NOTES ON THE REPRODUCTION OF THE OCEANIC WHITETIP SHARK, *CARCHARHINUS LONGIMANUS*, IN THE SOUTHWESTERN EQUATORIAL ATLANTIC OCEAN

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SUMMARY

A total of 104 oceanic whitetip sharks, 57 males and 47 females, were caught in the southwestern equatorial region and examined for their reproductive biology. Total length (TL) ranged from 72 to 253cm in males and from 74 to 252cm in females. These preliminary data suggest that size at first maturity is occurring from 160 to 196cm in males and from 181 to 203cm in females. A high proportion of the catch was composed by immature specimens, specifically 80.7% of males and 89.4% of females, suggesting a spatial size-segregation of this population. Three pregnant females were caught, with litters varying from 1 to 14 embryos. Even though at this stage there are not enough data to propose a reproductive cycle for this population, we forward the hypothesis that mating may be occurring early in the year, around March, and parturition might be occurring 10 to 12 months later, around January. As more data become available in this on-going study, we expect to define more clearly the size at maturity and the reproductive cycle of the oceanic whitetip shark for the southwestern equatorial region of the Atlantic Ocean.

RÉSUMÉ

Un total de 104 requins océaniques, 57 mâles et 47 femelles, ont été capturés au sud-ouest de la zone équatoriale et ont été examinés pour leur biologie reproductrice. La longueur totale a oscillé entre 72 et 253 cm chez les mâles et entre 74 et 252 cm chez les femelles. Ces données préliminaires suggèrent que la taille à la première maturité s'inscrit dans une fourchette de 160 à 196 cm chez les mâles et de 181 à 203 cm chez les femelles. Une forte proportion de la capture a été composée de spécimens immatures, notamment 80,7% des mâles et 89,4% des femelles, ce qui suggère une ségrégation spatiale de la taille dans cette population. Trois femelles en état de gestation ont été capturées, les portées variant de 1 à 14 embryons. Même s'il n'y a pas assez de données à ce stade pour proposer un cycle de reproduction pour cette population, nous émettons l'hypothèse que l'accouplement pourrait avoir lieu au début de l'année, aux environs du mois de mars, et que la parturition pourrait se dérouler 10 à 12 mois plus tard, vers janvier. Au fur et à mesure que de nouvelles données deviendront disponibles dans cette étude en cours, nous espérons définir plus clairement la taille à la maturité et le cycle de reproduction du requin océanique pour le sud-ouest de la zone équatoriale de l'océan Atlantique.

RESUMEN

En la región ecuatorial sudoccidental se capturó un total de 104 jaquetones de ley, 57 machos y 47 hembras que fueron examinados para estudiar su biología reproductiva. La longitud total (TL) oscilaba entre 72 y 253 cm en los machos y entre 74 y 252 cm en las hembras. Estos datos preliminares sugieren que la talla de primera madurez se produce entre 160 y 196 cm en los machos y entre 181 y 203 cm en las hembras. Una elevada proporción de la captura se componía de ejemplares inmaduros, específicamente el 80,7% de los machos y el 89,4% de las hembras, lo que sugiere una segregación espacial por tallas en esta población. Se capturaron tres hembras grávidas, con camadas que variaban entre 1 y 14 embriones. Aunque en esta etapa no existen datos suficientes para proponer un ciclo reproductivo para esta población, se

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plantea la hipótesis de que puede estarse produciendo el apareamiento a principios de año, aproximadamente en marzo, y el parto podría estarse produciendo 10 ó 12 meses más tarde, aproximadamente en enero. A medida que se disponga de más datos en el estudio en curso, esperamos definir más claramente la talla de madurez y el ciclo reproductivo del jaquetón de ley para la región ecuatorial sudoccidental del Atlántico.

