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BIOLOGICAL OBSERVATIONS OF SILKY SHARK (*Carcharhinus falciformis*) ON SPANISH SURFACE LONGLINERS TARGETING SWORDFISH IN THE PACIFIC OCEAN OVER THE PERIOD 1990-2011

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Abstract

A total of 3013 silky sharks (1325 females, 1621 males and 67 unidentified) were observed in the Pacific Ocean between 1990 and 2011. Most observations were made between 10ºN-10ºS / 90ºW-180ºW with some sporadic identifications in higher latitudes. The estimated prevalence of the silky shark was 1.1% or 2.6% if we take into consideration the catch of all combined species or the catch of sharks only, respectively. However, important differences can be seen among the different areas. Prevalences of silky and white tip shark were relatively balanced for all the analyzed areas. However, their prevalences in each area showed a negative correlation. Length distributions by sex and by combined sexes of the silky shark suggested two modal classes which characterize segregation in different areas. Individuals with the smallest length were mostly observed in the epipelagic layers with warmer waters located to the West of 140ºW and with a generally deeper thermocline. On the contrary, larger individuals were mainly found in less warm waters located to the East of 140ºW, more affected by the contribution of mild-cold waters and with a generally shallower thermocline. The nominal CPUE by length group confirms this segregation.

The female overall sex-ratio was 45.0%. Sex-ratio patterns by length class for all the Pacific showed similar sex proportions for small sizes and a trend towards a lower number of females as the size increases. These ratios are inverted in the case of large individuals.

3.2% of the analyzed females showed external or internal signs of fertilization (3.0% with embryos and 0.2 with mating injuries). The average size of females with embryos was 164 cm FL and the average litter size was 5.5 embryos per litter (minimum 2 and maximum 18). A lineal model between the size of pregnant females and their litter suggests the following relation: litter size = -18.5709 + 0.143531*FL, (P<0.01). The smallest embryo observed was 10cm FL and the largest was 53cm FL. Data on embryo size, sex-ratio and litter size per uterus are also provided.

Resumen

Un total de 3013 jaquetones sedosos (1325 hembras, 1621 machos y 67 no identificados) fueron observados en el Océano Pacífico entre 1990 y 2011. La mayoría de las observaciones se obtuvieron entre 10ºN-10ºS / 90ºW-180ºW con esporádicas identificaciones en mayores latitudes. La prevalencia del jaquetón sedoso se estimó en 1.1% o 2.6%, según se considere la captura de todas especies combinadas o sólo la de tiburones, respectivamente, aunque con importantes diferencias entre zonas. La prevalencia entre el jaquetón sedoso y el tiburón oceánico de aletas grandes (*C. longimanus*) se mostró relativamente balanceada para el conjunto de las zonas analizadas. Sin embargo, sus prevalencias dentro de cada zona mostraron una correlación negativa. Las distribuciones de talla por sexo y sexos combinados del jaquetón sedoso sugirieron dos clases modales características de su segregación por zonas. Los individuos de menor talla se observaron preferentemente en las capas epipelágicas con aguas más cálidas situadas al Oeste de 140ºW y con termoclina generalmente más profunda, mientras que los individuos de mayor talla se observaron preferentemente en zonas menos cálidas situadas al Este de 140º, más afectadas por el aporte de aguas templadas-frías y con termoclina generalmente más superficial. Los datos de CPUE nominal por grupos de talla confirman esta segregación.

El sex-ratio global de las hembras fue de 45.0%. Los patrones de sex-ratio por clase de talla para el conjunto del Pacífico mostraron proporciones similares entre sexos para las tallas pequeñas y una tendencia a la menor proporción de hembras con el incremento de la talla hasta invertirse estos ratios en el caso de los grandes individuos.

El 3.2% de las hembras analizadas presentaron síntomas externos o internos de fecundación (3.0% con embriones y 0.2% con mordeduras). La talla media de las hembras con embriones fue de 164cm FL y el tamaño

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medio de la camada fue de 5.5 embriones (mínimo 2 y máximo 18). Un modelo lineal entre el tamaño de las hembras preñadas y su camada sugiere la relación: tamaño camada = -18.5709 + 0.143531*FL, ($P<0.01$). El embrión de menor talla observado fue de 10cm FL y el de mayor talla fue de 53cm FL. Datos sobre el tamaño de los embriones, su sex-ratio y el tamaño de camada por útero, son también suministrados.

Key words: *C. falciformis*, silky shark, longline, reproduction.

1. Introduction

Silky shark *Carcharhinus falciformis* (CFO) is a widely distributed species which preferably lives in tropical and subtropical waters (Castro 1983). Its geographical distribution in the Pacific Ocean has been described or assumed as the most frequent within the intertropical strip (Compagno 1984). This is an abundant species in oceanic waters above the continental shelf and at open sea, although it is also found in relatively coastal waters, near the surface, at 18-500 m depths and frequently at surface temperatures between 23 and 24°C (Compagno 1984). The first studies conducted in the Guatemalan Pacific indicated that this species is numerous in traditional fleets operating at distances between 60-90 miles and up to 125 miles from the coast, their capture being more frequent in fishing areas near the Mexican coastline (Bonfil *et al.* 1993). Therefore, the studies conducted in relatively coastal areas, together with the observations in oceanic areas can help understand and interpret the behaviour and biology of this species.

C. falciformis is a species which can be up to 330cm TL long (Castro 1983). Its reproductive strategy is ovovivipary, with litter sizes between 2 and 14 specimens. Some authors indicate that the reproduction season in mild-warm waters takes place between June and August. Nonetheless, this shark does not seem to have a season-related gestation pattern (Branstetter 1990). When it comes to the maturation length, *C. falciformis* males have been reported to reach their sexual maturity between 187 and 217cm TL, whereas females reach maturity between 213 and 230cm TL (Compagno 1984).

Due to its relatively low prevalence when compared to other pelagic species and to its minor commercial interest, the taxonomic identification of some species of the Carcharhinus genus may pose certain difficulties. Generally, commercial registers of many fleets in the world identify this genus as a combined species or simply as “other sharks”, unclassified.

Catches of silky sharks and other pelagic sharks by the Spanish surface longline fleet in the Pacific Ocean have been scientifically estimated and reported since the beginning of this activity in 1990 (Mejuto *et al.* 2007). Additionally, on-board observations on commercial vessels have allowed to obtain size-weight ratios for this species and for other species captured by the surface longline (García-Cortés and Mejuto 2002).

