

EXPLORATORY FISHING FOR LARGE PELAGIC SPECIES IN THE MALDIVES

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EXPLORATORY FISHING FOR LARGE PELAGIC SPECIES IN THE MALDIVES

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Ministry **Of** *Fisheries and Agriculture Republic* **of** *Maldives*

Bay of Bengal Programme For Fisheries Development Madras, India, December 1990 Mailing Address : Post Bag 1054, Madras 600 018, India. Street Address : 91, St. Mary's Road, Abhiramapuram, Madras 600 018, India. Cable : FOODAGRI Telex : 41-8311 BOBP Fax : 044-836102 Phones : 836294, 836096, 836188, 836387, 836179 This paper discusses the aims, methodology and findings of the project "Exploratory tuna fishing in the Maldives" TCP/MDV/6651(1). It was established in 1987 as part of a TCP (technical cooperation) agreement between the FAO and the Government of Maldives. The project was completed in December 1988.

The project was executed by the Marine Research Station of the Ministry of Agriculture and Fisheries with some support from the BOBP (Bay of Bengal Programme for Fisheries Development).

Under the project, exploratory surveys were carried out by the *vessel Matha Hari*. Despite limited fishing operations, useful information was obtained on the status of pelagic fish stocks, and on the feasibility of operating multi-day gillnet-cum-longline offshore fishing trips Data were also obtained on offshore tuna and sharks,

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This document is a technical report and has not been cleared either by the FAO or by the government concerned.

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EXPLORATORY FISHING FOR LARGE PELAGIC SPECIES IN THE MALDIVES

Main Report

R C Anderson and A Waheed

Ministry of Fisheries and Agriculture Republic of Maldives

1 INTRODUCTION

Pole and line fishing for tuna is the backbone of the fisheries sector in the Maldives. Exploitation is almost entirely by traditional craft (dhoni). The Government of Maldives is eager to expand the fishery beyond the present range of operation to utilize the resources in the country's EEZ. To achieve this, more information is required on the availability of resources for commercial exploitation in the offshore region. But traditional craft, with traditional systems of carrying live bait. find it difficult to extend their method into distant offshore ranges.

To explore the availability of resources and to try other fishing methods, a project "Exploratory tuna fishing in the Maldives", TCP/MDV/6651(1) was established in 1987. The objectives were

- i. To obtain information on the availability of surface and deep swimming tunas and on the technical feasibility of their exploitation by small to medium size crafts in the 25-100 miles range of the EEZ of the Maldives.
- ii. To introduce driftnet fishing for tuna.

FAO contributed US \$ 96,000 to the project, and the duration was 22 months. However, due to delays in procuring a vessel, modifying and equipping it, fishing activities commenced only in November 1987 and were completed in December 1988. The Marine Research Station of the Ministry of Agriculture and Fisheries was the national agency responsible for the project. It was assisted in execution by the Bay of Bengal Programme (BOBP).

2. SURVEY METHODOLOGY/PROGRAMME

2.1 Survey Area

All operations were conducted off the eastern seaboard of the Maldives. All stations were in the range of 30-100 n miles offshore. Fishing operations were carried out in three latitudinal fishing zones:

Areas	Base atoll
Northern zone (north of 5°N)	Lhaviyani atoll
Central zone (3°N-5°N)	Male atoll
Southern zone (south of 3°N)	Laamu atoll

For logistic reasons (i.e. the proximity of the Felivaru cannery with its many facilities) most of the fishing was carried out in the north. Fig. 1 and 2 show the approximate positions of all stations.

2.2 Cruise schedule

Twenty four cruises, with a total of 49 stations, were carried out. Table 1 gives details of fishing effort by season and latitudinal zone.

2.3 Fishing methods/gear

A 52 ft wooden vessel Matha Hari, of 35 GT, was made available for the survey. This was by no means an ideal vessel for the work to be done but the only one readily available at that time. It was used after some modifications, and after installing deck equipment and a new steering system. The vessel was plagued with mechanical problems (notably frequent failure of the starter motor, fuel feeder pipes, fuel injectors, and exhaust outlet). Lengthy stays in Male were frequently necessary to rectify these recurrent faults. Another big problem, that of regular maintenance, also necessitated returning to Male.

Table 1: Distribution of fishing effort by area and season

		· •			
Fishing zone		North	Central	South	Total
Nights fished	(no)	18	6	-	24
Gillnet sets	(no)	16	3.25	-	10.25
Tuna hooks	(no)	450	60	-	510
Shark hooks	(no)	1700	455		2155
Total hooks	(no)	2150	515		2665
Time trolled	(hr)	335	155	-	490

(a) Northeast Monsoon Season (Dec. 87 - April 88)

(b) Southwest Monsoon Season (June 88 - Nov. 88)

Fishing zone		North	Central	South	Total
Nights fished	(no)	14	1	10	25
Gillnet sets	no	13.5	0.5	8.5	22.5
Tuna hooks	(no)	160	100	485	74s
Shark hooks	(no)	1440	100	970	2510
Total hooks	(no)	1600	200	1455	3255
Time trolled	(hr)	255	15	137	407

(c) Both Seasons (Dec. 87 - Nov. 88)

Fishing zone		North	Central	South	Total
Nights fished	(no)	32	7	10	49
Gillnet sets	(no)	29.5	3.75	8.5	41.75
Tuna hooks	(no)	610	160	4x.5	1255
Shark hooks	(no)	3140	555	970	4665
Total hooks	(no)	3750	715	1455	5920
Time trolled	(hr)	590	170	137	897

Matha Hari operated both longline and gillnet gear. A full set of longlines should have consisted of 100 tuna hooks and 100 shark hooks. Often, however, only the shark hooks were deployed for a variety of reasons, the chief of which was the problem of obtaining suitable bait. Only a limited number of tuna longline operations was possible, for there was not enough quality bait. Lowquality deep frozen mackerel and fresh pieces of tuna were the bait types used. Although such baitfish are not very effective for tuna species, they were apparently responsible for a high catch-rate of sharks. It was felt that good quality bait fish such as fresh mackerel and squids would have led to a higher tuna catch rate. However, it was only possible to obtain.low-quality frozen mackerel seized from foreign vessels fishing illegally in the Maldives.

The multifilament gillnets were arranged in two identical parts. Each half comprised 6 panels (1,000 meshes) of 5" mesh, 5 panels of 6" mesh and 4 panels of 7" mesh.

A full set of gillnets (ie. a total of 30 panels, covering roughly 2.5 km) should have been set each night. On some occasions, however, particularly at the start of operations, only half the set was used.

In addition to the longlines and gillnets, trolling lines were used during passage between stations.

The gear mentioned above would constitute a suitable mix and quantity of a commercial gear complement for a small-to-medium scale fishing boat. For further details of vessel, gear and operations, see Field Document I.

2.4 Operational bases and supplies

Since this was the first attempt at multi-day offshore fishing operations from the Maldives it had to make do with inadequate support facilities. The greatest concentration of facilities was at the cannery on Lh. Felivaru. Here, it was possible to buy ice and water, and sell small tunas. Fuel could sometimes be bought here but it was more often taken from vessels moored some distance away. Large tunas had to be sold to freezer vessels (for eventual export to Thailand), sharks

could be disposed of only at particular fishing islands. It took two whole days after a trip to get a buyer for the catches. In the northern fishing area, when based near Felivaru. it was normal to travel to R. Kandholudhoo to sell sharks. and on one occasion they could only be disposed of at Sh. Firubaidhoo. Also in the north a trip was made on two occasions to H. Dh. Hanimaadhoo (1.5 days away by sail from Felivaru) to collect bait from a freezer vessel.

In the South, it was normal to sell sharks at Th. Olugiri. and tunas to a vessel near M. Mulaku. Bait could he obtained from the same vessel But ice had to be taken from another vessel near L. Hitadhoo. Water had to be got from a village well and rowed to the vessel in drums.

In Male ice was not available. and it was very difficult to sell the catch. For these reasons, only one-day operations were carried out in the central zone.

This brief description. and the fact that although only 49 fishing stations were completed. as many as 160 days were spent away from the project base in Male. demonstrates the very serious logistics problems the survey faced. A practical option for any future operation would be to use Felivaru as a full-time centre of operations. If regular catches of sharks were guaranteed it should be possible to identify a buyer nearer than R. Kandholudhoo. In this way much of the time-consuming trawl undertaken by Matha Hari could be avoided.

2.5 Crew

The crew of the exploratory fishing vessel were trained in the fabrication. operation and mending of drift gillnets and drift longlines. They also acquired experience over the entire year of operation in night-time fishing and muttiday operation. A Sri Lankan masterfisherman, and the national fishing technologist assisted in training crew members.

The vessel crew were boatmen. not fishermen (although a few had some longlining experience). so they were not skilled in fishing. This problem was. however, gradually overcome as the project got under way and those who stayed with the project gained experience.

