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Small-Scale Fisherfolk Communities

REEF FISH RESOURCES SURVEY IN THE MALDIVES

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REEF FISH RESOURCES SURVEY IN THE MALDIVES

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This paper describes exploratory fishing trials carried out for over a year (1986-87) in the reefs of North Male Atoll in the Maldives. The aim was to assess the potential for reef fish in the Maldives and study the possibilities of developing a viable reef fish fishery.

The paper provides preliminary information on various reef fish species, their abundance and rates of exploitation, and the the relative efficiency of various fishing gear that can tap the reef fish resource.

The trials were conducted in co-operation with the Ministry of Fisheries, Maldives, using a modified dhoni as survey vessel. Some staff were provided by the Ministry's marine research section, while the FAO made available the services of a master-fisherman and a fisheries biologist.

The exploratory reef fish project, and this paper which reports on it, were fuaded by the UNDP (the United Nations Development Programme), and carried out for the FAO by the BOBP or the Bay of Bengal Programme for Fisheries Development.

The BOBP began in 1979 and covers seven countries around the Bay of Bengal — Bangladesh, India, Indonesia, Malaysia, Maldives, Sri Lanka and Thailand. Its main goals are to develop, demonstrate and promote new ideas, technologies or methodologies to improve the conditions of small-scale fisherfolk in the region.

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

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1. INTRODUCTION

1.1 Summary

This report, based on an exploratory fishing survey carried out in North Male Atoll for over a year, offers some insights into the potential that reef fisheries holds for the Maldives. It gives a preliminary description of the reef fishery in this atoll and provides information on the biology of many reef fish species (size distributions, growth parameters, gonad maturity. mortality, stomach contents and parasites).

Length-weight relationships for many species were established and used to calculate commercial catch rates. The relative abundance of the various species was estimated and the exploitation rates for some of the more important species were derived by applying length-based methods.

Reef fish resources inside and outside the atoll appeared, from all this,to be considerable. Reef fish catch rates were also obtained for different gears (trap, handline and bottom longline) under various conditions. The trap was found to be an unsuitable gear for reef fishing in the Maldives.

1.2 **The territory**

The Republic of Maldives is an island nation in the Indian Ocean. southwest of India. It comprises of about 1.200 islands in 26 atolls. However, only some 200 of these islands are inhabited. The country stretches longitudinally in a double chain of islands, which are 100 km apart at the widest points.

The country's main sources of income are fisheries and tourism. And the two have links, as this study shows. The fisheries industry in the Maldives is mainly based on the catch of tuna and tuna-like species. Relatively less attention is paid to the exploitation of reef fish. According to available catch statistics, the production of reef fish was about 3,000 tin 1979, increased to 11.000 tin 1984, then gradually declined to 5.0(X) t in 1987. when it amounted to less than 9% of the total marine production.

1.3 The project

Given the large surface area covered by reefs, it was felt that there would he scope to increase the production of reef fish. The Maldivian Government therefore requested UNDP assistance in 1985 to assess the reef fish potential and study the possibilities of developing a viable reef fishery. In response to this request. the UNDP/FAO Reef Fish Research and Resources Survey Project (MDV/851003) commenced work in November 1986 under the umbrella of the FAQ's Bay of Bengal Programme.

The project planned to conduct an exploratory fishing survey to:

—identify suitable fishing gear to catch reef fish;
—enhance information on the biology and relative abundance of commercially important reef fish species; and
—determine the possibilities of developing a viable reef fishery.

2. **MATERIAL AND METHODS**

2A Fishing gear and vessel

During the preparatory period, 15 traps of the arrowhead type were fabricated. Five traps were covered with 1.5" galvanized mesh netting, five with PE 2.5 mm twine netting material of 50 mm stretched mesh and the rest had a lower compartment of different meshes so that selectivity experiments could be carried out. The purpose of the "double bottom" traps was to find out which species and sizes of fish were retained by the big mesh and which would escape from the trap when it was being hauled.

Two longlines of 4 mm PP material, each with 115 hooks, were prepared. Five traditional handlines with one hook, and five multi-hook handlines with two hooks, were also prepared and tried out. Annexure 1 presents detailed drawings of traps, handlines and longlines.

The survey vessel (Annexure 2) was a modified 'second generation' *dhoni* equipped with pothauler and echosounder. Four crew and three scientists were on board during most of the study.

2.2 Survey area **and environment**

Exploratory fishing was conducted mainly in North Male Atoll (Kaafu Atoll) and occasionally in Alif Atoll (An Atoll) (Fig.1). The average depth in the atolls is around *45* m, although there are locations with depths of over 60 m. The outer reefs facing the ocean are very steep, but the slopes of the reefs bordering the north-south Male inter-atoll channel are less steep and the depth here has been estimated at being about 250-350 m. (Stromme, 1983). The following habitats or hiotopes were distinguished:

- *Island reef* (ISL): A reef system around an island;
- *Ring reef(RR):* A reef system inside the atoll or at the rim of the atoll, its distinct feature a ring near the surface;
- *Patch reef* (PATCH): Reefs that do not form a ring close to the surface and which do not necessarily reach the surface;
- *Atoll rim channel* (ARC): The channel between two large reef systems that are a part of the atoll rim:
- *Atoll rim inner* (ARI): The reefs on the inside of an atolirim reef;
- *Atoll rim outer* (ARO): The reef complex outside the atoll, up to 200 m depth; and
- *Sand* (SD): Sandy bottoms (inside the atoll) between reef systems and at a considerable distance from the reefs. (It should he noted that in most of the cases the bottom type was not determined). A schematic cross-section indicating the various reef types is presented in Fig. 2.

E)uring the exploratory study, water temperature was measured at various fishing stations. Visibility depending on the time of day, was also determined, using a Secchi disc, during the first half of the survey. On some occasions, the current speed was determined when the vessel was anchored.

The temperature of the surface water varied between 27.8°Cand 30.2°Cand the average water surface temperature was 29.0°Cduring the study period. The average Secchi disc reading was 22 m, and the visibility was between 15 m inside a ring reef and 34 m outside the atoll.

2.3 Personnel and training

The project personnel consisted of the national project coordinator, two fisheries biologists! trainees, a fishing technologist/trainee and a shore manager/trainee of the Marine Research Section of the Ministry of Fisheries (and Agriculture, since December 1988). The crew of the survey vessel consisted of a captain and three deckhands. A masterfisherman was provided by FAQ. from July 1987 to February 1988, as well as a fisheries biologist.

Before starting the fishing survey, the crew of the research vessel and the Maldivian scientists were made familiar with the various fishing gear, the method of data collection and catch analysis techniques during fishing trials carried out from September 2, 1987 to October 29, 1987 (coverage 0). Amongst the things studied during these preliminary trials were the effects of soaking times of traps and longlines on catch and catch composition. The position of the various gear in relation to the reef types. the depths and trap-webbing material were also investigated. During this initial period. 25 cruises were made and 110 trap fishing operations, 10 bottom longline trials and six night-time handline fishing operations were carried out. Traps were set for 1,2,3,4, and 5 days, close to islands, ring reefs and on sandy bottoms inside the atoll, and on an island reef at the outer edge of the atoll. Longlines were set at different depths. in various biotopes and at different times of the day. During six night fishing sessions. fish were collected for identification and biological sampling purposes. Traditional and multi-hook lines were tried out.

During the trials, fishing stations (Figs.3a, 3h.3c) were selected making use of an echosounder to discover bottom characteristics and depth.

The positions of the fishing stations were initially determined with a compass and, later, with a sextant. The total surface of North Male Atoll was calculated, making use of graph paper on which a chart of the atoll was photocopied. The results of these estimates were as follows:

Surface area of entire atoll	—	1,47 km^2
Surface area of atoll rim reef systems	—	358 km^2
Surface area of reef and island systems		194 km^2
Surface area of bottom of atoll (including deep bottom reefs)		995 km^2

2.4 The survey and methodology

The actual survey started on October 29. 1987. Three latitudina' transects (1. 2.3) were done in North Male Atoll, each of them subdivided into an eastern component (transects 1E, 2E and 3E) and a western component (transects 1W, 2W and 3W). The vicinity of Male was called transect 0 and the northern part of Alif Atoll transect 4. The transects in North Male Atoll and Alif Atoll are shown in Fig. 1

North Male Atoll was covered four times, each transect being fished for approximately 10 days, during which time the traps were lifted and set twice. Fishing started in the south-western part of North Male Atoll, and each clockwise coverage was terminated in the south-eastern area. During the same period, handline and longline operations were carried out whenever weather conditions were favourable and bait fish available.

The transects were covered during the following periods:

29 October 1987	—	16 February 1988
17 February 1988		21 April 1988
04 June 1988	—	16 August 1988
17 August 1988	—	01 November 1988

Alif Atoll was surveyed **from** 17 to 19 February 1988 and from 16 to 19 July 1988. More cruises had been initially planned in Alif Atoll, hut weather and sea conditions made this difficult.

During the entire survey. 462 trap settings and 124 longline operations were carried out. Thirty-seven handline sessions at night and 11 during the day were also conducted.

Traps were set in various hiotopes at different depths and with various soaking times. These traps included baited ones (with 150—251) g of cut pieces of little tuna or frigate tuna) as well as unhaited ones. The depth of each was recorded using an echosounder.

Longlines were set under various weather conditions at several depths, baited with different types of bait fish (i.e. cut pieces of eastern little tuna, frigate tuna. yellowfin tuna, skipjack. scad and mackerel). After experimentation, the number of hooks was increased to 150 and two extra longlines were also prepared. At a later stage of the project. a monofilament longline carrying 300 hooks was experimented with.

During fishing operations the time of capture was noted. In water deeper than 45 m, line fishing was carried out with the help of manual reels.

All fish caught were identified, by referring to Fischer (1984), Campagno (1984). Carcasson (1977), Jones and Kumaran (1980), Gloerfelt-Tarp and Kailola (undated). and Anderson and 1-lafiz (1987). Catch data (weight and number of fish) were collected for each fishing method. Fishing depth. soaking time and type of habitant were also noted.

In order to determine the catch rate of commercially valuable fish, 25.0 cm (fork length) was chosen as a minimum size for species that could be so exploited.

During double-bottom trap trials, fork length measurements were made with measuring-board and measuring tape. and girth measurements with tape. Fish less than 1 kg were weighed on 'K' scales and larger fish on 16 kg and 100 kg balances. Fish retained by the big wire mesh of the double-bottom traps were kept well separated from the fish that escaped into the lower compartment. Besides the usual measurements, the body depth, width and girth of the fish were also taken.