KEYWORDS

Reproductive cycle, Carcharhinidae, Carcharhinus longimanus, oceanic whitetip shark, southwest equatorial Atlantic Ocean

1. Introduction

The oceanic whitetip shark, *Carcharhinus longimanus*, is a widespread pelagic shark, ranging across entire oceans in tropical and subtropical waters, and is usually found offshore at or near the surface in the open ocean (Compagno, 1984). This shark prefers tropical warmer waters (Mather and Day, 1954), and usually withdraws from colder waters when the temperature gets lower than about 21ºC (Backus *et al.*, 1956). Even though it is usually a slow moving shark, often seen cruising slowly at or near the surface, it is a quite active species and seems to be equally active at daytime and at night (Compagno, 1984).

The oceanic whitetip shark is a relatively common species and in the past it has been described as one of the most common species in oceanic waters of some regions of the world. In the Gulf of Mexico their high abundance during the 1950's made them responsible for considerable damage to tuna caught by longline (Backus *et al.*, 1956). In the southwestern equatorial Atlantic, the oceanic whitetip is commonly caught as by-catch by tuna and swordfish longliners (Hazin *et al.*, 1990) and may be the second most abundantly by-catch elasmobranch species after the blue shark, *Prionace glauca* (Lessa *et al.*, 1999). Given its highly migratory nature, this species has been listed under annex I (Highly Migratory Species) of the United Nations Convention on the Law of the Sea and it currently listed as "Vulnerable" according to the IUCN Red List Criteria (IUCN, 2006).

Despite the fact that the oceanic whitetip shark is a globally widespread species, relatively common in oceanic tropical waters, information on its biology is still limited or even non-existent for many parts of the world. Reproductive parameters, including size at maturity, litter sizes and seasonality have been reported for the northwest Atlantic, including the Gulf of Mexico (Backus *et al.*, 1957), for the Pacific (Stevens, 1984; Seki *et al.*, 1998) and for the Indian Oceans (Bass *et al.*, 1973; Gubanov, 1978). For the southwestern Equatorial Atlantic, Lessa *et al.* (1999) estimated age and growth parameters, but nothing is known about the reproductive parameters of this species for this region.

Therefore, the objective of this study is to present preliminary data on the reproductive biology of the oceanic whitetip shark caught in the southwestern equatorial Atlantic Ocean, specifically in regard to size at maturity, fecundity and reproductive seasonality, with the expectation that they may be used as a baseline for management and conservation initiatives on this species.

2. Material and methods

From August 2007 to March 2008, 104 *C. longimanus* caught by commercial longline vessels fishing in the southwestern equatorial Atlantic Ocean were examined. Once taken aboard, these sharks were identified, sexed and measured for total length (TL), fork length (FL), pre-caudal length (PCL) and inter-dorsal space (IDS). The sharks were then dissected for the collection of the reproductive organs, which were then preserved in a sea-water 10% formalin solution. Subsequently, all samples were transported to the Fisheries and Oceanography Laboratory of the Federal Rural University of Pernambuco, where they were further analyzed.

The ovaries and oviductal glands of females were measured and weighed in the laboratory. The number of oocytes was counted and the diameter of the largest one measured using a caliper. Both uteri were measured for width and, following dissection, had their contents observed. Whenever there were developing embryos in the uteri, they were counted, sexed, measured for TL and weighted. For males, the testes were measured and

weighted and the presence of semen in the ampullae ductus deferens recorded. These macroscopic observations of the reproductive organs were used for establishing maturity stages for both sexes.

Preliminary sizes at maturity were determined by analyzing the size range of the specimens in each of the different maturity stages. Litter sizes were determined by direct counting of the developing embryos in the uterus of pregnant females. Seasonality was determined by analyzing the presence of both pre-ovulatory females and pregnant females with embryos at different stages of development along the year. Since this paper is only analyzing data from a restricted time period, specifically from August 2007 to March 2008, a complete scenario of the reproductive seasonality could not be established, even thought a preliminary hypothesis was forwarded. As more data will become available on this ongoing study, a more complete scenario of the reproductive strategy of this species for the southwest equatorial Atlantic will be established.