A more intractable problem was that the crew were not highly motivated to go out fishing. Even an incentive for fishing trips amounting to 50 % of the sales-had only a limited effect. White multiday offshore fishing trips were new to the Maldives, Mnldivians are not used to spending several days at a time on small vessels (a trip to Male from a distant island may take three days even in good weather, and lobster fishermen may spend several weeks at a time on a dhoni). For any operations in future. it would be important to identify active fishermen for crew. and to reward them appropriately. Because of the acute labour shortage in the Maldives this might not be easy. Matha Hari had problems in maintaining even a semi-skilled crew. and had to operate without a cook for some time.

2.6 Catch sampling procedures

As soon as fish were landed. catch compositions were estimated and biological sampling was done. A biologist and/or a fishing technologist was present on every cruise and his duty was to record details of capture of each fish (e.g. hook number if caught by longline. mesh size. and whether gilled or entangled if caught by gillnet), It did not always prove feasible to record in which section of the net (upper, middle or lower) the fish were caught, but some data were obtained from skipjack catches. (See Field Document II for details of biological sampling).

3. RESULTS OF FISHING

3. I Catches and catch rate

3

The total catch attained from 49 fishing nights (stations) during 23 cruises was 22.6 tonnes (t). It comprised of shark 68%, skipjack 2 1%, billfish 7%, yellowfin 3% and others 1% Sharks caught by longline constituted 50% of the total. Skipjack and shark caught by gillnet accounted for 20% each. The catch by other gear (trolling, handlinc and pole and line) was insignificant (2%). Details are given in Table 2.

The catch was distributed about equally over the two monsoon seasons-northeast (46%) and south-west (54%). The pattern of catch with regard to species and gear is almost identical for the two seasons.

Cruise nos: 1-24 Longline: 1255 tuna hooks				
Dates: Dec.	87 Nov. 88	Gi	llnet: 41 .75 sets	HOOKS
a. Number Of piece	es			
	Gillnet	Longline	Others	Total
Skipjack	1018		71	1089
Yellowfin	101	8	8	117
Shark	170	244	15	429
Billfish	21	41	1	63
Others	140	4	20	164
Total	1450	297	115	1862
b. Weight (kg)				
	Gillnet	Longline	Others	Total
Skipjack	4518.4		159.4	3677.8
Yellowfin	465.6	284.0	19.9	769.5
Shark	4133.9	11037. I	287.8	15458.8
.Billfish	896.4	541 .5	2.6	1440.5
Others	1X9.0	24.5	77.5	291 .о
Total	10203.3	11887.1	547.2	22637.6

Table 2: Matha Hari' catch summary for the whole project period

The average catch rate was 462 kg of fish per night's fishing at an average effort of 85 per cent of the standard set of gillnet and 121 longline hooks. (See Table 3.)

Table 3: Average catches per night by 'Matha Hari' for the whole project period

Cruise nos: 1 No. stations: 49 Dates: D	- 24 9 9ec. 87 - Nov. 88	Longline: 121 hooks/ Gillnet: 0.85 sets/ni	night ght	
a. Number of p	ieces per night			
	Gillnet	Longline	Others	Total
Skipjack	20.8	_	1.4	22.2
Yellowfin	2.0	0.2	0.2	2.4
Shark	3.5	5.0	0.3	8.8
Billfish	0.4	0.8	0.0	1.2
Others	2.9	0.1	0.4	3.4
Total	29.6	6.1	2.3	38.0
b. Weight (kg) j	ver night			

	Gillnet	Longline	Others	Total
Skipjack	92.2	_	3.3	95.5
Yellowfin	9.5	5.8	0.4	15.7
Shark	84.4	225.2	5.9	31.5.5
Billfish	18.2	11.1	0.1	29.4
Others	3.9	0.5	1.5	5.9
Total	208.2	232.6	11.2	462.0

There is a remarkable similarity in catch rates hetween the two seasons. The only difference that

might be of significance. is that fewer but larger sharks were caught during the southwest monsoon period.

The average catch rate of the shark longline was 237 kg per 100 hooks (Table 4). while the tuna longline yielded only 68 kg per 100 hooks (Table 5).

Table 4: Shark longline - average catch rates per 1000 hooks

NE season: 2155 hooks SW season: 2510 hooks Total : 4665 hooks

a. Number Of pieces per 1000 shark hooks

	NE season	SW season	Total
Skipjack			-
Yellowfin	1.4*	0.4	0.9
Shark	51.5	46.2	48.7
Billfish	5.1	8.0	6.6
Others	0.9	0.8	0.9
Total	58.9	55.4	57.1

h. Weight (kg) per 1000 shark hooks

	NE season	SW <i>season</i>	Total
Skipjack	-	-	_
Yellowfin	45.9*	19.9	31.9
Shark	2206.5	2252.1	223 1 .0
Billfish	101 .0	100.4	100.7
Others	4.4	6.0	5.3
Total	2357.8	2378.4	2368.9

* Includes one bigeye tuna of 29 kg.

Table 5: Tuna longline - average catch rates per 1000 hooks

NE	season:	510	hooks
SW	season:	745	hooks
Tota	1:	1255	hooks

Dates: Dec. 87 - Nov. 88

Dates: Dec. 87 - Nov. 88

a. Number of pieces pet000 tuna hooks

	NE season	SW <i>season</i>	Total
Skipjack	-		_
Yellowfin	5.9	1.3	3.2
Shark	9.8	16.1	13.5
Billfish	9.8	6.7	8.0
Others	-	-	-
Total	25.5	24.1	24.7

b. Weight (kg) per 1000 tuna hooks

	NE season	SWseason	Total
Skipjack	-	-	-
Yellowfin	158.9	72.5	107.6
Shark	288.2	646.9	501.2
Billfish	95.5	48.3	67.5
Others	-	-	-
Total	542.6	767.7	676.3

Assuming that the full complement of gear had been used. the theoretical catch rate would have been 561 kg per night's fishing composed as follows:

l set gillnet	245 kg	(Table 3 adjusted to full set)
100 shark hooks	237 kg	(Table 4)
100 tuna hooks	68 kg	(Table 5)
Other gear	11 kg	(Table 3)

3.2 Sharks

The bulk of the catch (68%) comprised of sharks (Table 2). Of these, about 70% (by weight) were caught by longline, the average weight of fish being 45 kg. The hooking rate for the shark longline was about five per 100 hooks (Table 4). against only one for the tuna longline. The species composition in the longline catch was (in number of fishes):

Silky shark	Carcharhinus falciformis	59%
Oceanic white-tip	Carcharhinus longimanus	29 %
Blue shark	Prionace glauca	8%
Others: (Silver-tip shark	Carcharhinus albimarginatus	: 4%
Tiger shark	Galeocerdo cuvier	
Shortfin mako)	Isurus oxyrinchus)	

Sharks caught by gillnets (27%) were only half as big (24 kg per fish) as those caught by longline. The dominating species was the silky shark (90%). The Oceanic white-tip accounted for the balance (10%).

A major problem encountered in the longline operation was to bring the sharks onboard. As much as 10% was lost at the time of gaffing. This corresponds to 5% of the total catch. The losses could perhaps be reduced as the crew gain experience.

While sharks formed the most valuable component of the catch, they were destructive, damaging the other fish caught and the fishing gear. It is estimated that:

- 3-4% of the skipjacks caught in gillnets,
- 20% of the billfish caught in gillnets and
- 15% of fish other than shark caught by longline

were damaged by shark bites. (No sharks were bitten.) These constituted about 2% of the total catch.

Some of the fish bitten were not badly damaged and could be used for bait or food. Most were, however, extensively damaged and of no further value. One consolation is that while attacking fish trapped in the gillnet, sharks sometimes got entangled'themselves. On the basis of unquantified observations it seems likely that the weight of sharks caught in this way might well compensate for the fish lost.

The number of hooks lost from longlines was recorded after most fishing nights. It is assumed that most of this damage was done by sharks, although large billfish may also have been responsible. The rate of hook loss is estimated at about 3%. This compares well with the hooking rate of sharks of about 5%. More hooks were seen to be lost whenever more sharks were caught. Shark catches could have been increased had stronger gear been used (notably chain rather than wire leaders). Sharks inflicted damage on gillnets too, but this could not be quantified.

3.3 Skipjack Tuna

Skipjack tuna *(Katsuwonus pelamis)* accounted for 21% of the catch by weight. Most skipjack were caught by gillnet (94%). Other gears were pole and line (4%) and trolling lines (2%).

The average catch rate by gillnet was 24. 4 fishes per set (Table 2) at an average weight of 4.4 kg per fish. Differences in catch rates between seasons and fishing zones were small.