In order to quantitatively model and assess stocks, it is advisable to know at least the distribution areas and their geographical limits, as well as to have credible data on the catch levels and other necessary information. Nevertheless, knowing the distribution limits is usually not enough, since observations may represent different groups-stocks and be segregated by area, season, sex or have a practically indifferent behaviour in presence of other species of their kind. Sometimes, the addition of several species of the Carcharhinus genus (including the silky shark) has been described (Springer 1967), so the joint study of this genus seems to be highly advisable. ERA-based qualitative assessments and other tools generally require representative and reliable biological information of the species-stock which allows the identification of the potential productivity, as well as the information of fishing data which may allow the assessment of their potential vulnerability to fishing activities.

The progressive geographic expansion of the Spanish surface longline fleet in the Pacific Ocean from 1990, together with the follow-up activities for research purposes through on-board observers, has allowed us to gather some sporadic observations on some of the shark species sporadically captured as bycatch. Using those data, the goal of this paper is to provide specific information on the silky shark which can supplement the information available on landing levels, including biological details and reproduction parameters for the different areas in the Pacific Ocean from which we have observation details.

2. Material and methods

Biological observations were exclusively conducted with scientific purposes by means of a research project which involved scientific observers on board commercial surface lonliners targeting swordfish (*Xiphias gladius*) in the Pacific Ocean over the period 1990-2011.

Observers received previous training and their criteria were standardized. Observations were conducted in different areas of the Pacific Ocean where the Spanish surface longline fleet fished over the 1990-2011 period. Initially, observations were grouped in areas of 5ºx5º (combined years), which were in turn classified in 8 different areas for descriptive purposes: PAC40, 41, 42, 43, 44, 45, 46 y 47 (figure 1).

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

The individuals' sex was identified visually 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 (mating injuries) caused by the males during mating (Pratt 1979) with no embryos observed in their uterus. Internal fertilization signs of females were defined by the dissection and internal detection of embryos in the uterus, in which case they were classified as pregnant females. In some occasions, if embryos were found, 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 size (FLcm) 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 combined sizes -overall sex ratio (SRo) -and by length class- sex ratio at size (SRs)-.

Catches per unit effort (CPUE) or nominal fishing efforts were calculated for 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

CFO observations in the Pacific Ocean took place between 34ºN-34ºS and 91ºW-142ºE (figure 1). Most observations were obtained in the warm intertropical strip (PAC43, 44 and 45) and, specifically, between 10ºN-10ºS/90ºW-180ºW. Only some sporadic observations reported as silky shark were identified in some areas at higher latitudes in both hemispheres (figure 2). In total, 4985539 hooks were observed in all the areas and years considered. In the PAC40 area 7300 hooks were observed although no CFO observations were reported. No fishing effort was developed in the area PAC41. The total number of observed specimens was 3013 individuals, 1325 of which were identified as females, 1621 as males and 67 were unidentified (unk) (table 1).

The overall prevalence of CFO for all the areas was 1.1% and 2.6% with regard to the total catch observed for combined species (number of individuals of the targeted species + bycatch) or with regard to the shark catch only, respectively. The highest prevalences by area were observed in PAC44 (11.6%) and PAC43 (82.0%) if we consider the total catch of combined species or the catch of the Carcharhinus genus only, respectively. Overall prevalences of *C. falciformis* (CFO) and *C. longimanus* (CLO) suggest that these species seem to be somehow balanced at a global level, although CFO has a slight dominance over CLO (52.1% and 45.1%, respectively). Similar results have been described by other authors (Springer 1967, Matsunaga and Nakano 1999). However, if we compare their respective prevalences within each area we can observe a negative correlation between both species, their respective prevalences being less unbalanced in areas PAC44 and PAC45 with warmer waters (table 2, figure 3).

Table 3 shows the frequency per length class observed for all sampled CFO in the combined areas of the Pacific and for the years for which observations are available. No specimens of this species were identified in the observed areas over the periods 1990-1997, 2000-2003, 2007 and 2009-2011. The length range (FL) went from 50-240cm to 55-225cm for females and males, respectively (table 4). Two modal classes could be observed in the length distributions by sex and the overall distribution for all the areas in the Pacific Ocean. Different length distributions amongst certain areas seem to be apparent too, both by sex and by combined sexes (figures 4 y 5). Modal distributions of specimens with very different lengths -large or small- were observed in the areas PAC44 and PAC45, respectively. In the PAC42, PAC46 and PAC47 areas, the number of observed specimens turned out to be lower than 10 and, as a result, their length distribution is unrepresentative. Figure 6 shows the length frequency in all the Pacific in terms of cumulative percentage, by sexes and combined sexes. 50% of the observed lengths were below 125cm FL, regardless of the sex. If we only consider those areas having more than 10 observed specimens, the average lengths by sex were below 119cm FL in the PAC43 and PAC 45 areas and below 144cm FL in the PAC44 area (table 4), which may suggest a certain size segregation by area as a result of the biological-migratory processes (figure 7).

Table 5 summarizes the number of specimens found by sex and area and their overall sex-ratios (SRo), as well as some variables related with the different reproductive states of females. The overall SRo obtained for the whole Pacific was 45.0% females. In areas with less than 10 observed individuals (PAC42 and PAC46), SRo was 50.0%, which differs from the 1:1.2 male:female ratio described by other authors (Branstetter 1987). In the PAC47 area, with only one female and two males present, the SRo was 33.3%. The SRo of the PAC43 and PAC45 areas was 46.6% and 47.6%, respectively and in the PAC44 area, the sex ratio was 42.5% (table 5, figure 8). Nonetheless, as in other large pelagic species with a space-time segregation by length and/or sex, the SRo value must be carefully interpreted, as it may be influenced by the size interval included in the observations. Therefore, it is more advisable to use SRs in order to establish comparisons.

SRs values by area show the typical variability caused by the availability of observations of the different length classes. Slight differences or similarities amongst areas may be suggested (figure 9). However, these SRs patterns are affected by the spatial definition accepted, as well as by the temporal variability of SRs, which could not be considered in the analysis. In general, the SRs pattern for all Pacific shows similar proportions between sexes for lengths below 110cm FL, with a trend towards a progressive lower proportion of females up to sizes of 180cm FL. When analyzing the three areas with a representative number of specimens, we can observe a certain similarity between the patterns of the PAC43 and PAC45 areas, in which the female proportion tends to be lower from the 145 size FL onwards, increasing again in sizes over 180cm FL. However, in the PAC44 area, the proportion of females starts to decrease from the 105cm FL size and it does not increase again up to the 165cm FL size. Nonetheless, these data should be further analyzed in order to identify any potential significant differences.

