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Biology and fishery of silky shark (*Carcharhinus falciformis*) of Negombo, Sri Lanka

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Original Article

Abstract

A total of 208 silky sharks, which were collected by single-day and multi-day boats using gillnets and longlines, were gathered from the Negombo fishing harbour, Sri Lanka, from August to December 2020 to study their biological parameters. The total length range of the silky sharks was 39.0-285.0 cm, while their weight range was 3.5-75.0 kg. The length-weight relationship was obtained for males and 55 females, and the pooled samples were $W = 0.0957\ TL^{1.0644}$, $W = 0.0346\ TL^{1.2769,}$ and $W = 0.0557\ TL^{1.,1781}$ and the 'b' values were 1.0651, 1.2776 and 1.1788 respectively. All the 'b' values were significantly different from 3 ($P < 0.05$) and showed negative allometric growth. One hundred fifty-three 153 males were examined as immature, maturing and mature. Of that, the highest percentage of male silky sharks were immature (39%) than the maturing (27%) and mature stages (33%). Stomach contents were fish remains (84.21%), arthropod remains (15.79%) and molluscan remains (5.26%). Among the 48 fishing vessels observed, there were single-day boats (27.1%) and multi-day boats (72.9%). Of 98 silky sharks, 77.6% were caught by multi-day boats while 22.4% were by single-day boats. And longlines accounted for capturing a higher percentage of silky sharks (61.2%) than gillnets (38.8%). The identified other by-catch species caught by the boats during the study were sharks, billfishes and rays. The silky shark is considered the dominant shark species in the total shark landing in Sri Lanka. Due to the K-selected life histories of sharks, silky shark populations are also vulnerable to overexploitation. Therefore, having sound knowledge of the biology of silky sharks is helpful for the conservation and management of them.

Keywords: *Negative allometric growth, Negombo, silky shark, stomach content*

Introduction

Sharks are caught as targeted fishery or as by-catch, but mainly, the shark products come from the by-catch of incidental catches that target more valuable fish species (Dent and Clarke, 2015). Mostly, they come as a by-catch from the longline fisheries which target tuna and billfishes on high seas (Stevens *et al*., 2000). Recent global assessments show that every year about 8,30,000 t of sharks and rays are reportedly landed and the landing rates increase by around 2% annually (Camhi *et al*., 2009). Usually, sharks are caught targeting the worldwide shark fin trade or for consumption. Shark meat is consumed as fresh, dried or salted and also used as a fish meal, while shark fins are used in preparing expensive soup in Asia (Dulvy *et al*., 2017). Their skin and liver oil are also popular to some extent (Clarke *et al*., 2007). Silky shark (*Carcharhinus falciformis*), Blue shark (*Prionace glauca*) and Oceanic whitetip shark (*Carcharhinus longimanus*) are considered the most common three pelagic sharks and are caught by longlines and tuna purse seines as by-catch species in Pacific, Atlantic, and Indian oceans (Hazin *et al*., 2007). The silky shark and the blue shark are extremely exploited (Stevens, 2010). Silky sharks are most commonly caught in the eastern tropical Pacific, Gulf of Mexico, Atlantic Oceans, Indian Oceans and tropical Australian waters as a by-catch of tuna fisheries (Bonfil, 2008). The silky sharks are being highly threatened due to unsustainable fisheries (Bonfil, 1999). The International Union for Conservation of Nature (IUCN) states that the conservation status of silky sharks is Near Threatened. But it says it can be either near threatened or vulnerable according to the ocean they live. Therefore, the Indian, Western and Central Pacific Ocean appear to be near threatened, while in the Eastern Pacific and Atlantic Ocean, it is vulnerable (Lopez *et al*., 2017).

The silky shark (*Carcharhinus falciformis*) is a dark grey shark with a long, rounded snout (Molony, 2008) that belongs to the family Carcharhinidae (Bonfil, 2008). And they can grow up to 330 cm in total length (Compagno, 1984). Silky sharks are mostly distributed in tropical and subtropical waters (Strasburg, 1958). The main food items of silky sharks consist of pelagic fishes, cephalopods and crabs (Randall *et al*., 1998). Tuna is an integral part of the diet of silky sharks, as they are commonly found near surface tuna schools (Molony, 2008). Also, they are considered non-selective feeders, where the availability of the prey affects their feeding more than their selectivity (Perera *et al*., 2016).

