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Distribution and abundance of the life stages of the blue shark *Prionace glauca* in the Southwest Atlantic

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ABSTRACT

The composition and magnitude of the catches of the life stages of both sexes of the blue shark *Prionace glauca* were recorded at sea from 2004 to 2006 during seven commercial longline fishing cruises off Southern Brazil between latitudes of 24°S and 38°S and longitudes 29°W and 52°W. *P. glauca* occurred in all sets and constituted 63% of the pooled catch in numbers. Fork length (FL) ranged from 84 to 262 cm in the males and from 73 to 247 cm in the females. Sea surface temperature ranged from 16.2 to 28.3 °C. The Subtropical Convergence (STC) of the Southwest Atlantic occurred in the sampling area from autumn to spring (June–December). Small juveniles (FL, 70–129 cm) of both sexes were abundant only in the area of the STC. Of the large juveniles (FL, 130–179 cm), males were abundant south of latitude 23°S and females were scarce in the entire study area. Of the small adults (FL, 180–219 cm), males occurred in the entire study area without a seasonal pattern and females were abundant only in the summer (March) north of latitude 26°S. Large adults (FL, 220–262 cm) of both sexes were scarce at all times. In analogy with the spatial distribution of the life stages of *P. glauca* in other oceans, the distribution patterns of the life stages in the study area justify the hypothesis that the STC comprises a nursery area of *P. glauca* in the Southwest Atlantic, where small juveniles of both sexes remain until they reach FL of 130 cm. After that stage the large juvenile males disperse northwards, whereas the large juvenile females move to the south of the STC or to the Southeast Atlantic off Africa. The subadult females move northwards in late summer (March) to areas beyond latitude 25°S. Because of the limitations of the fishery-dependent data and patchy coverage of the study area, no definitive conclusions are presented, but the above hypotheses may orient further study of the spatial distribution of the blue shark in the Southwest Atlantic.

1. Introduction

The blue shark *Prionace glauca* (Linnaeus, 1758) is the dominant shark species in the world's oceanic longline fisheries. Annual world catches by this fishery are of the order of two to four million individuals (Castro et al., 1999; Bonfil, 1994; Camhi et al., 1998; Matsunaga and Nakano, 2005). The effect of such large catches on population processes of *P. glauca* is a matter of debate. A fishery-independent estimate of the global blue shark catch for the fin trade suggests that current trade volumes are close to or possibly exceed maximal sustainable yield (Clarke et al., 2006).

In the Northwest Atlantic, decline of catch rates of *P. glauca* was 80% from 1987 to 1994 (Simpfendorfer et al., 2002), 60% from 1986 to 2000 (Baum et al., 2003), 5–6% per year from 1995 to 2003 (Campana et al., 2006), 86% from logbooks and 24% from observer datasets from 1986 to 2006 (Cortés, 2008), and 30% from 1957 to 2000 (Aires-da-Silva et al., 2008). However, in the North and Southeast Atlantic, blue shark catch rate of the Japanese longline fishery varied in 1971–2003 around the stable level of 1.5 sharks/1000 hooks (Nakano and Clarke, 2005). In the Southwest Atlantic, nominal annual blue shark catch rates increased during the years 1971–1985 and then fluctuated around the stable level of 9.0 sharks/1000 hooks until 1996 (Hazin and Lessa, 2005), while standardized annual catch rates were stable from 1978 to 2006 (Mourato et al., 2007; Hazin et al., 2008), and the annual standardized catch rate of the Uruguayan longline fleet from 1999 to 2006 was 44% of that from 1992 to 1998 (Pons and Domingo, 2008). In spite of much evidence of declining catch rates of *P. glauca* in the Atlantic Ocean, the International Commission for the Conservation of Atlantic Tunas – ICCAT assessed that in 2008 the biomass of *P. glauca* in the North and South Atlantic Oceans was close to the unfished biomass level and that blue shark stocks in the Atlantic are not overfished (Anonymous, 2008a). The divergences between the published assessments of the state of the stocks of *P. glauca* in the Atlantic Ocean justify the need of further study of the distribution and abundance of those stocks.