The patterns observed in SRs may also be explained by the nominal CPUE data obtained for each area. In general, the CPUEw in most areas (for sizes and combined sexes) suggests that the prevalence of males in the catch is slightly higher (table 6, figure 10). The area with the greatest CPUE was observed in PAC44 with 95.8 kg DW and 4.2 individuals, followed by PAC45 with 35.4 kg DW and 3.3 specimens for thousand hooks. This high CPUE seems to be largely due to the higher prevalence of males, as it was observed in most of the analyzed areas.

The CPUE# data per length category suggest a geographical segregation of the smallest individuals (CAT1), especially in the PAC45 area, where they coexist with CAT2 specimens. In the PAC43 and PAC44 areas, the CAT2 sizes are predominant, in coexistence with CAT1. The CPUE# data show a similar pattern by category of length and sex. The smallest specimens are predominant for both sexes (CAT1) in the PAC45 area, whereas the CAT2 size specimens are predominant in the PAC43 and PAC44 areas (figure 10).

Of all the observed females, only 42 showed external or internal signs of fertilization (3.2%). Of those, 40 females (3.0%) had embryos in their uteri (pregnant females) and 2 females (0.2%) showed external mating signs (mating injuries) (table 5). PAC44 turned out to be the area with the largest number of pregnant females (4.0%) and it is also the area with the lowest SRo (42.5%) and SRs, having less females than males in the length classes between 105 and 165cm FL and being the area where nominal efforts are higher both in terms of number and weight.

A total of 199 embryos were observed in the 40 females identified as pregnant. The average litter size per female was 5.5 embryos (CI90%: ±0.8). A minimum number of 2 embryos per litter was observed in 158cm FL females and a maximum of 18 embryos by litter was observed in a 240cm FL female. The minimum size observed in pregnant females was 150cm FL and their average size was 168.5cm FL (CI90%:±3. 5). 50% of pregnant females were observed in the 165 FL size class. The average size of the two 176cm and 225cm FL females which showed tooth cuts (mating injuries) was 200.5cm FL (CI 90%: ±40.3). Table 7 contains a summary of the average sizes of the embryos and the average number of embryos with their respective confidence intervals (CI90%) per size class of the females identified as pregnant. A lineal model between the female size and the size of its litter suggest that this relation exists (litter size = -18.5709 + 0.143531*FL female). The ANOVA indicates that there is a statistically significant relationship ($P<0.01$), the correlation coefficient (0.7916) indicates a moderately strong relationship between the variables and R-squared statistic indicates that the model as fitted explains the 62.7% of the variability of the litter size (figure 11). In spite of having very few available observations for this species, this relationship does not seem unusual, as it has been described in another species (*Prionace glauca)* belonging to the same family (Castro and Mejuto 1995, Mejuto and García-Cortés 2005).

Embryo sizes were obtained for 28 pregnant females. The female with the lowest average embryo size (10.0cm FL, PAC44) was 170cm FL. A 187cm FL female showed the greatest average embryo size with 53.0cm (PAC45). The average embryo size of 25.5 FL (CI90%: ±3.7) was observed in the PAC44 area on 20 females with an average size of 164.3cm FL (CI90%: ±3.8). The average size of embryos was 37.1cm FL (CI90%:±11.0) in the PAC45 area for 7 females with an average size of 174.9cm FL (CI90%:±7.0). Only one female (240cm FL) was observed in the PAC46 area, with an average embryo size of 30.0cm FL. No embryo measurements were taken in the PAC43 area (figure 12).

The average number of embryos observed per month is shown in figure 13. The resulting average for the first six months of the year was 5.4 (CI90%: ±1.1) embryos for a female average size of 170.8cm FL (CI90%: ±5.0). This figure turned out to be slightly lower than the one obtained for the second half of the year, with 6.0 embryos (CI90%: ±1.7) for an average female size of 174.2cm FL (CI90%: ±9.1). The data obtained suggest that CFO might not have a marked seasonal gestation cycle, as already reported by other authors (Hazin *et al.* 2007). The average sizes of pregnant females and the embryos found per month are in table 8.

The total number of embryos found in pregnant females, their average, maximum and minimum number, as well as the number of embryos by sex and their corresponding sex-ratios per area are summarized in table 9. The overall sex-ratio obtained for embryos was 52.9% of females (figure 14).

In 25 pregnant females it was also possible to obtain the number of embryos found in each uterus. For all the Pacific, the average number of embryos found was 2.6 (CI90%: ±0.5) and 2.5 (CI90%: ±0.5) in the right and left uterus, respectively. Table 10 summarizes the total number of embryos observed in each uterus (left and right), the average number of embryos found by uterus with their confidence intervals (CI90%) and the average size of the embryos with their confidence intervals (CI90%) for each area considered in the analysis.

Despite the long period of time for the analysis and the number of available observations, the diversity of areas, seasons and years makes it difficult to suggest a fertilization, gestation and labour period due to the low prevalence of this species in the surface longline fishery. On the other hand, its preferred distribution areas make it different from other species from the same family (such as *P. glauca*), which are much more cosmopolitan and have shown very specific behaviours when it comes to choosing the areas for the different stages of their complex reproductive process (Mejuto and García-Cortés 2005).

The results indicate that large numbers of juveniles (CAT1) and subadults (CAT2) of both sexes are coexisting only with a few adult females (CAT3 y CAT4) in the areas of observation. Of the females considered as sub-adults and adults only a few of them (3.2%) showed fertilization symptoms. In the observations, pregnancy processes were predominant over the mating ones and showed relatively developed embryos. Consequently, the data suggest that the initial reproductive processes of this species may take place in areas which are not accessible to the ocean surface longliners or that these specimens are hardly vulnerable to this fishing gear in the studied areas while these processes are taking place. The data also suggest the presence of many males -which are clearly predominant in some occasions- with sex-ratios ranging from 1.10 to 2.0 in favour of males. These results become more apparent if only the PAC44 area is considered.