The marine fishery industry of Sri Lanka consists of two subsectors: coastal and offshore and high sea (Hasarangi *et al*., 2012; Herath and Maldeniya, 2013). The coastal fishery is a traditional, small-scale fishery carried out in the continental shelf, while the offshore fishery is done in the EEZ and on high seas (Jayathilaka *et al*., 2016). Offshore fisheries mainly contribute to shark production in the country (Herath and Maldeniya, 2013). The highest shark production achieved in Sri Lanka was 34,842 Mt, which was reported in 1999, and after that, it showed a gradual decline (Hasarangi *et al*., 2012). Silky sharks are considered the dominant shark species in the offshore fishery of Sri Lanka (Herath and Maldeniya, 2013). The records of 2011 showed that about 66% of the total shark landings by weight were dominated by silky sharks (Hasarangi *et al*., 2012). In 2014 also, the highest percentage of the total shark landings belonged to silky sharks, and it was 70% by weight (Herath *et al*., 2019).

As fishery plays a significant contribution to global food production, it is necessary to know about the biology and the health status of the fish. Information on fish biology helps to know about the ecological relationships and general condition of the water (Ridanovic *et al*., 2015). Length-weight relationship on fish is essential in stock assessments (Filmalter *et al*., 2012; Herath *et al*., 2019) as well as obtaining information on their growth patterns, general health, habitat condition, life history, fish fatness, condition and also morphological characteristics (Schneider *et al*., 2000). Also, this relationship is helpful in the estimation of biomass for given lengths and in comparing the condition of fish among different regions (Herath *et al*., 2019). There is a direct proportional relationship between the habitat condition and the length-weight relationship of fish (Kachari *et al*., 2017).

Knowing the food and feeding habits of fish is important to figure out the biology, abundance, distribution and efficient management ways of that fish stock (Kohler, 1988). Data on feeding ecology are useful in creating food webs and predicting the potential variations in food chains and materials and energy transfer between and within ecosystems (Nakano and Murakami, 2001). Stomach content analysis is a standard practice used for studying the diets and food habits of fish as well as other marine vertebrates (Hyslop, 1980). This method is also useful in assigning trophic levels to aquatic food webs (Domi *et al*., 2005). Stomach content analyses usually focus on feeding habits within a short temporal scale, such as hours to days (Plumlee and Wells, 2016). Analysis of stomach contents is done for different shark species in the world (Ellis *et al*., 1996). Sharks, which are positioned at the apex of the food chain (Wetherbee *et al*., 1990; Oshitani *et al*., 2003), are one of the largest predators in the ocean that play a crucial ecological role in structuring the oceanic community through predatory behaviour (Estrada *et al*., 2003). Preference for various food items of predatory fish, including sharks, depends on factors such as prey mobility and availability, prey abundance, size, seasonal changes, and environmental factors (Cabrera-Chavez-Costa *et al*., 2010). However, there is a restriction on the knowledge of the trophic ecology of sharks in many places of the world due to a lack of data (Matich *et al*., 2011). As there is a lack of biological information on silky sharks in the Indian Ocean, this study aimed to provide biological information on silky sharks, which is helpful in strengthening their conservation and management of them. Hence, this study is focused on the length-weight relationship, maturity analysis of male silky sharks, and feeding habits of silky sharks landed in Negombo fishery harbour.

Material and methods

Biological data of 208 silky sharks (*C. falciformis*) captured by single-day and multi-day boats from high seas as well as from coastal waters were collected from the Negombo fishery harbour from August to December 2020. Biological data such as total length (TL), weight, and clasper length were measured, and the sex was recorded. The total length of each silky shark was measured from the tip of the snout to the end of the caudal fin using a measuring tape to the nearest 0.1 cm. Body weight

Fig. 1. a) Ventral side of male silky shark (with claspers), b) Ventral side of female silky shark (no claspers)

was measured using an electronic balance to the nearest 0.1 kg. The sex of the silky sharks was determined visually by the presence or absence of the clasper (Fig. 1). Clasper length of each male silky shark was measured to the nearest 0.1 cm.

