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# Assessment of the artisanal shark fishery in the Pacific coast of Panama highlights a high proportion of immature and threatened species

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**Abstract.** A total of 5,034 sharks of 19 species from the Pacific coast of Panama were examined between 2009 and 2014. The most abundant species were *Sphyrna lewini* (74.8%) and *Rhizoprionodon longurio* (15.4%). Captures of these two species consisted of high proportions (> 90%) of immature individuals. According to the IUCN conservation status, 63.2% of the species recorded are threatened.

**Key words:** nursery area, conservation, elasmobranches, *Sphyrna lewini*.

**Resumen**. **Evaluación de la pesca artesanal de tiburones en la costa Pacífica de Panamá resalta proporciones elevadas de inmaduros y especies amenazadas.** Un total de 5,034 tiburones de 19 especies se examinaron en la costa Pacífica de Panamá entre 2009 y 2014. Las especies más comunes fueron *Sphyrna lewini* (74,8%) y *Rhizoprionodon longurio* (15,4%). Las capturas de estas especies estuvieron conformadas por proporciones elevadas (> 90%) de individuos inmaduros. De acuerdo al estatus de conservación UICN, 63,2% de las especies registradas se encuentran amenazadas.

**Palabras clave**: áreas de cría, conservación, elasmobranquios, *Sphyrna lewini*

Currently, 25% of global shark and ray species are considered threatened and at high risk of extinction, as a consequence of overfishing and habitat degradation (Ferretti *et al*. 2008, Dulvy *et al*. 2017). Artisanal fisheries can have a negative impact on ecosystems and marine resources, but particularly on species vulnerable to overfishing such as sharks (Knip *et al*. 2010). In addition, the capture of a high proportion of juvenile sharks (*i.e.*, sexually immature) has contributed to a decrease in the abundance of this group of fishes (Camhi *et al*. 1998). From the point of view of species conservation, the protection of areas inhabited by juvenile sharks (*i.e*. nursery areas) is of great value, since these areas are directly related to recruitment. Despite the ecological and commercial importance of sharks, in Panama there is a significant lack of knowledge regarding the basic fishing data and life history of sharks. Although the National Plan of Action (NPA) for the conservation of sharks in Panama (Gaceta Oficial 2009) urges the institutions in charge of the administration of fishery resources to make an effort to generate strategic information, there continues to be little interest in initiating a conservation program that leads to the long-term sustainable use. The objective of this work was to

characterize artisanal shark fishing and the catch composition by species on the Pacific coast of Panama.

The Pacific coast of Panama, with an extension of 1,700 km, is characterized by a great diversity of fishing resources. The coastal region is subject to oceanographic phenomena, such as El Niño Current and periods of coastal upwelling, which produce seasonal fluctuations in marine productivity and fishing resources (Kwiecinski & Chial 1983, D'Croz *et al*. 2003). During the months of January to April the surface water temperature registers the lowest average values (15-25 °C), while during the rest of the year the temperature (27-29 °C) remains relatively stable (D'Croz *et al*. 2003, González & D´Croz 2007). The information was generated from seven fishing ports located on the Pacific coast: (1) Punta Chame (2) Boca Parita (3) El Agallito (4) Mensabé (5) Búcaro (6) Mutis and (7) Remedios (Fig. 1).

During the period 2009-2014, a total of 32 research trips were carried out, usually lasting 5-20 days each. Research trips were scheduled based on the presence of fishing activity in the different locations sampled through direct and previous communication with fishermen. The distribution of the sampling effort (numbers of fishing trips and sampling days) by fishing locality is shown in Table I. The fishery and biological information was collected through forms following the protocol developed by the Organización del Sector Pesquero y Acuícola del Istmo Centroamericano (OSPESCA 2003). Sharks were identified to the taxonomic level of species, and the date of capture, size and sex were recorded. In the landing ports of Panama, most sharks are landed without their guts, heads, and fins (called as trunks), and therefore these specimens were measured in terms of inter-dorsal length (IDL in cm), while the animals that were landed intact were measured for total length (TL in cm) and also IDL (Fig. 2). This allowed inferring TLs by applying linear regression analysis. Additionally, the identification of the species from the trunks was validated through genetic analysis (using the mitochondrial gene Cytochrome b) at the beginning of the study with the support of the Smithsonian Tropical Research Institute from Panama. With these analyses, it was possible to verify the accuracy of the species identification done by the field staff.