Therefore, the PAC43 and PAC45 areas have quite similar SRo and SRs. Both areas, the former with milder waters and the latter with warmer waters, have the greatest concentration of CAT1 sizes and differ from the

PAC44 area, in the middle of them, where SRo and SRs were lower than in other areas and showed a greater concentration of CAT2 sizes.

Much of the available observations or positive sets observed are from fishing areas rarely visited by the Spanish longline fleet targeting swordfish. Most of them are from sporadic prospecting fishing activities done in the past. The data suggest that in the areas of regular an commercial activity of this fleet in SEPO (PAC43,46,47) usually in temperate waters of the Southern hemisphere between 17º and 21ºC, the interaction with CFO is expected to be very scarce.

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Literature

BONFIL, R., R. Mena, D. de Anda. 1993. Biological parameters of commercially exploited silky sharks, *Carcharhinus falciformis*, form the Campeche Bank, Mexico. NOAA Technical report NMFS 115:73-86.

BRANSTETTER, S. 1987. Age, growth and reproductive biology of the silky shark, *Carcharhinus falciformis*, and the scalloped hammerhead, *Shyrna lewini,* from the northwesteren Gulf of Mexico. Environmental Biology of Fishes Vol. 19, No. : 161-173.

BRANSTETTER, S. 1990. Early life history implications of selected Carcharhinoid and Lamnoid sharks of the northwest Atlantic. *In* Elasmobrachs as living resources: advances in the biology, ecology, systematics, and the status of fisheries (H.L.Pratt Jt., D. S.H. Gruber, and T. Taniuchi, eds.). NOAA Tech. Rep. NMFS, 90: 17-28.

CASTRO, J. 1993. The shark nursery of Bulls Bay, South Carolina, with a review of the shark nurseries of the southeastern coast of the United States. Env. Biol. Fish. 38: 37-48.

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.

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

GARCÍA-CORTÉS, B., J. Mejuto. 2002. Size-weigth relationship of the swordfish (*Xiphias gladius*) and several pelagic shark species caught in the Spanish surface longline fishery in the Atlantic, Indian and Pacific Oceans. Collect. Vol. Sci. Pap. ICCAT, 54(4): 1132-1149.

HAZIN, F. H. V., P. G. V. Oliveira, B. C. L. Macena. 2007. Aspects of the reproductive biology of the silky shark, *Carcharhinus falciformis* (Nardo, 1827), in the vicinity of archipelago of Saint Peter and Saint Paul, in the Equatorial Atlantic Ocean. Collect. Vol. Sci. Pap. ICCAT, 60(2): 648-651.

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. 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, A. Ramos-Cartelle, J. Ariz. 2007. Preliminary overall estimations of bycatch landed by the Spanish surface longline fleet targeting swordfish (X*iphias gladius*) in the Pacific Ocean and interaction with marine turtles and sea birds: years 1990-2005. *6th Meeting of the Bycatch Working Group,* 9-10 February 2007. Doc. IATTC/2007/BYC-6-INF A.

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

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 *Carcharhinus falciformis* sampled by area, sex and total, and total number of hooks observed by area and total Pacific.

Area	Females	Males	(F+M+Unk)	Hooks
PAC40	0	0	0	7300
PAC42	5	5	10	322410
PAC43	124	142	270	1975371
PAC44	628	849	1500	353716
PAC45	565	621	1226	375949
PAC46	2	2	4	1024002
PAC47	1	2	3	926791
Tot. Pac.	1325	1621	3013	4985539

Table 2. Prevalences (%) of *Carcharhinus falciformis* (CFO) with regard to the total catch (SWO+ByC), with regard to the bycatch (ByC) and with regard to the shark catch (SHK). Prevalence of *Carcharhinus falciformis* (CFO) and *Carcharhinus longimanus* (CLO) with regard to the total catch of Carcharhinus spp. (CAO) observed by area and total Pacific in the 1990-2011period.

	Prevalence CFO							
	PAC40	PAC42	PAC43	PAC44	PAC45	PAC46	PAC47	Tot. PAC
SWO+ByC	0	0.10	0.22	11.60	8.05	0.03	0.01	1.06
ByC	0	0.12	0.60	17.20	12.33	0.04	0.03	2.04
SHK	0	0.13	0.78	23.39	19.27	0.05	0.04	2.57
CAO	0	15.47	82.04	69.13	41.35	11.86	2.02	52.07
	Prevalence CLO							
CAO	0	56.97	16.45	30.63	60.09	52.80	80.52	45.15

Table 3. Size frequency (FLcm) of *Carcharhinus falciformis* in the Pacific Ocean by year with available data.

Size \Year	1998	1999	2004	2005	2006	2008
T050	0	0	1	0	0	0
T055	1	0	2	0	0	0
T060	4	1	10	0	0	0
T065	7	8	14	0	0	0
T070	8	12	41	0	0	0
T075	15	5	48	0	0	0
T080	20	12	73	0	0	0
T085	18	5	92	0	0	0
T090	23	16	147	1	0	0
T095	24	9	105	1	0	0
T100	17	7	108	0	0	0
T105	16	13	72	0	0	0
T110	20	12	61	0	0	0
T115	33	14	61	1	0	0
T120	74	24	56	0	1	0
T125	95	26	43	0	0	0
T130	103	32	43	0	0	0
T135	100	37	42	0	0	0
T140	99	32	44	0	0	0
T145	111	24	32	0	0	0
T150	128	53	31	0	0	0
T155	131	60	17	0	1	0
T160	110	43	24	0	0	0
T165	70	26	22	0	0	0
T170	38	11	22	0	0	1
T175	7	8	8	1	0	0
T180	5	0	3	1	0	0
T185	3	0	2	0	0	0
T190	0	0	2	0	1	0
T195	0	0	0	0	0	0
T200	0	0	0	1	0	0
T205	0	0	1	0	0	0
T210	0	0	0	0	0	0
T215	0	0	0	1	0	0
T220	0	0	0	1	0	0
T225	0	0	1	1	0	0
T230	0	0	0	0	0	0
T235	0	0	0	1	0	0
T240	0	0	1	0	0	0
T245	0	0	0	0	0	0
T250	0	0	0	0	0	0
Total	1280	490	1229	10	3	1

Table 4. Number (n) of *Carcharhinus falciformis* sampled, size intervals observed (FLcm) and average size by sex and for the total individuals by areas defined in the Pacific Ocean.

