

# SHARK LONGLINE FISHERY IN THE NORTHERN MALDIVES

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## SUMMARY

The island of Kulhudhuffushi in the north of Maldives was until recently the most important shark fishing island in the country. Shark longlining was carried out by up to 80 boats at the height of the fishery in about 1998-2000. Subsequently the fishery declined, due to poor catches and low economic returns. The fishery closed in 2010 with the national ban on shark fishing, which was reinforced with a ban on trade in shark products in 2011.

This report summarizes the findings of four missions to Kulhudhuffushi in Haa Dhaalu (H.Dh.) Atoll between October 2000 to March 2004, during which the local shark fishery was investigated. Sampling was carried out on 180 landings from shark fishing boats (dhonis). Silky sharks (*Carcharhinus falciformis*) made up 84% of the catch. A considerable body of biological and socio-economic data on these sharks and the fishery was collected.

The various shark stocks that supported the Kulhudhuffushi shark fishery were sequentially overfished. **Reef sharks** in the northern atolls had been grossly overfished by the 1980s. **Nearshore pelagic sharks** around the northern atolls had been overfished by the 1990s. **Offshore oceanic sharks** had been declining in abundance for some years before the fishery closed in 2010. Reef shark and nearshore pelagic sharks were overfished by local boats. But the decline in oceanic shark catches was the result of high (and probably unsustainable) levels of fishing by overseas fisheries.

## INTRODUCTION

Fisheries was traditionally the most important economic activity in the Maldives. It has been eclipsed in importance by the tourism industry in the last two decades, but fishing still remains a significant economic activity in many islands. Maldivian fisheries have traditionally concentrated on oceanic tunas, notably skipjack (*Katsuwonus pelamis*) and yellowfin (*Thunnus albacares*). These were, and still are, caught by livebait pole and line, although handlining for large yellowfin has become more important in recent years.

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Shark fishing has been carried out in the Maldives for centuries if not millennia, but it was of relatively minor importance (Anderson and Ahmed, 1993; Anderson and Waheed, 1999). Longlining was introduced to the Maldives in the 1960s when far eastern tuna longliners began operating in the central and western Indian Ocean. Maldivian fishermen soon adopted this technique for sharks, first within the atolls, and subsequently offshore.

In the 1970s and 1980s, shark fishing developed on some islands in the Maldives, but not others, which maintained their focus on tuna fishing. H.Dh. Kulhudhuffushi in the north of Maldives became one of the most, if not the most, important of these shark fishing centres. Up to 80 dhonis were involved in shark fishing from this one island during the peak of the fishery in about 1998-2000, but participation in the fishery subsequently declined. The main fishing method used was pelagic longline.

This report presents information (including both biological and socio-economic information) from the Kulhudhuffushi shark longline fishery, mostly collected during 2000-04.

## METHODS

Shark landings were sampled during four visits to Kulhudhuffushi in 2000-04 (Table 1). One shark fishing trip was accompanied in November 2000. Fishermen and fin buyers were interviewed informally whenever the opportunity arose. However, during a period of bad weather in May-June 2002, when most fishermen were on the island, a more formal socio-economic survey was conducted. 106 households (9.5% of the island total) were visited at that time.

**Table 1.** Summary of sampling activities at Kulhudhuffushi (landings were made on 24 of the 33 days sampled, and not all sharks landed were measured)

Dates	No. days	No. landings	No. sharks landed	Sharks/landing (range)
29 Oct to 19 Nov 2000	15	104	493	4.7 (1-21)
26 May to 6 June 2002	10	17	104	6.1 (0-22)
13 to 20 Oct 2002	7	36	262	7.3 (1-24)
18 March 2004	1	16	44	2.8 (1-5)
	33	173	903	5.2 (0-24)

## DEVELOPMENT OF THE SHARK FISHERY

The Kulhudhuffushi shark longline fishery was reported to have started in the 1970s. In the early days only about six dhonis were involved in the fishery, with perhaps only 10 sharks being landed per day on average. The fishery concentrated on reef sharks initially, but good catch rates were sustained only until about 1981-82. Once the reef shark resources were overfished, attention turned to pelagic sharks. The fishery remained small throughout the 1980s, with the number of dhonis engaged in the shark fishery increasing slowly to about 10 in 1992.

1996 and 1997 were widely reported to have been years with very good shark catches. As a direct result, many new participants entered the fishery. Many returning seamen invested in secondhand dhonis. The Bank of Maldives branch in Kulhudhuffushi issued several loans for the purchase of shark fishing gear in 1996-97. The number of vessels engaged increased rapidly to a peak of about 80 vessels during the 1997-98 high season:

**Table 2.** Numbers of dhonis engaged in shark longlining at Kulhudhuffushi

Date	Full-time	Part-time	Total	Source
Pre-1990	0	6	6	Anderson (2000)
Aug 1992	0	10	10	Anderson & Ahmed (1993)
May 1996	...	...	30	Anon (1997)
Jan 1998	60	20	80	Anderson & Waheed (1999)
Nov 2000	20	55	75	MEP (2000)
June 2002	10	50	60	MEP (2002)
Mar 2004	...	...	45	MRC (2004)
2008	...	...	10	MRC (2009)
2011	0	0	0	This report

After 2000, the number of dhonis engaged in the shark fishery declined. The reason for this was declining catches and earnings. This is also reflected in a decline in the number of active shark fishermen which also declined after 2000, as many left in search of better incomes in other sectors. By 2002, no new bank loans had been issued in the previous two years for purchase of shark fishing gear, and no new boats were being built for shark fishing.

## DESCRIPTION OF THE SHARK FISHERY

Shark longlining was carried out from Kulhudhuffushi overnight. Shark fishing dhonis typically left Kulhudhuffushi in the morning, caught bait and travelled offshore, set the longline in the evening, hauled it in the morning, and returned to the island by late afternoon or early evening on the second day. One trip therefore usually lasted for about 30-36 hours. Each dhoni could thus make a maximum of 3 trips per week. The catch was

dominated by silky sharks, which made up some 84% of landings, although at least 12 other species were taken as well (Table 2).

The fishery was rather seasonal. The peak season was during the northeast monsoon season and subsequent intermonsoon (December to April) with the very best period often being reported to be during the *nakaiy* (local calendar periods) of *reyva* and *assidha* (March 26 to April 21). During the northeast monsoon season the best catches were made to the east of the atoll, when many sharks were reported to be associated with drifting objects coming with the current towards the west (*oiy kuri miyaru*). In addition, one particular area that was reported to provide good shark catches was a seamount 55 nautical miles (approx. 100 km) from Kulhudhufushi, due east of Sh. Feevah. Boats usually travelled 30-60 miles (50-110 km) offshore, but did go 100 miles (180 km) offshore on occasion.

