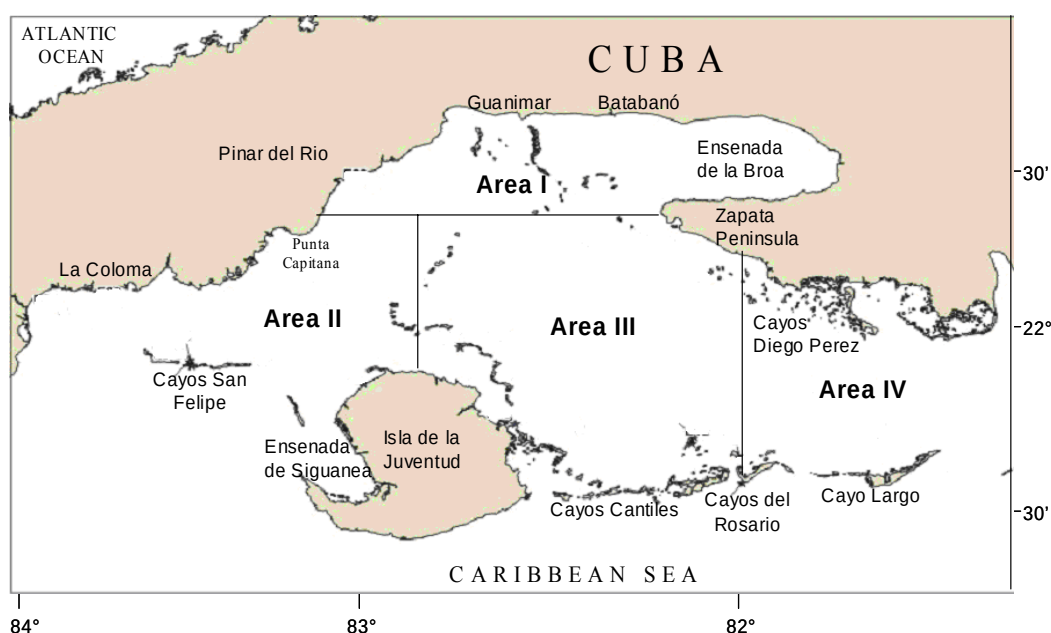


Figure 2. The Gulf of Batabanó divided in four study areas.

periods, species abundances vs. sampling sites matrixes were constructed for echinoderms, crustaceans and molluscs. These three taxonomic groups were the only ones for which raw abundance data were available for the period 1981-85. Matrix data were then subjected to a Multi Dimensional Scaling (MDS) ordination with the help of the software PRIMER v.5.2.9. We used the stress value to select the better MDS representation following the rule of thumb, in which any stress value under 0.1 is excellent and any over 0.15 is unacceptable.

Results

Percentages of occurrence of seagrass in the Gulf of Batabanó for the periods 1981-85 and 2003-04 are presented in Table I. The turtle grass *Thalassia testudinum* (Banks and Soland. ex Koenig 1805) was the most widely distributed plant within the gulf in both periods. However the species was found in 69% of the sampling sites during 2003-04 compared to 91% during 1981-85. Average leaf biomass of turtle grass at the different sampling stations ranged from 12 ± 16 to 102 ± 130 g dw/m² in 2003-04 and from 21 to 100 g dw/m² for the 1981-85 period (Jiménez 1990).

Macroalgae were found at almost all sampling sites during 2003-4, with Chlorophyta being the most common group recorded (96% of occurrence) (Table 1). The most frequent genera identified were *Caulerpa*, *Halimeda*, *Penicillus*, *Udotea*, *Avrainvillea* and *Anadyomene*.

Rhodophyta from the genera *Laurencia*, *Hypnea* and *Bryothamnion* occurred in 33% and Phaeophyta in only 11% of the sampling sites. Jiménez (1990), who registered 54 species of Chlorophyta, 15 of Rhodophyta and 11 of Phaeophyta for the period 1981-85, reported the same pattern for the presence of macroalgae in the gulf, with percentages of occurrence in sampling sites of 93%, 73% and 7% for these three algae groups respectively (Table I). The most frequent genera were again *Penicillus*, *Halimeda*, *Udotea*, *Avrainvillea* and high biomass values of *Anadyomene* at the northwest of Isla de La Juventud and south of Zapata Peninsula (59.65 in 1981-85 and 31.2 g/m² in 2004). The genus *Rhipocephalus*, which was registered in 51% of the sampling sites in 1981-85, was not registered in 2004. In both periods, Phaeophyta were found associated with oceanic waters.

Thirteen species of sponges were found during the sampling in 2004 in comparison with seventy-two species during 1981-85. Among the sponges, *Aplysina fistularis* (Pallas 1766) and *Chondrilla nucula* (Schmidt 1862) were the most

frequent species in both periods. Some common species found during 1981-85 were absent during our surveys (Table I). Sponge's average biomass was also considerable lower for the 2003-04 surveys except in the case of sandy bottoms (Table II).

For the Mollusca, a total number of 51 species were registered in 21 sampling sites in 2004 compared to 188 species at 170 sampling sites in 1981. Filter feeders accounted for 61% of the species, herbivores 23% and carnivores 16% in 2004 and 59%, 23% and 4% respectively in 1981; the remaining species were detritivores (10%) and omnivores (4%). Average biomass was slightly lower during 2003-04, except at the substrate with medium dense vegetation (Table II). Maximum biomass registered was 7.72 g dw/m² during 2004 compared with 20 g dw/m² during 1981. Maximum densities were very similar with 11.16 ind/m² in 2004 and 7-10 ind/m² in 1981.

Echinoderm's group composition between 1981-1985 and 2004 is shown in Figure 3. The presence of Asteroidea and Echinoidea was almost identical while some Ophiuroidea were apparently replaced by species of the Holoturoidea group in 2004. The green urchin *Lytechinus variegatus* (Lamarck 1816) was the most conspicuous species for both periods with around 50% of occurrence at sampling sites. Echinoderms showed a maximum biomass of 10 g dw/m² during 2004 and 14.2 g dw/m² in November 1981; maximum densities were also much lower in 2004 (0.9 ind/m²) compared with 7.5 ind/m² in 1981.

Considerable differences were registered in the composition of the most important groups within the macroinfauna between the two periods. Sandy bottoms showed a lower representation of major taxa compared with 1981; the substrate was mainly dominated by polychaetes (85%) and there was a total absence of crustaceans (Figure 4). Lower quantities of different phyla were also registered in muddy substrates, with predominance of molluscs during 2003 and absence of nematodes during both periods. In the mixed and the sandy substrates with vegetation a slightly decrease in the number of echinoderms was recorded, apparently replaced by crustaceans (Figure 4).

Macrozoobenthos showed lower number of individuals per square meter in three of the four substrates sampled in 2003 and slightly higher densities of the sand and mud with vegetation substrate compared with 1981 (Figure 4). Only the sandy bottom substrate presented a similar number of individuals during both periods. Within the polychaeta, a higher number of species (86) was registered during May 2003 compared with May

Table I. Percentages of occurrence of seagrass, macroalgae and sponges in the Gulf of Batabanó.

Species	Period 1981-1985 (15 sampling sites)	Period 2003-2004 (44 sampling sites)
SEAGRASS		
<i>Thalassia testudinum</i>	91	69
<i>Halodule beaudetii</i> (wrigthii)	50	54
<i>Syringodium filiforme</i>	31	12
<i>Halophila decipiens</i>	9	6
MACROALGAE		
Chlorophyta	93	96
Rodophyta	73	33
Phaeophyta	7	11
SPONGES		
<i>Aplysina fistularis</i>	46	38
<i>Amphimedon viridis</i>	10-15	30
<i>Chondrilla nucula</i>	38	30
<i>Cliona vesparia</i>	40	23
<i>Haliclona implexiformis</i>	no data	23
<i>Halichondria melanodocia</i>	< 10	23
<i>Suberites aurantiaca</i>	no data	23
<i>Geodia gibberosa</i>	10-15	15.4
<i>Hyrtios violacea</i>	32	15.4
<i>Cliona varians</i>	40	7.7
<i>Haliclona molitba</i>	no data	7.7
<i>Ircinia felix</i>	18	7.7
<i>Tedania ignis</i>	27	0
<i>Hyrtios proteus</i>	22	0
<i>Clathria schoenus</i>	22	0
<i>Ulosa ruetzleri</i>	18	0

1981 (62 species); the most important species according to their frequency of occurrence were entirely different between both periods but with similar trophic components (Table III). During 2003-04, macrofauna biomass reached values close to 3 g dw/m² while during 1981 the highest biomass value corresponded to 6.4 g dw/m².

Meiofauna samples showed lower density values during 2004 (1-3 ind/10cm²) in comparison with 1981-85 (18-80 ind/cm²). Nematodes, polychaeta and copepods were the most frequent groups during both periods.

Spatial analysis

Seagrass

Area I embracing, Ensenada de la Broa, the adjacent waters of Guanímar and Batabanó and eastern portion south of Pinar del Río, showed three different distribution patterns of marine angiosperms biomass in 1981-85 (Figure 5). In this area,

Ensenada de la Broa presented a total absence of seagrass except from the coastal portion north of Zapata Peninsula, where a rocky bottom with some turtle grass patches was recorded (0-80 g/m²). Around Guanímar and Batabanó, there was very light seagrass coverage, in contrast to the southern part of Area I and the portion south of Pinar del Río, where high densities of turtle grass were registered in 1981-85. During 2003-04, Ensenada de la Broa showed the same distribution of angiosperms, with total absence of seagrass coverage except at the north coast of Zapata Peninsula. The same pattern of seagrass cover was also recorded for the areas adjacent to Guanímar, Batabanó and the southern portion of Area I, though the segment of Pinar del Río showed absence of seagrass coverage towards the southwest border of Area I.

Area II showed medium to high seagrass biomass on a strip parallel to the coast between south of Pinar del Río and La Coloma and around

Table II. Average biomass of different taxonomic groups (g dw/m²) in the Gulf of Batabanó at different bottom substrates.

Substrate	Period 1981-1985	Period 2003-2004
SPONGES		
Sandy bottom	4.8	4.4
Muddy bottom	6.4	1.8
Medium dense seagrass cover	12.4	2.0
High dense seagrass cover	4.3	0.8
MOLLUSCA		
Sandy bottom	0.8	0.6
Muddy bottom	1.6	1.0
Medium dense seagrass cover	2.0	3.9
High dense seagrass cover	no data	2.3
MACROINFAUNA		
Sandy bottom	1.5	0.5
Muddy bottom	2.1	0.4
Medium dense seagrass cover	2.1	0.8
High dense seagrass cover	3.5	0.7

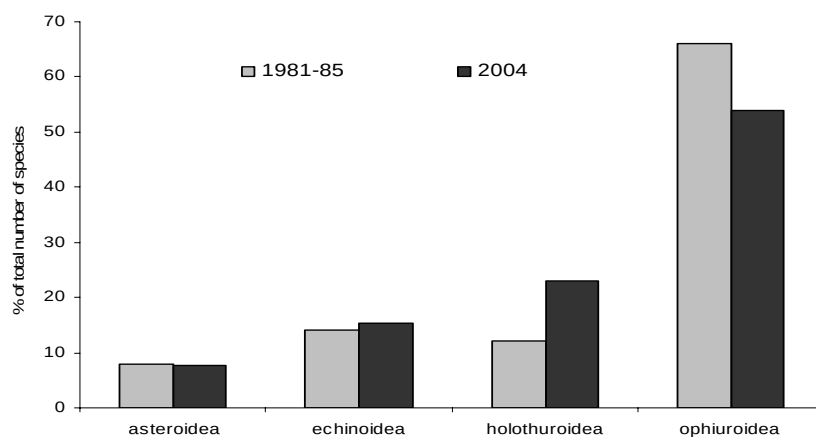
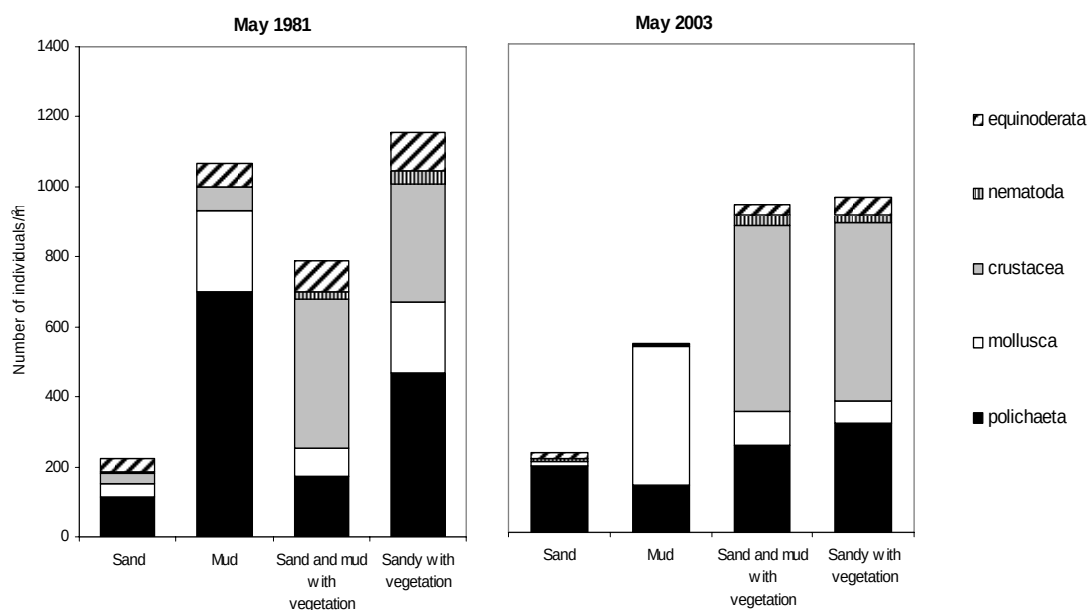
**Figure 3.** Echinoderms composition in the Gulf of Batabanó during 1981-85 and 2004.**Figure 4.** Macrozoobenthos composition in the Gulf of Batabanó for four different bottom types.

Table III. Percentages of occurrence of polychaeta species in the Gulf of Batabanó.

May 1981		May 2003	
Species	%	Species	%
<i>Eupolymnia crassicornis</i>	57	<i>Syllis mexicana</i>	65
<i>Notomastus hemipodus</i>	57	<i>Axiothella mucosa</i>	57
<i>Paraprionospio</i> sp.	50	<i>Exogone</i> sp.	48
<i>Lumbrineris latreilli</i>	43	<i>Nereis riseii</i>	44
<i>Ehlersia mexicana</i>	43	<i>Prionospio cirrobranchiata</i>	39
<i>Exogone dispar</i>	43	<i>Armandia maculata</i>	39

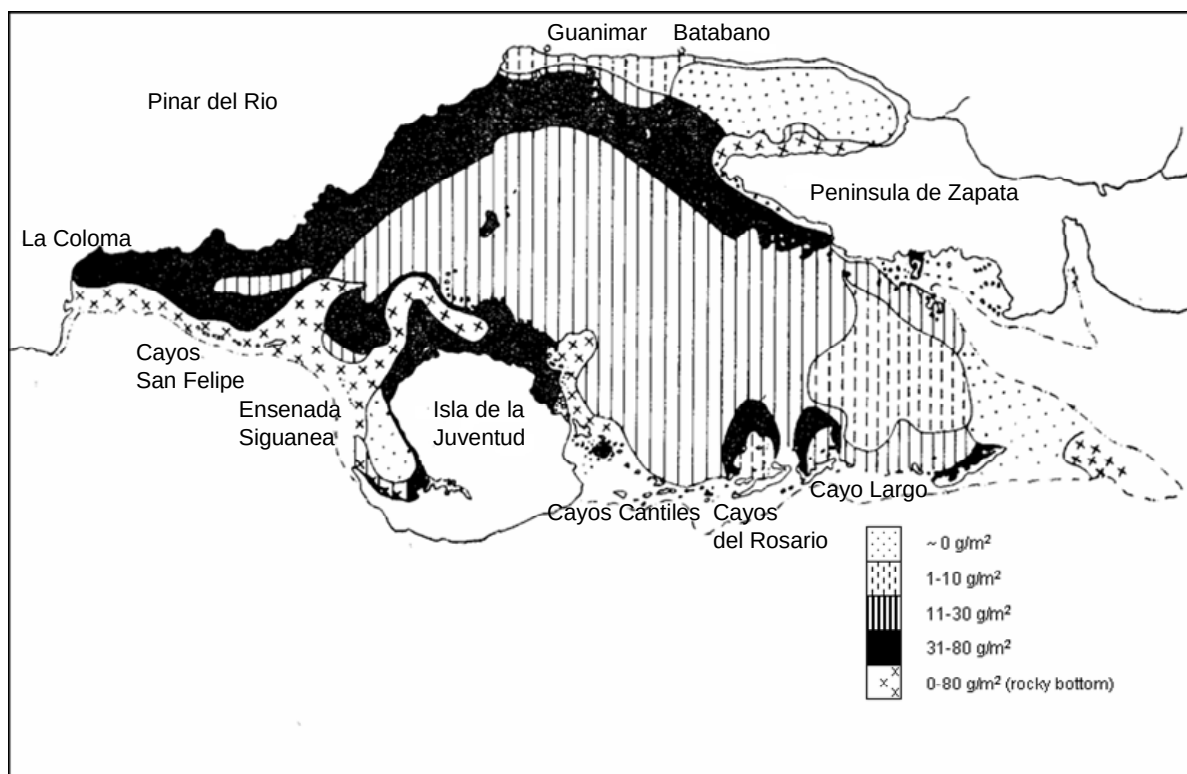
the north coast of Isla de la Juventud; rocky bottom poor seagrass abundances at the northeast border with Area I and no seagrass cover at Ensenada de Siguanea in 1981-85 (Figure 5). During 2003-04, the same pattern was observed only around Cayos de San Felipe (west of Isla de la Juventud) and the north of the island, where medium to high marine angiosperms biomass was registered. As mentioned for Area I, in this period the sampling sites corresponding to south of Pinar del Río and La Coloma in Area II showed absence of seagrass coverage. Ensenada de Siguanea was not sampled during 2003-04.

Area III and Area IV showed poor seagrass coverage except for the north and east central waters of Isla de la Juventud, south coast of Zapata Peninsula (Area III) and small patches north of Cayo Cantiles, del Rosario and Largo respectively in 1981-85 (Figure 5). For the period 2003-04, sampling sites at Area III around Isla de la Juventud

with seagrass patches to the west of the island and and south of Zapata Peninsula showed a decrease in seagrass coverage with low biomass of angiosperms (0.8 g/m^2) and some patches of high densities were also found close to those Cayos.

Other groups

For the period 1981-85, high biomass of sponges ($21\text{-}70 \text{ g/m}^2$) were also distributed inside the gulf in the central west part of areas III and IV and northwest of Isla de la Juventud. Low biomass of this group was associated with coastal areas with terrigenous affluence. These areas corresponded to a broad strip from the north west coast of the gulf at La Coloma, passing through south of Pinar del Río, Guanímar, Batabanó to Ensenada de la Broa in the east (Areas I and II), and the waters adjacent to Cayo Cantiles, del Rosario and Largo, northeast coasts of the island and Ensenada Siguanea. During 2004, none of the sampling sites recorded sponge biomass

**Figure 5.** Seagrass biomass distribution (dry weight) for the period 1981-85 (taken from Jimenez 1990).

similar to the ones observed in the 1980s. A maximum biomass of only 8.2 g/m² was found at sampling site 25 south to Pinar del Río.