In order to determine the importance of the species in the fishery, the catch composition by species was expressed in numerical percentages. The length structure by sex was described for the most frequently captured species and the expected sex ratio (1:1) was statistically evaluated using the chi-square test. The proportion of sexually immature individuals in the catches was estimated based on the lengths of sexual maturity reported in the scientific literature (Bejarano-Álvarez *et al*. 2011, Corro-Espinosa *et al*. 2011). Because gillnets can have a negative impact on juvenile shark populations, catches were examined according to the length of the sharks and the mesh size of the nets used by fishermen. To this end, length data were grouped according to mesh sizes in the following categories: G1 (10.6-14.2 cm), G2 (17.7-32.5 cm) and G3 (46.0-49.6 cm). The length data was then normalized by log-transforming in order to compare the mean TL between groups of mesh sizes with an analysis of variance (ANOVA). All statistical analyses were performed using the R program (R Development Core Team 2018).

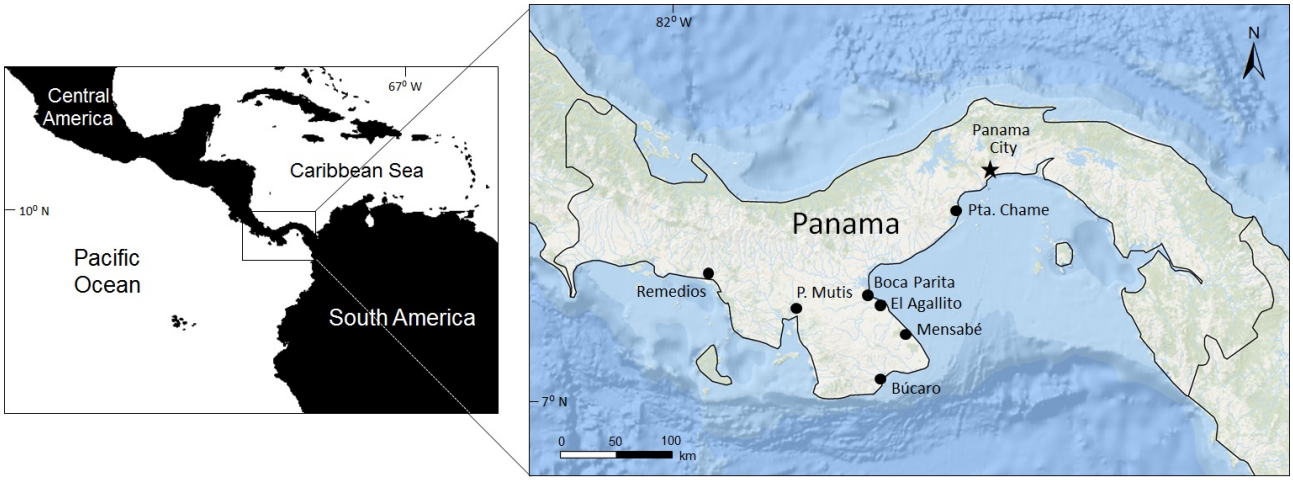


**Figure 1**. Map of the study area showing the fishing ports in the Pacific coast of Panama. (Map source: ESRI 2017).

**Table I**. Distribution of the sampling effort by fishing locality from the Pacific coast of Panama, between 2009 and 2014.