Catches of skipjack could vary dramatically from day to day. For example, on the last cruise undertaken, in November 1988, only one skipjack was caught by during the first three nights, but 65 were caught the following two nights. Catch on full moon nights was poor presumably because the fish could see the net and avoid it, or were swimming deeper. Other factors which the crew felt influenced catch rates were cloud cover and wind speed/sea state. These observations were quantified by scoring each factor on a scale of 1 to 3 (with much moonlight. little cloud cover and calm conditions all scoring lowest). Scores were summed up to give an overall catchability index' for each night's fishing. The correlation of these indices with skipjack catches for the 35 nights for which a complete data set was available showed a highly significant positive relationship. The highest skipjack catches were made on rough, cloudy. moonless nights. This also suggests that mean catches of skipjack by gillnet could be improved in a commercial fishery by concentrating the fishing effort to suitable periods and at nights.

The experiment with different mesh sizes in the gillnet indicates that the 5 and 6 inch meshes are about equally good while the the 7 inch mesh is about 80% as efficient as the others. Details are as follows :

Mesh size (inches)	5	6	7
1. No. of fishes caught (%)	43	33	24
2. Average weight (kg)	3.6	4.8	5.4
3. Catch efficiency (1 x 2)	155	158	130

3.4 Billfish

The contribution from billfish to the total catch was 7%. Relatively large fishes (33 kg) were caught in gillnets and smaller ones (13 kg) by the longline.

The dominant species was the swordfish, Xiphias gladius (83%). The others were sailfish (8%) and black marlin (6%).

3.5 Yellowfin Tuna

The yellowfin, Thunnus albacares accounted only for 3% of the total catch. Small fishes (4.6 kg) were caught in the gillnets and a few (8) larger ones (36 kg) by longline.

4. COMMERCIAL FEASIBILITY

The results from exploratory fishing cannot by themselves establish or negate commercial feasibility. There are many reasons :

- The vessel was not suitable, being too large, and therefore too expensive to operate and maintain.

- The logistics for obtaining supplies (including bait for tuna long lining) and selling fish were poor.

- The crew lacked experience in operating the gear and staying out on multi-day trips.

There is therefore no point in comparing the costs and earnings of the exploratory fishing. In fact the earnings were only MRF 50,000 against operational costs of MRF 350.000.

However, the catch rates attained provided valuable information for assessing the prospects of commercial exploitation of the offshore resources. A very similar fishery, recent but well established, exists in Sri Lanka; input costs from that fishery may provide pointers to the potential in the Maldives. But let us first examine the fish prices in the Maldives.

4.1 Fish Prices

4

The Maldivians prefer high-quality tuna for consumption, and they do not eat shark. Any commercial gillnet and/or longline operation would therefore probably be export-oriented. The Government's State Trading Organization (STO) controls the export of most tuna and shark products. It buys fresh tuna for canning or freezing. but does not buy fresh shark. The prices it paid in 1988 are:

Tuna less than 2 kg per fish	1-10 MRF/kg	
Tuna more than 2 kg per fish	1.95 MRF/kg	
Salt dried shark meat -1st grade	7.80 MRF/kg	Note: 9.7 Maldivian
-2nd grade	6.00 MRF/kg	Rufiya (MRF) = 1 U.S. \$

During the survey, sharks were salted by the crew on one occasion when no buyer could be found. After most fishing trips a buyer was found on one of the fishing islands, but sometimes only after an extensive search. Typical prices paid were:

Whole sharks	2.50 MRF/kg
Sharks minus fins	2.00-2.20 MRF/kg
Shark fins (large size only)	50 MRF/kg
Billfish	0.60-0.75 MRF/kg

It was very difficult to sell the catch at Male and prices were much lower in the central fishing zone.

The actual prices realized for the fish caught during exploratory fishing were:

Skipjack	1.90 MRF/kg
Yellowfin	1.95 MRF/kg
Shark	2.77 MRF/kg
Billfish & others	0.82 MRF/kg

4.2 Costs

In order to get an idea of the cost structure for a new fishery similar to that undertaken on an exploratory basis, a "typical" offshore vessel from Sri Lanka is used for comparison. This boat (introduced under an Abu Dhabi loan) is 10.4 m long, has a fish hold of 7.5 m^3 and a 60 hp engine. It commercially operates 60 panels (500 meshes each) of driftnets and 200 longline hooks (40 baskets) i.e. the same amount of gear that was used during the exploratory fishing in the Maldives. The cost picture (1988) of such a boat is as follows (in MRF converted from SRL Rs. at a ratio of 1:4).

Investment		525 000
Boat including SSB radio and gear hauling equipment	465,000	555,000
Fishing gear	70,000	
Annualfixed cost of Depreciation and insurance		70,000
Annual variable costs		260,000
Fuel*	60,000	
Ice*	45,000	
Food	15,000	
Repairs	15,000	
Crew Share	110,000	
Miscellaneous	15,000	
Total Annual Cost		330,000

* The Sri Lankan figures for fuel and ice have been adjusted (a) upwards for higher prices in the Maldives-35% and 120% respectively and (b) downwards for fewer days at sea in the Maldives-180 against 216.

One can therefore assume that it would cost about MRF 330,000 per year to operate a suitable boat engaged during 180 days of the year in driftnetting and shark longlining.

4.3 Earnings

Maldivian fishing boats are supposed to operate a minimum of 180 days per year to maintain their fishing license. If we assume that our hypothetical vessel would do that, the number of fishing days would probably be about 150, the balance being spent on travel to fishing areas and between bases. But such an operation would be uneconomical with the catch rates attained during the

survey. The earnings would be only MRF 150,000 against the costs of MRF 330,000. The question is therefore whether the catch rates could be more than doubled in fully commercial fishing operations.

4.3.1 Tuna Longlining

The tuna longline was the least successful of the three gear used. Better bait would have generated a higher catch, but regular supply of bait would be a problem for a commercial venture. Locally caught scads may be used as bait, but freezing facilities would be required to ensure regular supplies. Obviously this fishery can be successful, as the presence of Far Eastern longliners in the Indian Ocean over the last 35 years demonstrates. However, these vessels rely for profit on very high prices in their home markets for an excellent quality product. Two recent tuna longlining ventures in the Maldives were not much of a success. STO carried out longlining operations using a confiscated Far Eastern longliner in mid-1986. Fishing was carried out for a short while only as the vessel was felt to be of more value as a freezer. A private joint venture operation involving two Taiwanese longliners was carried out in 1987. This did not last long, because licensing arrangements for fishing in the EEZ were too restrictive (they have since been relaxed). Tuna longlining is therefore ruled out as a viable option for our purpose.

4.3.2 Driftnetting and Shark Longlining

The fishing gear in use under this option would consist of 30 panels of driftnets and 200 longline hooks. According to the survey results (see 3.1) this would produce $245 + 2 \times 237 + 11 = 730 \text{ kg}$ of fish per day.

- By using only 5" and 6" mesh nets, the driftnet catch of skipjack will increase (section 3.3)
- BY not fishing during the full moon period but using this time for vessel maintenance and crew holidays average catch rates will be **higher**
- By using stronger longline gear and the shark-fishing experience gained by the crew, the shark catch rates will go up.

The combined effect of these factors would, at a conservative estimate, push up catch rate by 20% to 875 kg per fishing day.

Considering the prices obtained during the exploratory fishing and the new catch composition, one may assume an average price of 2.45 MRF/kg with 150 fishing days. This would produce a yearly gross revenue of MRF 320,000. Such an operation would thus nearly cover the costs, but would not of course be an attractive investment proposition.

4.3.3 Shark Longlining

A second option would, be to use only longlines because of the relatively high catch rates. Our hypothetical vessel could easily operate 400 longline hooks driftnets. The catch rates during the exploratory fishing indicate that the daily catch rate would be $4 \times 237 + 11 = 960$ kg.

The catch rate could easily be pushed up by 20% i.e. to 1150 kg in a specialized fishery with appropriate gear and an experienced crew.

With 150 days of fishing and a shark price of 2.77 MRF/kg the gross revenue would be MRF 475,000. The operation would thus produce a yearly surplus of MRF 145,000 which is equivalent to nearly 30% of the invested capital-in other words, a proposition worth further consideration.

It is important to assess whether an assumption of 150 days of fishing and 180 days of total operation is realistic.

The breakeven point for revenue would be attained at 103 fishing days. The cost items would also need to be checked. A positive finding in this regard during the exploratory fishing was that the shark catch rate doesn't vary with distance offshore. This suggests that there is no need for boats to go far out-a fact that keeps the fuel bill down and makes it less streneous for the crew.