3. Results and discussion

From the sample of 104 specimens, 57 were males and 47 were females, resulting in a sex ratio (male:female) of 1.2:1. This sex ratio is different to what had been observed for the Gulf of Mexico population, where most of the catches are females (Backus *et al*., 1956). Our sample size range was very similar on both sexes, with males ranging from 72cm to 253cm TL and females from 74cm to 252cm TL, and with most specimens measuring from 100cm to 220cm TL (**Figure 1**). Again, some differences were found to what was recorded by Backus *et al*. (1956) in the 1950´s for the Gulf of Mexico, where most specimens caught were much larger, ranging mainly from 170cm to 240cm TL.

Males were divided into three reproductive stages: immature, maturing and mature. Immature males in the sample ranged from 72 to 170cm TL (n=40; 70.2%) and were characterized for having small and non-calcified claspers and small immature testis, usually with less than 15g in weight. Maturing specimens in the sample ranged from 150 to 196cm TL (n=6; 10.5%) and were characterized for having larger and developing testes, usually from 15g to 30g in weight. The mature specimens in the sample ranged from 160 to 253cm (n=11; 19.3%), had large and calcified claspers, and large testis, with more than 30g in weight (**Figure 2**).

Females in this study were found in four maturity stages: immature, maturing, pre-ovulatory and pregnant. Immature specimens ranged from 74 to 193cm TL (n=38; 80.9%) and were characterized for having a small and narrow ovary weighting less than 20g. Maturing females ranged from 176 to 203 cm TL (n=4; 8.5%) and were similar to the immature ones, with the ovary slightly more developed but still with less than 50g in weight. Two mature pre-ovulatory specimens were found at 181 and 187cm TL (n=2; 4.2%). That stage was characterized by having a large and highly developed ovary, weighing between 200 and 300g with large and developed oocytes greater than 10mm in diameter (**Figure 3**). Three pregnant females ranging in size from 213 to 252 cm TL (n=3; 6.4%) were characterized by the presence of developing embryos in the uterus. The embryos ranged from 30 to 33cm TL (140 to 260g in weight) in one individual caught in September to 52cm TL (790g in weight) in another female caught in November.

Males of oceanic whitetip shark seem to be maturing at smaller sizes than females, a fact common in many elasmobranch fishes (Cortés, 2000). The largest immature female found was 203cm TL, while the smallest mature was 181cm TL. In males, the largest immature specimen found was 196cm TL, while the smallest mature was 160cm TL. Thus, males in this population seem to be maturing between 160cm to 196cm TL, while females mature at slightly larger sizes, between 181 and 203cm TL. Other authors have determined similar, although slightly different, sizes at maturity for other populations of the oceanic whitetip shark around the world (**Table 1**). Specifically, Bass *et al*. (1963) suggested that in the southwest Indian Ocean males matured from 185 to 198cm TL and females from 180cm to 190cm TL; Seki *et al*. (1998) determined that in the Northwest pacific males matured from 125cm to 135cm PCL (168cm to 196cm TL, converted) and females from 125cm to 135cm PCL (175cm to 189cm TL, converted); and Stevens (1984) suggested that females in the southwest Pacific were maturing at around 200cm TL.

Most of the specimens caught during this study, both males and females, were immature. Thirty-six (80.7%) of the 57 males caught were immature (either juveniles or maturing) while only 11 specimens (19.3%) were mature. For females, the percentage of immature specimens in the sample was even higher, with 42 of the 47 specimens (89.4%) being immature (either juvenile or maturing). This observation of a large predominance of juveniles in the study area might be tentatively explained by a size related spatial segregation of this species, with the southwestern equatorial Atlantic Ocean being an area of concentration for juveniles of both sexes. However, even though juveniles tended to dominate the area during all sampled months, the period of the late

austral spring / early summer (September to January) seemed to have a slightly larger concentration of adults of both sexes (**Figure 4**). Given that in this preliminary study we only analyzed data from August 2007 to March 2008, we do not know the population structure during the remaining months of the year. As more data becomes available the population size structure in the region throughout the year will be further clarified.