| Fishing ports | Number of fishing trips | Number of sampling days |
|---|---|---|
| Punta Chame | 4 | 28 |
| Boca Parita | 3 | 13 |
| El Agallito | 2 | 6 |
| Mensabé | 6 | 30 |
| Búcaro | 8 | 35 |
| Puerto Mutis | 8 | 27 |
| Remedios | 1 | 8 |

The artisanal fishing fleet is mainly composed of fiberglass boats (89.2%), and a minority of wooden boats (10.8%); with lengths that varied between 5.1 and 12.0 m, and propelled by outboard motors between 10 and 75 Hp. The fishing gears used to catch sharks were: gillnets (72.3%; length 90-1,250 m, mesh size 10.4-49.6 cm), bottom longline (16.6%; number of hooks 200-1,300), and handline (10.1%). Fishing operations are conducted relatively close to shore, from distances of 2 to 30 km from the shoreline, and at depths that varied between 1 and 90 m. The artisanal fishing fleets operating along Pacific coast of Panama are very similar in characteristics. Fishing occurs year-round, but catch depends on the seasonality and abundance of fish. These fishing activities, despite their scarce technical capacity, contribute significantly to the fish production and seafood consumed in Panama (Batista & Bernal 2008). Regarding to landings, during the study period a total of 5,034 sharks were recorded, distributed among 19 species (Table II). The most frequent species caught were *Sphyrna lewini* (74.8%) and *Rhizoprionodon longurio* (15.4%). Other relatively important species in the fishery were *Sphyrna corona* (2.5%), *Carcharhinus cerdale* (2.0%), *Mustelus henlei* (1.6%) and *C. limbatus* (1.3%). Seventy-six percent (n = 3,864) of the sharks were caught with gillnets, while 14.3% (n = 721) and 9.1% (n = 459) of the individuals were captured with longlines and handlines, respectively.

