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Reproduction and seasonal occurrence of the copper shark, *Carcharhinus brachyurus*, from north Patagonia, Argentina

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The copper shark, *Carcharhinus brachyurus*, is the only member of its genus with a preferred habitat in temperate waters, and it usually gives birth in the cooler extremes of its range. Maturation patterns, reproductive condition, monthly sex ratios, and seasonal occurrence of copper sharks were analysed, mostly from Anegada Bay (Argentina), a presumed nursery area for the species. Males mature between 200 and 220 cm total length (L_T), with a 50% size at maturity (L_{50}) of 216.18 cm L_T. Females mature between 215 and 223 cm L_T (with an L_{50} of 222.16 cm L_T). Maturity off Argentina is at a slightly smaller size than off South Africa and Australia. There is no sexual dimorphism in size at maturity. Only two pregnant females, each carrying 16 advanced embryos, were caught. The hepatosomatic index (I_H) of adult males showed significant monthly changes, related possibly to an increase in the gonadosomatic index (I_G). I_H and I_G of adult females showed no significant trend throughout the fishing season. The I_H of adult females was significantly correlated with maximum diameter of ovarian follicles. Small translucent ovarian follicles in two gravid females indicated that ovarian and gestation cycles run sequentially, with maturation of oocytes subsequent to parturition. Neither newborns nor significant numbers of females bearing term embryos were recorded, and there was no evidence of a copper shark primary nursery area in Anegada Bay. However, most copper sharks in Anegada Bay were large juveniles and sub-adults. The species is found off Argentina from October to late March, but they do not move southwards to Anegada Bay until December, and they leave the bay again by April. These movements appear to be related more to water temperature rather than to migration of potential prey. Monthly variation in sex ratios is associated mainly with fluctuations in the sex ratios of juveniles.

Keywords: Chondrichthyes, copper shark, life history, nursery area, South America.

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Introduction

The genus *Carcharhinus* consists of 30 described species of medium- to large-sized sharks (Compagno, 1999), which live mainly in tropical and warm-temperate waters throughout the world (Garrick, 1982), where they usually complete their life cycle. Carcharhinid sharks generally give birth in a restricted part of their range, known as a primary nursery area (Springer, 1967), which is characterized by the occurrence of both free-swimming newborns and pregnant females carrying term embryos (Castro, 1993a). Most coastal species of *Carcharhinus* have nursery areas in tropical or subtropical protected waters (Sadowsky, 1971; Castro, 1993b, 1996; Villavicencio-Garayzar, 1996; Carlson, 1999; Lessa *et al.*, 1999).

The copper shark, *Carcharhinus brachyurus*, is distributed in the northwest, northeast, and southeast Pacific, southern Australia and New Zealand, southern Africa, Northeast Atlantic, Mediterranean, and Southwest Atlantic (Garrick, 1982; Compagno, 1984; Last and Stevens, 1994). Copper sharks are unique within the genus in that they inhabit temperate rather than tropical coastal waters (Garrick, 1982). In contrast to the other species of the genus *Carcharhinus*, the nursery areas of the copper shark are at the highest latitudes of the species' regional distributional ranges (i.e. Mediterranean coast of Morocco, Muñoz-Chápuli, 1984; temperate Cape waters, Smale, 1991; central Namibian waters, Walter and Ebert, 1991).

Large (>150 cm total length, L_T) sharks from coastal temperate habitats are highly vulnerable to human impact. This is due to the proximity of their habitat to human populations, which leads to degradation by human impact, and which renders them a common target of coastal fisheries (Camhi *et al.*, 1998). Their life history also makes their populations much less resilient to exploitation than other sharks (Smith *et al.*, 1998; Cortés, 2002). In spite of being one of the less productive shark species, and hence potentially one of the most vulnerable (Cortés, 2002), the life history and ecology of the copper shark is not well known. The only detailed study of its reproductive biology is for the South African population (Cliff and Dudley, 1992), and much less is known from other populations. From the Southwest Atlantic, the biology is almost completely unknown (Menni, 1986). There, copper sharks are found from Rio de Janeiro (23°S Brazil; Bigelow and Schroeder, 1948) to Peninsula Valdés (43°S Argentina; Chiaramonte, 1998). Based on the observations from other regions cited above, it has been hypothesized that the nutrient-rich coastal waters from Bahía Blanca to Bahía San Blas (Figure 1) might be used as a primary nursery area by copper sharks in the Southwest Atlantic (Chiaramonte, 1998). Moreover, both commercial and recreational fisheries catch them (Chiaramonte, 1998), so information on their life history is needed to assess the status of the population.