Biological sampling was carried out on 5.078 fish of commercial value. Gonad maturity, gonad weight, stomach contents, parasites and otoliths were all studied. Gonad maturity was identified making use of a five-point maturity scale (Holden and Raitt, 1974). The Gonado-Somatic Index (OS!) was defined as (gonad weight/body weight) x 1000. Otoliths were cleaned, dried, wrapped and coded. The object was to collect three pairs of sagittal otoliths for each class of the different species of commercial value. In all, 1,192 pairs of sagittal otoliths were collected from 82 species. Sagittal otoliths collected from a specimen of *L. kasmira* were sent to an institute in Denmark where they were cut and photographed. Otoliths of several species *(Lutjanus bohar, Lethrinus rubrioperculatus, Caranx melampygus)* were also sent to a university in Spain for analysis.

The presence of parasites, internal as well as external, was recorded. The parasites, however, could not he identified because of lack of appropriate literature. Some varieties were preserved and sent to an institute in Australia for identification.

Information on fishing operations, biological sampling and otoliths were summarized on special data forms and cards.

Regular sampling of morning landings at Male market was started in March 1987. Sampling of catches.landed in the afternoon commenced in August 1987. The length of fish was measured with a measuring tape since the fishermen were reluctant to allow the fish to be handled.

Sampling of commercial landings was carried out in collaboration with a reef degradation study project being executed by the University of Newcastle-upon-Tyne on behalf of ODA (UK). Catch rates of the commercial fisheries were calculated making use of a computer programme specially designed for this purpose. Length-weight relationships to convert length measurements into weight were made use of to convert the total number of fish caught in kilo-weight of fish.

On some occasions, catches by contract fishermen were sampled at tourist resort islands. Some resort islands kept recoids of the number of fish purchased from contract fishermen. This information gave an idea of fish consumption at the resorts.

All information was compiled in databases on an IBM-compatible personal computer. Biological and fishing data was analyzed using the dbase 3+ program; length frequencies were analysed using the ELEFAN programs; and length-weight relationships were established for tape and board length separately, making use of the SPSS statistical program. After application of the length-weight relationships to 11,475 fish measurements, the mean weight was calculated. This weight was found to he 1.450 grams.

3. RESULTS

3.1 The initial trials

The initial trials not only enabled personnel to he trained, hut also indicated the best methodology to he used to get reliable results.

Although the number of experiments was relatively small, there was indication that the effective soaking time for traps should he at least four or five days. Another observation was that the number of dead fish did not increase when soaking time was longer than four days. Baiting of the catches seemed to have a positive influence on the catch (catch rate as well as composition).

Longline results were not very consistent and the number of trials was too small to draw conclusions. It was observed, however, that bait should be fresh and that soaking time should not exceed two hours.

It was felt that multi-hook type handlines performed slightly better than traditional ones, although more bait was required to operate the former.

3.2 The exploratory survey

3.2.1 *Catches and catch rates*

Catch details for each cruise, such as the number of fishing operations, total catch and commercial catch, coverage, overall totals and mean values are summarized in Table 1. In the following analysis, all results including those from the initial trials are considered, unless stated otherwise.

3.2.1.1 *Traps*

A total of 572 trap fishing operations were carried out from the beginning of the project. Catches varied considerably, depending on the soaking time, presence of bait, fishing depth, habitat etc. The total catch amounted to 1,057 kg of fish. The best yield was 34.2 kg; on the other hand, the traps were found empty in 184 instances. In all. 2,561 fish were caught alive; 133 fish were found dead. During the survey. 462 trap settings were made in the transects and they provided a catch of 618.! kg of fish.

Traps were operated in different habitats at different seasons and at different depths, for different durations, using various types of bait. The average catch per set in the different habitats is shown in Fig. 4. The highest average catch rate (3.4 kg/set) was obtained in habitats at the greatest distances from the reefs (SD) (irrespective of soaking time, depth, bait type, type of trap, season etc). It should be noted that no traps were soaked outside the atoll or in the atoll rim channels.

Table I: Exploratory Fishing Cruises, North Male and An Atoll, 1987-1988,
MDV/85/003

Cruise No.	Date/Period of Cruise	No. of Days	*Traps*			*Longline*			*Handline*		
			No. Set	*Total Catch (Kg)*	*Comm Catch (Kg)*	*No. Sets*	*Total Catch (Kg)*	*Comm Catch (Kg)*	*Effort Man hours*	*Total Catch (Kg)*	*Comm Catch (Kg)*
1	2/9/87	1							40	40.7	34.6
2	8/9	1							36.4	57.9	42.3
3	15/9	1									
4	16/9	1	3	0.1	0				42	49.7	40.5
5	17/9	1	3	0.5	0						
6	18/9	1	3	9.6	0						
7	19/9	1	3	0.4	0						
8	20/9	1	14	5.6	0						
9	21/9	1	2	2.9	0.4						
10	24/9	1	10	30.2	25.8						
11	26/9	1	4	9.8	7.5						
12	27/9	1				2	39.4	33.4	8.73	1.5	0.5
13	28/9	1	2	3	1.1	2	32.5	19.6	10	6.9	6.2
14	29/9	1	9	15.3	8.6						
15	30/9	1							25.33	61.3	56.9
16	3/10	1	5	28.3	16						
17	4/11)	1	4	15.9	6.4	2	36.2	12.7	1.67	4	2.7
18	6/10										
19	8/11)	1	7	40.1	26						
20	9/10	1				2	45	20.3	8	2.4	1.1
21	11/10	1				2	29.2	8.7			
22	14/10	1	8	105.6	79.1						
23	19/10	1	8	61.8	37.7						
24	24/10	I							30.75	39.1	31.7
25	26/10	1	7	42.9	30.3						
26	29/10—2/11	5	19	39.8	22	3	52.6	29.4	8.75	16	9
27	3/11	1	2	5.8	5.1						
28	9/11	1	2	6.9	3.7						
29	10/II	1	13	22.3	20.7	1	0	0			

Table I (Contd.)

Cruise No.	Date/Period of Cruise	No. of Days	*Traps*			*Longline*			*Handline*		
			No. Set	*Total Catch (Kg)*	*Comm Catch (Kg)*	*No. Sets*	*Total Catch (Kg)*	*Comm Catch (Kg)*	*Effort Man hours*	*Total Catch (Kg)*	*Comm Catch (Kg)*
30	14/11	1				1	9.6	9.6			
31	15/11	1	2	19.8	11.1						
32	17/11—19/11	3	13	13.6	6.8	6	287.1	127.3			
33	21/li	1	1	2.8	0						
34	23/11—24/11	2	13	30.6	20.4	2	81.8	58.8			
35	24/11	–							11.07	5.9	5.8
36	29/11	–	2	8.7	6.4						
37	29/11—1/12	2	12	23.7	10.2	5	108.4	76.5	12.50	26.1	17
38	5/12	1	2	1.7	0.4						
39	6/12—7/12	2	12	34.7	21.1	4	97.4	71.9			
40	9/12	1	2	11.3	0						
41	10/12	1							35.75	56.8	40.8
41A	14/12—17/12	4									
41B	8/1/88—9/I										
42	17/1—18/1	2				2	85.2	24.5			
43	21/1—23/1	3	14	10.9	9.3	2	22	19.2	18.25	26.2	24.3
44	25/1	1							15	14	6.8
45	27/1—28/1	2	14	27.5	23.2	2	31.3	22.8	7.5	4.9	3.1
46	31/1—1/2	2	14	11.3	5.6	2	25.3	11			
47	2/2	1							24	23.5	15.6
48	6/2—7/2	2	14	19.6	12.9	2	65.4	33.6			
49	11/2	1	11	13	6.7	2	58.2	26.3			
50	14/2	1				2	48	27.6			
51	16/2	1	10	24.2	18.8						
52	17/2—19/2	4				5	70.7	49.6	13.75	21.9	19.6
53	21/2	1	10	32.7	18.4						
54	23/2—24/2	2				3	188.6	171.3	5.5	11.6	11.6
55	27/2	1	10	22.5	15.5						
56	28/2	1	10			1	18.6	18.6			
57A	2/3	1									
57	3/3	1	7	4.7	1.5						
58	6/3	1							21.33	38.4	36.6
59	7/3	1				1	64.3	64.3			
60	8/3—10/3	3	7	3	1.6	5	103.7	62	11.25	45.3	38.9
61	13/3—14/3	2	7	7.5	1.3	2	59.2	34.4			
61A	16/3—18/3	3									
61B	19/3	1									
62	21/3—22/3	2	7	4.4	1.8	3	76.3	30.1			
63	26/3—27/3	2	5	5	2.2	2	61.6	54.4	4.5	7.2	1.1
64	30/3—31/3	2	6	5	2.3	3	36.2	22.5	2	0.5	0.5
65	31/3										
66	4/4—5/4	2	6	24.8	23.6	3	29	15.6	1.5	12.7	12.5
66A	7/4	1									
67	9/4—10/4	2	6	1.2	0	2	5.7	5.2			
68	12/4	1				1	29.3	29.3			
69	13/4	1									
69A	15/4	1									
70	16/4	1	5	2.9	2.9						
71	21/4	1	5	3.7	3.5						
71A	25/4										
71B	*3/5*	1									
71C	22/5										
72	30/5	1				1	51	50			
73	31/5	1				1	9.9	5.1	13.5	22	20.3

