Article

Catch composition, seasonality and biological aspects of sharks caught in the Ecuadorian Pacific

Jesús Briones-Mendoza[1]*, Diego Mejía[1] and Pol Carrasco-Puig [2]

[1] Facultad Ciencias del Mar, Universidad Laica "Eloy Alfaro" de Manabí, Ciudadela Universitaria vía San Mateo, Manta, Manabí, Ecuador. 130802.; betobriomen@gmail.com; diegoamejia98@gmail.com
[2] CATSHARKS, Association for the study and conservation of elasmobranchs and its ecosystems, Passeig Marítim de la Barceloneta, 37-49. E-08003, Barcelona, Spain. (PCP); pol.carrasco.puig@gmail.com
* Correspondence: betobriomen@gmail.com

Abstract: Although sharks have a fundamental role in maintaining the balance of aquatic ecosystems, exerting a great influence at lower levels, their populations are declining worldwide due, to a large extent, to overfishing. Of the 64 species registered in Ecuador, from January to December 2019, 19 species were recorded in Manta from 15455 captured individuals, with the family Carcharhinidae being the family most present in the catches (69.4%), and the most abundant species was *Prionace glauca* (57.9%). In the case of threatened species, such as *Carcharhinus longimanus*, *Sphyrna lewini* and *Sphyrna zygaena*, a greater presence of immature specimens was observed in landings, suggesting a possible existence of nursery areas. However, information on the composition and biological aspects of shark species in the Ecuadorian Pacific is very scarce. Therefore, research on the characteristics of life history (age, growth and maturity) are of utmost importance for the analysis evolution of the populations that are being exploited, especially in developing countries, where this information is very scarce, causing inadequate management of fishery resources.

Keywords: diversity; abundance; cartilaginous fish

1. Introduction

Sharks have a fundamental role in maintaining the balance of aquatic ecosystems since, being at higher trophic levels, they can exert a great influence on lower levels [1]. However, they are currently declining worldwide due, to a large extent, to overfishing [2,3]. This decrease is intensified by its biological characteristics, such as slow growth, late maturity and few offspring [4]. Regional information on shark catches is essential to be able to know the patterns of catches at a global level [5]. Likewise, research on life history characteristics (age, growth and maturity) is very importance for the analysis of the exploited populations evolution [6]. However, in developing countries this information is very scarce [7,8]. This lack of information can lead to the use of information from other regions, which can lead to inadequate management of fishery resources [9,10].

According to the FAO [11], in South America from 1950 to 2020, 4 133 991 tons-live weight of cartilaginous fish were reported. In Peru, González-Pestana *et al.* [12] reported that 6 099 tons (t) of sharks were landed per year from 1950 to 2010. The most abundant species in Peruvian waters were: *Prionace glauca*, *Isurus oxyrinchus* and *Sphyrna zygaena*. In the Ecuadorian Pacific, Jacquet *et al.* [13] estimated that 7 000 t of sharks were landed per year from 1979 to 2004. About 119 species of cartilaginous fish have been recorded in Ecuador, of which 64 correspond to sharks [14]. The most frequently landed shark species in the Ecuadorian Pacific are: *Alopias pelagicus*, *Prionace glauca* and *Carcharhinus falciformis* [15]. The main ports where sharks are landed in Ecuador are: Manta, Santa Rosa, Esmeraldas, Antoncito, Puerto López and Puerto Bolívar, with Manta being the port with the highest number of shark landings [16]. In addition, the dry season (April-November) presents the highest number of shark catches [15]. The information that exists on the composition of species and some biological aspects in the Ecuadorian Pacific is very scarce and dates back more than 10 years [15-19]. Therefore, the objective of this study is to update the information on the species composition, seasonality, size structures, sexual proportion, morphometric relationships and sexual maturity size.

2. Materials and Methods

From January to December of 2019, field trips were made to the "Playita mía" pier in Manta (0°56'59"S, 80°42'34"W), the visits were daily throughout the year with the objective of having a good sampling effort. The sharks came out whole and were accurately identified at a species level using the guide of Martínez-Ortiz and García-Domínguez [20]. The landed organisms were sexed and measured with a measuring tape graduated in centimeters (cm). The measurements taken were total length (TL), precaudal length (PCL) and interdorsal length (IL). In males, the clasper length (CL) was recorded in centimeters (cm), as well as clasper characteristics such as rotation, non-calcification, partial calcification, total calcification, riphiodon aperture, and absence or presence of sperm [21,22].

Like other studies [23-25], weight was estimated from TL using the following potential equation:

$$W = aTL^b , \quad (1)$$

Where W is the weight, a is the intercept and b the slope. The values of these parameters for each of the shark species recorded in this present study were obtained from previous studies as shown in Table 1.

For the adjustment of a logistic model to the binomial maturity data (0, immature; 1, mature), categories 0, non-calcified; 1, semi-calcified, were grouped as immature and category 2, calcified, as mature. Maturity size for males was estimated using the following equation [26]:

$$\boldsymbol{P = P_{max}\left(1 + e^{-ln\,(19)\left(\frac{l - l_{50}}{l_{95} - l_{50}}\right)}\right)^{-1}} , \quad (2)$$

Where P_{max} is the maximum proportion of mature specimens, l_{50} and l_{95} correspond to the length when the 50 and 95% of individuals have reached sexual maturity, respectively.

The inflexion point is estimated using the following equation [27]:

$$LC_i = LC_{min} + (LC_{max} - LC_{min})\left[1 + e^{b\,(a - L)}\right]^{-1}, \quad (3)$$

Where a is the inflexion point, LC_{min} and LC_{max} are the maximum and minimum clasper lengths, respectively. The inflexion point was only estimated when the data were adjusted to the logistic function [28,29].

The lengths of the most abundant species (n ≥ 20) were plotted in frequency histograms. If the data met the normality and homoscedasticity assumptions, the student's t test was performed, otherwise, the Mann-Whitney U test was performed, in order to know whether or not there are differences between the lengths of the sexes. The chi-square test (χ^2) was also performed to determine whether the sexual ratio is significant with respect to the expected 1:1 ratio [30].

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 June 2022 doi:10.20944/preprints202206.0268.v1

All analyses and graphs were performed in the statistical environment R [31] using the AquaticLifeHistory [32,33], cowplot [34] and tidyverse [35].

3. Results

3.1. Composition of catches

A total of 15 455 sharks (5 508 males, 7 788 females and 2 159 non-sexed) were recorded during 2019 in Manta (Table 2). Of the total number of sharks recorded, 3 690 individuals (1 739 males, 1 934 females and 17 unsexed) were measured, with an estimated biomass of 197.9 t (Table 3). The landed specimens were composed of 9 families and 19 species. The most abundant families in number were Carcharhinidae (69.4%), Alopiidae (23%) and Sphyrnidae (4.9%). The most abundant species recorded during the sampling were *Prionace glauca* (57.9%), *Alopias pelagicus* (20.3%) and *Carcharhinus falciformis* (10.7%) (Figure 1). During the 12 months of sampling, the most abundant season was the dry season, representing the 60.8% of the total caught sharks (Figure 2).

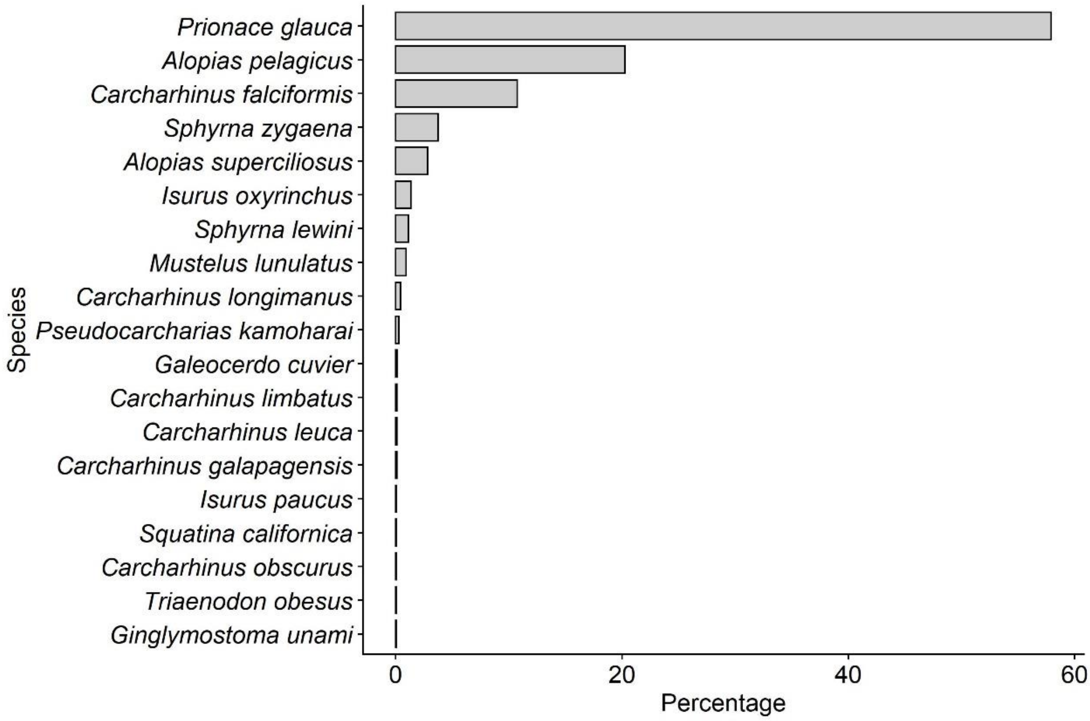


Figure 1. Composition of landed shark species in Manta during the year 2019.

3.2. Composition of sizes, sexual proportion, morphometric relations and maturity size

3.2.1. *Carcharhinus falciformis*

A total of 1 656 *Carcharhinus falciformis* were recorded, of which 887 were females (54%), 693 males (42%) and 76 unsexed (5%). Females were significantly more abundant than males (χ^2 = 23.82, $p < 1.058 \times ^{-6}$), but in the months of February, May, June, July, September, November and December they were not significantly different from parity (Table 4a). The sizes of the females fluctuated between 61 and 246 cm TL (mean ± S.E. = 180.35 ± 1.99), while the males had lengths between 66 and 272 cm TL (mean ± S.E. = 176.46 ± 1.83) (Figure 3a). Females were significantly larger than males (Mann–Whitney U-test, U = 68223.5, p = 0.015). A strong correlation was found between TL and PCL for combined sexes (TL = 1.3135PCL + 4.9085, n = 734, R^2 = 0.99, $p < 2.2 \times ^{-16}$), females (TL = 1.3185PCL + 4.2645, n = 350, R^2 = 0.99, $p < 2.2 \times ^{-16}$) and males (TL = 1.3082PCL + 5.5774, n = 384, R^2 = 0.99, $p < 2.2 \times ^{-16}$).

The claspers of 376 *Carcharhinus falciformis* were measured, of which 158 were not calcified (66-214 cm TL and 1-19 cm CL), 24 semi-calcified (129-195 cm TL and 5-21 cm LC) and 194 calcified (164-272 cm TL and 10-33 cm CL) (Figure 4a). The estimates of L_{50}

and L_{95} for males were 182.10 cm TL ± 1.20 S.E. and 200.82 cm TL ± 2.32 S.E., respectively (Figure 5a). The inflexion point was estimated at 188.5 cm TL.

