# Bay of Bengal Programme

## Fishery Resources

REEF FISH RESOURCES SURVEY IN THE MALDIVES

- Phase II

BOBP/WP/80

FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS

BAY OF BENGAL PROGRAMME
Reef Fish Research and Resources Survey

BOBP/WP/80
MDV/88/007

# Reef Fish Resources Survey in the Maldives — Phase II

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**BAY OF BENGAL PROGRAMME**
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This paper describes the second phase of a reef fish resources survey carried out in the Maldives and presents preliminary estimates of reef fish densities and maximum potential yields. This follows an earlier phase carried out during 1987-88 in North Male Atoll from the research vessel *Faruinas* (Van der Knaap *et al* 1991) of the Ministry of Fisheries and Agriculture. That first survey phase established that handli.nes and longlines are the best gear for catching Maldivian reef fish, it collected a considerable quantity of information of value for long-terni stock assessment and for potential developers, and it made a first estimate of potential yields from N. Male Atoll.

The second phase was conducted in Shaviyani, Alifu and laaniu Atolls during 1989-91. Species compositions and catch rates for the major gear and fishing areas were established, regional and seasonal differences were noted and a considerable quantity of information on the biological characteristics of commercial species was collected.

Preliminary estimates indicate a maximum potential yield of commercial reef fish *(i.e.* medium to large snapper, grouper, emperor and reefassociated jack) of the order of 30,000 ± 13,000 t/year. The atoll basins (which constitute by far the largest part of the Maldivian atolls) are identified as having relatively large reef fish resources. The deep reef slopes outside the atolls support some high value species, hut their total potential yield is relatively small. It must, however, be noted that the stock assessment presented here is only of a preliminary nature and if the reef fishery is to be expanded, possibilities for which appear to be good, detailed monitoring wifl he required to make a more precise stock assessment.

The effort of several persons who worked on this survey need to be acknowledged. The staff of the Marine Research Section, particularly Hussein Shareef, Au Waheed, Ahmed Shareef, Ibrahim Naeem, Hussein Zahir, gave assistance with fieldwork and data compilation. Ali Naeem of MOFA assisted with the installation and the maintenance of electronic equipment on *Farumas.* The skippers (Yoosuf Idrees, Ibrahim Naseem, Adam Fulhu, Abdul Ghanee) and crew of *Farumas* cheerfully carried out the fieldwork, often in conditions that were far from ideal. Maizan Hassan Maniku, Lars Engvall, K. Sivasubramaniam, Martin Van der Knaap, Janne Fogeigren and Michel Kulbicki contributed by making useful comments on an early draft of this report. Constructive comments were also received from Drs. Daniel Pauly and Jeffrey Polovina.

The Bay of Bengal Programme (BOBP) is a multi-agency regional fisheries programme which covers seven countries around the Bay of Bengal — Bangladesh, India, Indonesia, Malaysia, Maldives, Sri Lanka, Thailand. The Programme plays a catalytic and consultative role it develops, demonstrates and promotes new techniques, technologies or ideas to help improve the conditions of small-scale fisherfolk communities in member-countries. The BOBP is sponsored by the governments of Denmark, Sweden and the United Kingdom, by member-governments in the Bay of Bengal region, and also by AGFUND (Arab Gulf Fund for United Nations Development Organizations) and UNDP (United Nations Development Programme). The main executing agency is the FAO (Food and Agriculture Organization of the United Nations).