Table 1 **(Contd.)**

Cruise No.	Date/Period of Cruise	No. of Days	*Traps* No. Set	*Traps* Total Catch (Kg)	*Traps* Comm Catch (Kg)	*4ongline* No. Sets	*4ongline* Total Catch (Kg)	*4ongline* Comm Catch (Kg)	*Handline* Effort Man hours	*Handline* Total Catch (Kg)	*Handline* Comm Catch (Kg)
74	4/6	1									
75	7/6	1							8.25	17.2	16.8
76	9/6	1	6	1.5	0						
77	13/6—15/6	3	6	1.8	0.9	3	140.5	58.5	14	11.9	8
78	20/6—21/6	2	11	11.2	5	2	49.9	32.4	13.5	14.1	10.4
79	25/6	1									
80	28/6—29/6	2	11	21.1	7.6	3	56.4	43.2			
81	3/7—5/7	3	11	22	17	4	162.7	99.1	5.83	18.9	5.7
82	6/7—7/7	2	11	10.8	5.3	2	71.7	34	2.25	2.5	0.5
83	11/7—14/7	4	22	9.3	3.5	6	134.3	78.8	47.5	52	45.6
83A	15/7										
84	16/7—19/7	4	11	7.9		4	132.7	109	18.67	62.4	51.8
85	31/7—1/8	2	10	28	23.8	3	52.2	9.3	6.67	7.4	6.7
86	6/8—7/8	2	10	11	7.8	2	39	37			
87	10/8	1	10	16.2	13.4	2	19.3	17.5			
88	11/8	1							36	21.2	17.6
89	16/8	1	9	13	12.4	1	151.3	15.3			
89A	19/8										
91)	20/8—21/8	2	8	2	0	3	39.2	35.2	9.75	9.3	9
91	24/8	1	8	3.7	3.5						
92	27/8	1							18.33	10	6.4
92A	28/8—31/8	4									
93	1/9	1							35	23.5	17
94	3/9—4/9	2	9	18.4	4.7	3	94.3	84.8			
94A	6/9	1									
95	8/9	1	8	3.2	0.3						
96	10/9—11/9	2				1	68.4	68.4	12.67	117.7	18.7
97	14/9—15/9	2	8	10.1	3.5	5	196.8	138.5	2	3.5	3.1
98	18/9—19/9	2	8	2.2	1.1				3.75	3.2	3.2
99	21/9—22/9	2	8	1.9	1.2	3	43.3	21	6	0	0
100	26/9	1							15	16	15.6
101	27/9—28/9	2	8	3.8	3.5						
102	5/10—6/10	2				2	30.4	17.2			
102A	7/10	1									
103	10/10—11/10	2				2	37.2	19.2	7	4.4	3.8
103A	12/10	1									
104	16/10	1									
105	20/10	1									
106	25/10	1				1	132.6	130.5			
107	1/11	1				2	56.6	43.4			
Overall Total		180	538	1017	632.4	133	3667	2338	671.2	991.7	719.9
Average			1	1.89	1.17	1	27.57	17.58		1.48	1.07
Total Initial Period		25	92	372	238.9	10	182.3	94.7	202.88	263.5	216.5
Average			1	4.04	2.60	1	18.23	9.47		1.30	1.07
Total1stCoverage		49	172	328.2	204.4	41	1043	588.1	146.57	195.3	142
Average			1	1.91	1.19	1	25.44	14.34		1.33	0.97
Total2ndCoverage		34	81	117.4	74.6	26	672.5	507.7	46.08	115.7	101.2
Average			1	1.45	0.92	1	25.86	19.53		2.51	2.20
Total3rdCoverage		37	128	153.8	96.7	34	1071	589.2	166.17	229.6	183.4
Average			1	1.20	0.75	1	31.50	17.33		1.38	1.10
Total 4th Coverage		35	65	45.3	17.8	22	698.8	558.2	109.5	187.6	76.8
Average			1	0.70	0.27	1	31.76	25.37		1.71	0.70

The overall average catch rate was 1.9 kg per set, of which 63 per cent was of commercial importance. The mean catch rate by weight, total catch and weight of commercially valuable fish, by coverage, are presented in Table 2.

Table 2: Total catches **and average catch** rates **for traps** in **the** North Male **Atoll, according to** seasonal **coverages**
(in weight-g-or number per **trap operated)**

Trap inside atoll

Period Coy.	*Total catch weight (g)*	*Total no. of fish*	*Total comm. fish catch weight (g)*	*Total no. of traps settings*	*Average catch per trap (g)*	*Average no. of fish per trap*	*Average catch of comm. fish catch weight per trap (g)*	*Average no. of comm. fish per trap*
Sept – Oct 0	438914	728	267997	110	3990	6.6	2436	1.7
Oct–Feb 1	261281	807	175555	155	1686	5.2	1133	1.2
Feb – Apr 2	118325	391	73950	81	1461	4.8	913	1.0
Jun – Aug 3	154095	394	99690	126	1223	3.1	791	0.8
Aug–Nov4	84375	241	48145	100	844	2.4	481	0.5

Trap catch rates also appeared to vary with depth. From Figure *5.* it appears that the highest catch of commercial species is likely to be obtained between 40 and 49 m depth and next, between 30 and 39 m depth. The catch rate in absolute numbers shows that the largest number of fish was caught between 0 and 10 m, but the number of fish of commercial value was very small. From Table 3 it appears that the average catch rate of snappers and emperors is highest in the 40—49 m **depth range, while the highest average catch of groupers** is between 10 and 19 m depth.

Table 3: Trap catch rates and total catches by species group and depth ranges of fishing, irrespective of seasons and transects, in the North Male Atoll

(a) Catch rates (gltrap)

Trap inside atoll

Depth (m)	*Total catches*	*Snappers*	*Emperors*	*Groupers*	*Jacks*	*Sharks*	*Rest*
00—09	1341	45	0	223	0	0	1072
10 – **19**	**1331**	260	33	438	0	0	*553*
21) – 29	1044	274	159	339	66	7	200
30 – 39	1462	302	404	292	0	58	400
40 – 49	2804	750	910	288	0	0	855
50 – **59**	841	267	192	0	0	0	382

(b) Catch weights (grams)

Trap inside atoll

Depth (m)	*Total catches*	*Snappers*	*Emperors*	*Groupers*	*Jacks*	*Sharks*	*Rest*
00 – 09	8050	275	0	1340	0	0	6435
10 – **19**	**17310**	**3385**	**440**	**5695**	**0**	**0**	**7190**
20 – 29	86705	22793	13206	28198	5490	600	16618
30 – 39	374279	77355	103476	74970	0	15000	102528
40 – 49	558021	149272	181189	57506	0	0	170254
50 – 59	12625	4005	2880	0	0	0	5740

The average total catch appeared to increase steadily up to six days and then declined. The catch rate of commercially valuable fish showed the same pattern (Fig. 6). The number of observations made for soaking time in excess of 10 days was insufficient to draw firm conclusions.

An average catch of 2 kg of commercially valuable fish, after six days' soaking, is relatively poor.

Although it was decided after initial experiments to bait the traps, it was observed that unbaited traps also caught fish. Use of yellowfish tuna and eastern little tuna as bait resulted in better catch rates. Traps baited with big-eye scad, mackerel, frigate tuna, skipjack and fusiliers gave catch rates lower than those of the unbaited traps. The number of traps baited with frigate tuna was much higher than those baited with other types of bait; some of these had been broken open by large predators.

Average catch rates by transects are presented in Table 4. From the trap catch data available it may be concluded that the catch rate in the vicinity of Male was considerably higher than in the other transects. The mean total catch rate by weight for transects I and 2 are more or less similar, but for transect 3 the average catch rate is lower. In the case of the catch close to Male, it should be noted that the results are based on the initial trials which covered just one period, while the values for the other transects are the averages of four coverages.

Table 4: Average catch rates and catch per trap according to the transects covered in the North Male Atoll, irrespective of seasons (in weight-g-or number per trap operated)

Trap Inside atoll

Transect	*Total weight* (g)	*No. of fish*	*Comm. fish weight* (g)	*No. of trap settings*	*Avg. catch per trap* (g)	*Avg. No. of fish per trap*	*Avg. comm. fish per trap* (g)	*Avg. No. of comm. fish per trap*
0	438914	728	267997	110	3990	6.6	2436	1.7
1W	125825	416	81480	80	1573	5.2	1019	0.8
2W	117740	331	60775	79	1490	4.2	769	0.9
3W	100820	389	45325	82	1230	4.7	553	0.8
3E	67875	201	49215	80	848	2.5	615	0.6
2E	107250	236	85245	73	1469	3.2	1168	1.0
IE	98566	260	75300	68	1450	3.8	1107	1.2

Calculation of catch per day of soaking was considered inappropriate since the catch rates were rather low.

As mentioned earlier, traps were found empty in 184 instances. The reasons for empty traps could be the following:

- Predators breaking into them.
- Traps being placed sideways or obliquely on the bottom.
- While being hauled up, a trap could rip open on the reef, resulting in fish escaping from the trap.
- During the soaking period, big fish (presumably sharks and groupers) may enter the trap through the entrance funnel or the webbing and escape through the webbing; most such "cannon shot" holes were found close to the bait pouch and, in one case, two big holes were found, one entrance and one exit.
- Traps being hauled up and emptied by outsiders.
- Traps being hauled up with the door open.

3.2.1.2 *Set bottom longlines*

A total catch of 3,763.2 kg was obtained from 134 longline operations carried out at various depths, times of day and in different biotopes. Soaking time, number of hooks and type of bait were also varied. During the actual survey, 3,581 kg of fish was caught in 124 longline experiments.

Longline fishing was initially tried out inside the atoll, but, later, trials were also done outside the atoll at greater depths. Fishing inside the atoll was performed between 12 and 65 m, depending on the type of habitat, while outside it was done between 20 and 210 m depth.

It was intended to set longlines on an even bottom with only small variations in depth, but, in practice, this was difficult, although the depth contours in the area were investigated with an echosounder before shooting the longline.

While the overall average catch rate for all longline operations was 28.1 kg/operation, only 17.1 kg/operation was of commercial value (61%). The lowest average catch rate, 17.4 kg/set, was observed in the channels that offered access to the atoll. The average catch rates on the outer and inner sides of the atoll rim reef were 36.3 kg and 21.4 kg per operation respectively, but with larger variances. Very good catches were recorded outside the atoll, between 140 and 170 m as well as between 75 and 95 m depths. Inside the atoll, at relatively large distances from islands or reefs reaching the surface, the average catch rate recorded was 29.8 kg per operation. All these catch rates were irrespective of soaking time, the number of hooks and the time of year. Total and commercial catch rates, however, have been calculated for 100 hooks and are presented by transects in Fig. 7a.

Average catch rates for commercial fish for the various habitats ranged between 6.9 kg and 17.6 kg per 100 hooks, while the total number of fish hooked ranged between 4.6 and 8.4 per 100 hooks (Table 5a). The peak catch was for a soaking time of 90 minutes. The catch rates inside and outside the atoll showed relatively similar variations with depth; but the outside being deeper, the higher catch rates were realised on the outside, at depths of 80—100 m (Table Sb and c).

The possible relationship between the catch rate and the time of day was also investigated. The starting time of the operation was used to correlate with average catch rates. It appears that total catch rate was highest for operations started between 7.30 and 9.30 a.m., while the best catch rate for commercial species was when operations were started between 9.30 and 11.30 a.m. It should be noted that these operations did not cover the full 24-hour cycle.

Figure 7 shows catch rates of commercial species by depth range inside as well as outside the atoll. Inside the atoll, the.catch rate increased slightly with depth, while outside the atoll a clear peak was observed between 80 and 100 m depth. The number of experiments carried out at depths greater than 100 m was too small to draw conclusions.