The southwest monsoon season (May to October) was less productive, but this was in large part due to poor weather at that time of year. June and July were usually especially rough, and few boats went fishing then. Throughout the southwest monsoon season the best fishing was to the west, between the latitudes of H.A. Innafinolhu and R. Alifushi (approx. 7°N to 6°N). Boats travelled as far as 100 miles (180 km) west of the atolls to fish during this season. Few boats fished in the Eight Degree Channel (north of Haa Alifu) in either season because of the dangers of fishing at night in this international shipping lane.

**Table 3.** Species of shark landed at Kulhudhuffushi

English name	Maldivian name	Scientific name
Pelagic Thresher Shark	Kandi miyaru	<i>Alopias pelagicus</i>
Bigeye Thresher Shark	Kandi miyaru	<i>Alopias superciliosus</i>
Longfin Mako Shark	Woshimas miyaru	<i>Isurus paucus</i>
Silvertip Shark	Kattafulhi miyaru	<i>Carcharhinus albimarginatus</i>
Bignose Shark	Theyo miyaru	<i>Carcharhinus altimus</i>
Grey Reef Shark	Uradashu miyaru	<i>Carcharhinus amblyrhynchos</i>
Silky Shark	Mas miyaru	<i>Carcharhinus falciformis</i>
Oceanic Whitetip Shark	Feekanfaiy miyaru	<i>Carcharhinus longimanus</i>
Tiger Shark	Femunu	<i>Galeocerdo cuvier</i>
Lemon Shark	Olhufathi miyaru	<i>Negaprion acutidens</i>
Blue Shark	Andhun miyaru	<i>Prionace glauca</i>
Scalloped Hammerhead	Kaaligandu miyaru	<i>Sphyrna lewini</i>
Smooth Hammerhead	Kaaligandu miyaru	<i>Sphyrna zygaena</i>

Note: Dhivehi names are those used by Kulhudhuffushi fishermen. For a longer list of Maldivian shark names see Anderson and Ahmed (1993).

There was no fishing on Fridays before midday prayers. As a result there were no shark landings on Friday evenings. Few fishermen left for fishing on Friday afternoons, so landings on Saturday evenings were limited. Most landings occur on the other five evenings of each week. During four missions to Kulhudhuffushi, a total of 33 days'

sampling was carried out (Table 1), but due to rough weather on some occasions, landings were made on only 24 of these days. On fishing days, an average of 7.2 dhonis landed an average of 37.3 sharks, ie an average of 5.2 sharks each.

Numbers of dhonis fishing was strongly affected by the weather. During May-June and October 2002 strong westerly winds (force 4-7) restricted fishing operations. Paradoxically, numbers of sharks landed per dhoni were sometimes higher during periods of poor weather. This was because only the best dhonis went out in such conditions; they had the most capable skippers and tended to use longer longlines than other boats (150-160 hooks v 100-120 hooks). The number of hooks used on each longline averaged 141 (n=12). Most longlines had 100-175 hooks; the maximum used was 300 hooks, the minimum 80 hooks.

Shark fishing dhonis typically returned to Kulhudhuffushi in the late afternoon or early evening, and unloaded their sharks whole to the beach, where the catch was sold. During 2000-04 there were six shark buyers/processors on Kulhudhuffushi, who purchased sharks directly from returning fishermen at regular sites on the beach in the harbour. Prices paid were based on pectoral fin length (measured in inches). Buyers were responsible for all processing and for exporting the products (essentially dried fins and salt dried meat) to Malé.

## **SOCIO-ECONOMIC ISSUES**

The clear decline in participation in the Kulhudhuffushi shark fishery (Fig. 1, Table 2) is ultimately being caused by a decline in shark catches. This in turn is believed to be a result of high levels of fishing mortality on the oceanic shark stocks. That particular issue is discussed in Section 5. However, the decline in shark fishing activity is also affected by, and a reflection of, larger socio-economic forces affecting Kulhudhuffushi and the Maldives as a whole. These include the two related issues of fewer young men entering the fishery, and the consequent aging of the fishing population.

Maldives has traditionally been a fishing nation. Historically, ie pre-1960, fishing was the only major employer and perhaps 20% or more of the entire population were fishermen. Today less than 5% of the population are fishermen. This dramatic decline is caused in part by the spectacular growth of employment opportunities in other sectors, notably tourism. But it is also in part a reflection of the reluctance of young men to enter the fisheries sector. Young men do not want to become fishermen for a number of reasons including: increased expectations following (now universal) school education; low perceived social status of fishermen; and the hard physical work involved in fishing. Low income is not a major factor: many fishermen earn good incomes, but most young men would rather work in a relatively poorly paid office job. Although there are certainly some counter-examples, most young men have no intention of ever becoming fishermen.

Because so few young men are becoming fishermen, the average age of active fishermen is increasing. In the survey conducted on Kulhudhuffushi in June 2002, information was collected on the ages of fishermen. The average age of active shark fishermen was estimated to be 47. The youngest man in the sample was 32, the oldest 62. Even without

the recent ban on shark fishing, it was almost inevitable that the Kulhudhuffushi shark fishery would eventually close because of lack of fishermen.

## SHARK SAMPLING RESULTS

A total of 769 sharks were sampled on landing, from a total of 154 dhonis (out of an estimated total of 947 sharks from 173 dhoni landings). A summary of the species composition of shark landings during the four sampling periods is presented in Tables 4 and 5. The silky shark was by far the most important species, making up about 84% of the total catch by numbers. Four other species together made up 12% of the catch by numbers: oceanic whitetip, blue, longfin mako and silvertip sharks. The remaining 3% of the catch was made up of 8 different species (including some reef species, which were reported to have been caught inside or adjacent to the atolls by reef fishermen).

There were some important differences in fishing activity between the three sampling periods. During Oct-Nov 2000 and May-June 2002 fishing was mainly carried out to the west to the Maldives. In contrast, in Oct 2002 fishing was carried out to the east of the Maldives. In addition, there was more rough weather in May-June 2002 and October 2002 than in Oct-Nov 2000; this limited fishing activity to just the best boats on some days. These factors all had an impact on species and size composition, and catch rates (Table 6).