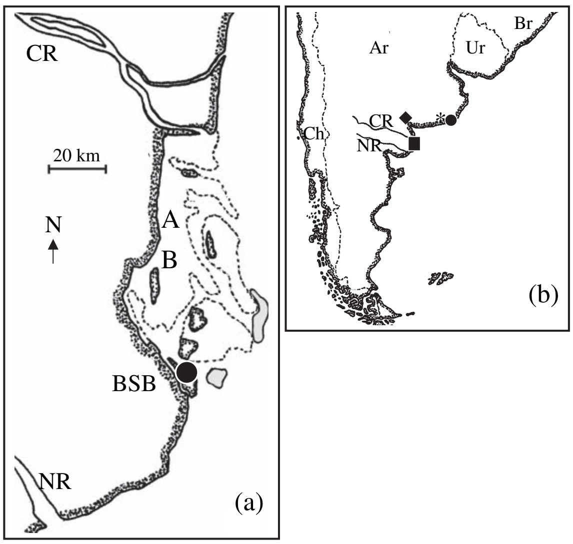

Figure 1. (a) Map of Anegada Bay (AB), Argentina, showing the location of fishing grounds for copper sharks, *Carcharhinus brachyurus* (grey areas). Areas within dashed lines are shallow banks that may be exposed during low tides. CR and NR are the Colorado and Negro rivers, respectively, and the black circle is the town of Bahía San Blas (BSB). (b) Map of southern South America showing the location of Anegada Bay (black square) and other localities mentioned in the text. Ar: Argentina, Br: Brazil, Ch: Chile, Ur: Uruguay, CR: Colorado River, NR: Negro River, solid circle: Mar Chiquita coastal lagoon, asterisk: Necochea, diamond: Bahía Blanca.

In this paper, we describe the reproductive biology of copper sharks from Anegada Bay, north Patagonia, Argentina (40°30′S 62°00′W), and present information on size at maturity, reproductive cycle, occurrence, relative abundance, and sex segregation.

Material and methods

This study was conducted during three consecutive shark-fishing seasons (November 1998–April 1999, October 1999–April 2000, and October 2000–March 2001). Most sharks were obtained from the rod-and-reel recreational fishery from Anegada Bay (Figure 1), the steel hooks ranging from 1.5 to 4.5 cm at the widest point. All the sampled specimens were landed in Bahía San Blas (Figure 1), where sampling was carried out. Anegada Bay is shallow, with many banks and small islands, impacted by nutrient-rich continental water discharge from the Colorado and Negro rivers (Figure 1; Guerrero, 1998). The region is an important nursery area for many teleosts (Macchi and Acha, 1998), and some elasmobranchs (Cousseau *et al.*, 1998; Mabragaña *et al.*, 2002). Shark fishing grounds, where the copper sharks were caught, are located in the outer (eastern) part of the bay, usually at depths of 5–20 m (Figure 1).

Sharks were identified, measured (L_T with the tail in its natural position, and precaudal length, L_{PC}, both in cm), and dissected within 2–4 h of landing. Prior to the removal of internal organs, the inner clasper length of males, and the width of the uterus and oviducal gland in females, were measured. Once removed, internal organs were examined, and liver weight (g) was recorded. Epigonal organs were removed at the posterior end of the gonad. Therefore, gonads were weighed (g) without most of the epigonal organ. Colour and size (diameter in mm) of ovarian follicles were also recorded. The relationship between L_{PC} and L_T was determined, because the caudal fin of 110 of the sharks in the sample had been removed before they could be measured.

Male copper sharks were considered mature when claspers were calcified and rotated freely forward. In addition to pregnant ones, females with enlarged oviducal glands, uteri widened all along their length, and with oocytes containing yolk, were considered mature. Size at maturity was estimated from the allometric pattern of clasper growth (in males), and of uteri and oviducal glands (in females) with respect to L_T (Clark and von Schmidt, 1965; Bass *et al.*, 1973; Lyle, 1987; Cliff and Dudley, 1992; Joung and Chen, 1995; Castro, 1996; Wetherbee *et al.*, 1996; Lessa *et al.*, 1999). The length at which 50% of the sharks were sexually mature (L_{50}) was estimated from a logistic curve fitted to the data by maximum-likelihood procedures (Roa *et al.*, 1999).

Given that total weight could not be recorded, hepatosomatic (I_H) and gonadosomatic (I_G) indices were calculated following Lucifora *et al.* (2002):

$$I_G \text{ or } I_H = (\text{gonad or liver weight})/L_T^3 \times 100$$

These indices were used to assess changes in the reproductive condition of adults in the study area. Monthly changes in I_G and I_H of adult males and females were evaluated using one-way ANOVA (Zar, 1984). When significant differences were detected, the Tukey test for unequal sample sizes was used to locate the differences. The correlation between maximum diameter of ovarian follicles and female I_H was determined using a Spearman rank correlation coefficient, and the null hypothesis of no correlation was tested.

In addition to examining landings of boats targeting large sharks, catches from boats that targeted both teleosts (e.g. striped weakfish, *Cynoscion guatucupa* and whitemouth croaker, *Micropogonias furnieri*) and small elasmobranchs (e.g. narrownose smoothhound, *Mustelus schmitti* and young-of-the-year broadnose sevengill shark, *Notorynchus cepedianus*) were examined for newborn and/or young-of-the-year copper sharks.

Monthly relative abundance of copper sharks in Anegada Bay was estimated through catch per unit effort (cpue) during the three fishing seasons. Cpue was calculated as the number of sharks caught per boat per fishing trip per day, and monthly differences in mean cpue were assessed by means of a Kruskal–Wallis test. The Kruskal–Wallis multiple comparisons test was used to locate significant differences (Conover, 1980).

The sex ratio was calculated separately for each month from December to March. Monthly sex ratios were compared for juveniles and adults separately. In all cases, the null hypothesis of no difference from the ratio 1:1 was tested with a χ^2 test with a Yates' correction (Zar, 1984). Length frequency distributions for both sexes were also generated.

Distribution and seasonal data obtained from Anegada Bay were combined with published records for copper sharks along their entire range off the east coast of South America (Rio de Janeiro to Peninsula Valdés) in order to elucidate their seasonal movements. Two unpublished records from Uruguayan waters were also included. Those two specimens were caught on 1 and 3 May 1994, at 36°52′S 53°20′W and 36°31′S 53°22′W, respectively (P. Meneses, Dirección Nacional de Recursos Acuáticos, Uruguay, unpublished data).

Results

We examined 303 (96 male and 207 female) copper sharks. Most were from Anegada Bay, but three additional ones came from Mar Chiquita coastal lagoon (Figure 1). The smallest specimen examined was a male of 100 cm L_T from Mar Chiquita and the largest a female of 256 cm L_T from Anegada Bay. The largest male examined measured 247 cm L_T, and the smallest female was 119 cm L_T, both from Anegada Bay.

The relationship between L_{PC} and L_T was described by the following equation (n = 187; size range = 76–190 cm L_{PC}; r = 0.986):

$$L_T = 1.319 L_{PC} + 3.167$$

Males attain sexual maturity between 200 and 220 cm L_T (Figure 2a). However, most mature males were larger than 210 cm L_T, and L_{50} was 216.18 cm L_T (Figure 2b). Male I_G showed marginally significant monthly changes (Figure 3a; F = 2.784, d.f. = 3 and 48, p = 0.051). There appears to be an increase in I_G from December to January, and then no further trend until March. The I_H of males changed significantly throughout the season (Figure 3b; F = 4.725,

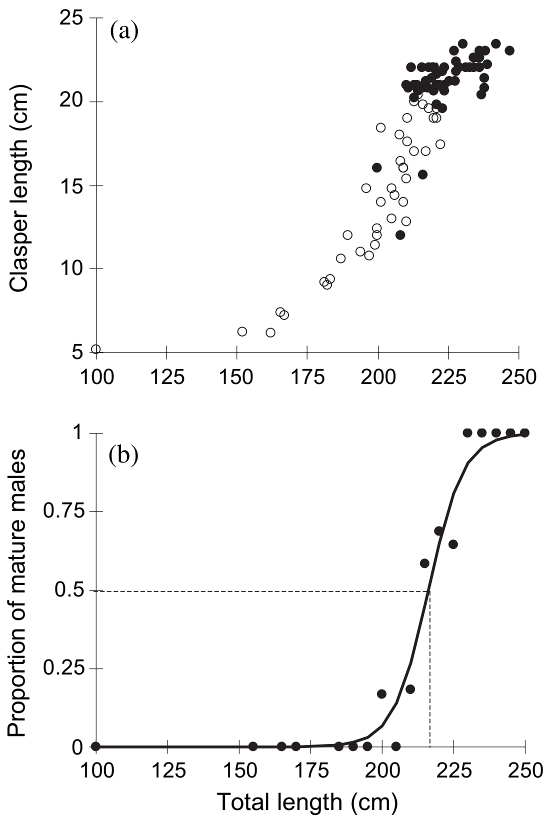

Figure 2. (a) Relationship between total length and inner clasper length relationship in copper sharks, *Carcharhinus brachyurus*, from the Southwest Atlantic. Open circles: immature individuals; solid circles: mature individuals with calcified claspers, n = 96 sharks. (b) Proportion of mature males of *C. brachyurus* in different length classes, n = 18 size classes.

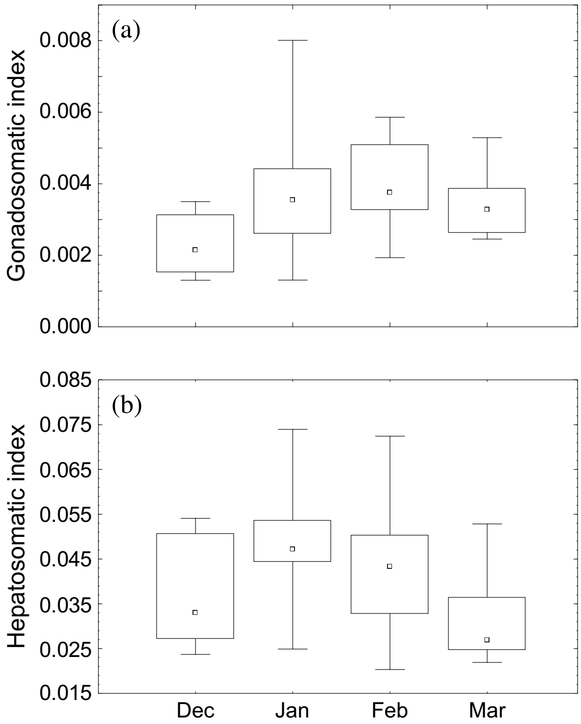

Figure 3. Monthly variations in (a) gonadosomatic ($n = 57$) and (b) hepatosomatic ($n = 52$) indices of adult male copper sharks from Anegada Bay, Argentina. Median values are indicated, boxes include values between the 25th and 75th percentiles, and whiskers show the range of the data.

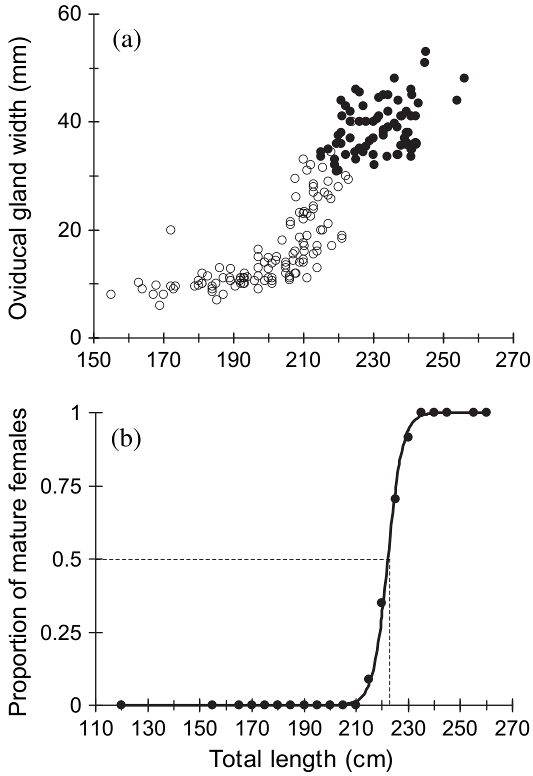

Figure 4. (a) Relationship between total length and oviducal gland width in female copper sharks, *Carcharhinus brachyurus*, in the Southwest Atlantic. Open circles: immature individuals; solid circles: mature individuals, $n = 207$ sharks. (b) Proportion of mature females of *C. brachyurus* in different length classes, $n = 21$ size classes.

d.f. = 3 and 48, $p = 0.006$), with I_H from January significantly higher than that from March ($p = 0.020$).

Female copper sharks in the Southwest Atlantic mature between 215 and 223 cm L_T (Figure 4a), with L_{50} at 222.16 cm L_T (Figure 4b). Neither the I_H ($F = 0.641$, d.f. = 3 and 60, $p = 0.592$), nor the I_G ($F = 1.036$, d.f. = 3 and 54, $p = 0.384$), of adult females showed any trend throughout the season. The maximum diameter of ovarian follicles was positively correlated with I_H in adult females (Figure 5; Spearman $r = 0.752$, $n = 61$, $t = 8.77$, $p \ll 0.001$).

Two gravid females were sampled. One was caught during February, and carried 16 embryos 38.8−42.8 cm L_T (mean = 41.05 ± 1.101 cm). Ovarian follicles from this female were minute (<1 mm in diameter) and translucent, resembling those from immature females (Figure 6). The other pregnant copper shark observed was caught in December, and had 16 embryos ranging from 57.0 to 60.6 cm L_T (mean = 58.92 ± 0.982 cm). The maximum ovarian follicle diameter in this shark was 14.5 mm, and the follicles were pale yellow, indicating that vitellogenesis had begun. No newborn or young-of-the-year copper sharks were caught either by boats targeting large sharks ($n = 475$ boats) or by those targeting smaller species ($n = 156$ boats). The mode of the length frequency distribution was in the range 206−220 cm L_T, and two secondary peaks are apparent at 181−185 cm and 236−240 cm (Figure 7).

Copper sharks were present in Anegada Bay from December to early April in the three fishing seasons studied. There were significant changes in cpue among different months (Figure 8; $H = 41.66$, groups = 5, $n = 166$, $p \ll 0.001$). Multiple comparisons showed that, in October and November, the cpue was significantly lower than in January through April ($p < 0.05$), and that April cpue was significantly lower than those of January, February, and March ($p < 0.05$). Copper sharks suddenly appeared and disappeared from the area. The overall sex ratio was not different from the 1:1 ratio in December. In contrast, in January, February, and March, females significantly outnumbered males (2−3 females to each male; Table 1). Sex ratios of immature copper sharks showed the same trends as overall sex ratios (Table 1), but in contrast, monthly sex ratios of adults were not significantly different from 1:1, except in March, when females outnumbered males (Table 1). Juvenile females were more numerous than adult females (1.87:1; $n = 204$;

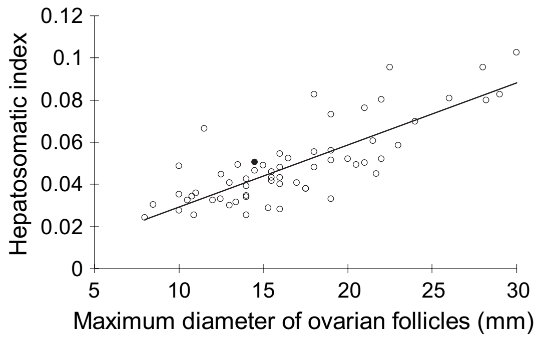

Figure 5. Relationship between maximum diameter of ovarian follicles and hepatosomatic index in adult female copper sharks, *Carcharhinus brachyurus*, in the Southwest Atlantic. The solid circle is a pregnant female, and n = 64.

$\chi^2 = 110.42$; $p = 4.78 \times 10^{-26}$). The ratio of juvenile to adult males was not different from 1:1 (0.792:1; n = 95; $\chi^2 = 1.05$; p = 0.259).

Discussion

Most estimates of male size at maturity of copper sharks from southern African waters (200−240 cm L_T, Bass *et al.*, 1973; Smale, 1991; Walter and Ebert, 1991) are in the same range as the Southwest Atlantic population (200−220 cm L_T, $L_{50} = 216.18$ cm L_T). However, Cliff and Dudley (1992) found that male copper sharks mature between 228 and 255 cm L_T, slightly larger than other estimates. Last and Stevens (1994) reported a size at maturity of 235 cm L_T for male copper sharks from Australia, larger than the value from the Southwest Atlantic. Several independent estimates of female size at maturity exist for South African specimens (Bass *et al.*, 1973; Smale, 1991; Walter and Ebert, 1991; Cliff and Dudley, 1992). The smallest pregnant female observed by Cliff and Dudley (1992) off South Africa was 238 cm L_T. Bass *et al.* (1973) stated that the smallest of six pregnant females measured 247 cm L_T. The smallest mature female copper shark examined by Smale (1991) was 231 cm L_T. Walter and Ebert (1991) estimated the size at maturity of female copper sharks at 229 cm L_T. In Australian waters, females mature at 245 cm L_T (Last and Stevens, 1994). Those studies therefore estimate a larger female size at maturity than in the Southwest Atlantic (215−223 cm L_T, $L_{50} = 222.16$ cm L_T), perhaps reflecting population differences. Interpopulation differences in size at maturity have been observed in several species of the genus *Carcharhinus* (Bonfil *et al.*, 1993; Wintner and Cliff, 1995; Castro, 1996). However, the conversion of one measurement of length to another as

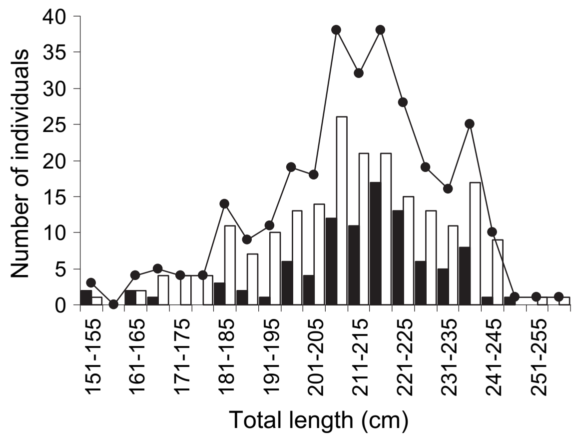

Figure 7. Length frequency distribution of copper sharks, *Carcharhinus brachyurus*, from Anegada Bay, Argentina. Open bars: females; solid bars: males; solid circles united by a line: sexes combined, n = 303.

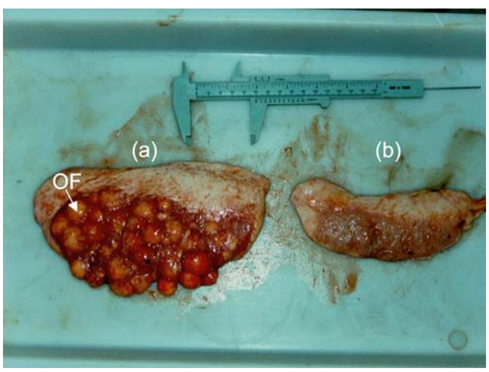

Figure 6. Functional ovary of two adult female copper sharks, *Carcharhinus brachyurus*, from Anegada Bay, Argentina. (a) Non-pregnant female 231.4 cm L_T with developed ovarian follicles (OF) about 20 mm wide, (b) pregnant female 239.4 cm L_T with undeveloped OF <1 mm wide. Caliper aperture = 5 cm.

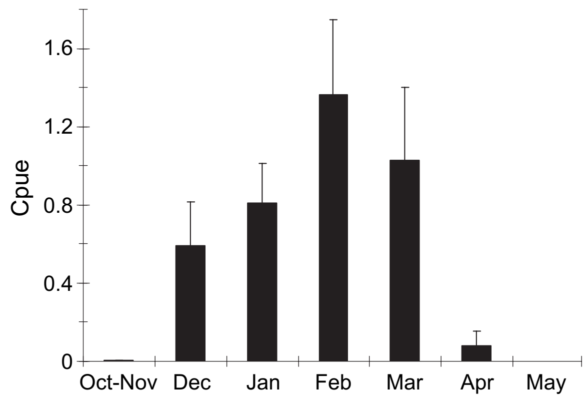

Figure 8. Monthly catch per unit effort (cpue), defined as number of sharks caught per fishing trip per day, of copper sharks, *Carcharhinus brachyurus*, in Anegada Bay, Argentina, averaged through the fishing seasons 1998/1999, 1999/2000, and 2000/2001. Lines are 95% confidence intervals.

Table 1. Monthly sex ratios (overall, for juveniles and for adults) of copper sharks, *Carcharhinus brachyurus*, from Anegada Bay, Argentina. Significance was assessed with a χ^2 test. Null hypothesis: monthly sex ratio is not different from the 1:1 ratio. The Yates' correction was applied to the statistic χ^2.

Comparison		December	January	February	March
Overall (females to males; n)		1.26; 43	1.97; 113	3.04; 88	2.44; 55
	χ^2	0.372	11.469	21.753	8.8
	p	0.542	0.0007	3.10×10^{-6}	0.003
Juveniles (females to males; n)		1.58; 31	2.94; 67	8.5; 57	1.86; 20
	χ^2	1.161	15.284	33.965	1.25
	p	0.281	9.25×10^{-5}	5.61×10^{-9}	0.263
Adults (females to males; n)		0.71; 12	1.19; 46	0.94; 31	2.89; 35
	χ^2	0.083	0.196	0.000	7.314
	p	0.773	0.658	0.950	0.007

a result of the different definitions of length used by different authors may contribute to some of the difference.

Size-at-maturity ranges for female and male copper sharks in the Southwest Atlantic overlap considerably. This appears to be common in the genus, because nearly equal sizes at maturity for both sexes have been reported for a number of *Carcharhinus* species (*C. melanopterus*, Lyle, 1987; *C. isodon*, Castro, 1993b; *C. limbatus*, Castro, 1996; *C. amblyrhynchos*, Wetherbee *et al.*, 1997; *C. porosus*, Lessa *et al.*, 1999).

Sadowsky (1967) found mating males in September with an I_H, computed from his data in the same way as in this study, two orders of magnitude lower than the males studied here, which suggests that some reserves are passed from the liver to the testes. The monthly differences in I_H found in adult males suggest that energy stored in the liver is used between December and March. However, no trend was apparent in male I_G as I_H decreases. Further work is needed to test the pattern found by Sadowsky (1967). The I_H of adult females was positively correlated with ovarian follicle size. Moreover, gravid females had I_H values (0.02 and 0.05) falling in the lower range of mature non-pregnant females (0.02−0.1). The data suggest that female liver reserves peak at ovulation, and that these reserves are used during gestation. Nevertheless, Cliff and Dudley (1992) found no correlation between liver mass and embryo length in copper sharks from South Africa. The few pregnant females available for the present study precludes inferences on the dynamics of the liver during pregnancy in copper sharks from the Southwest Atlantic.

The occurrence of small ovarian follicles in females from Anegada Bay carrying near-term embryos indicates that ovarian and gestation cycles are sequential. Off South Africa, the reproductive cycle of female copper sharks is biennial (with 12 months of gestation, Cliff and Dudley, 1992), as in most carcharhinids (Castro *et al.*, 1999). Our data do not give information on the absolute duration of the female reproductive cycle, but they do indicate that females do not ovulate immediately after giving birth, because maturation of oocytes occurs subsequent to parturition.

Garrick (1982) reported litter sizes between 7 and 23 embryos. Cliff and Dudley (1992) observed 46 litters ranging from 8 to 20. Only four pregnant female copper sharks are known from the Southwest Atlantic, all from Argentina. The numbers of pups in these litters were 17, 24 (Chiaramonte, 1996), and two litters of 16 (this study), and were roughly within the ranges recorded elsewhere. The smallest free-swimming juvenile copper sharks seen off South Africa's Eastern Cape measured 67 cm L_T (Smale, 1991). Garrick (1982) reported that the smallest free-swimming copper shark he observed was 58.5 cm L_T, whereas the largest embryo measured 67 cm L_T. The mean reported lengths of copper sharks in litters in Argentine waters other than from this study were 56.86 ± 1.57 cm and 62.61 ± 2.03 cm (Chiaramonte, 1996). The smallest free-swimming copper sharks reported from the Southwest Atlantic are seven animals of 65.0−69.5 cm L_T from Rio de Janeiro, Brazil (Bigelow and Schroeder, 1948). Litters with embryos >60 cm L_T are near the sizes of the smallest free-swimming individuals from the Southwest Atlantic. Litters with embryos 56−62 cm L_T were observed in October off Necochea (Figure 1; Chiaramonte, 1996), and in December in Anegada Bay (this study). The only litter with embryos 38−42 cm L_T was seen in February. These limited data suggest that birth may occur from October to December (i.e. spring to early summer), coinciding with the findings for South Africa (Cliff and Dudley, 1992).

Only two of the 72 adult females in the current sample were pregnant. Chiaramonte (1996) recorded two gravid females in a sample of 40. Furthermore, we recorded no juveniles <100 cm L_T despite having sampled angling catches (both for sharks and for smaller species) during three whole fishing seasons. Neonates of other large shark species were consistently recorded (i.e. the broadnose sevengill shark, *Notorynchus cepedianus*; Lucifora, 2003) during the sampling, which suggests that the fishing technique was adequate for catching copper shark neonates if they were present. These results do not support a hypothesis that there is a primary nursery area of copper sharks in Anegada Bay. This is an unexpected finding given the patterns observed elsewhere (i.e. primary nursery areas in higher latitudes). The absence of copper sharks during the austral winter (May–September) off Argentina (Chiaramonte, 1998) invalidates an alternative hypothesis of birth during winter in Anegada Bay. The smallest free-swimming copper sharks from the Southwest Atlantic have been recorded from Rio de Janeiro at the equatorial extreme of the species' regional range. Clearly, more data are needed to locate primary nursery areas of copper sharks from the Southwest Atlantic.

In the Southwest Atlantic, the copper shark is considered rare in southern Brazilian waters (Vooren, 1997), and it is only sporadically captured in coastal Uruguayan waters (Abella, 1972; Nion, 1999). Copper sharks are rarely taken by longliners in oceanic waters beyond the South American continental shelf (Amorim *et al.*, 1998; Marín *et al.*, 1998). Specimens recorded from Brazil (Sadowsky, 1967; Vooren, 1997; Soto, 2000) or Uruguay (Abella, 1972; this study) were always caught between autumn and early spring, allowing for a partial overview of copper shark seasonal distribution off the east coast of South America. It seems that copper sharks spend the spring and summer in Argentine coastal waters, then leave by the end of March, though the location of wintering grounds is unknown. Intensive sampling is needed along the Uruguayan coast to assess that area as a possible wintering location.

Off South Africa, copper sharks are abundant in the warm waters off KwaZulu-Natal during winter; there, their numbers decline dramatically in spring and summer (Cliff and Dudley, 1992), when they move to cooler Cape waters (Smale, 1991). Similarly in the Southwest Atlantic, copper sharks are most common in warm-temperate waters during cool months. In temperate waters of New Zealand, copper sharks are found in coastal waters only during summer (Cox and Francis, 1997). Off New South Wales, Australia, copper sharks are present between September and May, the numbers peaking between February and April (Krogh, 1994). This pattern is similar to that found in Anegada Bay, and the longer period of occurrence in New South Wales could be due to the lower latitude (33–35°S) compared with Anegada Bay (40°S). A latitude effect is also apparent along the Argentine coast, because the copper shark is abundant north of Anegada Bay as early as October (Chiaramonte, 1998). In Anegada Bay, the earliest captures of copper sharks were in early December, suggesting that they do not move southwards until late spring (i.e. December). This pattern could be directly related to temperature, which may directly affect the distribution of copper sharks (Cliff and Dudley, 1992). During spring (September–November), water 14–15°C is found off Necochea, while the water temperature in Anegada Bay is about 12°C (Martos and Piccolo, 1988). In summer (December–March), the water in Anegada Bay warms to about 16°C (Martos and Piccolo, 1988). Spring water temperature in Anegada Bay appears to be too cold for copper sharks.

Off South Africa, copper sharks arrive in KwaZulu-Natal waters following schools of sardine *Sardinops sagax*, their most common prey in the region (69–95% in frequency of occurrence; Cliff and Dudley, 1992). The situation differs for copper sharks from Anegada Bay, for which stomach content analysis reveals that the main prey consumed varies with sex and ontogeny, indicating that movements of copper sharks there are not related to the migration of a particular prey item (Lucifora, 2003).

The sex ratio of juvenile sharks shows the highest deviations from the ratio 1:1 in January and February (Table 1). In March, the sex ratio of adults differs from unity (Table 1). Combining our data with those of Chiaramonte (1998) reveals that from October through December, the sex ratio does not significantly deviate from the ratio 1:1. The overall proportion of females during October off Necochea (1.75:1; Chiaramonte, 1998) is lower than during the months January–March in Anegada Bay (Table 1), suggestive perhaps that females move south during summer, so segregating from males. Male copper sharks largely outnumbered females during summer in the warm KwaZulu-Natal waters (Cliff and Dudley, 1992), suggesting that females move either south or offshore then.

Most copper sharks caught in Anegada Bay are juvenile females. Walter and Ebert (1991) showed that the copper shark is a slow-growing species. In waters of Argentina, the species is taken in both commercial (Chiaramonte, 1998) and recreational fisheries (Chiaramonte, 1998; Lucifora, 2001). The effect of the fisheries on the Southwest Atlantic copper shark population is unknown, but fishing on large juvenile and sub-adult carcharhinid sharks will produce the biggest declines in their populations (Cortés, 1999). Therefore, Anegada Bay could be considered an important area for conservation of copper sharks, because it appears to be a concentration zone for large juveniles and sub-adults. However, more detailed information on the life history (e.g. age, growth, population structure, mortality rates) of the copper shark is needed to assess fishery impacts on the population.

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