The monthly average catch rate of commercial species, irrespective of depth, habitat, type of bait and transect, does not appear to exhibit any seasonality trend (Fig. 8).

The monofilament longline was operated only four times. The catch rate of commercially **valuable fish it yielded was only between 4.8 and 6.2** kg/100 hooks, which was less than that of the standard bottom longline. Besides a lower catch rate, the operation was much more labour-intensive. This type of longline had 300 hooks, instead of 150; whenever it snagged on the reef, the short distance between the hooks gave rise to risk of injury to any crew attempting to retrieve the line. Consequently, this gear was abandoned.

During the two trips to Arif Atoll, five and four longline operations were conducted respectively with catch rates in the range of 1.2 to 1.5 kg/100 hooks during the first trip and between 7.0 and 29.2 kg/100 hooks during the second trip. During the latter period, very large-sized snappers and emperors were caught.

3.2.1.3 *Handline*

Forty-three handline sessions at night and 16 during the day were carried out with operators of varying skills in different habitats at depths ranging from 10 to 40 m. A total of 933 kg of fish was caught during 620 hours of night fishing and 61.4 kg during 51 hours of daytime operations.

Table *5(a):* **Catch rates for bottom longline operations in different habitats in North Male Atoll, irrespective of** seasons **and transects covered**
(in kg/i® hooks)

Reef Type	*Total catch (g)*	*No. of fish caught*	*Comm. fish weight (g)*	*No. of longline operations*	*Avg. catch per operation (g)*	*Avg. No. offish per operation*	*Avg. weight ofcomm. fish per operation (g)*
ISL	77631	38	56434	6	12939	6.3	9406
RR	366851	100	134439	16	22928	6.3	8402
PAT	275292	122	182954	18	15294	6.8	10164
ARC	186766	74	117169	16	11673	4.6	7323
ARI	152622	66	76436	11	13875	6.0	6949
ARO	642851	244	510298	29	22167	8.4	17596
SD	708343	236	396762	38	18641	6.2	10441

Table *5(b)* **and (c): Bottom longline catches and catch rates inside (b) and outside (c) the North Male Atoll, according to fishing depth**
(in weight-g-or number per **operation)**

(b) Inside Atoll

Depth (m)	*Total catch (g)*	*No. of fish caught*	*Comm. fish catch (g)*	*No. of operations*	*Avg. catch per operations (g)*	*Avg. No. offish per operations*	*Avg. catch comm. fish per operation (g)*
15 – 29	309727	126	205325	17	18219	7.4	12078
30–39	117125	67	74590	8	14641	8.4	9324
40 – 49	1474955	495	741695	54	27314	9.2	13735
50–59	664671	243	359385	21	31651	11.6	17114
60 – 69	138050	41	79500	4	34513	10.3	19875

(c) Outside Atoll

Depth (m)	*Total catch (g)*	*No. of fish caught*	*Comm. fish catch (g)*	*No. of operations*	*Avg. catch per operations (g)*	*Avg. No. offish per operations*	*Avg. catch comm. fish per operation (g)*
15 – 29	29216	8	8716	2	14608	4.0	4358
30—39	0	0	0	0			
40–49	28730	10	13780	2	14365	5.0	6890
50–59	11250	3	5800	1	11250	3.0	5800
60–69	14250	10	10850	2	7125	5.0	5425
70 – 79	108140	43	72220	4	27035	10.8	18055
80—89	537995	221	456425	**11**	48909	20.1	41493
90 – 99	79385	41	64885	2	39693	20.5	32443
100 – 129	20425	**15**	**18075**	1	20425	15.0	18075
130 – 170	229359	52	175439	5	45872	10.4	35088

Traditional single-hook and multi-hook handlines were used, baited with pieces of eastern little tuna or frigate tuna. Fishing took place when the vessel was anchored currents up to 2 knots were measured. While fishing, the time of capture for each fish was noted. The 37 night-fishing sessions and the 11 day-fishing sessions during the actual survey period resulted in 682 kg and 49.1 kg of fish respectively.

The total catch rates varied between 0 and 8.5 kg/line/hour. The average total catch rates by transect, inside the atoll, varied between 0.5 and 4.9 kg/line/hour, while catch rates of commercially valuable fish varied between 0.4 and 2.8 kg/line/hour (Table 6a). Average catch rates outside the atoll ranged from 0.8 to 4.3 kg/line/hour for all species combined and from 0.8 to 3.5 kg/line/hour for commercial species (Table 6b). Overall catch rate was 1.8 kg/line/hour of which 1.3 kg/line/hour was of commercial value (71%).

Occasionally, while soaking longlines during the day, handline fishing was also carried out in waters up to 45 m depth. Lines on manual reels were used in waters deeper than 45 m. Fishing was generally of short duration.

Manual reef fishing could not be conducted outside the atoll on more than two transects due to sea and weather conditions. On these two transects, the catch rate was between 0 and 3.7 kg/line/hour. Average day time catch rates outside the atoll, however varied between 1.6 and 1.9 kg/line/hour. Catch rates for all types of handline operations inside the atoll varied between 0.3 and 6.3 kg/line/hour. Inside the atoll, average day time catch rates were in the range of 0.3 to 4.0 kg/line/hour. Almost all operations with manual reels were carried out while drifting. While fishing in deep water (outside the atoll), it appeared as though the position of the vessel was changing continuously due to the current.

Table 6(a) and (b): Handline catch rates in transects, by day (a) and night (b), inside the North Male Atoll (in weight-g-or number per fishing operation)

(a) By day

Daytime handlining inside atoll

Transect	*Catch per operation Total (g)*	*Catch per operation Total (number)*	*Catch per operation comm. fish (g)*	*CPUE of comm. fish (number)*	*No. of operations*
O	394	0.8	319	0.4	4
1W	4225	4.5	4008	4.0	3
2W	1306	0.8	928	0.6	1
3W					0
3E	1983	1.8	1425	1.4	4

(b) By night

Night time handlining inside atoll

Transect	*Catch per operation Total (g)*	*Catch per operation Total (number)*	*Catch per operation comm. fish (g)*	*CPUE of comm. fish (number)*	*No. of operations*
O	736	2.6	412	0.7	3
1W	801	*1.5*	483	0.8	4
2W	522	0.9	444	0.7	1
3W	2045	2.1	1021	1.5	4
3E	1068	1.2	809	0.9	7
2E	4881	3.7	2783	3.1	4
1E	621	0.9	536	0.6	1
4	1709	2.3	1558	1.5	2

The handline catch rate variation with depth was highest at 50—60m depths inside the atoll. Outside the atoll, the catch rates were much higher, being more or less uniformly high from 10.-60 m, but they declined thereafter (Table 6c).

The monthly average catch rates of commercial species, for the entire survey period, are presented in Fig. 9. It should be noted that the peak in April is based on just one observation. The average catch rates from exploratory fishing seldom exceeded 2 kg/line/hour for all types of lines.

Only in a few cases were the catches by traditional handlines and multi-hook ones kept strictly separate. On one occasion the average catch rates for multi-hook and traditional handlines were 1.6 kg/line/hour and 1.0 kg/line/hour respectively; on another occasion they were 2.7 kg/line/hour and 0.8 kg/line/hour respectively. It should be noted that the former used more bait (not quantified because of individual differences in fishing effort). It was observed that crew members and Maldivian scientific staff preferred to use the traditional handline, since less entanglement occurred. Three.night-fishing sessions took place during two trips to Alif Atoll and the catch rates varied between 1.4 and 3.4 kg/line/hour.

Table 6(c) and (d): Handline catch rates in transects, by day (c) and by night (d), outside the North Male Atoll (in weight-g-or number per fishing operation)

(c) By day

Daytime handlining outside atoll

Transect	*Catch per operation Total (g)*	*Catch per operation Total (number)*	*Catch per operation comm. fish (g)*	*CPUE of comm. fish (number)*	*No. of operations*
O	**2339**	**3.0**	1.633	1.2	1
1W	**1933**	**1.3**	**1.933**	**1.3**	**3**

(d) By night

Night time handlining outside atoll

Transect	*Catch per operation Total (g)*	*Catch per operation Total (number)*	*Catch per operation comm. fish (g)*	*CPUE of comm. fish (number)*	*No. of operations*
O	**1339**	**2.1**	**1145**	**1.7**	**16**
1W					0
2W					0
3W	4022	3.3	3456	2.5	1
3E	840	0.3	840	0.3	1
2E					0
1E					0
4	4253	3.3	3427	2.6	1

Table 6(e) and (f): Handline catch rates for total fish catch and for commercially valuable fish catch by depth ranges, inside (e) and outside (f) the atolls

(e) Handlining inside atoll

Depth range (m)	*Total catch (g)*	*Total catch (number)*	*Comm. fish catch (g)*	*No. of operations*	*Catch per operation Total (g)*	*Catch per operation Total (number)*	*Catch per operation comm. fish (g)*	*Catch pen operation comm. fish (number)*
10–29	95075	116	62520	9	10564	12.9	6947	8.4
30–39	242345	275	110995	18	13464	15.3	6166	7.6
40—49	59510	80	47535	9	6612	8.9	5282	6.2
50–59	24530	22	20190	2	12265	11.0	10095	7.5

(f) Handlining outside atoll

Depth range (m)	*Total catch (g)*	*Total catch (number)*	*Comm. fish catch (g)*	*No. of operations*	*Catch per operation Total (g)*	*Catch per operation Total (number)*	*Catch per operation comm. fish (g)*	*Catch per operation comm. fish (number)*
10–29	198599	274	171096	6	33100	45.7	28516	35.3
30–39	299418	493	247280	11	27220	44.8	22480	35.0
40–49	0	0	0	0	*****	***	*****	***
50–59	59555	74	46350	2	29778	37.0	23175	23.5
60–69	3898	5	2721	2	1949	2.5	1361	1.0
70–79	0	0	0	0	*****	***	*****	***
80–89	7350	5	7350	1	7350	5.0	7350	5.0
90—99	0	0	0	0	*****	***	*****	***
100–129	4250	3	4250	1	4250	3.0	4250	3.0

3.3 Species composition

The most common fish caught by handline was *L.gibbus* (25.6% of total weight) followed by *L. bohar* (Table 7). The latter was the fish (18.8% of total weight) most caught by longline and was followed by *A. virescens* among longline catches. The best trap catches were *L. elongatus* (15.7% of total weight) and *L. rubrioperculatus.*

The following table and Figs. lOa, b, c and d provide a revealing picture of the break-up of fish catches by the way they were caught.