The maturity status of the males was recorded according to the nature of their clasper; Immature, juvenile:–Undeveloped, not calcified, small and very soft claspers; maturing, adolescent:–Not fully calcified, moderate and still soft claspers; Mature, adult:–Fully calcified, very large and hard claspers (Stehmann, 2002). Only male silky sharks' maturity status was recorded here due to the difficulties of obtaining the female gonads while waiting until the end for fishermen to cut and remove them from sharks' bodies, as it is time-consuming. Thirty-two (32) gut samples of silky sharks were collected from the Negombo fishery harbour, and they were placed in ice boxes and transported to the laboratory of the Department of Zoology and Environmental Management at the University of Kelaniya where they were kept at -20 °C until further analysis. Collected gut samples were thawed before the analysis. The fullness of each cut-opened stomach was evaluated as empty (0%), one-fourth filled (25%), half filled (50%), three-fourths filled (75%) or full (100%) by visual examination. Each prey species (food items) in the stomach content was categorized under three categories: fish remains, molluscan remains, and arthropod remains. Cephalopod parts were included in molluscan remains, and crab parts were included in arthropod remains. And recognizable prey species were identified to the lowest possible taxon. The dominance of each food category was evaluated by the percentage frequency of occurrence (Hynes, 1950). Length-weight relationships of the male, female and pooled sample were determined by the $W= aL^b$ equation (Ricker, 1973). Data were transformed to log values, and $\log W= \log a + b \log L$ equation was used for determining the 'a' and 'b' values (W = Weight in kilogram (kg), L=Total Length in centimetre (cm), a= constant (intercept of the graph), b = slope of the graph). One sample t-test was carried out to determine whether 'b' values were significantly different from 3, using Minitab (Version 19). Fisheries aspects data such as the size of the vessel, depth, gear type, bait, number of days boat in the sea and the crew were recorded by interviewing the multi-day and single-day boat skippers in Negombo fishery harbour.

Results

Two hundred and eight (208) silky sharks were recorded during the study. Out of that, 153 were male and 55 were female. The total length (TL) of the silky sharks ranged between 39.0 – 285.0 cm, and their weight ranged from 3.5 to 75.0 kg. They were grouped into total length (TL) classes, and the number of silky sharks in each length class was analysed (Fig. 2). According to that, the highest number of male silky sharks were in the TL class 150.0 – 170.0 cm while the highest number of female silky sharks were in the TL class 130.0 – 150.0 cm.

Length-weight relationship

The length-weight relationship of male silky sharks (n = 43), female silky sharks (n = 55) and pooled data was analyzed separately. The TL range of males was between 52.0 cm – 225.0 cm, while the TL range of females was between 39.0 cm – 285.0 cm. The weight ranges of males and females were 3.8 – 70.0 kg and 3.5 – 75.0 kg, respectively. Length-weight relationship (LWR) parameters obtained for silky sharks during the study are given in Table 1. The graphical representation of the logarithmic transformation of the length-weight relationship

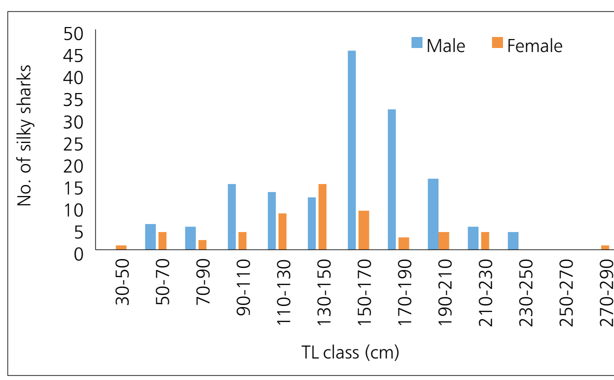

Fig. 2. Number of silky sharks according to total length (TL) classes

Table 1. Length-weight relationship parameters of silky shark (*C. falciformis*)