3.2.2. *Carcharhinus longimanus*

A total of 67 *Carcharhinus longimanus* were reported, which were composed of 37 females (55%), 29 males (43%) and 1 non-sexed individual (1%). There were no differences in the sexual proportion (χ^2 = 0. 96, p = 0. 32). This parity pattern was maintained during all months (Table 4b). Females had a size range of 117-215 cm TL (mean ± S.E. = 154.10 ± 5.43), males 112-185 cm TL (mean ± S.E. = 159.36 ± 4.10) and the unsexed individual measured 130 cm TL (Figure 3b). No significant differences were found in mean lengths between sexes (t-test, t = -0.78, p = 0.43). A significant correlation was observed between TL and PCL for combined sexes (TL = 1.3602PCL + 4.6311, n = 29, R^2 = 0.99, $p < 2.2 \times ^{-16}$).

A total of 17 *Carcharhinus longimanus* claspers were examined, of which 14 were not calcified (82%), 2 semicalcified (12%) and 1 calcified (6%). Specimens with non-calcified claspers had a size range of 128-177 cm TL and 3-7 cm CL, semicalcified 174-185 cm TL and 9-12 cm TL, while the single calcified individual measured 175 cm TL and 12 cm CL (Figure 4b).

3.2.3. *Prionace glauca*

A total of 8 956 *Prionace glauca* were reported, which were composed of 4 786 females (53%), 2 798 males (31%) and 1 372 unsexed (15%). Females were significantly more abundant than males, with a sexual ratio of 1M:1.7F (χ^2 = 52 1.7, $p < 2.2 \times ^{-16}$), however, in the months of February, May, June, July and August there was no difference found in the sexual proportion (Table 4c). The lengths of the females ranged between 130 and 314 cm TL (mean ± S.E. = 207.93 ± 1.35), the males were between 94 and 299 cm TL (mean ± S.E. = 214.36 ± 1.82), while the unknown 177-233 cm TL (mean ± S.E. = 205.40 ± 28) (Figure 3c). Significant differences were observed between the lengths of females and males (Mann–Whitney U-test, U = 82685.5, p = 0.00037). The relationship between TL and PCL for combined sexes was significant (TL = 1.2759 PCL + 8.2472, n = 762, R^2 = 0.90, $p < 2.2 \times ^{-16}$), females (TL = 1.2532PCL + 10.933, n = 417, R^2 = 0.88, $p < 2.2 \times ^{-16}$) and males (TL = 1.2883PCL + 7.3407, n = 345, R^2 = 0.93, $p < 2.2 \times ^{-16}$).

Fourty (11.80%) of the 339 *Prionace glauca* claspers analyzed were not calcified, 48 semicalcified (14.16%) and 251 fully calcified (74.04%). Individuals with non-calcified classpers had sizes of 94 to 203 cm TL and 4 to 15 cm CL, semicalcified had lengths of 132 to 209 cm TL and 9 to 22 cm CL, while calcified had a size range of 180-299 cm TL and 8-29 cm CL (Figure 4c). The L_{50} and L_{95} for males were 191.44 cm TL ± 1.55 S.E. and 210.93 cm TL ± 2.75 S.E., respectively (Figure 5b). The inflexion point was not estimated as the data did not fit the logistics function.

3.2.4. *Isurus oxyrinchus*

A total of 203 *Isurus oxyrinchus* were sampled, being 94 females (46.3%), 93 males (45.8%) and 16 unsexed (7.9%). The sexual ratio was not significant with respect to the expected ratio 1:1 (χ^2 = 0. 005, p = 0. 94), as well as all sampling months (Table 4d). The sizes of the females ranged from 83 to 341 cm TL (mean ± S.E. = 187.74 ± 5.56), the males from 119 to 251 cm TL (mean ± S.E. = 178.14 ± 3.45) and the unsexed measured 230 cm TL (Figure 3d). There were no significant differences between male and female sizes of *Isurus oxyrinchus* (Mann–Whitney U-test, U = 1757.5, p = 0.17). A significant correlation was found for combined sexes between TL and PCL (TL = 1.2432PCL + 2.3802, n = 49, R^2 = 0.98, $p < 2.2 \times ^{-16}$).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 June 2022 doi:10.20944/preprints202206.0268.v1

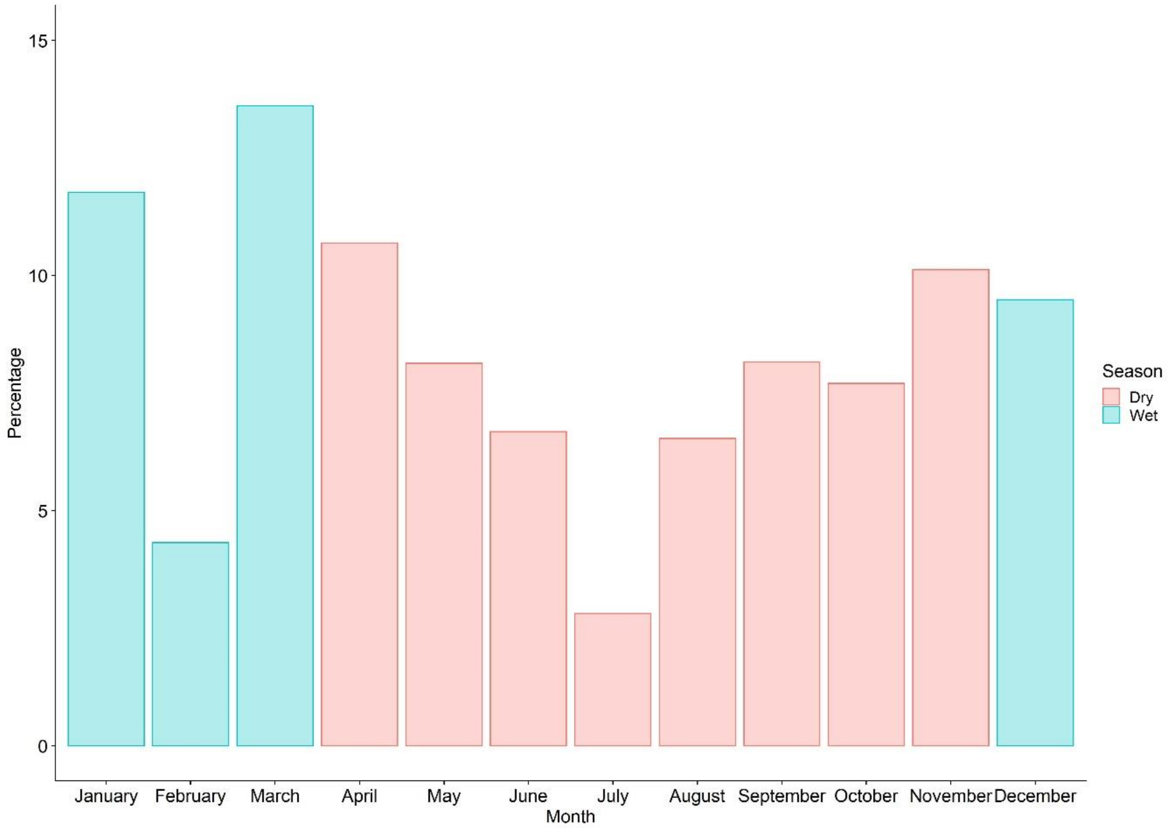


Figure 2. Catches of sharks by the artisanal fishing fleet in Manta from January to December 2019.

Fifty-nine *Isurus oxyrinchus* claspers were examined, of which 29 were not calcified (49.2%), 14 semicalcified (23.7%) and 16 were fully calcified (27.1%). Individuals who did not have calcified claspers had a length range of 119-197 cm TL and 3-19 cm CL, semicalcified had lengths of 154-195 cm TL and 6-19 cm CL, while calcified showed sizes of 194-251 cm TL and 19-25 cm CL (Figure 4d). The estimations of L_{50} and L_{95} for males were 194.52 cm TL ± 1.85 S.E. and 200.67 cm TL ± 3.76 S.E., respectively (Figure 5c). The inflexion point was estimated at 178.82 cm TL.

3.2.5. *Pseudocarcharias kamoharai*

A total of 40 *Pseudocarcharias kamoharai* were recorded, of which 17 were females (42.5%) and 23 males (57.5%). The sexual ratio was not significantly different from the expected 1:1 ratio (χ^2 = 0.9, p = 0.34). Females had sizes of 73-114 cm TL (mean ± S.E. = 100.35 ± 2.98), while males 69-102 cm TL (mean ± S.E. = 88.61 ± 1.91) (Figure 3e). The average length of females was significantly longer than the males (t-test, t = 3.46, p = 0.0013). The relationship between TL and PCL was significant for combined sexes (TL = 1.2835PCL + 1.5187, n = 38, R^2 = 0.98, $p < 2.2 \times ^{-16}$), females (TL = 1.2736PCL + 2.8587, n = 16, R^2 = 0.99, $p < 1.1 \times ^{-15}$) and males (TL = 1.2232PCL + 5.2416, n = 22, R^2 = 0.98, $p < 2.2 \times ^{-16}$).

A total of 23 *Pseudocarcharias kamoharai* claspers were examined, which were composed of 2 non-calcified (73-77 cm TL and 4-6 cm CL), 3 semicalcified (69-76 cm TL and 6-9 cm CL) and 18 calcified (84-102 cm TL and 7-10 cm CL) (Figure 4e). The L_{50} was estimated at 80.52 cm TL (Figure 5d).