**Table 4.** Numbers of sharks landed at H.Dh. Kulhudhuffushi by species, during four sampling periods

<b>Species</b>	<b>Oct-Nov 2000</b>	<b>May- June 2002</b>	<b>Oct 2002</b>	<b>March 2004</b>	<b>Total</b>
Silky Shark	313	69	230	36	648
Oceanic Whitetip	23	1	3	0	27
Blue Shark	14	0	11	1	26
Longfin Mako	21	1	0	0	22
Silvertip Shark	5	1	9	4	19
Tiger Shark	1	0	5	2	8
Grey Reef Shark	4	2	0	0	6
Pelagic Thresher	1	1	2	0	4
Scalloped Hammerhead	2	0	1	0	3
Smooth Hammerhead	2	0	0	0	2
Bignose Shark	1	0	1	0	2
Bigeye Thresher	1	0	0	0	1
Lemon Shark	0	0	0	1	1
<b>Total</b>	<b>388</b>	<b>75</b>	<b>262</b>	<b>44</b>	<b>769</b>

Note: Not all sharks landed were sampled.

**Table 5.** Percentage of sharks landed at H.Dh. Kulhudhuffushi by species, during four sampling periods

<b>Species</b>	<b>Oct-Nov 2000</b>	<b>May- June 2002</b>	<b>Oct 2002</b>	<b>March 2004</b>	<b>Total</b>
Silky Shark	80.7	92.0	87.8	81.8	84.3
Oceanic Whitetip	5.9	1.3	1.1	0.0	3.5
Blue Shark	3.6	0.0	4.2	2.3	3.4
Longfin Mako	5.4	1.3	0.0	0.0	2.9
Silvertip Shark	1.3	1.3	3.4	9.1	2.5
Tiger Shark	0.3	0.0	1.9	4.5	1.0
Grey Reef Shark	1.0	2.7	0.0	0.0	0.8
Pelagic Thresher	0.3	1.3	0.8	0.0	0.5
Scalloped Hammerhead	0.5	0.0	0.4	0.0	0.4
Smooth Hammerhead	0.5	0.0	0.0	0.0	0.3
Bignose Shark	0.3	0.0	0.4	0.0	0.3
Bigeye Thresher	0.3	0.0	0.0	0.0	0.1
Lemon Shark	0.0	0.0	0.0	2.3	0.1
Total Numbers	388	75	262	44	769
Percentage of Total	50.5	9.8	34.1	5.7	100

Note: Not all sharks landed were sampled.

**Table 6.** Catch rates (sharks / dhoni) at H.Dh. Kulhudhuffushi by species, during four sampling periods.

<b>Species</b>	<b>Oct-Nov 2000</b>	<b>May-June 2002</b>	<b>Oct 2002</b>	<b>March 2004</b>	<b>Total</b>
Silky Shark	3.40	6.90	6.39		4.43
Oceanic Whitetip	0.25	0.10	0.08		0.20
Blue Shark	0.15	0.00	0.31		0.18
Longfin Mako	0.23	0.10	0.00		0.16
Silvertip Shark	0.05	0.10	0.25		0.11
Tiger Shark	0.01	0.00	0.14		0.04
Grey Reef Shark	0.04	0.20	0.00		0.04
Pelagic Thresher	0.01	0.10	0.06		0.03
Scalloped Hammerhead	0.02	0.00	0.03		0.02
Smooth Hammerhead	0.02	0.00	0.00		0.01
Bignose Shark	0.01	0.00	0.03		0.01
Bigeye Thresher	0.01	0.00	0.00		0.01
Lemon Shark	0.00	0.00	0.00		
Total	4.22	7.50	7.28		5.25
No. dhonis sampled	92	10	36	44	136

## Species Accounts

### Silky Shark, *Carcharhinus falciformis*

Silky sharks were by far the most important component of the catch, accounting for about 84% of all shark landings by number. Length frequency distributions for the different sampling periods, separately and combined, are presented in Fig. 2. A number of features are apparent:

1. Most silky sharks taken were within the length range 140-250 cm TL. The largest individual landed was a 263 cm TL female, the smallest a 77 cm female.
2. In Oct-Nov 2000, when fishing was mainly to the west of the atolls, a distinct cohort of mainly female large sharks, 220-250 cm TL was present. This was much reduced in 2002 samples. The change may reflect regional or seasonal variation, or it might be taken to suggest high fishing mortality impacting the largest size classes.
3. Medium sized sharks (about 180-210 cm TL) appear to be underrepresented. These sharks may be absent from the fishing areas as a result of differential migration (Anderson and Ahmed, 1993).
4. Sharks less than about 150 cm TL are also underrepresented in the catch. These small sharks do appear to be present (since they are taken by Maldivian pole and line vessels), but they may not be vulnerable to longline.

Catch rates (Table 6) were highest in May-June 2002 (6.9 silky sharks / dhoni landing); the prevailing rough weather at the time appeared to deter all but the most competent fishermen from venturing out. In Oct-Nov 2000 when fishing was mainly to the west of the atolls catch rates were roughly half those in October 2002 when fishing was mainly to the east (3.40 v 6.39 silky sharks / dhoni).

Sex ratio was fairly even overall. However, there were profound changes in sex ratio with size, with males predominating at intermediate lengths but being almost absent from the largest size classes:

77-263 cm TL	(n = 595)	0.48 ± 0.04 males: 0.52 ± 0.04 females
77-189 cm TL	(n = 285)	0.46 ± 0.06 males: 0.54 ± 0.06 females
190-229 cm TL	(n = 196)	0.66 ± 0.07 males: 0.34 ± 0.07 females
230-263 cm TL	(n = 114)	0.22 ± 0.08 males: 0.78 ± 0.08 females

A similar pattern was observed in catches of silky sharks during the Exploratory Offshore Fishing Survey in 1987-88, (Anderson and Waheed, 1990; Anderson and Ahmed, 1993). The simplest explanation for this pattern is differential growth of the two sexes after about 180 cm TL (ie the length at which males start maturing, see below). After this length, growth of males presumably slows down relative to that of females, the latter continuing to grow and reaching a larger maximum size than males. The largest female measured was 263 cm TL, compared with 242 cm TL for the largest male. Several shark species are known to show such differential growth, large size being advantageous for breeding females (Klimley, 1987).