Pre-ovulatory specimens with enlarged oocytes in the gonads were caught during January. These oocytes were considered developed as they were enlarged and measured from 10.2 to 30.6mm in diameter. In Australia, Stevens (1984) found females in similar stages a little later in the year, between March and May, with oocytes slightly larger than in this study (25-42mm in diameter), and noted that one female with these large oocytes bore possible mating scars. Therefore, these females, considered to be in pre-ovulatory stage, may, in fact, need a few more weeks until their oocytes reach the fully developed size and mating in this population may also be occurring around March, a situation that would be similar to what is occurring in the southwest Pacific (Stevens 1984).

Litter sizes in the 3 pregnant females found ranged from 1 to 14 embryos, similar to what other studies have found for other populations in other regions (**Table 1**). Pregnant females with mid-sized embryos (around 30cm in length and 140 to 260g in weight) were found in September, while near-term embryos (around 52cm in length and 790g in weight) were found later in the year, during November. Given that the size at birth for this species has been described to be 55 to 65cm TL (Compagno, 1984), the embryos found in November with 52cm TL were close to being fully developed, and parturition would be expected to occur shortly after, possibly around January. This would again be similar to what Stevens (1984) observed for the Southwest Pacific region, where parturition seems to be occurring from January to March.

Even thought at this stage there is not yet enough data to establish a definitive reproductive cycle for this species in this region of the Atlantic, at this stage, we forward the hypothesis that mating can be occurring early in the year, around March, and that embryo development might be taking almost one year, with parturition occurring around January. This would imply a 10 to 12 month gestation period, a fact previously described for this species and that seems to take place even when reproduction is occurring at different periods of the year (Backus *et al.*, 1956; Bass *et al.*, 1973; Stevens, 1984; Seki *et al.*, 1998). If this hypothetical reproductive cycle is indeed confirmed as more data become available, then the population from the southwestern equatorial Atlantic has a reproductive cycle occurring at different months of the year than the northwestern Atlantic population, but with a similar seasonality. In both regions mating and parturition seems to be occurring in late spring / early summer, with a six months delay due to the time difference in the boreal and austral summer periods.

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Table 1. Summary of the reproductive data available worldwide for *Cacharhinus longimanus* from scientific literature.

Area	*Size at maturity (TL; cm)*		*Litter size*	*Reproductive cycle*		*Ref.*
	Males	*Females*		*Mating*	*Parturition*	
South-west equatorial Atlantic	160-196	181-203	1-14 (avg = 9.6)	Possibly around March	Possibly around January	Present study
North-west Atlantic			1-9 (avg = 5.5)	Late spring-early summer	Late spring-early summer	Backus et al. (1956)
South-west Pacific		200	4-8 (avg = 6.8)	March-May	January-March	Stevens (1984)
North-west Pacific	168-196*	175-189*	1-14	June-July	February-July	Seki et al. (1998)
South-west Indian Ocean	185-198	180-190	6-8 (avg = 7.0)	Early summer	Early summer	Bass et al. (1973)

*Seki *et al* (1998) presented values of pre-caudal length (PCL) that for comparison purposes were converted into TL through their formula (TL=1.397xPCL).

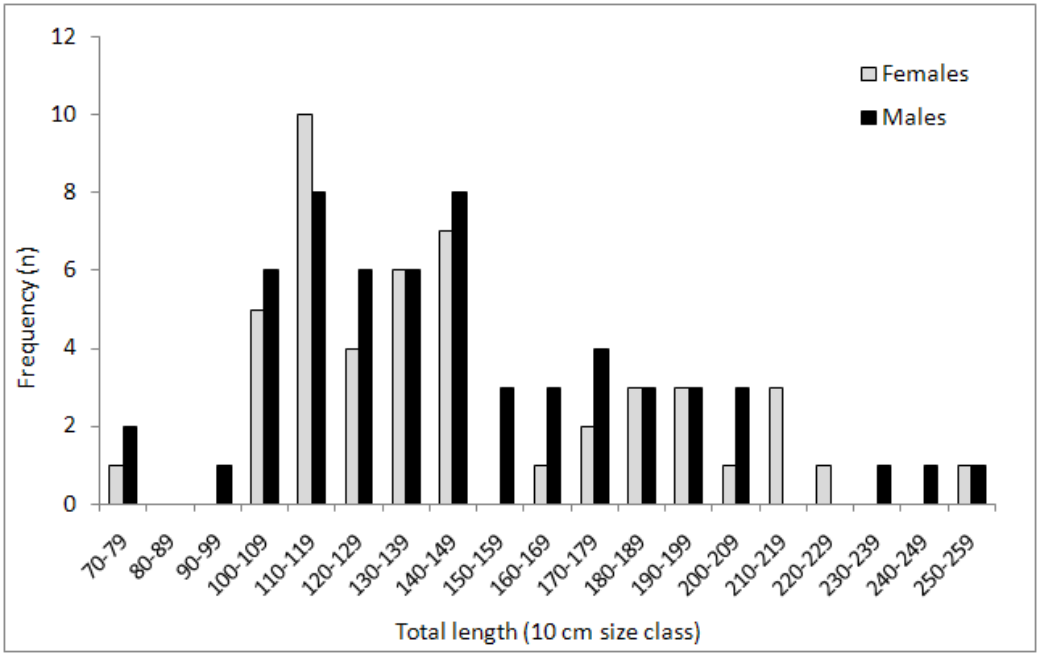

Figure 1. Length-frequency distribution of female and male oceanic whitetip sharks caught in the southwestern equatorial Atlantic Ocean, between August 2007 and March 2008.

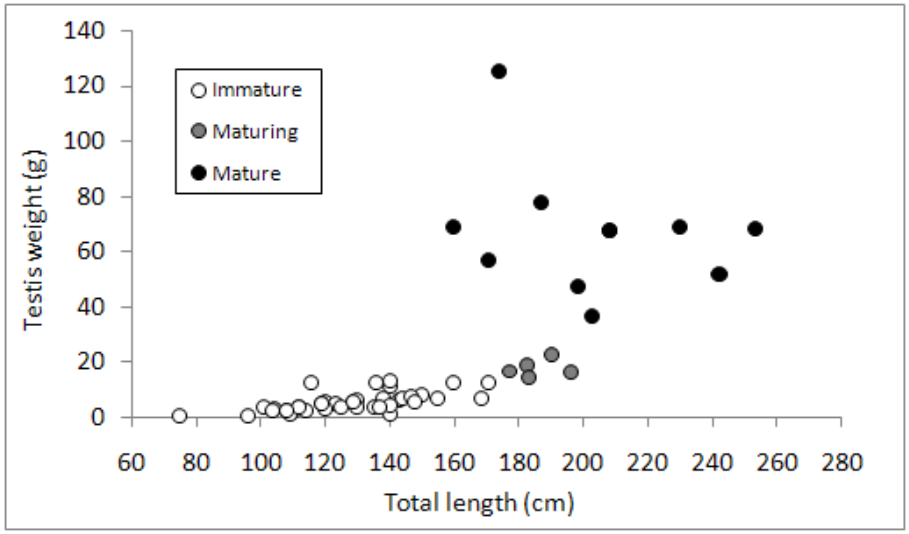

Figure 2. Relationship between total length and testis weight for *Carcharhinus longimanus*.

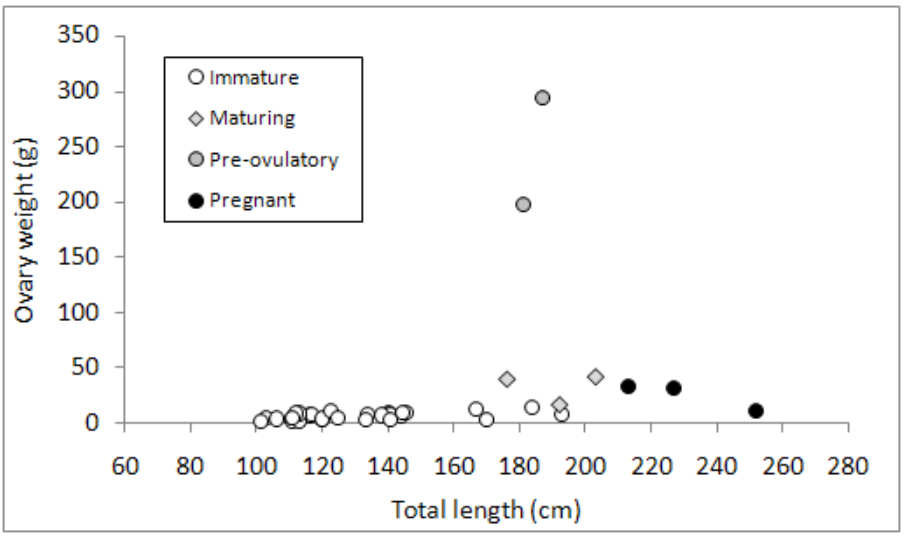

Figure 3. Relationship between total length and ovary weight for *Carcharhinus longimanus*.

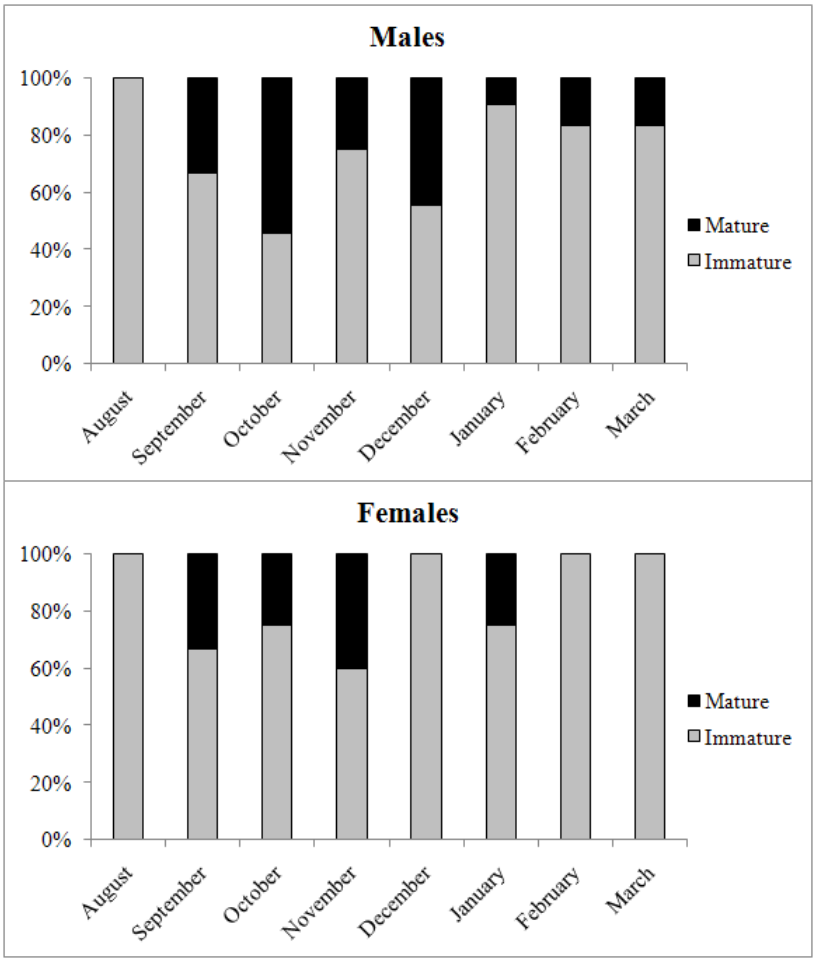

Figure 4. Proportion of mature and immature male (above) and female (below) *Carcharhinus longimanus* in the southwestern equatorial Atlantic Ocean, during the sampling period.