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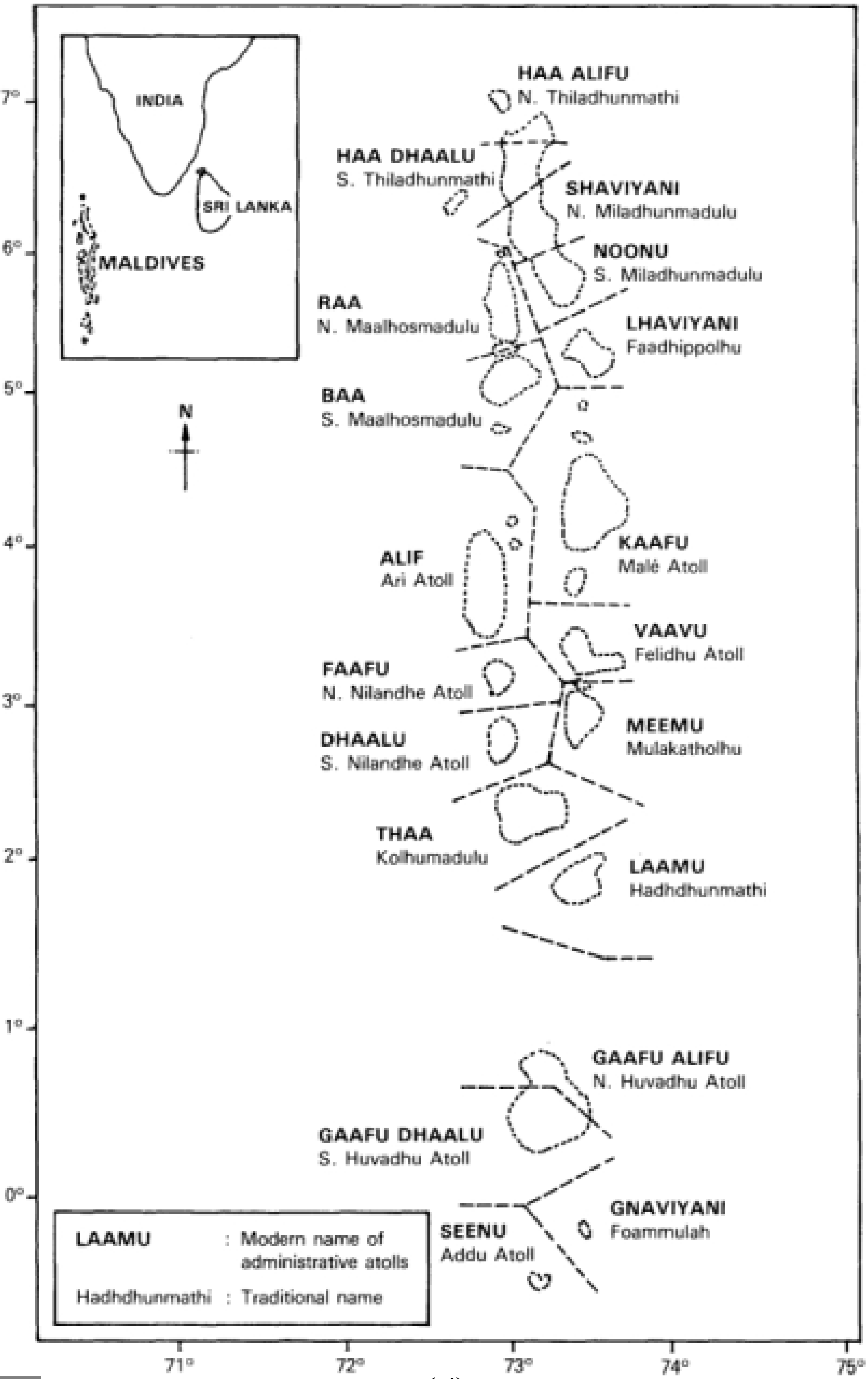
## Maps, Charts and Figures

<< *Hauling aboard the R. V.* Farumas *a sting ray caught on the long/me.*

**Fig 1: Map of the Maldives**



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# INTRODUCTION

## 1.1. *Background*

The Republic of Maldives has a vast area of coral reefs, but reef-associated demersal species are not heavily exploited. The Government of Maldives felt that there would be scope to increase the production of reef fish. The 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/85/003) was carried out during 1986-1988. A major part of this project was a 14-month fishing survey of the reef fish resources of N. Male Atoll. During that survey the following results were obtained (Van der Knaap *et a!* 1991)

- Different types of fishing gear were tried; it was found that handlines and longlines were efficient at catching commercially valuable reef fish, while traps were unsuitable for reef fishing in the Maldives.
- The abundance of commercial species was estimated, and first estimates of potential yields were made. In addition, a considerable quantity of biological information of value for longer-term stock assessment was collected.
- **A** preliminary examination of the economic feasibility of expanding the reef fishery was undertaken.