Clasper growth is illustrated in Fig. 3. Males of less than about 180 cm TL were clearly immature, with claspers only 4-6% of TL. Between about 185-190 and 200-205 cm TL most males were maturing with uncalcified claspers of intermediate length (Table 7). By about 205 cm TL most males were mature, with calcified claspers about 12-13% of TL. The smallest mature male recorded was an individual of 196 cm TL, with calcified claspers 13% of TL. The largest immature male recorded was an individual of 210 cm TL, with uncalcified claspers 11% of TL. Taking 205 cm TL as the average length at maturity for males, and 242 cm TL as the maximum male length observed in this study, then maturity is attained at 85% of maximum length. This is a relatively high figure, compared for example with 72% for Silky Sharks from the Gulf of Mexico (Bonfil et al., 1993). Such a figure is caused by an absence of very large males (this species can grow to over 3 m TL), which in turn might suggest high levels of fishing mortality.

**Table 7.** Silky shark – Relative size of male claspers

Length class (cm TL)	Average clasper size (% of TL)	Range of clasper size (% of TL)	Number
180-184	6.3 %	5.0 – 7.0 %	7
185-189	7.1 %	5.0 – 11.5 %	13
190-194	8.5 %	5.7 – 12.1 %	11
195-199	10.1%	7.4 – 13.5 %	13
200-204	10.9 %	7.0 – 12.8 %	11
205-209	12.8 %	11.8 – 13.3 %	6
210-214	13.0 %	10.7 – 14.2 %	14
215-219	12.9 %	11.6 – 13.9 %	23

Several females were clearly pregnant, although it was not possible to sample most animals because of the requirements of the shark buyers and processors. A few litters were sampled (Table 8) but several of these were aborted on the beach; as a result it is unlikely that all foetuses were measured, and likely that the sample was biased towards near-term litters.

The largest foetus measured was 72 cm TL. The smallest free-swimming silky shark measured at Kulhudhuffushi was 77 cm TL, but the smallest recorded in the Maldives is 56 cm TL (Anderson and Waheed, 1990). It seems likely that most silky sharks in Maldivian waters are born within the range 56-72 cm TL. This is smaller than the size at birth quoted by most other workers, ie 70-87 cm (Compagno, 1984; Branstetter, 1987; Bonfil et al, 1993). The presence of several litters with large foetuses (>60 cm TL) in October and November does lend some support to the suggestion that there might be a peak in births in November and December (Anderson and Ahmed, 1993), but further sampling will be required to test this.

**Table 8.** Silky shark – Summary of pregnancies

Date	TL of mother (cm)	No. foetuses	No. male foetuses	Av. TL of foetuses (cm)	TL range of foetuses (cm)
29.10.00	228	8	8	55.1	52-57
30.10.00	na	10	na	60.7	55-64
2.11.00	245	12	10	70.6	69-72
4.6.02	236	3	na	26.7	26-27
4.6.02	249	6	1	30.3	30-31
17.10.02	237	3	2	68.0	66-70
20.10.02	244	2	0	43.5	39-48
20.10.02	na	2	1	65	65

Note: Not all foetuses were measured from all females

The relationship between fork length (FL) and total length (TL) is linear, and of the form:

$$FL = 0.8218 TL - 3.620$$

(n = 192; R<sup>2</sup> = 0.997; TL range = 84-254 cm)

Pectoral fin lengths (PL in mm) increase from an average of about 14% of TL at sizes less than 90 cm TL to an average of about 20% of TL at sizes greater than 240 cm TL. This change suggests that the swimming behaviour of these sharks changes as they grow, with juveniles perhaps being more active than adults. This is probably related to the juveniles' habit of associating with drifting objects (*oivaali*). This also makes large adults, with their disproportionately large fins, particularly valuable. The relationship can be expressed as:

$$PL = 0.3308 TL^{1.3234}$$

(n = 447; R<sup>2</sup> = 0.979; TL range = 77-263 cm)

### **Oceanic Whitetip Shark, *Carcharhinus longimanus***

A total of 27 oceanic whitetip sharks were landed, 3.5% of the total shark landings. 23 of the 27 were caught in Oct-Nov 2000, to the west of the atolls. In contrast, only 3 were landed in October 2002, when fishing was to the east of the atolls. Catch rates were 0.21 oceanic whitetip sharks per dhoni in Oct-Nov 2000, but only 0.08 oceanic whitetip sharks per dhoni in October 2002. This suggests distinct regional and seasonal changes in abundance.

The Exploratory Offshore Fishing Survey in 1987-88 reported catch rates for oceanic whitetip sharks were twice as high off the south of the Maldives (south of 3°N) than they were off the north (Anderson and Waheed, 1990). More significantly, in the centre and north of Maldives, oceanic whitetip sharks contributed 19.9% of the total shark longline catch by numbers during that survey in 1987-88. Oceanic whitetip sharks contributed just 3.5% of the shark longline catch landed at Kulhudhuffushi in 2000-04. In addition, that

offshore survey in 1987-88 noted that oceanic whitetips frequently approached the vessel (Anderson and Waheed, 1990), while more recent offshore surveys by divers around FADs reported no sightings of oceanic whitetips off the north or centre of the Maldives.

The length frequency distribution of landings is presented in Fig. 4. Note the bimodal distribution, which is quite unlike the near-normal distribution previously reported from the Maldives (Anderson and Waheed, 1990; Anderson and Ahmed, 1993). The reason(s) for this are unknown, but presumably relate to seasonal and regional differences in fishing area. The small sample size should also be noted. The relationship between TL and FL is linear, and of the form:

$$FL = 0.7847 TL + 1.211$$

(n = 26; R<sup>2</sup> = 0.997; TL range = 93-186 cm)

The relationship between total length and pectoral fin (PL in mm) length is quasi-linear. Fin length decreases only slightly in proportion to TL with increasing TL. Pectoral fins average about 24% of TL over the size range sampled, but vary from about 25% of TL in smaller individuals to about 23% of TL in larger individuals.

$$PL = 2.8966 TL^{0.9632}$$

(n = 22; R<sup>2</sup> = 0.981; TL range = 90-186 cm)

Of the 27 Oceanic Whitetip Sharks there were 17 males and 10 females, so the sex ratio favoured males:

$$0.63 \pm 0.18 \text{ males}; 0.37 \pm 0.18 \text{ females} \quad (n = 27; \text{ TL range} = 90\text{-}186 \text{ cm})$$

This is in contrast to the findings of the Exploratory Offshore Fishing Survey, which reported an overall excess of females (Anderson and Waheed, 1990). However, given the small sample size here this difference may not be significant.

### **Blue Shark, *Prionace glauca***

A total of 26 blue sharks were landed, 3.4% of all shark landings. All 25 individuals for which sex was recorded were males, within the size range 217-274 cm TL (Fig. 5). This is remarkably similar in sex and size composition to two previous samples of Blue Sharks from Maldivian waters (Table 9).