Fish	*Handline*	*Longline*	*Trap*
L.gibbus	25.6	0.07	4.34
L. bohar	12.46	18.82	10.63
A. virescens	4.27	18.75	2.28
Loxodon macnorhinus	1.36	14.05	–
Nebniusferrugineus	11.17	3.34	–
L. elongatus		6.22	15.69
L. rubrioperculatus			11.66

Table 7: Percentage composition and price ranges of some of the important species with over 1% contribution to catches during the survey and during commercial landings

Species	*Survey Catch*				*Commercial Landings*	*Price ranges according to size (MRF)*
	Handline	*Longline*	*Reel*	*Trap*	*Handline*	
Aphareus rutilans	0.05	0.78	7.05	0	1.0	
Aprionvirescens	4.27	18.9	15.5	2.3	17.1	5-35
Caranxmelampygus	0.6	0.1	0	0.5	4.8	10-180
Cararrgoides orthogrammus	0.2	0	0	0	1.1	
Caranxsexfesciatus	2.5	0.0	0	0	2.5	8-80
Caranx ignobilis	1.05	2.0	0	0	2.0	15-100
Carcharhinusspp	0.5	2.8	0	0	3.0	5-10
Carcharhinuswheeleri	1.2	1.05	0	0	0.2	
Cephalopholis sonnerati					1.0	
Coryphaena hippurus					1.5	
Diagramma pictum	0.3	0.1	0	4.1	–	
Elagatisbipinnulata	0.2	0	11.3	0	7.9	12
Epinephelusareolatus	0.1	0.5	2.1	0.1	0.1	
Epinephelusfuscoguttatus	0	0	0	0	0.2	
Epinephelus multinotatus	0.1	0.6	2.6	0.8	0.4	3-12
Epinephelusepestictus		1.3	0	0	–	
Epinephelus milians	0	1.1	4.7	0	–	
Epinephelusmicrodon	1.1	0.03	0	1.1	0	
Euthynunus affinis	–	–	–	–	11.8	20
Gymnocraniusrobinsoni	0.5	0.8	4.2	0.2	0.1	
Gymnosardaunicolor	1.0	0.0	0	0.0	3.6	20-6
Lethrinusconchyliatus	0.76	1.14	10.9	0.4	0.1	
Lethrinus elongatus	1.42	6.2	5.6	15.7	2.1	50
Lethrinus pink stripe	2.1	0.1	3.22	0.1	0	
Lethrinusrubrioperculatus	2.45	0.75	0	11.66	0.7	2-5
Lethrinusxanthochilus	1.85	0.56	0	0.4	1.2	10-15
Luxodonmacrorhinus	1.3	14.0	6.6	0	0.1	
Lutjanusbengalensis	0	0	0	1,74	–	
Lutjanus bohar	12.46	18.78	0	10.63	1.7	1-50
Lutjanusgibbus	25.61	0.1	0	4.3	0.1	1-10
Lutjanus biguttatus	0	0	0	0.5	–	
Lutjanuskasmira	1.9	0	0	3.2	–	
Marlin spp	–	–	–	–	5.4	
Nebriusferrugineus	11.17	3.33	0	0	–	
Plectropomusareolatus	0.5	0.4	0	1.9	1.1	
Plectropomus laevis						
Pinjalo lewisi	0.35	0.54	0	7.1		
Platax orbicularis	0.75	0.3	0	0	–	
Plectorhynchus orientalis	0	0	0	0.4	–	12
Sphyraenaforsteri	3.9	0	0	0	2.0	2-15
Sphyraena barracuda					1.1	
Sphyraenaputnamiae	0.6	0	0	0	1.9	10-15
Sphyraena spp					1.2	
Variolalouti	1.06	0.06	0	0.16	0.3	
Wattsiamossambica	0	2.14	26.2	0	–	

Major Families in Commercial Landings	*%*
Carangidae	21.9
Carcharhinidae	3.2
Coryphaenidae	1.5
Istiophoridae	5.4
Lethnnidae	6.7
Lutjanidae	21.0
Scombridae	17.7
Serranidae	14.7
Sphyraenidae	6.2

3.4 Performance of the gear

3.4.1 *Traps*

Of 39 traps fabricated, 30 were lost for various reasons in a one-year period. At the end of the survey, only one of the first batch of traps were left. On three occasions, traps were inspected under water. Not all traps were positioned horizontally; some were kept above the bottom by coral heads. In one case, the actual trap depth did not correspond with the depth recorded at the time of setting (using echosounder).

Double-bottom traps caught 722 fish. Small species like *Chaetodon kleinii, Dascyllus tn-maculatus, Apolemichthys trimaculatus, Chromis weberi, Heniochus diphreutes, H. monoceros, Scolopsis bilineatus, Ctenochaetus* species, *Lactoria fornasini* and *Gnathodentex aurolineatus* escaped through the big mesh. Of the 123 specimens of *C. bengalensis* caught, 120 escaped, and the other three should have too. None of these species is valuable as food.

Species that are of low or no commercial value in the Maldives but which were retained by the big mesh because of their size included the large *Acanthurus bleekeri, A. xanthopterus, Rhynchos-tracion rhinorhynchos, Arothron hispidus, Alutera scripta, Sargocentron spiniferum, Poma-canthus imperator* and *Ostracion meleagris.*

In some cases the fish retained had not attained 25 cm in length, in other cases their sizes overlapped the size range of the fish that escaped. The fish that escaped through the big mesh were plotted by length class and some, for instance C. *melampygus, L. bohar* and *L. elongatus* (Fig. ha), showed a "knife-edge" selection. Others, such as *L. kasmira* and *L. rubrioperculatus,* did not show such a clear selection pattern (Fig. lib) and in these cases, selection took place over a relatively wider size range. This phenomenon was due to the level of expansion of the swim-bladder and, consequently, depended on the depth from which the trap was hauled up. Due to this reason, the pattern of retained and escaped fish is somehow disturbed. An explanation for the overlap of size ranges could be that the sizes of the big mesh wire varied between 48 and 52 mm and the diagonal .between 67 and 73 mm.

Echeneis naucrates and all *Chaetodontidae* (butterfly fish) exhibited a clear selection pattern. From the plots it will be seen that 50% of the escaping *L. kasmira, C. melarnpygus, L. elongatus, Chaetodontidae, L. bohar, L. rubrioperculatus* and *E. naucrates* were of maximum length 20.3 cm, 21.9 cm, 13.5 cm, 27.0 cm, 24.0cm and 53.5 cm respectively.

3.4.2 *Longline*

On several occasions, longline hooks got entangled with the reef and lines broke when hauled. In cases of breakages, the hauling was continued from the other end (longlines always had at least two buoys). If a longline broke at both ends it could not be retrieved.

In some cases, bait that had not been taken by fish appeared to contain sand on its surface. Underwater observations showed that the longline stood horizontally on the bottom, floats performed well, baited hooks hung down vertically. If the longline was set over a coral patch or outcrop, then some hooks were surrounded or hidden by coral; close to coral outcrops, numerous small fish nibbled at the bait (damselfish and triggerfish). It was also observed that if one or more sinkers were missing, the longline remained too far above the bottom. These observations were made when there was hardly any current. The behaviour of the longline when currents prevailed was not observed.

3.4.3 *Handline*

The difference between the two types of handline is the position of the sinker and the number of hooks. In case of the traditional handline, the sinker is positioned above the hook, while in case of the multi-hook line the sinker is positioned underneath the two hooks (Annexure 1). The advantage of the latter is that less lines get stuck on the coral reef. Although the catch rate of multi-hook handlines is slightly higher, the quantity of bait used is greater.

4. BIOLOGICAL INFORMATION

4.1 Size composition

Length frequencies obtained during the exploratory fishing were pooled according to gear used for *L. bohar, L. gibbus, A. virescens, L. elongatus, L. rubrioperculatus* and *L. macrorhinus.*

Size frequencies of various species caught by the three different gear are as illustrated in Figs 12 a-f. The composition of the *A. virescens* catch, both commercial and total survey, is shown in Figs. 13 a and b.

Traps caught wide-ranging sizes of snappers and emperors, but in terms of numbers the catches were not large enough for a proper modal progression analysis.

The average weight of fish caught on longline is distinctively higher than of fish caught by other gear (except for *E. areolatus* and *L. rnacrorhinus,* of which only few specimens were caught by other gear). In the case of *L. bohar,* it is interesting to note that the average weight of this species caught by handline was 1,115 grams, by trap 1,652 g and by longline 3,614g.

The same pattern was observed for *Aprion virescens,* viz 1,586 grams for handline, 1,857 grams for trap. 1.95() grams for reel and 2,701 grams for longline.

4.2 Growth and mortality

Length frequencies of *Lutjanus bohar, A. virescens, L. gibbus, L. elongatus* and *L. rubrioperculatus,* obtained from the sampling of survey commercial catches between March 1987 and October 1988 were analysed making use of the ELEFAN and Modified Wetherall method programs (Gayanilo, Soriano and Pauly, 1988). The growth parameters obtained are presented in Table 8. The growth curve for *L. bohar* indicates that it originated around November and a

Table 8: Summary of growth parameters and mortality rates obtained through length-based analysis

		ELEFAN-I Method		*Wethenall Method*				
Specie.s	*Data Source*	*Loo (cm)*	*K*	*Loo (cm)*	*ZIK*	*Z*	*M*	*E**
L. bohar	Longline (survey data)	82.0	0.31	79.3	2.192	0.68		
	Longline(surveydata)	83.0	0.295	79.3	2.192	0.61		
	Handline (survey data)	79.3	0.36	–	–	–		
	Handline (Commercial catch data) (Tape length) (1987/88)	85.5	0.35	75.5	*1.55*	0.54		
A. virescens	Commercial(86–88) Handline data	78.0	0.348	79.3	1.95	0.68	0.49	0.279
	Commercial (85) Handline data	78.0	0.348	79.2	1.397	0.49	0.49	–
	Commercial (86) Handline data	78.0	0.348	78,1	1.603	0.56	0.49	0.125
	Commercial (87) Handline data	78.0	0.348	87.2	3.679	–	–	–
	Commercial (88) Handline data	78.0	0.348	80.9	2.398	0.80	0.49	0.39
	SurveyLonglinedata	81.6	0.31	81.0	2.526	'0.78	0.49	0.37
L. gibbus	Handline (Survey data)	39.65	0.27					
	Trap (Survey data)	39.75	0.275					
	Handline + trap (Survey data)	36.35	0.37	35.95	1.096	0.41		
L. elongatus	Trap + longline (Survey data)	80.25	0.40	77.3	0.858	0.38		
		81.0	0.44	77.3	0.858	0.38		
L. rubnio-perculatus	Trap (Survey data)	36.6	0.30	36.8	2.232	0.67		

* E is the exploitation rate =

fish maturation peak occurred in December. It also appears that a growth curve of a second cohort perhaps originated around June. K and Lcd values obtained by the ELEFAN and Weatherall methods of analysis of the length frequencies of *A. virescens* collected from commercial landings between October 1985 and October 1988, are also presented in Table 8.