In 1981 (May and December) high values of polychaeta biomass (> 2g/m²) were registered only in only one small patch inside the gulf, one facing northwest to Isla de la Juventud and the other north of Cayo del Rosario. Polychaeta biomass in the remaining areas of the Gulf was 0.1 – 1.4 g/m². Higher numbers of individuals (>2500 ind/m²) were observed north of Cayo Largo (Area IV). During 2003-04, sampling sites located to the right side of Area III (E4,E15,E6, E12 in 2004) and north of Cayo Largo, exhibited the highest densities (1000-2500 ind/m²).

Mollusc biomass was higher in the central and southern portion of Area III (66-200g/10m²), exhibiting lower biomass in other areas for the period 1981-85. Higher densities of molluscs were observed north of Cayo Largo (Area IV), at the northwest coast of Isla de la Juventud and the southwest corner of Area I at Pinar del Río. During 2004 sampling sites E11, E15 and E23 showed the maximum mollusc biomass, the areas corresponding to waters adjacent to Cayo El Rosario, central portion of Area III and La Coloma. The biomass values at these sites were similar to values in 1981-84 (<25g/m²), except for sampling site E15 where mollusc biomass has apparently considerably decreased. High mollusc densities were found south of Pinar del Río (7-10 ind/m²) during 1981-85 compared with a density of only 1.4 ind/m² (sampling site E 25) in 2004.

In the case of the echinoderms, the maximum biomass for the period 1981-85 was registered northwest to Isla de la Juventud in Area II (16 –35 g/m²). Area I was characterized by the lowest biomass of echinoderms (0.6 – 2 g/m²) and Areas III and IV presented medium biomass of this taxonomic group (2-16 g/m²). During 2004, maximum biomass of echinoderms did not reach past values and were registered at sampling sites E23 (10 g/m²) and E25 (9.9 g/m²) corresponding to La Coloma and the center of Area II. In contrast to the high values of echinoderms biomass northwest to Isla de la Juventud in 1981-85, a very low biomass was registered in this area in 2004 (2.06 g/m² at sampling site E17). For both periods biomass at Ensenada de la Broa showed the lowest values (<1g/m²).

Meiofauna presented the higher densities in the middle of Peninsula de La Broa, close to La Coloma, northwest and central east portions of Isla de la Juventud, north of Cayo Largo and close to Cayo Diego Pérez. The same pattern was observed

during 2004 except for the sites close to La Coloma.

The spatial analysis of macroinfauna during 1981, showed higher biomass at the north and northwest of La Isla de la Juventud (Area III) and north of Punta Capitana (Area II), with values higher than 4 and close to 7 g/m². In the remaining areas of the Gulf, biomass values ranged from 0.3-3.7 g/m². When considering number of individuals, patches of high densities (>4000 ind/m²) were registered in Area IV and the north section of Area III. In 2003-04, lower biomass values between 0.1 and 1.3 ind./m² were found close to Isla de La Juventud and north of Punta Capitana. Similarly density spatial distribution values decreased from a range of 4000 to 4700 ind/m² to 1500-3600 ind/m² north of Area III and IV.

Multivariate analysis

The multidimensional scaling plot for the year 1981 showed differences in the benthic assemblages at the south portion of Peninsula Zapata, the eastern border of the Gulf and northwest of Isla de la Juventud (sampling sites 5 and 7, 13). Figure 6a shows that the benthic communities presented similar assemblages of echinoderms, crustacean and mollusks at all the other sampling sites. During 2004, additional differences in benthic assemblages were added to the results of 1981 (Figure 6b). E29 and E24, corresponding to South of Pinar del Río and close to La Coloma present different benthic characteristics compared to other areas of the Gulf, Ensenada de la Broa and Zapata Peninsula show also differences in benthic structure.

Discussion

Marine species diversity is recognized as one of the most widely used indicators to assess environmental changes. Case studies of the effects of human activities around the United Kingdom coastline, suggest that the number of species and the Shannon-Wiener diversity index were most suited to identifying impacts on the benthic macrofauna in the vicinity of known anthropogenic disturbance (Rees *et al.* 2003). The present study uses number, densities and biomass of species as indices to compare and analyse the biological quality of the Gulf of Batabanó within a 25-year period. Long-term comparisons of benthic communities have been carried out in temperate and tropical areas (Pearson *et al.* 1986, Pearson & Bannet 1987, Service & Feller 1992, Molina Lara & Zamora 1995, Laine *et al.* 1997, Fromentin *et al.* 1997, Laine *et al.* 1997, Davoult *et al.* 1998, Gremare *et al.* 1998, Frid *et al.* 1999, Currie & Parry 1999, Raut *et al.* 2005). A major problem arising from this kind of comparisons

is that methodological factors like different sampling gears and effort, as well as natural factors like seasonality, succession processes, changes in hydrological regimes, long term climatic cycles; or the combination of several of these factors, may also significantly impact the benthos communities and subsequently the study results. However we expect those factors to impact the entire study area and therefore a spatial analysis is presented here to

corroborate and support our deductions. We assumed in this study that long-term comparisons between sub-areas of the Gulf will allow us to identify sections with apparent habitat degradation due to anthropogenic activities. We also assumed communities, which seems to be the case for tropical aquatic ecosystems (Yule & Pearson 1996).

Our results suggest that the overall seagrass that seasonal changes do not have a significant

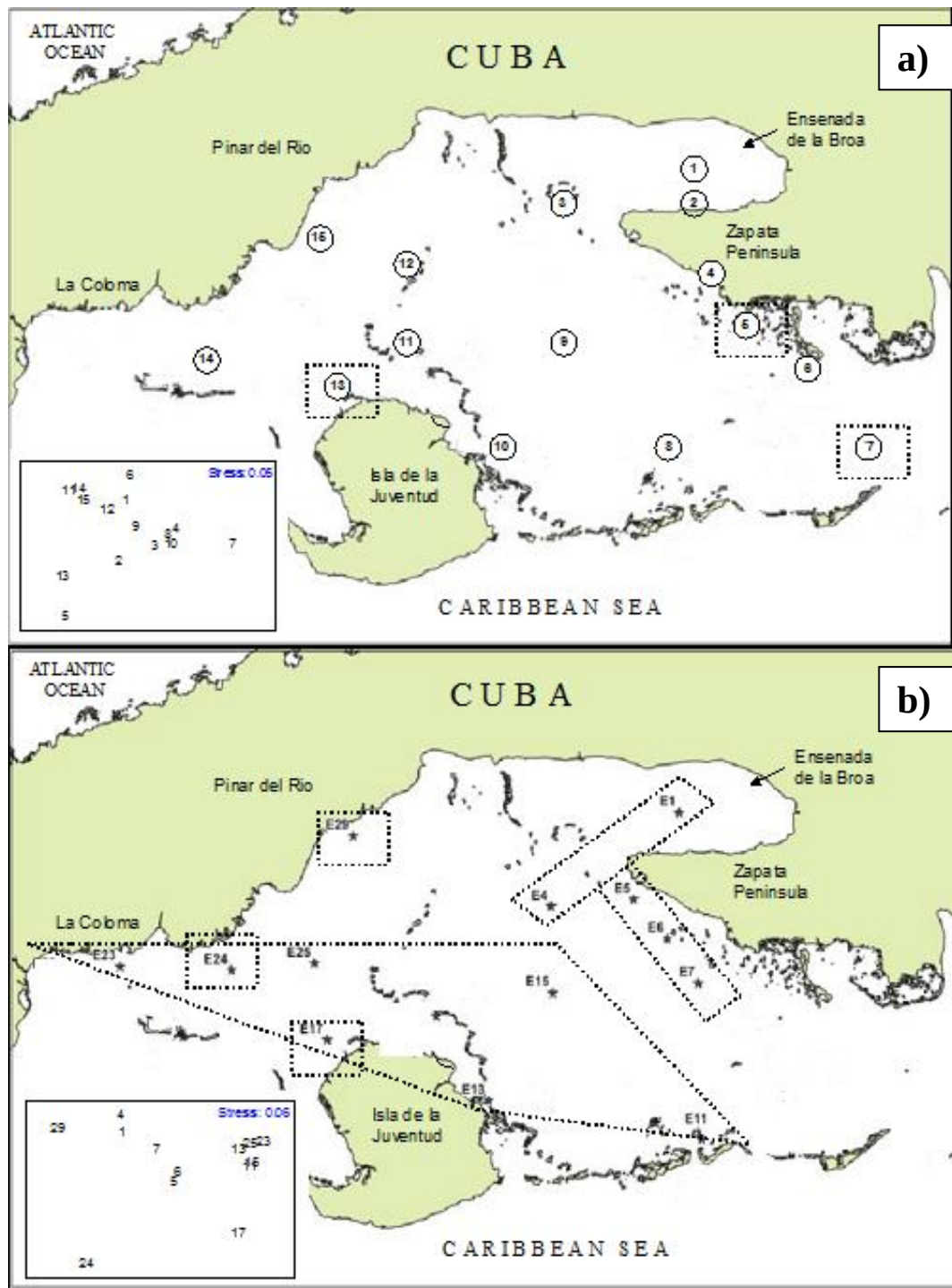


Figure 6. Multidimensional scaling analysis for the sampling sites in 1981 (a) and 2004 (b).

impact on the overall structure of the benthos composition in the gulf is similar for both periods, except for a slightly general increase in the occurrence of the shoal grass *Halodule wrightii*. This species has been described as a pioneer colonizer of disturbed areas where other seagrass cannot grow, and can withstand the widest range of temperatures and salinities (Phillips & Meñez 1988, Gallegos 1994). Its higher occurrence during 2003-04, in addition to the lower occurrences for the other seagrass may thus be indicative for a certain level of disturbance in the Gulf. The picture becomes clearer when the spatial patterns of biomass distribution are analysed. Important extensions with high to medium seagrass coverage South of the Province of Pinar del Río and close to La Coloma in 1981-85, were absent in the recent surveys of 2003-04 and a reduction in the seagrass coverage was evident for at least some areas around Isla de la Juventud and Zapata Peninsula. The same pattern could be observed from the multidimensional scaling plots where sampling sites around Pinar del Río, La Coloma and Zapata Peninsula showed different benthic assemblages compared to the rest of the Gulf during 2004 (Figure 6b). These results agree with Lorenzo (2005), who reports muddy areas without vegetation based on satellite images all around the northern borders of the gulf and Perigó (2001) who classifies the waters around La Coloma as eutrophic waters, while Alcolado (1990) based on primary production data from 1968, describes the waters of the Gulf as mesotrophic waters (except NNW to Isla de la Juventud and probably Ensenada de la Broa).

As indicated by Alcolado *et al.* (2004) sponges diversity in Cuba is higher at coral reefs and decreases towards sandy-muddy bottoms, and mangrove roots. In contrast to the 1981-85 period, during 2004 only soft bottom areas were sampled, and the significance of the difference found in number of species remains doubtful. A general decrease in average biomass was observed in the results in the case of sponges, molluscs, crustacean and equinoderms, however the species composition of these groups stayed similar. For the polychaeta group the overall abundance decreased, a higher diversity was observed in 2003 and the species composition was different between 1981 and 2003. Polychaeta densities and also probably biomass decreased from one period to the other, however the higher species richness recorded in 2003 could be a result of an improvement in the identification and knowledge of the group. The diversity increment in this group could be also a response to organic

enrichment at moderately disturbed zones as reported by Samuelson (2001) for sub-arctic tidal flats. High densities of opportunistic species of polychaeta close to Zapata Peninsula support the idea of a disturbed zone around this area. Low biomass and number of individuals in the case of meio and macroinfauna particularly south of Pinar del Río considering the spatial analysis, agree with the results from the multidimensional scaling and the changes in the distribution of seagrass in this area between the two periods.

This study has demonstrated that benthos community assemblages have changed considerably in some areas of the Gulf of Batabanó, despite the problems of comparing surveys that were not designed specifically for this purpose. Benthic assemblages, unlike most pelagic fauna reflect local environmental conditions (Gray 1979) and the analysis of benthos data from the Gulf between both periods has result in the identification of disturbed zones and habitat loss South of Pinar del Río and La Coloma and moderately disturbed areas around Zapata Peninsula and the northeast portion of Isla de la Juventud. Further research on these four sectors is recommended in order to identify the sources of disturbance and their impacts to the fishery.

Acknowledgments

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As capturas do tubarão-azul, *Prionace glauca* Linnaeus (Elasmobranchii, Carcharhinidae), na pescaria de espinhel-de-superfície (monofilamento), sediada em Itajaí (SC), Brasil

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Abstract. Blue shark, *Prionace glauca* Linnaeus (Elasmobranchii, Carcharhinidae), catches by the surface longline fishery based in Itajaí, Santa Catarina State, Brazil. This paper analysed the length structure and the spatial-temporal distribution of blue shark, *Prionace glauca* (Linnaeus, 1758) catches by the pelagic longline fleet based in Itajaí, Santa Catarina State, Brazil, from 1997 to 2005. The fishing area was the southwest Atlantic Ocean, between 15° and 40°S and 25° and 55°W. Most of the blue sharks caught were below the first maturation size. Fishing recruitment use to occur throughout the year with approximately 70 cm total length. On the other hand, smaller sharks, between 70 and 100 cm enter the fishery with higher intensity during winter months. The exploitation pattern, with respect the length classes caught, seems to be constant throughout the year. Multiple linear regressions showed that the interaction between fishing effort and area represented a significant effect ($P < 0,01$) on the value and distribution of blue shark catches. From 2002 to 2005, the highest CPUE values (blue sharks/1000 hooks), were mainly concentrated along the southern Brazil slope, Rio Grande Plateau, and Trindade-Vitória Seamounts.

Key words: Length composition, generalized linear models, south Atlantic.

Resumo. O presente estudo analisou a estrutura de tamanhos e a distribuição espaço-temporal das capturas do tubarão-azul, *Prionace glauca* (Linnaeus, 1758), pela frota espinheira de superfície (monofilamento), sediada em Itajaí (SC), entre os anos de 1997 a 2005, que operou no Atlântico SO, entre -15° a -40° de latitude e -25° a -55° de longitude. A frota capturou ao longo de todo o ano essencialmente tubarões-azuis com tamanhos abaixo do comprimento total médio de primeira maturação sexual. O recrutamento à pesca de indivíduos de aproximadamente 70 cm ocorre o ano todo, porém a intensidade da entrada de indivíduos de menor tamanho (entre 70 e 100 cm) é maior durante os meses de inverno. O padrão de exploração, em termos de classes de tamanhos, se manteve praticamente constante ao longo dos meses do ano. Modelos de regressão linear múltipla mostraram que a interação esforço*área de pesca foi significativa ($P < 0,01$) na distribuição e no valor de capturas. Entre os anos de 2002 e 2005, os melhores rendimentos (em número de indivíduos/1000 anzóis), estiveram concentrados na zona de talude da região Sul do Brasil, Elevação de Rio Grande e cadeia Trindade-Vitória.

Palavras-chave: Composição de tamanhos, modelos lineares generalizados, Atlântico sul.

Introdução

O espinhel-de-superfície do tipo “americano” é o mais utilizado no sul do Brasil, tendo como espécies-alvo os tubarões, principalmente *Prionace glauca* (Linnaeus, 1758), *Isurus oxyrinchus* (Rafinesque, 1810), as albacoras,

Thunnus obesus (Lowe, 1839), *Thunnus alalunga* (Bonnaterre, 1788), *Thunnus albacares* (Bonnaterre, 1788) e o espadarte, *Xiphias gladius* (Linnaeus, 1758). Embora as capturas de albacoras, espadartes e barbatanas de tubarões destinem-se ao mercado

externo, a carne dos tubarões é comercializada no mercado doméstico (Azevedo 2003).

A principal área de pesca da frota espinheleira sediada em Itajaí-SC é o ponto de encontro das correntes do Brasil e das Malvinas, gerando a convergência Subtropical do Atlântico Sudoeste, caracterizada por fortes gradientes termohalinos (Castello & Möller 1977, Ciotti *et al.* 1995, Zavialov *et al.* 1999, Azevedo 2003). Durante o inverno as águas superficiais são dominadas pelas águas subantárticas, que empurram a corrente do Brasil para fora da costa. Já no verão, a região é influenciada pelas águas tropicais, transportadas pela corrente do Brasil. Ocorrem ressurgências no local, aumentando a produtividade primária, resultando no aumento da biomassa de anchoita, *Engraulis anchoita* (Hubbs & Marini 1935), cavalinha, *Scomber japonicus* (Houttuyn 1782) e lulas, que é o principal alimento de atuns, espadarte e tubarões, principalmente entre os meses de maio e outubro (Weidner & Arocha 1999).

O tubarão-azul, *Prionace glauca*, é o Chondrichthyes mais amplamente distribuído nos oceanos do mundo, sendo o mais abundante nas capturas do espinhel pelágico. De acordo com Hazin *et al.* (2000), anualmente no Atlântico são capturados dois milhões de indivíduos. Conhecer a distribuição espaço-temporal e os aspectos biológicos do tubarão-azul é de extrema importância para a conservação deste importante recurso pesqueiro explorado por diversas frotas de espinhel de diversos países.

A estatística pesqueira para o Estado de Santa Catarina entre os anos de 2000 e 2005 (Univali 2001, 2002, 2003, 2004, 2007) mostrou que *Prionace glauca* é a espécie de tubarão que mais se destacou no volume desembarcado pela frota de espinhel-de-superfície industrial, representando em média 33,8 % da produção mensal dessa pescaria. O pico de produção ocorreu no mês de maio, sendo considerados períodos de “safra” os meses de dezembro a agosto. No período de setembro a novembro a produção de tubarão-azul diminuiu, estando a pescaria mais direcionada ao espadarte, *Xiphias gladius*.

O presente estudo teve como objetivo avaliar a estrutura de tamanhos e a distribuição espaço-temporal das capturas do tubarão-azul, *Prionace glauca*, pela frota espinheleira de superfície (monofilamento), sediada em Itajaí (SC), entre os anos de 1997 a 2005, e que operou no Atlântico SO. Os resultados destas análises serviram para mostrar o padrão de exploração sobre as classes de tamanhos considerados, a significância ou não dos efeitos ano, trimestre e área (e suas interações

com o esforço de pesca) sobre as capturas em peso (kg), bem como a estreita relação entre a captura e o esforço de pesca. Também foi possível de se analisar o comportamento dessas capturas nas diferentes áreas e tendências nos níveis de CPUE ao longo dos anos, fornecendo subsídios técnicos ao manejo e conservação desta espécie-chave no ambiente pelágico do sul do Brasil.

Material e Métodos

Os dados de captura e esforço de pesca, utilizados no presente estudo foram extraídos dos mapas de bordo fornecidos pelo Centro de Pesquisa e Gestão de Recursos Pesqueiros do Litoral Sudeste e Sul – CEPESUL (IBAMA) e pelo Grupo de Estudos Pesqueiros (GEP) da Universidade do Vale de Itajaí (UNIVALI) para os anos de 2002 a 2005. Foi analisado um total de 1788 lances de pesca, estes dados foram agrupados (n=112), para posteriormente ser feita a análise de covariância. As posições dos lances (latitude e longitude) e os dados de captura e esforço foram agrupados em blocos de 5° de latitude por 5° de longitude, e temporalmente separados por trimestres (Figura 1).