**Table 9.** Blue shark - Sizes caught in Maldivian waters in three separate studies

	Gubanov and Grigoryev (1975)	Anderson and Waheed (1990)	This Study
Mean Length (cm)	232	244	250
Length Range (cm)	190-273	219-273	217-274
Mean Weight (kg)	50.7	56	na
Percentage male	96%	94%	100%

All blue sharks encountered at Kulhudhuffushi were assumed to be maturing, with claspers in the range 7.6-9.7 % of TL (n = 20). Compagno (1984) notes that males are maturing at 182-281 cm, while Last and Stevens (1994) suggest that both sexes mature at about 220 cm.

The blue shark is known to be a highly migratory oceanic species, and to show a high degree of sexual segregation (Strasburg, 1958; Gubanov and Grigoryev, 1975; Compagno, 1984; Last and Stevens, 1994). It is most common in subtropical and warm temperate waters. Within the Indian Ocean, blue sharks make up over 50% of the total shark catch by longline south of 20°S (Sivasubramaniam, 1969). At lower latitudes it is less common, and males predominate; it may also show tropical submergence, being found at greater depths in equatorial waters than elsewhere. Interestingly, shark fishermen in Addu Atoll report relatively high catches of Blue Sharks, which they say includes larger individuals than are caught near Kulhudhuffushi (RCA, unpubl. data).

The relationship between total length (TL) and fork length (FL) is linear, and of the form:

$$FL = 0.822 TL + 1.754$$

(n = 10; R<sup>2</sup> = 0.995; TL range = 217-265 cm)

### **Longfin Mako Shark, *Isurus paucus***

A total of 22 Mako Sharks were landed, 2.9% of all shark landings. The identification of these sharks was not straightforward. There are two species of mako shark, the shortfin (*Isurus oxyrinchus*) and the longfin (*Isurus paucus*) (Garrick, 1967; Compagno, 1984; Moreno and Moron, 1992). The shortfin mako is the more widespread and apparently the commoner of the two, and it has been recorded from the Maldives before (Compagno, 1984; Anderson and Ahmed, 1993). Differences between the two species, and results from Kulhudhuffushi specimens, are summarized below:

**Table 10.** Mako sharks – Summary of differences between the two species and specimens from Kulhudhuffushi

	Shortfin Mako	Longfin Mako	Kulhudhuffushi
Pectoral fin length	16-22% of TL	22-31% of TL	23-29% of TL
Pectoral fin length	70-84% of HL	PL ≈ HL	85-95% of HL
Pectoral fin shape	Pointed	Rounded	Rounded
Mouth colour	White	Dark	Dark

It is concluded that the Kulhudhuffushi specimens were longfin mako sharks, although there are two outstanding difficulties, which should be resolved with additional sampling:

1. Total length of mako sharks at Kulhudhuffushi was not measured, only fork length. Estimates of total length were made using the relationship of Kohler et al. (1995) for shortfin makos. Pectoral fin length in Kulhudhuffushi specimens was 28% of fork length (range 25-31%, n=18). Assuming the conversion of fork length to total length is appropriate, pectoral length as a percentage of total length does fall within the known range for longfin mako.

2. Pectoral length in relation to head length is more problematic. Compagno (1984) states that pectoral fins are “as long or longer than head”. However, other authors suggest that the pectoral fins are nearly equal to or slightly less than head length (Garrick, 1967; Moreno and Moron, 1992). In the case of the Kulhudhuffushi specimens, pectoral fins were 85-95% of head length. This is distinctly less than head length, but nevertheless distinctly longer than the normal size in shortfin makos. It is likely that these differences are due to differences in methodology between studies. In this study head length was measured with tape (rather than calipers) to the last gill opening (rather than to the pectoral origin). Both these methodological differences may tend to overestimate head length in this study.

All 22 mako sharks were caught on the west side of the Maldives (catch rate 0.17 sharks per dhoni); no makos were landed from the east of the Maldives. All were within the length range 120-187 cm FL (Fig. 6). Of the 22 mako sharks 10 were males and 12 were females:

$$0.45 \pm 0.21 \text{ males: } 0.55 \pm 0.21 \text{ females} \quad (n = 22; \text{ FL range} = 120\text{-}187 \text{ cm})$$

Two males of 177 and 181 cm FL had claspers 12.7% and 15.3% of FL respectively and are assumed to have been mature. The next smallest male, 168 cm FL, had claspers 9.5% of FL as is assumed to have been maturing.

### **Silvertip Shark, *Carcharhinus albimarginatus***

Nineteen silvertip sharks within the size range 89-217 cm TL were landed. Most were small juveniles, with 15 being 130 cm TL or less. All 19 silvertips were landed by just seven dhonis. In five of these cases (accounting for 18 silvertips) catches were made during periods of bad weather; they were landed with bignose sharks (2 cases), grey reef sharks (1 case) or by themselves (3 cases); and they were mostly of relatively small size (max 170 cm TL). This suggests that these catches were made close to reefs, either of the atoll or of an offshore seamount. In the case of the remaining one silvertip shark, it was a relatively large individual (217 cm TL) and was landed with silky and oceanic whitetip sharks, suggesting that it had been caught offshore. The occurrence of small juveniles inside the atolls and large adults offshore has been noted before in the Maldives (Anderson and Ahmed, 1993). Numbers of males and females were nearly equal:

$$0.53 \pm 0.25 \text{ males: } 0.47 \pm 0.25 \text{ females} \quad (n = 15; \text{ TL range} = 93\text{-}217 \text{ cm})$$

The relationship between total length (TL in cm ) and pectoral fin length (PL in mm) is shown below. This suggests that relative length of the pectoral fins increases slightly with increasing size, from about 16% of TL at 100 cm TL to about 18% of TL at 200 cm TL.

$$PL = 0.6858 TL ^ 1.1845$$

(n = 10; R<sup>2</sup> = 0.961; TL range = 93-217 cm)

### **Tiger Shark, *Galeocerdo cuvier***

Eight Tiger Sharks of 193-295 cm TL were landed. There were 3 males and 3 females. Five were landed in October 2000 when fishing was mainly to the east of the atoll (catch rate 0.14 sharks per dhoni) but only one in October-November 2000 when fishing was to the west (0.01 sharks per dhoni). In all cases the tiger sharks were landed with silky sharks and other pelagic species, indicating that they had been caught offshore.