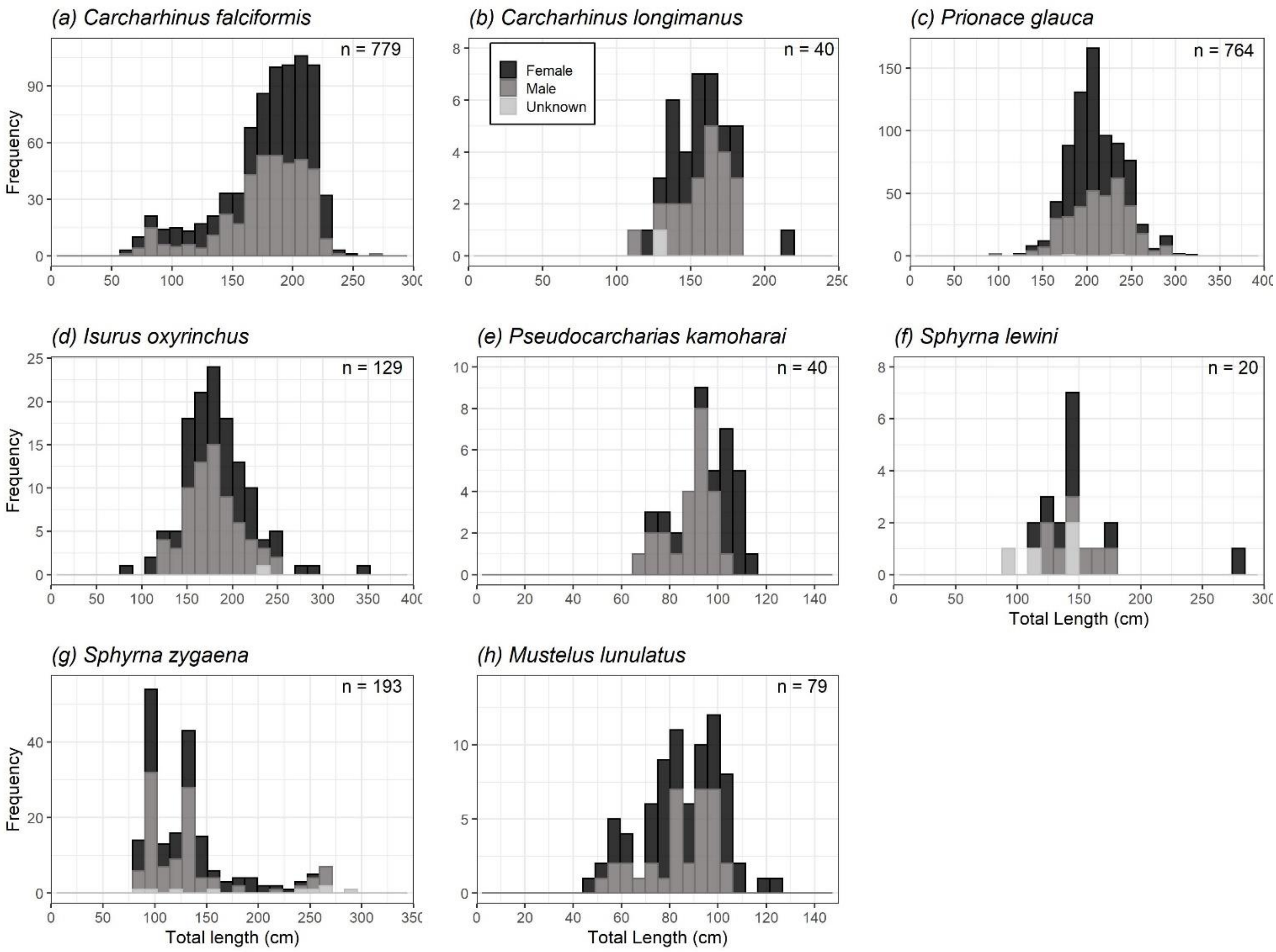


Figure 3. Composition of sizes of shark species (n ≥ 20) landed in Manta

3.2.6. *Sphyrna lewini*

A total of 174 *Sphyrna lewini* were sampled, composed of 45 females (26%), 27 males (16%) and 102 unsexed (59%). Females were more abundant than males (χ^2 = 4. 5, p = 0. 03). As for the months, only March was significantly different from the expected 1:1 ratio (Table 4e). Females had lengths ranging from 117 to 276 cm TL (mean ± S.E. = 156.12 ± 16.06), males from 122 to 177 cm TL (mean ± S.E. = 147.05 ± 7.41) and unidentified males from 92 to 150 cm TL (mean ± S.E. = 124.30 ± 13.35) (Figure 3f). There were no differences between sex sizes (Mann–Whitney U-test, U = 31.5, p = 0.95). The relationship between TL and PCL for combined sexes was significant (TL = 1.4335PCL - 1.1776, n = 9, R^2 = 0.98, p < 8.2 × $^{-8}$).

Six immature males were recorded, of which 3 were not calcified and 3 were semi-calcified. The non-calcified measured between 122 and 140 cm TL and 5-9 cm CL, while the semicalcified 145-177 cm TL and 12-13 cm CL (Figure 4f).

3.2.7. *Sphyrna zygaena*

During field trips, 179 (31%) of the 577 individuals of *Sphyrna zygaena* were females, 181 males (31.4%) and 217 unsexed (37.6%). No differences in sexual proportion were observed (χ^2 = 0. 01, p = 0. 91), with the exception of the months of January, March and May, where the sexual proportion was different from parity (Table 4f). Females had a size range of 82-251 cm TL (mean ± S.E. = 130.63 ± 4.22), males 85-272 cm TL (mean ± S.E. = 130.66 ± 4.82) and unknown males 83-287 cm TL (mean ± S.E. = 196.90 ± 26.92) (Figure 3g). There were no differences between the lengths of females and males (Mann–Whitney U-test, U

= 3953.0.5, p = 0.46). A significant relationship was found between TL and PCL for combined sexes (TL = 1.3654PCL + 2.3627, n = 180, $R^2 = 0.99$, $p < 2.2 \times ^{-16}$).

A total of 82 *Sphyrna zygaena* claspers were measured, of which 77 were not calcified (93.9%), 5 calcified (6.1%) and none were semicalcified. Organisms with non-calcified claspers measured between 85-184 cm TL and 1-10 cm CL, while calcified 218-271 cm TL and 17-29 cm CL (Figure 4g). Consequently, the average maturity size was estimated at 200.81 cm TL (Figure 5e).

Table 1. Parameters used to estimate the weight from the length of the sharks landed in the Ecuadorian Pacific.

Species	a	b	Source
Alopias pelagicus	4.61×10^{-5}	2.494	[37]
Alopias superciliosus	1.02×10^{-5}	2.78	[38]
Carcharhinus falciformis	2.92×10^{-6}	3.15	[39]
Carcharhinu longimanus	1.66×10^{-5}	2.891	[40]
Carcharhinus leuca	2.71×10^{-6}	3.20	[41]
Carcharhinus limbatus	2.512×10^{-9}	3.1253	[42]
Carcharhinus obscurus	1.2334×10^{-5}	2.855	[43]
Carcharhinus galapagensis	5.7×10^{-6}	3.0283	[44]
Isurus oxyrinchus	1.1×10^{-5}	2.95	[45]
Sphyrna zygaena	1.6×10^{-6}	3.20	[46]
Sphyrna lewini	3.99×10^{-6}	3.03	[47]
Prionace glauca	3.1841×10^{-6}	3.13	[48]
Mustelus lunulatus	2×10^{-6}	3.1538	Briones-Mendoza unpubl. Data
Galeocerdo cuvier	1.41×10^{-6}	3.24	[49]
Triaenodon obesus	1.8×10^{-6}	3.344	[50]
Squatina californica	$7.81 x^{-9}$	3.02	[51]
Ginglymostoma cirratum	9.006×10^{-6}	2.911	[52]
Pseudocarcharias kamoharai	9.0843×10^{-3}	1.3455	[53]

3.2.8. *Mustelus lunulatus*

A total of 140 *Mustelus lunulatus* were recorded, composed of 88 females (63%) and 52 males (37%). The sexual proportion was significantly different from parity ($\chi^2 = 9.3$, p = 0. 002), while it was not in the months of February, March, April, May, August, September, October and November (Table 4g). The size range of the females was 49-123 cm TL (mean ± S.E. = 85.03 ± 2.66), the males 52-102 cm TL (mean ± S.E. = 84.42 ± 2.42) and the non-sexed individual measured 75 cm TL (Figure 3h). No significant differences were observed between the mean lengths of females and males (t-test, t = 0.16, p = 0.86). The relationship between TL and PCL was significant for combined sexes (TL = 1.2313PCL + 0.4659, n = 73, $R^2 = 0.98$, $p < 2.2 \times ^{-16}$).

A total of 32 *Mustelus lunulatus* claspers were analyzed, of which 15 were not calcified (46.9%), 9 semicalcified (28.1%) and 8 were fully calcified (25%). Individuals with non-calcified claspers had a size of 52-94 cm TL and 2-9 cm CL, semicalcified 78-98 cm TL and 6-9 cm CL, while calcified 93-102 cm TL and 9-11 cm CL (Figure 4h). The average maturity size was 95.83 cm TL (Figure 5f).

3.2.9. Family Alopiidae

The biological aspects of *Alopias pelagicus* and *Alopias superciliosus* were previously published by Briones-Mendoza *et al.* (see[36]).

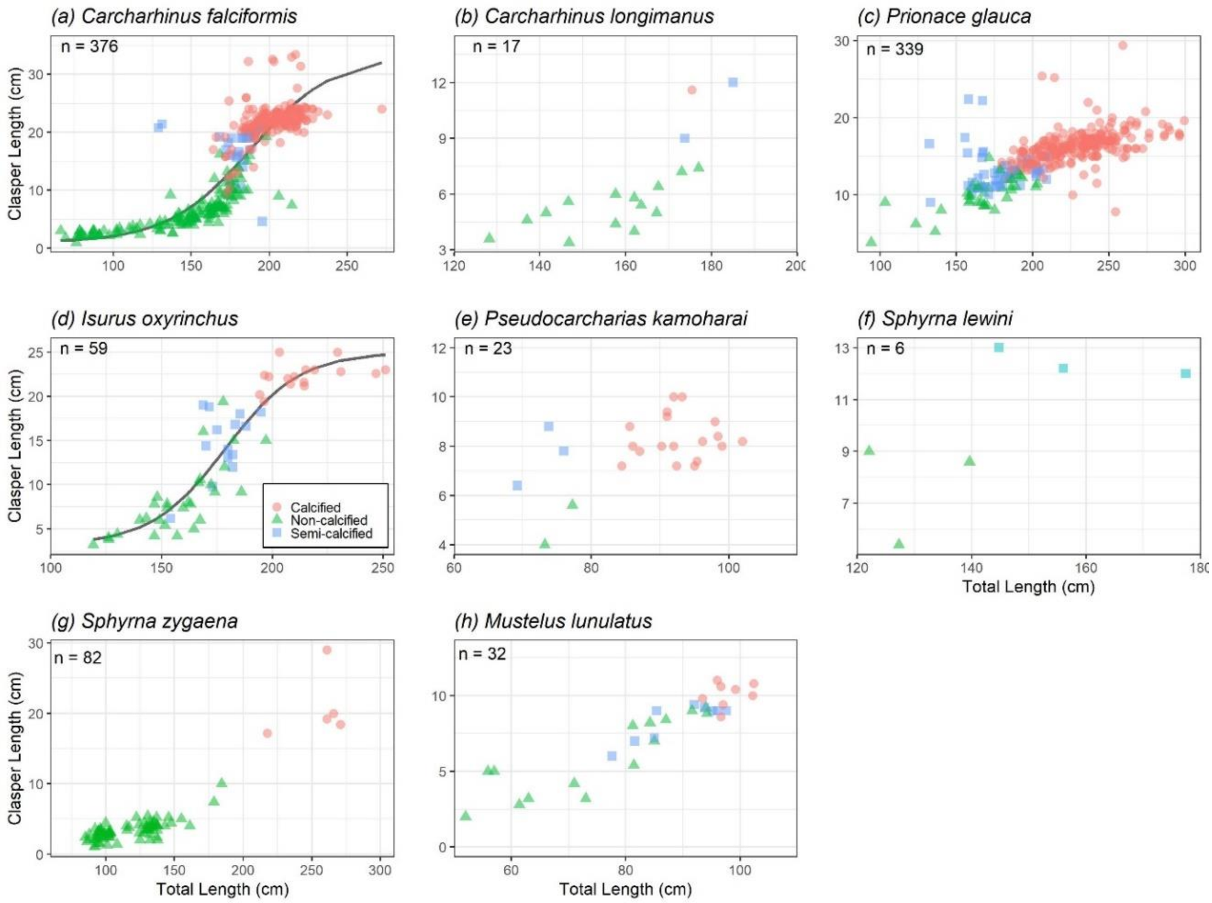


Figure 4. Relationship between the total length and the clasper length of the most abundant species.