	Females			Males			(F+M+Unk)		
Area	n	FL cm	Ave.	n	FL cm	Ave.	n	FL cm	Ave.
PAC40	0	-	-	0	-	-	0	-	-
PAC42	5	93-225	167.4	5	96-190	148.0	10	93-225	157.7
PAC43	124	65-180	114.0	142	64-178	118.3	270	64-180	116.2
PAC44	628	58-186	140.8	849	65-187	142.6	1500	58-187	141.7
PAC45	565	50-191	107.7	621	58-183	113.3	1226	50-191	109.9
PAC46	2	239-240	239.5	2	203-218	210.5	4	203-240	225.0
PAC47	1	170	170.0	2	205-225	215.0	3	170-225	200.0

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

Area	(F+M)#	F#	SRo	F Fec.#	%Fec.	F Pre.#	%F Pre.	%F Mat.
PAC42	10	5	50.0	1	20.0	0	0	100
PAC43	266	124	46.6	3	2.4	3	100	0
PAC44	1477	628	42.5	25	4.0	25	100	0
PAC45	1186	565	47.6	12	2.1	11	91.7	8.3
PAC46	4	2	50.0	1	50.0	1	100	0
PAC47	3	1	33.3	0	0.0	0	-	-

Table 6. Nominal match rates per thousand hooks of *Carcharhinus falciformis,* in number of specimens (CPUE#) and in weigth (CPUEw) -kg dressed weight: DW-, by sex and combined sexes for the defined areas of the Pacific Ocean.

AREA	SEX	CPUE#	CPUEw	SEX	CPUE#	CPUEw	SEX	CPUE#	CPUEw
PAC40	Female	-	-	Male	-	-	Total	-	-
PAC42	Female	0.0	0.7	Male	0.0	0.4	Total	0.0	1.1
PAC43	Female	0.1	0.8	Male	0.1	1.1	Total	0.1	1.9
PAC44	Female	1.8	39.7	Male	2.4	54.9	Total	4.2	95.8
PAC45	Female	1.5	15.1	Male	1.7	19.6	Total	3.3	35.4
PAC46	Female	0.0	0.1	Male	0.0	0.1	Total	0.0	0.3
PAC47	Female	0.0	0.0	Male	0.0	0.2	Total	0.0	0.2

Table 7. Average size of embryos (Emb. ave. FL) and average number of embryos (Ave. emb#) with their respective confidence intervals (CI90%) of *Carcharhinus falciformis* by size class of the pregnant females (F_FL).

F_FL	CI90%	Emb. ave. FL	CI90%	Ave emb.#	CI90%
150	1.5	29.7	12.0	4.5	0.8
155	1.0	31.3	6.4	3.5	0.7
160	0.8	20.0	4.1	4.4	1.7
165	1.2	36.4	8.1	5.0	1.5
170	0.9	29.5	11.7	6.4	0.8
175	1.4	47.0	3.3	6.0	3.3
180	-	53.0	-	3.0	-
185	0.8	43.0	16.4	9.5	0.8
190	-	52.0	-	5.0	-
240	-	30.0	-	18.0	-

Table 8. Average size (FL cm) of *Carcharhinus falciformis* pregnant females (F Pre.FL), average size (FLcm) of embryos (Emb.ave.FL) and their confidence intervals (CI90%) per month.

Month	F Pre. FL	Emb. ave. FL	CI(90%)
1	162.2	42.5	9.4
2	173.3	29.3	10.9
5	158.0	20.0	-
6	172.9	44.8	8.4
7	170.0	16.0	-
10	164.6	27.3	9.4
11	186.0	33.0	-
12	168.5	25.6	6.3

Table 9. Number of *Carcharhinus falciformis* pregnant females (F Pre#), total number of embryos observed (emb.#), average, maximum and minimum number of embryos and confidence interval (CI90%), total number of female embryos (emb.F#), total number of male embryos (emb.F#) and overall sex-ratio of the embryos found by defined area in the Pacific.

		Embryos							
Area	F Pre.#	emb.#	Ave.	Mín.	Máx	CI(90%)	emb.F#	emb.M#	SRo
PAC42	0	0	-	-	-	-	0	0	-
PAC43	3	11	3.7	2	6	2.4	0	0	-
PAC44	25	125	5	2	10	0.8	54	45	54.5
PAC45	11	45	6	2	9	1.6	17	21	44.7
PAC46	1	18	18		18	-	11	7	61.1
PAC47	0	0	-	-	-	-	0	0	-

Table 10. Total number of embryos found by uterus (right, left) in *Carcharhinus falciformis*, average number of embryos per uterus, confidence intervals (CI90%). Total number of measured embryos, average size and confidence intervals per each area considered of the Pacific.

	Emb.#						Emb.FL		
	U_right			U_left					
Area	n	Ave.	CI(90%)	n	Ave.	CI(90%)	n	Ave.	CI(90%)
PAC42	-	-	-	-	-	-	-	-	-
PAC43	6	2.0	0.9	5	1.7	1.1	-	-	-
PAC44	64	2.8	0.5	55	2.4	0.5	20	25.4	4.6
PAC45	18	3.0	1.0	18	3.0	0.4	7	32.5	11.0
PAC46	7	7.0	-	11	11.0	-	1	30.0	-
PAC47	-	-	-	-	-	-	-	-	-

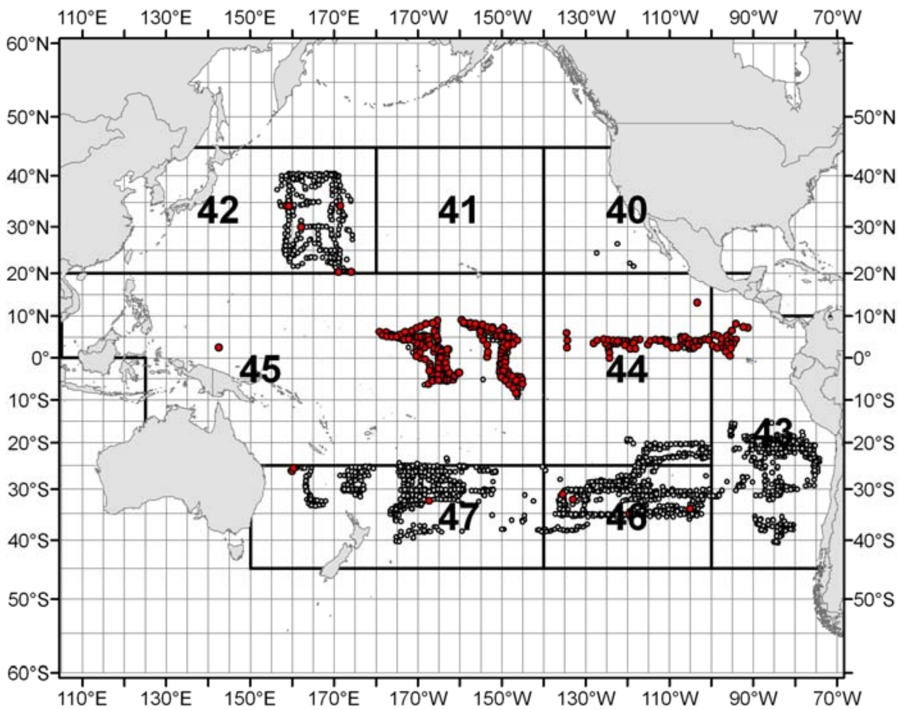

Figure 1. Map of the Pacific areas considered in the analyses and sets observed. The sets with positive observations of *Carcharhinus falciformis* are coloured in red.

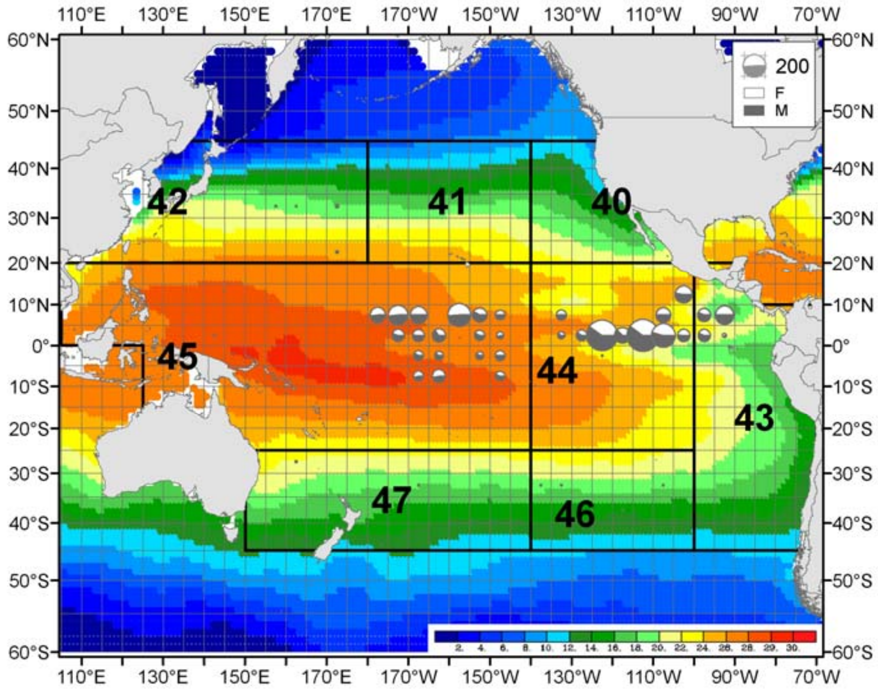

Figure 2. Observations of *Carcharhinus falciformis* by 5ºx5º areas and sex. The size of the circles is proportional to the number of observations available for both sexes. Sea temperature at 50m depth (yearly average) according to the colour scale.

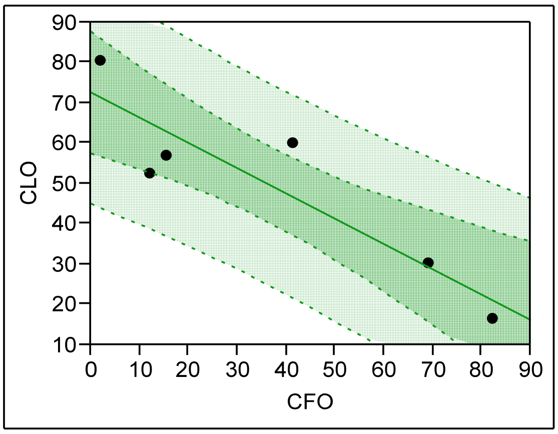

Figure 3. Bivariate fit and 90% confidence intervals between the prevalences (%) of C*archarhinus longimanus* (CLO) and *Carcharhinus falciformis* (CFO) within the Carcharhinus genus, according to the data obtained in each of the areas defined in the Pacific Ocean with available observations: CLO = 72.711 - 0.6256*CFO (R^2=0.816, Prob > F =0.0136).

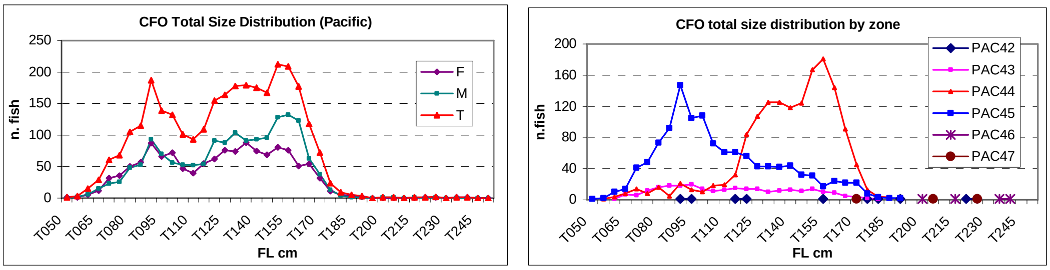

Figure 4. Total distribution of sizes of *Carcharhinus falciformis* in the set of areas of the Pacific Ocean by sexes and combined sexes and total distribution of sizes by areas.

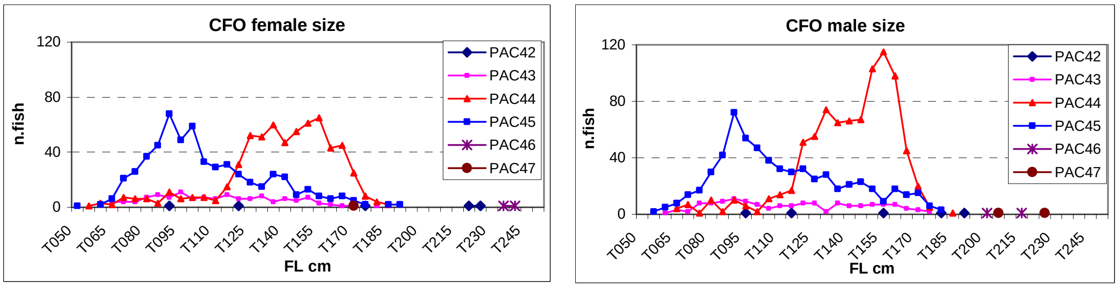

Figure 5. Size distribution of female (left) and male (right) *Carcharhinus falciformis* according to the analyzed areas in the Pacific Ocean.

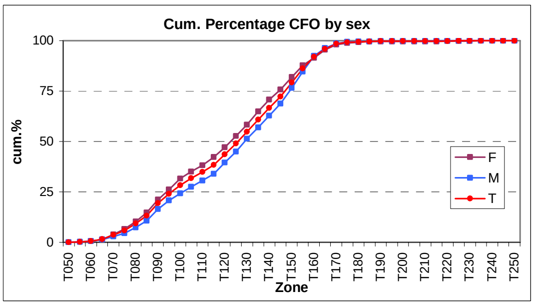

Figure 6. Cummulated percentage of *Carcharhinus falciformis* sizes by sexes and combined sexes for the set of areas in the Pacific Ocean.

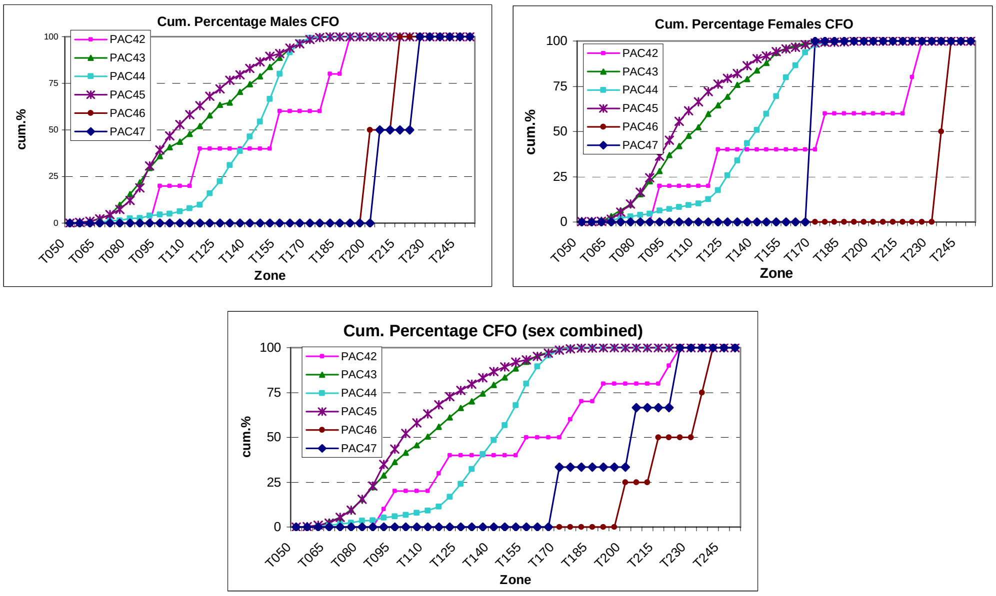

Figure 7. Cumulated percentage of *Carcharhinus falciformis* sizes by sex, combined sexes and by defined area in the Pacific Ocean.

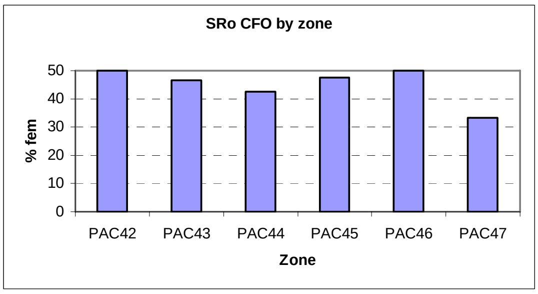

Figure 8. Overall sex ratio (SRo) of *Carcharhinus falciformis* obtained for each area defined of the Pacific Ocean.

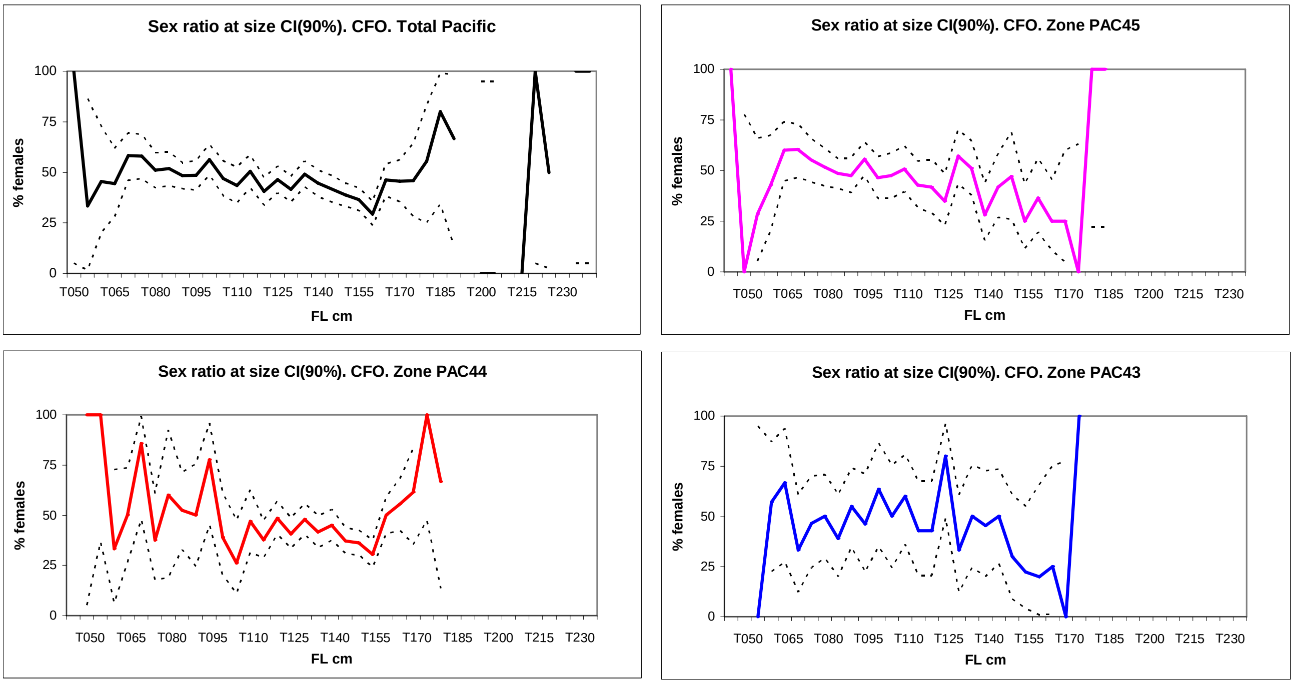

Figure 9. Sex ratio at size (SRs) values and their CI90% obtained for all areas combined and for three of the areas defined (PAC45, PAC44 and PAC43) considered as most representative.