### **Grey Reef Shark, *Carcharhinus amblyrhynchos***

Six grey reef sharks of size range 82-166 cm TL were landed. In the case of three sharks (two landings), they were landed by themselves or with silvertip sharks and are believed to have been caught in or adjacent to the atolls, when fishing was carried out inshore during periods of bad weather. However, in the case of the other three sharks (three landings) they were landed with silky sharks and were reported to have been caught offshore. This species is essentially a reef dweller, but it is known to venture offshore on occasion (Compagno, 1984). Five of the six sharks were males. Two of the males were immature (TL ≤ 125 cm), while three were mature (TL ≥ 158 cm).

### **Pelagic Thresher Shark, *Alopias pelagicus***

Four pelagic thresher sharks were landed. All four were females of precaudal length 149-156 cm (TL of three 291-316 cm). The 149 cm PCL female was pregnant with two male foetuses, 120 and 121 cm TL. In two of the females and both male foetuses, caudal length was greater than precaudal length. This is contrary to Compagno (1984) who states that the upper caudal lobe is nearly as long as the body in this species. There has been only one previous record of this species from the Maldives (Anderson et al, 1998). Gubanov (1978) recorded *Alopias vulpinus* from Maldivian waters, but that species has not been recorded since, and has been regularly confused with *A. pelagicus* (Compagno, 1984). It seems possible that Gubanov might have misidentified at least some of his specimens.

### **Scalloped Hammerhead Shark, *Sphyrna lewini***

Three scalloped hammerheads of size range 177-230 cm TL were landed. The largest was a pregnant female landed on 1 November 2000 with a litter of at least 10 foetuses, average length 46 cm TL (range 45-48 cm TL).

### **Smooth Hammerhead Shark, *Sphyrna zygaena***

Two immature males were landed. One of 189 cm TL on 9 November 2000 (head width 465 mm, first dorsal height 274 mm), the other of 180 cm TL on 13 November 2000 (head width 431 mm, first dorsal height 272 mm). These were the first records of this species from the Maldives, although it is known from India and Sri Lanka (Compagno, 1984). The discovery of this species in Kulhudhuffushi catches was an indication of the poor state of knowledge of sharks and shark fisheries in the Maldives.

### **Bignose Shark, *Carcharhinus altimus***

Only two bignose sharks were landed: an immature male of 164 cm TL on 29 October 2000 and a female of 184 cm TL on 17 October 2002. In contrast to Compagno (1984) who characterizes this species as 'fairly slender' and 'light grey above', the second Kulhudhuffushi animal at least was rather stocky and dark. The latter was said by fishermen to have been caught near a seamount southeast of Kulhudhuffushi. Both specimens were landed from dhonis that had also caught silvertip sharks at the same time. The bignose shark (and to a lesser extent the silvertip shark too) is characteristic of the 'nearshore' shark fauna. It is not found in shallow reef environments, nor is it found far offshore in very deep water. Rather, it is found in areas with intermediate bottom depths: atoll deep slopes, seamounts and between the atolls. It is largely deep-benthic, but does come up into shallow waters at night, where some are caught by pelagic longline (Anderson and Stevens, 1996). The low level of landings at Kulhudhuffushi suggest that local stock(s) have been heavily fished. In contrast, relatively large catches of this species were reported from shark longline fishery that had newly started in Addu Atoll in 2002 (RCA, unpubl. data); these were reported to have been made in the vicinity of the seamount known as Addu Thila.

### **Bigeye Thresher Shark, *Alopiis superciliosus***

A single female bigeye thresher of 125 cm PCL was landed on 15 November 2000. This species is poorly known from the Maldives, but Gubanov (1978) noted pregnant females in longline catches in February and March 1970.

### **Sicklefin Lemon Shark, *Negaprion acutidens***

A single individual of 169 cm TL was landed in March 2004. No other sharks were landed from that dhoni, which had probably been fishing inside the atoll.

## **STATUS OF MALDIVIAN SHARK STOCKS**

Three main types of shark were exploited by Kulhudhuffushi fishermen: reef sharks, nearshore pelagic sharks, and offshore oceanic sharks. Time series of catch and effort data are not available, but some measure of the size of the fisheries can be made from national export data (Anderson and Ahmed, 1993; Anderson and Waheed, 1999); and some indication of stock status was obtained from interviews with Kulhudhuffushi shark fishermen.

### ***Reef Sharks***

Atoll-associated reef sharks have been grossly overfished in the northern atolls, and in other atolls as well. Kulhudhuffushi fishermen report that catch rates dropped to very low levels within just a few years of starting the fishery (ie between the late 1970s and the early 1980s). Stocks have not recovered. Kulhudhuffushi fishermen only very rarely fished inside the atolls in recent years; when they did it is normally because rough weather prevented them fishing outside, and when they did catch rates were invariably very low. In addition, divers reported seeing no reef sharks during surveys inside the northern atolls (MEP, 2002: 14)

### ***Nearshore Pelagic Sharks***

In the zone immediately outside the atolls to about 10 miles offshore, there is a transition from the reef shark fauna of the atolls to the truly offshore shark fauna of the open ocean. In this transition zone, both reef sharks and offshore sharks are taken. However, there is also a unique component to the shark fauna, notably bignose shark and scalloped hammerhead shark, as well as relatively large numbers of the more ubiquitous tiger shark and silvertip shark.

This transitional zone has not been well-characterized in the Maldives, although the occurrence of bignose sharks and mantas within the zone has been noted (Anderson and Stevens, 1996; Anderson et al., 2011). The fauna of this zone appears to be comparable with the 'boundary community' described off Hawaii (Reid et al., 1991).

As with reef sharks, the nearshore sharks have been overexploited in the north of the Maldives, and probably throughout most of the rest of the country too. Kulhudhuffushi fishermen reported that fishing outside but close to the atolls produced good returns for a few years after reef shark stocks were exhausted. However, these nearshore shark stocks were also overexploited within just a few years, i.e during the late 1980s. Species typical of the nearshore shark fauna (eg bignose and hammerhead sharks) were only rarely landed at Kulhudhuffushi in later years. In contrast, relatively large numbers of nearshore sharks were reported in 2002 from a then newly started shark longline operation in Addu Atoll in the south of Maldives (RCA, unpubl. data).