4. Discussion

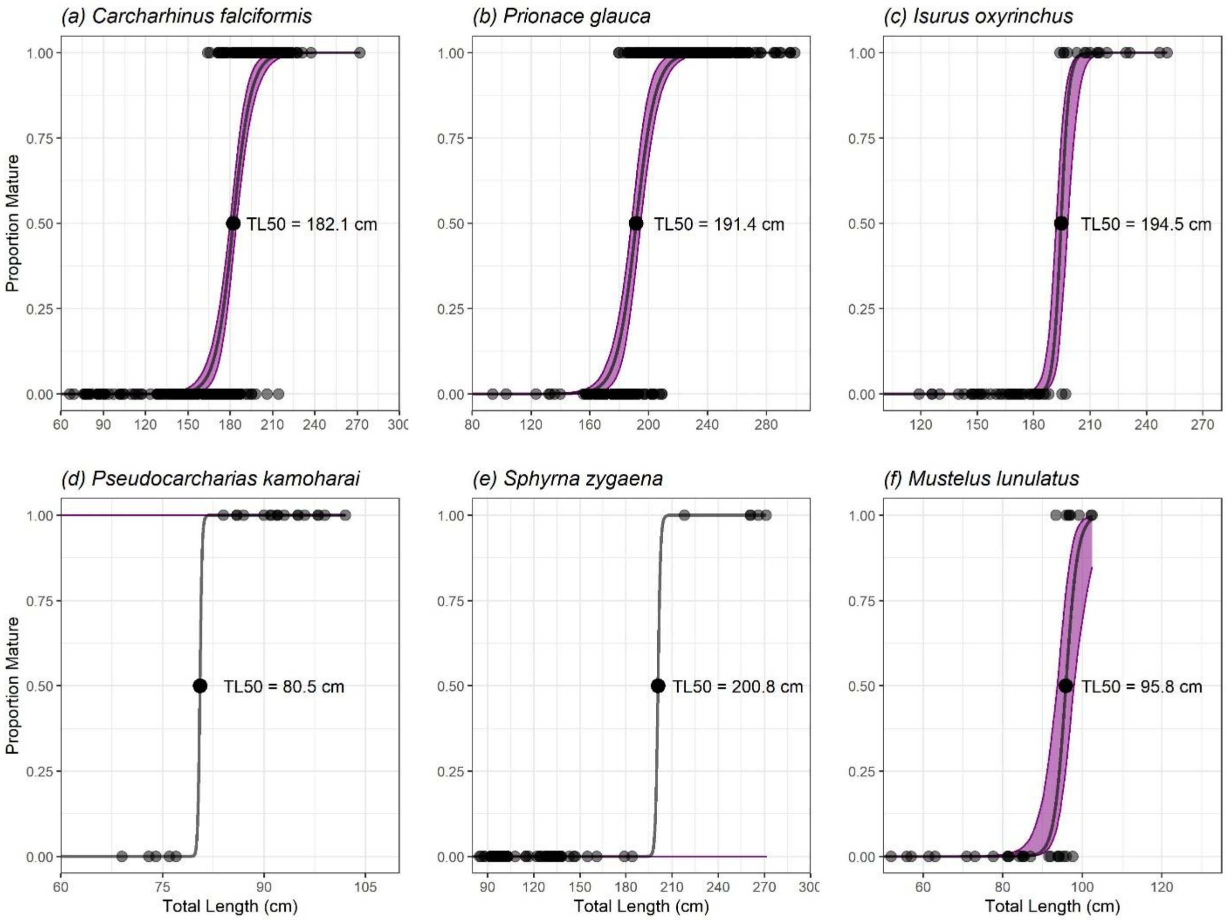
4.1. Composition of catches

Approximately 64 shark species have been reported in Ecuador [14]. Between 2003 and 2006, Martínez- Ortíz *et al.* [15] documented 34 species of sharks in Manta. However, only 19 species were recorded in this study. This could be possible due to the fact that the sampling in this study was only one year, while that of Martínez-Ortíz *et al.* was 3 years, although a possible loss of diversity as a result of increased fishing effort should not be discarded [5,54,55]. Sixteen years ago, Martínez-Ortíz *et al.* reported that the dominant species in landings in Manta was *Alopias pelagicus*, representing the 36% of the total species landed. However, in this study a decrease of 15.7% has been observed, while *Prionace glauca* has become the dominant species in landings in Manta, with an increase of 33.9% (Figure 6). It is possible that these changes are due to overfishing and differences in the life history characteristics of both species. For example, *Prionace glauca* has an average of 30 offspring per litter [56], while *Alopias pelagicus* has only 2 offspring per litter [37]. *Carcharhinus falciformis* remains in third place. However, it has suffered a decrease of 4.8%. In the case of vulnerable species, such as *Sphyrna zygaena* [57], and a critically endangered species, such as *Sphyrna lewini* [58], a decrease in landings [15] (Figure 6). It is possible that this is related to the implementation of Ministerial Agreement 116, which allows Ecuadorian artisanal vessels the bycatch of a maximum of five hammerhead sharks (juveniles up to 150 cm LT), which must have their fins attached to the body [59]. The season of greatest shark landings was during the dry season (April-November). This could be due to 2 reasons, according to Martínez-Ortíz *et al.* [15] : firstly, the type of material and the depth at which the hooks operate during the dry and rainy season

(December-March). Secondly, directed fishing at sharks due to the low abundance of target species during the dry season.

Figure 5. Average maturity length of male individuals of the main shark species landed in Manta.

4.2. Composition of sizes, sexual proportion, morphometric relations and maturity size



4.2.1. *Carcharhinus falciformis*

The size range (61-272 cm TL) reported in this study was lower than that recorded in Manta, between 2003 and 2006 (61-309 cm TL) [15], and in Campeche Bank, between 1985 and 1989 (65-314 cm TL) [60]. However, the size range of this study closely resembles to what was reported in the Central-Western Pacific in 2014 (65-271 cm TL) [9]. The sexual proportion was skewed towards females, which coincides with what was reported by Hoyos-Padilla *et al.* [61] and Varghese *et al.* [62]. However, it differs from other studies [15,63,64], where they found no difference in abundance between females and males. The maturity size for males was 182.10 cm TL, which was very similar to that recorded in the Central-Western Pacific (183 cm TL) [9], in the Mexican South Pacific (180 cm TL) [63] and on the West Coast of Baja California Sur (182 cm TL) [61]. However, the maturity size seems to be bigger in the Eastern Indian Ocean (207.6 cm TL) [64], in the Eastern Arabian Sea (218.98 cm TL)[62] and in Campeche Bank (225 cm TL) [60]. These results suggest that males of *Carcharhinus falciformis* reach sexual maturity at a smaller size in the Pacific. The estimated inflexion point in the Eastern Indian Ocean was at 196.9 cm TL [64], which appears to be above than the one that reported by this study for the Ecuadorian Pacific (188.5 cm LT).

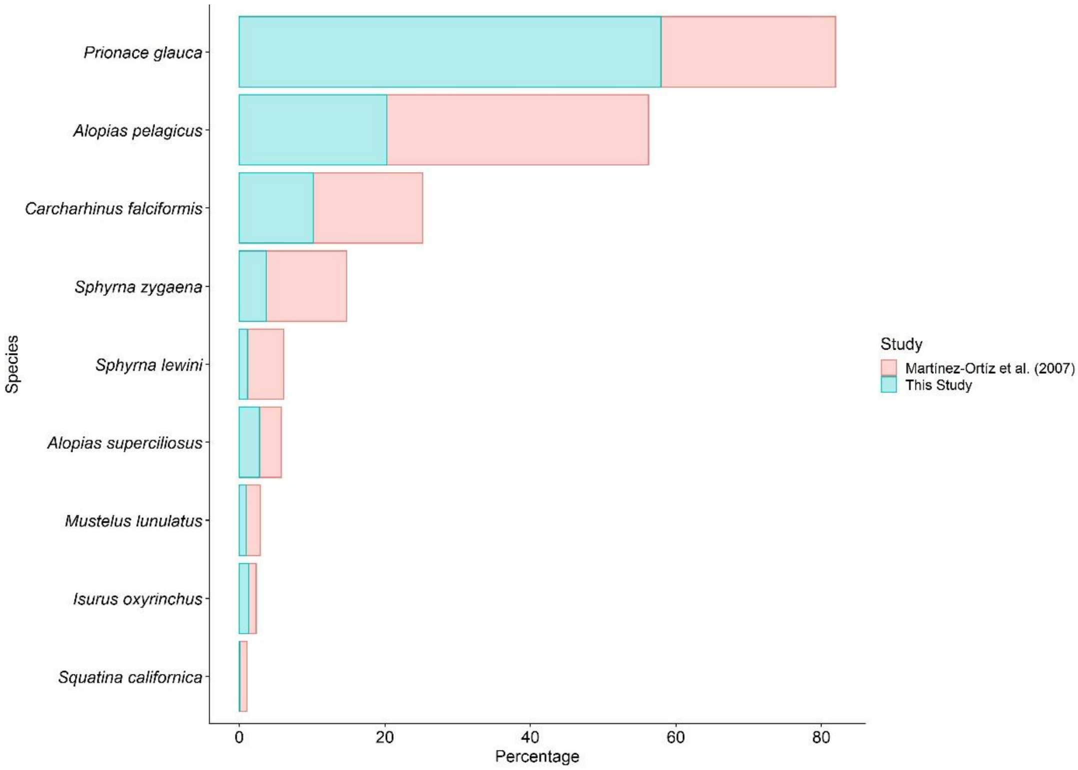


Figure 5. Comparison of changes in landings of the shark species most frequently landed in Manta.

4.2.2. *Carcharhinus longimanus*

The maximum length recorded in this work for *Carcharhinus longimanus* was lower than other lengths reported by other studies [65-68]. Like other studies [40,68], no significant differences in sexual proportion were found in this study. In the Western Central Pacific Ocean, D'Alberto *et al.* [69] reported that the smallest mature male of *Carcharhinus longimanus* averages 190 cm TL, while the larger immature one 195 cm TL. In the Western North Pacific Ocean, Joung *et al.* [40] found that the smallest mature male averaged 172 cm TL, while the larger immature averaged 202 cm TL. In this study only one mature individual was found, which averages 175 cm TL and the largest immature male measured 185 cm TL. 94% of the males of *Carcharhinus longimanus* examined had not reached sexual maturity, while all females were immature, taking as a reference the maturity length estimated by D'Alberto *et al.* (224 cm TL) [69]. Due to this fact, it is possible that the females of *Carcharhinus longimanus* approach coastal areas to give birth to their young [70], which would facilitate the capture of juvenile specimens [71]. Therefore, these results suggest possible breeding areas for *Carcharhinus longimanus* in Ecuadorian waters.

4.2.3. *Prionace glauca*

The maximum size of *Prionace glauca* is similar to what is reported by other studies[72-75]. However, the minimum size was larger than that documented in Mexican waters [71,76]. This is likely due to the breeding areas found in the Mexican Pacific [77]. The sexual proportion was skewed towards females in this study, which is consistent with what Cruz-Ramírez et al reported [76]. However, Carrera-Fernández *et al.* [71] found a biased proportion toward males, while other studies found no difference in abundance between females and males [72,78]. The average maturity size was 191.44 cm TL, which is similar to that recorded in the southeastern Pacific Ocean (190.3 cm TL) [78], in the Ecuadorian Pacific (187.1 cm TL) [72], although compared to northeastern Brazil much higher values have been reported compared to this study (225 cm TL) [75]. However, da Silva *et al.* [79], in one review, found no difference in the mean maturity sizes of the different studies between oceans.