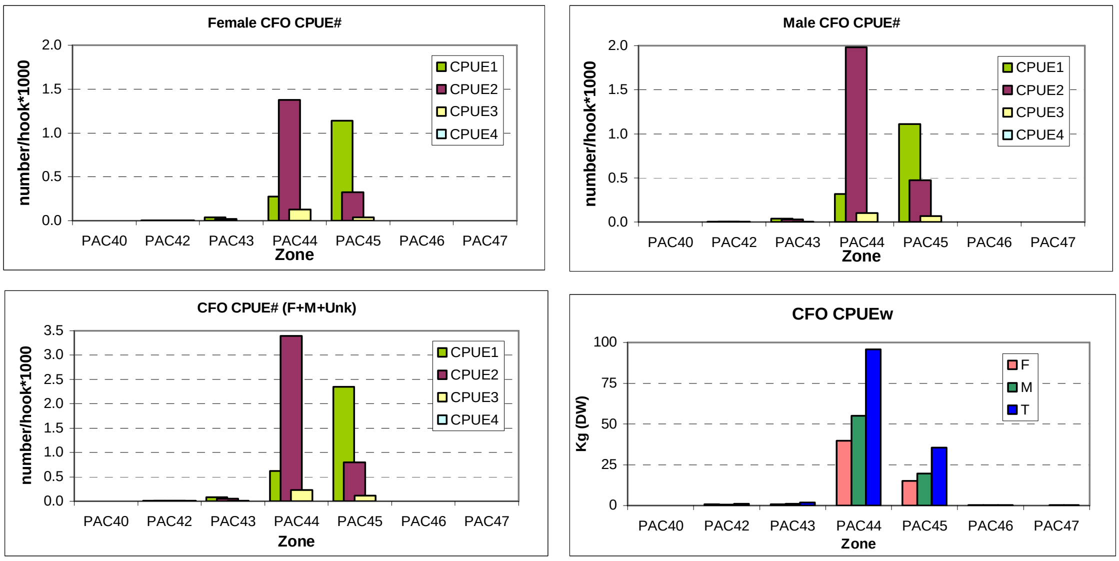

Figure 10. Nominal catch per unit of effort (CPUE), in number of fishes by size categories (CAT) for sizes combined, by area, and CPUE in kg of dressed weight of *Carcharhinus falciformis* by sex and sexes combined.

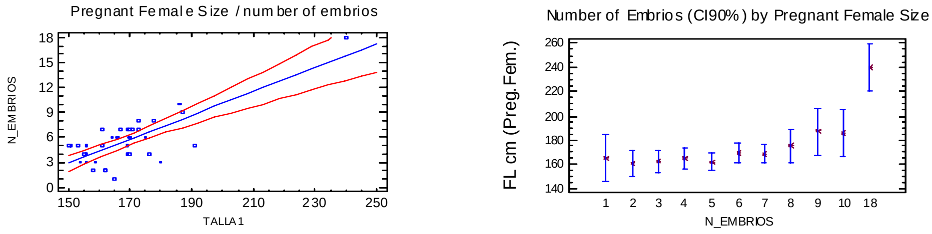

Figure 11. Number of embryos per length class of pregnant females (left) and number of embryos and confidence intervals (CI90%) (right) of *Carcharhinus falciformis* in the Pacific Ocean.

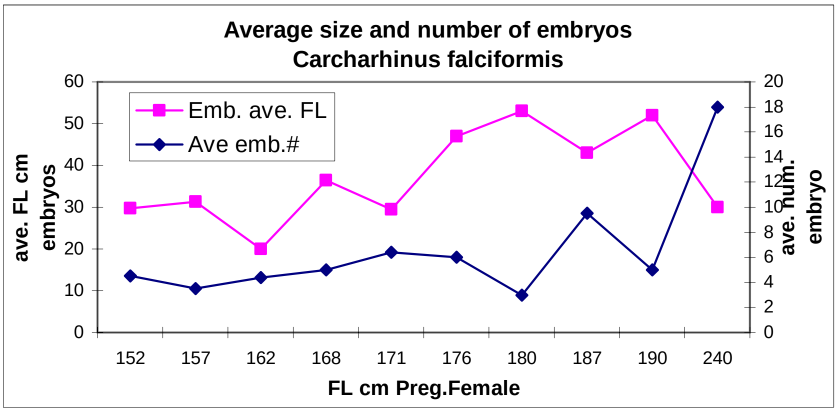

Figure 12. Embryo average size and embryo average number by average size of observed *Carcharhinus falciformis* pregnant females, in the Pacific Ocean.

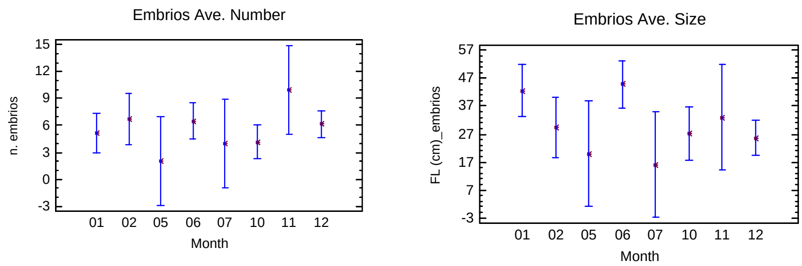

Figure 13. Average number and size (CI90%) of *Carcharhinus falciformis* embryos observed by month in all the Pacific Ocean.

Figure 14. Number of *Carcharhinus falciformis* embryos and average size of the embryos by area (upper). Number of male-female embryos and SRo of the embryos per area (lower).