4.4 Comparison with the Commercial Pole and Line Fishery,

During the course of the exploratory fishing, *Matha Hari* caught an average of 108 kg of skipjack and 11 kg of yellowfin per complete gillnet set. Pole and line vessels operating inshore of *Matha Hari* in the same areas at the same times recorded an average catch of 539 kg of skipjack and 51 kg of yellowfin per day trip. At no time was the pole and line catch lower than the gillnet catch. (The pole and line data are based on monthly catch rates by atoll-the smallest unit of comparison

available). A word of caution, though. The catch rate by mechanized masdhonis (i.c. pole and line boats) in the atolls nearest to the areas of operation of Matha *Hnri* were twice the average pole and line catch rate for the Maldives as a whole in recent years. The catch rate of *Matha Hnri* would certainly have been higher under commercial conditions by (i) using a full set of nets (ii) by using only S-6" mesh nets and (iii) by avoiding fishing during the full moon. But it seems unlikely that the rates would even reach the national average of about 260 kg of skipjack per day.

Another factor to consider is that of quality of skipjack and yellowfin. A multi-day gillnetter can compete on quality, but this requires relatively short soaking time and careful icing.

It is concluded that drifting gillnets for tuna do not constitute a suitable alternative to the existing pole and line fishery.

5. CONCLUSIONS

Despite the rather limited fishing operations by *Matha Hari*, the Prime aims of the survey-to find out more about the status of pelagic fish stocks and the feastbility of operating multi-day gillnet-cum-longline offshore fishingtrips in the Maldivian EEZ-were to a large extent fulfilled. Much information on offshore tuna and sharks was collected. The new shark data are particularly valuable. As for the feasibility assessment, the survey clearly encountered many of the constraints to be faced by such an operation. The use of gillnet as an alternative to pole and line for catching tuna was shown to be unviable. Shark catches were high, and a preliminary assessment of the shark longline fishery shows good potential.

However, a realistic approach towards a regular and continuous supply of consumable itemssuch as fuel, block or crushed ice and fresh water necessary for medium range fishing operationsis essential. At present, the market for fresh fish in the Maldives is centralized at the Felivaru Canning Factory and the Male local fish market. As a result, it's difficult to operate in other regions where disposal of the catch is practically impossible at present. Therefore, careful consideration to the issue of catch disposal will be essential for the development of medium-scale fishing in the Maldives. The human crew factor is also very important. Are Maldivian fishermen prepared to work regularly on multi-day fishing boats-and at what price⁴? As noted by Engvall (1987) the development of the offshore fishery in Sri Lanka took 20 years to materialize from the time the potential was realized. From the admittedly limited data obtained during this survey it may appear that the time is not yet ripe for a similar development in the Maldives.

Tuna fishing has been the mainstay of the Maldivian economy for centuries. In recent years the Government has invested heavily in developing and improving collection, freezing and canning facilities, in order to increase export earnings (Saleem, 1987). Because of this enormous investment, and its traditional importance, the fishing industry of the Maldives is likely to remain focussed on tuna fishing in the foreseeable future.

Therefore, while the identification of 'new' fishery resources (such as pelagic sharks, reef fishes or beche-de-mer) is of course of great value to the country, the greatest developments are likely to be seen within the existing tuna fishery. The mechanization of masdhonis, starting in 1974, was a particularly important step since it more than doubled tuna catch rates (Anderson, 1987). Largely because of this, a steady decline in the number of active fishermen-attracted by higher wages and easier working conditions in other sectors such as tourism, transport and construction-has not led to a drop in total tuna production. Nevertheless, there is concern that if the number of active fishermen continues to fall; so too will fish catch. Any fishing method that can improve the tuna catch rate would then be very attractive. The results of this survey are therefore of value in allowing a comparison of gillnet and pole and line. The survey results indicate that even an improved gillnetting operation would not catch more tuna than the pole and line vessels: a negative finding, but important nevertheless.

One way in which tuna catch rates by the existing pole and line fleet might be improved is by the deployment of FADs. The Ministry of Fisheries has been conducting FAD trials for some time (Naeem, 1988). A more drastic departure would be to allow purse seining in the outer waters of the Maldivian EEz. This, however, would have other serious implications.

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Tuna species in the Maldives.





monsoon season (July—Nov.'88)

(Numerator: Cruise number. Denominator = Station number)

EXPLORATORY FISHING FOR LARGE PELAGIC SPECIES IN THE MALDIVES Technological Report

By Ali Waheed

Ministry of Fisheries and Agriculture, Republic of Maldives

1. THE FISHING BOAT

Initially a Ministry of Fisheries fishing boat was earmarked for the exploratory fishing operations. But BOBP staff who inspected the boat found that repairs and modifications required to make the boat seaworthy and suitable for the work would be expensive and take several months. Consequently a private 15m wooden boat *MA THA HA RI* was chartered on the understanding that the owner would repair and modify it as required. As the converted *Matha Hari* was to perform more than one task during the fishing voyage, an attempt was made to provide a deck layout that allowed smooth and simultaneous fishing operation of driftnets and drift longlines, with trolling being complementary and to be performed from and to the fishing ground. With these points in mind, the original specifications of the boat did not change significantly. They were as follows:

Length overall	—	15.6 m
Beam overall	—	5.0m
Draft max to DWL	—	1.65 m
Engine type	—	Yanmar HFD Diesel
Power		Continuous 125 hp
Cooling system	—	Water cooled
Propeller diameter	—	1.5 m
Speed	—	9kn
Fuel tank capacity		2400 1
Fresh water capacity		1000 1
Fish hold capacity		6 tons of fish in ice
Crew accommodation	—	8 persons
Navigation equipment	—	Satellite navigator
Communication equipment	—	SSB Radio/VHF Radio
Gear handling devices	—	Hydraulic net hauler
-		Hydraulic longline hauler
		Manual longline drum

a) General arrangement

The general arrangement also remained nearly unchanged (Fig. 1).

Below the deck, the forward compartment was used for crew accommodation. The compartment aft, the crew accommodation compartment, was used to store provisions, fishing boat and gear accessories. Aft to this compartment, an insulated fish hold was provided. The aft compartment was used as the engine room with fuel and a fresh water tank.

The deck house was located forward above the crew accommodation with its access from inside the deck house. In order to provide more deck space on forward and starboard deck and better crew accommodation, the deck house was offset on the port side of the boat. Besides steering, engine control, navigation equipment, toilet and cooking facilities, sleeping bunks were provided for two men. It was also designed to provide the skipper with a clear vision to steer the boat, observe the working deck and see what each crew member was doing during the fishing operation.

h) Deck Layout

Good fishing gear handling practices require that driftnets and longlines are hauled from as forward as possible and are preferably shot under power from the stern. This implies the need for a free deck space on the forward side, and for convenient and safe storage of fishing gear ready for shooting on the aft deck. Nothing, however small, should interfere with the smooth and swift operation of the fishing gear and of catch handling. An efficient working deck must also be as spacious as possible.

The offsetting of the deck house to the portside provided deck space on the forward starboard side for installing a hydraulic net hauler and for removing fish from driftnets while hauling and stacking fishing gear for shooting again.

Aft of the deck house, enough deck space was available for installing a hydraulic longline hauler and for removing the fish on the starboard side during hauling operations.

A deck bin was also provided on the portside to keep catch on deck for loading into the fish hold after completing the hauling operation.

At the centre and portside of the aft deck. space was provided for a removable fishing gear bin where driftnets and/or drift longline accessories were stored safely. ready for fishing.

Other free space around'the deck was used for the crew to safely handle fishing gear and catch.

c) Deck Equipment

A central mast with boom was provided for a rigging tackle to lift the catch and the trolling outriggers.

For hauling the drift longline with the hydraulic line hauler, a rail lead with one horizontal and two vertical rollers was provided and positioned on the starboard railing. It was made removable so as to stack it away when hauling driftnets with the net hauler.

For hauling a long fleet of nets or longlines of more than 2 and 10 kms respectively with this size of boat, a net and line hauler are an essential part of the deck equipment. Given the location of the installation and the large size of fish caught with driftnets, a hydraulically driven net hauler with wide rubberized sheaves mounted on a pedestal was selected and installed on the forward starboard side. (Fig.2) For hauling the drift longlines and heaving the catch on board, a hydraulically driven capstan-cum-line hauler was provided and installed on the central mast (Fig.3)

Handling and storing several kilometres of drift longline manually is tedious and hard work and requires deck space which is limited on a medium size boat. For this boat a manually operated drift longline drum with a capacity of about 10,000 m was constructed locally and installed on the aft starboard side for storing longlines and free running shooting operations. Fig.4 shows the drift longline drum and its position on deck.

2. FISHING GEAR AND METHODS

To exploit the known offshore large pelagic resources with this type and size of boat, driftnetting and drift longlining are the two most suitable fishing methods. Trolling is a complementary fishing method for use from and to the fishing ground.

a) Driftnets

6

The fishing trials to be conducted with this 15.6 m boat being exploratory in nature, designs of driftnet commercially proven in this region were to be used. The designs and specifications of driftnets given in Fig.5 were therefore based on the following criteria:

PA multifilament nylon was selected because of its proven cost-effectiveness for constructing driftnets for large pelagic species and its availability in the region. The superiority of the PA multi monofilament versus PA multifilament nylon netting for this fishery is still to be proven in this region.