### ***Offshore Oceanic Sharks***

Offshore (oceanic) shark stocks appear to have been exploited at a relatively high level. Kulhudhuffushi fishermen reported declining catch rates after about 2000; the

disappearance of very large silky sharks from their catches; and having to travel further offshore to find good fishing. As a result of declining earnings many fishermen and boats left the fishery, and there was no new investment in boats or gear. Evidence suggestive of high levels of fishing mortality from catch sampling includes: lack of very large silky sharks in any catches; lack of large female silky sharks in 2002 samples; and high ratio of size of first maturity to maximum length in male silky sharks.

Anderson and Jauharee (2009) reported on opinion polls of islanders and shark fishermen, which suggested significant declines in the abundance of silky sharks during recent decades. Although not reported by Anderson and Jauharee (2009) several fishermen in that survey also reported marked decreases in their sightings of oceanic whitetip sharks. In that regard, the apparent decline in relative abundance of oceanic whitetip sharks (from 19.9% of longline shark catch in 1987-88 to just 3.5% of shark landings at Kulhudhuffushi in 2000-04) is also of note.

## ACKNOWLEDGEMENTS

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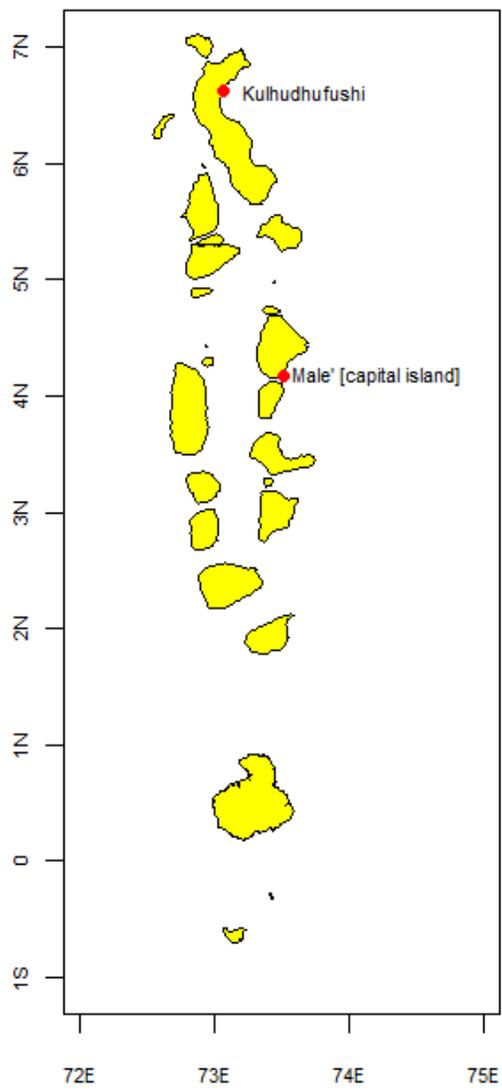
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**Figure 1.** Location map.

