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BIOLOGICAL OBSERVATIONS OF OCEANIC WHITETIP SHARK (*Carcharhinus longimanus*) ON SPANISH SURFACE LONGLINE FISHERY TARGETING SWORDFISH IN THE INDIAN OCEAN OVER THE PERIOD 1993-2011

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Abstract

A total of 7107 oceanic whitetip sharks (3440 females, 3444 males and 223 unidentified) were observed in the Indian Ocean between 4ºN-34ºS and 34º-109ºE during the period 1993-2011. The observed prevalence –all data combined- of the oceanic whitetip shark totaled 1.4% or 5.0% depending on whether we take into consideration the catch of all species combined or the catch of sharks only, respectively. However, great differences can be seen among the different areas, affecting the overall prevalence when data are geographically stratified. Standard length (FL) ranged from 50 to 250 cm and 50-260 cm for females and males, respectively. Individuals with the smallest lengths were mostly observed to the East of 75ºE and North of 20ºS. The nominal CPUE by length groups also confirms this segregation. The female overall sex-ratio was 50.0%. A total of 11.2% of the females specifically analyzed showed external or internal signs of fertilization (92.3% of them had embryos in their uteri). The average litter size per pregnant female was 8.9 embryos (CI90%: ±0.6) (minimum 2 and maximum 20). The smallest embryo observed was 12 cm FL and the largest was 61cm FL. Data on embryo length, sex-ratio, litter size per uterus and embryo length by month are also provided.

Key words: *C. longimanus*, oceanic whitetip shark, surface longline, reproduction.

1. Introduction

Some 29 species have been described as belonging to the genus Carcharhinus, which is one of the genera of sharks having the highest number of identified species (Compagno 1984). *Carcharhinus longimanus* is one of the most characteristic species within this genus and can be observed relatively frequently in warm waters of the oceanic epipelagic system of the Atlantic, Indian and Pacific oceans . This species has also been reported sporadically in coastal zones and in the proximity of oceanic islands surrounded by warm waters. It is identified by its common name in English, "oceanic whitetip shark" but its common names differ widely from country to country and even within regions of the same country (Anon. 1984, Negedly 1990).

Its taxonomic identification is fairly simple as compared with that of other species of the same genus, owing to a number of visible details, the most outstanding of which is its large, rounded first dorsal fin and its large, characteristic pectoral fins. Moreover on the outer margins of the three fins and the large caudal fin there are white spots (whitetip) which are very characteristic and highly visible during both submarine observation and capture. These four large whole fins, along with other smaller fins, contribute significantly to the individual's body weight, accounting for a mean estimated ratio of 9.60% of its round weight and between 16%-21% of its dressed weight according to the criteria followed by the EU fleet (Mejuto & García-Cortés 2004, 2009, Ariz *et al.* 2006, 2008).

The geographic distribution of this species is fairly extensive, going from temperate regions to warm water zones, preferably –although not exclusively- within a SST range that usually fluctuates between 20º and 28º C. For this reason, the species is more likely to be observed in intertropical oceanic regions, even though it may also appear in areas with greater latitude, generally related to the large warm currents that flow in the respective hemispheres and oceans. As happens with many large pelagic sharks, the spatial and temporal segregation of this species has been described according to size-sex (Coelho *et al.* 2009). Its reproduction is viviparous with yolk-sac placenta (Compagno 1984). The females are believed to attain maturity at around 180 cm TL, which would correspond to roughly 4 years of age (Seki *et al.* 1998) with litters consisting of between 1 and 15 individuals. At birth pups measure approximately 60-65 cm in length (TL) after an estimated gestation period of around one year (Compagno 1984). Its spatial distribution often overlaps with other epipelagic species that are much more prevalent and sometimes with other species of the same genus as well. However, different preferential habitats

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have been described among the various species of the genus, and negative correlations between the species have even been reported owing to their different preferences in the environmental conditions selected (García-Cortés *et al.* 2011).

C. longimanus may be caught by fleets dedicated to sport, recreational and recreational-charter activities. These fisheries are sometimes used as a way to lure tourists to the coastal zones. It may also be caught as by-catch by commercial fisheries using different types of fishing gears. In the case of the purse seine fleet targeting tropical tunas, the genus Carcharhinus, and particularly *C. longimanus*, is reported fairly often as a by-catch associated with sets targeting schools of tropical tuna (Delgado de Molina *et al.* 2005, Poisson *et al.* 2011, Anon. 2006). This species can reach the 23% of the total shark bycatch when FADs are used in this fishery (De Molina *et al.* 2007). This genus may also be caught as by-catch in drifnets and deep and surface longline fisheries. Scientific observations carried out on board longliners targeting swordfish or tropical tunas in different oceans have identified *C. longimanus* as a potential by-catch species, although with an overall low prevalence versus the target species or other by-catch species (Semba & Yokawa 2011, Poisson & Taquet 2001, Mejuto *et al.* 2007, Mejuto *et al.* 2009). Some fleets have reported a higher prevalence of this species (Coelho *et al.* 2009) probably due to the environmental characteristics of the equatorial Atlantic areas selected for the fishing operation and/or strategy to target the preferential species in that fishery.

However, due to its relatively low prevalence when compared to other pelagic species, commercial records of many fleets in the world identify this genus as a combined species or simply as "other sharks", unclassified.

Scientific estimations on the levels of annual landings of *C. longimanus* in the EU-Spain longline fishery in the Indian Ocean have been reported for the period 1993[2]- 2008 (García-Cortés & Mejuto 2001, 2005; Ramos-Cartelle *et al.* 2008, 2009) or as an estimation of the landings for the most recent years 2009-2010. The mean annual landing of this species carried out by this fishery during the 1998-2010 period was estimated as being 24.5 t/year (CI95%: 42.7 t - 9.4 t) and its mean prevalence for the period as a whole was estimated at 0.31% (CI95%: 0.52%-0.13%) or 0.55% (CI95%: 0.92%- 0.23%) depending on whether the total landed species are considered or if swordfish are excluded, respectively.

This study aims to provide information on the biology and reproduction of this species based on the observations carried out in the Spanish longline fishery targeting swordfish.

2. Material and methods

Biological observations on oceanic whitetip shark *C. longimanus* (OCS) were conducted with standardized criteria on board commercial surface longliners targeting swordfish, *Xiphias gladius,* (SWO) in different zones of the Indian Ocean where the Spanish surface longline fleet fished over the 1993-2011 period. The records were voluntarily obtained and provided in the framework of a research activity. A large amount of the observations are from areas where the commercial fishing activity is unusual, minor or obtained during experimental surveys. The records were classified into 4 different zones for descriptive purposes, taking into consideration the average annual thermal structure at 50 m depth (figure 1).

The length of oceanic whitetip shark individuals and the embryos found in pregnant females was measured in a straight line to the nearest centimeter, from the anterior most part of the head to the fork in the caudal fin -fork length- (FL cm) accepted and recommended as the standard size. The FL of the individuals observed was subsequently grouped into 5cm classes. The FL of the embryos was analyzed using 1 cm length classes. In both cases, the length classes were defined by using their respective lower limits.

The sex of the individuals was visually identified according to the presence or absence of claspers in the pelvic fin. Special care was taken when observing juveniles, since at first sight young males may be erroneously identified as females as their claspers may not go beyond the further edge of the pelvic fin.

Most identified females could be specifically analysed in order to detect the absence or presence of external or internal fertilization signs. External fertilization signs were detected by identifying external tooth cuts or mating injuries (Mat.) caused by the males during mating (Pratt 1979) with no embryos observed in their uterus. The internal fertilization signs in females were defined by the dissection and internal detection of embryos in the uterus, in which case they were classified as pregnant females (Pre.). On some occasions, if embryos were found,

[2] Note that the EU-Spain longline fishery in the Indian Ocean began in 1993.

the litter size was counted and/or measured in order to estimate their degree of development and their sex. The average values of the number of embryos per female (litter size) were calculated, as well as the average length (FL cm) of the embryos found by female and by area.