Double weaver's knot which ensures good knot stability has therefore been specified for the netting. Single weaver's knots have not proved to be stable enough for large pelagic species driftnets.

For reinforcement of the top and bottom edge of the netting, a half mesh selvedge is used. In order to use the same twine size for all parts of the netting, it was made with a double twine of the same size as used for the netting.

Netting was made of medium-twist twine, because of its softness.

Nets of different colours are being used without significant technical justification. A widely used colour (light green) was selected.

For comparing catch efficiency of different mesh sizes, three mesh sizes were selected (125, 150. 180 mm stretched mesh).

For easy construction of driftnets, a depthwise knot direction was adopted.

Depth of nets for offshore driftnetting differs from one fleet of nets to another. For the Maldives trials, the deeper nets so far used in Sri Lanka were put to use. The stretched depth of nets of different mesh sizes was kept the same for easy comparison. Likewise. the length of nets (1000 meshes) was kept the same regardless of mesh sizes, for easy reference to design and specification of nets.

The hanging ratio (length of framing line : stretched length of netting) ranges in the commercial fishery from 0.50 to 0.60. A hanging ratio of 0.55 within that range was adopted. It ensures good enmeshing or entangling of fish of different sizes.

Large PVC floats of 120 mm and 150 mm were selected, because of their cost effectiveness, ease of handling and local availability.

Galvanized steel rings were selected as ballast for similar reasons.

b) Drift longlines

Ocean-going drift longliners carry as much as 100 km of lines, which differ in design and specification according to fishing conditions.

The main difference between the deep-swimming tuna drift longline referred to above and the close surface shark billfish drift longline is that the float and branch lines are made much shorter so that the baited hooks hang much closer to the surface. This type of drift longline is successfully used by small offshore boats of Sri Lanka. Similar types of drift longlines were provided for this boat.(Fig.6).

The supply and quality of bait fish are very important for the success of drift longlining. Bait must be always available and of good quality. The pre-requisites ofdrift longline bait are freshness and hardbone, reducing drop off from the hooks. The most common species used – mackerel pike, squid and sardine. For shark drift longline, cut pieces of fresh blood fish are prime quality bait. In small boats of this class, bait fish is kept in ice or may be collected daily from the catch of driftnets and/or trolling lines when combined fishing operations are carried out.

c) Driftnetting-cum drift-longlining operations

On reaching the selected fishing areas, driftnets and drift longlines are generally put out for fishing before sunset. If drift longlines and driftnets are simultaneously used, the drift longlines will be shot first, then the driftnets after being attached to the last end of the drift longlines. When the laying of the drift longlines and/or driftnets is completed, the boat is attached to the last end of the fleet and kept adrift. The soaking time varies from 6 to 12 hours depending on the fishing conditions but never exceeds 8 hours for the driftnets and 12 hours for the drift longlines. Then hauling operations commence in reverse order - driftnet and/or drift longline. As the driftnets or drift longlines are hauled onboard, fish are removed from the nets, or hooks prior to restacking, and kept ready for shooting. The fish are kept in a deck bin till the hauling operation is completed and then transferred to the fishhold for preservation in ice.

d) Trolling

Trolling lines for small and large tuna are commonly usedby small-scale offshore fishing boats in Sri Lanka and Maldives. It may be used as the main fishing gear when shoals of tunas are spotted on the surface or as complementary fishing gear from and to the fishing ground. For this boat engaged in combined fishing operations, trolling was considered a complementary fishing method for use from and to the fishing ground. A maximum of six lines were deployed at a time on the portside outrigger and the stern.

d) Others

Multihook handlines were also rigged to catch squids attracted to the light of the boat as it drifts. **Pole** and line were also rigged to catch skipjack feeding near the boat.

CONCLUSIONS

Fishing operations of the Exploratory Offshpre Fisheries Survey lasted a total of 366 days. The following table details the duration of various activities:

	In Male	Out of Male	Total	
Fishing days		49	49	
Sailing to and from fishing ground		24	24	
Disposal of catch and buying supplies	11	33	44	
Sailing between operational areas		20	20	
Repairs	34	16	50	
Regular maintenace of boat	52		52	
Modification of boat	13		13	
Maintenance of fishing gear	8		8	
Poor weather conditions	12	7	19	
Crew shortage/sickness	20	1	21	
Holidays	56	10	66	
TOTAL	206	160	366	

Table 1:	Number of days spent by survey vessel "Ma	tha Hari" on different activities,
	1 December 1987 to 30 November 1988.	

Ship-to-shore communication between the boat, the Ministry of Fisheries and the Fish Purchasing Company (TEL) greatly facilitated the overall fishing operation of the boat.

To conduct this exploratory fishing operation, eight persons were required on board. The Fishery Biologist and the Assistant Fishing Technologist of the Marine Biological Research **Station were to collect** reliable biological data, ensure good operation of the fishing boat and gear arid mobilize **crew members to** operate and maintain the fishing boat and gears.

While the general arrangement of the boat was found suitable, the hull as well as engines and other equipment needed too many repairs, somewhat hampering the exploratory work programme. Of a total of 366 days of the survey, 115 days were spent on minor modifications, maintenance and repairs of the boat.

The deck layout and deck equipment worked very well and facilitated the work of the crew. Driftnets and drift longlines were handled simultaneously with ease by the crew, which over time improved the handling of the fishing gear.

The following table details the time spent for hauling and shooting of fishing gear during the earlier and the latter part of the project:

	Driftnets		Drift Longlines	
	Shooting	Hauling	Shooting	Hauling
First 5 operations (12/87-1/88)	73 mins	243 mins	47 mins	151 mins
Last 5 operations (11/00)	51 111115	162 111115	20111115	117 111115

The difference in time taken for the operations shows the changes in skill levels over a period of about 10 months.

The soaking time varies for fishing gear. Over the full period of fishing operations, the soaking time on an average was eight hours 50 minutes for driftnets and 12 hours 50 minutes for the drift longlines.

Each fishing gear was operated in the following depth range:

Trollinglines	:0 ₋ 1m
Driftnets	:2 _ 13 m
Shark drift longline	: <i>25—50</i> m
Tuna drift longline	: 60—100 m

The short term assistance provided by the BOBP Fishing Technologist and the Masterfisherman in preparing the fishing boat and gear and in training technical personnel was appreciated.



Exploratory fishing vessel used in the Maldives - the Matha Hari.



GENERAL ARRANGEMENT OF THE BOAT "MATHA HARI'









Fig. 5.

DESICN OF DRIFTNETS

All dimensions in mm unless otherwise stated.

E = 0.55



69-83-100 m PP Ø 4

E = 0.55





DESIGN OF DRIFT LONGLINES

All dimensions in mm unless otherwise stated.



EXPLORATORY FISHING FOR LARGE PELAGIC SPECIES IN THE MALDIVES

Biological Report

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1. BIOLOGICAL SAMPLING PROCEDURES

Length and weight of each fish. Small fish were measured on a \perp m measuring board, larger ones with a tape. Tunas were measured to fork length, billfish to lower bill-fork length, and sharks to total length. All measurements were to the nearest centimetre below. It was not always easy to weigh fish on the rocking vessel, and overestimation of weights may have been common. So, lengthweight relationships for skipjack and yellowfin, which are already well documented, are not presented. Most large sharks were weighed at the point of sale.

In general, this recording programme went well, with about 9.5% of all fish caught being measured. Further biological sampling was carried out only when a fisheries biologist was on board as observer. This was the case in over half of all stations (30 out of 49). The following information was recorded.

1.1 Sex of fish where it could be determined (i.e. not immature fish or some billfishes). Sex ratios are presented here in the form p males : q females (where $\mathbf{p} = 1 - \mathbf{q}$) so that approximations of 95% confidence limits can be estimated as follows :

C.I.of p and q = $1.96\sqrt{p.q/N}$

1.2 Gonad maturity stages for tunas, maturity stages of sharks and billfishes were not readily identifiable. It did not prove feasible to weigh gonads on board. The maturity of tuna gonads was recorded according to an approximate six point scale :

I -immature	IV -mature
II -early maturing	V -ripe
III -late maturing	VI -spent

1.3 Stomach contents : Skipjacks and yellowfins of all sizes were inspected but only small sharks were cut open because of the great loss in value if large sharks were opened. It did not prove feasible to weigh stomach contents, and these were roughly quantified by eye.

1.4 Information on any other non-commercial species.

I.5 Anything else of note, for example weather conditions, presence of fish schools and water temperature (only during the latter part of the project).