4.2.4. *Isurus oxyrinchus*

This present study reported a greater size range (83-341 cm TL) than the ones in eastern Indonesia (130.8-310 cm TL) [80], in the Eastern Arabian Sea (97-269 cm TL) [62] and in the southeastern Pacific Ocean (75.5-240 cm TL) [78]. However, it was lower than the Northwest Pacific (80-375 cm TL) [45]. No differences in sexual proportion were found, which is consistent with other studies [62,78,81,82], although other ones have shown bias toward males [83] and females [84]. The maturity size for males was estimated at 194.52 cm TL, which is similar to that reported in New South Wales, Australia (195 cm TL) [81] and South Africa (194 –206 cm TL) [85]. However, in the Northwest Pacific a larger maturity length (210.2 cm LT) was recorded [45], while in eastern Indonesia (185.7 cm TL) [80], on the southwest coast of Baja California (180 cm TL) [82] and in the southeastern Pacific Ocean (180.2 cm TL) the maturity sizes were smaller than those reported in this present study for the Ecuadorian Pacific. The estimated inflexion point in this study (178.82 cm TL) was higher than that of eastern Indonesia (164.8 cm TL) [80].

4.2.5. *Pseudocarcharias kamoharai*

In the Ecuadorian Pacific, between 2003 and 2009, a maximum length of 113 cm TL [86], which coincides with what is reported in this present study (114 cm TL). However, it was lower than the recorded length in the southwest Atlantic Ocean (122 cm TL) [87]. In this study the sex ratio was not significantly different from the expected 1:1, which differs from some studies that found a sex ratio skewed towards females [80,86,87] and males [88,89]. The sexual maturity size recorded in this study for the Ecuadorian Pacific was 80.52 cm TL, which is quite similar to the ones recorded in the same area, between 2003 and 2009 (78.9 cm TL) [86] and in the southwest Atlantic Ocean, between 2005 and 2007 (80 cm TL) [87]. However, the maturity size of this study was higher than reported in eastern Indonesia (72.5 cm TL) [80] and lower than that recorded in the eastern tropical Atlantic (89.4 cm TL) [90].

4.2.6. *Sphyrna lewini*

The maximum length recorded in this study (276 cm TL) was smaller than that observed in the Ecuadorian Pacific, between 2003 and 2009 (310 cm TL) [91], in the Gulf of California (363 cm TL) [92], in Indonesian waters (316.8 cm TL) [93] and in northeastern Brazil (321 cm TL) [94]. It is possible that this is due to the fact that in Ecuador only the incidental capture of a maximum of 5 individuals with a size less than 150 cm TL is allowed, according to Ministerial Agreement 116 [59]. However, in this present study 5 specimens of *Sphyrna lewini* exceeding 150 cm TL were reported. The sexual proportion was significantly different from parity, which coincides with that reported in Ecuadorian Pacific, where a sex ratio biased towards females was recorded [91], but differs from that reported in Indonesian waters [93], where they found no differences in sexual proportion. All males reported in this study were immature, as they did not have fully calcified claspers. Taking as a reference the maturity size for females reported by Estupiñán-Montaño *et al.* in the Ecuadorian Pacific (219.4 cm TL) [91], 88.9% (n = 8) of the females reported in this study were immature, while only 11.1% (n = 1) were mature. These results coincide with those documented by Estupiñán-Montaño *et al.* [91], who also found a greater presence of immature specimens in landings, suggesting possible breeding areas.

4.2.7. *Sphyrna zygaena*

As mentioned before, it is forbidden to catch specimens of hammerhead sharks greater than 150 cm Tl in Ecuador. However, this study recorded 38 specimens of *Sphyrna zygaena* with sizes exceeding 150 cm Tl. Therefore, a greater vigilance and the application of stricter laws are needed [95,96]. Regarding the sexual proportion, no significant differences were found, disagreeing with what was reported in the Ecuadorian Pacific, between 2003 and 2006, where the sexual proportion was biased towards males [15], while another study carried out between 2007 and 2012 in the same region registered bias towards females [97]. The maturity size for males in this study (200.81 cm Tl) was higher than that reported in the Gulf of California, between 1995 and 2000 (193.7 cm TL) [46], but lower than reported in the Ecuadorian Pacific, between 2003 and 2006 (215 cm TL) [98], and between 2007 and 2012 (263.7 cm TL) [97]. According to the maturity size of this study, 89.80% of the landed male individuals were immature, while 97.67% of the females had not reached sexual maturity, taking as a reference the maturity size estimated by López-Martínez *et al.* (239.3 cm TL) [97]. These results are consistent with other studies conducted in the Ecuadorian Pacific [16,19], where most of the individuals landed were immature. The concordances in the results of these studies seem to be associated with the fact that *S. zygaena* remains in coastal areas during the first years of life [70,99] and, therefore, are more susceptible to be captured.

4.2.8. *Mustelus lunulatus*

The size range of this work (49-123 cm TL) was very similar to that documented in the Colombian Pacific in 2001 (50-125 cm TL) [100], but in the Ecuadorian Pacific the size range was wider in 2013 (41.4-135 cm TL) [101]. Females were significantly more abundant than males, disagreeing with what was documented in the Colombian [100] and Ecuadorian [101], where the sexual proportion was no different from parity. The length at maturity for males of this work (95.93 cm TL) was similar to that reported in the Gulf of California (91.5 cm TL) [102] and in the Ecuadorian Pacific (97.2 cm TL) [101]. 75% of the males examined were immature. As for females, 82% had not reached sexual maturity, according to the maturity size estimated by Pérez-Jiménez and Sosa-nishizaki (103.2 cm TL) [102]. These results coincide with those reported by other studies [100-102], which also recorded a greater number of immature individuals.

Author Contributions: Jesús Briones-Mendoza: Conceptualization, Data curation, Formal analysis Investigation, Methodology, Software, Writing-original draft, Writing-review and editing.: Diego Mejía: Conceptualization, Investigation, Methodology, Supervision, Visualization, Writing-original draft, Writing-review and editing, Software. Pol Carrasco-Puig: Investigation, Methodology, Supervision, Visualization, Writing-original draft, Writing-review and editing.

Funding: This research received no external funding

Institutional Review Board Statement: Not applicable

Data Availability Statement: Not applicable

Acknowledgments: The authors thank the fishermen of Playita Mía for having facilitated this research.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Bornatowski, H.; Navia, A.F.; Braga, R.R.; Abilhoa, V.; Corrêa, M.F.M. Ecological importance of sharks and rays in a structural foodweb analysis in southern Brazil. *ICES Journal of Marine Science* **2014**, *71*, 1586-1592.
2. Dulvy, N.K.; Pacoureau, N.; Rigby, C.L.; Pollom, R.A.; Jabado, R.W.; Ebert, D.A.; Finucci, B.; Pollock, C.M.; Cheok, J.; Derrick, D.H. Overfishing drives over one-third of all sharks and rays toward a global extinction crisis. *Current Biology* **2021**, *31*, 4773-4787. e4778.
3. Pacoureau, N.; Rigby, C.L.; Kyne, P.M.; Sherley, R.B.; Winker, H.; Carlson, J.K.; Fordham, S.V.; Barreto, R.; Fernando, D.; Francis, M.P. Half a century of global decline in oceanic sharks and rays. *Nature* **2021**, *589*, 567-571.
4. Simpfendorfer, C.; Heupel, M.; White, W.; Dulvy, N. The importance of research and public opinion to conservation management of sharks and rays: a synthesis. *Marine and Freshwater Research* **2011**, *62*, 518-527.
5. Arunrugstichai, S.; True, J.; White, W. Catch composition and aspects of the biology of sharks caught by Thai commercial fisheries in the Andaman Sea. *Journal of fish biology* **2018**, *92*, 1487-1504.
6. King, J.; McFarlane, G. Marine fish life history strategies: applications to fishery management. *Fisheries management and ecology* **2003**, *10*, 249-264.
7. Hacohen-Domené, A.; Polanco-Vásquez, F.; Estupiñan-Montaño, C.; Graham, R.T. Description and characterization of the artisanal elasmobranch fishery on Guatemala's Caribbean coast. *PloS one* **2020**, *15*, e0227797.

8. Tyabji, Z.; Wagh, T.; Patankar, V.; Jabado, R.W.; Sutaria, D. Catch composition and life history characteristics of sharks and rays (Elasmobranchii) landed in the Andaman and Nicobar Islands, India. *PloS one* **2020**, *15*, e0231069.
9. Grant, M.I.; Smart, J.J.; White, W.T.; Chin, A.; Baje, L.; Simpfendorfer, C.A. Life history characteristics of the silky shark *Carcharhinus falciformis* from the central west Pacific. *Marine and Freshwater Research* **2018**, *69*, 562-573.
10. Smart, J.; Chin, A.; Tobin, A.; Simpfendorfer, C.; White, W. Age and growth of the common blacktip shark *Carcharhinus limbatus* from Indonesia, incorporating an improved approach to comparing regional population growth rates. *African Journal of Marine Science* **2015**, *37*, 177-188.
11. FishstatJ, F. FishStatJ-Software for fishery and aquaculture statistical time series. *FAO Fisheries Division [online]. Rome. Updated* **2020**, *22*.
12. Gonzalez-Pestana, A.; Kouri, C.; Velez-Zuazo, X. Shark fisheries in the Southeast Pacific: A 61-year analysis from Peru. *F1000Research* **2014**, *3*.
13. Jacquet, J.; Alava, J.J.; Pramod, G.; Henderson, S.; Zeller, D. In hot soup: sharks captured in Ecuador's waters. *Environmental Sciences* **2008**, *5*, 269-283.
14. Calle-Morán, M.D.; Béarez, P. Updated checklist of marine cartilaginous fishes from continental and insular Ecuador (Tropical Eastern Pacific Ocean). *Cybium: Revue Internationale d'Ichtyologie* **2020**.
15. Martínez-Ortíz, J.; Galván-Magaña, F.; Carrera-Fernández, M.; Mendoza-Intriago, D.; Estupiñán-Montaño, C.; Cedeño-Figueroa, L. Abundancia estacional de tiburones desembarcados en Manta-Ecuador. In *Tiburones en el Ecuador: Casos de estudio*, Martínez-Ortíz, J., Galván-Magaña, F., Eds.; EPESPO-PMRC: 2007; pp. 9-27.
16. Coello, D.; Herrera, M. Desembarque de tiburones en las pesquerías artesanales del Ecuador durante el 2012. *Revista Científica Ciencias Naturales y Ambientales* **2018**, *12*, 1-8.
17. Aguilar, F.; Revelo, W.; Coello, D.; Cajas, J.; Ruíz, W.; Díaz, M.; Moreno, J. Desembarques artesanales de tiburones y rayas en los principales puertos pesqueros del Ecuador durante 2006. *Informe Interno, Instituto Nacional de Pesca, Guayaquil, Ecuador* **2007**.
18. Ruiz, W.; Díaz, M. Desembarques artesanales de tiburones y rayas en los principales puertos pesqueros del Ecuador durante 2007. *Instituto Nacional de Pesca. Informe Final de Tiburón* **2007**.
19. Herrera, M.; Coello, D.; Cajas, J. Desembarques y aspectos biológicos de Elasmobranquios en las pesquerías artesanales del Ecuador durante 2011. *Boletín científico y técnico* **2012**, *22*, 1-08.
20. Martínez-Ortiz, J.; García-Domínguez, M. Guía de campo. Condrictios del Ecuador. Quimeras, tiburones y rayas. *Ministerio de Agricultura, Ganadería, Acuacultura y Pesca (MAGAP)/ViceMinisterio de Acuacultura y Pesca (VMAP)/Subsecretaria de Recursos Pesqueros (SRP). Ecuador* **2013**.
21. Mejía-Falla, P.; Navia, A.; Cortés, E. Reproductive variables of *Urotrygon rogersi* (Batoidea: Urotrygonidae): a species with a triannual reproductive cycle in the eastern tropical Pacific Ocean. *Journal of Fish Biology* **2012**, *80*, 1246-1266.
22. White, W. Catch composition and reproductive biology of whaler sharks (Carcharhiniformes: Carcharhinidae) caught by fisheries in Indonesia. *Journal of Fish Biology* **2007**, *71*, 1512-1540.
23. White, W.T.; Baje, L.; Appleyard, S.A.; Chin, A.; Smart, J.J.; Simpfendorfer, C.A. Shark longline fishery of Papua New Guinea: size and species composition and spatial variation of the catches. *Marine and Freshwater Research* **2019**, *71*, 627-640.
24. White, W.; Baje, L.; Simpfendorfer, C.; Appleyard, S.; Chin, A.; Sabub, B.; Rochel, E.; Naylor, G. Elasmobranch bycatch in the demersal prawn trawl fishery in the Gulf of Papua, Papua New Guinea. *Scientific reports* **2019**, *9*, 1-16.
25. Appleyard, S.; White, W.; Vieira, S.; Sabub, B. Artisanal shark fishing in Milne Bay Province, Papua New Guinea: biomass estimation from genetically identified shark and ray fins. *Scientific reports* **2018**, *8*, 1-12.
26. Walker, T.I. Reproduction in fisheries science. *Reproductive biology and phylogeny of chondrichthyes: sharks, batoids and chimaeras* **2005**, *3*, 81-128.