Fig. 2a. Silky Shark - Length frequency distribution, Oct-Nov 2000

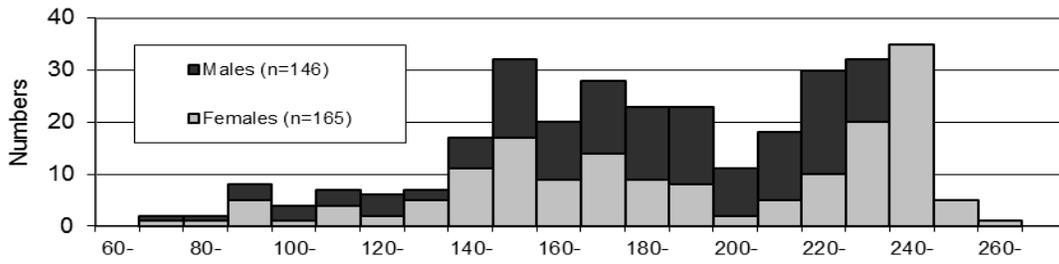


Fig. 2b. Silky Shark - Length frequency distribution, May-June 2002

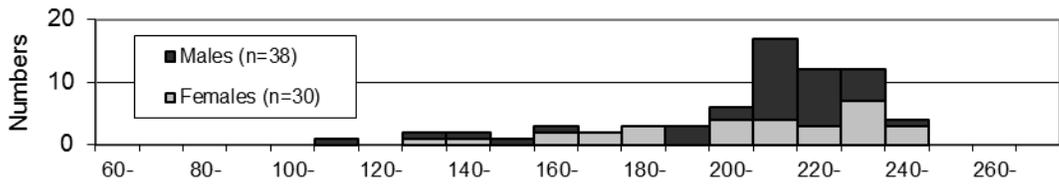


Fig. 2c. Silky Shark - Length frequency distribution, October 2002

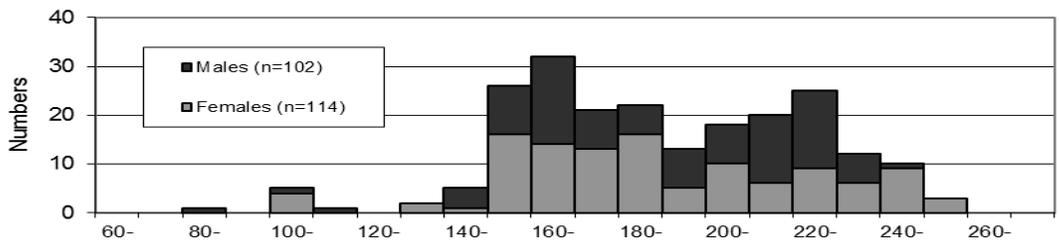


Fig. 2d. Silky Shark - Length frequency distribution, March 2004

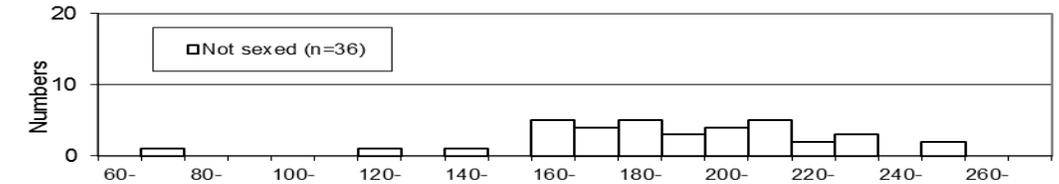


Fig. 2e. Silky Shark - Length frequency distribution of all sexed samples

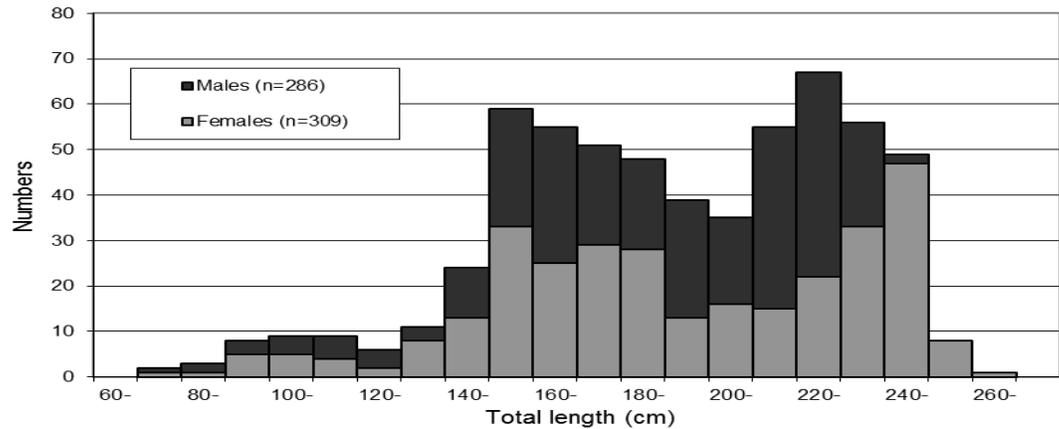


Fig. 3. Silky Shark - Relative length of male claspers

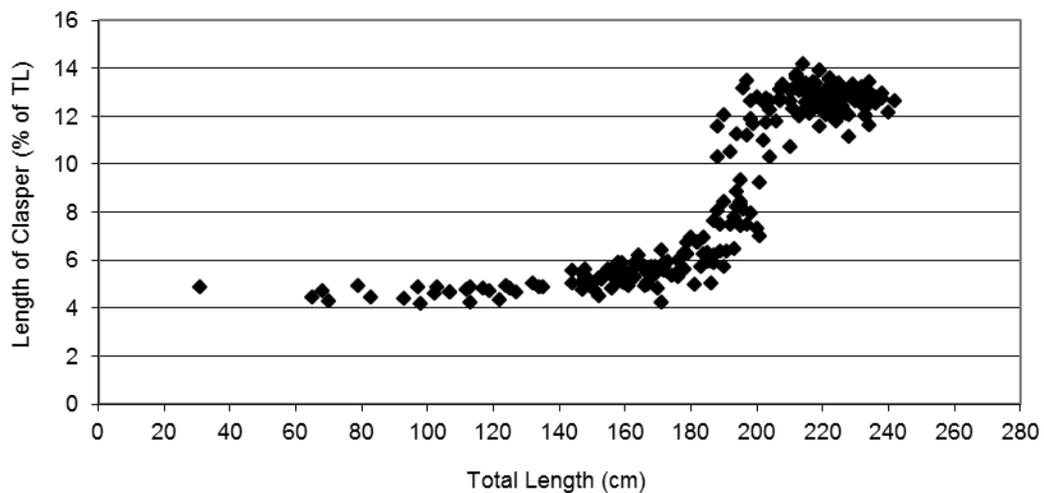


Fig. 4. Oceanic Whitetip Shark - Length frequency distribution

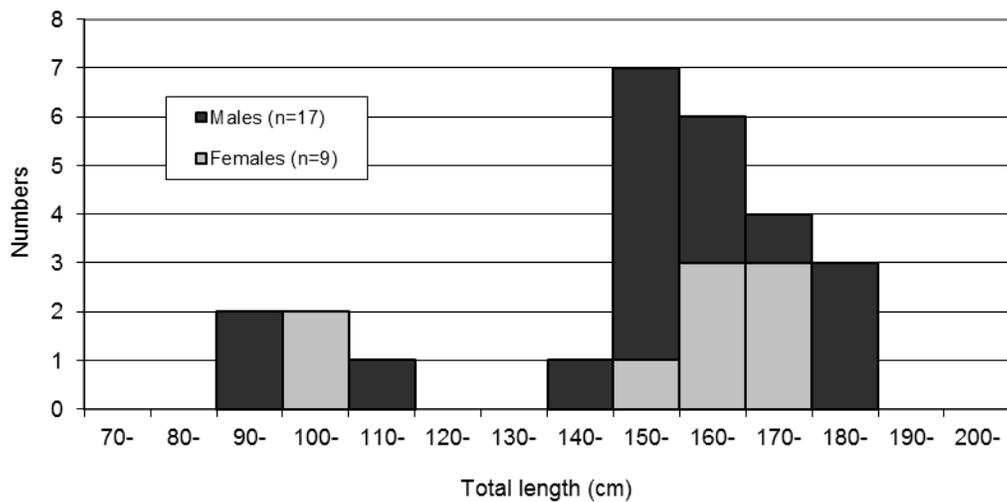


Fig. 5. Blue Shark - Length frequency distribution

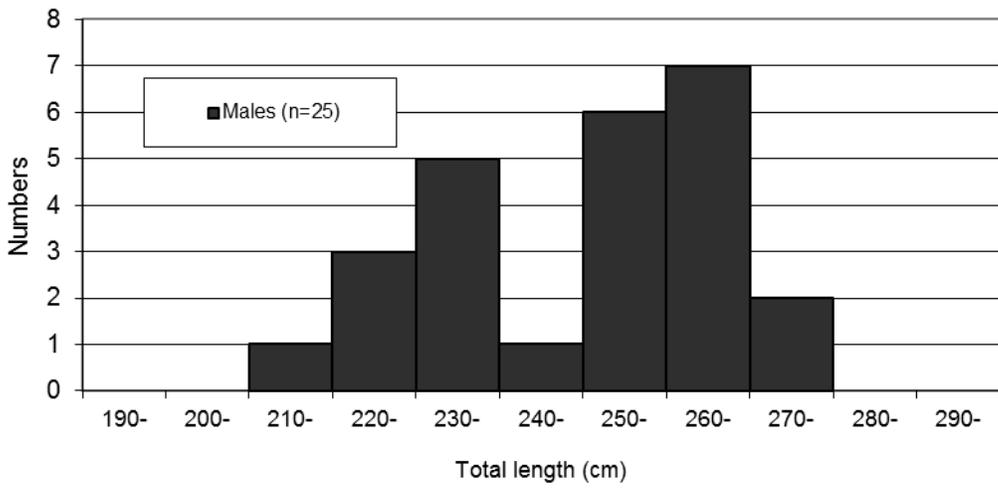


Fig 6. Longfin Mako Shark - Length frequency distribution