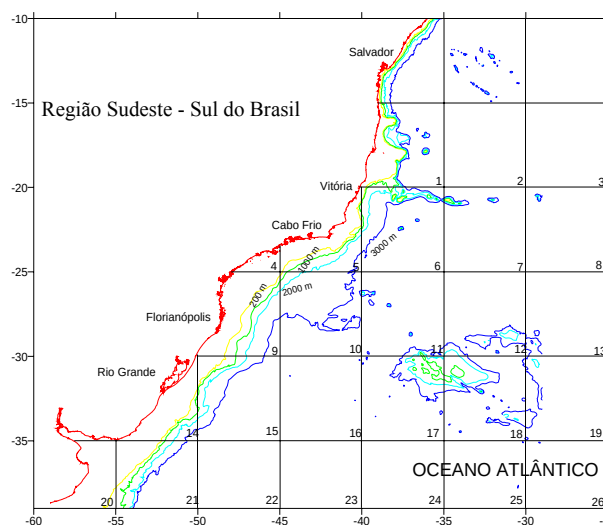


Figura 1. Divisão da área de estudo em blocos de 5° de latitude por 5° de longitude.

Aplicaram-se modelos de regressão linear e análise de covariância (ANCOVA) aos dados de captura e esforço (Huitema 1980, Zar 1999). Os rendimentos de pesca (CPUE em número de indivíduos/1000 anzóis e em kg/1000 anzóis) foram plotados trimestralmente em mapas. Para os modelos de regressão linear, foi aplicado o teste de normalidade Lilliefors (1967) nos resíduos, cujos gráficos foram visualmente inspecionados para verificar se havia tendências à não-linearidade e heterogeneidade de variâncias.

Uma análise de covariância múltipla, com três fatores: ano, trimestre e área de captura (Petrere

1978, Huitema 1980, Abuabara 1996), foi aplicada com o objetivo de averiguar a influência desses fatores sobre as capturas de tubarões-azuis (em peso, kg) na pesca de espinhel-de-superfície. As covariáveis testadas foram o esforço de pesca (em número de anzóis) e a temperatura da água da superfície (em °C). Neste caso, o modelo é o seguinte:

Equação 1.

$$Y_{ijk} = \mu + \alpha_i + \pi_j + \gamma_k + \beta_1(X_{1ijk} - \bar{X}_{1...}) + \beta_2(X_{2ijk} - \bar{X}_{2...}) + \text{interações} + \varepsilon_{ijk}$$

Onde,

Y_{ijk} = captura em peso (kg) no ano i, trimestre j e área k.

μ = média populacional

α_i = efeito do i-ésimo nível do fator ano (i = 1, ..., 4).

π_j = efeito do j-ésimo nível do fator trimestre (j = 1, 2, 3, 4).

γ_k = efeito do k-ésimo nível do fator área (k = 1, 2, 3, ..., 26).

β_1 = coeficiente angular da covariável temperatura

X_{1ijk} = valor médio da covariável temperatura no ano i, trimestre j e área k

$\bar{X}_{1...}$ = média da temperatura para todas as observações, ou seja, lances de pesca

β_2 = coeficiente angular da covariável esforço de pesca

X_{2ijk} = valor da covariável esforço de pesca no ano i, trimestre j e área k

$\bar{X}_{2...}$ = média do esforço de pesca para todas as observações, ou seja, lances de pesca

ε_{ijk} = componente de erro aleatório, suposto N (0; σ^2)

Com relação aos registros de temperatura da água de superfície para cada lance, estes foram obtidos das leituras das ecosondas das embarcações espinheleiras em °F e convertidos em °C, pela seguinte relação °C = (°F – 32)*(5/9). Com relação à ANCOVA, é importante esclarecer que todas as variáveis foram embasadas na operação de pesca (lance).

Uma condição do modelo de análise de regressão é a de os erros e_i e e_j , associados com as respectivas i e j observações devem ser independentes entre si. Quando isto não ocorre, dá-

se o nome ao fenômeno de autocorrelação. Esta sugere que outra(s) variável (eis) exploratórias podem ter sido omitidas do modelo. Uma das formas de determinar a presença ou não de autocorrelação, é a aplicação do teste de Durbin-Watson (1951), utilizado no presente estudo. O teste é baseado na condição de que os erros constituem uma série autoregressiva de primeira ordem, ou seja:

Equação 2.

$$e_t = \rho e_{t-1} + \varepsilon_t \text{ sendo que } |\rho| < 1$$

Onde, e_t = resíduo no intervalo de tempo t;

e_{t-1} = resíduo no intervalo de tempo t-1;

ρ = autocorrelação de primeira ordem;

ε_t = normalmente distribuídos com média zero e variância constante.

Desta forma a estatística d é definida como:

Equação 3.

$$d = \frac{\sum_{t=1}^n (e_t - e_{t-1})^2}{\sum_{t=1}^n e_t^2}$$

Esta estatística d é utilizada para testar a hipótese nula H_0 ($\rho = 0$) contra uma hipótese alternativa H_1 ($\rho > 0$). Os erros não são correlacionados quando $\rho = 0$.

O parâmetro ρ é estimado através de r , onde:

Equação 4.

$$r = \frac{\sum_{t=1}^n e_t e_{t-1}}{\sum_{t=1}^n e_{t-1}^2}$$

Uma relação aproximada entre d e r existe, ou seja:

Equação 5.

$$d = 2(1-\gamma)$$

Considerando que r é uma estimativa de ρ , fica claro que d está próximo de 2 quando $\rho = 0$ e próximo de 0 quando $\rho = 1$. Quanto mais próximo o valor de d estiver de 2 mais forte é a evidência de que não existe autocorrelação presente na estrutura de erros. O teste formal para autocorrelação positiva é baseado na estatística d que é comparada com valores (d_L , d_U) obtidos para diferentes níveis de significância (1 e 5%) em uma tabela (Chatterjee & Price 1990, página 273), sendo que na mesma os

valores de d_L , d_U são obtidos através do tamanho amostral n e do número de variáveis k na regressão. Neste caso:

1. $d < d_L$, rejeita H_0
2. $d > d_U$, aceita H_0
3. $d_L < d < d_U$, o teste é inconclusivo

Para a análise das composições de tamanhos, fichas de desembarques das carcaças para o período de 1997 a 2003, foram obtidas da firma Comércio e Indústria de Pescado Kowalsky Ltda., sediada no município de Itajaí, SC. Um total de 35.585 carcaças de tubarões-azuis foram utilizadas na análise. Os pesos individuais das carcaças (kg) foram convertidos em comprimentos totais (cm), através da seguinte equação matemática (Azevedo 2003):

Equação 6.

$$CT = 12,49 (PC)^{0,28}$$

Onde,

CT = comprimento total em cm;

PC = peso da carcaça em kg;

Após a conversão, foram elaborados histogramas anuais, mensais e sazonais, e feita análise de variância.

Resultados

Composição de tamanhos

A frota de espinhel-de-superfície capturou ao longo de todo o ano essencialmente tubarões-azuis com tamanhos abaixo do comprimento médio de primeira maturação sexual, tanto para machos como fêmeas. O comprimento total médio dos tubarões-azuis amostrados foi de 112,86 cm ($n = 35585$; $s = 13,53$ cm) e mediana igual a 112,47 cm (Figura 2).

Nas águas oceânicas que banham o Brasil, a maturidade sexual das fêmeas é atingida em torno de 228 cm de comprimento total, com idade de aproximadamente 5 anos. Os machos por sua vez maturam com aproximadamente 225 cm de comprimento total (Hazin *et al.* 1994, Hazin *et al.* 2000). Portanto, as capturas eram compostas, em sua maioria, de indivíduos que ainda não haviam ingressado na sua fase reprodutiva. Os histogramas mensais das frequências de comprimentos totais mostraram não haver fortes alterações no padrão de exploração da espécie ao longo do ano, ou seja, os indivíduos estariam sendo recrutados à pesca em torno dos 70 cm de comprimento total, sendo que a mortalidade por pesca incidiria principalmente sobre os animais com comprimentos totais de até aproximadamente 150 cm (Figura 3).

A comparação entre as médias mensais de comprimento total, para o período de 1997 a 2003,

através de um modelo de análise de variância (Tabela I e Figura 4), confirma esse padrão constante de exploração, já que a amplitude das médias mensais foi pequena, de apenas 9 cm, ou seja, entre 109 a aproximadamente 118 cm de comprimento total.

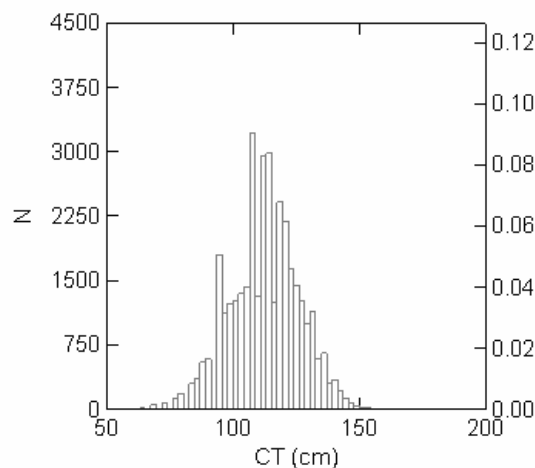


Figura 2. Composição de tamanhos das capturas dos tubarões-azuis (*Prionace glauca*) na pesca de espinhel de superfície (monofilamento) sediada em Itajaí e Navegantes (SC), durante o período de 1997 a 2003. CT – comprimento total em cm.; N - nº de indivíduos. O comprimento total médio amostrado foi de 112,86 cm ($n = 35.585$; $s = 13,53$) e mediana 112,47.

Alguns adultos (≥ 225 cm para machos e ≥ 228 cm para as fêmeas) ocorreram nas capturas, porém em quantidades muito pequenas se comparado ao total da biomassa capturada durante o período considerado. O maior indivíduo capturado apresentou um comprimento total de 242,48 cm. Em termos sazonais se observa que o recrutamento à pesca de indivíduos de aproximadamente 70 cm ocorre o ano todo, porém a intensidade da entrada de indivíduos de menor tamanho (entre 70 e 100 cm) é maior durante os meses de inverno (Figuras 5 e 6).

Análise das capturas

Foi elaborado o diagrama de dispersão das capturas cumulativas (em kg) versus o esforço de pesca cumulativo (em números de anzóis), para verificar a existência de uma relação linear entre as variáveis, condição esta essencial para a aplicação de modelos de análise de covariância (Huitema 1980) (Figura 7a). É importante entender que cada valor cumulativo de “anzóis” é o somatório x_s do número x_i de anzóis em cada uma das sucessivas viagens de pesca, de modo que para a n -ésima viagem de pesca, $x_{s,n} = \sum x_i$, onde i vai de 1 a n . Da mesma forma, para o valor cumulativo da captura na n -ésima viagem de pesca $y_{s,n} = \sum y_i$, onde i vai de 1 a n . Desta forma, cada uma das sucessivas viagens de pesca tem um valor de y_s e x_s e cada ponto no gráfico representa

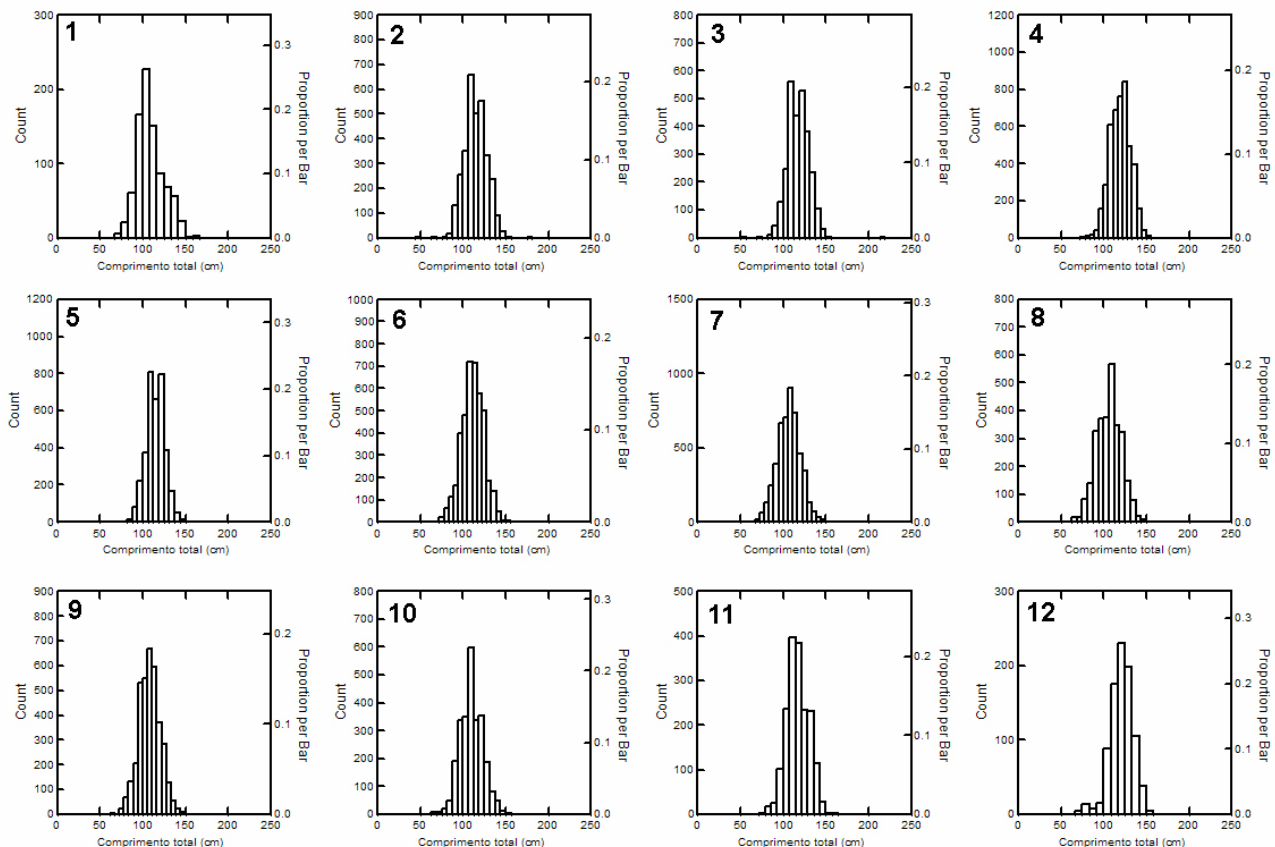


Figura 3. Histogramas das distribuições mensais das freqüências das classes de comprimento total (cm), nas capturas de tubarões-azuis, *Prionace glauca*, para a pesca de espinhel de superfície (monofilamento) sediada em Itajaí e Navegantes (SC), durante o período de 1997 a 2003. Os números acima dos gráficos, se referem aos meses do ano. Count – número de indivíduos; Proportion per Bar – proporção em cada classe de comprimento total.

uma viagem de pesca. A dispersão dos pontos seguiu uma tendência linear positiva, porém sem homogeneidade na variância. Houve, portanto a necessidade de logaritmização das variáveis (Zar 1999). Feita a transformação matemática, visualizou-se a relação linear positiva entre as variáveis (Figura 7b).

O modelo de regressão linear mostrou uma elevada correlação, ou seja, $r^2 = 0,87$. Os coeficientes do modelo, interseção ($a = -1,01$) e inclinação da reta ($b = 1,01$) foram significativos ($P < 0,01$). A análise de variância indicou que a variação explicada pela linha de regressão ($MS = 182,85$) foi bem maior do que a residual ($MS = 0,25$), sendo a inclinação da reta significativamente diferente de zero. O teste estatístico de Durbin-Watson (1956), ficou bem próximo de 2 ($d = 1,94$), não havendo sinais de autocorrelação nos resíduos. O teste de Lilliefors (1967) foi aplicado sobre os resíduos do modelo e o resultado ($D_{obs} (0,18) > D_{critico}(0,08)$) não mostrou uma distribuição normal, com tendência à não-linearidade e heterogeneidade de variâncias. Como o ajuste do modelo de regressão linear aos dados foi linear positivo, isto possibilitou a utilização do esforço de pesca (logaritmizado)

como covariável em modelos ANCOVA.

Devido à agregação dos dados, ficou a alternativa de fazer modelos, considerando um fator de cada vez, visto que não é possível testar a interação entre eles por falta de replicação.

Inicialmente foi testado um modelo linear considerando o fator ano e a interação ano vs. $\ln(\text{anzóis})$, ou seja:

Equação 7.

$$\ln(\text{captura, kg}) = \text{constante} + \text{ano} + \ln(n^{\circ} \text{ anzóis}) + \text{ano} * \ln(\text{anzóis})$$

Apesar de o modelo apresentar uma elevada correlação, $r^2 = 0,88$, o fator ano e a interação $\text{ano} * \ln(n^{\circ} \text{ de anzóis})$ não foram significativos ($P > 0,05$) (Tabela II).

O teste estatístico de Durbin-Watson (1956), ficou próximo a 2 ($d = 1,89$), não havendo sinais de autocorrelação nos resíduos. O teste de Lilliefors (1967) foi aplicado sobre os resíduos do modelo e o resultado ($D_{obs} (0,19) > D_{critico}(0,08)$), não mostrou uma distribuição normal, com tendência à não-linearidade e heterogeneidade de variâncias. Portanto, foi eliminada a interação

Tabela I. Resultados da análise de variância (ANOVA) aplicada aos dados de comprimento total (cm) para o tubarão-azul, *Prionace glauca*, tendo como fator os meses dos anos. Pesca de espinhel-de-superfície (monofilamento). Período de 1997 a 2003. O efeito mês foi significativo ($P < 0,01$).

Fonte	Soma dos quadrados	Graus de liberdade	Quadrados Médios	F	P
MES	786595,58	11	71508,69	444,50	0,000
Error	5722738,96	35573	160,87		

Estatística D de Durbin-Watson = 1,52. N: 35585. R^2 : 0.12. Análise de Variância

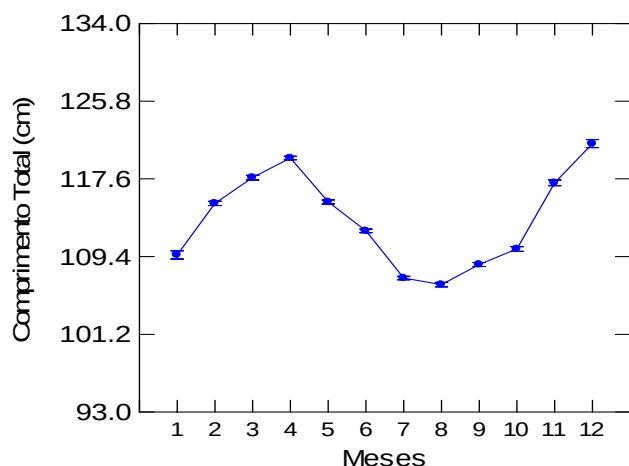


Figura 4. Evolução mensal no comprimento total médio do tubarão-azul, *Prionace glauca* capturado na pesca de espinhel-de-superfície (monofilamento) sediada em Itajaí e Navegantes (SC), durante o período de 1997 a 2003.