It was recognized that extrapolation of results from the survey of N. Male AtoJ,1 to the country as a whole could lead to erroneous conclusions. In order to make an assessment of the reef fish potential of the entire Maldives it was recommended, in particular, that experimental reef fishing be carried out in at least three other atolls of varying ecological characteristics. Therefore, during the second phase of the UNDP/FAO Reef Fish Research and Resources Survey (MDV/88/007), fishing surveys of the reef fish resources of Shaviyani, Alifu and Laamu Atolls were carried out. These three atolls* were chosen because they are representative of the following conditions

Shaviyani Northern atoll, with atoll rim reefs poorly developed; numerous wide channels to the open sea; moderate number of reefs inside the atoll basin. A little reef fishing is carried out.

Alifu : Central atoll, with well developed atoll rim, but also with numerous channels; large number of internal reefs. There is moderate reef fishing.

**Laamu** Southern atoll with well developed encircling reefs; few atoll channels and few internal reefs. Has no reef fishery.

In each of these target atolls, three major habitats were surveyed

1. the atoll basins;
2. the shallow reefs inside and outside the atolls; and
3. the deep reef slope outside the atolls (50-2lOm).

The major aims of the second phase of the Reef Fish Research and Resources Survey were to categorize the reef fish resources of different habitats in the target atolls, and to use this information to make an assessment of the size of the Maldivian reef fish resources.

## 1.2. *Existing reeffisheries*

The Maldives is a tuna fishing nation. The majority of fishermen are engaged in livebait pole-and-line fishing for tuna; the majority of Maldivians prefer eating tuna to any other kind of fish; and the majority of the country's direct export earnings come from tuna. There is, however, some fishing for demersal reef-associated fish.

* Use of the term 'atoll' can be somewhat ambiguous, as it refers to both geographic and administrative units. The Maldive archipelago comprises 26 geographic atolls, which are divided into 19 administrative atolls (20, including the municipality of Maté). Traditional names and modern, alphabetically based 'abbreviations' are nowadays used more or less interchangeably, and are given in Figure 1 (on the facing page).

The reef fish fishery has been siudied by Brown et *al.* (1989), Van der Knaap et al. (1991) and Waheed (1991). The main gear used in reef fishing is a simple, single hook handline. Live bait handlining is also sometimes carried out, targeting fcr jack and large snapper. Maldivians do eat reef fish, particularly when tuna fishing is poor, hut the majority of reef fish caught in the Maldives is probably eaten b foreigners. There are three main markets for reef fish

a. **Maté fish market.** Reef fish are landed here early in the morning by rowing boats that have been night fishing, and, in the afternoon, by a variety of boats that have been day handlining. There is a steady demand for fresh reef fish at Male market, with reef fish being bought mainly by Male teashops, by foreigners living in Male, and by nearby resorts.

h, Resorts. The Maldives now has nearly 70 resorts on islands specially reserved for foreign visitors. These are all in central Maldives, mostly in Male and Alifu Atolls. As imported meat is expensive and serving tuna everyday is unacceptable, the resorts buy significant quantities of reef fish. Resorts close to Male can make use of Male market, but those further away usually employ fishermen under contract to supply reef fish.

c. **Sri Lanka.** There is an export market for low value, salt-dried reef fish, mainly to Sri Lanka. This market is generally supplied by fishermen from the outer atolls, who do not have access to the higher value fresh fish markets of Male and the resorts.

In addition to these commercial activities, recreational ‘angling’ is popular among Maldivians, particularly in Male. Most resorts also organize night handlining trips for their guests at least once a week. Much of the reef fish caught recreationally is consumed fresh. It should be noted that there have been no reported cases of ciguatera poisoning in the Maldives.

The size of the reef fish catch is difficult to estimate. The Ministry of Fisheries and Agriculture collects fisheries data from every inhabited island, hut this system is geared towards tuna. There are three separate size categories for ‘reef fish’ on the statistics collection forms, but ‘reef fish’ is taken to mean anything that is not tuna. Thus, these categories actually include large quantities of pelagic species and not just demersal, reef-associated species. During the period 1986-89 the four main tuna species accounted for an average of 94 per cent of the total recorded catch. The remaining 6 per cent amounted to some 4400 t annually. The total catch of reef-associated fish is likely to he smaller than this (although it should be noted that ‘reef fish’ catches are probably under-reported).