27. Piner, K.R.; Hamel, O.S.; Menkel, J.L.; Wallace, J.R.; Hutchinson, C.E. Age validation of canary rockfish (Sebastes pinniger) from off the Oregon coast (USA) using the bomb radiocarbon method. *Canadian Journal of Fisheries and Aquatic Sciences* **2005**, *62*, 1060-1066.
28. White, W.T.; Giles, J.; Potter, I.C. Data on the bycatch fishery and reproductive biology of mobulid rays (Myliobatiformes) in Indonesia. *Fisheries Research* **2006**, *82*, 65-73.
29. White, W.; Dharmadi. Species and size compositions and reproductive biology of rays (Chondrichthyes, Batoidea) caught in target and non-target fisheries in eastern Indonesia. *Journal of Fish Biology* **2007**, *70*, 1809-1837.
30. Zar, J.H. *Biostatistical analysis-5th ed*; Prentice Hall: 2010.
31. R Core Team *R: A language and environment for statistical computing*, R Foundation for Statistical Computing: Vienna, Austria, 2020.
32. Smart, J.J.; Chin, A.; Tobin, A.J.; Simpfendorfer, C.A. Multimodel approaches in shark and ray growth studies: strengths, weaknesses and the future. *Fish and Fisheries* **2016**, *17*, 955-971.
33. Smart, J. AquaticLifeHistory: Fisheries life history analysis using contemporary methods. **2019**.
34. Wilke, C.O.; Wickham, H.; Wilke, M.C.O. Package 'cowplot'. *Streamlined Plot Theme and Plot Annotations for 'ggplot2* **2019**.
35. Wickham, H.; Averick, M.; Bryan, J.; Chang, W.; McGowan, L.D.A.; François, R.; Grolemund, G.; Hayes, A.; Henry, L.; Hester, J. Welcome to the Tidyverse. *Journal of open source software* **2019**, *4*, 1686.
36. Briones-Mendoza, J.; Carrasco-Puig, P.; Toala-Franco, D. Reproductive biology aspects of *Alopias pelagicus* and *A. superciliosus* (Lamniformes: Alopiidae) in the Ecuadorian Pacific. *Neotropical Ichthyology* **2021**, *19*.
37. Liu, K.-M.; Chen, C.-T.; Liao, T.-H.; Joung, S.-J. Age, growth, and reproduction of the pelagic thresher shark, *Alopias pelagicus* in the Northwestern Pacific. *Copeia* **1999**, 68-74.
38. Liu, K.-M.; Chiang, P.-J.; Chen, C.-T. Age and growth estimates of the bigeye thresher shark, *Alopias superciliosus*, in northeastern Taiwan waters. *Fishery Bulletin* **1998**.
39. Joung, S.-J.; Chen, C.-T.; Lee, H.-H.; Liu, K.-M. Age, growth, and reproduction of silky sharks, *Carcharhinus falciformis*, in northeastern Taiwan waters. *Fisheries Research* **2008**, *90*, 78-85.
40. Joung, S.-J.; Chen, N.-F.; Hsu, H.-H.; Liu, K.-M. Estimates of life history parameters of the oceanic whitetip shark, *Carcharhinus longimanus*, in the Western North Pacific Ocean. *Marine Biology Research* **2016**, *12*, 758-768.
41. Branstetter, S.; Stiles, R. Age and growth estimates of the bull shark, *Carcharhinus leucas*, from the northern Gulf of Mexico. *Environmental Biology of Fishes* **1987**, *20*, 169-181.
42. Castro, J.I. Biology of the blacktip shark, *Carcharhinus limbatus*, off the southeastern United States. *Bulletin of marine science* **1996**, *59*, 508-522.
43. Simpfendorfer, C.A.; Unsworth, P. Gill-net mesh selectivity of dusky sharks (*Carcharhinus obscurus*) and whiskery sharks (Furgaleus macki) from south-western Australia. *Marine and Freshwater Research* **1998**, *49*, 713-718.
44. Wetherbee, B.M.; Crow, G.L.; Lowe, C.G. Biology of the Galapagos shark, *Carcharhinus galapagensis*, in Hawai'i. *Environmental Biology of Fishes* **1996**, *45*, 299-310.
45. Joung, S.-J.; Hsu, H.-H. Reproduction and embryonic development of the shortfin mako, *Isurus oxyrinchus* Rafinesque, 1810, in the northwestern Pacific. *ZOOLOGICAL STUDIES-TAIPEI-* **2005**, *44*, 487.
46. Nava Nava, P.; Márquez-Farías, J.F. Talla de madurez del tiburón martillo, *Sphyrna zygaena*, capturado en el Golfo de California. *Hidrobiológica* **2014**, *24*, 129-135.
47. Stevens, J.; Lyle, J. Biology of three hammerhead sharks (Eusphyra blochii, *Sphyrna mokarran* and *S. lewini*) from northern Australia. *Marine and Freshwater Research* **1989**, *40*, 129-146.
48. Kohler, N.E.; Casey, J.G.; Turner, P.A. Length-weight relationships for 13 species of sharks from the western North Atlantic. *Fishery bulletin* **1995**, *93*, 412-418.
49. Branstetter, S.; Musick, J.A.; Colvocoresses, J.A. A Comparison Of The Age And Growth Of The Tiger Shark, *Galeocerdo-Cuvieri*, From Off Virginia And From The Northwestern Gulf-Of-Mexico. *Fishery Bulletin* **1987**, *85*, 269-279.

50. Kulbicki, M.; Guillemot, N.; Amand, M. A general approach to length-weight relationships for New Caledonian lagoon fishes. *Cybium* **2005**, *29*, 235-252.
51. Williams, C.M.; Williams, J.P.; Claisse, J.T.; Pondella, D.J.; Domeier, M.L.; Zahn, L.A. Morphometric relationships of marine fishes common to central California and the southern California bight. *Bulletin, Southern California Academy of Sciences* **2013**, *112*, 217-227.
52. Castro, J.I. The biology of the nurse shark, *Ginglymostoma cirratum*, off the Florida east coast and the Bahama Islands. *Environmental Biology of Fishes* **2000**, *58*, 1-22.
53. Ariz, J.; de Molina, A.D.; Santana, J. Length-weight relationships, conversion factors and analyses of sex-ratio, by length-range, for several species of pelagic sharks caught in experimental cruises on board Spanish longliners in the South Western Indian Ocean during 2005. *Third Session of the IOTC Working Party on Ecosystems and Bycatch (previously the Working Party on Bycatch) Victoria, Seychelles* **2007**, 11-13.
54. Stevens, J.; Bonfil, R.; Dulvy, N.K.; Walker, P. The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *ICES Journal of Marine Science* **2000**, *57*, 476-494.
55. Jennings, S.; Kaiser, M.J. The effects of fishing on marine ecosystems. In *Advances in marine biology*; Elsevier: 1998; Volume 34, pp. 201-352.
56. Nakano, H.; Stevens, J.D. The biology and ecology of the blue shark, *Prionace glauca*. *Sharks of the open ocean: Biology, fisheries and conservation* **2008**, *1*, 140-151.
57. Rigby, C.; Barreto, R.; Carlson, J.; Fernando, D.; Fordham, S.; Herman, K.; Jabado, R.; Liu, K.; Marshall, A.; Pacoureau, N. *Sphyrna zygaena*. The IUCN Red List of Threatened Species 2019. **2019**.
58. Rigby, C.; Dulvy, N.; Barreto, R.; Carlson, J.; Fernando, D.; Fordham, S.; Francis, M.; Herman, K.; Jabado, R.; Liu, K. *Sphyrna lewini*. The IUCN Red List of Threatened Species 2019: e. T39385A2918526. *línea].[Último acceso: 22 04 2021]* **2019**.
59. MAGAP. *MAGAP aplica medidas de conservación para tiburones martillos en el Ecuador*; 2013.
60. Bonfil, R.; Mena, R.; De Anda, D. Biological paramenters of commercially exploited silky sharks, *Carcharhinus falciformis*, from the Campeche Bank, Mexico. *NOAA Tech. Rep. NMFS* **1993**, *115*, 73-86.
61. Hoyos-Padilla, E.M.; Ceballos-Vázquez, B.P.; Galván-Magaña, F. Reproductive biology of the silky shark *Carcharhinus falciformis* (Chondrichthyes: Carcharhinidae) off the west coast of Baja California Sur, Mexico. *Aqua Int. J. Ichthyol* **2012**, *18*, 15-24.
62. Varghese, S.P.; Gulati, D.; Unnikrishnan, N.; Ayoob, A. Biological aspects of silky shark *Carcharhinus falciformis* in the eastern Arabian Sea. *Journal of the Marine Biological Association of the United Kingdom* **2016**, *96*, 1437-1447.
63. Galván-Tirado, C.; Galvan-Magaña, F.; Ochoa-Báez, R. Reproductive biology of the silky shark *Carcharhinus falciformis* in the southern Mexican Pacific. *Journal of the Marine Biological Association of the United Kingdom* **2015**, *95*, 561-567.
64. Hall, N.; Bartron, C.; White, W.; Potter, I. Biology of the silky shark *Carcharhinus falciformis* (Carcharhinidae) in the eastern Indian Ocean, including an approach to estimating age when timing of parturition is not well defined. *Journal of Fish Biology* **2012**, *80*, 1320-1341.
65. Lessa, R.; Santana, F.M.; Paglerani, R. Age, growth and stock structure of the oceanic whitetip shark, *Carcharhinus longimanus*, from the southwestern equatorial Atlantic. *Fisheries Research* **1999**, *42*, 21-30.
66. Seki, T.; Taniuchi, T.; Nakano, H.; Shimizu, M. Age, growth and reproduction of the oceanic whitetip shark from the Pacific Ocean. *Fisheries Science* **1998**, *64*, 14-20.
67. Coelho, R.; Hazin, F.H.; Rego, M.; Tambourgi, M.; Oliveira, P.; Travassos, P.; Carvalho, F.; Burgess, G. Notes on the reproduction of the oceanic whitetip shark, *Carcharhinus longimanus*, in the southwestern Equatorial Atlantic ocean. *Collect. Vol. Sci. Pap. ICCAT* **2009**, *64*, 1734-1740.
68. Tambourgi, M.R.d.S.; Hazin, F.H.; Oliveira, P.G.; Coelho, R.; Burgess, G.; Roque, P.C. Reproductive aspects of the oceanic whitetip shark, *Carcharhinus longimanus* (Elasmobranchii: Carcharhinidae), in the equatorial and southwestern Atlantic Ocean. *Brazilian Journal of Oceanography* **2013**, *61*, 161-168.