The Lcx values for 1985, 1986 and 1988 are reasonably similar, but the value for 1987 deviates considerably. It was assumed that the growth constant K did not vary very much over the study period and, therefore, estimates of Z, calculated by substitution of K (= 0.348) for 1985, 1986 and 1988, were 0.49, 0.56 and 0.80 respectively (Table 8). It is not known when the exploitation of A. *virescens* started, but it is likely that its level of exploitation in 1985 was relatively low or it was hardly exploited. If this assumption is true, then the natural mortality would be slightly less than, or equal to, 0.49 (assuming that no major migration took place; there is evidence that catch rates of this species at greater depth outside the atoll were much lower than inside the atoll) and the fish mortality in subsequent years increased to reach 0.80 in 1988.

ELEFAN and Weatherall methods of analysis of the length frequencies of the same species from exploratory longline fishing indicated that Z = 0.78 (Table 8). This value does not differ much from the Z value mentioned above for the commercial length frequencies for 1988 (viz. 0.80).

To help compare these estimates, growth parameters of these demersal reef fish from other parts of the world are summarized in Annexure 3.

Regarding the age and growth of these species, using the otoliths, the results were as follows:

The sagittal otoliths of a specimen of *Lutjanus kasmira* were removed, cleaned, dried and sent to Dr. Erik Steffersen of Denmark who cut the otoliths to find out whether reading them would be feasible. When interesting structures were found, it was decided to collect otoliths from the commercially important reef fish species. Thereafter, over 1,200 pairs of otoliths of snappers, emperors, groupers and jacks, up to a maximum of three pairs per centimetre size class, were collected in the North Male Atoll. An institute in Spain was then approached to read selected otoliths of *Lutjanus bohar, Lethrinus rubrioperculatus* and *Caranx melampygus.*

Dr. Beatriz Morales-Nm applied scanning electron microscopy to sagitally sectioned otoliths and found that the number of increments in one translucent and one opaque ring (which are visible with dissecting microscope), did not differ significantly from the number of days in a year.

The main obstacle to reading the otoliths was their shape. This shape made it difficult to obtain sections across the core that included all growth sequences. Various sections, therefore, had to be made of each otolith, making the procedure very time-consuming and expensive. Thereafter, using the age determinations arrived at by Dr. Morales-Nm, the dates of birth were calculated.

Species	*Length in cm*	*Date of capture*	*Age in days*	*Date of birth*
Lutjanus bohar	16.6	23.11.87	248	21.01.87
	38.5	19.11.87	1173	14.07.84
	67.5	30.09.87	2840	06.02.80
	73.0	24.09.87	3102	08.08.79
Lethrinus rubrioperculatus	19.4	17.09.87	735	14.09.85
	24.3	28.09.87	795	25.07.85
	33.6	02.11.87	1043	24.12.84
	35.1	23.11.87	1267	30.06.84
Caranxmelampygus	09.6	17.08.87	208	–
	09.6	17.08.87	350	–
	10.2	17.08.87	391	–

K is the growth function relative to the rate of growth and Loc is the theoretical maximum length to which the species is expected to grow. These parameters influence the annual rate of natural deaths (Natural Mortality Rate, M) and the mortality rate caused by fishing (Fishing Mortality, F). M+F adds up to Z, which is the total mortality rate of the fish.

These growth parameters also determine the longevity of the fish. Thus, the level of fishing effort on a species has different degrees of influence on the population depending on the rate of growth and maximum length or the life span of the fish. The population of short-lived species may tend to have a higher natural mortality rate than long-living species. Consequently the fishing mortality rate of the former could, by benefitting from the higher natural mortality rate, be made higher.

Some interesting observations may he made. Two specimens of *Caranx melampygus* of the same length appear to have significantly different ages; this might indicate that the method is unsuitable for age reading. On the other hand, when studying the *Lutjanus bohar* results, it may be concluded that two of the four fish were born in January and February and the other two in July and August. This corroborates the findings of the gonad maturity study of *Lutjanus bohar,* wherein Gonado Somatic Index peaks were found in December and June (See section 4.5). Unfortunately, the OSI picture for *Lethrinus rubrioperculatus* is not clear enough to draw any firm conclusion.

The results of this study of age and size are very encouraging and a further study of *Lutjanus bohar* otoliths may result in growth parameters which could then be compared with the results of the length-based methods.

4.3 Stomach contents

Each fish caught during the survey was investigated for its stomach contents; doctorfish, pufferfish, butterflyfish and triggerfish were excluded. The majority of the fish studied had empty stomachs. Fish caught in traps generally had empty stomachs; in cases where fish were found in the stomachs, the possibility of these having been preyed upon inside the trap could not be excluded. (Stomachs of some groupers and moray eels caught in the traps contained few snappers). Large snappers and groupers caught on the longline often had empty stomachs. This could have been because their stomachs were everted when the fish were being hauled to the surface. The stomachs of sharks often contained pieces of bait and even hooks.

The stomach contents of *L. bohar* were studied qualitatively. Out of 121 fish caught by handline, 23 appeared to contain one or more organisms. Thirty nine out of 195 fish caught by longline had some content in their stomachs and ten out of 68 specimens trapped also appeared to have some stomach content. Fish were found in the stomachs of specimens in the 16—70 cm size range, shrimp were found in fish of 34—67cm size range, other crustaceans in fish of size range 31—65 cm, octopus in fish of 62 and 64 cm length, a polychaet in a 35 cm long fish, bird feathers in a fish of 58 cm length and unidentified organisms in specimens between 41 and 73 cm length. From the overlap in size ranges it may be concluded that there is no preference for a particular food. Fish were found in stomachs throughout the year, shrimp from July to October and other crustaceans from July to February. Octopuses were observed in October and February. Commercially important snappers and emperors appeared to have preferred triggerfish as a diet.

4.4 Length-weight relationships

Using data from the exploratory fishing operations, length-weight relationships were established, both for measuring-board and tape-length measurements. The results for over 50 species and species groups are summarized in Annexure 4.

In several cases, the length range caught was relatively small (e.g. *Diagramma pictum, E. epistictus* and *S. caudimaculatum),* and it was not evident how much this could have influenced deviation from the standard factor 3 in the length weight relationship. Data for species belonging to the following genera have been grouped, and subsequently, analyzed: *Epinephelus, Ctenochaetus, Cephalopholis, Plectropomus, Variola, Myripristis* and *Sphyraena.* The results of the combined analysis for the *Epinephelus* species show a particularly better fit than for each of the individual species (this, however, may be the consequence of the small number of observations of several species).

4.5 Gonad maturity

The Gonado Somatic Index (GSI)[3] was calculated for all fish sampled and it was plotted for seasonal variations by size groups, for seasonal variations by sex and for GST variations with fish length.

The seasonal variations in the OSI by sex are illustrated for a few species in Figures 14a, b, c and d.

The estimated sizes at first maturity by sex, peak'[4] seasons of GSI and other size ranges which

2Standard factor 3 refers to the concept that, generally the weight of a fish is proportionate to the cube of its length.

The Gonado Somati! Index is an index of the degree of development of the ovary in females and of the testes in males.

4Gonado Somatic peaks are noticeable increases in the index (GSI) values and indicate size of a fish at a period when maturity or spawning is imminent, or size during its spawning period.

showed peak GSI during the seasons for *L. bohar, A. virescens, L. elongatus* and *L. gibbus* were as follows:

Species	*Size at first maturity*		*GSJ peak season*	*Other size ranges with GSI peaking*	
	male	*female*		*male*	*female*
L. bohar	32 cm	46 cm	Dec-Feb & June/Jul	50-59, 60-69	50-59 60-69
A. virescens	44 cm	37 cm	Jan-Feb & June/Jul	50-54 60-69	50-54 60-69 70-79
L. elongatus	42-44 cm	34-36 cm	April & Aug-Oct	50-59	60-69 69-70
L. gibbus	30-39 cm	30-39 cm	Jan/Feb & Jul-Sep	–	–

4.6 Sex ratio

The snappers were split into two groups, one group with the males predominant among the adults *(L. bohar, L. gibbus,* and *L. kasmira),* the other with the females predominant *(L. biguttatus, L. bengalensis* and A. *virescens).* The proportion of males in the *L. bengalensis* samples was very low.

All species of emperors exhibited a predominance of females. The proportion of males increased with size in most of the species *(L. rubrioperculatus, L. elongatus, W. mossambica, G. griseus).* The absence of this pattern in the other species *(L. conchyliatus, L. xanthochilus, L. "pink stripe")* was probably due to the relatively small samples. *E. spilotoceps* and *P. laevis* show a clear predominance of males in the largest sizes. No males were found among the 20 specimens of *P. areolatus* and among the 39 specimens of *E. miliaris.* Samples of *E. areolatus, E. microdon, C. miniata, C. sonnerati* and *C. argus* indicated a predominance of females.

No clear pattern was obtained in the case of *S. forsteri,* possibly due to the small samples in the larger size ranges. This is true of *C. sexfasciatus* too.

The sex ratio by gear for *L. bohar* was calculated and is summarized as follows:

	Female	*Male*	*Immature*	*Ratio*
Handline	42	49	26	0.86 : 1: 0.53
Longline	119	73	3	1: 0.61 : 0.03
Trap	19	21	28	0.68 : 0.75 : 1
Total	180	143	57	1: 0.79 : 0.32

It may be observed that males are predominant in handline catches, females in longline catches and immature fish (i.e fish whose sex could not be determined due to the small size of their gonads) in trap catches. The small number of immature fish in longline catches is remarkable.

Males predominated in handline catches during July, August, October 1987, from January to April 1988 and in September 1988. As far as longline catches are concerned, males were predominant in April and August 1988. Males and females were more or less equally distributed in trap catches.

The sex ratio of *L. gibbus* in handline catches (1: 1: 19) and in trap catches (0.92 : 1) did not indicate very significant differences.