	Male	Female	Overall
No.of samples	43	55	98
(LWR)	$W= 0.0957\ TL^{1.0644}$	$W = 0.0346\ TL^{1.276}9$	$W = 0.0557\ TL^{1.1781}$
Logarithmic-transfor-mation	logW=1.0644 logTL-1.0192	logW=1.2769 logTL -1.4612	logW = 1.1781 logTL-1.2538
b value	1.0651	1.2776	1.1788
a value	0.0957	0.0346	0.0557
Length range (cm)	52.0 - 225.0	39.0 - 285.0	39.0 - 285.0
Weight range (kg)	3.8 - 70.0	3.5 - 75.0	3.5 - 75.0

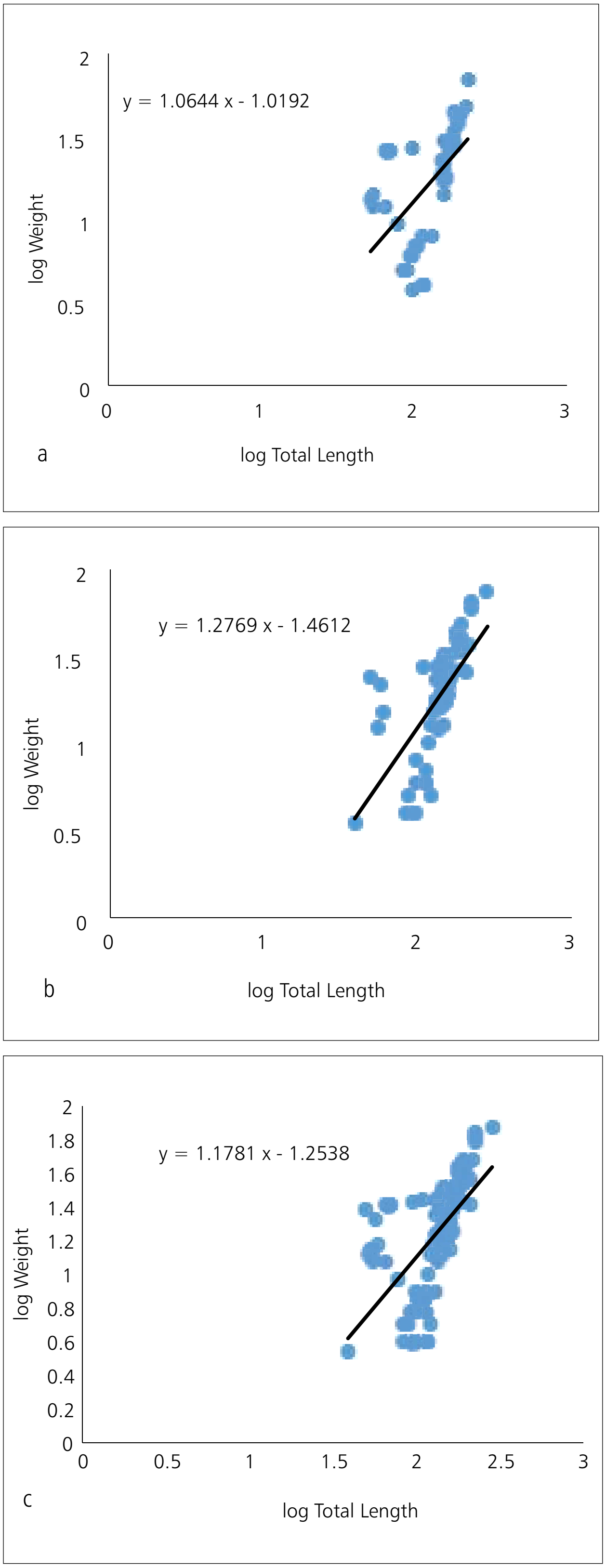

Fig. 3. log Weight vs. log total length relationship for a) male b) female c) total silky sharks

for male, female and pooled data is shown in Fig. 3. The 'b' values for males, females and pooled sample were tested with one sample t-test, and they were significantly different from 3 (the isometric value) respectively (P = 0.000). All the 'b' values of the present study were less than 3, showing negative allometric growth. This shows that the rate of length increment is faster than their weight increment.