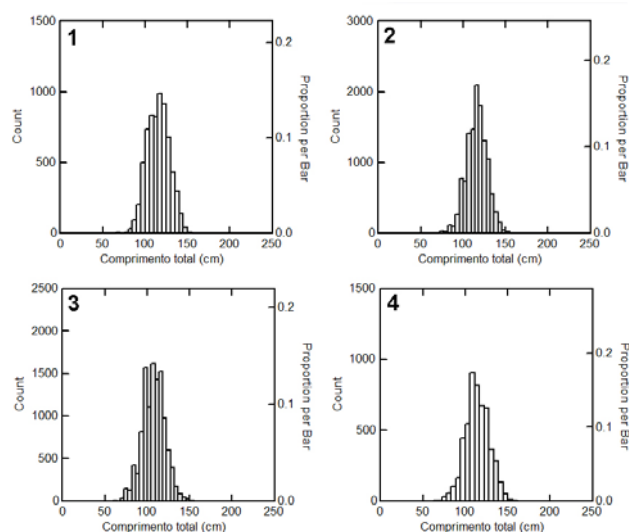


Figura 5. Comportamento sazonal dos histogramas das distribuições das freqüências das classes de comprimentos totais (cm), para o tubarão-azul, *Prionace glauca*, capturado na pesca de espinhel de superfície (monofilamento) sediada em Itajaí e Navegantes (SC), durante o período de 1997 a 2003. 1 – verão; 2 – outono; 3 – inverno; 4 – primavera. Count – número de indivíduos; Proportion per Bar – proporção em cada classe de comprimento total.

ano*ln (nº de anzóis) do modelo, sendo testado um novo modelo ANCOVA considerando apenas o fator ano, ou seja:

Equação 8.

$$\ln(\text{captura, kg}) = \text{constante} + \text{ano} + \ln(\text{nº anzóis})$$

O modelo apresentou elevada correlação, $r^2 = 0,88$, porém o fator ano não foi significativo ($P > 0,05$) (Tabela III).

O teste estatístico de Durbin-Watson (1956), ficou bem próximo de 2 ($d = 1,96$), não havendo sinais de autocorrelação nos resíduos. O teste de Lilliefors (1967) foi aplicado sobre os resíduos do modelo e o resultado ($D_{\text{obs}}(0,18) > D_{\text{critico}}(0,08)$), não mostrou uma distribuição normal, com tendência à não-linearidade e heterogeneidade de variâncias. Portanto, o efeito ano não foi responsável pela variação das capturas e este último modelo foi descartado da análise.

Passou-se então a outro modelo ANCOVA, onde foi avaliada a interação do fator trimestre vs. ln(anzóis):

Equação 9.

$$\ln(\text{captura, kg}) = \text{constante} + \text{trimestre} + \ln(\text{nº anzóis}) + \text{trimestre} * \ln(\text{anzóis})$$

Este modelo também apresentou uma alta correlação, $r^2 = 0,88$, porém a interação trimestre*ln(anzóis) não foi significativa ($P < 0,05$) (Tabela IV).

O teste estatístico de Durbin-Watson (1956), ficou bem próximo de 2 ($d = 1,97$), não havendo sinais de autocorrelação nos resíduos. O teste de Lilliefors (1967) foi aplicado sobre os resíduos do

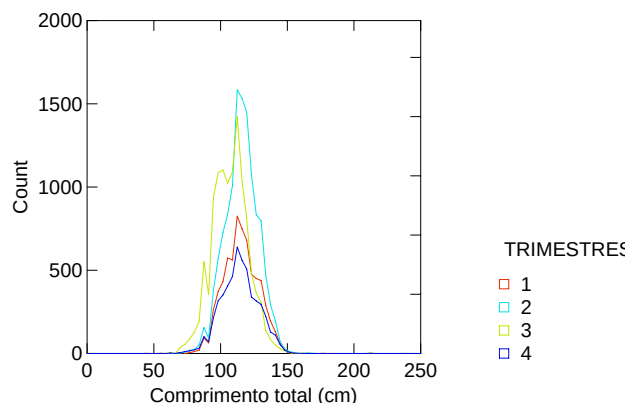


Figura 6. Comportamento sazonal dos polígonos de freqüências das classes de comprimentos totais (cm), para o tubarão-azul, *Prionace glauca*, capturado na pesca de espinhel de superfície (monofilamento) sediada em Itajaí e Navegantes (SC), durante o período de 1997 a 2003. 1 - verão; 2 - outono; 3 - inverno; 4 - primavera. Count - número de indivíduos; Proportion per Bar – proporção em cada classe de comprimento total.

modelo e o resultado ($D_{\text{obs}}(0,18) > D_{\text{critico}}(0,09)$), não mostrou uma distribuição normal, com tendência à não-linearidade e heterogeneidade de variâncias. Pelo fato do efeito trimestre não exercer nenhum efeito sobre a variabilidade das capturas este modelo também foi descartado da análise.

O próximo modelo ANCOVA a ser testado, utilizou o efeito área e a sua interação com esforço de pesca da seguinte forma:

Equação 10.

$$\ln(\text{captura, kg}) = \text{constante} + \text{trimestre} + \ln(n^{\circ}\text{anzóis})$$

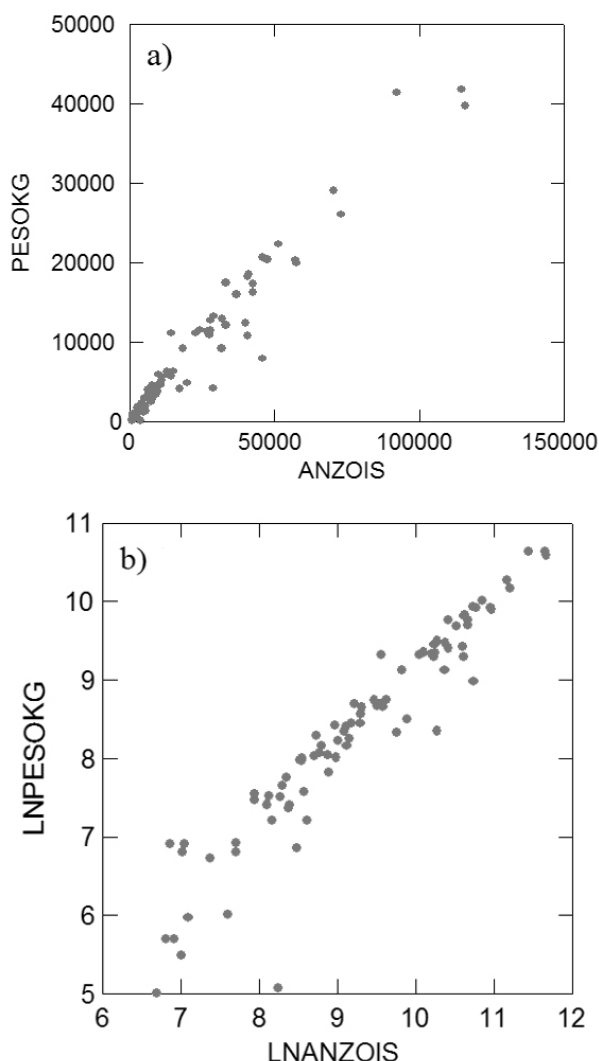


Figura 7. Relações (a) entre as capturas cumulativas em peso (kg) e do esforço de pesca (em número de anzóis), (b) entre os logaritmos (base e) das capturas cumulativas em peso e do esforço de pesca do tubarão-azul, *Prionace glauca*, na pescaria de espinhel-de-superfície (monofilamento), sediada em Itajaí e Navegantes (SC). Período: 2002 - 2005. PESOKG – Peso das capturas cumulativas (kg); ANZOIS – Esforço de pesca cumulativo, em número de anzóis; LNPESOKG – Logaritmo (base e) da captura cumulativa em kg; LNZOIS – Logaritmo (base e) do esforço de pesca cumulativo (em número de anzóis).

O modelo apresentou elevada correlação, $r^2 = 0,88$, porém o fator trimestre não foi significativo ($P < 0,05$) (Tabela V).

O teste estatístico de Durbin-Watson (1956), ficou bem próximo de 2 ($d = 1,97$), não havendo sinais de autocorrelação nos resíduos. O teste de Lilliefors (1967) foi aplicado sobre os resíduos do modelo e o resultado ($D_{\text{obs}}(0,18) > D_{\text{critico}}(0,08)$), não mostrou uma distribuição normal, com tendência à não-linearidade e heterogeneidade de variâncias.

O próximo modelo ANCOVA a ser testado, utilizou o efeito área e a sua interação com esforço de pesca da seguinte forma:

Equação 11.

$$\ln(\text{captura, kg}) = \text{constante} + \text{área} + \ln(n^{\circ}\text{anzóis}) + \text{área} * \ln(n^{\circ}\text{anzóis})$$

Este modelo mostrou uma correlação alta, $r^2 = 0,95$, sendo que a interação entre a área e o esforço de pesca foi significativa ($P < 0,05$) (Tabela VI).

A covariável esforço de pesca foi a responsável pela maior parte da variação no modelo, com $MS = 6,37$. O teste de Durbin-Watson (1951), indicou a presença de autocorrelação temporal nos resíduos, pois $D < dL$ ($D = 0,03$; $dL = 1,63$) e portanto foi rejeitada a hipótese nula ($H_0: \rho = 0$) (Chatterjee & Price 1991). Foi também aplicado o teste de Lilliefors (1967) sobre os resíduos do modelo e o resultado ($D_{\text{obs}}(0,19) > D_{\text{critico}}(0,08)$) não mostrou uma distribuição normal, com tendência à não-linearidade e heterogeneidade de variâncias. As áreas onde ocorreram as maiores capturas em peso foram próximas a Cadeia Vitória-Trindade e ao Canal Hunter (Figura 8).

Finalmente, um modelo ANCOVA, considerando os três fatores simultaneamente, foi também testado, ou seja:

Equação 12.

$$\ln(\text{captura, kg}) = \text{constante} + \text{área} + \text{trimestre} + \text{ano} + \ln(n^{\circ}\text{anzóis})$$

Neste caso, os efeitos área, trimestre e ano não foram significativos ($P < 0,05$), ficando a covariável esforço de pesca responsável pela variabilidade nas capturas (Tabela VII).

O teste estatístico de Durbin-Watson (1956), ficou bem próximo de 2 ($d = 1,97$), não havendo sinais de autocorrelação nos resíduos. O teste de Lilliefors (1967) foi aplicado sobre os resíduos do modelo e o resultado ($D_{\text{obs}}(0,18) > D_{\text{critico}}(0,08)$), não mostrou uma distribuição normal, com tendência à não-linearidade e heterogeneidade de variâncias.

Tabela II. Resultados da análise de covariância (ANCOVA) aplicada aos dados de captura (em peso, kg) para o tubarão-azul, *Prionace glauca*, na pesca de espinhel-de-superfície (monofilamento). Modelo: $\ln(\text{peso, em kg}) = \text{constante} + \text{ano} + \ln(\text{número de anzóis}) + \text{ano} * \ln(\text{número de anzóis})$. $\ln$ = logaritmo base e.

Fonte	Soma dos quadrados	Graus de liberdade	Quadrados Médios	F	P
ano	0,92	3	0,31	1,17	0,33
lnanzóis	48,49	1	48,49	184,51	0,00
ano*lnanzóis	0,91	3	0,30	1,16	0,33
Resíduos	24,70	94	0,26		

Estatística D de Durbin-Watson = 1,89. N: 102. R²: 0,88. Análise de Variância.

Tabela III. Resultados da análise de covariância (ANCOVA) aplicada aos dados de captura (em peso, kg) do tubarão-azul, *Prionace glauca*, na pesca de espinhel-de-superfície (monofilamento). Modelo: $\ln(\text{peso, em kg}) = \text{constante} + \text{ano} + \ln(\text{número de anzóis})$. $\ln$ = logaritmo base e.

Fonte	Soma dos quadrados	Graus de liberdade	Quadrados Médios	F	P
ano	0,04	3	0,02	0,06	0,98
ln anzóis	179,07	1	179,07	678,08	0,00
Resíduo	25,62	97	0,26		

N: 102. R²: 0,88. Análise de covariância. Estatística D de Durbin-Watson = 1,96.

Tabela IV. Resultados da análise de covariância (ANCOVA) aplicada aos dados de captura (em peso, kg), para o tubarão-azul, *Prionace glauca*, na pesca de espinhel-de-superfície (monofilamento). Modelo: $\ln(\text{peso, em kg}) = \text{constante} + \text{trimestre} + \ln(\text{número de anzóis}) + \text{trimestre} * \ln(\text{número de anzóis})$. $\ln$ = logaritmo base e.

Fonte	Soma dos quadrados	Graus de liberdade	Quadrados Médios	F	P
trimestre	0,60	3	0,20	0,76	0,52
lnanzóis	162,87	1	162,87	613,74	0,00
trimestre*lnanzóis	0,54	3	0,18	0,68	0,57
Resíduos	24,95	94	0,27		

N: 102. R²: 0,88. Análise de covariância. Estatística D de Durbin-Watson = 1,93.

Tabela V. Resultados da análise de covariância (ANCOVA) aplicada aos dados de captura (em peso, kg) para o tubarão-azul, *Prionace glauca*, na pesca de espinhel-de-superfície (monofilamento). Modelo: $\ln(\text{peso em kg}) = \text{constante} + \text{trimestre} + \ln(\text{número de anzóis})$. $\ln$ = logaritmo base e.

Fonte	Soma dos quadrados	Graus de liberdade	Quadrados médios	F	P
Trimestre	0,17	3	0,06	0,22	0,88
Lnanzois	175,05	1	175,05	666,21	0,00
Residuo	25,49	97	0,26		

N: 102. R²: 0,88. Análise de covariância. Estatística D de Durbin-Watson = 1,97

Tabela VI. Resultados da análise de covariância (ANCOVA) aplicada aos dados de captura (peso em kg) para o tubarão-azul, *Prionace glauca*, na pesca de espinhel-de-superfície (monofilamento) de sediada em Itajaí e Navegantes. Modelo: $\ln(\text{peso em kg}) = \text{constante} + \text{área} + \ln(\text{número de anzóis}) + \text{área} * \ln(\text{número de anzóis})$. Os efeitos área e esforço (em número de anzóis, logaritmizado) e a interação entre área e esforço foram significativos ($P < 0,05$). $\ln$ = logaritmo base e.

Fonte	Soma dos quadrados	Graus de liberdade	Quadrados médios	F	P
area	10,40	19	0,55	3,51	0,00
lnanzóis	6,37	1	6,37	40,83	0,00
area*lnanzóis	10,06	18	0,56	3,59	0,00
Resíduo	9,82	63	0,16		

Estatística D de Durbin-Watson = 0,03. N: 102. R²: 0,95. Análise de Variância. Estatística D de Durbin-Watson = 0,03.

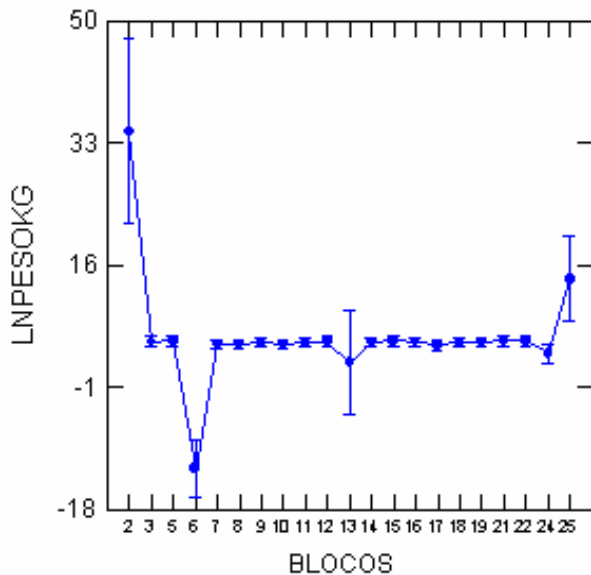


Figura 8. Distribuição das médias ajustadas das capturas logaritmizadas em peso (kg), por área de pesca, do tubarão-azul (*Prionace glauca*), na pescaria de espinhel-de-superfície (monofilamento), sediada em Itajaí e Navegantes (SC). O ajuste das médias foi feito através de um modelo de análise de covariância do tipo $\ln(\text{captura em kg}) = \text{CONSTANTE} + \text{ÁREA} + \ln(\text{anzóis}) + \text{ÁREA} * \ln(\text{anzóis})$. Dados de capturas cumulativas para o período: 2002- 2005. LN PESOKG – Logaritmo (base e) das capturas cumulativas em peso (kg); BLOCOS – áreas de pesca. Círculos – médias; barras verticais – erros padrões.

Foi também avaliada a existência ou não de relação linear entre as capturas cumulativas de tubarões-azuis (em peso) e a temperatura da água de superfície (°C). Neste caso, trabalhou-se com médias de temperaturas para o ano *i*, trimestre *j* e área *k*. Os diagramas de dispersão das capturas se apresentaram sem tendência alguma, e com pontos muito dispersos, mesmo após a logaritmização das variáveis (Figura 9). Portanto, neste caso, a temperatura não pode ser utilizada como covariável em modelos de análise de covariância (ANCOVA).

Distribuição dos rendimentos (CPUE'S)

Entre os anos de 2002 e 2005, os melhores rendimentos (nº de indivíduos/1000 anzóis) foram observados sobre o talude sul do Brasil, nas profundidades de 200 até 3.000m (Tabela VIII).

O verão e outono foram as épocas onde ocorreram os maiores índices de CPUE chegando a um pico de 53,7 indivíduos/1000 anzóis no outono, na zona de talude do Rio Grande do Sul. Por sua vez no inverno e primavera os rendimentos foram menores chegando a um máximo de 9,3 indivíduos/1000 anzóis no inverno, na zona de talude do sul do Brasil.

Os resultados dos rendimentos em peso (kg/1000 anzóis) foram semelhantes aos anteriores (Tabela IX).

As épocas do ano com maiores CPUE's foram o verão e outono, na zona de talude do Rio Grande do Sul, com um máximo de 3363,6 kg/1000 anzóis no outono. Já no inverno e primavera os rendimentos foram inferiores, atingindo um máximo de 163,7 kg/1000 anzóis no inverno, no talude sul do Brasil (Figura 10).

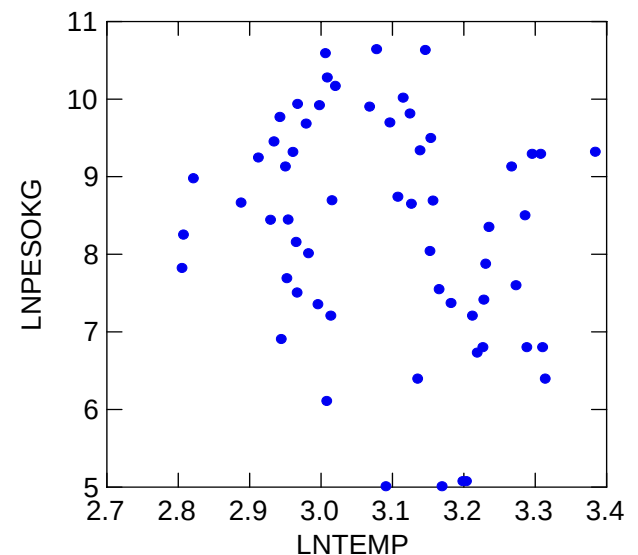
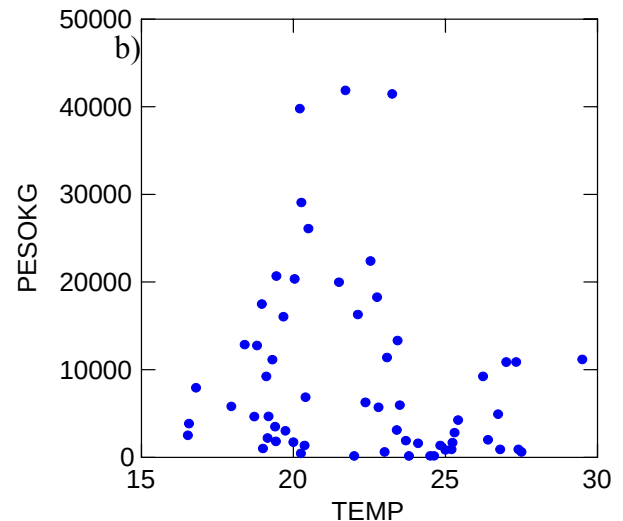


Figura 9. Relações: (a) entre as capturas cumulativas em peso (kg) e as temperaturas da água de superfície (°C), (b) logaritmo das capturas cumulativas em peso (kg) e as temperaturas da água de superfície (°C). Tubarão-azul, *Prionace glauca*, na pesca de espinhel-de-superfície (monofilamento), sediada em Itajaí e Navegantes (SC). Período: 2002 - 2005. PESOKG – capturas (kg); TEMP – temperatura média da água de superfície (°C), para cada ano *i*, trimestre *j*, e área *k*; LN PESOKG – logaritmo (base e) da captura em kg; LNTEMP – logaritmo (base e) da temperatura (°C).

Tabela VII. Resultados da análise de covariância (ANCOVA) aplicada aos dados de captura (peso em kg) para o tubarão-azul, *Prionace glauca*, na pesca de espinhel-de-superfície (monofilamento), sediada em Itajaí e Navegantes. Modelo: $\ln(\text{peso em kg}) = \text{constante} + \text{ano} + \text{trimestre} + \text{área} + \ln(\text{número de anzóis})$. Os efeitos ano, trimestre e área, não foram significativos ($P > 0,05$). $\ln$ = logaritmo base e.

Efeito	Coefficiente	Erro padrão	t	P
Constante	-30,83	116,57	-0,26	0,79
Ano	0,02	0,06	0,25	0,80
Trimestre	0,01	0,04	0,23	0,82
Área	0,02	0,01	1,60	0,11
Lnanzóis	1,01	0,04	25,31	0,00

N: 99 R2: 0,87.

Fonte	Soma dos quadrados	Graus de liberdade	Quadrados médios	F	P
Regressão	169,55	4	42,39	162,37	0,00
Resíduo	24,54	94	0,26		

Estatística D de Durbin-Watson = 1,97

Tabela VIII. Amplitudes de CPUE (número de indivíduos/1000 anzóis), por época do ano e áreas de pesca, para o tubarão-azul, *Prionace glauca*, capturado pela frota espinheleira de superfície sediada em Itajaí e Navegantes. Período de 2002 a 2005. CPUE = captura por unidade de esforço.

ÉPOCA	CPUE (ind./1000 anzóis)	ÁREA
Verão	9,6 – 14,5	Zona de Talude de SC
Outono	35,8 – 53,7	Zona de Talude de RS
Inverno	7,0 – 9,3	Zona de Talude de SC e RS
Primavera	4,8 – 7,2	Zona de Talude de SC e RS e Elevação de Rio Grande

Tabela IX. Amplitudes de CPUE (kg/1000 anzóis), por época do ano e áreas de pesca, para o tubarão-azul, *Prionace glauca*, capturado pela frota espinheleira de superfície sediada em Itajaí e Navegantes. Período de 2002 a 2005. CPUE = captura por unidade de esforço.

ÉPOCA	CPUE (kg/1000 anzóis)	ÁREA
Verão	148,2 – 222,3	Zona de Talude de SC
Outono	545,5 – 3363,6	Zona de Talude de RS
Inverno	109,1 – 163,7	Zona de Talude de SC e RS
Primavera	75,0 – 112,6	Zona de Talude de SC e RS e Elevação de Rio Grande

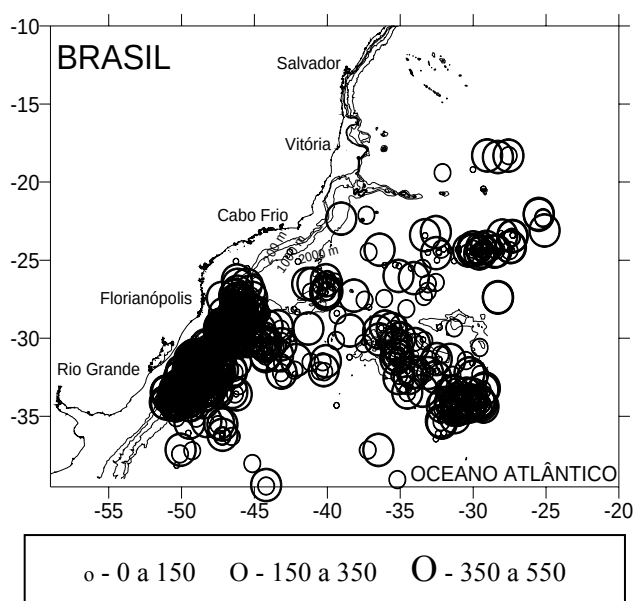


Figura 10. Distribuição dos rendimentos (kg/1000 anzóis), observados para o tubarão-azul, *Prionace glauca*, capturado pela frota de espinhel-de-superfície sediada em Itajaí e Navegantes – SC. Período: 2002 a 2005. Legenda – CPUE (kg/1000 anzóis).

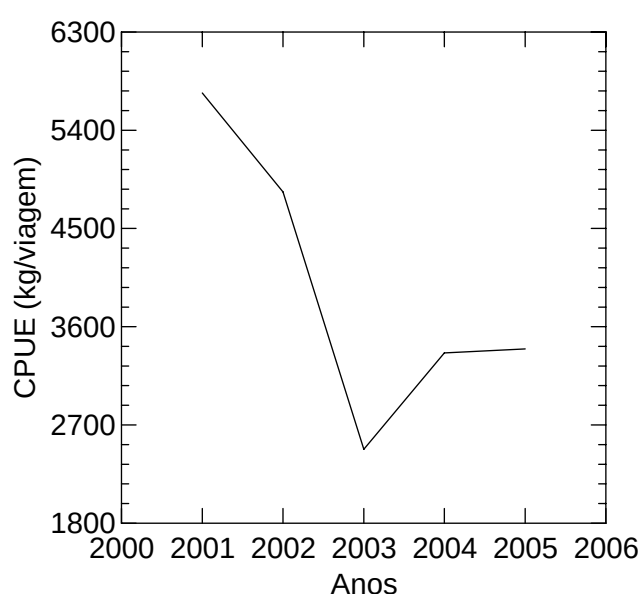


Figura 11. Comportamento da CPUE (kg/nº viagens) do tubarão-azul, *Prionace glauca*, no Estado de Santa Catarina, capturada pela frota industrial de espinhel-de-superfície. Fonte: Univali 2007.

Discussão

A captura incidental de organismos por um determinado petrecho de pesca, segundo Hall *et al.* (2000), afeta a biodiversidade, causando impactos sobre os predadores de topo. O interesse pelos tubarões é grande na pesca de espinhel-de-superfície (Hazin 1991, Weidner *et al.* 1999). A atividade tornou-se bastante lucrativa em função da grande quantidade de capturas, principalmente do tubarão-azul, *Prionace glauca* e do elevado preço das barbatanas, as quais têm levado ao redirecionamento da pesca, que inicialmente era mais direcionada aos atuns. Os tubarões estando no ambiente oceânico, este de baixa produtividade e pouco alimento disponível, os torna altamente vulneráveis a esta pescaria (Azevedo 2003).

A análise da composição de tamanhos capturada pela frota espinheleira sediada em Itajaí, durante o período considerado (1997 a 2003), mostrou um padrão constante de exploração, ou seja, ao longo dos meses do ano, os tubarões-azuis são recrutados à pesca em torno de 70 cm de comprimento total, sendo a amplitude de comprimentos totais na captura entre 70 e 150 cm. Embora se observe um padrão de exploração relativamente constante, ao longo dos meses do ano, a grande captura de tubarões-azuis que ainda não atingiram a sua maturidade sexual é preocupante (Cushing 1974). No sul do Brasil os machos e as fêmeas atingem a maturidade sexual com aproximadamente 225 e 228 cm de comprimento total respectivamente (Hazin *et al.* 1994, Hazin *et al.* 2000). O tamanho dos neonatos é em média 56,4 cm (Lessa *et al.* 2003). A continuar essa pressão pesqueira sobre esse extrato populacional de tamanhos, a pescaria do tubarão-azul sediada em Itajaí-SC, ao longo dos anos, estará fadada ao seu declínio. Os sinais de declínio já se manifestaram nos níveis de CPUE durante o período considerado (Figura 9).

Como o inverno deu indícios de ser a época de maior intensidade de indivíduos menores nas capturas (entre 70 e 100 cm), e as condições do mar são mais adversas para a prática do espinhel, este poderia ser um período de defeso para a espécie. Essa maior intensidade de indivíduos pequenos no inverno, possivelmente esteja associada ao fenômeno oceanográfico da convergência subtropical (Castello & Moller 1977). No Atlântico sul, as fêmeas de *Prionace glauca* estariam entrando no período de parto no inverno e primavera (Mejuto & Cortés 2005). A área de parto é desconhecida, mas provavelmente ocorra, em águas temperadas, onde a disponibilidade de alimento é maior como na costa Sul da África, área esta de ressurgência, até a

zona de convergência subtropical (Nakano 1990, Mejuto & Cortés 2005). A primavera e o verão são as épocas em que ocorreria a ovulação, seguida da fertilização e gravidez (Legat 2001). Foi proposta a existência de um ciclo reprodutivo anual para as fêmeas de tubarão-azul no Atlântico Sul Ocidental, com embriões em vários estágios de desenvolvimento e as fêmeas fazendo o ciclo reprodutivo inteiro, nessa mesma região, exceto o parto (Legat 2001). Segundo Hazin & Lessa (2005), as fêmeas dos tubarões-azuis, saem do sudeste e sul do Brasil, onde ocorre a cópula, para a região nordeste, onde ocorre a ovulação, e depois para o Golfo da Guiné, onde as fêmeas no início da gravidez são encontradas. É de fundamental importância para a sustentabilidade desta pescaria no sul do Brasil, que se implementem pesquisas que visem determinar com precisão as épocas do ano e áreas críticas para a conservação desta espécie (áreas de cópula e parto bem como as de concentração dos neonatos) no ambiente oceânico.

A figura 7 indicou haver uma forte relação entre a captura e o esforço de pesca cumulativos, sendo esta relação quase uma reta. Isto significa que, em uma escala temporal, quanto mais se pescava, mais se capturava, numa proporcionalidade quase direta. Isto significa que a CPUE da frota espinheleira considerada, com o esforço em número de anzóis, é um bom indicador da biomassa de *Prionace glauca* na área em questão. Aliado a isto, a análise de covariância mostrou que os efeitos ano, trimestre, área e temperatura não explicaram uma porção significativa da variação da captura em kg. Estes dois fatos levam a inferir de que a biomassa do tubarão-azul se manteve constante, em toda a grande área estudada, durante os quatro anos de 2002-2005. O fato de *Prionace glauca* ser a espécie de tubarão mais abundante no ambiente oceânico, ressalta a elevada importância ecológica desta espécie como componente constante desse ambiente. Dados disponíveis de captura por unidade de esforço de diversas frotas tanto em número como biomassa sugerem que a abundância desta espécie no ambiente pelágico é uma das mais altas, inclusive maior do que outras espécies de atuns, agulhões, espadartes e outras espécies de tubarões pelágicos. A grande abundância desta espécie, aliada a sua provável elevada taxa de renovação populacional, ampla distribuição geográfica no ecossistema pelágico, eficiente e complexo ciclo reprodutivo, são fatores do sucesso do tubarão-azul no ambiente oceânico, sendo um dos elementos-chave nesse ecossistema (Mejuto & Cortés 2005). Segundo Smith *et al.* (1998), os tubarões oceânicos, com taxas de crescimento relativamente rápidas são mais

resilientes à pesca, ao contrário das espécies mais costeiras. Vários estoques nesse grupo estão menos propensos à depleção devido à maior probabilidade de reposição por parte de estoques vizinhos. Por sua vez, estas espécies estão entre as espécies mais vulneráveis às extensivas e produtivas pescarias oceânicas, que em geral apresentam altas taxas de exploração. Mundialmente, em torno de 10 a 20 milhões de tubarões-azuis são retirados dos oceanos (Hilton-Taylor 2000). Por isso é de fundamental importância o monitoramento contínuo das capturas do tubarão-azul e análises de tendências, para garantir de que a pesca não exceda a capacidade de reposição do estoque. Entretanto, o monitoramento dessas capturas nas zonas econômicas exclusivas da maioria dos países é problemático (Stevens 1996). Os registros históricos internacionais dessas capturas em geral são subestimados, por uma série de motivos, entre eles a grande quantidade de descartes (Mejuto & Cortés 2005). Pelo fato desses monitoramentos serem muitas vezes inadequados, fica praticamente impossível de se avaliar o declínio populacional (Walker 1998, Hilton-Taylor 2000, Velasco *et al.* 2007). A implementação de um plano de ação seguindo os moldes da FAO para a conservação e manejo dos tubarões deverá em um futuro breve melhorar essas estatísticas de capturas de tubarões-azuis no Brasil. Aliado a isto, cabe ressaltar a importância da realização de cruzeiros de pesquisa que avaliem a real biomassa de tubarões azuis, na área em questão (Atlântico sudocidental) (Velasco *et al.* 2007).

Para a nuvem de pontos observada na figura 7, não pode ser desprezada a inegável leve curvatura na relação entre a captura e o esforço cumulativos, para o período 2002-05. Foi possível efetuar um bom ajuste de curva potencial a esses pontos expressa na forma $Y = 0,784 X^{0,94}$; $r^2 = 0,97$ (Figura 12).

Portanto, fica claro de que, com o passar do tempo, enquanto o esforço se acumulava, a captura se acumulava um pouco menos rapidamente, havendo desta forma, uma redução na CPUE. Isso pode significar que na realidade houve uma diminuição da abundância do tubarão-azul durante esse período de quatro anos de pesca. Esse declínio é corroborado pelo comportamento observado na CPUE (captura por unidade de esforço, em kg/nº de viagens) para esta espécie, durante o período de 2001 a 2005, no Estado de Santa Catarina (Figura 11). Por outro lado, é importante salientar que a frota espinheleira de Santa Catarina explora apenas uma fração do estoque do tubarão-azul no Atlântico Sul (Valeiras & Abad 2006) e de que precisas estimativas de biomassa desta espécie

são necessárias para a área em questão (Velasco *et al.* 2007).

Segundo Hazin *et al.* (1990), a abundância desta espécie aumenta em maiores latitudes, como é o caso do sul do Brasil. Também a densidade populacional de tubarão-azul, medida pela média de CPUE, varia sazonalmente no sul do Brasil. Segundo Azevedo (2003) ela oscilou entre 37,5 indivíduos/1000 anzóis no inverno de 1997 a 9,17 indivíduos/1000 anzóis no verão-outono de 1998. No presente estudo, a CPUE foi maior no outono, com valores entre 35,8 e 53,7 indivíduos/1000 anzóis e menor na primavera com valores entre 4,8 e 7,2 indivíduos/1000 anzóis. Entretanto, nenhum dos modelos apresentados mostrou efeitos significativos do trimestre do ano sobre a CPUE.

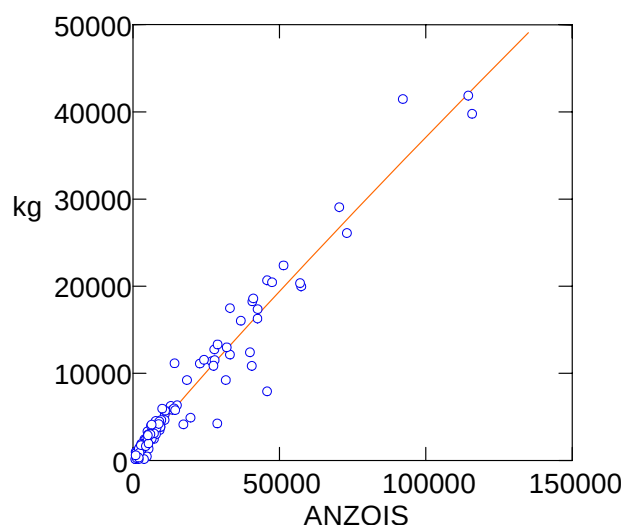


Figura 12. Ajusta de curva potencial aos dados de captura cumulativa do tubarão-azul (kg) em relação ao esforço cumulativo (número de anzóis), na pescaria de espinhel-de-superfície (monofilamento), sediada em Itajaí e Navegantes (SC). Período: 2002 - 2005. O modelo de curva potencial ajustada foi $Y = 0,784 X^{0,94}$ ($r^2 = 0,97$).

Conforme apresentado na figura 10, a frota comercial direciona o seu esforço de pesca para determinadas áreas, como a Elevação de Rio Grande e talude do Rio Grande do Sul. Segundo Ferreira *et al.* (2005), essas áreas estão intimamente relacionadas com a disponibilidade de alimento (e.g., lulas), diferenças na salinidade, temperatura da água e correntes, atraindo predadores oceânicos como é o caso do tubarão-azul. No verão, nas áreas próximas às Ilha de Trindade e Martin Vaz, e na Bacia Abissal Brasileira, há uma elevada CPUE de tubarões-azuis, devido à disponibilidade de alimento, já que a porcentagem de estômagos vazios é bem baixa, e em sua maioria em estágio inicial de digestão (Mazzoleni & Schwingel 2002). As elevadas concentrações de tubarões-azuis na Elevação de Rio Grande, provavelmente estejam

relacionadas com o comportamento alimentar e reprodutivo desta espécie, porém maiores estudos são necessários à respeito.

Finalmente, cabe comentar que simulações feitas com modelos multiespecíficos ecotróficos, indicaram que os elasmobrânquios são negativamente afetados por quase todas as modalidades de pesca (arrasto, emalhe, espinhel, etc.). Nestas simulações este grupo de peixes mostrou sinais de recuperação apenas através da redução generalizada dos níveis de esforço de pesca nas diversas modalidades (Velasco *et al.* 2007).

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Proposal for creation of a “zoning with regulation of use in the Cananéia estuarine-lagoon complex” aiming the conservation of the estuarine dolphin, *Sotalia guianensis* (van Bénédén) (Cetacea, Delphinidae)

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Abstract. The increase in human activities in the coastal region has affected the stability of certain cetacean populations. In the Southeastern Brazilian coast, the populations of estuarine dolphins, *Sotalia guianensis* (van Bénédén, 1864) suffer strong pressure as a result of long exposure to pollution, reduction of habitats, by-catch and tourism. Since 1981, the Instituto de Pesquisas Cananéia (IPEC) studies the biology and ecology of the estuarine dolphin in the Cananéia-Paranaguá estuarine-lagoon complex. Since then, we have obtained information on group structure, population density, reproduction, foraging, behavior, acoustics, video identification and interactions with other species, including the local human community. These data indicates that the traffic of fishing boats does not interfere in the activities of the estuarine dolphin. However, small boats with outboard motor may interfere physically; through collisions with dolphins or stressing them, and also may interfere in their acoustic behavior. Therefore, with the intention of acting effectively in the conservation of the estuarine dolphin, without excluding human activities we formulated a proposal for creation of an area of "zoning with regulation of use" which consists in outlining sectors of greater density of dolphins in the Cananéia estuarine-lagoon complex.

Key words: Boats, tourist activities, human impact, acoustics, behavior, conservation.

Resumo. Proposta de criação de “zoneamento com regulamentação de uso no Complexo Estuarino Lagunar de Cananéia” visando à conservação do boto-cinza, *Sotalia guianensis* (van Bénédén) (Cetacea, Delphinidae). O aumento de ações humanas na região costeira tem afetado a estabilidade das populações de cetáceos. Nas baías da costa sudeste, as populações de boto-cinza, *Sotalia guianensis* (van Bénédén, 1864) vêm sofrendo forte pressão por estarem expostas à poluição, diminuição dos habitats, captura acidental e ao turismo. Desde 1981, o Instituto de Pesquisas Cananéia (IPEC) estuda a biologia e ecologia do boto-cinza no Complexo Estuarino Lagunar Cananéia/Paranaguá. Durante este período, obtivemos diferentes informações sobre estrutura de grupo, densidade populacional, reprodução,

alimentação, comportamento, acústica, videoidentificação e interações com outras espécies, incluindo comunidade local. Estes dados denotam que o tráfego de embarcações pesqueiras não interfere nas atividades do boto, mas que pequenas embarcações com motor de popa, podem interferir tanto impactando fisicamente os animais, estressando e colidindo com os mesmos, quanto no seu comportamento acústico. Assim, com o intuito de atuar efetivamente na conservação do boto-cinza, sem contudo, excluir atividades humanas, formulamos uma proposta de criação de uma área de “zoneamento com regulamentação de uso” que consiste na delimitação de setores de grande densidade de botos no Complexo Estuarino Lagunar Cananéia.

Palavras-chave: Atividades turísticas, embarcações, impactos humanos, acústica, comportamento, conservação.

Introduction

Over the past decades, environmental questions have become the central focus of great world-wide discussions given that they are directly related to the maintenance of basic conditions of survival in our planet. Basic research must be the starter for such discussions. In Brazil, basic studies involving cetaceans have gained new perspectives with the publication of the Action Plan for Aquatic Mammals of Brazil (IBAMA 1997, 2001). Although the species *Sotalia fluviatilis* is classified in the category “data deficient” in this Action Plan, it is under strong anthropogenic pressure, such as pollution, loss of habitat, by-catch and intentional harassments by tourism and leisure boats (Siciliano 1994, Di Benedetto *et al.* 1998, Rosas 2000, Kajiwarra *et al.* 2004, Kunito *et al.* 2004). The confirmation of two species of the genus *Sotalia* is recent (Monteiro-Filho *et al.* 2002, Cunha *et al.* 2005, Caballero *et al.* 2007) and the status of conservation of *S. guianensis* until now was not evaluated by the IUCN (IUCN 2007).

In the Cananéia estuary, southern coast of São Paulo State, the estuarine dolphin *S. guianensis* (van Bénédén, 1864) is seen in a positive way by the local community. Especially considering the interaction displayed during foraging activities, in which the dolphin conducts shoals of fish to the “cerco-fixo” (a local traditional fish trap), helping the fishermen to capture the fish (Monteiro-Filho 1995). The species is also seen as a great tourism attraction in the region, which constitutes of an important source of income for the community. Although dolphin-watching tourism may promote economic benefits (IFAW 1995); it may disturb the balance in dolphins’ populations if it is not regulated (Coscarella *et al.* 2003). The EMBRATUR National Tourism Project (1992 *apud* Becker 1995) considers the southern coast of São Paulo State as one of the greatest areas of potential increase in nautical facilities, with the possibility of implantation of marinas in the coast.

A team of 33 researchers has been investigating the estuarine dolphin in that area for the past 26 years, which enabled an effective monitoring of different aspects of the biology and ecology of this dolphin population. This kind of research is of fundamental importance so that we can suggest conservation proposals in the region where dolphins are present all year round; mating, nurturing their calves and feeding, including during the night. It is worth stressing that a good part of the studies developed by us follow the suggestions stated in the item “Projetos e Ações Prioritárias” (Projects and Priority Actions) from the Action Plan for Aquatic Mammals from Brazil (IBAMA 2001).

Considering this reality, and the fact that in the Cananéia estuarine-lagoon complex, the estuarine dolphin has been suffering impacts by human action, such as possible collisions with high speed boats; noise interference generated by boats (Gonçalves 2003, Rezende 2008), organochlorine contamination (Kajiwarra *et al.* 2004, Kunito *et al.*, 2004), by-catch (Rosas 2000) and by the increase of the local tourism (Filla 2008); a proposal of zoning with regulation of use was elaborated aiming the protection and conservation of the population of estuarine dolphins inhabiting this area.

Material and methods

Study area

The Cananéia Estuarine-Lagoon Complex (Fig. 1) is located in the southern coast of São Paulo State. The region has 110km of extension, consisting of a protected channel (Mar Pequeno), a bay (Baía de Trapandé) and three islands (Ilha Comprida to the east, Ilha do Cardoso to the south and Ilha de Cananéia to the west), with narrow coves to the north (Barra do Icapará) and to the south (Barra de Cananéia). This estuarine system represents one of the most preserved ecosystems in the Brazilian coast and since it is part of a State and Federal Area of Environmental Protection, the complex is legally protected (Schaeffer-Novelli *et al.* 1990).

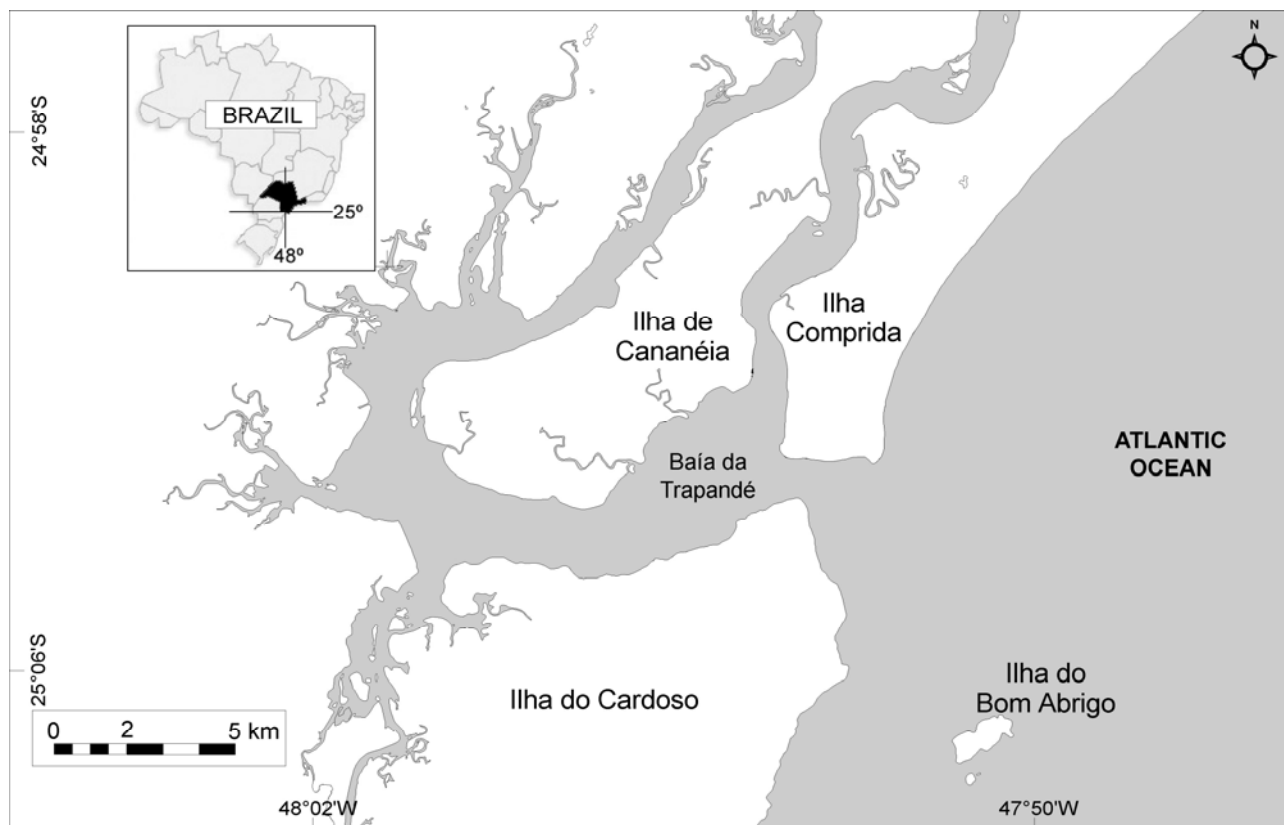


Figure 1. Cananéia estuarine-lagoon complex, southeastern Brazil: area where the zoning with regulation of use will take place. (Source: Domit, 2006).

Research Procedures

The different studies regarding the biology and ecology of the estuarine dolphin were gathered with the intention of formulating a proposal of an area for the protection of the estuarine dolphin in the region of Cananéia. These studies are already available in different scientific journals and were carried out by the team of researchers working in the Estuarine Dolphin Project from 1981 to 2007.

Having all the data mentioned above and based on the present Brazilian legislation, we are contacting the Brazilian governmental agency responsible for the environmental policies (IBAMA-Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis) to make possible that the rules proposed herein can be implemented in the Estuarine region of Cananéia.

Results

During the 26 years of estuarine dolphin research in Cananéia, many studies were carried out. The main results of the studies regarding the estuarine dolphin biology and ecology are shown in Table I.

After putting together the data collected and having contacted the IBAMA; it was possible to elaborate the "Proposal of zoning with regulation of use" for the Cananéia estuarine-lagoon complex

(Table II), where the sectors with greater densities of estuarine dolphins in the region are considered priority for the conservation of this species. In addition, the human activities occurring in these sectors should be monitored.

Discussion

According to the Action Plan for Aquatic Mammals of Brazil (IBAMA 2001), the main threats that affect the genus are related directly to the destruction of habitats within its distribution area, including pollution resulting from industrial waste, toxic substances used in agriculture, river dam for both electricity production and irrigation, as well as the deforestation of riverbanks, lakes and mangrove areas. The increase of boat traffic and urban development in the coastal areas along with the mangroves and estuaries are gradually affecting the stability of dolphin's populations. In coastal bays along the Brazilian Southeast region the *Sotalia* populations are under severe human pressure resulting in exposition to the synergic effects of pollution, habitat loss, bycatch and intentional molesting by leisure and tourist boats. In the state of Santa Catarina, for instance, the unorganized and non regulated practice of cetacean observation tourism is also a threat to the local population (IBAMA 2001).

Table I. Themes developed during several studies on the biology, ecology and conservation of the estuarine dolphin, *S. guianensis*, in the Cananéia estuarine-lagoon complex, southern coast of São Paulo State, Brazil, with the respective sampling periods and results that contributed to the elaboration of the proposal of zoning with regulation of use in Cananéia.

Study Theme	Sampling Periods	Contribution for the proposal
Individual Identification	Two sampling periods: From 06/2001 to 08/2002; From 08/2004 to 08/2005.	48 individuals with natural marks on the dorsal fin, on the head and on the back were identified (De Oliveira & Monteiro-Filho <i>in press</i>).
Density estimation	Two sampling periods: From 01/2001 to 09/2001; From 05/2003 to 05/2004.	Besides the estimation of the dolphin population, it was also possible to observe a difference in use and in spatial and temporal distribution by the dolphins (Bisi 2001, Havukainen 2004).
Reproductive biology	From 04/1997 to 10/1999	Size and age of sexual maturity, length of birth, time of gestation and lactation, fetal growth rate, reproductive cycle and observation of senescent ovaries in females above 25 years, were estimated. Promiscuous reproductive systems, with sperm competition were also observed (Rosas & Monteiro-Filho 2002, Rosas & Barreto <i>in press</i>).
Pollution	From 04/1997 to 10/1999	Organochlorine values (DDT and PCBs) in the bubbler and hepatic concentrations, especially Cu and Zn, were detected in similar levels to what was found in dolphins from highly industrialized regions (Kajiwara <i>et al.</i> 2004, Kunito <i>et al.</i> 2004).
Behavior	Two sampling periods: From 1981 to 1991 From 01/2004 to 07/2005.	The behavioral studies demonstrated the great importance of the Cananéia estuary for the performance of elaborated and complex foraging strategies, with many different patterns performed individually or in associations (Monteiro-Filho 1992, Rautenberg & Monteiro-Filho <i>in press</i>).
Infant's Behavior	From 1981 to 2005.	The results demonstrated that calves have great variation of behavioral patterns in different ages. They occur in different frequencies and were grouped in eleven categories (Domit 2002, 2006, Monteiro-Filho <i>et al. in press</i>).
Group Structure	From 1984 to 1999	Describes the category "family" as the most frequent grouping in the estuarine dolphin in Cananéia (Monteiro-Filho 2000).
Nocturnal Activities	1) Behavior: from 03/2003 to 10/2003; 2) Acoustics: from 08/2002 to 07/2005.	During the nocturnal period, the dolphins, including calves, remain in the region of Cananéia engaged in feeding activities and demonstrating great acoustic activity (Atem & Monteiro-Filho 2006, Oliveira <i>et al. in press a</i>).
Strandings on beaches in the region	Since 1981	Information collected since the beginning of the project. The specimens are deposited in the collections of the Museum of Natural History of UNICAMP (ZUEC) and at Instituto de Pesquisas Cananéia (IPeC).
Skull morphometric analysis	From 1998 to 2001	The data collected in this study support the description of two species for the <i>Sotalia</i> genus (Monteiro-Filho <i>et al.</i> 2002).
Ethnic knowledge	From 2001 to 2006	Diagnosis of specific traditional knowledge about the species, as well as, the local communities' socio-environmental needs (Oliveira & Monteiro-Filho 2006, Oliveira <i>et al. in press b</i>).
Interaction with local fishermen community	From 1982 to 1990	Description of the interactions between dolphins and fishermen, especially close to the "cercos-fixos" (traditional fish trap) (Monteiro-Filho 1995).
Acoustics	From 1989 to 1998	Four categories of sound emissions were described (Monteiro-Filho & Monteiro 2001).
Acoustic and vessel interference	Two sampling periods: From 1998 to 2000 From 06/2002 to 01/2003	The sound produced by outboard motor boats interferes in the dolphin's sound emission and behavior (Gonçalves 2003, Rezende 2008).
Impact of touristic activities	From 12/2004 to 03/2007.	Just as the acoustics, preliminary results about the impact of tourism show that small (and high speed) boats with outboard motors cause immediate reaction by the dolphins (Filla 2008).

Table II. Items that compose the "Proposal of zoning with regulation of use" in the Cananéia Estuarine-Lagoon Complex, submitted to the IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis).

<i>Item</i>	<i>Proposal</i>
Boat Traffic	Aluminum boats with outboard motor should transit in low speed whenever a dolphin is seen from a distance of 500 m, therefore, reducing the impact generated by the noise of the engine, and allowing the boats to be sighted from certain distance. All boats should keep a minimum distance of 50 meters from the animals and if/when the animal are being watched, they should keep the engines on neutral so that their presence and localization are easily noticeable by the animals. Never, under any circumstances, should the animals be separated from the group, especially calves from their mothers.
Nautical Sports	Jet-ski and water-ski should be avoided in the region, and totally forbidden in the areas of major occurrence of estuarine dolphins, which should be marked with signalizing buoys.
Tourism	Avoid changing direction of the boats when aiming to get closer or to follow an animal or group. The total time of observation of the same group of dolphins is limited to a maximum of 30 minutes. A maximum of 03 boats can stay close (less than 100m) to the same group of dolphins at the same time.
Scientific studies	Exceptionally, scientific research involving estuarine dolphins is allowed. Approaching cetaceans with boats and aircrafts can be done exclusively with scientific purposes. Invasive scientific research or biopsy techniques that perforate or remove living animal tissues without contention should be avoided at all costs and can only take place with official authorization from the Conservation Unit corresponding to the Federal Office in charge (IBAMA).
Responsibilities	The responsibility for breaking the rules must be attributed to the conductors of the boats and their owners.
Monitoring	A continuous monitoring of all nautical activities in the region should occur and the results of this monitoring should be forwarded to the local environmental authorities.

Continuous efforts which enable the monitoring, in an effective way, of different biological and ecological aspects of the estuarine dolphin populations, are of fundamental importance so we can base conservation proposals. This is the case of the Cananéia region where the dolphins are present throughout the year. The animals use the area to breed, feed and nurture their calves, and are very active including during the night (Monteiro-Filho 1992, Rosas & Monteiro-Filho 2002, Atem & Monteiro-Filho 2006, Monteiro-Filho *et al.* in press, Oliveira *et al.* in press a, Rautenberg & Monteiro-Filho in press, Rosas & Barreto in press). In this area, the estuarine dolphin also interacts with the traditional local communities (Monteiro-Filho 1995).

Regarding the impact evaluation, studies involving acoustic and monitoring of the tourism activities in the region point out to a negative impact when small sized boats with outboard motors are present in the area. The noise emitted by this kind of boat has been shown to make the dolphins swim away from the boat (avoidance reaction) or even cause change in the acoustic niche (Gonçalves, 2003, Rezende 2008). Moreover, the increase in boat

traffic is of great concern in some regions across the Brazilian coast (Valle & Melo 2006, Santos-Jr *et al.* 2006) since it may cause serious damage to the dolphin populations and may push the dolphins to abandon the area such as already has happened on other locations in the world (Watkins 1986 Richardson *et al.* 1995, Ritter 2002, Magalhães *et al.* 2002, Coscarella *et al.* 2003, Lusseau 2003, Ng & Leung 2003).

Studies concerning population density in different places have shown alarming rates of abandonment of area for certain cetacean species. For *S. guianensis*, two records of abandonment of area are reported. The first one was within the northern limit of its geographic distribution (Edwards & Schnell 2001) and the other nearby the southern limit (Filla 2004). In both cases the most likely cause for the abandoning of the area was the increase in human activities, especially the increase in boat traffic. Recent studies with this species, such as those carried out by Gonçalves (2003) and Rezende (2008), in Cananéia (SP) and Keinert (2006) Ilha das Peças Island (PR), have shown that not only the exaggerated proximity of the boats is damaging, but also the sound

produced by their engine can be harmful to the dolphin's population. The above-mentioned studies analyzed boats with central engine (diesel) and boats with outboard motor (petrol), showing that the acoustic emissions registered are within the *S. guianensis* acoustic range. As a result the increase in traffic may cause serious damage to the dolphins' population and force them to abandon the area.

One of the most serious consequences of the interaction of cetaceans with high speed boats is the possibility of collision. According to Ana Rita dos Santos Lopes (personal observations) 17.26% of the estuarine dolphins found in the beaches along the Cananéia region, over the past six years, showed evidences of crash with boats (scars, recent cuts and/or bruises and bleeding).

One way of protecting marine habitats is to create small protection areas, with special attention to particularly valuable places for certain species which offer great benefits for the local communities. The planning for marine protected areas should contain initiatives that have influence in the decisive processes within the society. In that sense, it is necessary to motivate the government, the people from the local communities, and national and international organizations to conserve the biological diversity and the cultural integrity (IUCN 2002).

Hence, an area of protection of zoning with regulation of use in the region of Cananéia is proposed herein following the orientations of the IUCN (1999) guide for marine protection areas. This work is a concrete and ethically consistent proposal to conserve the species, and does not exclude the human activities (Filla *et al.* 2002, Filla & Monteiro-Filho 2006), avoiding conflicts and bad utilization of the conservation areas such as those reported by Wedekin *et al.* (2002) in the Santa Catarina State and by Silva & Silva Jr. (2002) in the Fernando de Noronha Arquipelago.

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Qualidade das águas de riachos da região norte do Rio Grande do Sul (Brasil) através de variáveis físicas, químicas e biológicas

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Abstract: Water quality of streams in the north region of Rio Grande do Sul (Brazil) through use of physical, chemical and biological variables. The damages caused to the hydric bodies for the human activities beings generate the necessity of trust information in respect to the water quality. The present study objectified to evaluate the hydric quality of two hydrographic basins in north of Rio Grande do Sul, through a physical and chemical index (WQI) and another biological (BMWP), beyond other biological metric. Physical, chemical and microbiological variables were analyzed and, beyond the benthic macroinvertebrates collection, in four points of sampling of each basin, in the periods of winter/2005 and summer/2006. In the majority of the studied places the index WQI presented values that consider waters of satisfactory quality. The BMWP revealed more rigorous in this evaluation, verifying that the activities developed in the studied basins had modified the hydric quality of the places. In the sites where the anthropogenic activities are more evident the differences between the indices had been bigger, suggesting that in environments with higher degradation, a wide explication can be gotten using the biomonitoring. The differences between the index can be explained by the characteristic of the physical and chemical monitoring in to evaluate the point quality and to analyze only some variables, while the biological components present sensitivity to the environmental factors.

Key words: Anthropogenic activities, biological metrics, WQI, water quality.

Resumo. Os prejuízos causados aos corpos hídricos pelas atividades humanas geram a necessidade de informações confiáveis no que diz respeito à qualidade de água. O presente estudo objetivou avaliar a qualidade hídrica de duas bacias hidrográficas da norte do Rio Grande do Sul, utilizando um índice físico e químico (IQA) e outro biológico (BMWP), além de outras métricas biológicas. Foram mensuradas variáveis físicas, químicas e microbiológicas, além da coleta de macroinvertebrados bentônicos, em quatro pontos em cada bacia, nos períodos de inverno/2005 e verão/2006. Na maioria dos locais estudados o índice IQA apresentou valores que consideram as águas de qualidade satisfatória. O BMWP mostrou-se mais rigoroso nesta avaliação, verificando que as atividades desenvolvidas nas bacias estudadas alteraram a qualidade hídrica dos locais. Nos pontos onde as atividades antrópicas são mais pronunciadas as diferenças entre os índices foram maiores, sugerindo que, em ambientes com maior degradação, pode ser obtida uma resposta mais ampla utilizando o biomonitoramento. As diferenças entre os índices podem ser explicadas pela característica do monitoramento físico e químico de avaliar a qualidade pontual e analisar apenas algumas variáveis enquanto os componentes biológicos apresentam sensibilidade ao conjunto de fatores ambientais.

Palavras chave: Atividades antrópicas, métricas biológicas, IQA, qualidade da água.

Introdução

Os efeitos combinados da urbanização e das demais atividades antropogênicas associadas ao rápido crescimento populacional das últimas décadas são facilmente visualizados nos ecossistemas (Thorne & Williams 1997; Pompeu *et al.* 2005). Muitos rios, lagos e reservatórios têm sido prejudicados como consequência do aumento de atividades humanas. Sendo assim, o planejamento e gestão dos recursos hídricos dependem de informações confiáveis, tanto no que diz respeito à demanda como à oferta de água (Braga *et al.* 1999). Como a disponibilidade de água depende do grau de contaminação desta, a oferta total só poderá ser estimada se existirem redes de monitoramento confiáveis, que gerem dados sobre variáveis de interesse no setor qualitativo (Buss *et al.* 2003).

Dessa forma, diversas metodologias têm sido utilizadas visando o monitoramento da qualidade hídrica. O uso de variáveis físicas e químicas, principalmente através de índices de qualidade de água, que é um método bastante aplicado para esta finalidade (Da-Silva & Jardim 2006). A utilização de tais índices se baseia no fato de que, ao alterar o ambiente, o homem afeta as variáveis hídricas e pela análise destas, pode-se inferir sobre a integridade ambiental. De acordo com Rizzi (2001) determinados índices podem proporcionar um valor global de qualidade de água, incorporando valores individuais de uma série de parâmetros.

Por sua vez, o monitoramento biológico também é referido como eficaz na determinação da qualidade da água, pois utiliza a estrutura de comunidades intrinsecamente relacionadas ao ambiente como um indicador do grau de poluição (Fleituch *et al.* 2002). Vários trabalhos têm utilizado os macroinvertebrados bentônicos como bioindicadores no monitoramento biológico de rios, considerando este grupo como uma das mais promissoras ferramentas para avaliação da qualidade hídrica (Fleituch *et al.* 2002; Lazaridou-Dimitriadou 2002; Cota *et al.* 2002; Strieder *et al.* 2006; Arimoro *et al.* 2007; Hepp & Restello 2007). Os macroinvertebrados bentônicos formam um grupo que indica integralmente os efeitos produzidos por todas as substâncias existentes na água (Junqueira *et al.* 2000). Dentre as vantagens das ferramentas biológicas, destaca-se a capacidade de detectar os efeitos de uma perturbação ocorrida há várias semanas ou mais, oferecendo uma visão da situação antes da coleta de amostras (Alba-Tercedor 1996; Lazaridou-Dimitriadou 2002; Weigel *et al.* 2002).

Strieder *et al.* (2006) informa que há uma forte correlação entre os índices bióticos e a qualidade física e química da água, ainda que possam existir divergências nos resultados, pois estas formas de avaliação consideram diferentes componentes ambientais, as quais possuem vantagens e desvantagens. Hepp & Restello (2007) comentam que a comunidade bentônica pode apresentar relações positivas ou negativas com variáveis físicas e químicas. Dessa forma, há necessidade de avaliar o uso das diferentes abordagens de mensuração da qualidade de corpos hídricos de maneira integrada, pois, caso contrário, podem ser geradas informações isoladas e insuficientes (Pereira & Pereira 2005).

Neste contexto, o presente estudo objetivou avaliar a qualidade hídrica de ambientes lóticos da região norte do Estado do Rio Grande do Sul utilizando dois índices ambientais: um físico e químico (Índice de Qualidade de Água, IQA) e outro biológico (Biological Monitoring Working Party, BMWP), além de métricas biológicas como a densidade de organismos, riqueza taxonômica e a diversidade Shannon-Wiener.

Material e Métodos

Área de Estudo

O município de Erechim localiza-se na região norte do Estado do Rio Grande do Sul, a 27°37'54" de latitude sul e a 52°16'52" de longitude oeste. Situa-se a 768 m acima do nível do mar, apresentando clima subtropical com temperatura média anual de 18,7°C (Rampazzo 2003). Para a realização deste estudo, foram definidos oito pontos de coleta em duas Bacias Hidrográficas municipais (Figura 1; Tabela I): (i) Bacia Hidrográfica do Rio Tigre (pontos 1 a 4), localizada na porção Centro-Occidental, apresentando uma área de 90,71 km², abriga mais de 90% do perímetro urbano do município de Erechim, é responsável pelo fornecimento e manutenção do abastecimento de água potável à população domiciliada na área urbana (Rampazzo 2003). Esta bacia (principalmente o ponto 4) está diretamente exposta aos poluentes originados na cidade. (ii) Bacia Hidrográfica do Rio Campo (pontos 6 a 8), localizada na porção Sudeste do município e possui área de 80,35 km². Tem em sua área drenagem forte atividade agrícola mecanizada, resultando em elevada retirada da cobertura vegetal, principalmente na região ribeirinha, além da drenagem constante de banhados (Rampazzo 2003).

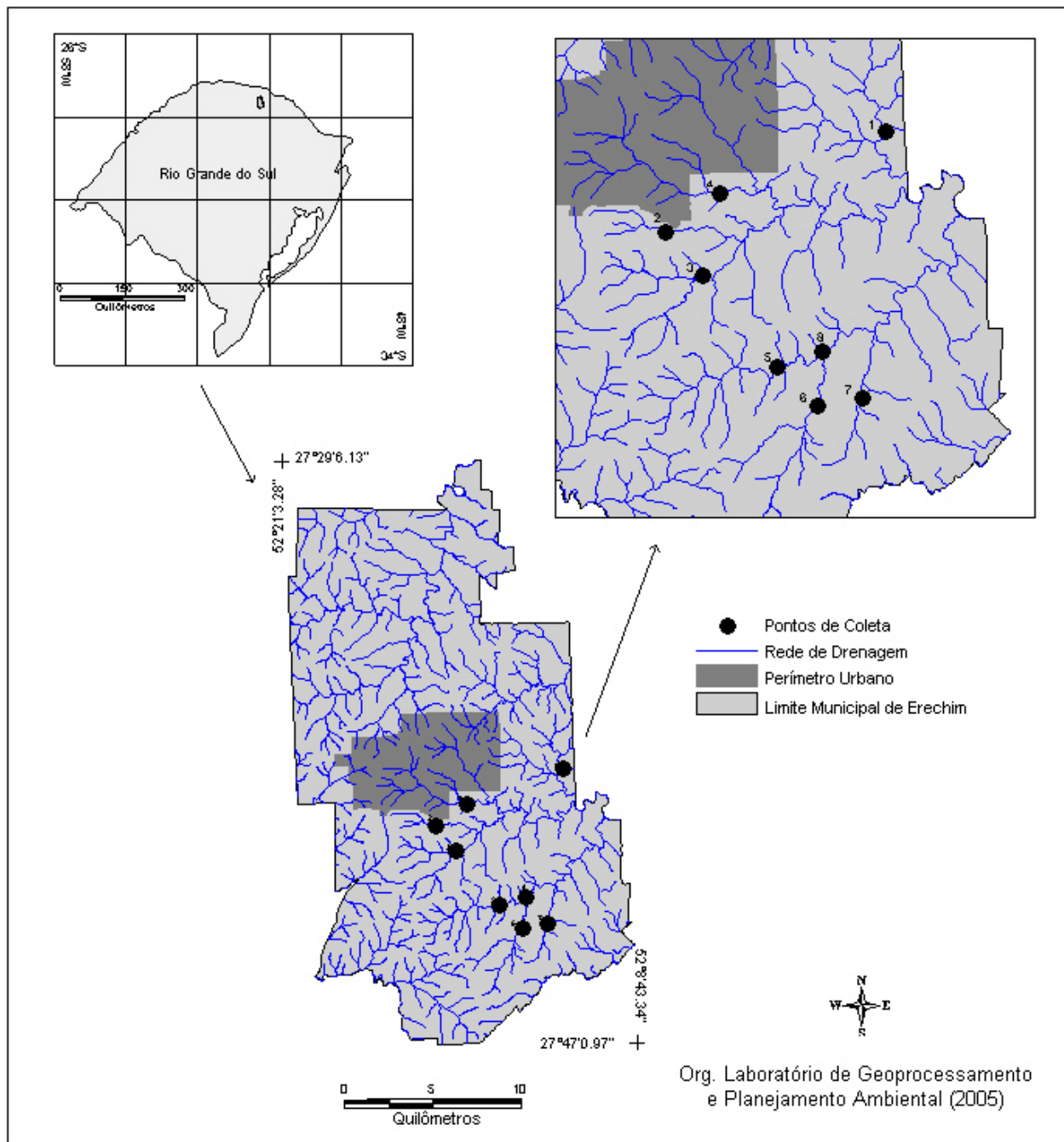


Figura 1. Localização do município de Erechim – RS e distribuição dos pontos de coleta.

Variáveis Biológicas

As coletas de macroinvertebrados foram realizadas no inverno de 2005 (agosto) e verão de 2006 (janeiro). Os organismos bentônicos foram coletados com um amostrador Surber, com malha de 250 μm e área de 0,1 m^2 (Merritt & Cummins 1996), sendo realizadas cinco réplicas em cada local. Estas contemplaram os diferentes tipos de substrato presentes no leito do corpo hídrico (pedras, folhiço, areia, etc). O material foi fixado com formol 10% e conduzido ao laboratório para triagem em peneiras com

malha de 2,00; 1,00; 0,5 e 0,25 mm, e identificação até menor nível taxonômico possível, utilizando chaves de Merritt & Cummins (1996) e Fernandez & Domingues (2001). Este nível taxonômico de identificação foi definido de acordo com recomendações de Dolédec *et al.* (2000), Melo (2005) e Corbi e Trivinho-Strixino (2006). Os organismos identificados foram tombados e depositados na Coleção de Invertebrados Bentônicos do Museu Regional do Alto Uruguai (MuRAU/URI – Campus de Erechim).

Variáveis Físicas e Químicas

Juntamente com cada coleta biológica, foi realizada a análise da água dos locais. Em campo foram mensurados: temperatura da água, pH e porcentagem de saturação de oxigênio, utilizando um oxímetro portátil YSI 55. Com amostras de água coletadas foram mensurados em laboratório: turbidez pelo método nefelométrico, utilizando um turbidímetro Policontrol AP2000, sólidos totais, por gravimetria (105 °C), DBO, determinada pela leitura de oxigênio dissolvido após 5 dias, com as amostras incubadas a 20 °C, nitrogênio total, pelo método de Kejhda, fósforo total, por espectrofotometria e coliformes termotolerantes a partir da incubação em Agar VRB a 44,5°C/48 horas. Os métodos para análise destes parâmetros estão descritos no Standart Methods (Clesceri 1998).

Análise dos Dados

Aos dados biológicos foram estimados os valores de densidade de organismos (ind./m²) e riqueza taxonômica, além do cálculo do índice de diversidade de Shannon-Wiener (Magurran, 2004). A partir da fauna identificada foi calculado o índice biológico BMWP, de acordo com Mandaville (2002). Neste cálculo foram descartados os organismos considerados raros (frequência < 0,5%), por se entender que as espécies raras não implicam em um bom retorno em termos de poder de detecção, visto que o uso de categorias taxonômicas amplas é suficiente na detecção de gradientes de perturbação (Norris 1995; Marchant 1999). Utilizando os resultados das variáveis físicas, químicas e microbiológicas foi calculado o Índice de Qualidade da Água (IQA) proposto pela CETESB (2005). Os resultados obtidos para o BMWP e IQA foram correlacionados pela análise de Correlação de Pearson ($p < 0,05$) (Gotelli & Ellison 2004). Foi avaliada, também, a variabilidade dos resultados em escala temporal (estações do ano) e espacial (bacias hidrográficas) aplicado o teste *One-Way ANOVA* ($p < 0,05$) (Gotelli & Ellison 2004). Aos dados biológicos foi aplicada uma transformação $\log(x + 1)$ a fim de garantir a normalidade e, principalmente a homogeneidade de variâncias.

Resultados

A análise das variáveis amostradas aponta que, na bacia hidrográfica do Rio Tigre, o ponto 4, com altos valores de nutrientes, resíduos totais e coliformes termotolerantes, além de baixos índices de saturação de oxigênio (Tabela II) foi o que mais se diferenciou dentre os pontos, sendo que, para os demais, a maioria das variáveis apresentou valores

considerados aceitáveis pela resolução nº 357/05 do CONAMA (Brasil 2005) para Classe I. Na bacia hidrográfica do Rio Campo destacaram-se os valores de fósforo total, pois 75% das amostras estiveram acima do limite estabelecido (0,1 mg/L). A média desta variável foi de $0,192 \pm 0,212$ mg/L para o inverno e $0,218 \pm 0,009$ mg/L para o verão. No geral, as demais variáveis apresentaram médias dentro dos níveis recomendados pela resolução 357/05 do CONAMA para a Classe I.

Com exceção do ponto 4, todos os locais das duas bacias hidrográficas estudadas apresentaram valores de IQA superiores a 66, sendo caracterizados com qualidade “boa” a “excelente” em ambas as épocas do ano. A qualidade das águas da bacia do Rio Campo foi levemente melhor do que a bacia do Rio Tigre (79,9 e 73,3, respectivamente) (Figura 2), não apresentando diferença significativa entre elas ($p > 0,05$) nas escalas espacial e temporal.

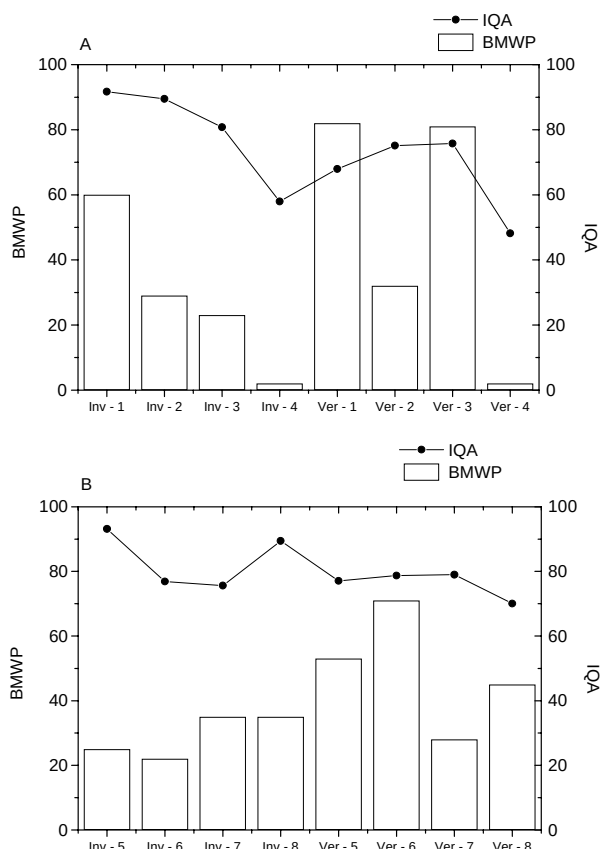


Figura 2. Valores de BMWP e IQA nas bacias do Rio Tigre (A) e Rio Campo (B) nos períodos de inverno de 2005 (inv) e verão de 2006 (ver).

No período do inverno foi registrada uma densidade média de $8277 \pm 7751,17$ ind./m² na bacia do Rio Tigre, havendo uma diminuição no verão, quando foram encontrados $2998,5 \pm 1145,72$ ind./m². O total de táxons do estudo foi de 40, sendo 32 no inverno e 30 no verão. Na bacia do Rio Campo, a

Tabela I. Caracterização dos riachos localizados nas bacias hidrográficas dos Rios Rio Tigre e Campo, Erechim/RS.

Características	Pontos							
	1	2	3	4	5	6	7	8
Coord. Geográficas (UTM)	382709 6941758	375463 6938433	376693 6936994	377256 6939672	379157 6933958	380474 6932677	381936 6932915	380628 6934444
Altitude (m)	636	693	682	673	658	647	633	620
Substrato	Pedra e folhiço	Pedra, terra e folhiço	Pedra e folhiço	Pedra	Pedra	Pedra e terra	Pedra (inverno) e terra (verão)	Pedra
Vegetação ribeirinha	Arbórea	Rasteira	Arbustiva	Rasteira	Arbustiva	Ausente	Ausente	Ausente
Impacto Observado	Agricultura (verão)	Pastagem	Agricultura (verão)	Atividades urbanas (resíduos domésticos)	Agricultura	Agricultura	Agricultura	Alteração do leito do rio para captação de água
Erosão nas margens	Pouca	Acentuada	Pouca	Acentuada	Moderada	Acentuada	Acentuada	Moderada

Tabela II. Resultados dos parâmetros abióticos mensurados nas Bacias Hidrográficas dos rios Tigre e Campo, Erechim/RS, nos períodos do inverno/2005 e verão/2006.

Parâmetro	1		2		3		4		5		6		7		8	
	I	V	I	V	I	V	I	V	I	V	I	V	I	V	I	V
O.D. (%saturação)	86,6	69,2	90	73,43	86,3	71,4	54,8	23,07	99,8	83,9	107,8	85,53	122,03	89,3	92,2	69,93
pH	6,53	5,47	6,32	6,07	5,22	6,26	7,1	7,08	7,47	6,4	7,48	7,38	6,44	6,86	7,15	7,52
DBO5 (mg/L)	0,86	1,36	0,98	1,05	1,04	1,09	4,04	1,61	1,89	0,74	2,07	1,09	3,46	0,9	1,5	0,87
Nitrogênio Total (mg/L)	0,835	1,063	1,005	0,884	0,56	0,804	2,828	3,81	1	1,13	0,989	1,061	0,949	1,259	1	1,233
Fósforo Total (mg/L)	0,001	0,048	0,001	0,021	0,001	0,026	0,566	0,734	0	0,22	0,42	0,224	0,021	0,206	0,33	0,225
Temp. da Água (°C)	17,4	20,1	19,6	19,4	17	19,97	24,6	25,67	21,3	20,8	25,2	21,1	20,97	23,5	19	22,9
Turbidez (UNT)	3,09	17,13	3,57	6,05	6,12	6,71	7,63	9,23	4,41	5,19	5,46	4,8	7,68	5,19	4,79	14,8
Sólidos Totais (mg/L)	100	107,33	220	51,33	150	83,33	273,33	178	60	126	146,67	119,3	106,67	76	0	469,33
Colif. Termot.(UFC/ml)	< 10	2,7x10 ²	< 10	5,9x10 ²	< 10	2,6x10 ²	3,1x10 ³	1,9x10 ³	< 10	7x10 ²	2,9x10 ²	3x10 ²	1,4x10 ²	2,8x10 ²	< 10	3,8x10 ²

densidade média foi de $4607 \pm 869,77$ ind./m² no verão e $3508 \pm 2556,15$ ind./m² no inverno, com 31 e 36 táxons registrados, respectivamente (Figura 3). Chironomidae foi o táxon mais representativo na maioria dos ambientes, principalmente nos pontos 2, 4 e 7. Simuliidae, Elmidae, Baetidae, Leptohyphidae, Hydropsychidae e Oligochaeta também foram registrados com alta abundância na maioria dos pontos (Tabela III). Os valores de densidade e riqueza não apresentaram diferenças significativas quando comparados em escala espacial e temporal. A diversidade média registrada foi menor na bacia do Rio Tigre em comparação a do Rio Campo, tanto no inverno (1,79 e 2,06, respectivamente) quanto no verão (2,00 e 2,39, respectivamente), não sendo observado diferenças significativas entre as estações do ano e bacias hidrográficas.

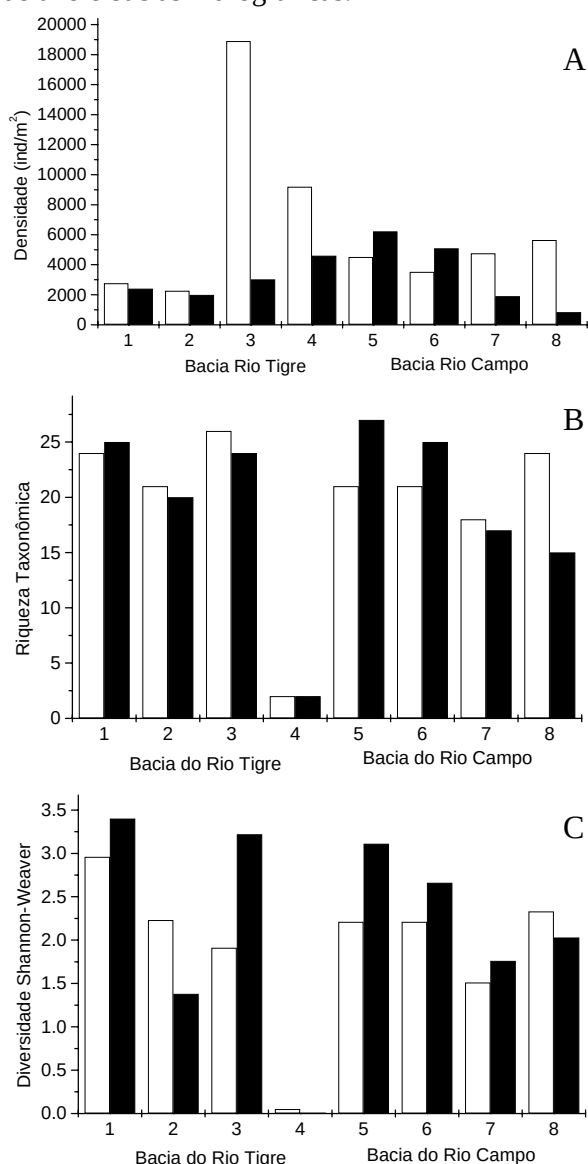


Figura 3. Valores de densidade (ind/m²) (a), riqueza de taxa (b) e diversidade (c) de macroinvertebrados coletados nas bacias do Rio Tigre (1 a 4) e Rio Campo (5 a 8) nos períodos de inverno de 2005 (colunas brancas) e verão de 2006 (colunas pretas).

O BMWP mostrou-se mais rigoroso que o IQA na avaliação da qualidade das águas, sendo que, temporalmente (verão e inverno, respectivamente), a classificação em ambas as bacias variou de “ruim” a “regular” (28,5 e 49,2, na bacia do Rio Tigre e 29,2 e 49,2 na bacia do Rio Campo). IQA apresentou correlação significativa com BMWP ($r = 0,73$; $p = 0,03$; $n = 8$) e riqueza taxonômica ($r = 0,81$; $p = 0,01$; $n = 8$) na bacia do Rio Tigre. Para a bacia do Rio Campo não houve correlação significativa entre o IQA e as métricas biológicas ($p > 0,05$). Ao analisar a resposta do BMWP frente as variáveis físicas, químicas e microbiológicas quantificadas, obteve-se correlações significativas apenas para nitrogênio total ($r = -0,55$; $p = 0,02$; $n = 16$) e fósforo total ($r = -0,53$; $p = 0,03$; $n = 16$).

Discussão

A bacia hidrográfica do Rio Tigre está diretamente exposta às atividades urbanas e aos poluentes originados na cidade. Tal fato ocorre com intensidade no ponto 4, onde o lançamento de resíduos é acentuado, sendo constatadas altas concentrações de nutrientes, o que altera a diversidade e riqueza de organismos aquáticos. Neste local é encontrada abundância de organismos tolerantes a condições ambientais adversas, como é o caso de Oligochaeta e Chironomidae. Tais aspectos ratificam as considerações de Meyer *et al.* (2005) ao citar algumas das principais características dos cursos d'água urbanos: elevada concentração de nutrientes e contaminantes, alteração na morfologia e estabilidade do canal, reduzida riqueza biológica, com a dominância de espécies mais tolerantes.

Na bacia do Rio Campo, a retirada da vegetação ciliar e a implementação de culturas ao longo das duas margens podem ter sido fatores que limitaram o desenvolvimento da macrofauna, pois, de acordo com Stewart *et al.* (2000) e Callisto *et al.* (2001), os atributos da vegetação ripária, que dependem do uso da terra na bacia hidrográfica, exercem influência sobre os padrões de distribuição da comunidade bentônica. Conseqüentemente, as medidas biológicas refletiram tais condições e mostraram que a qualidade hídrica dos locais está comprometida. O IQA não revelou tal degradação, possivelmente devido ao fluxo de água que acaba carreando o material particulado oriundo das áreas de entorno para locais de remanso, onde ocorre deposição deste. No entanto, observam-se concentrações elevadas de nutrientes, provenientes, possivelmente, de atividades rurais onde há aplicação de fertilizantes agrícolas (Tundisi 2003).

Tabela III: Abundância relativa de macroinvertebrados bentônicos nos oito pontos de amostragem das bacias hidrográficas dos rios Tigre e Campo, Erechim/RS, durante o período do inverno/2005 e verão/2006.

Táxons	Bacia Hidrográfica do Rio Tigre				Bacia Hidrográfica do Rio Campo			
	1	2	3	4	5	6	7	8
Annelida								
Hirudinea	0	0	0	0,15	0	0	0,06	0
Oligochaeta	10,43	12,44	1,08	0,19	2,05	1,42	7,40	1,48
Mollusca								
Bivalve	2,25	2,87	1,52	0	2,11	0,91	2,68	0,43
Gastropoda	0,39	0	0,64	0	0,11	0,16	0,15	0,19
Platyhelminthes	0,50	0,14	0,43	0	1,94	0,58	0	0,03
Arthropoda								
Crustacea								
Aeglidae	0	0,24	0,02	0	0,06	0	0	0,56
Aracnida								
Acarina	0,19	0,24	0,09	0	0,54	0,56	0,06	0,68
Insecta								
Collembola	0,12	0,05	0,03	0,01	0	1,30	0,39	0,28
Coleoptera								
Elmidae	10,43	4,85	4,73	0	9,08	5,92	4,36	3,22
Hydrophilidae	0	0	0	0	0	0	0,06	0
Psephenidae	2,95	0,24	0,01	0	0,11	0,14	0	0,03
Diptera								
Ceratopogonidae	1,28	0,28	0,25	0	0,11	0,16	0,42	0,31
Chironomidae	22,15	65,79	24,41	99,65	26,79	51,71	72,01	50,21
Empididae	0,04	0,24	0,01	0	0,19	0,63	0,09	0,03
Psychodidae	0,12	0,66	0,12	0	0	0,46	0	0
Simuliidae	9,89	1,65	51,32	0	14,58	3,92	1,14	11,97
Tabanidae	0,04	0	0	0	0	0	0	0
Tipulidae	0,35	0,09	0,06	0	0,17	0	0	0,31
Ephemeroptera								
Baetidae	7,72	6,92	8,20	0	17,76	13,79	6,38	19,67
Caenidae	1,47	0,14	0,05	0	0,48	0,63	2,32	2,10
Leptohyphidae	14,23	0,33	0,39	0	1,29	1,18	0,30	1,55
Leptophlebiidae	0,78	0,57	2,16	0	4,19	3,41	0,63	5,32
Hemiptera								
Corixidae	0	0	0	0	0	0	0	0,37
Gerridae	0	0	0	0	0	0	0	0,03
Naucoridae	0,04	0	0	0	0,02	0	0	0
Veliidae	0,16	0	0	0	0,02	0	0	0,03
Lepidoptera	0	0	0,19	0	0,56	0	0,03	0,15
Megaloptera								
Corydalidae	0	0,09	0,17	0	0,26	0,26	0	0
Odonata								
Coenagrionidae	1,01	0,47	0,47	0	0,15	0,23	0,18	0,56
Corduliidae	0,04	0	0	0	0	0,02	0,12	0
Gomphidae	0,04	0	0	0	0,09	0	0,27	0,03
Lestidae	0,04	0	0,02	0	0,02	0,21	0,15	0,12
Libellulidae	0,08	0	0	0	0	0	0	0
Plecoptera								
Gripopterygidae	0,04	0,14	0,35	0	0,13	0	0	0
Perlidae	2,68	0,28	0,21	0	0,32	0,23	0	0,06
Trichoptera								
Hydrobiosidae	0	0	0	0	0,04	0	0	0
Hydroptilidae	0	0	0	0	0,04	0	0	0
Hydropsychidae	9,73	1,04	2,11	0	10,68	10,68	0,51	0,25
Philopotamidae	0,27	0	0,58	0	5,85	0,07	0	0
Polycentropodidae	0,54	0,24	0,38	0	0,26	1,42	0,27	0,03

Nos locais onde as atividades antrópicas são mais pronunciadas, como nos pontos 4 (influência urbana) e 7 (influência agrícola, principalmente no verão), as diferenças entre os índices foram maiores, sugerindo que, em ambientes com maior degradação, pode ser obtida uma resposta mais ampla utilizando o biomonitoramento. Silva *et al.* (2007), ao estudarem o desempenho de dois índices biológicos baseados na comunidade bentônica, também verificaram um decréscimo nos valores destes, ao longo dos pontos mais degradados e sugerem sua utilização após considerar as diferentes características ambientais dos ecossistemas estudados.

Dentre as atividades aqui consideradas, as urbanas (bacia do Rio Tigre) foram mais amplamente detectadas pelas medidas biológicas, pois riqueza e BMWP apresentaram correlação com o IQA (na bacia do rio Tigre). Os resultados estão de acordo com os obtidos por Strieder *et al.* (2006) que, ao compararem medidas biológicas e índices de qualidade de água em uma microbacia no Sul do Brasil, também constataram a eficiência da utilização de macroinvertebrados em ambientes com poluição urbana. De acordo com Marques & Barbosa (2001), outras alterações passíveis de serem monitoradas por macroinvertebrados bentônicos e de difícil mensuração através de análises químicas é a presença de elementos poluentes, a introdução de espécies exóticas e a ação mecânica.

Este estudo ressalta alguns aspectos relativos à aplicação dos dois diferentes índices. Um destes consiste na escolha das variáveis abióticas a serem utilizadas em um índice físico e químico. Toledo & Nicolella (2002) indicam que vários componentes podem ser modificados quando ocorre um efeito perturbador, no entanto, somente alguns são mensurados, aos quais é dada maior importância. Além disso, o IQA não considera a presença de substâncias tóxicas na água. De acordo com Alba-Tercedor (1996), existem milhares de produtos catalogados como altamente contaminantes e que podem prejudicar a qualidade da água para consumo ou proteção da vida aquática. Nos locais mais afetados das bacias hidrográficas estudadas, uma variada gama de substâncias pode estar fazendo parte do componente hídrico e seus efeitos exercendo pressão sobre a biota local. Da Silva & Jardim (2006) aplicaram diferentes índices de qualidade de água em um rio no interior de São Paulo e verificaram que aquele cuja metodologia considerava a concentração de algumas substâncias tóxicas apresentou maior eficiência de avaliação

em relação ao IQA da CETESB.

No presente estudo, as diferenças entre as duas diferentes abordagens (biológica - física e química) também podem ter ocorrido devido à característica das análises baseadas em fatores abióticos de indicar a qualidade pontual. Buss *et al.* (2003) indicam que as variáveis físicas e químicas representam apenas o estado das águas em um local e momento determinados e variações significativas entre dois instantes de amostragem são facilmente perdidas, deixando de ser consideradas. A fauna de macroinvertebrados necessita de um tempo mínimo de recolonização após um impacto, próximo a um mês ou as vezes mais e, conseqüentemente, os efeitos de uma perturbação podem ser detectados após esta ser produzida (Alba-Tercedor 1996). Com o tempo, o impacto gerado nos locais do estudo pode ter sido abrandado devido à autodepuração do corpo hídrico, não tendo influência sobre o IQA, mas sendo detectado pela macrofauna.

Pode-se concluir que há uma relação positiva entre degradação ambiental e diminuição do número de grupos de macroinvertebrados sensíveis a tal degradação, com conseqüente queda da qualidade da água pela avaliação biológica. No geral, a qualidade hídrica das bacias hidrográficas foi insatisfatória, sendo encontrados grupos tolerantes à poluição em grande quantidade (Chironomidae e Oligochaeta, por exemplo). O índice biológico BMWP e as medidas de diversidade e riqueza podem constituir um eficiente recurso para o monitoramento, principalmente em locais com perturbação antrópica de origem urbana. No entanto, o estudo das propriedades abióticas pode informar, muitas vezes, sobre quais variáveis estão sendo determinantes para a qualidade da água e sobre a influência dos processos ambientais associados a estas variáveis. Portanto, para avaliar a integridade ecológica, também devem ser quantificadas as características físicas e químicas como parte do habitat, além das biológicas, ou seja, a combinação de informações é fundamental para o monitoramento eficiente do ecossistema.

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As capturas do tubarão-azul, *Prionace glauca* Linnaeus (Elasmobranchii, Carcharhinidae), na pescaria de espinhel-de-superfície (monofilamento), sediada em Itajaí (SC), Brasil

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ERRATUM

Pág 64, coluna 1

Equação 6.

$$CT = 12,49 (PC)^{0,28}$$

Onde,

CT = comprimento total em cm;

PC = peso da carcaça em kg;

Considerar PC = peso da carcaça em gramas e não em quilogramas como está publicado;

Nós autores nos desculpamos e agradecemos a compreensão dos leitores.

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Original Scientific Photographs

BY THELMA DIAS

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The goldspotted eel *Myrichthys ocellatus* (Lesueur, 1825) is a bony fish typically found in shallow waters such as reef environments (Smith, 1997). Similarly, the king helmet *Cassia tuberosa* (Linnaeus, 1758) inhabits shallow waters to depths of 10 m, especially on sandy bottoms and among algae (Thomé et al., 2004). Both the goldspotted eel and the king helmet have been frequently observed during the day at low tide on the coastal reefs at Cabo Branco Beach, João Pessoa, Paraíba, northeastern Brazil (7°08'50"S, 34°47'51"W) at depths between 0.5 and 2 m. A casual interaction between these species was first recorded on Cabo Branco reef in January 6, 2007 during a field research in the area. On that occasion, I was following *M. ocellatus* to register its foraging behavior when the eel (about 35 cm in total length) had a chance encounter with *C. tuberosa* (18 cm in shell length). They remained "face to face" for approximately 30 seconds while the eel carefully observed the anterior end of the gastropod (Figure 1). Soon after, *M. ocellatus* changed its swimming direction and continued its search for prey along the rubble bottom. During the event, no aggressive behavior was observed, reinforcing the casual nature of the interaction. Interspecific interactions have previously been registered between *M. ocellatus* and other reef fish in Brazil, such as the grouper *Epinephelus marginatus* (Gerhardinger et al., 2006), but possible ecological associations between *M. ocellatus* and *C. tuberosa* need to be more closely investigated. Picture's characteristics: Digital Machine model Canon PowerShot S50, 5 megapixels resolution (180 dpi), diaphragm aperture 2.8, time of exposition 1/1000.

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Original Scientific Photographs

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Mulletts are ubiquitous fish species that are found in tropical and semi-tropical regions of the globe. The white mullet, *Mugil curema* Valenciennes, 1836, is a catadromous fish, inhabiting sandy coasts and littoral pools but also occurs in muddy bottoms of brackish lagoons and estuaries being widely distributed along the Atlantic and Eastern Pacific (Froese & Pauly 2007). At Patos Lagoon in southern Brazil, juvenile mullets change their diet from zooplankton to iliophagous (a combination of benthic microorganism, detrital material and inorganic sediment), their most important food items are diatoms, dinoflagellates and mineral particles (accidentally ingested) (Vieira 1991). Although it is a common bottom feeder (on microscopic or filamentous algae) it can be an actively planktonic feeder, as observed on FEB 2006, from 8:30 to 9:00 a.m., where a small school of white mullets were intensively foraging on planktonic organisms on the air-water interface, over a rhodolith bank at Arvoredo Marine Biological Reserve, Santa Catarina, Brazil. Schools and swimming patterns of juvenile forms of this species were already studied (Carvalho *et al.* 2001) and it was also observed associated to the striped mullet (*Mugil cephalus*) by Odum (1968) feeding heavily upon a bloom of the dinoflagellate *Kryptoperidinium* in an estuarine river near Sapelo Island (USA); which were obtained near the air-water interface. It is also reported that after the four-day-bloom the mullet returned to a "normal" benthic diet of *Spartina* detritus particles, benthic diatoms and sediment particles, which conducted to the conclusion the *Mugil* presents a low efficiency in assimilating this energy source. Morphology studies of gill arches revealed that the species do not select food chemically but obtain it mechanically with the rakers and aggregate it with mucus (Eiras-Stofella *et al.* 2001). Picture Characteristics: A. Canon 20D; resolution of 8 megapixels (300 dpi), Speed ISO-400, diaphragm aperture F/9, time of exposition 1/640, Canon 75-300 mm lenses; B. Canon PowerShot S70, resolution of 7 megapixels (180 dpi), autofocus mode, Speed ISO-50, diaphragm aperture F/2.8, time of exposition 1/250.

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