4.7 Parasites

Some internal parasites taken from reef fish in the Maldives were identified by the Queensland Museum in Brisbane, Australia. Large cysts found in *L. gibbus* were caused by young, developing tape worms i.e. a plerocercus or metacestode belonging to the order of the Trypanorhinchida; these worms have very characteristic spiny eversible processes growing from their scolex. As adults, tape worms live in the intestines of sharks and rays. A study of their entire life cycle has not been completed, but the eggs, it is thought, are eaten by small crustaceans and the first juvenile stage develops in them. These juveniles are then transferred through the food chain to fish and then to sharks. The juveniles (also referred to as 'larvae'), it is stated, are quite harmless to man.

The tapeworms found in *L. gibbus* were identified as *Nybelinia* (family *Tentaculariidae)* and *Floniceps* (family *Dasyrhynchidae).*

5. EXISTING REEF FISHERIES IN NORTH MALE ATOLL

5.1 Male and vicinity

Reef fish are exploited in the vicinity of Male, where about ten *bokkuras* (row boats) land their catch between 0530 and 0730 every morning.

Each of these row boats is operated by one or two fishermen who fish during the night while drifting. These full-time fishermen fish from 8 p.m. to 3 am. The part-timers on the other hand, fish either from 8 p.m. to around midnight or from 3 a.m to 4 am, as they must get to the regular day-time jobs they hold. Sometimes, some of these fishermen make two trips a day. The times mentioned, it should be noted, are only indicative and vary with current, weather conditions and lunar phases.

The main gear used is the handline with a small sinker and a hook. The bait used is cut pieces of skipjack bellies, eastern little tuna, frigate tuna, barracuda or big-eye scad. Their catch mainly consists of *L. bohar, S. forteni, C. sexfasciatus, C. ignobilis* and, occasionally, *L. gibbus, A. viresens,* serranids and lethrinids.

Depending on the season, fishing rods are used by these fishermen to catch big-eye scad *(Selar crumenophthaltnus)* and round scad *(Decapterus macarellus).* The line, which is as long as the rod, has a small hook and is provided with a lure. While fishing for scad, fishermen often operate a handline with a live scad to catch large *A. virescens, Caranx* spp and *Sphyraena.*

Besides the *bokkuras,* small *dhonis* are also used in catching reef fish. They are manned by fishermen who go out during the day and use 'muguran' or live bait. The live bait is caught with special nets cast from a *dhoni* (moored close to a reef or patch of coral) by at least four fishermen, two on board the *dhoni* and two in the water who use snorkelling equipment. The rectangular net is set close to the bottom and 'muguran' are attracted into it with scraped fish flesh as bait. When the fish are above the net, it is rapidly hauled up. The species caught include *Anthias* spp., *Chromis* spp, pomacentrids and caesionids. Sometimes adult sturgeon fish *(Naso vlamingii* and *Acanthurus* spp) are also caught. Hauled on board, the bait fish are removed from the net and kept alive in the bait compartment of the *dhoni,* where exchange of water is possible. Catching bait usually takes two to three hours. Then, while drifting along the reefs, handlines are used with live bait to catch mainly *Caranx melampygus, Gymnosarda unicolon, Elegatis bipinnulata, A. virescens* and *L. bohar.* The fishermen search for these fish using glass-bottom boxes or diving masks and attract them by chumming.

Another type of bait used in this fishery is cut pieces of tuna. This tuna is caught by fishermen using trolling lines before they start handlining. It's mainly eastern little tuna *(Euthynnus affinis)* and frigate tuna *(Auxis thazard)* that are caught with trolling lines, but rainbow runners, jacks and garfish are also hauled in. Fish species exploited by handlining with this type of bait are *L. bohar, A. virescens, L. elongatus,Cephalopholis sonnerati, Plectropomus areolatus, L. sebae, L. gibbus* and some lutjanids and serranids.

In case bait fish is hard to catch, the *gaa-vadhu* is used. This is a hook provided with a lure (feather-like structure), to which a piece of coral (dead or alive) is fixed by means of a thin strip of palm leaf. The coral is used as a sinker; when the sinker reaches the depth required, the line is jerked to release the hook and the lure is hauled to the surface catching *E. bipinnulata, A. virescens, C. melampygus, Gymnosarda unicolor, L. bohar* or *Aphareus furcatus.*

There is usually an increase in night-fishing operations two or three days before the full moon. Catches of especially large *L. bohar* are generally good at this time and they are sold at Male market in the morning or taken straight to the tourist resorts.

The small *dhonis* fish further from Male. Their fishing grounds are shown in Fig. 1. They sometimes cross the Vadhu channel to fish on the outer side of South Male Atoll. Catches are landed at Male market by most boats after 1330 hrs, though some land their catches directly on resort islands.

Line fishing is also often indulged in at various jetties in Male.

At the end of the south west monsoon a tendency was observed among fishermen to start using *mas vadhu* (fish as a lure on trolling lines) or practising *hemas helun* (whereby sailfish and wahoo are attracted to the *bokkura,* using wooden fish-like lures, and then speared). At the end of this season there is a shift back to handline fishing.

5.2 **Resort islands**

The Maldives has several tourist resorts on islands specially reserved for foreign visitors. Much fish is bought by these resorts. The resorts contract fishermen to supply reef fish. *Kuda dhonis* and *mas dhonis* (small *dhonis* and pole-and-line *dhonis)* are generally used for fishing by these contractors and each boat is operated by a crew of four to six. These fishermen catch live bait early in the morning and use handlines for reef fish from 9 a.m. to 4 p.m. At some resorts, catches are landed up to 8 p.m. Some of these fishermen also undertake line fishing, using *gaa-vadhu,* on the west side of North Male Atoll, in waters up to 300 m deep, during the north east monsoon.

When contract fishermen have to go to their home islands or their craft needs repairs or maintenance, they arrange temporary replacements. Some fishermen from Rasdu Atoll (north of Alif Atoll), contracted in North Male Atoll, leave for Rasdu every Thursday to spend the weekend and start fishing again only on Saturday in Rasdu or Alif Atoll. But they land these catches too at the contracted resort. Trolling lines are generally operated during the crossing of the inter-atoll channel.

The tourist resorts provide the fishermen with food, fuel and lubricants. One resort provides a crew of five men with 9 kg of rice, 9 kg of flour, 6 kg of sugar, 1.5 kg of onions, 0.3 kg of chillies and 0.5 kg of tea every three days and supplies five gallons of fuel a day as well. Prices of fish are variable. At one resort, the following prices were, noted: MRF 2 for small tuna and garfish, MRF 3 for demersal reef fish, MRF 15 for larger reef fish like *Aprion* and *Caranx,* MRF 25 for dog-tooth tuna and wahoo and MRF 50 for billfish.

At other resorts, fixed prices were noted for each fish (MRF 3 to MRF 5), except for large dogtooth tuna, wahoo and sailfish for which prices were variable. At one resort, there were only two prices, MRF 2.50 for small tuna and garfish and MRF 5 for reef fish. But prices between MRF 6 and MRF 20 were offered for larger fish bought in there.

At another resort, the management determined when the contract fishermen should go out fishing. When they had enough fish in stock, fishing was suspended and the crew were paid MRF 10 per head per day.

At many resorts a weekly night handline fishing trip is organised for visitors, weather permitting.

There is an increasing trend in a number of resorts to include game fishing with rod and reel (for bilifish, Spanish mackerel and barracuda) in their entertainment programmes. Compared to the total commercial production of reef fish, production from this night fishing is negligible.

At Male market, prices are variable; those of snappers and groupers are often much higher than at the resorts (Table 7).

5.3 Commercial catch statistics

5.3.1 *Catch rates*

Mean catch rates of the commercial handline fishery in North Male Atoll, for the period March 1987 to March 1989, are presented in Fig. 15. Only catches of demersal reef fish species are dealt with, no distinction is made between row boats and small *dhonis* **and the analysis** is irrespective of the type of bait and biotope. There is no particular trend evident from this chart. The peak in August 1987 is, however, repeated in July 1988, but the peak in December 1988 is not to be found in 1987. The catch rates presented are based on a total of 120 fishing trips for which complete fishing effort data was available.

Commercial catch rates were compared with those from the exploratory fishing and the former exceeded 2 kg/line/hour for all but one month, while it was *vice versa* for exploratory fishing. The fishing time during exploratory fishing was recorded accurately, but whether this was the case in the commercial fishery is not known.

5.3.2 *Resort catches*

The number of fish purchased from contract fishermen by four resort islands is presented in Fig. 16 a-d. Since fish obtained from other sources, such as the Male market and by visitors themselves, is not included, the total fish consumed by guests at, and the staff of, these resorts might be slightly higher than the quantity of fish actually supplied by the contract fishermen.

The four resorts purchased 100,078 in 1988, the equivalent of about 145 t (conversion factor: 1.45 kg per fish). Extrapolation of these figures would indicate a total purchase of 1,015 **t** by the 28 resorts in North Male Atoll in 1988. Resorts without contract fishermen obtain their fish supply from Male and, hence, this estimate would include fish landed at Male market also.

Further extrapolation, based on one resort's fish purchase in 1988, its occupancy rate and the number of beds it has, indicates that for each tourist night, 1.67 kg of fish was purchased to feed the guest and staff. The total number of beds in all resorts in the Maldives was 5,559 in 1988 and the occupancy rate was 60.9% (Ministry of Tourism, personal communication). Thus, for a total of 1,235,682 tourist nights, the fish purchased by all resorts would have been about 2,064 tin 1988.

Catch sampling at resorts indicated that the major component of the catch was the rainbow runner. Snappers, emperors and groupers contributed about 38 per cent of the total landings, and added up to a catch of about 390 t of these species in 1988.

Large reef fish catches landed at Male market are mainly sold to resort islands in the vicinity of Male. Catches from North Male Atoll are sold to resorts in South Male Atoll. It is difficult to estimate the production by fishermen based in Male, because they regularly sell fish to the resorts directly (these catches are not recorded, since the fishermen are not contracted and are paid in cash). But the number of Male-based boats exploiting reef fish does not exceed 10.

5.3.3 *Demersal reef fish production*

From the resort statistics it appears that a full-time crew can catch approximately 25,000 fish a year; this is the equivalent of roughly 35 **t, resulting in a maximum of 350 t of** fish for the 10 craft. Of this, 38 per cent consists of demersal reef fish, i.e. about 135 t. Adding these figures to the earlier estimated 390 t, the total production of demersal reef fish in North Male Atoll appears to be about 525 t.

5.3.4 *Species composition of the commercial fishery*

The catch composition by species and the families of reef fish catches landed at Male market and at some resorts is presented in Table 9. It should be noted that the landings dealt with are only those where the fishing effort is known; this table should, hence, be considered merely preliminary (this means that data is also available for landings for which the corresponding effort data could not be obtained).

The most important fish species in terms of weight is *A. virescens,* followed by *Euthynnus affinis.* 7.9 per cent of the total landings consists of *E. bipinnulata.* Billfish contributed 5.4 per cent and *C. tnelampygus* 4.8 per cent. It should be noted that the percentage of *L. bohar* is rather low; however, night fishing activities around full moon may result in significant amounts of this species.

It is felt that the contribution by some species is not entirely reflected in the composition presented. The demersal fish species belonging to Lutjanidae (19%), Lethrinidae (6.1%) and Serranidae (13.3%) together contribute 38.4% to the total landings.

6. RELATIVE ABUNDANCE

Of the various gear used during the survey, the longline was chosen as the relatively most efficient sampling gear to study fish densities and abundance of reef fish. Very poor catch rates, damage to gear and loss of gear reduced the effectiveness of traps for abundance estimation. Handline results obtained during the survey were considered insufficient for this type of analysis, but were complementary to those from the longline. The longline was operated consistently, and the advantage was that relatively large fish were caught. Although the use of catch rate, particularly of hook and line methods, as an index of abundance is open to question, it is the only means, in the present study, to discuss this subject.

The average catch rate of several species groups on various transects during the four coverages is presented in Fig. 17a, b, c, d and e. Snappers show the highest catch rates on longlines, followed by sharks, emperors, groupers and jacks. The highest catch rate of snappers was in the fourth coverage and on transects 2W and 3W, while emperors peaked during transects 1W and 3W in the same coverage. Grouper catch rates were highest on transects 1W and 2W during the fourth and second coverages respectively. There is no real trend in the catch rates of jacks because they were not caught consistently during all coverages nor in all transects. Big sharks do not usually get caught on the longline, but there was one occasion when a large nurse shark was caught on transect 1W, contributing to a high peak in catch rate during the last coverage.

Average longline catch rates by species group by transect (inside the atoll) are presented in Fig. 18. The catch rates of snappers throughout the survey were of the same order of magnitude on all transects, including Male and its vicinity (transect 0) and the northern part of Alif Atoll (transect 4). The catch rates on transects 2E and 3W were the lowest and highest respectively. Emperors exhibited a slightly different pattern in their catch rates, the highest being in the vicinity of Male and in Alif Atoll. The highest grouper catch rates were in transects 1W and 2W and also in Alif Atoll. Shark catch rates were the highest on transects 1W and 1E but remarkably low in Alif Atoll.

Catch rates for species groups caught by longline outside the atoll rim (Fig. 18) reveal that snapper catch rates were relatively good on all transects, except 3E. Emperors showed highest catch rates on 1W and 2E, while groupers appeared to have a high average catch rate on OW, mainly influenced by the very good results in the 140—170 m depth range. The highest shark catch rates were in 2W and 3W.

Note: (1) The average values are based on relatively small numbers of observations; (2) No trials were conducted outside Alif Atoll.

Relatively large portions of the average catch on all transects consisted of snappers and sharks the year round. Relatively higher catch rates of emperors, however, were only in the second coverage. Jacks and groupers, on the other hand, did not contribute significantly to the longline catches.

In Alif Atoll, snappers contributed the largest portion of the catch rate, followed by emperors and sharks.

7. BIOMASS, POTENTIAL YIELD AND EXPLOITATION RATE

In the absence of time series data on catch and effort, there is no suitable method to estimate the biomass and potential yield of a coral reef area by using such data as may be available from the exploratory fishing with hook and line methods. A rough estimate is, however, attempted here by applying longline catch rates per unit area to the total surface of the atoll.

Longline catch rates were calculated for 100 hooks. The average distance between hooks is 5.9 m $\pm$0.9 m (which is the length of the branch line). A longline with 100 hooks contains 19 sinkers. Hooks and sinkers are distributed equidistantly along the mainline, making a total length of (99 x *5)* + (9 x *5)* = 590 m. The area in which the longline gear would be effective is, therefore, estimated to be between 2950 and 4012 sq.m. (590 x 5.9 $\pm$ 0.9 sq.m.). The total area of the atoll is 994.25 sq.km. If the average bottom longline catch rate of 10.44 kg/100 for the bottom of the atoll (habitat SD) is applied to the total surface area of the atollon the assumption that:

Total area/area covered by the longline gear x average catch rate for the area covered by the longline = biomass value,

then, 994.25 x 10^6(2950 x 10.44 = 3518.6
and 994.25 x 10^6/4012 x 10.44 = 2587.2 t.

Biomass estimate is, thus, between 2600 and 3500 t for the total bottom inside the atoll. In this case it is assumed that all fish in the 'longline area' take the bait and do not swim from one 'longline area' to the other. These conditions are unlikely to prevail and, therefore, these estimates are considered underestimations of the biomass of commercially valuable fish. However, the number of fish that do not respond to the bait is not known. Further, small fish or small-mouthed fish (damselfish, triggerfish, boxfish) only nibble at the bait on the hooks, while big fish, like groupers and sharks, bite off the snoods, thus reducing the effectiveness of the gear. It should be noted that the majority of the fish caught are adults, which would imply that juveniles are not included in the biomass estimate.

Although estimates of the surface area of the islands, reefs reaching the surface of the sea and atoll rim are available, the entire stretch of all reefs together is not known. Due to the absence of this information, the average catch rates for the reef area cannot (as yet) be applied. It is felt that other biotopes might also contribute a certain amount of demersal fish to the total biomass of commercial value, but to what extent is not known.

The biomass figures mentioned earlier include the demersal fish resources outside the atoll up to the depth of the atoll basin, i.e. approximately 50 m. The resources in waters deeper than 50 m (outside the atoll) are considerable, but the amount of information collected through the exploratory fishing was insufficient to assess these resources.

It should be noted that the estimate of the 'longline area' over which the longline gear is assumed to be effective in catching fish influences the estimated biomass. Underestimation of the 'longline area' results in an overestimation of biomass.

Keeping in mind the limitations of this methodology, the amount of standing stock in and around the atoll is only indicative until more data and other methods are available for better estimations. The second phase of the Reef Fish Research and Resources Survey, during which three other atolls will be surveyed, may lead to more precise estimates of the biomass of demersal fish.

In the atoll basin, *A. virescens* is one of the major components of the demersal biomass. This species hardly ever migrates to the deeper waters outside the atoll, therefore it is assumed that, as commercial fishing is negligible, the total mortality value (Z = 0.49), obtained from the analysis of the length frequencies collected in 1985, approximates the rate of natural mortality.

The maximum total catch of demersal reef fish of commercial interest in 1988 was estimated at 524 t. By applying the estimated values of biomass, natural mortality rate and present yield, the Maximum Potential Yield (Y_{max}) – obtained by using a modified version of Gulland's formula (Y_{max} = 0.5 x (Present Yield C + Natural Mortality M x Biomass B)) – is likely to be between 900 and 1120 t of demersal reef fish of commercial value, which is about double the present production. Therefore, there appears to be scope for increasing the catch of adult demersal reef fish by 400 to 600 tin North Male Atoll.

Taking into account the total surface of the entire atoll (approximately 1550 km^2) and assuming that demersal reef fish is around 38% of the total production reported under 'reef fish' category, the maximum potential yield of all demersals, per unit area, would be between 1.5 and 1.9 t/km, using just the existing fishing methods. These values are low compared to MSY values from other parts of the world [e.g. 4.1 t/km^2 around Jamaica (Munro, 1977); 5.0 t/km2 in East Africa (Gulland, 1979): 7.6 t/km in Papua New Guinea (Lock, 1986)1.

This analysis indicates there is some room for expanding the reef fishery in the Maldives. A study of the length frequencies from commercial sampling of *A. virescens* indicates there is some room for increasing the production of this species. The analysis of *L. bohar, L. gibbus, L. elongatus* and *L.rubrioperculatus* length frequency data resulted in total mortality values of such an order of magnitude (Annexure 4) that the exploitation rate did not exceed E = 0.5.

The snapper *A. virescens* appears to contribute 18.75% to the total longline production resulting in biomass estimates between 488 t (18.75% of 2600 t) and 656 t (18.75% of 3500 t), i.e. an average of 572 t.

This species contributed 40.4% to the total estimated production of demersal reef fish of commercial value (524 t of lutjanids, lethrinids and serranids), i.e. 212 (the percentage was obtained by grouping all demersal fish families, and *A. virescens* contributed 40.4% of this total). Therefore the exploitation rate was estimated at 0.37/0.79 = 0.47. This value is slightly higher than the results of the length-based analysis: viz. 0.37 and 0.39 respectively.

A comparison of the two methods could be done only for *A. virescens* as an estimate of M was obtained only for this species. Furthermore, this species was the most common fish caught on the longline as well as in the commercial reef fishery. The order of magnitude of the exploitation rates obtained through the two methods corroborates the results of the biomass estimation by means of the so-called longline-area method.

Note: The figures presented in this report should be viewed with caution since (very) slow-growing fish species are dealt with. When more or less virgin stocks are fished, the large and adult fish are initially especially susceptible to fishing pressure, resulting in an overestimation of the potential. As soon as the large and adult fish have been captured, it takes a long time before the young fish become a part of the fishery resource. A local overexploitation may be the result. There are many examples from the Caribbean and Bermudas where reef fish are overexploited and where fisheries have collapsed.

A big advantage of reef fish in the Maldives is that there is no history of fish poisoning (Ciguatera). The very same species caught in other parts of the world (The Great Barrier Reef, Australia and many parts of the Pacific) are discarded because of the possible toxicity of these fish. Ciguatera is caused by a dinoflagellate organism, *Gamhiei'discus toxicus,* being eaten by herbivorous fish, which, in turn, are eaten by carnivorous predators. 0_f the herbivores, mainly the parrotfish, doctorfish and mullets are vulnerable, while, of the carnivores, snappers, emperors, jacks, groupers and barracudas are the main fish susceptible to poisoning.

The absence of a fish poisoning problem in this area may trigger a greater demand for these fish, in case serious exploitation starts. The development of reef fisheries in the Maldives should, however, be carefully monitored and regulated. It is recommended that expansion of the reef fisheries in the tourist zones be discouraged so as not to jeopardise the present levels of reef fish supply to the resorts and to safeguard the large predators on the reefs, which are a major attraction to tourists/divers.

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