2. BIOLOGY OF SPICES CAUGHT

2.1 Skipjack

2.1. I Length frequency distribution

Length frequency distribution of skipjack caught in gillnets of three different mesh sizes during the northeast and southwest monsoons are given in Figures la and lb respectively. Fig.3 summarizes this data, and also presents data from the Maldivian pole and line fishery, for comparison. The following points are of note :

The northeast season catch had a distinctly bimodal length frequency distribution with modes at about 48 cm FL and 63 cm FL (Fig.1). The southeast season catch appeared to have a trimodal length frequency distribution, with modes at about 49 cm, 57 cm and 66 cm FL (Fig.2).

The gillnet catch by *Marha* Hari shows remarkable similarities in its length frequency distribution to that of the pole and line catch landed at Male (Fig.3-the only comparative skipjack data available from the Maldives). The same modes (plus or minus a couple of centimetres) can be identified in both data sets. The major difference is in the relative importance of these modes. The gillnet used would appear to slightly underestimate the abundance of small skipjack, while **the pale** and line technique appears to seriously underestimate the abundance of large skipjack. Maldivian fishermen do in fact say that large skipjack are much more difficult to land by pole and line than small skipjack.

The bimodal length frequency observed from December 1987 to April 1988 appears **to be a regular** feature of skipjack catches off the east coast of Maldives in the northeast monsoon season (Anderson and Hafiz, 1986, Hafiz and Anderson, 1988). The southwest monsoon season length frequency distributions were more variable but also appear to show some modes that are stationary **for** several months and are repeated year after year. For the skipjack catch as a whole (Fig.3, bottom) there is a relative scarcity of fish of 50-60 cm FL. Amarasiri and Joseph (1988) show that a **sub**-stantial proportion of the Sri Lankan gillnet catch of skipjack is within this size range. These **observa**-tions suggest that skipjack off the east coast of Maldives undertake constant large scale migrations.

2.1.2 Sex ratio and Gonad Maturity

A total of 419 skipjack was sexed-269 were male, 143 female and 7 were immature and of indeter**minute** sex. The estimated sex ratio for skipjack is :

$$0.65 + 0.05$$
 males: $0.35 + 0.05$ females.

There is a significant excess of males. This was' the case in both seasons, all three fishing zones, and all size classes. A preponderance of males in skipjack catches has been reported previously for both the Maldives and Sri Lanka (Hafiz, 1988; Amarasiri and Joseph, 1988). However, an excess of females has been reported for the Laccadives (Mohan and Kunhikoya, 1985). Whether this is indicative of latitudinal segregation is yet to be confirmed.

Gonad maturity data are summarised in Table 1. For convenience of presentation, immature fish

Fork	Gonad maturity stage					Total	
length (cm)	1	11	<i>III</i>	ĪV	V	VI	TULAT
< 34	2	-	-	-	-	-	2
35-39	3	1	-	1	_	-	5
40-44	2	8	8	7	-	-	25
45-49	-	3	14	32	1	-	50
50-54	-	1	8	16	2	-	27
55-59		-	3	17	7	-	27
6064	-	-	-	63	28	-	91
65-69	-	-	-	30	9	2	41
70-74	-	-	-	7	1	-	8
Total	7	13	33	173	48	2	276

Table 1: Skipjack sexual maturity

(a) Males and immature fish

(b)	Females	
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Fork		Gonad maturity stage					Total
length (cm)	Ι	II	<i>III</i>	ĪV	V	VI	TULAT
40-44	_	10	7	1	_	1	18
45-49	-	5	8	20	-	-	33
50-54	-	-	3	14	1	-	18
55-59	-	-	3	9	2	-	14
6064	-	-	-	34	5	-	39
65-69	-	-	-	9	10	1	20
70-74	-	-	-	1	-		1
Total	0	15	21	88	18	1	143

are arbitrarily combined with males. Data from both seasons and all three fishing zones are combined because there were no apparent differences between them. Ripe fish were observed in all months during which samples were taken, which suggests that spawning occurs year round. These data are presented also in Fig. 4, from which the lengths by which 50% of **skipjack reach** maturity are estimated to be within the following ranges:

 Males
 44 - 47 cm

 Females
 45 - 49 cm

The categorization of maturity stages is somewhat subjective so these estimates must be considered as rough only.

2.1.3 Stomach Contents

A summary of stomach contents from 423 skipjack is given in Table 2.77% of the skipjack examined had empty stomachs. For the remainder, raising the frequency of occurrence of food items by stomach fulness gives the following measures of importance of each major food category to the total diet:

Fish	70.7%
Squid	19.0%
Crustaceans	5.4%
Unidentified	4.9%

It was normally possible to identify fish remains because of their advanced stage of digestion, But, of the wide variety of prey species that were sometimes identifiable, flying fish (Exocetidae) were particularly common, and anchovies (Engraulidae), myctophids (Myctophidae) and file fishes (Monacanthidae) were noticeably abundant on a few occasions. The crustacean component was composed almost entirely of planktonic shrimps, notably euphausiids.

Table 2: Summary of tuna stomach contents

Stomach	Number of stomachs containing				
fullness	Fish	Squids	Crustaceans	Unidentified	IOLAI
0	-				325
1/8	9.5	11.5	4	1	26
1/4	17	8	1	-	26
112	13.5	2	2.5	2	20
3/4	7	0.5	0.5	-	8
Full	13.5	3.5	-	1	18
Total					423
Percent contribution	70.7%	19.0%	5.4%.	4.9%	100%

(a) Skipjack

(b)	Yel	lowfin

Stomach fullness) Fish	Vumber of <i>s</i> i <i>Squids</i>	tomachs contain Crustaceans	ing Unidentified	Total
0			-	-	34
1/8	2	3	1	-	6
1/4	2.5	5	1.5		9
1/2	3.3	4.83	0.83		9
3/4	4	1	-		5
Full	1	1			2
Total					65
Percent contribution	49.4%	43.7%	6.9%	0.0%	100%

2.2 Yellowfin Tuna

2.2.1 Length frequency distribution

Length frequency data are summarized in Fig. 5. The catch rate for yellowfin hy tuna longline was about half that achieved by Far Eastern longliners operating in the Indian Ocean in recent years (Suzuki, 1988). This may be due to chance, regional differences or the inadequate bait used during the survey. The gillnet and trolling lines tended to catch smaller surface swimming fish (average weight = 4.5 kg) while the longline caught larger deep swimming fish (average weight = 36.4 kg). The mean lengths of yellowfin caught by the different gears were :

Trolling line	50.3 cm	(SD = 2.5. n = 8)
Gillnet	58.2 cm	(SD = 15.1, n = 97)
Longline	127.5 cm	(SD = 22.8, n = 6)

2.2.2 Gonad maturity

Gonad sampling was done but almost all the yellowfin opened were immature.

2.2.3 Stomach Contents

A summary of stomach contents from 65 yellowfin is given in Table 2. Three major food categories contributed to the diet in the following proportions' :

Fish	49.4%
Squid	43.7%
'Shrimps'	6.9%

Fish remains were not normally identifiable, but in addition to flying fish, small tunas appeared to be a significant component of the diet. Squid formed a much more important component of the diet of yellowfin than skipjack (44% v. 19%). 52% of yellowfin sampled had empty stomachs, compared with 77% of skipjack. perhaps indicating more nocturnal feeding or slower gastric evacuation rates.

2.3 Bigeye Tuna

A single bigeye tuna, *Thunnus* obesus, was caught by shark longline in December 1987. It was a maturing (Stage II) male of 115 cm FL, weighing 29.0 kg. During the course of gut and gonad sampling during the SW season a note was made of liver morphology in order to distinguish juvenile yellowfin and bigeye. After some initial confusion over the pyloric caecae. all the fish sampled (n = 22) proved to be yellowfin.

2.4 Silky sharks

Nearly 70% of the sharks caught (by number) were silky sharks, *Carcharhinus falciformis*. The length frequency distribution of silky shark catches, by fishing gear and sex, is given in Fig.6. A distinctly bimodal distribution is apparent, with a relative scarcity of silky sharks of about 130-1 70cm TL. Since silky sharks weie caught fairly efficiently by both gillnet and longline it seems unlikely that this is due to gear selection. Size segregation as a result of differential migration may be involved.