The overall and area-specific sex ratios were calculated as the percentage of females present with regard to the total number of sexed individuals. Sex ratios were obtained for all sizes combined -overall sex ratio (SRo)- as well as by length class -sex ratio at size (SRs)- including, in the last case, their respective confidence intervals (Restrepo 1998).

Catches per unit effort (CPUE) were calculated per thousand hooks, by sex and by combined sexes, both in kg dressed weight (CPUEw) and in number of fish (CPUE#) as well as for each category or size group: juveniles CAT1= 50-120cm FL, CAT2= 125-165cm FL (initially considered as sub-adults), adults CAT3= 170-200cm FL, large adults CAT4= 205+ cm FL.

3. Results and discussion

OCS observations in the Indian Ocean took place within a broad geographical range 4ºN-34ºS and 34º-109ºE. However, most of them were obtained within the warm intertropical strip (Zones 1 and 2) with annual temperatures regularly greater than 24ºC at 50 m depth. Some observations were also described in the Southern latitude frequently linked to the seasonal expansion of the warm sea masses and/or the warm stream current flowing South along Africa (Zone 3). Sporadic observations reported as oceanic whitetip shark were also identified at latitudes near or above 30º-35ºS with average temperatures at 50 m depth currently below 22ºC (figures 1 and 2). The total number of specimens observed was 7107 individuals, 3440 of which were identified as females, 3444 as males and 223 were sex-unidentified (unk) (table 1). Zones with the highest number of observations of OCS do not match the regular commercial fishing areas of this fishery.

The overall prevalence of oceanic whitetip shark observed in all the zones-years combined was 1.4% or 5.0% with regard to the total catch of species combined (dressed weight of the targeted + bycatch species) or with regard to the shark catch only, respectively. The maximum prevalence vs. the different groups of species considered was observed in Zone 2 and the minimum in Zone 4. However, the highest prevalence within the Carcharhinus genus was only observed in Zone 4 (61.8%) (table 2). The overall prevalence levels of *C. falciformis* and *C. longimanus* suggest that these species seem to be somewhat balanced at a global level, although the silky shark has a slight dominance (53.0%) over the oceanic whitetip shark. Similar results have been described in other oceans (García-Cortés *et al.* 2011, Matsunaga & Nakano 1999, Springer 1967). The bivariate fit between their respective prevalence by zone suggests a negative and significant correlation C. falciformis% = 137.03 – 2.061 * C. longinanus%, (R^2= 0.9787, Prob >F= 0.0107) (figure 3) as was also described in the case of the Pacific Ocean (García-Cortés *et al.* 2011).

Table 3 shows the frequency per length class observed for all oceanic whitetip shark sampled in the combined zones of the Indian Ocean and for the years during which observations are available. Any conclusions about trends over time should be taken because most size data from some years pertain only to specific zone/s. The length range (FL) went from 50-250 cm to 50-260 cm for females and males, respectively, with similar overall length distributions for both sexes. However, different length distributions among certain zones seem to be apparent by sex and combined sexes (figures 4 and 5, annex I). Modal distributions of specimens with very different lengths -small or large- were observed in Zones 1 and 4, respectively. Zone 1 shows the largest amount of small individuals observed. Figure 6 shows the cumulative-relative length frequency for the Indian Ocean by sex and combined sexes. Roughly 50% of the overall individuals observed measured less than 120cm FL regardless of their sex and for all zones combined. However, great differences in length were observed among zones. 50% of individuals observed in Zone 1 were smaller than 90 cm FL; in zone 2 they measured less than 130cm FL; in Zone 3 under 160 cm FL; and in Zone 4 less than 190 cm, suggesting a clear size segregation probably owing to the migratory processes among biological regions. Cumulative percentages of the respective length distribution facilitate comparisons among zones-sexes (figure 7).

The overall CPUEw per thousand hooks shows a relatively moderate variation among zones for each sex and sex combined. The biomass prevalence of males in the catch is slightly lower in Zones 1 and 2 and clearly higher in Zones 3 and 4 (table 4). The greatest CPUEw per thousand hooks was observed in Zone 3 with 38.80 kg DW, followed by Zone 2 with 36.54 kg DW. However, a much higher difference among zones was observed in the case of the CPUE# as result of the spatial segregation by size. The greatest CPUE# was observed in Zone 1 with 4.3 specimens per thousand hooks. The CPUE# data per length category also suggest the geographical segregation of the smallest individuals (CAT1) for both sexes especially in Zone 1 in coexistence with CAT2. In Zone 2, the CAT1 coexists with CAT2 specimens. In Zones 3 and 4 there appear to be more individuals of CAT3 and a larger number of males in particular (figure 8). The mean dressed weights sex-combined obtained from the CPUE data corroborate this segregation: 6.79 kg, 15.55 kg, 24.48 kg and 33.02 kg dressed weight for Zones 1, 2, 3 and 4, respectively.

The overall SRo obtained for the whole Indian Ocean was 50.0% females. The SRo values by zone were 51.4%, 52.7%, 37.6% and 33.9% for zones 1, 2, 3 and 4, respectively (figure 9). The SRs values by zone show slight differences or similarities among each other (figure 10). However, these SRs patterns are affected by the spatial definition assumed as well as by the temporal variability of SRs which could not be considered in this analysis because of data limitations. In general, the SRs pattern for the whole Indian Ocean combined shows similar proportions between sexes, at least for sizes smaller than 200 cm FL, supporting the absence of significant growth differences between sexes previously reported (Seki *et al.* 1998). A similarity between SRs patterns can be observed between Zone 1 and Zone 2 (warmer zones) but there is a dissimilarity with Zone 3 where the proportion of females tends to decrease for sizes larger than 130 cm FL. Due to the scarce observations from Zone 4, it is not possible to draw conclusions about SRs for this zone.

Table 5 summarizes the number of specimens found by sex and area and their overall sex-ratios (SRo) as well as some data related to the different reproductive stages of females. A total of 1009 females were specifically observed to identify external or internal signs of fertilization. The results showed that most of the females observed exhibited no signs of fertilization (88.8%). Only 11.2% (113 individuals) showed signs of fertilization (F_Fec). Zone 2 turned out to be the zone with the highest SRo values (52.7%) and largest number of females observed with signs of fertilization, but with a low prevalence, 5.3%. Moreover most of these females were in some stage of pregnancy. A large number of females (709 individuals) were observed in Zone 1 but no females were identified with signs of fertilization.

A total of 829 embryos were observed in 105 oceanic whitetip pregnant females. The total number of embryos found, their average, maximum and minimum number, as well as the number of embryos by sex and their corresponding sex-ratios per zone are summarized in table 6. The average litter size was 8.9 embryos per female (CI90%: ±0.6). A minimum number of 2 embryos per litter were observed in a female of 174 cm FL and a maximum of 20 embryos was observed in a female of 206 cm FL. The minimum, maximum and average length observed of the pregnant females was 164 cm, 230 cm FL and 191.9 cm FL (CI90%:±2.2), respectively. Table 7 contains a summary of the average number and length of embryos with their respective confidence intervals (CI90%) per length class of the individuals identified as pregnant females. A correlation coefficient (0.60313) of a linear model between the female length and its litter size (litter size = -16.1178 + 0.130184*FL female) points to a moderate relationship between the variables and the R-squared statistic indicates that the model as fitted explains 36.7% of the variability of the litter size. A positive correlation between female length and its litter size was also found in the northwestern Atlantic (Bigelow & Schroeder 1948) as has been described in other species such as *Prionace glauca* and *C. falciformis* belonging to the same family (Castro & Mejuto 1995, Mejuto & García-Cortés 2005, García-Cortés *et al.* 2011).