Van der Knaap *et a!.* (1991) estimated that resorts purchase 167 kg of fish per tourist night to feed guests and staff. Of this, 38 per cent was estimated to he reef fish (snapper, emperor and grouper). From data supplied by the Ministry of Tourism and the Maldives Association of Tourism Industry it is possible to estimate tourism-related consumption of fish, as follows

| *Year* | No. *tourist nights (‘000’s)* | *Total fish consumption(t)* | *Reeffsh cunsumption(t)* |
|---|---|---|---|
| 982 | 593 | 990 | 376 |
| 984 | 792 | 1323 | 503 |
| 1986 | 1036 | 1730 | 657 |
| 1988 | 1236 | 2064 | 784 |
| 1990 | 1682 | 2809 | 067 |
| 1992 (projected) | 1933 | 3228 | 227 |
| 1994 (projected) | 2300 | 3840 | 1460 |

If tourist consumption accounted for half of all reef fish caught in the Maldives, then the total reef fish catch would currently be less than 3000t per year.

Apart from demersal reef fish, there arc sev eral other reef-associated resources that are exploited in the Maldives. Thcsc include the following :

a. **Scad.** The bigeye scad or mushimas* (Mal.) — *Selar crumenophthalamus (and to a* lesser extent the round scad or *rimmas* (Mal.) — *Decapterus macarellus)* are caught in large quantities off some islands. These species form dense aggregations in shallow lagoons by day and move out into the atoll basins to feed at night. They are caught by pole-and-line.

b. **Shark.** Shark support major fisheries in the Maldives, with something of the order of 2000-2500t being taken annually. Reef species are caught by handline, longline, and bottomset tenglenet. There is concern being expressed by the tourism industry that increased shark fishing will reduce the number of shark at popular shark-watching dive sites.

c. **Livebait.** The pole-and-line tuna fishery require large quantities of mall, livebait fish. Thcsc arc generally caught close to reefs early in the morning hta simple liftnet, The main varieties caught arc small, reef-associated semi-pelagics, including silver sprat or *rehi* (Mal.) *Spratelloides,* juvenile fusilier or *muguraan* (Mal.) — *Caesionidaem* and cardinal fish or boadhi (Mal.) -- Apogonidae. The total annual catch of livebait may be of the order of 5000 t.

d. **Aquarium fish.** There arc a few small export-orientated businesses collecting aquarium fish. Collection is done by divers with nets. The main market is Western Europe.

e. **Turtle.** Green and hawksbill turtle are exploited for their eggs and meat. Hawksbill turtle are also taken for their 'tortoise shell'. It is widely recognized that turtle resources have decreased substantially in recent years.

f. **Sea cucumber.** The sea cucumber or bechc de mer fishery has expanded rapidly since its inception in 1985 to become perhaps the most important of all reef-associated fishcrics. There is no local consumption of bechc de rner. Exports in 1990 amounted to 746t with an FOB value of US $ 3.3 million. There are clear signs of overfishing of this resource.

g. **Giant clam.** An export-oriented fishery for giant clam or *gaahaka* (Mal.) — *Tridacna squamosa,* started in 1990. This rapidly spread through many atolls, leading to concern that the local stocks would soon be wiped out and that significant damage would be done to the coral by removing so many clams. As a result of these concerns, the issuing of export licences for giant clam was terminated in 1991, effectively stopping the fishery.

h. **Lobster.** There is a demand for spiny lobster or *ihi (Mal.) - Panulirus* spp, from the tourist resorts. A few fishermen (particularly from Sh. Komandhoo) make extensive trips; around the reefs of several atolls, collecting lobsters by skindiving, especially at night. The lobsters are kept alive and sold direct to the resort. This fishery peaks during the NE monsoon season, when tourist arrivals are greatest and the seas are calm.

i. **Black coral.** There is a steady demand for black coral *or endheri* (Mal.) — *Antipathes,* for tourist curios and jewellery. Black coral is collected by aqualung divers and processed by skilled craftsmen, mostly on the 'jewellers islands' in Dhaalu Atoll. Black coral has been wiped out from many reefs, particularly in the central Maldives. A few divers are now collecting pink coral, which is usually found on very deep outer reef slopes.

j. **Mother of pearl.** Mother of pearl shells or *ithaa* (Mal.) — including *Pteria* and *Atrina,* are also collected for tourist curios and jewellery. Much of the *Pteria* collected is actually attached to black coral.

k. **Coral.** As there are no other indigenous rocks available in the Maldives, coral mining is a major activity. Specialized workers collect coral rock, including living coral, from shallow reef flat areas.