In all size classes below 160cm TL more silky sharks were caught by gillnet than longline; for sizes larger than 160cm TL the opposite is true. The mean length of silky sharks caught by gillnet was 142cm TL and by longline 191cm TL. The mean length of silky sharks caught at different depths are listed below :

2-14.5m	(Gillnet)	142cm TL $(n = 119)$
23-30 m	(Shark longline Hooks l&S)	181 cm TL (n = 46)
33-48 m	(Shark longline Hooks 2&4)	190cm TL ($n = 37$)
38-54 m	(Shark longline Hook 3)	212cm TL $(n = 20)$

There appears to be a clear increase in size with depth, but there is considerable variability associated with these mean length estimates. Because the length frequency distribution of the catch is not normal, it is difficult to quantify this variability ; it is, however, large. Only four silky sharks were recorded as being caught by tuna longline. The overall catch rate by shark longline is estimated at

2.9 silky sharks per 100 hooks, while that by tuna longline is only 0.3 per 100 hooks. This may be due as much to differences in the bait used as to the vertical distribution of silky sharks (there are no significant differences in catch rates between hooks at different depths on the shark longline). The mean catch rate for the gillnet is estimated at 3.6 silky sharks per complete set.

The three smallest silky sharks (a 56 cm male, a 57 cm female and a 59 cm male) were all caught by gillnet in December 1987, 30 miles east of Male (Cruise 4). This is smaller than the sizes at birth quoted by most authorities, i.e. 70-87 cm (Compagno 1984; Randall 1986). It is possible that data on this one cruise were recorded incorrectly. However, the next smallest individual measured, a female of 63cm TL taken by gillnet in November 1988 30 miles cast of Lh.Atoll (Cruise 24). was definitely measured accurately.

From this limited data it appears that size at birth in this ocean may be smaller than in others, and that there may be a peak in November to December. More small silky sharks were caught during the NE monsoon (69% of silkys were less than 160 cm) than during the SW monsoon (19% less than 160 cm), and this is reflected in higher catch rates by gillnets in the NE season. The mean length of silky sharks caught during the NE season was 133 cm TL, while during the SW season it was 193 cm TL. There is no evidence of significant differences in the sizes of silky sharks caught in different areas. Catch rates were over three time's higher off the northern and central parts of the Maldives compared to the southern fishing area. This is a highly significant departure from random expectations (catch number chi squared = 26.9; df = 1; p < 0.01). Despite the low catch estimates achieved while fishing in the southern zone during the southwest season, the catch rate for the southwest season as a whole marginally was actually greater than that of the northeast season (5.3 silkies per day v.4.5). The reason for this was that the catch rate in the northern and central regions was higher. in the southwest season than the northeast (7.7 silkies per day v.4.5). This difference is significant (catch number chi square = 15.9; df = 1; p < 0.01). Note that these tests for significance in differences in catches between strata depend on an assumption that the silky sharks are distributed randomly within strata. This may not be true. During fishing operations it was sometimes observed that silky sharks catches tended to be clumped, three or four sharks being landed from a relatively short stretch of longline or gillnet.

The overall sex ratio of silky sharks caught by Matha Hari was 0.42 females: 0.58 ± 0.06 males (n = 234). This pattern was observed in both the NE and SW monsoon seasons. Sivasubramaniam (1969) also noted an excess of males in longline catches of C. falciformis for the north-central Indian Ocean.

A length weight relationship for silky sharks is illustrated in Fig.7. A total of 208 length-weight measurements were available but 5 were excluded from the analysis as outliers, leaving a total of 203 measurements for which the following relationship is estimated :

$$W = 8.174 * 10^{-6} L^{2.914}$$
 (r² = 0.98)

There may be a slight bias in this relationship, as a result of a tendency to overestimate the weight of small sharks (those of less than 10 kg were weighed on board the frequently rocking vessel) and to overestimate the length of big sharks (those over | metre in length were measured by tape, not board). Nevertheless it is probably a reasonable working relationship. A notable feature is that 'fat' silky sharks are commonly as much as 40% heavier than 'thin' silky sharks of the same length.

20 silky sharks were examined for stomach contents. Most were empty or contained only bait. The major components were the remains of fish and squid. Some pelagic crabs and Spirula shells were also recorded.

2.5 Oceanic white-tip sharks

The oceanic white-tip, Carcharhinus longimanus, was the second most common shark species caught, after the silky shark. Oceanic white-tips accounted for some 23% of shark catches by number. Most were taken by longline. This is in contrast to the silky sharks, an equal number of which was caught by longline and gillnet. Possible explanations for this difference include the following : oceanic white-tip sharks may be more readily attracted to baits than silky sharks; with their more leisurely swimming style oceanic white-tips may be less likely to blunder into gillnets than silkies; there may be differences in depth distribution between the two species. Far more

oceanic white-tips were taken by handline than any other species; individuals would quite frequently approach and slowly circle the vessel while it was drifting, by day or night, and they were then not too difficult to catch if good bait was available. In this respect they seem much more curious or loss cautious than the more common silky sharks.

Length frequency distributions by fishing gear and sex are presented in Fig.8. The length frequency distribution is roughly normal, with the modal length of about 160cm TL. The smallest individual measured was a 74 cm male, the largest a 263 cm female. Although all size classes are represented in both gillnet and longline catches there is some indication of vertical size segregation.

The mean lengths of oceanic white-tips caught by different gears are listed below in order of increasing mean depth of operation :

0-10m	(Handline)	149 cm TL (S.D. 27. n = Y)
2-14.5m	(Gillnet)	152 cm TL (S.D. 57, n = 13)
23-54m	(Shark longline)	165 cm TL (S.D. 47, n = 47)
65-101m	(Tuna longline)	186 cm TL (S.D. 46, $n = 8$)

While there is considerable variability in the data, there is a clear suggestion that larger sharks tend to be found deeper than small ones, on average. This possibility is further suggested by data from shark longline catches. Sharks caught on deeper hooks tend to be larger:

Hooks nos. 1 & 5	(depth 23-30m)	.151 cm	TL	(S.D.28,	n	=	18)
Hooks nos.2 & 4	(depth 33-48m)	155 cm	ı TL	(S.D.52,	n	=	18)
Hooks no.3	(depth 38-54m)	204 cm	n TL	(S.D.47,	n	=	11)

The overall sex ratio was 0.42 ± 0.11 males: 0.58 ± 0.11 females (n = 74). The excess of females was most noticeable within the length range 110-179 cm TL. Within this range the sex ratio was 0.29 ± 0.14 males: 0.71 ± 0.14 females, a significant departure from 0.5 : 0.5

Available length and weight data are summarised in Fig.7. From this data (n = 65) the following length-weight relationship is estimated:

 $W = 1.822 * 10^{-5} L^{2.780}$ ($r^2 = 0.98$)

2.6 Blue Sharks

The blue shark, Prionace glauca, was the third most abundant species, constituting nearly 5% of the total shark catch by numbers. A total of 17 blue sharks was caught, of which 16 were males - a clear indication of sexual segregation. Compagno (1984) noted that in the Atlantic, female blue sharks are more abundant than males at higher latitudes. Blue sharks are the most widespread of all sharks, being found from cool temperate to equatorial waters. But they are less abundant in the equatorial than other areas of their range. Sivasubramaniam (1969) noted that the blue shark formed only about 10% of the total shark catch in the Indian Ocean between 10° N-10° S but over 50% of the catch south of 20° S. Compagno (1984) suggests that blue sharks prefer relatively cool waters, and exhibit tropical submergence to avoid high surface temperatures. No blue sharks were caught by the relatively shallow gillnet. However, more (8 out of 17) were taken by the shallowest hooks of the longline than the deeper ones. The fact that the only female caught was taken by a deep hook (tuna longline hook 3, depth about 86-101m) suggests the possibility that sexual segregation could have vertical as well as horizontal components.

All the blue sharks caught were relatively large. The length frequency distribution is summarised in Fig.5. Of 17 specimens the mean total length was 244 cm (range 219-273 cm). Of 9 specimens weighed the mean weight was 46 kg (range 31 kg at 220 cm (female) to 56 kg at 273 cm).

There was no difference in catch rates between seasons, and differences in catches between areas are too small to warrant discussion.

2.7 Other sharks

Silvertip sharks, Carcharhinus albimarginatus, were only caught during the northeast monsoon season. There was some confusion in the recording of catches of this species since one of its local names (ainu miyaru means schooling shark) is shared with the silky shark. However, it seems that six specimens were caught, mainly by longline. All were large, between 205 cm and 233 cm in total length.

Four tiger sharks Galeocerdo cuvier were caught, all by longline in the northern fishing area. One of these was taken on cruise 11 in March 1988, during which biological data were not properly recorded and most sharks were not identified to species; it is therefore not recorded. They were a male of 300 cm TL. two females of 210 cm and 287 cm TLm and one of unknown sex and size. Three were taken in the northeast season, the other in the southwest season.

A single shortfin mako, Isurus oxyrinchus, was caught. It was a 150 cm TL female weighing 22 kg. It was caught by longline in the northern fishing area during the northeast monsoon.

In addition to these species taken during offshore fishing operations, juveniles of three other sharks were taken by night handlining while Matha Hari was moored inside the atolls between trips. These were the grey reef shark, Carcharhinus amblyrhynchos, the spottail shark, Carcharhinus sorrah , and the scalloped hammerhead, Sphyrna lewini.