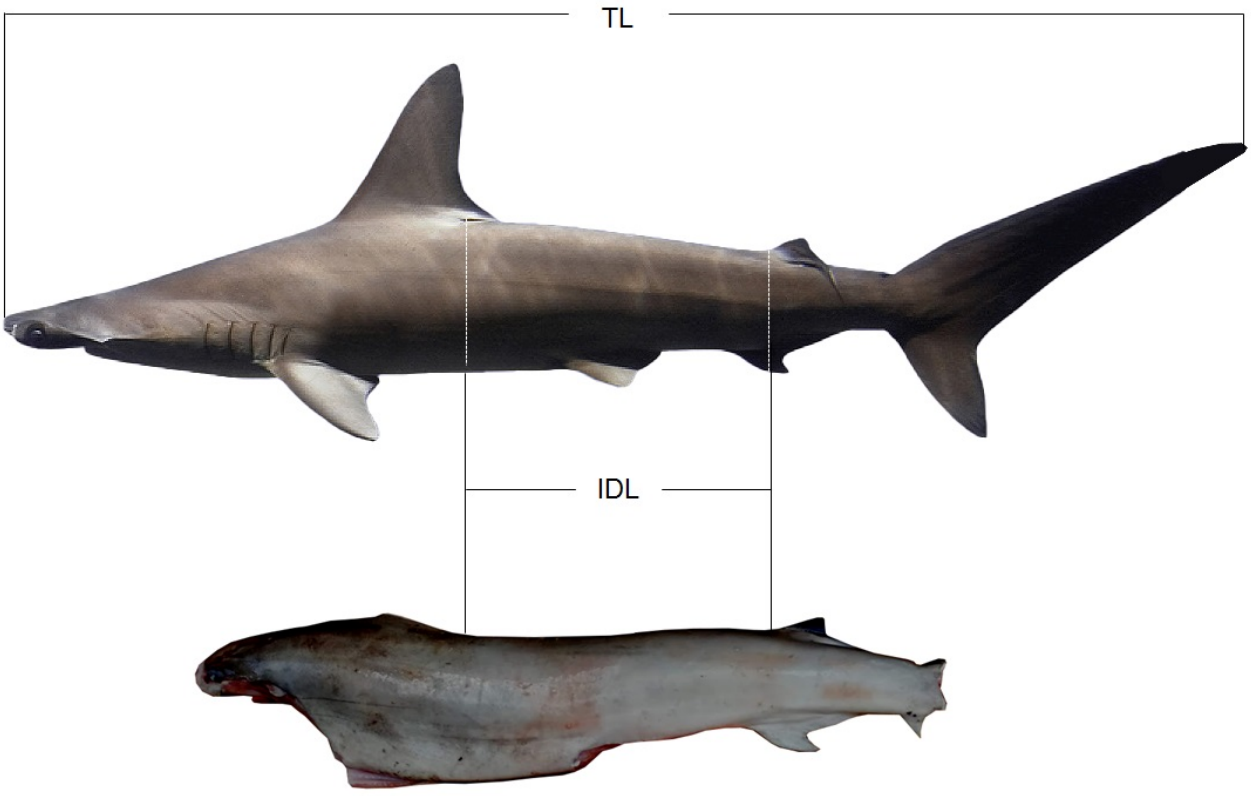


**Figure 2.** Size measures (total length, TL and inter-dorsal length, IDL) registered for sharks captured in the artisanal fishery from the Pacific coast of Panama, between 2009 and 2014.

**Table II.** Species catch distribution according to the fishing gears employed by the artisanal shark fishery from the Pacific coast of Panama, between 2009 and 2014. IUCN conservation status: Critical Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC) and Data Deficient (DD). *Group of threatened species (CR+EN+VU).

| Species | Gillnet | Longline | Handline | Total | | IUCN |
|---|---|---|---|---|---|---|
| | n (%) | n (%) | n (%) | n | % | status |
| *Sphyrna lewini* | 3145 (84.6) | 281 (7.5) | 338 (9.0) | 3764 | 74.77 | *CR |
| *Rhizoprionodon longurio* | 415 (53.5) | 299 (38.5) | 62 (8.0) | 776 | 15.42 | *VU |
| *Sphyrna corona* | 122 (98.4) | 1 (0.8) | 1 (0.8) | 124 | 2.46 | *CR |
| *Carcharhinus cerdale* | 88 (86.3) | 13 (12.7) | 1 (1.0) | 102 | 2.03 | CR |
| *Mustelus henlei* | 3 (3.7) | 42 (51.2) | 37 (45.1) | 82 | 1.63 | LC |
| *Carcharhinus limbatus* | 48 (75.0) | 9 (14.1) | 7 (10.9) | 64 | 1.27 | NT |
| *Nasolamia velox* | 1 (3.7) | 16 (59.3) | 10 (37.0) | 27 | 0.54 | *EN |
| *Carcharhinus leucas* | 8 (44.4) | 10 (55.6) | | 18 | 0.36 | NT |
| *Sphyrna tiburo* | 11 (84.6) | | 2 (15.4) | 13 | 0.26 | *EN |
| *Ginglymostoma cirratum* | 3 (23.1) | 10 (76.9) | | 13 | 0.26 | DD |
| *Carcharhinus obscurus* | 7 (70.0) | 3 (30.0) | | 10 | 0.2 | *EN |
| *Carcharhinus falciformis* | 1 (11.1) | 8 (88.9) | | 9 | 0.18 | *VU |
| *Prionace glauca* | | 9 (100.0) | | 9 | 0.18 | NT |
| *Carcharhinus galapagensis* | | 7 (87.5) | 1 (12.5) | 8 | 0.16 | LC |
| *Alopias pelagicus* | | 6 (100.0) | | 6 | 0.12 | *EN |
| *Galeocerdo cuvier* | 1 (20.0) | 4 (80.0) | | 5 | 0.10 | NT |
| *Sphyrna zygaena* | | 2 (100.0) | | 2 | 0.04 | *VU |
| *Sphyrna media* | 1 (100.0) | | | 1 | 0.02 | *CR |
| *Alopias superciliosus* | | 1 (100.0) | | 1 | 0.02 | *VU |
| Total | 3854 (76.6) | 721 (14.3) | 459 (9.1) | 5034 | 100 | --- |