Maturity status

The male silky sharks (n = 153) were identified in three maturity stages: immature, maturing and mature. The study showed that the percentage of the immature male silky sharks captured is higher (40%) than the male silky sharks at maturing (27%) and mature stages (33%) (Fig. 4). Concerning the data obtained by male silky sharks, catching more immature silky sharks may negatively affect the population of silky sharks to decline as they do not get chance to grow and reproduce. TL range of immature male silky sharks was 52.0 – 157.0 cm, and in maturing and mature male silky sharks, it ranged between 150.0 – 193.0 cm and 170.0 – 245.0 cm, respectively. The relationship between the clasper length and the total length (TL) of male silky sharks was also analysed (Fig. 5). According

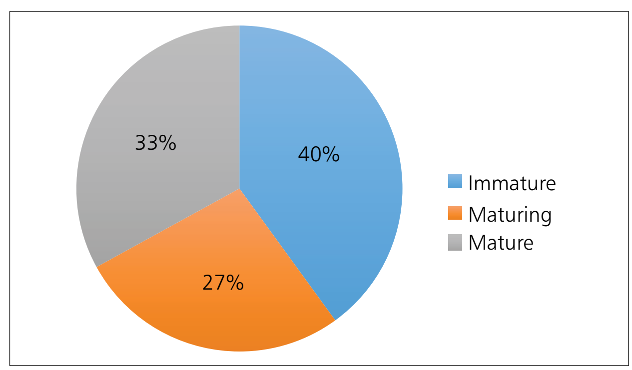

Fig. 4. Percentage of male silky sharks in different maturity stages observed during the study

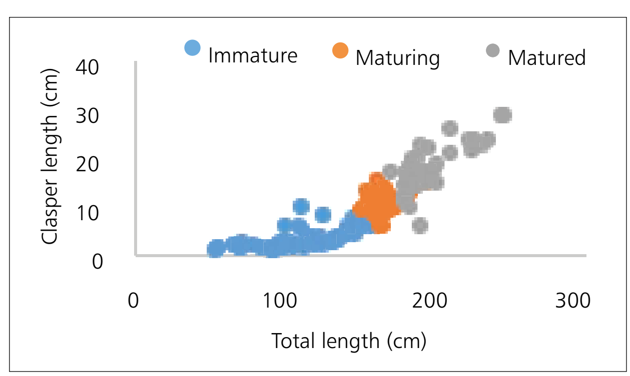

Fig. 5. Relationship between the clasper length and the total length (TL) of male silky sharks

to that, the immature male silky sharks who have small total lengths (TL) have clasper lengths between 1.0 – 10.0 cm while maturing and mature male silky sharks with medium and large total lengths (TL) have clasper lengths ranged between 6.0 – 15.4 cm and 10.0 – 29.0 cm, respectively.

Feeding habits

Out of the 32 stomach samples, 59.4% were contained with food items, while 40.6% were empty. The overall percentage of the fullness of the stomachs was obtained as 40.6% was empty (0%), 40.6% was one-fourth filled (25%), 3.1% was half filled (50%), 6.3% was three fourth filled (75%) and 9.4% was full (100%). The percentage frequency of occurrence of the food categories of the stomach contents of the silky sharks was evaluated as fish remains (84.21%), arthropod remains (15.79%) and molluscan remains (5.26%) (Fig. 6). The inspected stomach contents were contained with fish bones, fish vertebrae, milkfish (*Chanos chanos*), *Amblygaster* sp., *Sepia* sp., *Decapterus* sp., *Auxis* sp. and tissues of crabs.