2.8 Swordfish

Roughly 80% of the billfish caught was swordfish (Table 3). A total of 52 swordfish was recorded. Four were no more than heads, left after being eaten by sharks. These are not included in estimates of catch or catch rates. There were four billfish not recorded to species (Table 3). These were almost certainly swordfish and are included as such in the following estimates of catch rates.

The mean catch rate by gillnet was 0.29 swordfish per complete set (n = 12). For shark longline the mean catch rate was 0.64 swordfish per 100 hooks (n = 30) and for tuna longline it was 0.72 per 100 hooks (n = 9). There were some differences in estimates of catch rates in different seasons and areas, but these are not significant. The annual average catch rate was 1.14 swordfish per night.

The length frequency distribution of the swordfish catch is illustrated in Fig.9. All billfish were measured from the tip of the lower bill to the fork, a measurement known as body length (BL). The smallest individual measured was 45 cm BL, the largest 201 cm BL. There was a large proportion of juvenile swordfish in the catch. The median length was only 97 cm BL. There was no obvious pattern to the occurrence of juveniles, with small swordfish being caught in both seasons and all three fishing areas. The estimated mean lengths and weights of swordfish caught by different gears were :

Gillnet $(n = 9)$ Mean BL 120cm $(SD = 39)$ Mean W = 24.8kg $(SD = 25.2)$
Shark (n = 26) Mean BL = 97cm (SD = 21) Mean W = 10.8kg (SD = 8.5) longline
Tuna (n = 8) Mean BL = 87cm (SD = 21) Mean W = 7.7 kg (SD = 4.1) longline
All $(n = 37)$ Mean BL = 96cm (SD = 23) Mean W = 10.8kg (SD = 9.0) longline
All $(n = 47)$ Mean BL = 100cm (SD = 28) Mean W = 13.3kg (SD = 14.8) gear

Although there appears to be a tendency for larger swordfish to be caught on shallower gears, these differences are not significant. Indeed further analysis of shark longline catches shows that larger swordfish tended to be caught on deeper hooks; the differences are again not significant. It is concluded that there is no evidence of vertical size segregation within the depth range fished.

	Gillner	Longline	Handline	Total
Swordfish	10	41	1	52
Sailfish	4	1		5
Black Marlin	-	1	-	1
Blue Marlin	4	-	-	4
Unknown Marlin	1		-	1
Unknown Billfish	3	1	-	4
Total	22	44	1	67

Table 3: Summary of billfish catches

Note: These records are of total billfish catches and include four swordfish (one taken by gillnet and 3 by longline) of which only the heads were left following attacks by sharks. There is therefore a difference between the total in this Table and Table 4, which records only catches of useable fish.

Available length and weight data (n = 33) arc summarized in Fig.9. The following length-weight relationship for swordfish within the range 50-130cm BL is estimated. $W = 5.316 \times 10^{-6} L^{3.138}$

In all 16 swordfish were cut open for stomach content and gonad analyxis. Nine (56%) were empty or contained only longline bait. The rest contained an estimated 70% fish, 26% squid and 4% 'shrimp'. It was not possible to reliably sex or stage the gonads of the majority of the swordfish examined.

2.9 Sailfish

The five sailfish caught did not vary much in size - from 195-217 cm BL (mean = 210 cm BL) and 3232 kg in weight (mean = 37 kg). This is within the size range of sailfish normally landed at Male market by inshore fishermen (Anderson and Hafiz, 1986). Sailfish is considered to be more coastal in habitat than other billfishes (Nakamura. 1985). The relatively small contribution of sailfish to the total billfish catch (about 7%. see Table 16) during the offshore fishing survey compared to their contribution to inshore billfish catches landed at Male market (over 90%; Anderson and Hafiz, 1986) support this view.

Sailfish were represented in catches by gillnet and longline, from northern and southern fishing zones. and at 'inshore' and 'offshore' fishing stations.

3.0 Marlins

A total of six marlins were caught. One was a black marlin of 226 cm BL, four were blue marlins of 193-207cm BL (mean = 200cm) and 63-73 kg in weight (mean = 67kg). One marlin of 230 cm BL was not identified to species. The blue marlins were all caught by gillnet at two consecutive fishing stations (16/4 and 71/1) east of Laamu Atoll, in mid-August.

3.1 Other Species

The size range of the undamaged 13 individuals of rainbow runners was 43-93 cm FL (mean = 71 cm, SD = 16). Using data from these fishes plus additional data from Male, the following length-weight relationship for rainbow runner within the range 30-95 cm FL is estimated :

$$W = 3.714 * 10^5 L^{2.691}$$
 (r² = 0.99; n = 57)

Fourteen dolphinfish were caught. These were taken by the widest variety of gears of any species: trolling line, handline, longline and gillnet. Two individuals caught by longline were bitten by sharks leaving just the heads. The length range of the remaining 12 was 38-121 cm FL (mean = 84 cm, SD = 25). Using additional data from Male the following length-weight relationship for dolphinfish within the range 38-140 cm FL is estimated :

$$W = 4.992 * 10^{-6} L^{3.077}$$
 ($r^2 = 0.94$; $n = 18$)

Eight little tunas of size range 36-51 cm FL were caught by trolling line and gillnet. All were taken during the SW monsoon season. Eight frigate tunas of 1742 cm FL were caught by trolling line and gillnet. Two had been damaged by other fish. A single dogtooth tuna of 77 cm FL was caught by trolling line. This fish, as well as most of the others taken by trolling line, was caught close to an atoll, not out in the open ocean.

The fishes of no commercial value caught during offshore fishing operations were:

Pilotfish	Naucrates ductor	(F.Carangidae)
Little dolphin fish	Coryphaena equise1is	(F.Coryphaenidae)
Driftfish	Psenes cyanophrys	(F.Nomeidae)
Manta ray	Manta hirostris	(F.Mobulidae)
Manta ray	Mobula diaholus	(F.Mobulidae)
Snake mackerel	Gempylus <i>serpens</i>	(F.Gempylidae)
Escolar	Lepidocybium flavobrunneum	(F.Gempylidae)
Oilfish	Ruvettus pretiosus	(F.Gempylidae)
Tripletail	Lobotes surinamensis	(F.Lobotidae)
Ocean trigger	Canthidermis maculatus	(F.Balistidae)
Snipe eel	Nemichthys sp.	(F.Nemichthyidae)

Relatively large numbers of pilotfish and little dolphinfish were caught by gillnet. Length frequency distributions are summarized in Fig. 10.

A total of six-manta rays were caught, all by gillnet. Three were identified as Manta birostris (1.5-4m across) and one as *Mobula* diabolus (195 cm across). As there is no local market for mantas all were discarded, and are therefore not included in the catch summary.

Two Olive Ridley turtles *Lepidochelys* olivacea (35cm and 55cm carapace length) and one leatherback turtle *Dermochelys coriacea* (120 cm carapace length) were caught and put back in the sea. A single dolphin (species unknown) was entangled in the gillnet and used for longline bait.

Although not taken directly by any gear, flying fish and small squid appear to be very abundant in the study area. Not only did they occur regularly in tuna and shark stomach contents, but they were also attracted in substantial numbers by the lights of the boat while it was drifting at night. While they may be of little direct commercial interest (except perhaps as bait) they undoubtedly form a major component of the near-surface oceanic food web.

4. SEA SURFACE TEMPERATURES

The temperature of the surface water was recorded at 10 stations in the southern zone in August (mean = 29.5" C, SD = 0.33) and 13 stations in the northern zone in October and November (mean = 30.2" C, SD = 0.79). For all 23 stations the mean sea surface temperature was 29.9" C (SD = 0.71).

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. 1(a) Length frequency distributions of skipjack caught by gilinets of different mesh sizes, Dec. '87 to April '88



Fig. 1(b) Length frequency distributions of skipjack caught by gilinets of different mesh sizes, July Nov. 1988

Numbers of skipjack



Fig. 2 Proportions of different sizes of skipjack gilled by gilinets of three different mesh sizes

Vertical bars represent approximate 95% confidence intervals

Matha Han catches

Pole and line catches



'Matha Hari and pole and line vessels landing at Male.

Shaded areas denote catches by 'Matha Hari by gears other than gillnet



Fig. 4 Proportions of skipjack catch of different length classes that had reached maturity

Vertical bars represent approximate 95% confidence intervals



Fork length (cm)



Fig. 5 Length frequency distributions of yellowfin tuna and blue shark catches



Fig. 6 Length frequency distribution of silky shark catches



Fig. 7 Length-weight relationships for two shark species



Fig. 8 Length frequency distribution of Oceanic White Tip Shark catches



Fig. 9 Length-frequency distribution and length-weight relationship of swordfish catches.



Fig. 10 Length frequency distributions of two species taken as 'by-catch' by the gilinet

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