69. D'Alberto, B.M.; Chin, A.; Smart, J.J.; Baje, L.; White, W.T.; Simpfendorfer, C.A. Age, growth and maturity of oceanic whitetip shark (*Carcharhinus longimanus*) from Papua New Guinea. *Marine and Freshwater Research* **2016**, *68*, 1118-1129.
70. Clarke, S.; Coelho, R.; Francis, M.; Kai, M.; Kohin, S.; Liu, K.; Simpfendorfer, C.; Tovar-Avila, J.; Rigby, C.; Smart, J. Report of the pacific shark life history expert panel workshop, 28-30 april 2015. *Western and Central Pacific Fisheries Commission, Scientific committee Eleventh Regular Session, Pohnpei, Federated States of Micronesia* **2015**.
71. Carrera-Fernández, M.; Galván-Magaña, F.; Ceballos-Vázquez, B.P. Reproductive biology of the blue shark *Prionace glauca* (Chondrichthyes: Carcharhinidae) off Baja California Sur, México. *aqua* **2010**, *16*, 101-110.
72. Briones-Mendoza, J.; Pincay-Espinoza, J.; Palma-Chávez, J.; Romero-Caicedo, A. Notas sobre la biología del tiburón azul *Prionace glauca* (Carcharhiniformes: Carcharhinidae) en aguas ecuatorianas. *Revista mexicana de biodiversidad* **2016**, *87*, 1387-1390.
73. Jolly, K.; Da Silva, C.; Attwood, C. Age, growth and reproductive biology of the blue shark *Prionace glauca* in South African waters. *African Journal of Marine Science* **2013**, *35*, 99-109.
74. Megalofonou, P.; Damalas, D.; De Metrio, G. Biological characteristics of blue shark, *Prionace glauca*, in the Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom* **2009**, *89*, 1233-1242.
75. Lessa, R.; Santana, F.M.; Hazin, F.H. Age and growth of the blue shark *Prionace glauca* (Linnaeus, 1758) off northeastern Brazil. *Fisheries Research* **2004**, *66*, 19-30.
76. Cruz-Ramírez, A.; Soriano-Velásquez, S.R.; Santana-Hernández, H.; Ramírez-Santiago, C.E.; Acal-Sánchez, D.E. Aspectos reproductivos del tiburón azul *Prionace glauca* capturado por la flota palangrera de mediana altura del Puerto de Manzanillo, Colima. *Ciencia Pesquera* **2012**, *20*, 39-48.
77. Salomón-Aguilar, C.; Villavicencio-Garayzar, C.; Reyes-Bonilla, H. Zonas y temporadas de reproducción y crianza de tiburones en el Golfo de California: Estrategia para su conservación y manejo pesquero. *Ciencias marinas* **2009**, *35*, 369-388.
78. Bustamante, C.; Bennett, M.B. Insights into the reproductive biology and fisheries of two commercially exploited species, shortfin mako (*Isurus oxyrinchus*) and blue shark (*Prionace glauca*), in the south-east Pacific Ocean. *Fisheries research* **2013**, *143*, 174-183.
79. da Silva, T.E.F.; Lessa, R.; Santana, F.M. Current knowledge on biology, fishing and conservation of the blue shark (*Prionace glauca*). *Neotropical Biology and Conservation* **2021**, *16*, 71-88.
80. White, W.T. Biological observations on lamnoid sharks (Lamniformes) caught by fisheries in eastern Indonesia. *Journal of the Marine Biological Association of the United Kingdom* **2007**, *87*, 781-788.
81. Stevens, J. Observations on reproduction in the shortfin mako *Isurus oxyrinchus*. *Copeia* **1983**, 126-130.
82. Conde-Moreno, M.; Galván-Magaña, F. Reproductive biology of the mako shark *Isurus oxyrinchus* on the south-western coast of Baja California, Mexico. *Cybium* **2006**, *30*, 75-83.
83. Maia, A.; Queiroz, N.; Cabral, H.; Santos, A.; Correia, J. Reproductive biology and population dynamics of the shortfin mako, *Isurus oxyrinchus* Rafinesque, 1810, off the southwest Portuguese coast, eastern North Atlantic. *Journal of Applied Ichthyology* **2007**, *23*, 246-251.
84. Canani, G.; Oddone, M.C. Reproductive biology of *Isurus oxyrinchus* captured by the south Brazilian surface longline commercial fleet in the Southwest Atlantic Ocean, with data on CPUE and size distribution by sex. *Journal of Northwest Atlantic Fishery Science* **2020**, *51*.
85. Cliff, G.; Dudley, S.; Davis, B. Sharks caught in the protective gill nets off Natal, South Africa. 3. The shortfin mako shark *Isurus oxyrinchu*s (Rafinesque). *South African Journal of Marine Science* **1990**, *9*, 115-126.
86. Estupiñán-Montaño, C.; Galván-Magaña, F. First Insight into the Biological Aspects of the Crocodile Shark *Pseudocarcharias kamoharai* in the Eastern Pacific Ocean. *Thalassas: An International Journal of Marine Sciences* **2021**, *37*, 229-233.
87. Oliveira, P.; Hazin, F.; Carvalho, F.; Rego, M.; Coelho, R.; Piercy, A.; Burgess, G. Reproductive biology of the crocodile shark *Pseudocarcharias kamoharai*. *Journal of Fish Biology* **2010**, *76*, 1655-1670.

88. Kiszka, J.J.; Aubail, A.; Hussey, N.E.; Heithaus, M.R.; Caurant, F.; Bustamante, P. Plasticity of trophic interactions among sharks from the oceanic south-western Indian Ocean revealed by stable isotope and mercury analyses. *Deep Sea Research Part I: Oceanographic Research Papers* **2015**, *96*, 49-58.
89. Kindong, R.; Wang, H.; Wu, F.; Dai, X.; Tian, S. Age, growth, and sexual maturity of the crocodile shark, *Pseudocarcharias kamoharai*, from the Eastern Atlantic Ocean. *Frontiers in Marine Science* **2020**, *7*, 857.
90. Wu, F.; Kindong, R.; Dai, X.; Sarr, O.; Zhu, J.; Tian, S.; Li, Y.; Nsangue, B.T. Aspects of the reproductive biology of two pelagic sharks in the eastern Atlantic Ocean. *Journal of Fish Biology* **2020**, *97*, 1651-1661.
91. Estupiñán-Montaño, C.; Carrera-Fernández, M.; Galván-Magaña, F. Reproductive biology of the scalloped hammerhead (*Sphyrna lewini*) in the central-eastern Pacific Ocean. *Journal of the Marine Biological Association of the United Kingdom* **2021**, *101*, 465-470.
92. Torres-Huerta, A.M.; Villavicencio-Garayzar, C.; Corro-Espinosa, D. Biología reproductiva de la cornuda común *Sphyrna lewini* Griffith & Smith (Sphyrnidae) en el Golfo de California. *Hidrobiológica* **2008**, *18*, 227-238.
93. White, W.; Bartron, C.; Potter, I. Catch composition and reproductive biology of *Sphyrna lewini* (Griffith & Smith)(Carcharhiniformes, Sphyrnidae) in Indonesian waters. *Journal of Fish Biology* **2008**, *72*, 1675-1689.
94. Hazin, F.; Fischer, A.; Broadhurst, M. Aspects of reproductive biology of the scalloped hammerhead shark, *Sphyrna lewini*, off northeastern Brazil. *Environmental Biology of Fishes* **2001**, *61*, 151-159.
95. Carr, L.A.; Stier, A.C.; Fietz, K.; Montero, I.; Gallagher, A.J.; Bruno, J.F. Illegal shark fishing in the Galápagos Marine Reserve. *Marine Policy* **2013**, *39*, 317-321.
96. Alava, J.; Barragán-Paladines, M.; Denkinger, J.; Muñoz-Abril, L.; Jiménez, P.; Paladines, F.; Valle, C.; Tirapé, A.; Gaibor, N.; Calle, M. Massive Chinese fleet jeopardizes threatened shark species around the Galápagos marine reserve and waters off Ecuador: Implications for national and international fisheries policy. *International Journal of Fisheries Sci Res* **2017**, *1*, 1001.
97. López-Martínez, J.; Cabanilla-Carpio, C.; Ruiz Choez, W.; Arzola-Sotelo, E.A. Interannual variability of distribution, abundance and population dynamics of the smooth hammerhead *Sphyrna zygaena* (Linnaeus, 1758) in the central-southeast Pacific Ocean. *Journal of Fish Biology* **2020**, *97*, 341-353.
98. Carrera-Fernández, M.; Martínez-Ortíz, J. Aspectos reproductivos de los tiburones martillo *Sphyrna lewini* (Grifftith & Smith, 1834) y S. zygaena (Linnaeus, 1758) en aguas del Ecuador. In *Tiburones en el Ecuador: Casos de estudio*, Martínez-Ortíz, J., Galván-Magaña, F., Eds.; EPESPO-PMRC: 2007; pp. 51-56.
99. Bolaño-Martínez, N. Ecología trófica de juveniles del tiburón martillo *Sphyrna zygaena* (Linnaeus, 1758) en aguas ecuatorianas. Instituto Politécnico Nacional. Centro Interdisciplinario de Ciencias Marinas, 2009.
100. Navia, A.F.; Giraldo, A.; Mejía-Falla, P.A. Notas sobre la biología y dieta del toyo vieja (*Mustelus lunulatus*) en la zona central de pesca del Pacífico colombiano. *Investigaciones marinas* **2006**, *34*, 217-222.
101. Briones-Mendoza, J.; Pincay-Espinoza, J.E.; Palma-Chávez, J.; Romero-Caicedo, A. Notas sobre la biología del tiburón mamona *Mustelus lunulatus* (Carcharhiniformes: Triakidae) en el Pacífico Central ecuatoriano. *Revista de biología marina y oceanografía* **2018**, *53*, 279-284.
102. Pérez-Jiménez, J.C.; Sosa-Nishizaki, O. Determining reproductive parameters for population assessments of two smoothhounds (*Mustelus californicus* and *Mustelus lunulatus*) from the northern Gulf of California, Mexico. *Bulletin of Marine Science* **2010**, *86*, 3-13.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 June 2022 doi:10.20944/preprints202206.0268.v1

Table 2. Sharks registered monthly in number during the year 2019 in Manta.