* The local name in the Dhivehi language

Interactions between these various activities are many. For example, the growing local population is creating an increasing demand for coral rock for construction, but coral mining destroys areas of reef that support many of the other living resources that are also increasingly in demand. The growing tourist industry creates demands for reef fish, lobster, turtle shell, black coral and mother of pearl, but would like these same resources left intact for visiting divers to see. Fishermen migrate between different fishing activities depending on availability and demand. Biological interactions include those of predator and prey *(e.g.* shark - reef fish - bait fish) and those of shelterer and sheltered *(e.g.* baitfish - coral, and mother of pearl shell - black coral).

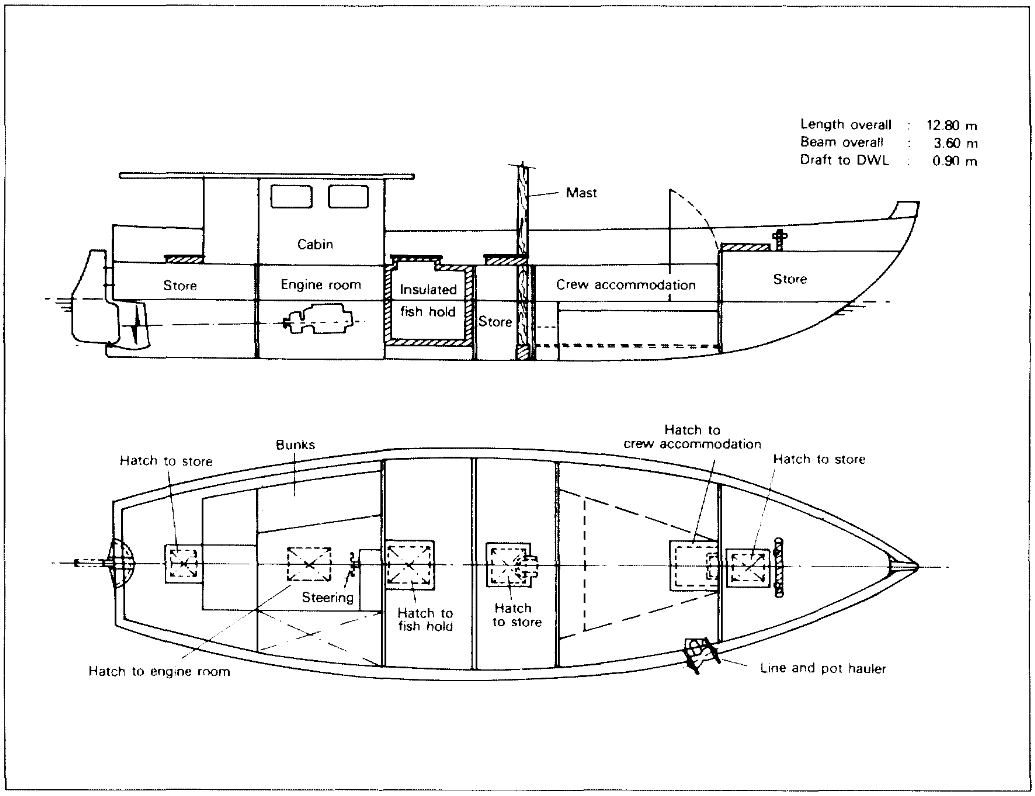
With the continuing growth of the Maldivian population, as well as the number of tourist arrivals, it is clear that demand for reef resources can only increase in the future. The problems of managing these reef resources for the long-term benefit of all can also only increase.

## 2. *MATERIALS AND METHODS*

### 2.1 *Fishing vessel*

All fishing activities were carried out from a modified 'second generation' *dhoni* equipped with line hauler and echosounder (Figure 2). This vessel (R.V. *Farumas)* was the same one as was used during the first phase of the survey. The only major difference was that the 22HP Lister diesel engine used during the first phase was replaced by a 39 HP Yanmar diesel engine. This change was necessary because of the long distances between survey sites in the second phase (even with the new engine, Shaviyani to Laamu is over three days steaming). The vessel was normally operated with one skipper, three crew, one scientist and one assistant.