Abbreviations: SJ, small juveniles; LJ, large juveniles; SA, small adults; LA, large adults; CS, continental slope of Southern Brazil; OR, international oceanic region.

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The data on the recapture of blue sharks tagged in the North Atlantic Ocean are evidence that one unit stock of this species occupies the entire northern half of the Atlantic Ocean (Stevens, 1976, 1990; Casey, 1985; Kohler et al., 1998; Aires-da-Silva et al., 2005; Fitzmaurice et al., 2005; Mejuto et al., 2005; Queiroz et al., 2005). From data and from published evidence (Castro and Mejuto, 1995; Hazin et al., 1994a; Amorim et al., 1998) on embryo size and female reproductive stages of *P. glauca* off Northeast and Southeast Brazil and in the Gulf of Guinea, Hazin et al. (2000) propose that one single stock of *P. glauca* inhabits the southern half of the Atlantic Ocean, where a clockwise migration cycle of life stages and breeding stages includes mating off Southeast Brazil, early gestation off Northeast Brazil and parturition and nursery off southwest Africa. However, Legat and Vooren (2004) observed the presence of early stages of gestation also off South Brazil and proposed therefore that two units stocks of *P. glauca* may exist in the southern half of the Atlantic Ocean, with separate migration cycles without spatial overlap. A further study of the spatial and temporal distribution and abundance of the life stages and breeding stages of *P. glauca* in the South Atlantic is therefore justified, in order to confirm the unit stocks and the migration circuits of *P. glauca* in that region.

Due to the large spatial scale of the distribution of the populations of *P. glauca*, the study of the parameters of population dynamics through synoptic scientific fishery surveys is logistically difficult. This problem has been addressed successfully through the compilation of time series of data obtained by scientific observation at sea of the catches of *P. glauca* by the commercial longline fishery in large areas of the Atlantic Ocean (Campana et al., 2005; Mejuto and García-Cortés, 2005). This approach was used in the present study. Itajaí is the major oceanic longline fishing port of South Brazil and its longline fleet operates in the Southwestern Atlantic between latitudes from 25°S to 35°S and longitudes from 30°W to 55°W (Mayer and Andrade, 2005). The composition and magnitude of the catches of *P. glauca* were recorded at sea from 2004 to 2006 during a series of commercial longline fishing trips in the fishing area of the fleet of Itajaí, in order to investigate the distribution and abundance of the sexes and the life stages of *P. glauca* in the oceanic area off Southern Brazil and in adjacent international waters.

2. Materials and methods

2.1. Data collection

Data were collected on board during seven commercial fishing cruises performed by the Brazilian longliners F/V Yamaya III and F/V Macedo IV from 2004 to 2006. The first author took part in the seven fishing cruises and collected all the data. Two cruises occurred in summer (February/2004 and March/2005), one in autumn (June/2004), three in winter (September/2004, July/2005, August/2006) and one in spring (December/2005) (Table 1). The seven cruises together covered the area between the latitudes 23°S and 38°S, and the longitudes between 29°W and 52°W. This area is denominated the sampling area. Within the sampling area, individual cruises covered the continental slope of Southern Brazil (CS) or international oceanic waters (OR). The spatial distribution of the sampling was determined by the decisions of the masters of the monitored vessels. Of the OR area, the northern portion OR1 was sampled in March/2005, the Rio Grande Rise area OR2 was sampled in February/2004, and the southern portion OR3 was sampled mostly in December/2005 (Table 1, Fig. 1). The autumn and winter cruises were made in the CS.

The two boats had 21 m overall length, load capacity of 28 t and 410 HP main engine, and the conformation and operational characteristics of the longline were the same in both boats. The mainline consisted of 70–80 km of monofilament polyamide with diameter of 4.0 mm. The buoy lines were of 20 m of monofilament polyamide with diameter of 3 mm. The branchlines consisted of 17 m monofilament polyamide with diameter of 1.8 mm, a 20 g swivel carrying 2.5 m polyamide line with diameter of 1.8 mm and 0.5 m steel wire leader 1.5 mm in diameter with a 9/0 J-type hook. Five branchlines were spaced between two adjacent buoys at intervals of 50–60 m. The number of hooks per set varied from 600 to 1250 about the mean of 1070 (s.d. = 125). The launching of the longline always began at dusk and lasted about 6 h. Retrieval began at dawn and lasted until the afternoon. The period between the launching of the first hook and the retrieval of the last hook, defined as the fishing time (Simpfendorfer et al., 2002), varied little about the mean of 19.8 h (Table 1). Aimed to catch swordfish and blue sharks near the surface, the main line was launched tautly stretched with the vessel steaming at 11–13 km/h and without the use of line setter. Light sticks were mounted on the two branchlines next to each buoy. The baits were Argentine squid (*Illex argentinus*), Skipjack (*Katswuonus pelamis*) and Brazilian sardine (*Sardinella brasiliensis*). With this same longline configuration and operational characteristics, Olavo et al. (2005) recorded hook depths of 32.8–99.6 m on F/V Yamaya III. This justifies the assumption that the hook depth in the present study was within the aforementioned depth range. *P. glauca* inhabits the epipelagic zone and remains during the night mostly at depths less than 100 m (Sciarrotta and Nelson, 1977; Carey and Scharold, 1990). Therefore, the fishing sets monitored in the present study were made in the habitat of *P. glauca*.

In each longline set, the sea surface temperature was recorded at the beginning and the ending of the launching and the retrieval. The temperature sensor of both vessels was located on the hull at depth of about 3.0 m. The mean of the temperatures at the beginning and end of the retrieval was used as the measure of surface temperature of the set. The number of individuals caught of each fish species was recorded in each longline set. All blue sharks were sexed and the fork length (FL) was measured in vertical projection according to Compagno et al. (2005), in the total catch of each set or in a random sample of it, depending on the working conditions.

Data about body weight of *P. glauca* were obtained from the catches made by R/V Atlântico Sul, during the series of 44 fish-

Table 1
Technical characteristics of cruises monitored on two commercial longline fishing vessels in the Southwest Atlantic from 2004 to 2006. The number of individuals (*n*) of *P. glauca* and *Xiphias gladius* caught and their respective proportion (%) of the total fish caught is shown. CS, continental slope off Southern Brazil; OR, international oceanic region (numbers correspond to the subareas within the OR); SST, mean sea surface temperature; FT, fishing time in hours.

Cruise	Season	Area	Latitude (°S)	SST (°C)	Sets (*n*)	Hooks (*n*)	FT, mean (s.d.)	*P. glauca*, *n* (%)	*X. gladius*, *n* (%)
February/2004	Summer	OR2	28–36	22.1	16	14,195	18.8 (0.8)	444 (86.0)	39 (7.6)
June/2004	Autumn	CS	27–33	21.5	16	17,600	20.0 (0.9)	491 (57.4)	138 (16.1)
September/2004	Winter	CS	27–34	18.7	19	19,054	21.4 (1.7)	863 (67.0)	111 (8.6)
March/2005	Summer	OR1	24–26	27.6	18	19,490	18.7 (0.9)	252 (44.8)	146 (26.0)
July/2005	Winter	CS	29–32	21.2	8	8,710	19.3 (0.7)	129 (39.1)	103 (31.2)
December/2005	Spring	OR3	33–38	18.1	15	16,640	19.9 (1.8)	1929 (71.4)	80 (3.0)
August/2006	Winter	CS	28–32	21.6	19	23,185	20.1 (1.2)	403 (44.1)	253 (27.7)
Pooled		CS + OR	24–38	21.6	111	118,874	19.8 (1.5)	4511 (62.9)	870 (12.1)