Species	Month												Total
	January	February	March	April	May	June	July	August	September	October	November	December	
Alopiidae													
Alopias pelagicus	190	213	622	522	354	456	124	209	160	102	70	109	3 131
Alopias superciliosus	31	33	71	30	65	41	31	13	29	35	27	24	430
Carcharhinidae													
Carcharhinus falciformis	45	70	428	215	222	213	95	118	36	98	57	59	1 656
Carcharhinus galapagensis	0	0	0	0	0	11	0	0	0	0	0	0	11
Carcharhinus leucas	0	6	5	0	0	1	0	0	0	0	1	0	13
Carcharhinus limbatus	0	1	8	2	2	1	0	0	0	0	0	0	14
Carcharhinus longimanus	1	1	9	9	14	7	1	3	7	7	6	2	67
Carcharhinus obscurus	0	0	0	1	0	0	0	0	0	0	0	0	1
Prionace glauca	1 464	295	817	651	381	211	98	595	982	886	1 355	1 221	8 956
Triaenodon obesus	0	0	1	0	0	0	0	0	0	0	0	0	1
Galeocerdidae													
Galeocerdo cuvier	0	0	1	9	1	1	2	1	2	0	1	2	20
Ginglymostomatidae													
Ginglymostoma unami	0	0	1	0	0	0	0	0	0	0	0	0	1
Lamnidae													
Isurus oxyrinchus	29	11	13	18	23	13	24	14	12	20	12	14	203
Isurus paucus	0	0	3	0	3	3	1	0	0	0	0	0	10
Pseudocarchariidae													
Pseudocarcharias kamoharai	0	0	0	40	0	0	0	0	0	0	0	0	40
Sphyrnidae													
Sphyrna lewini	20	24	19	23	27	9	9	8	8	9	6	12	174
Sphyrna zygaena	24	9	68	115	146	63	32	37	13	31	24	15	577
Squatinidae													
Squatina californica	0	0	4	1	3	0	2	0	0	0	0	0	10
Triakidae													
Mustelus lunulatus	14	4	33	15	16	2	15	12	12	3	6	8	140
Total	1 818	667	2 103	1 651	1 257	1 032	434	1 010	1 261	1 191	1 565	1 466	15 455

 doi:10.20944/preprints202206.0268.v1

Table 3. Descriptive statistics of shark species measured during the year 2019 in Manta. Meaning of the abbreviations of the categories of the Red List of Threatened Species of the International Union for the Conservation of Nature (IUCN): Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN) and Critically Endangered (CR).

Species	IUCN	n	Biomass (ton)	Interval TL (cm)	Mean TL ± S.E.	Interval Weight (kg)	Mean weight ± S.E.
Alopiidae							
Alopias pelagicus	VU	1 236	70.7	132-357	273 ± 1.19	9-108	57.2 ± 0.52
Alopias superciliosus	VU	354	28.9	153-381	300 ± 2.03	12-153	81.6 ± 1.40
Carcharhinidae							
Carcharhinus falciformis	VU	779	32.0	61-272	178 ± 1.35	1-136	41.1 ± 0.74
Carcharhinus galapagensis	LC	11	0.5	155-220	182 ± 5.81	24-71	41.3 ± 4.15
Carcharhinus leuca	VU	7	1.3	252-301	282 ± 5.95	131-232	189.7 ± 12.20
Carcharhinus limbatus	VU	10	0.5	177-210	197 ± 3.25	35-61	50.2 ± 2.55
Carcharhinus longimanus	CR	40	1.5	112-215	156 ± 3.35	14-92	38.8 ± 2.40
Carcharhinus obscurus	IN	1	0.0	223-223	-	63-63	-
Prionace glauca	NT	764	49.0	94-314	211 ± 1.11	5-208	64.1 ± 1.07
Triaenodon obesus	VU	1	0.0	138-138	-	26-26	-
Galeocerdidae							
Galeocerdo cuvier	NT	10	1.0	119-398	248 ± 23.03	7-373	104.4 ± 31.94
Ginglymostomatidae							
Ginglymostoma unami	IN	1	0.1	212-212	-	53-53	-
Lamnidae							
Isurus oxyrinchus	IN	129	7.5	83-341	183 ± 3.20	5-327	58.1 ± 3.47
Isurus paucus	IN	8	0.4	157-221	181 ± 8.19	33-91	52.2 ± 7.34
Pseudocarchariidae							
Pseudocarcharias kamoharai	LC	40	0.2	69-114	94 ± 1.89	3-5	4.1 ± 0.11
Sphyrnidae							
Sphyrna lewini	CR	20	0.4	92-276	147 ± 8.23	4-99	17.8 ± 4.46
Sphyrna zygaena	VU	193	3.1	82-287	134 ± 3.45	2-117	15.8 ± 1.66
Squatinidae							
Squatina californica	NT	7	0.5	79-106	89 ± 3.71	4-11	6.5 ± 0.89

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 June 2022 doi:10.20944/preprints202206.0268.v1

Triakidae							
Mustelus lunulatus	LC	79	0.3	49-123	85 ± 1.82	0.4-8	2.7 ± 2.70
Total		3 690	197.92				

Table 2. Monthly sexual proportions of the main species landed in the Ecuadorian Pacific.

(a) *C. falciformis*

Month	Female	Male	Sex ratio	χ^2	p-value
January	32	12	2.7F:1M	9.1	0.003
February	33	36	0.9F:1M	0.13	0.72
March	227	182	1.2F:1M	4.9	0.03
April	120	79	1.5F:1M	8.4	0.004
May	99	116	0.9F:1M	1.34	0.24
June	117	90	1.3F:1M	3.5	0.06
July	48	47	1.0F:1M	0.01	0.91
August	76	34	2.2F:1M	16.03	$<6.214x^{-5}$
September	21	12	1.8F:1M	2.5	0.11
October	56	36	1.6F:1M	4.34	0.03
November	26	28	0.9F:1M	0.07	0.78
December	32	21	1.5F:1M	2.28	0.13
Total	887	693	1.3F:1M	23.82	$<1.058x^{-6}$

(b) *C. longimanus*

Month	Female	Male	Sex ratio	χ^2	p-value
January	0	1	-	-	-
February	1	0	-	-	-
March	4	5	0.8F:1M	0.11	0.73
April	4	5	0.8F:1M	0.11	0.73
May	7	6	1.2F:1M	0.07	0.78
June	4	3	1.3F:1M	0.14	0.7
July	0	1	-	-	-
August	2	1	2F:1M	0.3	0.56
September	6	1	6F:1M	3.57	0.06
October	5	2	2.5F:1M	1.28	0.25
November	3	3	1F:1M	0	1
December	1	1	1F:1M	0	1
Total	37	29	1.3F:1M	0.96	0.32

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 June 2022 doi:10.20944/preprints202206.0268.v1

(c) *P. glauca*

Month	Female	Male	Sex ratio	χ^2	p-value
January	992	366	2.7F:1M	288.57	$<2.2x^{-16}$
February	171	119	1.4F:1M	0.01	0.89
March	420	230	1.8F:1M	55.53	$9.165x^{-14}$
April	341	193	1.8F:1M	41.01	$1.508x^{-10}$
May	159	155	1F:1M	0.05	0.82
June	87	95	0.9F:1M	0.35	0.55
July	58	39	1.5F:1M	3.72	0.053
August	267	227	1.2F:1M	3.23	0.071
September	478	301	1.6F:1M	40.21	$2.273x^{-10}$
October	411	297	1.4F:1M	18.35	$1.832x^{-5}$
November	701	467	1.5F:1M	46.88	$7.546x^{-12}$
December	701	309	2.3F:1M	152.14	$<2.2x^{-16}$
Total	4786	2798	1.7F:1M	521.71	$<2.2x^{-16}$

(d) *I. oxyrinchus*

Month	Female	Male	Sex ratio	χ^2	p-value
January	14	15	0.9F:1M	0.03	0.85
February	6	5	1.2F:1M	0.09	0.76
March	5	6	0.8F:1M	0.09	0.76
April	10	8	1.3F:1M	0.22	0.63
May	8	14	0.6F:1M	1.63	0.2
June	8	5	1.6F:1M	0.69	0.4
July	9	15	0.6F:1M	1.5	0.2
August	7	5	1.4F:1M	0.33	0.56
September	6	2	3F:1M	2	0.15
October	7	8	0.9F:1M	0.06	0.79
November	6	5	1.2F:1M	0.09	0.76
December	8	5	1.6F:1M	0.69	0.4
Total	94	93	1F:1M	0.005	0.94

(e) *S. lewini*

Month	Female	Male	Sex ratio	χ^2	p-value
January	6	2	3F:1M	2	0.15
February	2	1	2F:1M	0.33	0.56
March	7	1	7F:1M	4.5	0.03
April	5	2	2.5F:1M	1.28	0.25
May	9	6	1.5F:1M	0.6	0.43
June	3	4	0.8F:1M	0.14	0.70
July	4	2	2F:1M	0.6	0.41
August	3	1	3F:1M	1	0.31
September	3	2	1.5F:1M	0.2	0.65
October	1	2	0.5F:1M	0.33	0.56
November	1	2	0.5F:1M	0.33	0.56
December	1	2	0.5F:1M	0.33	0.56
Total	45	27	1.7F:1M	4.5	0.033

(f) *S. zygaena*

Month	Female	Male	Sex ratio	χ^2	p-value
January	12	1	12F:1M	9.3	0.002
February	4	4	1F:1M	0	1
March	45	19	2.4F:1M	10.56	0.001
April	42	55	0.8F:1M	1.74	0.18
May	30	50	0.6F:1M	5	0.025
June	24	34	0.7F:1M	1.72	0.18
July	12	10	1.2F:1M	0.18	0.66
August	2	3	0.7F:1M	0.2	0.65
September	1	1	11F:1M	0	1
October	3	1	3F:1M	1	0.31
November	2	1	2F:1M	0.33	0.56
December	2	2	1F:1M	0	1
Total	179	181	1F:1M	0.011	0.91

 doi:10.20944/preprints202206.0268.v1

(g) *M. lunulatus*

Month	**Female**	**Male**	**Sex ratio**	χ^2	**p-value**
January	12	2	6F:1M	7.14	0.007
February	3	1	3F:1M	1	0.31
March	17	16	1.1F:1M	0.03	0.86
April	10	5	2F:1M	1.6	0.19
May	9	7	13F:1M	0.25	0.61
June	2	0	-	-	-
July	12	3	4F:1M	5.4	0.02
August	7	5	1.4F:1M	0.33	0.56
September	6	6	1F:1M	0	1
October	1	2	0.5F:1M	0.33	0.56
November	2	4	0.5F:1M	0.66	0.41
December	7	1	7F:1M	4.5	0.033
Total	88	52	1.7F:1M	9.25	0.0021