**Fig. 2. General arrangement of exploratory research vessel,** R.V. *Farumas*



## 2.2 *Fishing gear*

The main survey gear used (handline and longline) were identical to those used during the first survey. The multifilament bottom set longline used is detailed in Figure 3. Usually Mustad No. 6 hooks were used, but, on occasion, Nos. 5 or 7 were used. When deployed below l30m outside the atolls there was a tendency for the buoy lines to be pulled down, so extra buoyancy was used. Also in deep water outside the atolls, the small floats on the sinker lines were crushed by the pressure. Therefore, towards the end of the survey, a few trials were made without these floats, but with a thicker (and, thus, more buoyant) mainline. Use of a 6mm diameter mainline did not appear to affect catches, but did make handling the line easier. Setting the longline took 7-10 mm. The line was allowed to soak for about 60 mm before hauling started. Hauling usually took *45-70* mm, depending on bottom conditions, crew skill and catch. Thus, average soak time was about 90 mm.

**Fig. 3. Muitifilament bottomset longline**

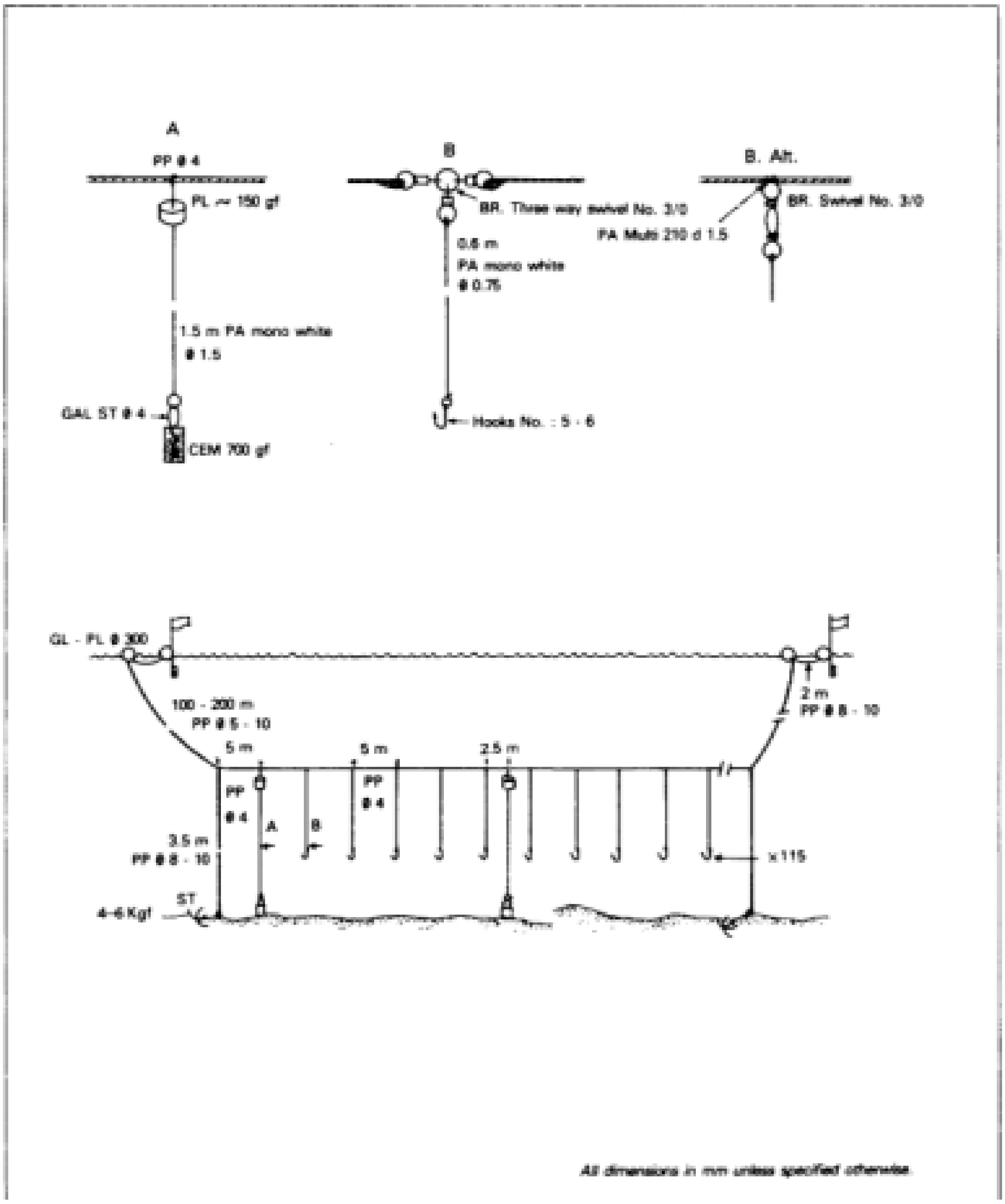





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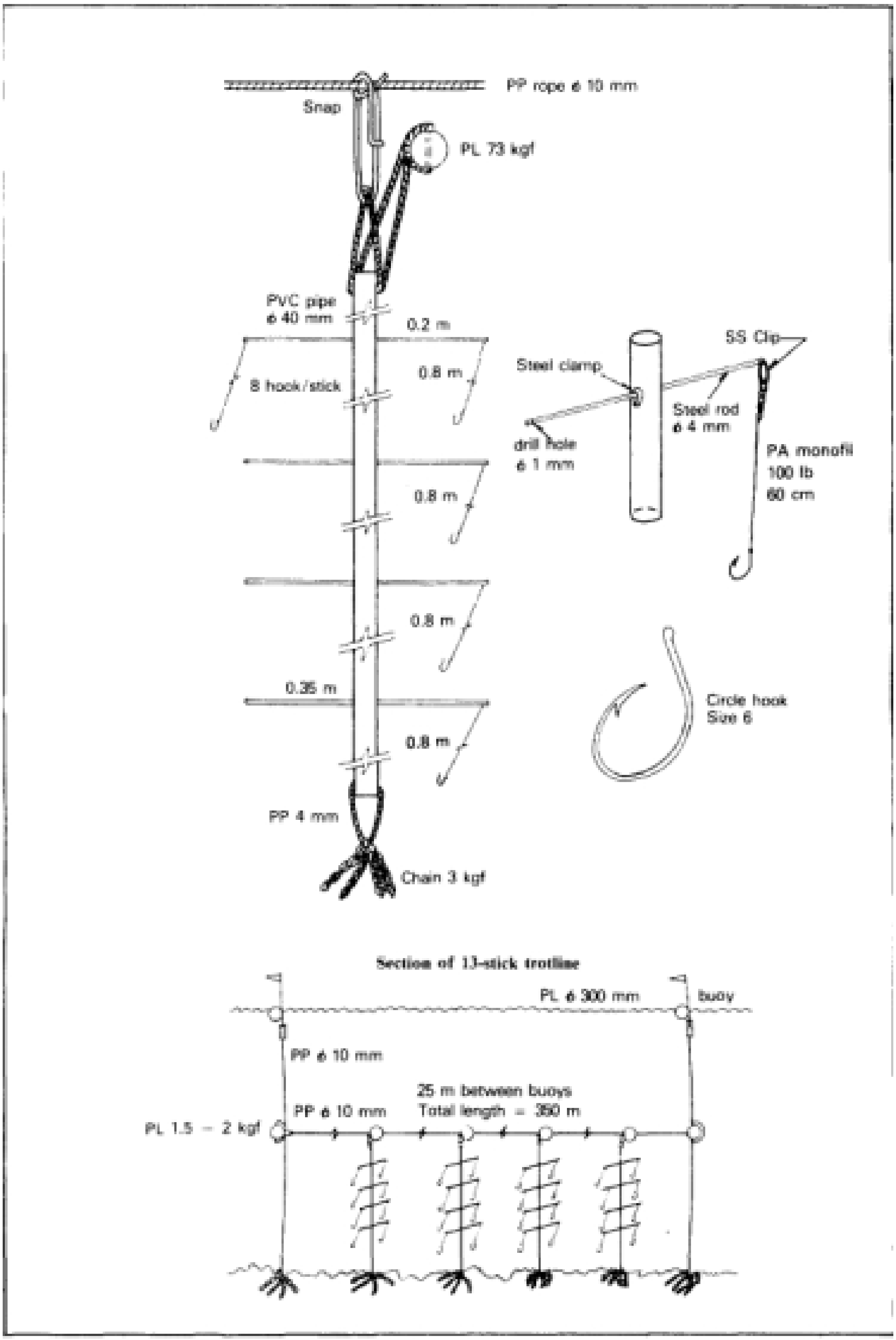
Fig.. 4. Ve.-tical stick longline