For the Pacific coast of Panama, Guzman *et al*. (2019) recently reported that the most abundant species (industrial and artisanal fisheries combined) were *S. lewini* (30.7%), *C. falciformis* (27.0%) and *C. porosus* (9.4%); however, the species *C. porosus* that these authors mistakenly report is not distributed in the eastern Pacific and most likely is *C. cerdale*. Although catch composition can vary according to fishing grounds and types, target species, and geographic zones, the species *S. lewini* and *R. longurio* appear to be common in other regions from the Pacific Coast of Central America such as Mexico and Costa Rica (Zanella *et al*. 2009, Furlong-Estrada *et al*. 2015).

For *S. lewini*, linear regression analysis between IDL and TL resulted in the following conversion equation: TL = 4.65 + 3.82*IDL ($r^2$ = 0.963; TL interval: 32-271 cm). The individuals of this species were represented by 1,899 males (50.5%) with 39 to 280 cm TL, and 1,865 females (49.5%) with 39 to 330 cm TL (Fig. 3). No significant difference in the sex ratio was observed (chi-square test, $\chi^2$ = 0.01, $P$ = 0.929). Taking into account the sexual maturity sizes of *S. lewini* (Fig. 3), it was determined that 96.8% of the males and 98.6% of the females corresponded to sexually immature specimens. The mean lengths according to the mesh size of the gillnets were 61.6 (± 19.2 cm TL) and 62.5 (± 25.8 cm TL) for groups G1 and G2, respectively; while for group G3 the mean value was 148.0 (± 67.7 cm TL) (Fig. 4). The analysis of variance for comparison of mean lengths was highly significant (ANOVA; $F$ = 446.78, $P$ < 0.0001). Although the mean length was significantly higher in the G3 gillnets, the catches also covered a large range of lengths (46-329 cm TL) and a high percentage of sexually immature individuals (76.6%) of both sexes.

The biometric relationship (IDL vs TL) for the species *R. longurio* resulted in the following

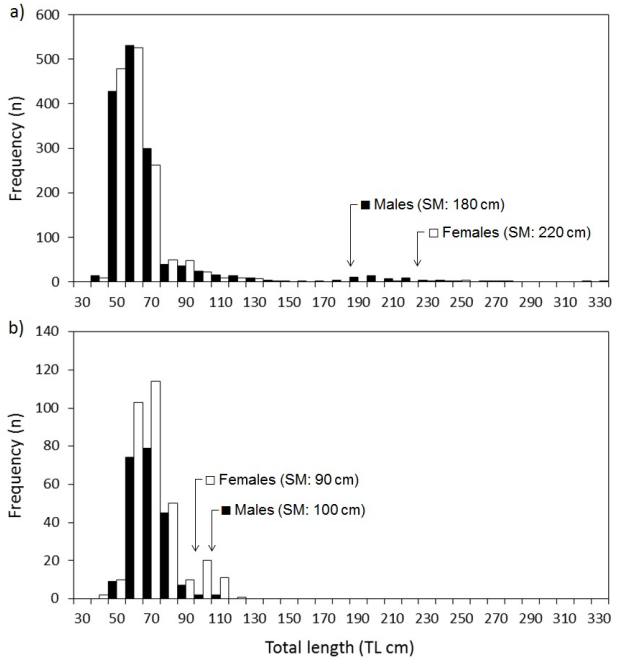


**Figure 3.** Size composition by sex of the species a) *Sphyrna lewini* and b) *Rhizoprionodon longurio* captured in the artisanal shark fishery from the Pacific coast of Panama, between 2009 and 2014. Also shown are the sizes of sexual maturity (SM) reported for *Sphyrna lewini* (Bejarano-Álvarez *et al*. 2011) and *Rhizoprionodon longurio* (Corro-Espinosa *et al*. 2011) from the Pacific coast of Central America.

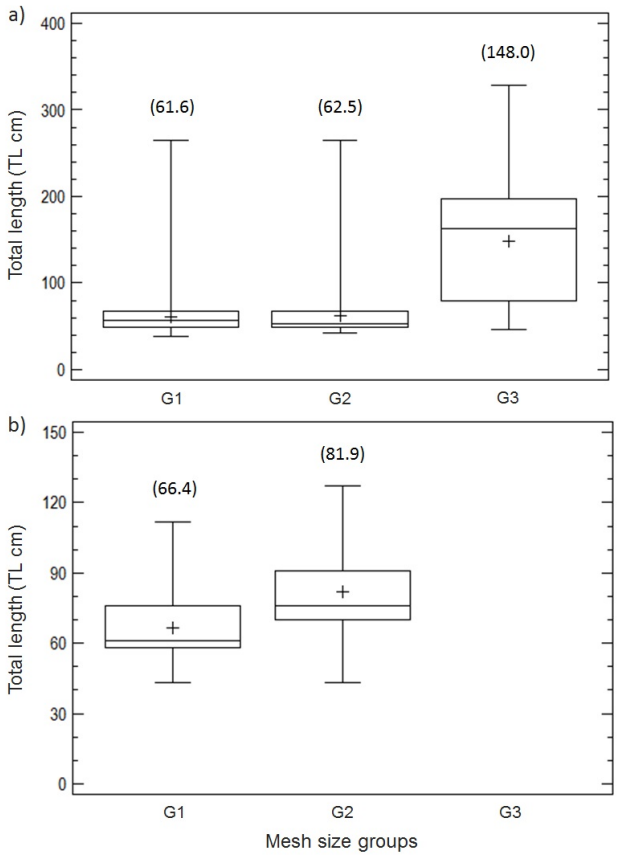


**Figure 4.** Mean sizes (TL) of sharks captured according to mesh stretch (G1, G2 y G3) of gillnets and corresponding to the species a) *Sphyrna lewini* and b) *Rhizoprionodon longurio* captured in the artisanal shark fishery from the Pacific coast of Panama, between 2009 and 2014. The mean values of total length (TL) are indicated in parenthesis for each group of mesh size

conversion equation: TL = 21.63 + 2.43*IDL ($r^2$ = 0.837; length interval: 35-95 cm TL). Catches of this species included 316 males (40.7%) with sizes between 43 and 107 cm TL, and 460 females (59.3%) with sizes between 31 and 114 cm TL (Fig. 3). The observed sex ratio did not differ significantly from expected ($\chi^2$ = 3.45, $P$ = 0.063).

According to the sizes at maturity (Fig. 3), the catches of this species were composed by 99.1% and 90.0% of immature males and females, respectively. The mean length values of *R. longurio* according to the mesh size groups (G1 and G2) of the gillnets were 66.4 (± 12.21 cm TL) and 81.5 (± 18.5 cm TL) (Fig. 4). There was a highly significant difference between the G1 and G2 groups (ANOVA; $F$ = 78.68, $P$ < 0.0001). The present work showed that artisanal shark fishery selects a high proportion of juvenile individuals, which seems to be a common characteristic in this type of fishing activities carried out near the Pacific coast (Castillo-Géniz *et al*. 1998, Tavares & Sánchez 2012). Excessive harvesting of individuals that have not reached sexual maturity can have a dramatic negative effect on shark populations by interfering with recruitment process.

In addition, the abundance and frequent occurrence of juvenile sharks (mainly *S. lewini* and *R. longurio*) along the Pacific coast of Panama indicates that this coastal area constitutes an important nursery area for these species. Nursery areas for *S. lewini* and *R. longurio* have been previously identified for the Pacific coast of Central America, in the Gulf of California and Oaxaca (Mexico), and Costa Rica (Corro-Espinosa *et al*. 2011, Alejo-Plata *et al*. 2018, Zanella *et al*. 2019). The importance and ecological benefits of the shark nurseries has been widely discussed in literature (Heithaus 2007, Heupel *et al*. 2007, Heupel *et al*. 2018). Basically, these essential areas characterized by their high productivity and resources abundance provide to juvenile sharks protection against predators and availability of food. As a consequence, the use of nurseries improves the survival of individuals, and thus supports greater contribution to the adult population (Branstetter

1990). On the other hand, according to evaluations of the global conservation status by the International Union for Conservation of Nature (IUCN 2020), 63.2% (n = 12) of the species recorded in this study are within one of the categories of threatened species (Table II). In the future, it is essential to continue generating scientific data necessary for the design of management plans for this group of species. A priority for the Pacific coast of Panama should be the identification and delineation of shark nursery areas with the purpose of protecting these vital habitats, in the medium, term through the creation of marine protected areas or wildlife refuges.

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**References**

Alejo-Plata, M. D. C., Ahumada-Sempoal, M. A., Guevara, G. C. L. & Gómez-Márquez, J. L. 2018. Estructura poblacional y biología reproductiva del tiburón martillo *Sphyrna lewini* (Carcharhiniformes: Sphyrnidae) capturado en la pesca artesanal de Oaxaca, México. **Hidrobiológica**, 28: 265-275.

Batista, M. & Bernal, L. 2008. Evaluación de la pesquería artesanal de tiburones en la costa suroeste del Golfo de Montijo, Puerto El Nance, Provincia de Veraguas. **Tesis de Licenciatura**. Universidad de Panamá, Ciudad de Panamá, 64 p.

Bejarano-Álvarez, M., Galván-Magaña, F. & Ochoa-Báez, R. I. 2011. Reproductive biology of the scalloped hammerhead shark *Sphyrna lewini* (Chondrichthyes: Sphyrnidae) off south-west Mexico. **Aqua International Journal of Ichthyology**, 17: 11-22.

Branstetter, S. 1990. Early life-history implications of selected carcharhinoid and lamnoid sharks of the northwest Atlantic. Pp 17-28. *In*: Pratt, H. L. Jr., Gruber, S. H. & Taniuchi, T. (Eds.). **Elasmobranchs as living resources: Advances in biology, ecology, systematics and the status of the fisheries**. NOAA, Technical Report NMFS 90, USA.

Camhi, M., Fowler, S., Musick, J. Bräutigam, A. & Fordham, S. 1998. **Sharks and their Relatives: Ecology and Conservation**. The IUCN Species Survival Commission, Cambridge, 39 p.

Castillo-Géniz, J. L., Márquez-Farias, J. F., Cruz, M. C. R., Cortés, E. & Prado, A. C. 1998. The Mexican artisanal shark fishery in the Gulf of Mexico: Towards a regulated fishery. **Marine and Freshwater Research**, 49: 611-620.

Corro-Espinosa, D., Márquez-Farías, J. F. & Muhlia-Melo, A. 2011. Size at maturity of the Pacific sharpnose shark *Rhizoprionodon longurio* in the Gulf of California, Mexico. **Ciencias Marinas**, 37: 201-214.

D'Croz, L., Kwiecinski, B., Maté, J. L. Gómez, J.A.H. & Del Rosario, J. B. 2003. El afloramiento costero y el fenómeno del Niño: implicaciones sobre los recursos biológicos del Pacífico de Panamá. **Tecnociencia**, 5(2): 35-49.

Dulvy, N. K., Simpfendorfer, C. A., Davidson, L.N., Fordham, S.V., Bräutigam, A., Sant, G. & Welch, D. J. 2017. Challenges and priorities in shark and ray conservation. **Current Biology**, 27: R565-R572.

ESRI. 2017. **Environmental System Research Institute**. ArcGIS Online10.3.1. Redlands CA, USA.

Ferretti, F., Myers, R. A., Serena, F. & Lotze, H. K. 2008. Loss of large predatory sharks from the Mediterranean Sea**. Conservation Biology**, 22: 952-964.

Furlong-Estrada, E., Tovar-Ávila, J., Pérez-Jiménez, J.C. & Ríos-Jara, E.. 2015. Resilience of *Sphyrna lewini*, *Rhizoprionodon longurio*, and *Carcharhinus falciformis* at the entrance to the Gulf of California after three decades of exploitation. **Ciencias Marinas**, 41(1): 49-63

Gaceta Oficial. 2009. Resolución ADM/ARAP No. 013 de 9 de febrero de 2009, por medio de la cual se adopta el Plan de Acción Nacional para la conservación y ordenación en las pesquerías de tiburones. Autoridad de los Recursos Acuáticos de Panamá (ARAP), República de Panamá.

González, L. M. & D´Croz, L. 2007. Variabilidad espacial del afloramiento en el Golfo de Panamá. **Tecnociencia**, 9(2): 107-119.

Guzman, H. M., Cipriani, R., Vega, A. J. & Morales-Saldaña, J. M. 2019. Fisheries and conservation assessment of sharks in Pacific Panama. **Aquatic Conservation: Marine and Freshwater Ecosystems**, 30: 315-330.

Heithaus, M. R. 2007. Nursery areas as essential shark habitats: a theoretical perspective. **American Fisheries Society Symposium**, 50(3): 3-13.

Heupel, M. R., Carlson, J. K. & Simpfendorfer, C. A. 2007. Shark nursery areas: concepts, definition, characterization and assumptions. **Marine Ecology Progress Series**, 337: 287-297.

Heupel, M. R., Kanno, S., Martins, A. P. & Simpfendorfer ,C. A. 2018. Advances in understanding the roles and benefits of nursery areas for elasmobranch populations. **Marine and Freshwater Research**, 70(7): 897-907.

Knip, D. M., Heupel, M. R. & Simpfendorfer, C. A. 2010. Sharks in nearshore environments: models, importance and consequences. **Marine Ecology Progress Series**, 402: 1-11.

Kwiecinski, B. & Chial, B. 1983. Algunos aspectos de la oceanografía del Golfo de Chiriquí, su comparación con el Golfo de Panamá. **Revista de Biología Tropical**, 31: 323-325.

OSPESCA. 2008. Protocolo de colecta de datos de los desembarques y muestreo biológico en la pesca artesanal e industrial de tiburones y rayas en América Central. **OSPESCA**, El Salvador. 31 p.

R Core Team. 2018. **R: A language and environment for statistical computing**. R Foundation for Statistical Computing. Vienna, Austria.

Tavares, R. & Sánchez, L. 2012. Áreas de cría de tiburones en el Golfo de Venezuela. **Ciencia**, 20: 112-119.

IUCN. 2020. **International Unión for Conservation of Nature**. Accessible at https://www.iucnredlist.org (Accessed 10/05/2020).

Zanella, I., Garro, A. L. & Rándall, A.V. 2009. Caracterización de la pesca del tiburón martillo *Sphyrna lewini*, en la parte externa del Golfo de Nicoya, Costa Rica. **Revista Ciencias Marinas y Costeras**, 1(1): 175-195.

Zanella, I., López-Garro, A. & Cure, K. 2019. Golfo Dulce: critical habitat and nursery area for juvenile scalloped hammerhead sharks *Sphyrna lewini* in the Eastern Tropical Pacific Seascape. **Environmental Biology of Fishes**, 102: 1291-1300.

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