The average embryo length observed was 35.6 cm FL (CI90%: ±1.8). The litter size scatter plot and the average litter size (and CI90%) by length class of the pregnant females are presented in figure 11. Two females measuring 177 cm and 189 cm FL in Zone 2 presented the lowest average embryo length (12.0cm FL). The only pregnant female found in Zone 4 of 225 cm FL showed the greatest average embryo length with 61.0 cm FL, similar to the birth length estimated of around 45-55 cm precaudal length in the Pacific (Seki *et al.* 1998). The highest number of pregnant females was observed in Zone 2. These data have been used for a specific analysis taking into account the month variable (figure 12). The average length of the embryos observed in this zone seems to increase from January to October which would suggest a possible parturition time around the last months of the year projecting a similar trend. The smallest mean value observed in November could be explained by the entry into this zone of new batches of pregnant females containing smaller embryos for a new cycle of embryonic development overlapping with the final development phases of previous batches.

The overall sex-ratio obtained for a total of 612 embryos sexed was 49.7% for females (figure 13). It was also possible to count a total of 366 and 322 embryos found in the right and left uterus, respectively. The range of embryos found per uterus was from 2 to 11 (right uterus) and 0 to 9 (left uterus). These ranges were lower than the range found in the North and South Pacific from 1 to 14 and 1 to 12 embryos, respectively (Seki *et al.* 1998) Table 8 summarizes the total number of embryos observed in each uterus (left and right), the total and average number of embryos found per uterus with their confidence intervals (CI90%) for each zone considered in the analysis.

The results confirm that the distribution of this species in the Indian Ocean would fall preferably within the warm water regions to North of 25ºS (Zones 1 and 2) and with less probability in some of the adjacent areas located a little farther to the South which are influenced by the seasonal expansion or displacement of warm water masses. The probability of *C. longimanus* being vulnerable as a possible bycatch would therefore be greater in Zones 1 and 2 than in the other zones analyzed. The size and CPUE data suggest spatial segregation between zones of the Indian Ocean. Zone 1 would include most of the juveniles under 2 years old, while Zones 2, 3 and 4 would comprise progressively larger individuals, suggesting the existence of a sequential migratory process carried out by individuals between the zones to select the most appropriate habitats for the development of the respective biological processes over the course of their life span. The data yielded support the relatively low prevalence described for this species in the commercial fishery of surface longline fleets targeting swordfish in waters with temperatures generally lower than those selected by this species as their preferred habitat. In this sense, the mean fishing effort data corresponding to the EU-Spain fleet for the 2007-2010 period (figure 14) indicate that only 2.15% of their mean annual effort was carried out at latitudes lower than or equal to 20º S and 6.24% of their effort was exerted at latitudes lower than or equal to 25ºS and longitudes lower than or equal to 75ºE. Null effort was reported in the regions with longitudes greater than or equal to 75ºE to the North of 20ºS, where a greater interaction with juveniles would have been expected.

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References

ANON. 1984. Multilingual dictionary of fish and fish products. OECD. Fishing News Books Limited.: 430pp.

ANON. 2006. Propuesta de evaluación exhaustiva de especies clave de tiburones capturadas en asociación con la pesca en el océano Pacífico oriental. IATTC. Grupo de Trabajo Sobre las Evaluaciones de Poblaciones, 7ª Reunión 15-19 mayo 2006. Doc. SAR-7-11.

ARIZ, J., A. DELGADO DE MOLINA, M. L. RAMOS, J. C. SANTANA. 2006. Body-weight (dressed weight) and fin-weight ratios of several species of shark caught by Spanish longliners in the Indian Ocean. IATTC Working Group to Review Stock Assessments, 7th Meeting, La Jolla, California (USA), 15-19 May 2006, Document SAR-7-09.

ARIZ, J., A. DELGADO DE MOLINA, M. L. RAMOS, J. C. SANTANA. 2008. Round-weight and fin-weight ratios for several species of sharks from data gathered by scientific observers on board Spanish surface longliners in the Indian Ocean during a pilot action. Working Paper IOTC-2008-WPEB-08.

BIGELOW, H.B., W.C. SCHROEDER. 1948. Fishes of the Western North Atlantic. Part 1. Lancelets, Cyclostomes, sharks (eds. A.E. Parr and Y. H. Olsen). Seas Foundation for Marine Research, New Haven, CT, 576 pp.

CASTRO, J., J. MEJUTO. 1995. Reproductive parameters of blue shark, *Prionace glauca*, and other sharks in the Gulf of Guinea. Mar. Freshwater Res., 46: 967-973.

COELHO, R., F. H. V. HAZIN, M. REGO, M. TAMBOURGI, P. OLIVEIRA, P. TRAVASSOS, F. CARVALHO, G. BURGESS. 2009. Notes on the reproduction of the oceanic whitetip shark, *Carcharhinus longimanus*, in the Southwestern equatorial Atlantic Ocean. Collect. Vol. Sci. Pap. ICCAT, 64(5):1734-1740.

COMPAGNO, L. J. V. 1984. Sharks of the world. FAO species catalogue. Carcharhiniformes. FAO Fisheries Synopsis, n.125, Vol. 4, Part. 2.

DELGADO DE MOLINA, A., J. ARIZ, R. SARRALDE, P. PALLARES, J.C. SANTANA. 2005. Activity of the Spanish purse seine fleet in the Indian Ocean and by-catch data obtained from observer programs conducted in 2003 and 2004. Working Paper IOTC-2005-WPBy-13.

DELGADO DE MOLINA, A. J. ARIZ, J.C. SANTANA, R. SARRALDE. 2007. Catch and distribution of bycatch species and discards from Spanish tropical purse-seine fishery. IOTC-2007-WPEB-05.

GARCÍA-CORTÉS, B., J. MEJUTO. 2001. Preliminary scientific estimations of by-catches landed by the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Indian Ocean: years 1993-2000. Working Paper IOTC Proceeding no. 4, WPDCS01-02:19-23.

GARCÍA-CORTÉS, B., J. MEJUTO. 2005. Scientific estimations of by-catches landed by the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Indian Ocean: 2001-2003 period. Working Paper IOTC Proceeding, WPBY-05-14:9pp.

GARCÍA-CORTÉS, B., A. RAMOS-CARTELLE, J. MEJUTO. 2008. Activity of the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Indian Ocean for the period 2003-2006. Working Paper IOTC-2008-WPB-05.

GARCÍA-CORTÉS, B., A. RAMOS-CARTELLE, J. MEJUTO. 2011. Biological observations of silky shark (*Carcharhinus falciformis*) on Spanish surface longliners targeting swordfish in the Pacific Ocean over the period 1990-2011. Contribution to the 2nd Technical Meeting on Sharks of the IATTC, 13-14 May, La Jolla California, USA.

MATSUNAGA, H., H. NAKANO, 1999. Species composition and CPUE of pelagic sharks caught by Japanese longline research and training vessels in the Pacific Ocean. Fisheries Science, 65 (1), 16-22.

MEJUTO, J., B. GARCÍA-CORTÉS. 2004. Preliminary relationships between the wet fin weight and the body weight of some large pelagic sharks caught by the Spanish surface longline fleet. Collect. Vol. Sci. Pap. ICCAT, 56(1): 243-253.

MEJUTO, J., B. GARCÍA-CORTÉS. 2005. Reproductive and reproduction parameters of the blue shark *Prionace glauca*, on the basis of on-board observations at sea in the Atlantic, Indian and Pacific oceans. Collect. Vol. Sci. Pap. ICCAT, 58(3): 951-973.

MEJUTO, J., B. GARCÍA-CORTÉS, J. ORTIZ DE URBINA. 2009. Ratios between the wet fin weight and body weights of blue shark (*Prionace glauca*) in the Spanish surface longline fleet during the period 1993-2006 and their impact on the ratio of shark species combined. Collect. Vol. Sci. Pap. ICCAT, 64(5): 1492-1508.

MEJUTO, J., B. GARCÍA-CORTÉS, A. RAMOS-CARTELLE, J. ARIZ. 2007. Preliminary overall estimations of bycatch landed by the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Pacific ocean and interaction with marine turtles and sea birds: years 1990-2005. IATTC Working-Group on by-catch.6th Meeting, La Jolla, California (USA), 9-10 February 2007, BYC-6-INF-A.