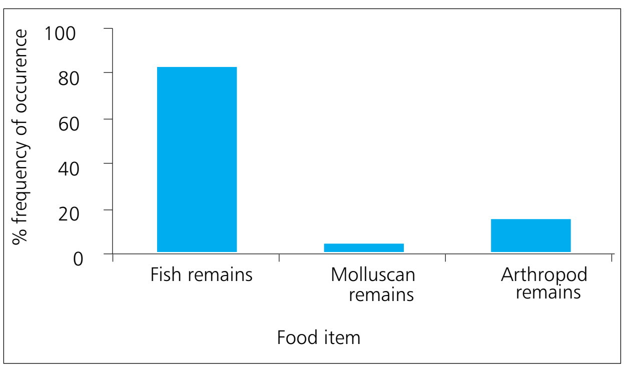

Fig. 6. Percentage frequency of occurrence of each food category found in the silky shark stomachs

Fisheries aspect information

Among the observed 48 fishing vessels, 27.1% were single-day boats, and 72.9% were multi-day boats. Based on the length of the vessel, these fishing vessels were further classified under UN1 (25%), UN2A (2.1%), UN3A (60.4%) and UN4 (12.5%) categories (BOBLME (2013). Multi-day boats were operated within a 5.5–182 m depth range, and single-day boats were operated within a 5.4–80 m depth range. The major gear types used by the boats were gillnet and longline. The percentage of the boats that used gillnets was 45.8%, while the percentage of the boats that used longlines was 54.2%. Of the 98 silky sharks, the highest percentage of silky sharks (77.6%) was caught by multi-day boats than single-day boats (22.4%). A higher percentage of silky sharks were caught by longlines, and it was 61.2%, while 38.8% were by gillnets. There were gill nets with different mesh sizes, and the mesh size ranged from 6 to 18 cm. The number of hooks used in the longlines varied, and the number ranged between 500-1500. The baits used in the longline include 'Hurulla' (*Amblygaster* spp.), Milkfish (*Chanos chanos*), Squid, 'Salaya' (*Sardinella* spp.) and 'Piyamessa' (*Cheilopogon* spp.). The other by-catch species which were caught by fishing vessels were identified as Swordfish (*Xiphias gladius*), Black marlin (*Istiompax indica*), Blue marlin (*Makaira mazara*), Scalloped hammerhead shark (*Sphyrna lewini*) and Smooth hammerhead shark (*Sphyrna zygaena*), Shortfin mako shark (*Isurus oxyrinchus*), Blue shark (*Prionace glauca*), Tiger shark (*Galeocerdo cuvier*), Chilean devil ray (*Mobula tarapacana*) and Manta ray (*Manta birostris*). The total length (TL) ranges of the sharks and billfishes, disc width (DW) of rays and their weight ranges were also analyzed (Table 2).

Table 2. Total length (TL) range and the weight range of shark by-catch

Shark species	TL range (cm)	DW range (cm)	Weight range (kg)
Blue shark	78.0 – 265.0	-	14.0 – 89.0
Scalloped hammerhead shark	100.0–225.0	-	28.0 – 78.0
Tiger shark	110.0 – 220.0	-	33.0 – 110.0
Shortfin mako shark	89.0 – 112.0	-	33.0 – 60.0
Smooth hammerhead shark	140.0 – 180.0	-	35.0 – 52.0
Swordfish	90.0 – 150.0	-	18.0 – 47.0
Black marlin	110.0 – 190.0	-	12.0 – 63.0
Blue marlin	119.0 – 175.0	-	12.0 – 56.0
Manta ray	-	110.0 –384.0	60.0 – 187.0
Chilean devil ray	-	87.0 – 121.0	24.0 – 56.0

Discussion

The range of total length (TL) of recorded silky sharks during the study was 39 -285 cm. In the study carried out by Hazin *et al.* (2007) in the equatorial Atlantic, the total length ranged between 83 -272 cm, where the minimum TL is higher than the minimum TL of the present study while the maximum TL is close to the value of the present study. The TL range of the silky sharks ranged from 67 -275 cm in the study done by Varghese *et al.* (2016) in the eastern Arabian Sea. These changes may be due to the environmental and resource variability seen in different regions of the world.