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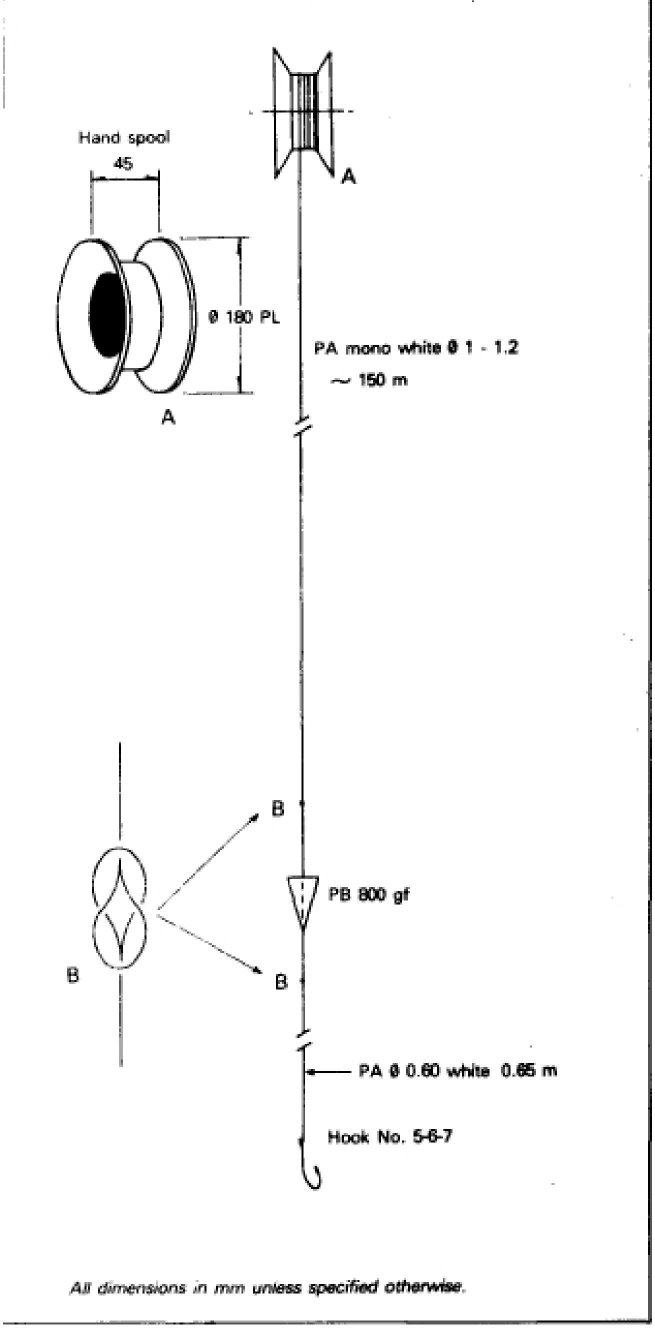
Trials were conducted with two other longline variations. A 104-hook, 13-stick trotline was employed on three occasions on the outer reef slope of N. Male Atoll for deepwater snapper (Figure 4, see facing page). A 12-hook vertical longline was employed twice in deep water for spiny dogfish. Details of typical Maldivian gear of this type are given in Waheed (1991).

Standard single hook handlines, as used by Maldivian fishermen were used on the survey (Figure *5).* The time spent handlining was counted in a conservative manner: only time spent actively fishing was recorded.

Fig. 5. **Traditional handline**




Standard Maldivian trolling gear was deployed while travelling between fishing areas. Both light gear (targeting for small tuna) and heavy gear (targeting for wahoo, sailfish, dogtooth tuna etc) were used. Details of Maldivian trolling lines are given in Waheed (1991).

One trial with traps for deepwater fish was carried out. