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Artículo de fondo

Captures of the night shark *Carcharhinus signatus* by surface longliners along the southern Brazilian coast

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Size composition of the night shark *Carcharhinus signatus*, caught by the pelagic longline fishery off the southeastern and southern Brazil, was described. Data were obtained from national longliners landings in Itajaí and Navegantes Fishing Terminal (State of Santa Catarina, Brazil), from sea-observers cruises aboard this commercial fleet, and by research vessels longline cruises between 1996 and 2008. The size composition caught by the commercial fleet was estimated through the conversion of carcass weight (CW) into fork length (FL). Additionally, the relative abundance level of this species was analyzed with its spatial and temporal variables. Total and fishing mortality were also estimated from catch curves. Catches were concentrated over the slope, between 500 and 4 000 meters deep, but they were also recorded over seamounts. Commercial catches were composed mainly of juveniles (between 100 and 120 cm FL), which represented 64.6 % of the total individuals (n = 5 522). The largest proportion of juveniles occurred in fall, with 74.4% from 1997 to 2002. The variables that produced a significant effect over the relative abundance ($p<0.05$) were the year, the season and the type of bait. Relative abundance declined over the years, and similar behavior was observed in each fishing vessel individually. Yields were higher in spring, when the bait was squid. Mortality estimates, obtained from catch curves, indicated a mean value of 29% deaths per year, while 15% were by natural causes and 14% by fishing.
Keywords: night shark, size composition, fishing mortality.

Capturas del tiburón nocturno *Carcharhinus signatus* por los palangreros pelágicos en la costa sur de Brasil

Se describe la composición de longitudes furcales del tiburón nocturno *Carcharhinus signatus* capturado en la pesquería de palangre pelágico en el ambiente oceánico de la costa sureste y sur de Brasil. Los datos fueron obtenidos de los desembarques de los palangreros en los puertos de Itajaí y Navegantes, estado de Santa Catarina, Brasil, de observadores a bordo de la flota comercial y por cruceros en buque de investigación entre 1996 y 2008. La composición de longitudes furcales (FL) fue obtenida por la conversión del peso de los tronchos (CW) desembarcados. Además se relacionaron sus niveles de abundancia relativa con variables espacio-temporales. Se estimó la mortalidad total y por pesca con las curvas de captura. La captura de la especie estuvo más concentrada en el talud continental entre 500 y 4 000 m, pero también en montes submarinos. Las capturas comerciales fueron en su mayoría de juveniles (entre 100 y 120 cm FL), lo que representó 64.6% del total de los individuos (n = 5 522). La mayor proporción de juveniles ocurrió en otoño, con 74.4%, de 1997 a 2002. Las variables con mayor efecto significativo sobre la abundancia relativa ($p<0.05$) fueron el año, la temporada y tipo de carnada. La abundancia relativa declinó a lo largo de los años y el mismo efecto se observó individualmente en las embarcaciones. Los mayores valores de captura fueron en primavera, cuando se utilizó calamar como cebo. Las estimaciones de mortalidad obtenidas con la curva de captura, señalaron una media de 29% de muertes al año, siendo 15% por mortalidad natural y 14% por pesca.
Palabras clave: tiburón nocturno, composición de tallas, mortalidad por pesca.

Introduction

The main cause of mortality in slow-growing species like chondrichthyans has been as bycatch in fisheries targeting another species (Bonfil 1994, Musick *et al.* 2011). The growing fishing pressure over sharks has mainly been driven in the last decades by the international demand for their

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fins, and by their meat and byproducts (Kotas *et al.* 1999, Hazin *et al.* 2000). The steep rise in the fishing intensity over these elasmobranchs, as to its low resilience, led many species to critical levels of biological extinction (Camhi *et al.* 1998, Dulvy *et al.* 2014, Davidson *et al*. 2016).

The night shark *Carcharhinus signatus* (Poey 1868), a deepwater coastal and semi-oceanic carcharhinid, endemic to the Atlantic Ocean, is distributed along the outer continental/insular shelves and off the upper slopes, preferentially between 50 to 100 m deep, in tropical, subtropical and warm/temperate waters (Compagno 1984, Soto 2001). Along the east American coast, *C. signatus* occurs from Delaware, United States of America (USA) (38°22' N, 69°35' W, Mather & Gibbs 1957) to southern Argentina (43° S). The species also occurs along the West African coast, from Cap Vert (Senegal) (14°45' N) to northern Namibia (18° S) (Krefft *pers. comm.* 1980[1], Compagno 1984, Garrick 1985, Compagno *et al.* 1989). There was also an unconfirmed register in the eastern Pacific (Panamá) (Compagno 1984). Poll (1951) recorded catches of this species at depths of 90 to 285 m, temperatures from 11 to 16 °C, salinity 36 ppt and oxygen 1.81 ml/l. They are commonly caught in schools (mainly at night or dawn), indicating a vertical migration. It inhabits the epipelagic environment (<183 m) at night and between 275 and 366 m during the day (Castro 1983). However, its vertical distribution ranges from the surface to 600 m deep (Bigelow & Schroeder 1948, Poll 1951, Boschung 1979, Raschi *et al.* 1982, Compagno 1984, Garrick 1985).

Historically, night sharks were overexploited by artisanal Cuban shark fishery being 60-75% of the catch from 1937-1941. However, in the beginning of the 70's a substantial decline in the abundance of this species was observed (Martinez 1947, Guitart-Manday 1975). Nowadays, the species is rare in the Caribbean Sea (Castro *et al.* 1999, IUCN 2017[2]). Night sharks comprised 26.1% of the shark catches in the pelagic USA longline fishery off the east coast of Florida from 1981-1983, but declined to 3.3% in 1994 (Berkeley & Campos 1988). In the southwest coast of the USA, the mortality of the night shark in the catches of the surface longliners was more than 80% (Beerkircher *et al.* 2002). In USA waters, the night shark *C. signatus*, is a Prohibited Species since 1992. Recent time/area closures off the Florida Straits and the Charleston Bump were established to reduce the bycatch of this species (Beerkircher *pers. comm.*[3]). Recent trends in catch rates, based on pelagic logbook data, indicated that the catches stabilized since 1992 and are still caught as bycatch making up only 2% of the shark catch (Brown & Cramer 2002).

Night sharks were commonly caught in the western Gulf of Mexico by small-scale Mexican shark fishermen (Rodríguez de la Cruz *et al.* 1996[4], Bonfil 1997, Castillo-Géniz *et al.* 1998). *C. signatus* is the commonest *Carcharhinus* in the Brazilian shelf breaks (Gadig & Moreira 1992, Menni *et al.* 1995, Soto 2001). For this species, there are two important fishing areas: one in the northeast and another in the southern coast. In the northeast coast, *C. signatus* occurs over shallow seamounts (3° to 4° S) (33° to 38° W) (Hazin *et al.* 1990, Menni *et al.* 1995). In this case, populations are extremely vulnerable, due to their gregarious behavior. There is a low or inexistent genetic exchange between adjacent populations (Santana *et al.* 2009). In southern Brazil and Uruguay, the species has been recorded over the continental slope (27° to 35° S), from 300 to 3 000 m local depth. Krefft *pers*. *comm.* (1980[1]) reported 12 juveniles caught off southern Brazil and Uruguay (33°-35°20' S, 51°20'-52°41' W). In this area, the Subtropical Convergence [defined by the confluence of Brazil Current (warm waters with few nutrients) with the Malvinas (Falkland) Current (cold waters rich in nutrients)] determines the distribution and migration pattern of *C. signatus* (Vaz dos Santos *et al.* 2007). Although there are

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2. IUCN. 2017. *IUCN Red list of threatened species*, www.iucnredlist.org. Downloaded on 11 September 2017.
3. Beerkircher L. 2017. South Atlantic and Gulf states, NOAA Fisheries.
4. Rodríguez de la Cruz MC, JL Castillo Géniz, JF Márquez Farías. 1996. Evaluación de la pesquería de tiburón del Golfo de México. Informe Final del Proyecto de Investigación 116002-5-13134N-9206. Consejo Nacional de Ciencia y Tecnología/Instituto Nacional de Pesca. México. 199p.

regional differences in the growth patterns of *C. signatus* from the northeast and southern coasts of Brazil, its population structure is unknown, *i.e*., if there is only one stock or if there are at least two, one in the northeast and another in the south (Hellebrandt 2001, Santana *et al*. 2006[5]).

The maximum total length (TL) and maximum weight (TW) registered for the adults of this species was a male 2.8 m (Sanches 1991) and 76.7 kg (IGFA 2001[6]), respectively (Froese & Pauly 2015). Springer & Thompson (1957) recorded a male of 2.4 m total length (TL) and Raschi *et al.* (1982) a female of 2.6 m TL (Garrick 1985). Guitart-Manday (1975) built a length-weight curve for the night shark caught in Cuba: $TW = 0.2998 \cdot 10^{-6} \cdot TL^{3.738}$ (TW = total weigth).

The reproductive pattern of *C. signatus* is placental viviparity (Wourms 1981, Compagno 1988, Dulvy & Reynolds 1997, Parsons *et al.* 2008). In the Atlantic Ocean, the number of embryos per litter ranges from 4 to 18 (Bigelow & Schroeder 1948, Poll 1951, Springer & Thompson 1957, Daiber 1960, Branstetter 1981, Cadenat & Blache 1981, Raschi *et al*. 1982). Uterine fecundity observed by Hazin *et al.* (2000) varied between four and 15 embryos per gestation and mean birth size between 40-67 cm TL (Guitart-Manday 1975, Applegate *et al.* 1979, Raschi *et al*. 1982, Hazin *et al.* 2000, Santana 2001). In Brazilian waters, births occur in spring/summer, *i.e.* between October and February (Santana 2001). Along the northeastern Brazilian coast, copulation occurs between November and December, over seamounts near Natal (State of Rio Grande do Norte) (Amorim *et al.* 1998). Gestation supposedly is one a year and the embryo sex ratio is 1:1 (Hazin *et al.* 2000, Santana 2001). The reproductive frequency is annual. Previous studies throughout the Atlantic found that males reach maturity from 154 cm TL onwards (Krumholz 1957, Springer & Thomson 1957, Krefft *pers. comm.* 1980[1], Cadenat & Blache 1981) and females from 174 cm TL onwards (Poll 1951, Daiber 1960, Krefft *pers. comm.* 1980[1], Branstetter 1981, Cadenat & Blache 1981, Raschi *et al*. 1982). In the northeastern Brazil, sexual maturity is estimated between 200 and 205 TL in females and 185-190 cm TL in males (Hazin *et al.* 2000). On the other hand, Santana & Lessa (2004) found the first maturity size at 180-190 cm TL for males and 200-205 cm TL for females. These lengths represent approximately eight and 10 years of age for males and females, respectively (Santana *et al.* 2006[5]).

Age and growth studies were done in this area from vertebral sections (n = 317). Von Bertalanffy parameters estimates were $L_\infty = 270$ cm TL, $k = 0.11$ yr^{-1} and $t_0 = -2.71$ yr. The maximum age was 17 years and no significant differences were detected in the growth functions between sexes (Santana & Lessa 2004).

Vaske-Júnior *et al.* (2009) found in the stomachs of the night shark 10 species of fish, 14 cephalopods, three crustaceans, one tunicate and one seabird, but there is a preference for migrant squids and pelagic teleosts. The species search for prey in the pelagic waters, around the oceanic banks and occasionally come near the shelf break of the banks. Patokina & Litvinov (2005) also found shelf break species in the stomachs of *C. signatus.* The species has a trophic level of 4.2 (Cortés 1999).

A parasitic copepod, *Kroyeria caseyi*, was found infesting the gills of night sharks in the western North Atlantic (Benz & Deets 1986).

Along the Brazilian coast, surface longliners began to operate in the 50's from Recife, State of Pernambuco, with Japanese leased vessels, multifilament longlines targeting tuna (*Thunnus obesus, T. albacares* and *T. alalunga*) and sharks were discarded (Amorim & Arfelli 1988[7]). The fishing strategy changed in the 80's due the rise of the fin market in Asia and sharks began to suffer the *finning* (Camhi *et al.* 1998). During the 90's, the pelagic longline fishery, using the "Japanese system" (multifilament) was replaced with the "American system" (monofilament), which was initially directed to areas where there were great chances of catching the swordfish (*Xiphias gladius*), and non-using steel wire gangions, they avoided catching sharks. However, with the increase

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demand for shark fins, driven by the Asian market, many vessels started to use steel wire gangions to catch them (Kotas *et al.* 1999, Neves & Mancini 2009). Even with the decrease in the yields of several species, as in the cases of the hammerhead (*Sphyrna lewini*, *S. zygaena*), the bigeye thresher (*Alopias superciliosus*) and the night sharks (*C. signatus*), these selachians continued to be caught using the steel wire gangions, threatening them with extinction (IUCN 2017[2]). Initially, the night shark was considered a bycatch of semi-oceanic longliners, but nowadays, it is considered a target species, due its meat and fins value, in areas of relative large abundance around seamounts (Hazin *et al.* 2000). However, the average total mercury (Hg) concentration found in the muscular tissues of *C. signatus* (1 742 μg/kg) was higher than the maximum limit allowed for human consumption established by the Brazilian Health Ministry for carnivorous fishes (1 000 μg/kg). Body length and sex cannot be used as an indicator of the Hg contamination degree for this species (Brasil 1975[8], Ferreira *et al.* 2004).

The aims of this study are: *1)* Analyze the spatial and temporal trends in the yields of *C. signatus* caught by industrial longliners placed in Itajaí and Navegantes, State of Santa Catarina; *2)* Test the main effects in the yields of this species; *3)* Assess the size composition of the night shark caught by this fleet; *4)* Estimate its total (Z) and fishing (F) mortality rates, using length-based catch curves.

This study is justified by the necessity to take measures to protect this shark species, thus avoiding stock depletion. *C. signatus* is a long-lived species and low-resilient to high levels of fishing mortality (Musick *et al.* 2011). The species is globally considered vulnerable (VU) (IUCN 2017[2]) and in Brazil (Subirá *et al.* 2012). However, except for USA jurisdictional waters, it continues to be caught throughout the Atlantic Ocean, without any specific control.

Material and methods

Data were collected from the commercial longliners placed in Itajaí and Navegantes, State of Santa Catarina, Brazil, and longline research cruises, between 1996 and 2008 (Table 1).

Length composition analysis

Morphometry and weight-length relationship in sharks are important to rebuild the original size compositions of the animals landed by the fleet (Hazin *et al.* 2000). Therefore, to convert carcass weight (CW) into fork length (FL), it was necessary to construct, the relationship with 39 night sharks sampled aboard commercial and longline research vessels from the REVIZEE Program and TAMAR Project, a model of the type $CW = \alpha\ FL^{\beta}$, for combined sexes, where the error structure was considered multiplicative and the dispersion diagram was nonlinear. The measurements registered aboard were total length (TL, cm), fork length (FL, cm), carcass length (CL, cm), total weight (TW, kg) and carcass weight (CW, kg) (*i.e.*, without head, fins and gut) (Table 2).

To estimate the parameters α and β, the model $CW = \alpha\ FL^{\beta}$ was linearized using neperian logarithms (*e* base):

$$\text{Ln}\ CW = \ln\alpha + \beta \ln FL + \epsilon \qquad \text{Eq. 1}$$

Where: ln = neperian logarithm (*e* base) and ϵ = error (unexplained variation).

After building the weight-length relationship, the CW of 5 459 *C. signatus* landed by longliners placed in Itajaí, from 1997 to 2006, were converted into FL to describe the annual and seasonal variation in the size composition caught by this fleet.

The morphometric relation between FL and TL and the age-length key used to convert total lengths into ages, was based on Santana & Lessa (2004) for the northeast Brazilian coast. The separation of modes in the length compositions of *C. signatus* was obtained using the routine NORMSEP in the FISAT II (version 1.2.2.) software package. The annual and seasonal length compositions were represented by histograms, with their respective means and standard deviations (SD).

Description of the fishing area

The spatial distribution of *C. signatus* catches was obtained from 605 longline sets. In this case, at the end of each set, date, time, position (latitude and

8. Brasil. 1975. Diário Oficial da União. Resolução n. 18/75.

Table 1
Source of data on *Carcharhinus signatus* captures

Program/project	*Source of data*	*Fishing gear*
Assessment Program of Living Resources from the Economic Exclusive Zone (REVIZEE – South Score).	Observers aboard national commercial longliners placed in Itajaí and Navegantes (State of Santa Catarina), between 1996 and 2001	Longliners used 195 to 1 088 hooks/set and "j" hook type (9/0 0° offset)
ARGO Project.	Longline research cruises aboard R.V. "Atlântico Sul" in 1996	Between 296 and 565 hooks/set and "j" hook type (8/0 0° offset)
Assessment Program of Living Resources from the Economic Exclusive Zone (REVIZEE – South Score).	Longline research cruises aboard R.V. "Soloncy Moura", between 2002 and 2003	300 hooks/set and "j" hook type (9/0 0° offset)
Sea Turtle Project (TAMAR).	Hook selectivity tests performed aboard R.V. "Soloncy Moura" between 2002 and 2008.	Test group composed of 500 hooks/set, being 250 "circle" hook types (18/0 10° offset) interspersed with 250 "j" hook types (9/0 0° offset)
Assessment Program of Living Resources from the Economic Exclusive Zone (REVIZEE – South Score).	Carcass weight (CW) (kg) of 5 459 *C. signatus* landed by longliners placed in Itajaí, from 1997 to 2006	Longliners used 195 to 1 088 hooks/set and "j" hook type (9/0 0° offset)
Albatroz Project	Observer's cruises aboard national commercial longliners placed in Itajaí, Navegantes and Santos (State of São Paulo), between 2001 and 2007.	Longliners used 230 to 1 550 hooks/set and "j" hook type (9/0 0° offset).

Table 2
Night shark *Carcharhinus signatus* sampled aboard commercial and longline research vessels to build the model $cw = \alpha \cdot FL^{\beta}$

Cruise	*Year*	*Season*	*Sex*	*FL (cm)*	*CW (kg)*
REVIZEE Program - R.V. Soloncy Moura	2002	Spring	M	156	22
”	2003	Fall	F	77	3
”	2003	Fall	F	191	42
”	2003	Fall	F	96	7
”	2003	Fall	F	99	7
”	2003	Fall	F	201	52
”	2003	Fall	M	128	17
”	2003	Fall	M	93	6
”	2003	Fall	M	94	6
”	2003	Fall	M	93	6
”	2003	Winter	M	91	5
REVIZEE Program - commercial longliner	1998	Fall	F	204	45
“	1998	Fall	F	143	20
“	1998	Spring	F	124	12
“	1998	Spring	F	143	19
“	1998	Spring	F	125	12
“	1998	Spring	F	138	18
“	1998	Spring	F	126	10
“	1998	Spring	F	111	9
“	1998	Spring	M	132	12
“	1998	Spring	M	120	8
“	1998	Spring	M	126	11
“	1998	Spring	M	111	10
“	1998	Winter	M	162	28
“	1998	Winter	M	132	14
TAMAR Project - R.V. Soloncy Moura	2002	Spring	M	156	22
“	2003	Fall	F	77	3
“	2003	Fall	F	191	42
“	2003	Fall	F	96	7
“	2003	Fall	F	99	7
“	2003	Fall	F	201	52
“	2003	Fall	F	86	5
“	2003	Fall	M	128	17
“	2003	Fall	M	93	6
“	2003	Fall	M	94	6
“	2003	Fall	M	93	6
“	2003	Winter	M	91	5
“	2005	Spring	F	108	8
“	2008	Summer	M	134	18
39 organisms					

longitude), number of hooks used/set, local depth (m), sea surface temperature (°C), atmospheric pressure (mm Hg), sea condition (Beaufort scale), type of bait used (squid, mackerel or sardine) and number of *C. signatus* caught/set were registered. Using the software Arcview 9.3, the occurrences of *C. signatus* were plotted on a map.

The seasonal distributions of the CPUE of *C. signatus* were also plotted on maps. The catch per unit effort (CPUE) used was number of sharks /1 000 hooks, obtained from 2 505 longline sets. To analyze the CPUE seasonality, these were defined: spring (from October to December), summer (from January to March), fall (from April to June) and winter (from July to September).

Temporal trends in the CPUE

The annual and seasonal trends in the mean CPUE (number of sharks landed/trip) of *C. signatus* caught by surface longliners placed in Itajaí, which landed more than 500 individuals from 1997 to 2005, were analyzed. Therefore, CPUE data from four fishing vessels were considered: Marbella (n = 1 400 sharks), Macedo IV (n = 1 054), Macedo I (n = 968) and Yamaya III (n = 516).

Testing the main effects in the CPUE

For the temporal trends in the CPUE analysis, the significance ($p<0.05$) of the temporal, spatial, oceanographic and fisheries effects on the variation of this relative abundance index was tested. The tested effects were: year, seasonality, latitude, bait, sea surface temperature and local depth. Analysis of variance (ANOVA) and generalized linear models (GLM) were tested on CPUE data, which were linked to their effects and interactions (Hilborn & Walters 1992, Zar 1999, Venables & Ripley 2002).

Mortality estimates

Natural mortality estimates (M) were indirectly obtained using the methods of Pauly (1980) and Jensen (1996), which were compared with the mean values of M, obtained by the methods of Peterson & Wroblewsky (1984), Lorenzen (1996) and Chen & Watanabe (1989). Finally, a general mean of M considering all the previous methods was calculated. For the method of Pauly (1980), growth parameters used in the empirical equation were from Santana & Lessa (2004): $L_\infty = 270$ cm; $k = 0.112$ yr^{-1} and the mean sea surface temperature, T = 22 °C, from the fishing cruises monitored.

The Hoenig (1983) method, based on longevity, was also used to estimate the total mortality (Z) of the night shark.

Additionally, among the empirical methods to estimate Z, length-based catch curves was used, and the fishing mortality (F) as the result of Z - M (Ricker 1975, Sparre & Venema 1997).

Initially, an estimate of Z of all the period, 1997 to 2005 was obtained. Afterwards, annual catch curves were used to estimate the values of Z separately for the years 1997, 1998, 2000, 2001, 2002, 2004 and 2005. The Microsoft Office Excel spreadsheets (2016 version) were used to analyze the catch curves.

With the estimates of Z, the proportion of individuals that die each year was obtained calculating the survival rate (S):

$$S = \frac{N_t}{N_0} = e^{zt} \qquad \text{Eq. 2}$$

Where: N_t = number of sharks alive at time t; N_0 = number of sharks alive at time 0; t = 1 year; S = Survival rate (%)

Finally, the exploitation rate (E) was calculated (Sparre & Venema 1997).

$$E = F/Z \qquad \text{Eq. 3}$$

The value of E ranges between 0 and 1. Fish stocks with values near one are overexploited and near zero are underexploited. The equilibrium is found with E = 0.5 (Pauly 1980).

Results

Spatial distribution of Carcharhinus signatus

From 1996 to 2008, the area where *C. signatus* was caught by the commercial longline fleet and research vessels was mainly delimited by the latitudes 18° to 36° S and longitudes 36° to 52° W. The species occurred mainly over the continental slope of southeastern and southern Brazil coast, in areas with local depths between 200 and 4 000 m.

A few registers occurred in shallower depths (Fig. 1). Although the species was caught throughout the year, the best yields were found in spring. During this season, CPUE reached values between 70 and 170 individuals/1 000 hooks (Fig. 2).

Conversion of CW into FL

A total of 39 *C. signatus* were measured (Fig. 3) to obtain parameters of the relationship between CW and FL, through linear regression analysis, the intersection $\ln \alpha = -10.77$, therefore $\alpha = e^{-10.77} = 0.0000209264$, and the slope $\beta = 2.76$. The coefficients α and β, estimated from the regression line, were significant ($p<0.01$) and its regression slope was different from zero. Therefore, the non-linear relationship CW *vs* FL was: $CW = 0.0000209264 \cdot FL^{2.76}$ ($n = 39$, $r^2 = 0.97$).

Size composition of Carcharhinus signatus caught by the longliners

From 1997 to 2008, the pelagic longline fleet placed in Itajaí, caught 5 622 *C. signatus* between 63.8 and 299.0 cm FL (mean = 140.9 cm, SE = 36.9 cm). A percentage of 64.6 were below the first sexual maturity size interval for males and females, which is between 156.0 and 173.0 cm FL (Hazin 2000). Fishing mortality affected juveniles and adults, but mainly juveniles. A bimodal pattern in size composition of *C. signatus* caught by the pelagic longliners was observed, with the first mode represented mainly by juveniles (recruits to the fishery) between three and four years of age (132.5 cm TL) and the second by adults between eight and nine years of age (192.5 cm TL) (Table 3 and Fig. 4).

The seasonal length composition of *C. signatus* caught by the longliners between 1997 and 2008 indicated that 74.4% of the individuals were during fall (n = 1 671, mean = 137.2 cm, SD = 41.1 cm),

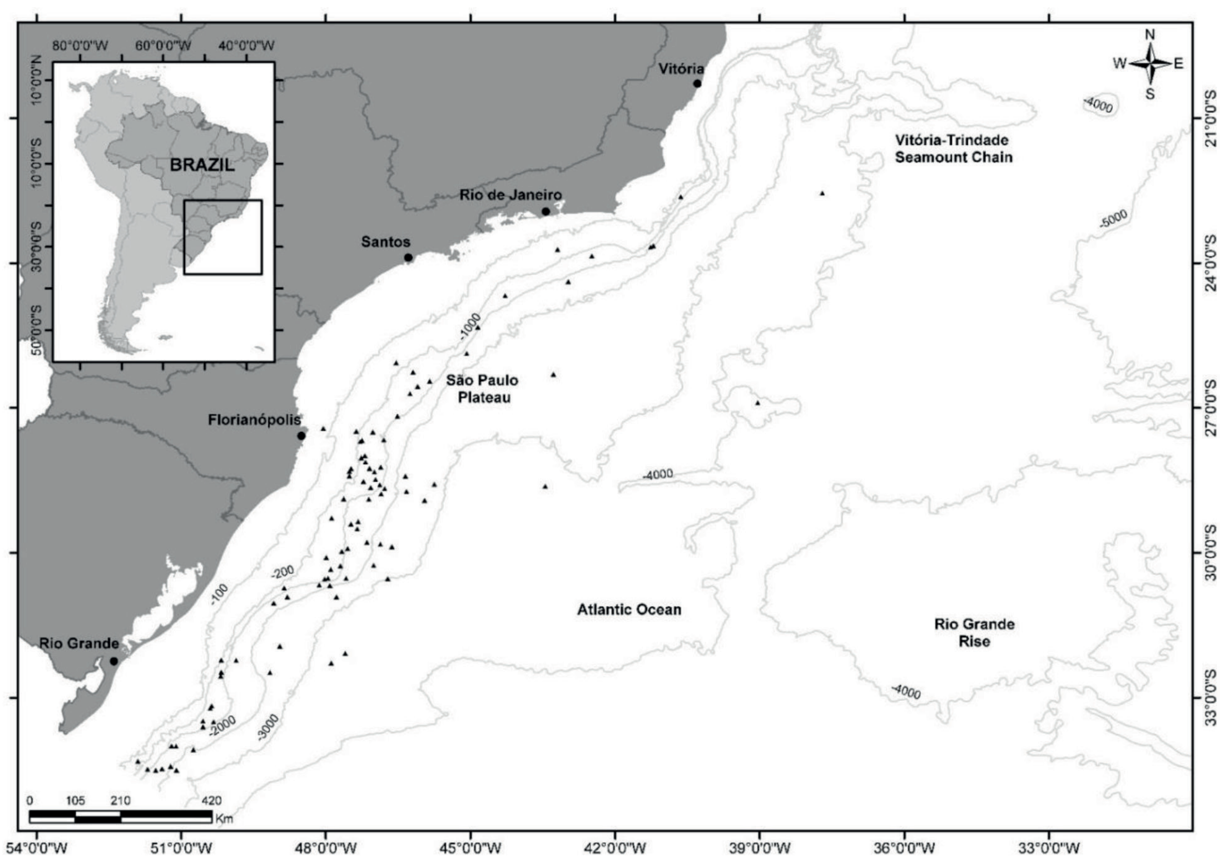

Fig. 1. Sites with occurrence of the longline catches of *Carcharhinus signatus* (1996 to 2008). Numbers are depths (m).

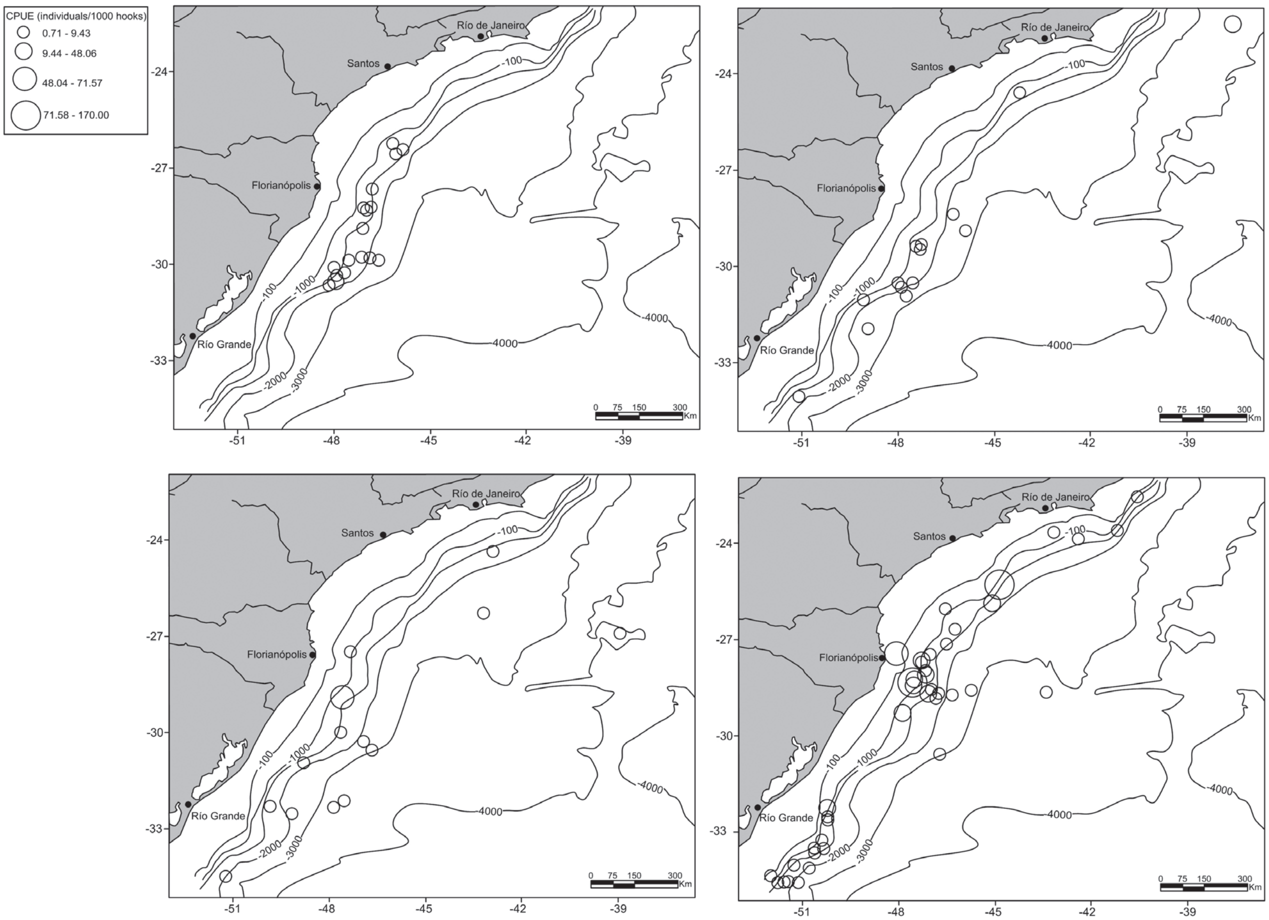

Fig. 2. Seasonal distribution of *Carcharhinus signatus* CPUE (individuals/1 000 hooks) (1996 to 2008).

64.9% in winter (n = 1 810, mean = 140.3 cm, SD = 35.5 cm), 60.4% in spring (n= 1 851, mean = 145.8 cm, SD = 37.8 cm) and 58.7% in summer (n = 205, mean = 147.4 cm, SD = 35.7 cm) were below the first maturity size. Therefore, the occurrence of juvenile's catches was high throughout the seasons, mainly in fall and winter (Fig. 5).

The seasonal mean lengths showed significant differences (F = 23.28, p<0.01). Afterwards, the paired comparisons through the Tukey's test evidenced significant differences between winter and spring (p<0.01), winter and summer (p<0.01), fall and spring (p<0.01) and fall and summer (p<0.01). Mean FLs were higher in spring and summer. Also, mean FL did not differ significantly between winter and fall (p = 0.79), or between spring and summer (p = 0.19) (Table 4).

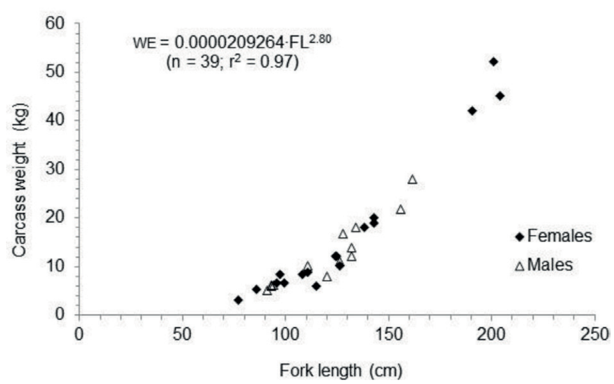

Fig. 3. Scatter plot between CW (kg) and FL (cm) for *Carcharhinus signatus.* Data obtained from sea observers aboard commercial longliners (REVIZEE Program) and research cruises (TAMAR Project). Females are represented by filled diamonds form and males by empty triangles.

Table 3
Age frequency (number of sharks) in each total length class (cm) of *Carcharhinus signatus* caught by the pelagic longline fishery between 1997 and 2008. The age-length key used was based from Santana & Lessa (2004), for the northeastern Brazilian coast. Grey zone is the first maturity interval (between 190 and 210 cm TL)

		Age (years)												
TL (cm)	*n*	**2**	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*15*	*17*
112.5	265	265												
117.5	273	273												
122.5	343	229	114											
127.5	347	43	304											
132.5	348		232	116										
137.5	237		142	95										
142.5	253	23	23	161	46									
147.5	343		43	214	43	43								
152.5	150			43	93	14								
157.5	246		6	50	139	50								
162.5	106		3	9	54	40	3							
167.5	229			35	79	79	26	9						
172.5	169				35	82	52							
177.5	86				16	45	12	12						
182.5	168					56	56	56						
187.5	145					12	60	60	12					
192.5	265							166	99					
197.5	152						25	76	38	13				
202.5	141								101	20	20			
207.5	198								66	132				
212.5	122									61	61			
217.5	200										100	100		
232.5	57												57	
242.5	30													30
Total	4 873	833	867	723	506	422	236	379	316	226	181	100	57	30

Table 4
Tukey's test applied to the seasonal means of the FL (cm) of *Carcharhinus signatus* caught by the pelagic longline fleet in the port of Itajaí (State of Santa Catarina) (1997 to 2002) (bold values p<0.01)

	Probabilities (p)			
Seasons	*Winter*	*Fall*	*Spring*	*Summer*
Winter		0.799637	**0.000008**	**0.000052**
Fall	0.799637		**0.000008**	**0.000015**
Spring	**0.000008**	**0.000008**		0.195384
Summer	**0.000052**	**0.000015**	0.195384	

The same pattern of numerous juvenile catches occurred throughout the years (Fig. 6), and the mean FL caught between 1997 and 2002 indicated this trend (Fig. 7). Again, significant differences were detected between the annual mean FL ($F = 73.85$, $p<0.01$). The Tukey's test indicated that the mean FL was higher in 2000 compared to the other years ($p<0.01$), with no significant differences between the mean FL of the other years ($p>0.05$) (Table 5).

Table 5
Tukey's test applied to the FL means (cm) of *Carcharhinus signatus* caught by the pelagic longline fishery in the port of Itajaí (State of Santa Catarina) (1997 to 2002), (bold values p<0.01)

	Probabilities				
Years	*1997*	*1998*	*2000*	*2001*	*2002*
1997		0.210589	**0.000017**	0.999853	0.977300
1998	0.210589		**0.000017**	0.276970	0.865030
2000	**0.000017**	**0.000017**		**0.000017**	**0.000017**
2001	0.999853	0.276970	**0.000017**		0.989692
2002	0.977300	0.865030	**0.000017**	0.989692	

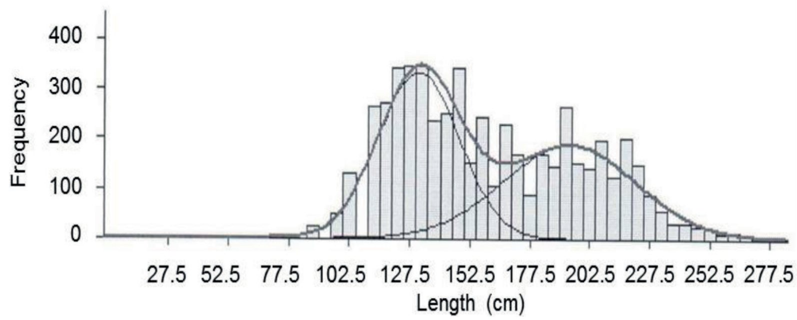

Fig. 4. Length frequency distribution caught by the pelagic longline fishery between 1997 and 2008. The size interval of first sexual maturity for both sexes is between 192.5 and 207.5 cm TL. Using the NORMSEP routine, two modes were drawn over the length composition.

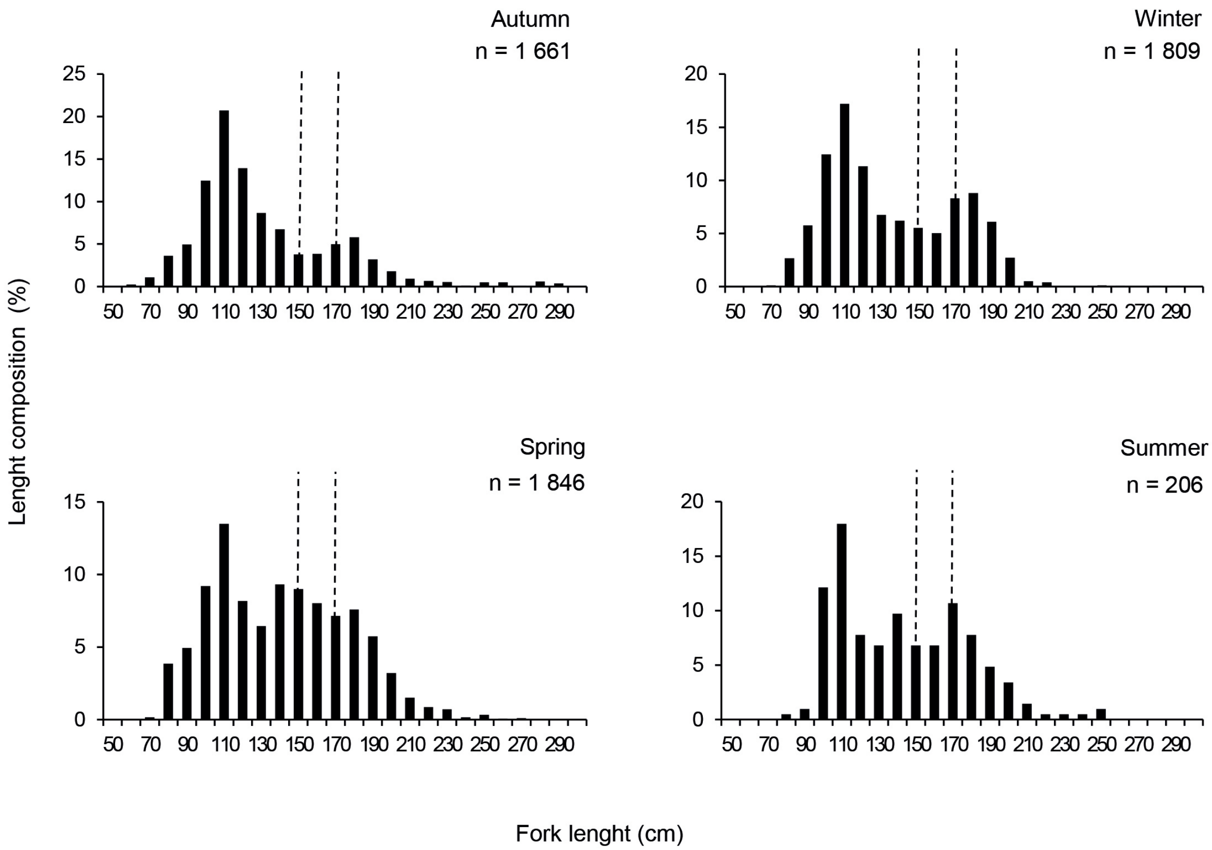

Fig. 5. Seasonal length composition of *Carcharhinus signatus* caught (1997 to 2008). Vertical dotted lines – interval of first maturity for both sexes (between 156 and 173 cm FL; n = 5 537)

Trends in the southern stock

Signs of declines in the southern stock of the night shark were detected when analyzing the annual landings (kg), yields (kg/trip) and relative proportion (%) of *C. signatus* in the total elasmobranch landings of industrial longliners placed in the State of Santa Catarina from 2000 to 2012. In 2000, the species represented 7.8% of the total elasmobranch catches. On the other hand, in 2010, the species did not surpass 0.4% (GEP 2012[9]) (Fig. 8). In winter and spring, the best mean yields (kg/trip) were found, *i.e.* 147 kg/trip and 130 kg/trip for winter and spring, respectively (Fig. 9).

9. GEP (Grupo de Estudos Pesqueiros/UNIVALI). Disponível em http://siaiacad04.univali.br/, acesso em 23 de abril de 2012.

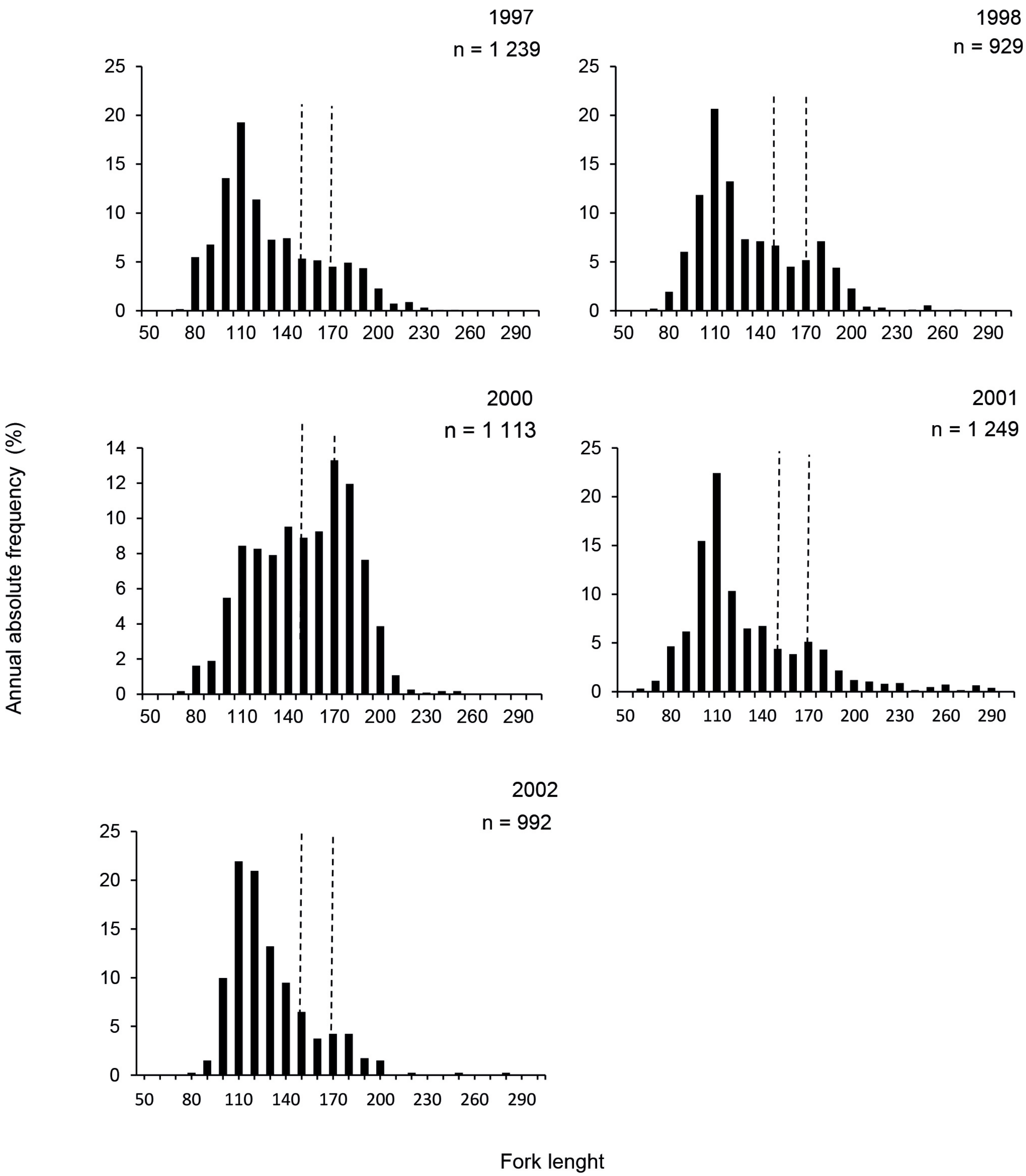

Fig. 6. Annual absolute frequency of the *Carcharhinus signatus* FL (cm) (1997, 1998, 2000, 2001 and 2002). Vertical dotted lines - interval of first maturity for both sexes (between 156 and 173 cm FL).

Annual trends in the mean CPUE (number of sharks landed/trip) of *C. signatus* caught by surface longliners placed in Itajaí from 1997 to 2006 also showed declines (Figs. 10 and 11). Considering CPUE data of the fishing vessels pooled, ANOVA test detected significant yearly differences ($p<0.01$). Through the Tukey post-hoc test, the differences were between 1996, 1998, 2002, 2003, 2005, and 2006 (Table 6). Considering each fishing vessel separately, ANOVA test showed significant yearly differences ($p<0.05$) only for the vessel Macedo I. In this case, the Tukey's test evidenced differences in the mean CPUE between 1997, 2001, 2004 and 2005 (Table 7).

Table 6
Tukey's test applied to the annual mean CPUE (number of sharks/trip) of *Carcharhinus signatus* caught by the longliners Macedo I, Macedo IV, Marbella and Yamaya III (data pooled) for the period 1996 to 2007 (**bold values** p<0.01)

	Probabilities								
Year	*1996*	*1997*	*1998*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
1996		0.544	**0.004**	**0.025**	**0.006**	0.062	**0.000**	**0.009**	0.086
1997	0.544		1.000	1.000	1.000	1.000	1.000	1.000	0.998
1998	**0.004**	1.000		0.998	0.992	0.999	0.987	0.997	0.988
2002	**0.025**	1.000	0.998		1.000	1.000	1.000	1.000	0.925
2003	**0.006**	1.000	0.992	1.000		1.000	1.000	1.000	0.841
2004	0.062	1.000	0.999	1.000	1.000		1.000	1.000	0.962
2005	**0.000**	1.000	0.987	1.000	1.000	1.000		1.000	0.652
2006	**0.009**	1.000	0.997	1.000	1.000	1.000	1.000		0.897
2007	0.086	0.998	0.988	0.925	0.841	0.962	0.652	0.897	

Table 7
Tukey's test applied to the annual mean CPUE (number of sharks/trip) of *Carcharhinus signatus* caught by the longliner Macedo I, for the period 1997 to 2006 (**bold values** p<0.01)

	Probabilities								
Year	*1997*	*1998*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*
1997		0.525	0.828	**0.028**	0.319	0.412	**0.035**	**0.042**	0.885
1998	0.525		1.000	0.828	0.971	0.989	0.849	0.897	0.999
2000	0.828	1.000		0.987	0.995	0.999	0.989	0.994	1.000
2001	**0.028**	0.828	0.987		1.000	1.000	1.000	1.000	1.000
2002	0.319	0.971	0.995	1.000		1.000	1.000	1.000	1.000
2003	0.412	0.989	0.999	1.000	1.000		1.000	1.000	1.000
2004	**0.035**	0.849	0.989	1.000	1.000	1.000		1.000	1.000
2005	**0.042**	0.897	0.994	1.000	1.000	1.000	1.000		1.000
2006	0.885	0.999	1.000	1.000	1.000	1.000	1.000	1.000	

Testing the main effects in the CPUE

The ANOVA test indicated significant effects (p<0.05) for the CPUE (number of sharks landed/trip) of *C. signatus* for the variables year, season and type of bait (Table 8). Using GLM model, the interaction year - season was significant (p<0.05) (Table 9).

The ANOVA test showed significance (p<0.05) for the type of bait on the CPUE (number of sharks/1 000 hooks) of *C. signatus* (Fig. 12). The Tukey's test indicated that squid was more efficient to catch the night shark than fish (Table 10).

The ANOVA test also indicated that the season effect was significant (p<0.05) on the CPUE (number of sharks landed/trip) of the night shark.

Table 8
ANOVA test applied to the logarithmized annual mean CPUE (number of sharks/trip) of *Carcharhinus signatus* caught by the longliners Macedo I, Macedo IV, Marbella and Yamaya III (pooled data) for the period 1996 to 2007 (**boldface** p<0.05)

Effects	*F*	*p*	*Degrees of freedom*	*MS*	*Error*	*n*
Year	4.932	**0.000**	8	1.331	0.27	98
Season	2.830	**0.043**	3	0.957	0.33	98
Bait	3.200	**0.046**	2	1.139	0.36	90
Depth (m)	0.016	0.984	2	0.004	0.27	90
Latitude	0.003	0.958	1	0.001	0.33	97
Sea surface temperature (°C)	0.658	0.419	1	0.180	0.27	90

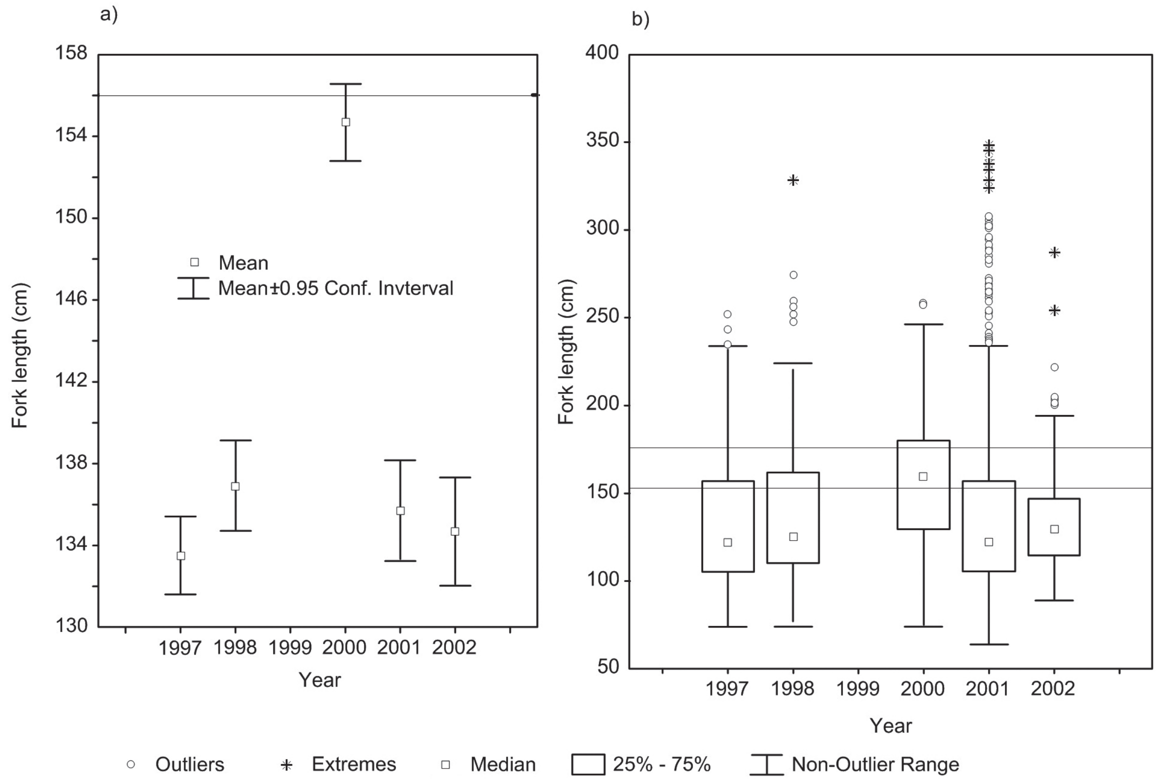

Fig. 7. Means (*a*) and medians (*b*) of the *Carcharhinus signatus* FL (cm), between 1997 and 2002, in relation to the interval of first maturity. In graph (*b*), the quartiles are represented by the vertical bars. Horizontal lines - interval of first maturity for both sexes (between 156 and 173 cm FL).

However, the Tukey's test evidenced no significant differences (p>0.05) between the seasons (Table 11). On the other hand, *figure 13* showed higher yields during spring, when the mean sea surface temperature was below 21°C. The seasonal CPUE maps also indicated this trend, with higher values (number of sharks/1 000 hooks) in spring (Fig. 2).

Table 9

Generalized linear models (GLM) results for the interactions of the effects (bait, year, season) on the variation of the logarithm of CPUE (number of sharks/trip) of *Carcharhinus signatus* caught by the longliners Macedo I, Macedo IV, Marbella and Yamaya III (pooled data) for the period 1996 to 2007 (**bold values** p<0.05)

Effects	*Degrees of freedom*	*MS*	*F*	*p*	*Error*
Bait/Year	2	0.192	0.539	0.586	0.357
Bait/Season	5	0.286	0.790	0.560	0.361
Year/Season	3	1.335	4.470	**0.006**	0.299

Table 10

Tukey's test applied to the mean logarithm of CPUE (number of sharks/1,000 hooks) of *Carcharhinus signatus* caught by surface longliners, using three types of bait for the period 1996 to 2007 (**bold values** p<0.05)

	Probabilities		
Fish		**0.035**	0.493
Squid	0.035		0.721
Fish and Squid	0.493	0.721	

Table 11

Tukey's test applied to the seasonal means of logarithm of CPUE (number of sharks landed/trip) of *Carcharhinus signatus*, caught by the surface longliners Macedo I, Macedo IV, Marbella and Yamaya III (pooled data) for the period 1996 to 2007

	Probabilities			
Season	*Spring*	*Summer*	*Fall*	*Winter*
Spring		0.526	0.113	0.076
Summer	0.527		0.997	0.884
Fall	0.113	0.997		0.895
Winter	0.076	0.884	0.895	

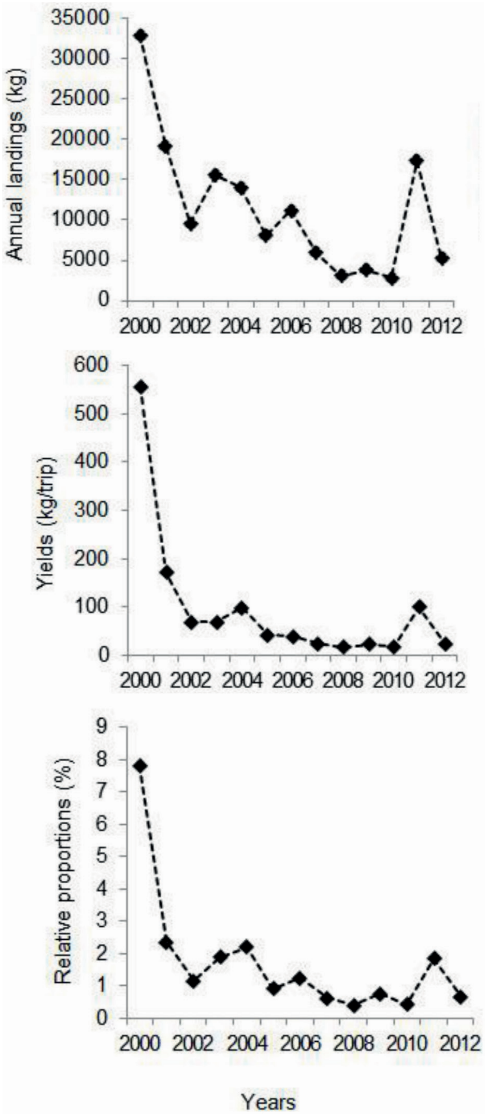

Fig. 8. Annual landings (kg), yields (kg/trip) and relative proportions (%) in the elasmobranch total landings of *Carcharhinus signatus* by industrial longliners placed in the State of Santa Catarina.

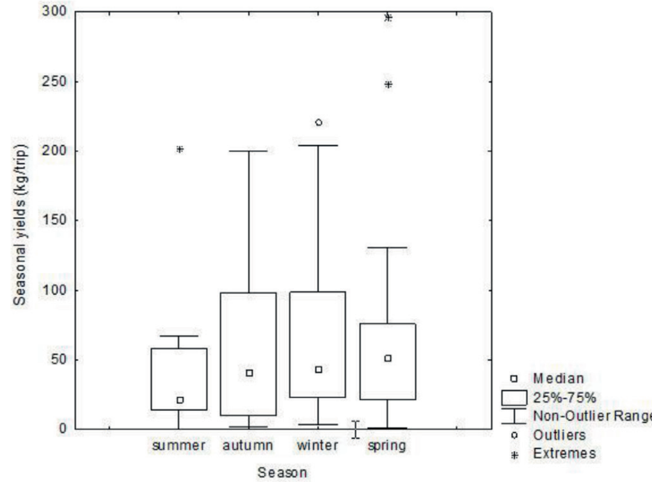

Fig. 9. Seasonal yields (kg/trip) of *Carcharhinus signatus* by industrial longliners placed in the State of Santa Catarina.

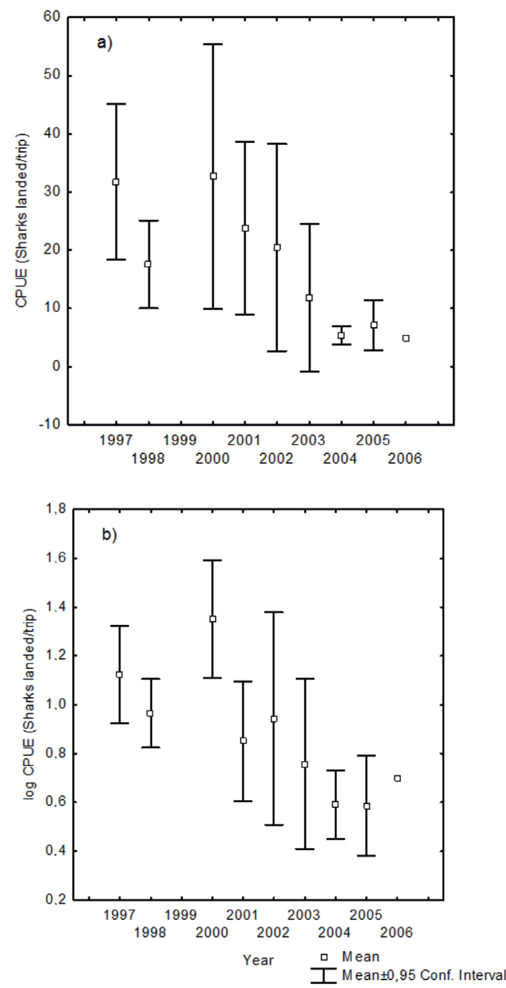

Fig. 10. *a)* Annual trend in the CPUE (number of sharks landed/trip) of the night shark caught by the longliners Macedo I, Macedo IV, Marbella and Yamaya III (pooled data) for the period between 1997 and 2006. *b)* Logarithm of the CPUE.

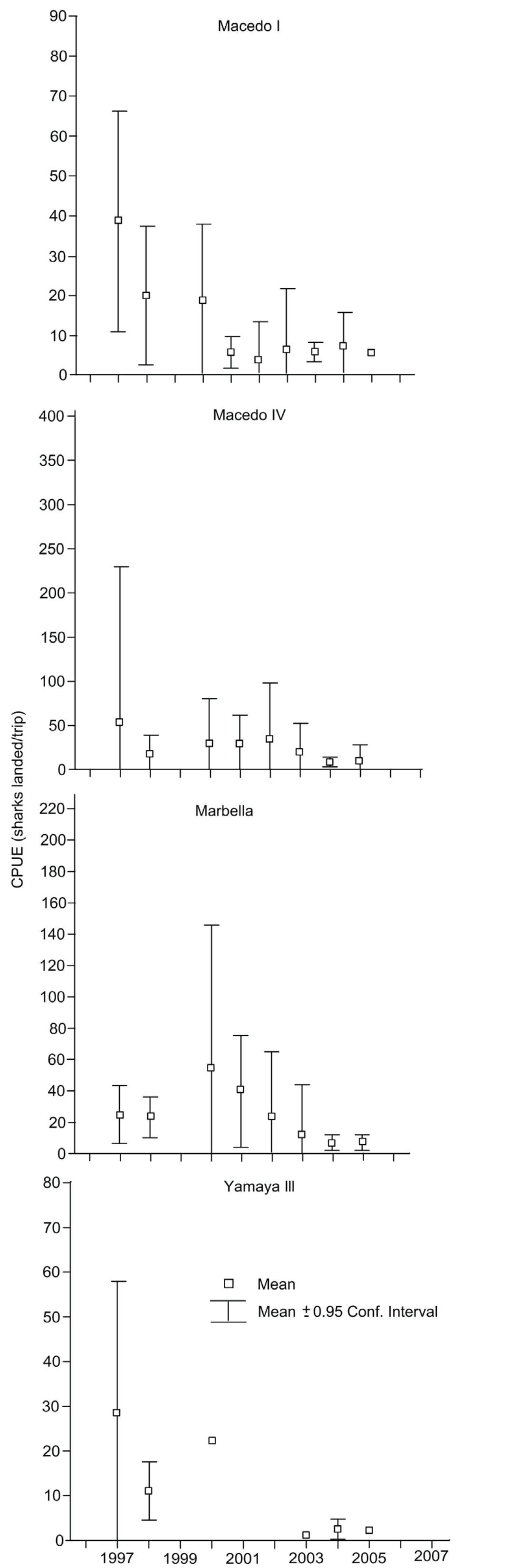

Fig. 11. Annual trends in the CPUE (number of sharks landed/trip) of the night shark caught by the longliners Macedo I, Macedo IV, Marbella and Yamaya III (data per fishing vessel) for the period between 1997 and 2006.

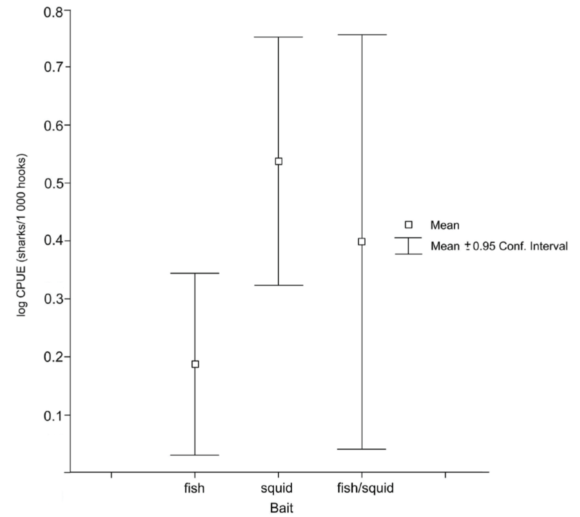

Fig. 12. Comparisons of the mean logarithmized CPUE (number of sharks/1 000 hooks) of *Carcharhinus signatus* caught by longliners, using three different types of baits. Period 1996 to 2007.

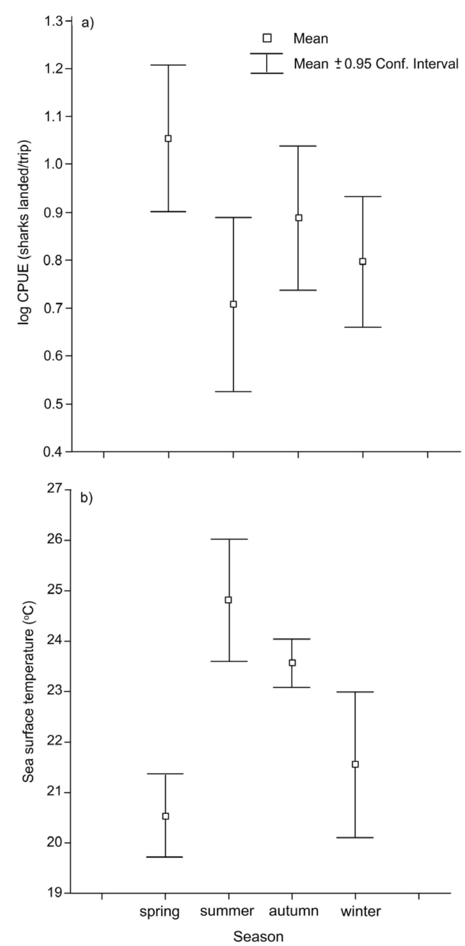

Fig. 13. *a)* Seasonal trend in the mean logarithmized CPUE (number of sharks landed/trip) of *Carcharhinus signatus* caught by the surface longliners Macedo I, Macedo IV, Marbella and Yamaya III (pooled data) between 1997 and 2005. *b)* Seasonal trend in the mean sea surface temperature (°C) between 1997 and 2007.

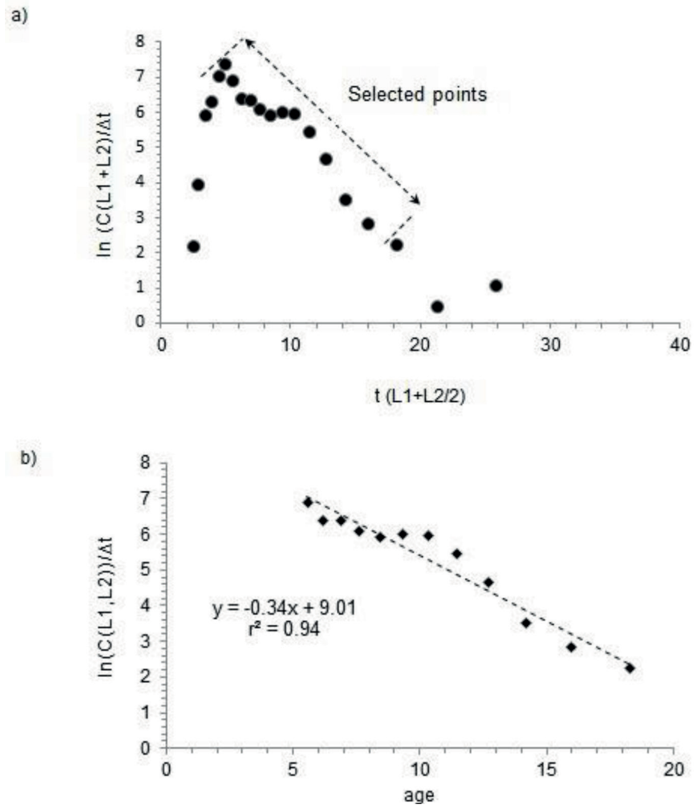

Fig. 14. *a)* Length-based curve of *Carcharhinus signatus* caught by surface longliners placed in Itajaí, between 1997 and 2005 (n = 5 509), *b)* selected points used to estimate Z = 0.34/year.

Table 12

Natural mortality (M) estimates of *Carcharhinus signatus*, using different empirical methods (Pauly 1980, Peterson & Wroblewsky 1984, Chen & Watanabe 1989, Jensen 1996, Lorenzen 1996) and the estimate of total mortality (Z) by the Hoenig (1983) method. FL – Fork Length, TW – total weight

			Mortalities ($year^{-1}$)						
Age (year)	*FL (cm)*	*WT (g)*	*Peterson & Wroblewski*	*Hoenig*	*Pauly*	*Chen & Watanabe*	*Jensen (1st maturity)*	*Jensen (K)*	*Lorenzen*
0	66.8	2 690	0.40	0.25	0.20	0.43	0.17	0.17	0.33
1	91.9	6 580	0.32	0.25	0.20	0.33	0.17	0.17	0.25
2	113.4	11 850	0.28	0.25	0.20	0.28	0.17	0.17	0.21
3	128.8	16 920	0.25	0.25	0.20	0.24	0.17	0.17	0.19
4	142.7	22 550	0.23	0.25	0.20	0.21	0.17	0.17	0.17
5	154.7	28 270	0.22	0.25	0.20	0.20	0.17	0.17	0.16
6	165.9	34 380	0.21	0.25	0.20	0.18	0.17	0.17	0.15
7	176.8	41 080	0.20	0.25	0.20	0.17	0.17	0.17	0.14
8	185.9	47 280	0.19	0.25	0.20	0.16	0.17	0.17	0.14
9	194.8	53 890	0.19	0.25	0.20	0.15	0.17	0.17	0.13
10	202.0	59 660	0.18	0.25	0.20	-0.01	0.17	0.17	0.13
11	206.9	63 800	0.18	0.25	0.20	-0.01	0.17	0.17	0.13
12	215.7	71 690	0.18	0.25	0.20	-0.01	0.17	0.17	0.12
13	222.2	77 910	0.17	0.25	0.20	-0.01	0.17	0.17	0.12
14	226.9	82 610	0.17	0.25	0.20	-0.01	0.17	0.17	0.12
15	231.7	87 600	0.17	0.25	0.20	-0.01	0.17	0.17	0.11
		Mean	0.22	0.25	0.20	0.14	0.17	0.17	0.16

Mortality estimates

The length-based catch curve estimated Z = 0.34/year for *C. signatus* caught by surface longliners placed in Itajaí, between 1997 and 2005 (Fig. 14). The value of M = 0.18/year, was obtained from the average estimates of the empirical methods (Table 12). Therefore, the estimate of F = 0.16/year was calculated, considering Z = F + M.

With the value of Z = 0.34/year, the survival rate of 71%/year and the total mortality rate of 29%/year were estimated for the night shark.

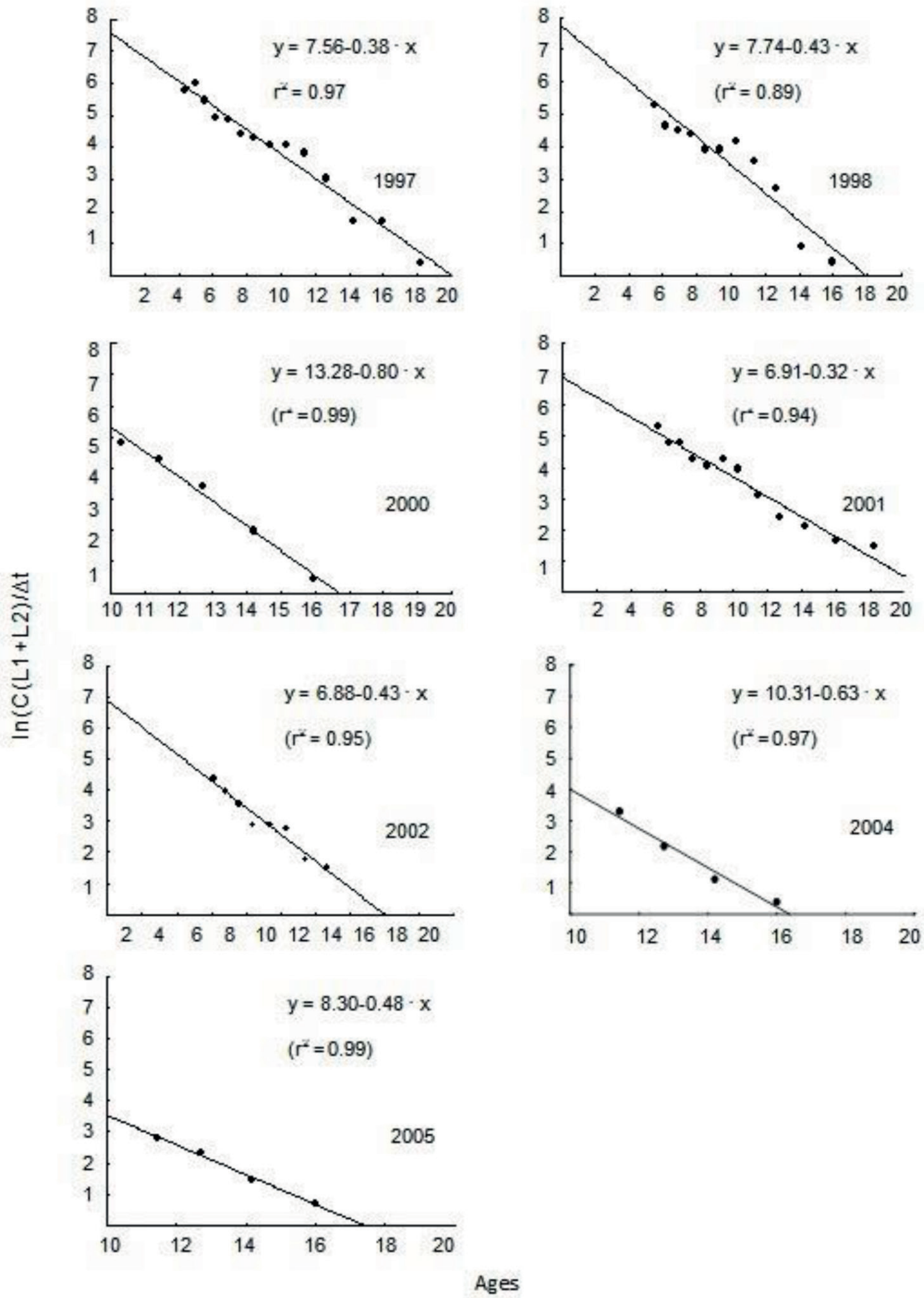

Fig. 15. Annual length-based curves of *Carcharhinus signatus* caught by surface longliners placed in Itajaí, between 1997 and 2005 (n = 5 509). The values estimated for Z were 0.38/year, 0.43/year, 0.80/year, 0.32/year, 0.43/year, 0.63/year and 0.48/year for 1997, 1998, 2000, 2001, 2002, 2004 and 2005, respectively.

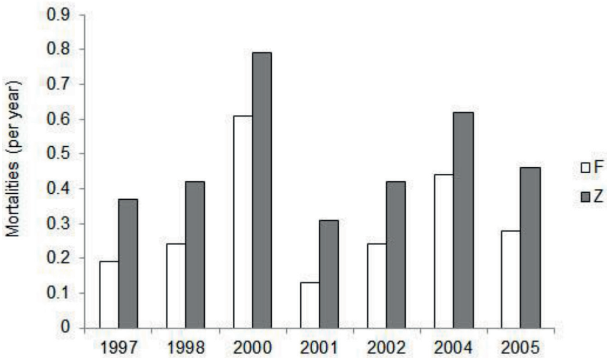

Fig. 16. Annual estimates of Z (black bars) and F (white bars) of *Carcharhinus signatus* caught by surface longliners placed in Itajaí, between 1997 and 2005 (n = 5 509). Values obtained of F were 0.19/year, 0.24/year, 0.61/year, 0.13/year, 0.24/year, 0.44/year and 0.28/year for 1997, 1998, 2000, 2001, 2002, 2004 and 2005, respectively.

This means that for the period 1997 to 2005, 15% deaths of *C. signatus* were due to natural causes (diseases, ageing and predation) and 14% due to fishing. However, annual differences occurred in the values of *F*, probably due to variations in the accessibility of the fleet to the resource. In fact, this could be observed, estimating separately the values of *Z* and *F* from the annual length-based catch curves for the period 1997 to 2005 (Fig. 15). For 2000 and 2004, it seems that the night shark was more accessible to the surface longliners (Fig. 16). The exploitation rate found for the period 1997 to 2005 was E = 0.47.

Discussion

The present paper showed that *C. signatus* was associated with the continental slope of the southeastern and southern Brazilian coast, as previously observed by Vooren *et al.* (1999[10]). Also, there were catches registered over seamounts. It is important to consider that the distribution of the fishing fleet is also beyond these areas. Similar behavior was recorded in the northeastern Brazilian coast, where the species represented a very important fishing resource for a national longline fleet operating over seamounts, representing more than 90% of the catches, with most of the specimens below the first maturity age (89%) (Santana *et al.* 2009).

From 1997 to 2002, the catches of *C. signatus* by the pelagic longline fleet placed in Itajaí were mainly composed of juveniles between 100.0 and 120.0 cm FL. As for the catches, 64.6% were below the first sexual maturity size interval (156.0 to 160.0 cm FL for males and 168.0 to 173.0 cm FL for females) (Hazin *et al.* 2000). Adults were also caught, but were less representative in the length composition. Therefore, the longliners exerted fishing mortality throughout different age-classes, but mainly affecting the juveniles.

In agreement with the observations of length-at-age made by Hellebrandt (2001), almost two decades ago, the intensive catch of *C. signatus* juveniles by the commercial longline fleets operating over the slope and seamounts of the southern Brazilian coast (delimited by the latitudes 15° to 40° S and longitudes 20° to 55° W) continues. According to this author about 83% of the individuals caught by the pelagic longline were up to four years of age. Considering that, for *C. signatus,* sexual maturity is reached at an age of eight years for males and ten years for females (Santana & Lessa 2004), the southern slope of Brazil is an important area for the concentration of *C. signatus* juveniles, a life-stage that is being intensively affected by the longline fishery. A possible explanation for the low occurrence of adults over the slope could be vertical or temporal migration performed by adults outside the area (Amorim *et al.* 1998). Vooren *et al*. (1999[10]) also observed the predominance of neonates and juveniles over the slope between Tramandaí and São Simão (30 to 31° S), as well as Amorim *et al.* (1998) along the southeastern Brazilian coast.

Along the northeast coast of Brazil, night sharks are recruited to the fishery stock with about five years of age, which means almost five years before the age of sexual maturity (Santana *et al.* 2009). This phenomenon represents approximately 90% of the catches of elasmobranchs carried out by pelagic longliners over seamounts (IUCN 2017[2]). Over the southern Brazilian slope,

10. Vooren CM, JP Castello, RTR Bem, IC Gomez, D Hellebrandt, MA Isoldi. 1999. Projeto Argo. Levantamento dos recursos vivos do ambiente pelágico da ZEE – Região Sul. V.2. Parte 1. Distribuição e Abundância dos Peixes. Relatório Final. Fundação Universidade do Rio Grande - Rio Grande. Brasil. 104p.

Hellebrandt & Vooren (2000[11]) reported that about 72% of the catches of *C. signatus* have been of individuals that have not reached the reproductive stage. This exploitation pattern, carried out by the longliners from the State of Santa Catarina, is a matter of concern, because *C. signatus* is a long-lived species (up to 35 years), and therefore low resilient to high levels of fishing effort (Hellebrandt 2001). In USA waters, the night shark presented very low value in its intrinsic rate of population growth (r = 0.021). Therefore, the fishing mortality over the juveniles caused a populational decline of 8.1% per year. This unsustainable situation leads the USA authorities to ban the catches of this species (Carlson *et al.* 2008).

Gallucci *et al.* (2006) and Kinney & Simpfendorfer (2009) commented that the removal of older juveniles, near the maturity age, as well as the adult stock, would present a greater risk of stock depletion. This means that the exploitation pattern carried out by the longliners placed in Itajaí, although affecting mainly juveniles (recruits to the fishery), also caught the subadults and adults in a lower proportion, a situation that is a matter of concern (Figs. 5 and 6), it endangers its recruitment. In this way, most of the sharks will not reach the adult phase, increasing overfishing (Hazin *et al.* 2000, Santana *et al.* 2009, Vaske-Júnior *et al.* 2009).

Considering the southern Brazilian slope, the fishing yields of *C. signatus* caught by surface longliners placed in Itajaí, declined in this area in the period 2000 to 2012 (Fig. 8). Although the year factor explained ($p<0.05$) most of the variation in the relative abundance (CPUE) of the night shark, this is a variable that includes several other elements that affect its catchability. These variables were not totally under control, due to lack of information about the vessel characteristics, the temporal fluctuation in the target species, the development of new technologies for school detection, and even the skipper's ability (Ruiz 2002[12]). Also in many regions of the world there were yearly declines in the catches of night shark (Amorim *et al.* 1998, Castro *et al.* 1999, Santana *et al.* 2006[5], IUCN 2017[2]).

The seasonal effect was also important in the yield variations of *C. signatus* in the southern Brazilian coast (Fig. 2). The catches were higher in spring, also verified by Nardi & Vooren (1997[13]). Hellebrandt (2001) observed that the best yields in the spring were related to the oceanographic phenomenon called Subtropical Convergence, more intense during this season, increasing the primary production over the slope and concentrating preys (squids, mackerels, anchovies), that attract oceanic predator like tunas, swordfish and sharks (Haimovici *et al.* 1996, Vooren *et al.* 1999[10], Carneiro *et al.* 2000[14], Silveira *et al.* 2000, Haimovici 2007). Moreover, during winter-spring the longline fleet concentrates in this area, targeting the swordfish *Xiphias gladius,* but also catching the night shark (Fiedler *et al.* 2015). The squid used as bait, was responsible for the best yields of *C. signatus* (Fig. 12). Vaske-Júnior *et al*. (2009) observed the dietary preference of the night shark for migratory squids (*Histioteuthis* sp., *Ommastrephes bartramii, Ornithoteuthis antillarum* and *Vampyroteuthis infernalis*).

With respect to mortality, the value of Z = 0.34/year obtained for the night shark caught by surface longliners placed in Itajaí between 1997 and 2005, was like that found by Santana & Lessa (2004) in the northeast coast of Brazil (Z = 0.36/year). Therefore, the mean value of M = 0.18/year obtained from empirical methods allowed to estimate F = 0.16/year for *C. signatus* caught by surface longliners along the southern coast of Brazil. Demographic analysis for *C. signatus* caught by tuna longliners operating over the seamounts in the northeast Brazil estimated M = 0.24/year and F = 0.12/year. However, this *F*

11. Hellebrandt D, CM Vooren. 2000. Composição da população de *Carcharhinus signatus* da região Sul do Brasil. II Reunião da Sociedade Brasileira para o Estudo de Elasmobranquios-SBEEL, Santos, p: 31.

12. Ruiz MS. 2002. Estandarización de series de CPUE con S-plus. Manual estatístico.
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14. Carneiro MH, L Fagundes, AO Ávila-da-Silva, MR Souza. 2000. Ambientes marinhos explorados pelas frotas pesqueiras de Santos e Guarujá (SP). *Anais do V Simpósio Brasileiro de Ecossitemas*. Publ. ACIESP, Vitória, 109: 83-91.

value was more than the double allowed to maintain the night shark population stable ($F_{Equilibrium}$ = 0.05/year), causing an annual decline in the stock by 4.4%/year (IUCN 2011). The same unsustainable pattern of exploitation seems to be occurring with the southern Brazilian stock with a F = 0.16/year. On the other hand, it is important to consider these initial estimates with caution, because most of the catches were juveniles, and the longline fleet used to operate on the nursery grounds of *C. signatus*, where the adult fraction of the stock is less represented. Demographic analyses have not been done for the night shark caught by surface longliners in southern coast of Brazil. The value of $F_{Equilibrium}$ was low for the northeast region of Brazil, and in the southern region, above the sustainable levels. Nevertheless, it is a matter of concern that the catches of the night shark are concentrated on individuals that have not reached the reproductive phase, evidencing the overfishing growth (Sparre & Venema 1997, Santana *et al.* 2009).

The annual trends in the values of *Z* and F (Fig. 16) presented fluctuations. This phenomenon could be explained by variations in the accessibility of the longline fleet to the night shark stock. For example, the chances to catch this shark species increase when fishing over the slope, targeting the swordfish *Xiphias gladius*. This could be the case of the years 2000 and 2004 (Fiedler *et al.* 2015).

The exploitation rate found for the period 1997 to 2005 was E = 0.47, which means an equilibrium. However, this value must be assessed with caution, because the longline fleet placed in Itajaí impacts mainly the juvenile portion of the stock. Also, the values of *Z* could be underestimated, due the fluctuations of points around the regression lines in the annual catch curves. Barreto *et al.* (2015), analyzing data from longline fisheries in the western and central South Atlantic, observed a steep decline in the mean annual catch rate of the category named *Other Sharks* (which includes sharks of the genus *Carcharhinus*, without considering *C. longimanus* and *C. falciformis*) from 5.24 sharks/1 000 hooks in the period 1998-2007 to only 0.43 sharks/1 000 hooks in the period 2008 to 2011.

The interest in the assessment of the size structure of *C. signatus* that has been fished by pelagic longliners placed in Itajaí, southern Brazil, during the period of 1996 to 2008, was due to a necessity of having an historic record of an uncontrolled fishing effort applied to a bycatch shark species of the Atlantic Ocean, which has low biological productivity. According to the IUCN Red List (IUCN 2017[2]), *C. signatus* has been considered globally as vulnerable (VU), due to its low resilience to fisheries capture (more than 14 years are required to double its population) (Froese & Pauly 2015).

The fishing area ranging between 20° S (Vitória - Trindade Chain) and 35° S (Maldonado, Uruguay) has being heavily exploited by the national longliners placed in the ports of Itaipava (State of Espírito Santo), Santos (State of São Paulo), Itajaí (State of Santa Catarina) and Rio Grande (State of Rio Grande do Sul) (Sales *et al*. 2008). These fleets have different fishing strategies to target albacores, blue sharks, swordfish and dolphinfish, a fact that will reflect in the selection of the fishing grounds (Fiedler *et al*. 2015). In the case of *C. signatus,* caught as bycatch along the southern Brazilian slope and sea mounts by Itajaí longliners, during the period 1996 to 2008, most are individuals below the age of first sexual maturity, and recruitment to the fishery occurred half the age necessary for sexual maturity to be reached. The same phenomenon occurred in the Caribbean and southern USA. Probably, the impact over the *C. signatus* juveniles seems to be continuing in this large area, because there are different national longliners, from different ports operating there. On the other hand, due the lack of a sea-observers monitoring program, it was not possible to gather information from the night shark's length composition in more recent years, from all the national fleets. In the Southwest Atlantic, the major problem is related to fragmented information of oceanic sharks with respect to its bycatches, abundance and biology (Molina & Cooke 2012).

Overfishing growth seems to be the main threat to the survival of *C. signatus* population, distributed along the southern Brazilian slope. The catch of a fraction of the adult stock is also a matter of concern (Kinney & Simpfendorfer 2009). The exploitation pattern used by the national longliners, *i.e*. catching high amounts of night shark juveniles as bycatch, using steel wire gangions along the mainline, continues. The international market for shark fins makes unsustainable this entire fishing pattern, which means that without fishing restrictions, the conservation perspective for the species is uncertain.

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