The length-weight relationship calculated for silky sharks in the southwest Atlantic Ocean in a study done by Domingues *et al.* (2016) revealed that the 'b' values for male, female and pooled data were less than three, which is similar to the present study results. The LWR studies carried out by Joung *et al.* (2008) in northeast Taiwan, and Wahyudin *et al.* (2019) in Tanjung Luar fish landing port in Indonesia showed that the 'b' values were greater than 3, indicating positive allometric growth in silky sharks. Similar studies carried out by Oshitani *et al.* (2003) for silky sharks in the Pacific Ocean and Filmalter *et al.* (2012) for silky sharks in the western Indian Ocean have obtained 'b' values that are less than three and greater than three, respectively. The difference in 'b' values might be due to the environmental effects on the growth patterns of fishes. Therefore, some other factors may also affect it, such as physiology, sex, gonadal development, behaviours, nutritional condition and water flow. How much strength in specimen number and a good representation of all size classes in the whole estimation is also important.

The study carried out by Hazin *et al.* (2007) near the archipelago of Saint Peter and Saint Paul, in the Equatorial Atlantic Ocean also had similar results as the present study, that the percentage of captured immature juvenile silky sharks (54%) was higher than the Maturing (27%); and Adult (19%). However, the results obtained by Oktaviyani *et al.* (2020) for silky sharks landed at Tanjung Luar Fish Landing Port in Indonesia were different from the present study results. It showed 51% of males were mature, while 11% and 38% were in maturing and immature stages, respectively. Concerning the present study results obtained from male silky sharks, catching more immature silky sharks may negatively affect the population of silky sharks to decline as they do not get a chance to grow and reproduce.

The total length ranges of each maturity stage of male silky sharks in the study are somewhat different from the study carried out by Oktaviyani *et al.* (2020) in Tanjung Luar Fish Landing Port of Indonesia, where their total length (TL) ranges were 65–170 cm, 140–207 cm and 180–283 cm for immature, maturing and mature male silky sharks respectively. The study carried out by Hazin *et al.* (2007) in Saint Peter, and Saint Paul showed that the total length ranges of immature (juvenile), maturing and mature (adult) stages ranged from 83 to 186 cm, 185 to 210 cm and 234 to 272 cm, respectively, where these results also varied from the present study results. The relationship between the clasper length and the total length of male silky sharks was analysed during the study. It showed the variation of the clasper length with the TL of the body. With increasing total lengths (TL), clasper length also increases. Therefore, small male silky sharks have small clasper lengths, while large male silky sharks have large clasper lengths

A similar pattern was observed, as in our study, by the study carried out by Filmalter *et al.* (2017) in the western Indian Ocean for feeding habits of silky sharks. The study carried out by Perera *et al.* (2016) also showed that the main food group in the silky shark diet was fish, while there the next major food group was cephalopods, followed by crustaceans. However, the study done by Varghese *et al.* (2016) mentioned that silky sharks in the eastern Arabian Sea majorly consume crabs. As silky sharks are non-selective predators, these variations may be due to the abundance of prey species in the areas where silky sharks inhabit.

Silky sharks in the Indian Ocean are mainly captured as a by-catch of tuna purse seines and tuna longlines (Anderson and Jauharee, 2009). In the present study, the major gear types used by the boats were gillnet and longlines. The percentage of longlines was higher than the percentage of the boats that used gillnets. When considering the vessels that carry out fishing activities to catch large pelagic fish, they are categorized as UN1, UN2A, UN3A, UN3B and UN4. The UN1 and UN2A type boats are single-day boats, and the others are multi-day boats (BOBLME, 2013). The observed single-day boats were under UN1 and UN2A categories, while the observed multi-day boats were under UN3A and UN4 categories. Of the single-day boats, the highest amount of boats were UN1-type vessels, and the highest amount of multi-day boats was under the UN3A category.

Conclusion

Most male silky sharks that landed in the Negombo fishery harbour were more immature than the maturing and mature ones. The length-weight relationship of *C. falciformis* landed in the Negombo fishery harbour indicated a negative allometric growth. The major food item found in the stomachs of silky sharks was fish, followed by arthropods and molluscs. The major gear types used by the boats were gillnet and longline. Among them, longline is the most used fishing gear, and it was the most susceptible fishing gear for capturing silky sharks.

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