NEGEDLY, R. 1990. Elsevier's dictionary of fishery, processing, fish and shellfish names of the world. Elsevier Science Publishers B.V.: 623pp.

POISON, F. AND M. TAQUET. 2001. L'espadon: de la recherche a l'explotation durable. Rapport final, Nov. 2001: Reference IFREMER 98/1212978/F.

POISSON F., VERNET A. L., FILMALTER J. D., GOUJON M. DAGORN L. 2011. Survival rate of silky sharks (*Carcharhinus falciformis*) caught incidentally onboard French tropical purse seiners. Working Paper IOTC–2011–WPEB07–28.

PRATT, H. W. JR. 1979. Reproduction in the blueshark, *Prionace glauca*, Fish Bull., 77 (2):445-470.

RAMOS-CARTELLE, A., B. GARCÍA-CORTÉS AND J. MEJUTO. 2008. Scientific estimates of by-catch landed by the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Indian Ocean with special reference to the 2004-2006 period. IOTC Proceeding. WPEB-08-03:9pp.

RAMOS-CARTELLE, A., B. GARCÍA-CORTÉS, J. FERNÁNDEZ, J. MEJUTO. 2009. Scientific catch estimations of by-catch species landed by the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Indian Ocean with special reference to the years 2007 and 2008. IOTC Proceeding. WPEB-09-03:7pp.

RESTREPO, V. 1998. Notes on analyses of sex-ratio at size (SRs) for swordfish. Collect. Vol. Sci. Pap. ICCAT, 49(1):381-386.

SEIKI, T. T., TANIUCHI, H. NAKANO, M. SHIMIZU. 1998. Age, growth and reproduction of the oceanic whitetip shark from the Pacific Ocean. Fisheries Science, 64: 14-20.

SEMBA, Y., Y. YOKAWA. 2011. Trend of standardized CPUE of oceanic whitetip shark (*Carcharhinus longimanus*) caught by Japanese longline fishery in the Indian Ocean. IOTC–2011–WPEB07–35.

SPRINGER, S. 1967. Social organization of shark populations, *In*: P.W. Gilbert, R.F. Matherwson & D. P. Rall (ed.). Sharks, skates and rays, J. Hopkins Press, Baltimore: 149-174.

Table 1. Number of *C. longimanus* sampled in the Indian Ocean by zone, sex and sex combined during the period 1993-2011.

ZONE	Female	Male	M+F+Unk
Zone 1	1219	1153	2425
Zone 2	1836	1646	3637
Zone 3	365	606	986
Zone 4	20	39	59
	3440	3444	7107

Table 2. Prevalence (%) of *C. longimanus* with regard to the total catch in dressed weight (SWO+ByC), with regard to the bycatch species (ByC) and with regard to shark catch species (SHK). Prevalence of *C. falciformis* and *C. longimanus* with regard to the total catch of Carcharhinus spp. (CAO) observed by zone in the Indian Ocean during the period 1993-2011 combined.

	Prevalence of *C. longimanus*			
Species	Zone 1	Zone 2	Zone 3	Zone 4
SWO+ByC	2.8	3.5	1.0	0.1
ByC	6.4	10.6	2.6	0.2
SHK	10.2	15.9	3.4	0.3
CAO	32.8	40.9	51.8	61.8
	Prevalence of *C. falciformis*			
CAO	66.0	55.7	33.9	6.4

Table 3. Length frequency (FL cm) of *C. longimanus* sampled in the Indian Ocean by year (zones combined) during the period 1993-2011.

Size/Year	1993	1994	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
T050	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0
T055	0	0	0	1	0	0	0	0	2	3	1	0	0	0	0	0
T060	0	1	0	3	0	0	0	0	4	6	8	0	0	0	0	0
T065	0	7	0	6	0	0	0	0	1	22	13	0	0	0	0	0
T070	5	11	0	1	0	0	0	0	2	83	35	2	1	0	0	0
T075	4	69	1	0	0	0	0	0	0	97	112	0	1	0	0	0
T080	3	79	2	2	0	0	0	0	3	116	221	0	1	0	0	0
T085	12	95	7	0	0	0	0	0	0	93	300	0	0	0	0	1
T090	11	177	4	3	0	0	0	0	1	70	396	0	4	0	0	0
T095	13	42	3	6	0	0	0	0	1	27	341	0	0	1	0	0
T100	24	44	3	7	1	4	1	0	6	20	223	0	0	4	0	3
T105	36	29	2	7	0	0	0	0	5	20	123	1	0	1	0	0
T110	54	62	4	28	0	1	0	0	6	44	69	0	1	2	0	2
T115	49	101	11	42	0	0	0	0	2	40	34	0	1	1	0	1
T120	31	95	11	26	0	7	0	1	1	39	62	0	3	0	0	2
T125	32	78	11	19	0	0	0	1	3	40	60	2	4	0	1	4
T130	38	80	8	19	0	7	0	0	3	41	92	1	2	2	0	6
T135	44	96	5	19	1	1	0	0	2	18	72	0	3	0	0	0
T140	35	94	6	35	1	6	0	1	1	11	39	1	4	1	1	2
T145	27	97	8	25	4	2	0	1	0	8	31	0	4	2	0	2
T150	32	98	9	29	7	7	0	0	0	4	28	0	4	3	1	8
T155	26	119	6	13	1	3	0	2	0	5	17	0	7	1	1	5
T160	22	97	10	28	4	7	0	0	1	5	8	0	2	4	0	11
T165	23	92	4	22	3	2	0	0	1	3	6	1	3	4	0	2
T170	17	101	5	16	0	7	0	2	0	2	8	0	1	5	0	8
T175	22	84	1	29	2	0	0	2	1	2	7	0	3	1	0	11
T180	23	74	1	28	3	3	0	4	2	0	6	0	0	5	1	3
T185	13	62	5	28	5	0	0	2	2	2	9	0	3	3	0	8
T190	15	60	4	20	0	1	0	3	2	3	8	0	1	1	0	3
T195	8	40	6	25	2	0	1	0	6	3	8	2	1	1	0	3
T200	5	38	4	13	2	3	1	7	2	1	7	1	7	5	0	8
T205	5	16	4	11	2	0	1	4	1	0	4	1	0	4	0	3
T210	1	11	3	12	1	2	1	1	2	0	5	1	2	1	0	2
T215	1	3	3	1	0	0	0	3	1	0	3	0	0	1	0	1
T220	1	0	0	0	0	0	1	0	0	0	1	1	1	2	0	0
T225	1	1	1	1	0	0	0	0	2	0	0	0	0	0	0	0
T230	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1
T235	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
T240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T245	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0
T250	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
T255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T260	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Total	633	2154	153	528	39	65	6	35	66	828	2360	14	65	56	5	100

Table 4. Nominal catch rates per thousand hooks of *C. longimanus,* in number of specimens (CPUE#) and in weight (CPUEw) -kg dressed weight: DW-, by sex and combined sexes, for zones of the Indian Ocean and years 1993-2011 combined.

	Female (F)		Male (M)		M+F+Unk	
ZONE	CPUE#	CPUEW	CPUE#	CPUEW	CPUE#	CPUEW
Zone 1	2.149	14.96	2.033	13.46	4.276	29.04
Zone 2	1.186	19.74	1.063	15.89	2.349	36.54
Zone 3	0.587	12.71	0.974	25.46	1.585	38.80
Zone 4	0.358	10.56	0.697	24.28	1.055	34.84

Table 5. Number of *C. longimanus* sexed (F+M)#, number of females sampled (F#), overall sex-ratio% (SRo), number of females showing internal or external signs of fec undation (F Fec #), percentage of females with fecundation signs relative to the females analyzed (%Fec), number of pregnant females (F Pre.#), percentage of females with signs of fecundation (%F Pre) and the percentage of females with mating injuries (%F Mat) relative to females with signs of fecundation; for each area defined.

	Zone 1	Zone 2	Zone 3	Zone 4
(F+M)#	2372	3482	971	59
F#	1219	1836	365	20
SRo (%)	51.4	52.7	37.6	33.9
F Fec.#	0	97	14	2
%Fec.	0.0	5.3	3.8	10.0
F Pre.#	0	91	13	1
%F Pre.	0.0	93.8	92.9	50.0
%F Mat.	0.0	6.2	7.1	50.0

Table 6. Number of *C. longimanus* pregnant females (F Pre#), total number of embryos observed (N_emb.), average, maximum and minimum number of embryos and confidence interval (CI90%), total number of female embryos (N_emb_fem.), total number of male embryos (N_emb_ma.) and overall sex-ratio (SRo) of the embryos found by defined zone in the Indian Ocean.

	Zone 1	Zone 2	Zone 3	Zone 4
F Pre.#	-	91	13	1
N_emb.	-	777	50	2
Ave_N_emb.	-	8.8	12.5	2.0
CI(90%)	-	0.5	5.0	-
Mín_N_emb.	-	4	5	2
Máx_N_emb.	-	15	20	2
N_emb_sexed	-	573	39	-
N_emb_fem.	-	282	22	-
N_emb_ma.	-	291	17	-
SRo (%)	-	49.2	56.7	-
N_FL_emb_sa.	-	80	6	1
Ave_FL_emb.	-	35.4	38.2	61.0
CI(90%)	-	1.9	6.8	-
Min_FL_emb.	-	12	20	-
Max_FL_emb.	-	57	50	-

Table 7. Average number of embryos (Ave_N_emb) and average length of embryos (Ave_FL_emb) with their respective confidence intervals (CI90%) by length class of the pregnant females (F_Pre_FL) observed in *C. longimanus.*

FL Females	Ave_N_emb	CI(90%)	Ave_FL_emb	CI(90%)
160	5.0	-	30.0	-
165	-	-	-	-
170	6.7	1.1	30.0	5.0
175	6.7	1.0	28.9	6.0
180	7.0	1.1	35.4	4.9
185	7.3	0.9	38.8	3.7
190	9.1	1.6	34.7	7.2
195	9.7	0.8	37.0	3.9
200	11.5	1.2	41.3	2.2
205	10.4	2.5	34.0	5.9
210	12.5	1.7	45.0	6.3
215	11.0	-	28.0	-
220	11.0	3.3	49.0	1.6
225	12.0	-	61.0	-
230	11.0	-	22.0	-

Table 8. Total number of embryos observed per uterus (right, left) in *C. longimanus*, average number of embryos per uterus and confidence intervals (CI90%) by zone defined for the Indian Ocean.

	U_right			U_left		
Zone	n	Ave.	CI(90%)	n	Ave.	CI(90%)
Zone 1	-	-	-	-	-	-
Zone 2	298	4.7	0.3	270	4.3	0.3
Zone 3	61	5.5	1.5	47	4.3	1.0
Zone 4	7	7.0	-	5	5.0	-

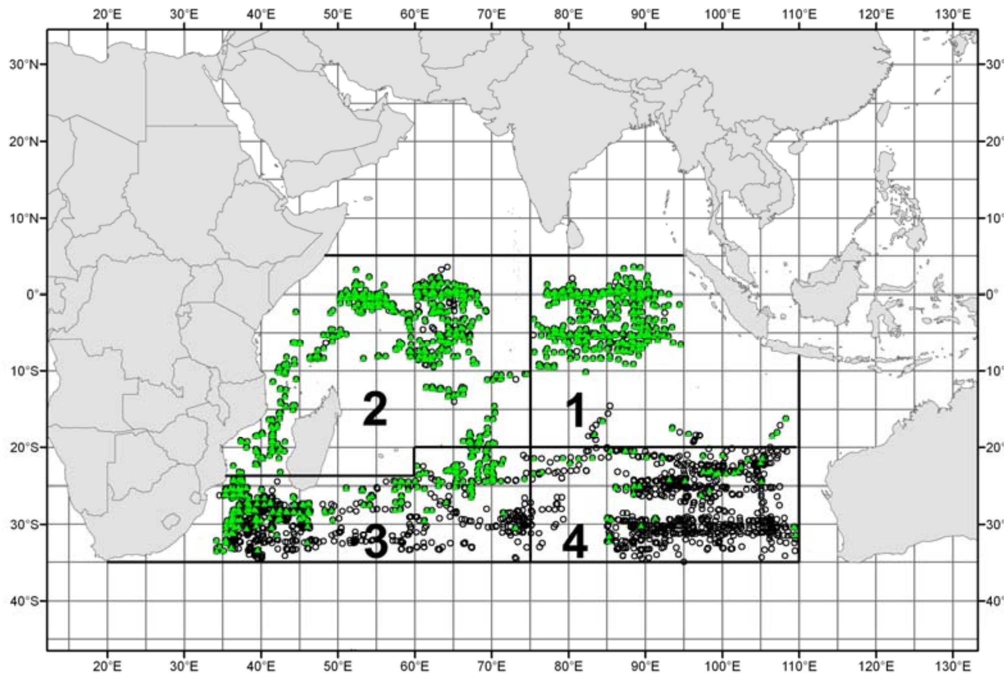

Figure 1. Map of the Indian Ocean zones considered in this analyses and sets observe d during the period 1993-2011. The positive sets with observations of *C. longimanus* are colored in green.

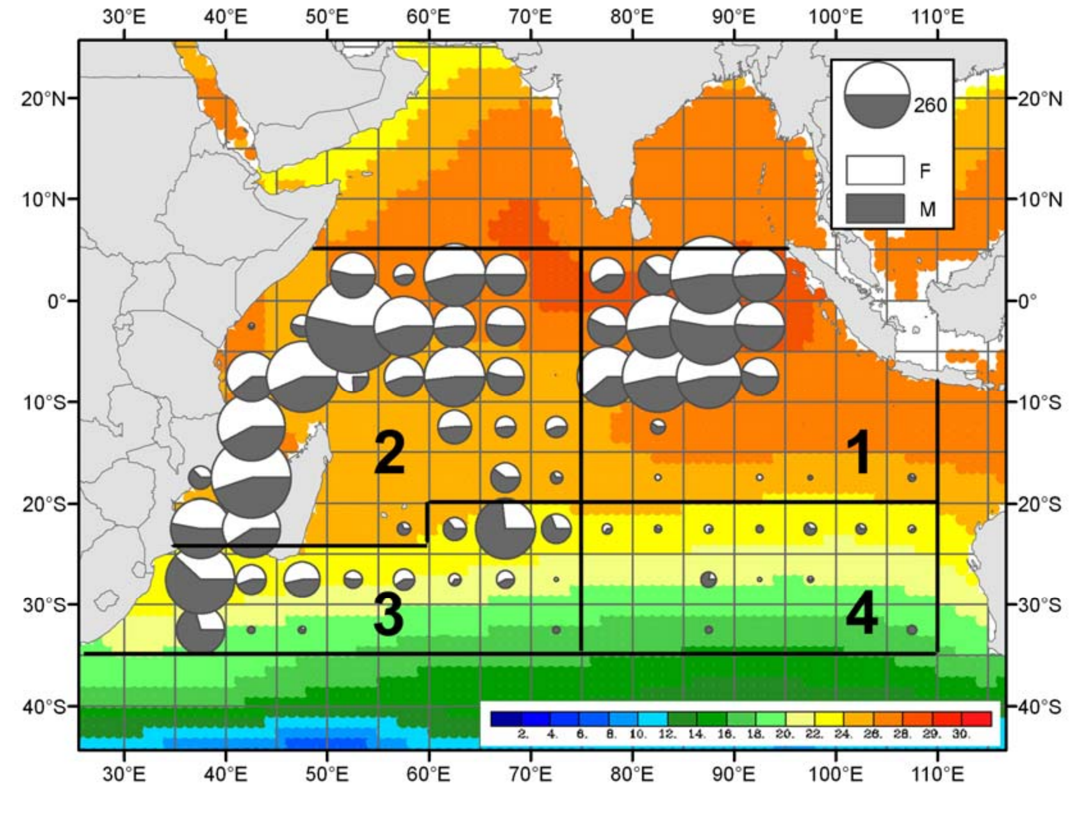

Figure 2. Observations of *C. longimanus* by 5ºx5º areas and sex. The size of the circles is proportional to the number of observations available for both sexes c ombined. Sea temperature at 50m depth (yearly average) according to a color scale.

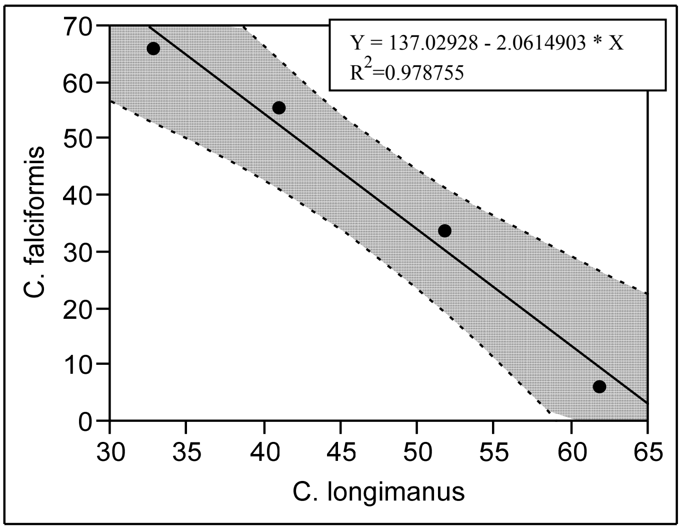

Figure 3. Bivariate fit bet ween prevalence (%) by zone of *C. longinamus* vs. *C. falciformis* within the Carcharhinus genus (C. falciformis% = 137.02928 - 2.0614903*C. longimanus%, R^2= 0.9787, Prob >F= 0.0107) and 95% confidence intervals (dashed area).

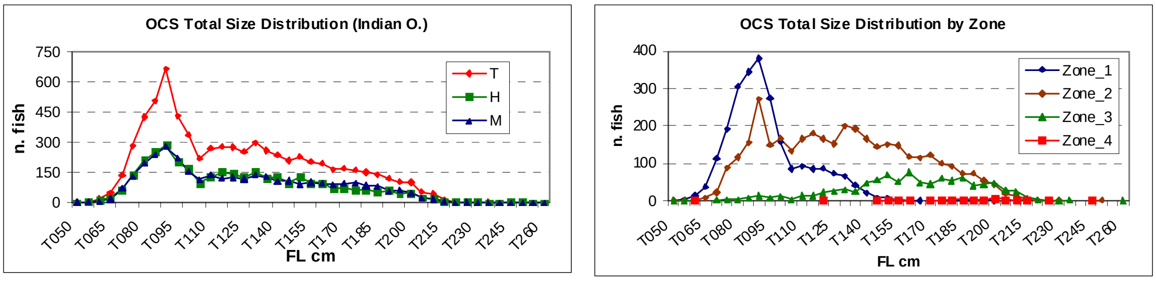

Figure 4. Total length distribution of *C. longimanus*, zones combined of the Indian Ocean by sex and combined sexes (left panel) and total distribution by zones (right panel).

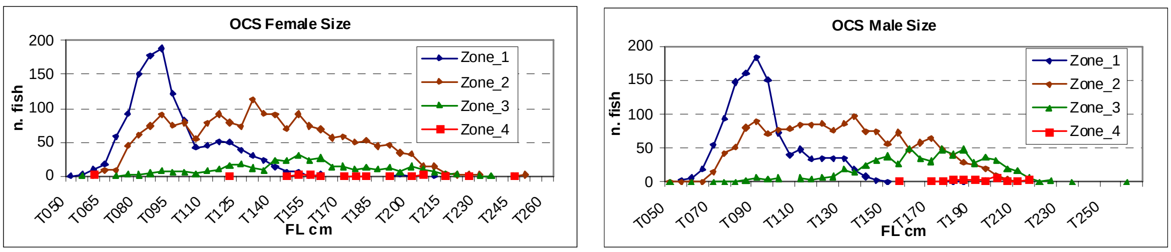

Figure 5. Length distribution of female (left panel) and male (right panel) of *C. longimanus* by zones defined in the Indian Ocean.

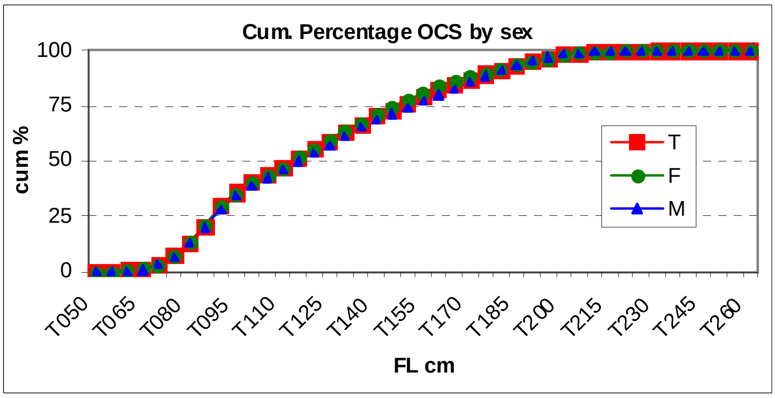

Figure 6. Cumulative percentage of *C. longimanus* length frequencies by sex and combined sexes for the whole Indian Ocean (zones combined).

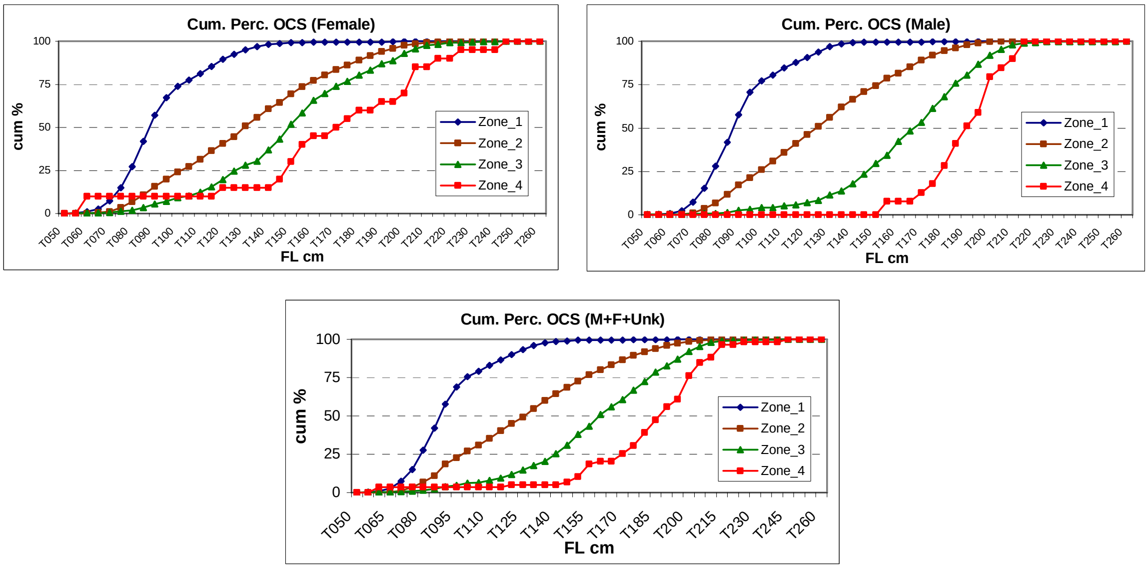

Figure 7. Cumulative percentage sizes of *C. longimanus* by sex, combined sexes and by defined zone in the Indian Ocean.

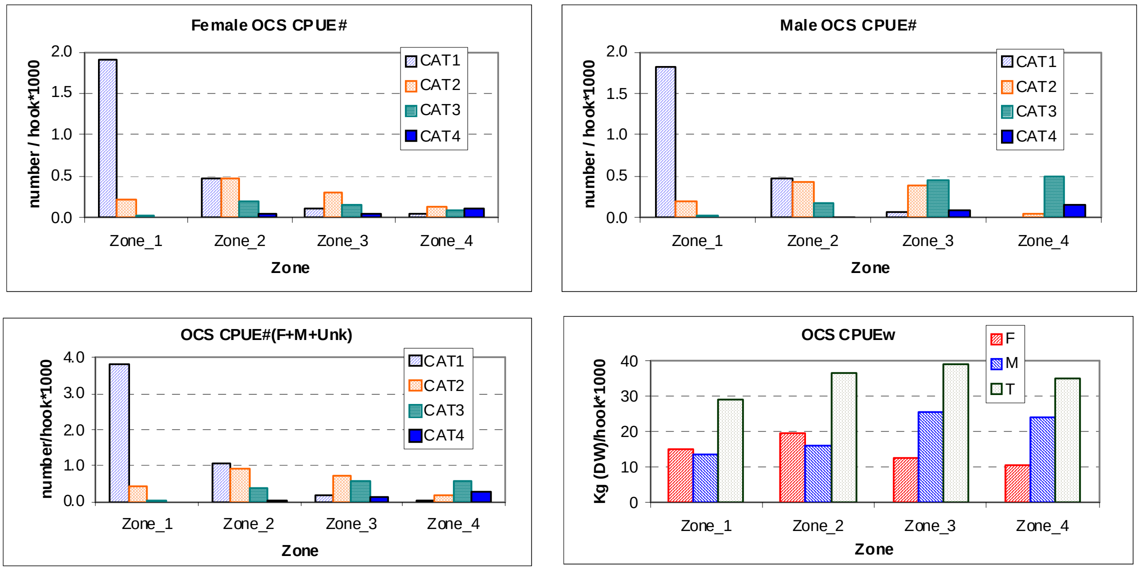

Figure 8. Nominal catch per unit of effort (thousand hooks) in number of fishes (CPUE#), by sex, sex combined, zone and size categories (CAT), CPUE in kg of dressed weight, of *C. longimanus* by sex and sexes combined by zone of the Indian Ocean.

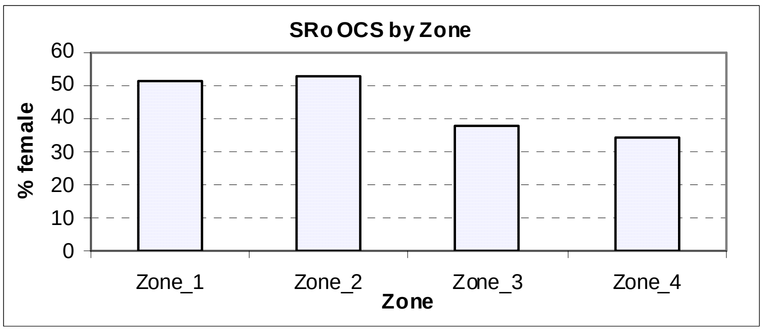

Figure 9. Overall sex ratio (SRo) of *C. longimanus* obtained for each zone defined of the Indian Ocean.

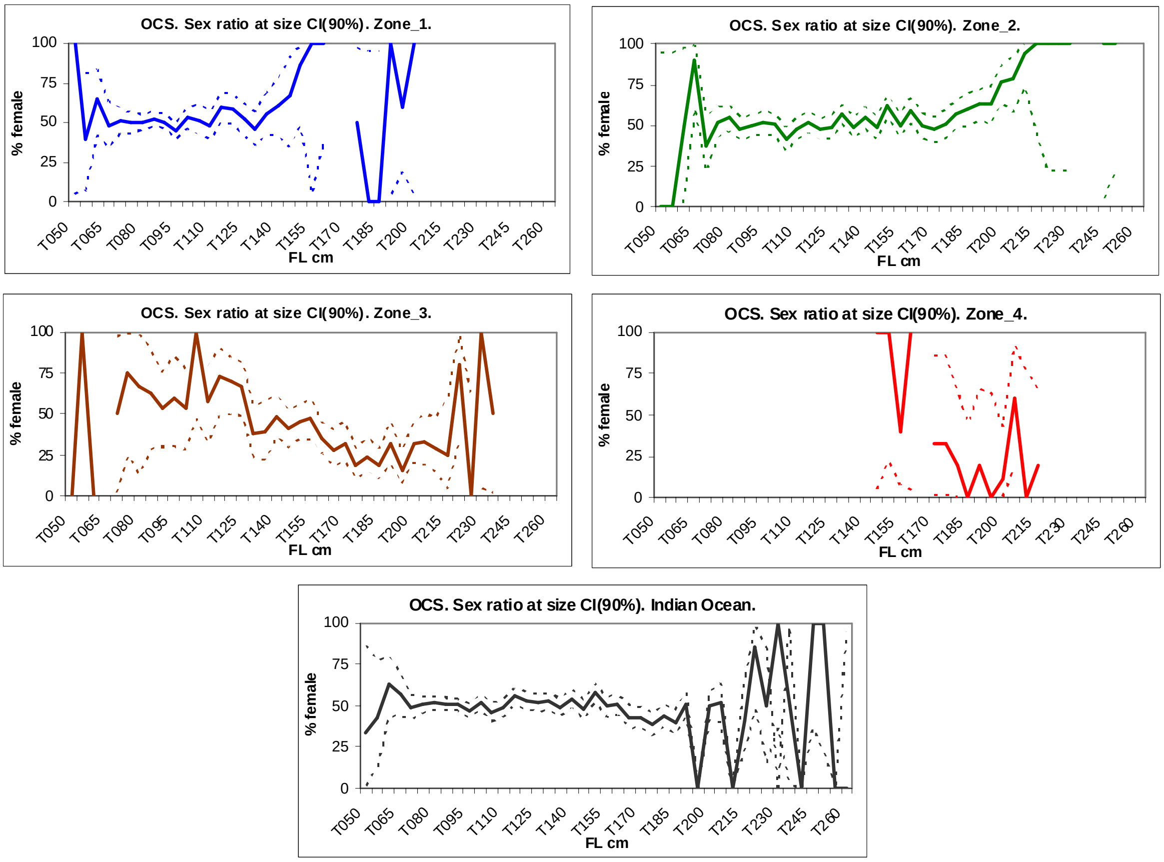

Figure 10. Sex ratio at size (SRs) values and their CI90% obtained for the zones defined in the Indian Ocean and for all zones combined.

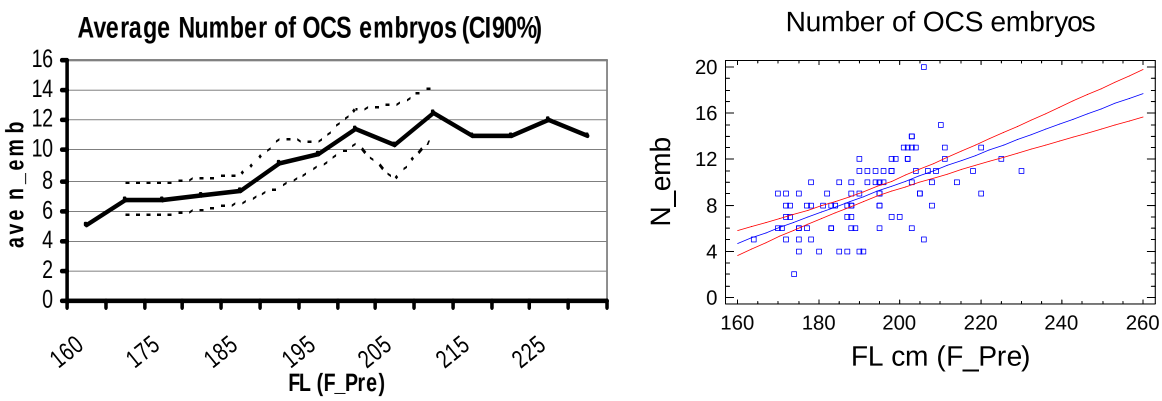

Figure 11. Mean number of embryos of *C. longimanus* per length class of pregnant females observed in the Indian Ocean and their respective confidence intervals (CI90%), (left panel). Scatter plot of the number of embryos per length class of pregnant females, linear fit and confidence interval (right panel).

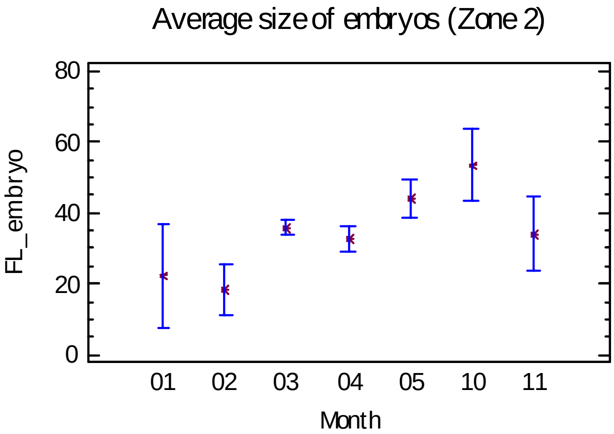

Figure 12. Average length (FL cm) and predicted confidence limits (CI90%) of embryos sampled in pregnant females of *C. longimanus*, by calendar month in Zone 2 of the Indian Ocean.

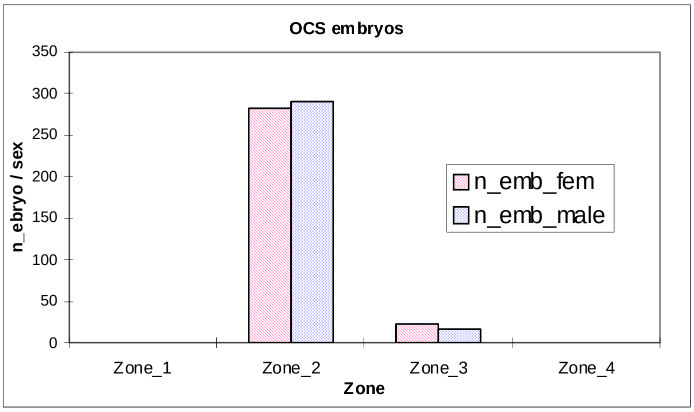

Figure 13. Number of male and female embryos per zone observed in the Indian Ocean.

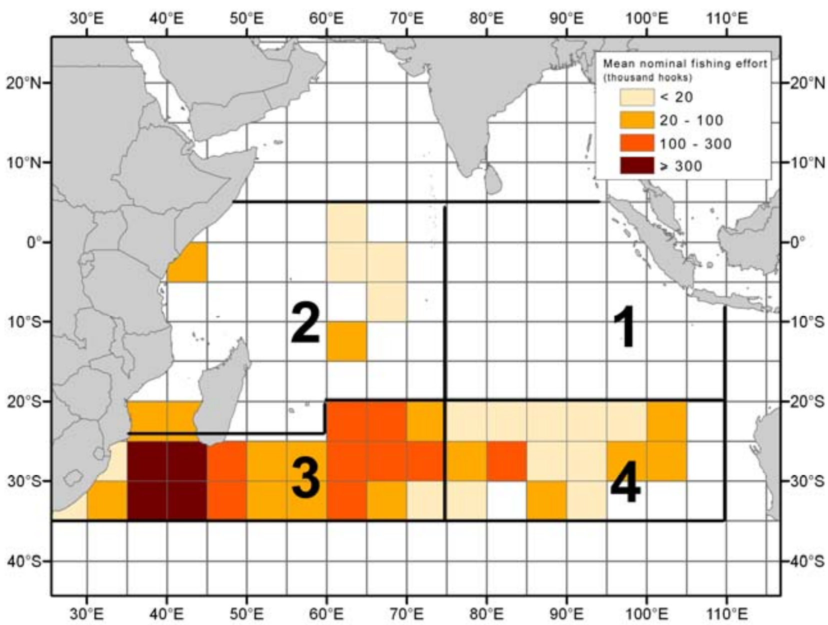

Figure 14. Average nominal fishing effort (thousand hooks) by 5ºx5º degree squares of the Spanish longline fishery during the recent period 2007-2010 as reported to IOTC and zone definition used in this paper.

Annex I. Length frequency (FL cm) of *C. longimanus* sampled in the Indian Ocean by zone and year.

YEAR	ZONE/FL	050	055	060	065	070	075	080	085	090	095	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240	245	250	255	260
1993	Zone_2					5	4	3	12	11	13	24	36	54	49	31	32	38	44	35	27	32	26	22	23	17	22	23	13	15	8	5	5	1	1	1	1							
1994	Zone_2	1		1	7	11	69	78	95	172	40	43	29	61	101	90	75	77	89	82	76	81	101	77	80	84	69	57	49	48	35	31	13	10	1		1							
1994	Zone_3							1		5	2	1		1		5	3	3	7	12	21	17	18	20	12	17	15	17	13	12	5	7	3	1	2									
1998	Zone_3						1	2	7	4	3	3	2	4	11	11	11	8	5	6	8	9	6	10	4	5	1	1	5	4	6	4	4	3	3		1		1					
1999	Zone_1	1		2	6			2		2	2	6	5	17	31	15	4	1	1		2	1									1													
1999	Zone_2		1	1		1				1	3	1	2	8	11	9	13	11	11	16	12	12	3	8	7	8	5	6	8	8	8	3	2	2							1			
1999	Zone_3										1			3		2	2	7	7	19	11	16	10	20	15	8	24	22	20	12	16	10	9	10	1		1		1					
2000	Zone_3											1							1	1	4	7	1	4	3		2	3	5		2	2	2	1										
2001	Zone_2											4		1		6		5	1	5	1	5	3	6	1	7		3		1		3		1								2		
2001	Zone_3															1		2		1	1	2		1	1									1										
2002	Zone_3											1																			1	1	1	1		1								
2003	Zone_1																1			1												1												
2003	Zone_4															1					1		2			2	2	4	2	3		6	4	1	3						1			
2004	Zone_1		2	2	1	2		3		1	1	6	5	6	2	1	3	3	2	1				1			1	1		1	3			1										
2004	Zone_3																								1			1	2	1	3	1	1	1			1							
2004	Zone_4			2																												1			1		1							
2005	Zone_1		3	6	22	77	86	102	89	65	25	15	17	34	33	29	33	28	11	6	1										1													
2005	Zone_2					6	11	14	4	5	2	5	3	10	7	10	7	13	7	5	6	4	4	3	2		1		1	1	1													
2005	Zone_3																				1		1	2	1	2	1		1	2	1	1												
2006	Zone_1			7	10	34	105	199	256	312	247	132	59	36	20	42	34	35	29	15	6	7	1	2	1		1		1															
2006	Zone_2				3	1	5	22	44	82	91	91	64	32	13	20	26	57	41	23	23	17	11	2	3	7	3	4	3	1	2	2	1	2	2	1		2						
2006	Zone_3		1	1			2			2	3			1	1				2	1	2	2	2	3	2		2	1	2	5	3	3	2	2							1			
2006	Zone_4																					2	3	1		1	1	1	3	2	3	2	1	1	1									
2007	Zone_3					2							1				2	1		1					1						2	1	1	1		1								
2008	Zone_3					1	1	1		4				1	1	3	4	2	3	4	4	4	7	2	3	1	3		3	1	1	7		2		1								1
2009	Zone_3	1									1	4	1	2	1			2		1	2	3	1	4	4	5	1	5	3	1	1	5	4	1	1	2								
2010	Zone_3																1			1		1	1					1																
2011	Zone_3								1			3		2	1	2	4	6		2	2	8	5	11	2	8	11	3	8	3	3	8	3	2	1			1						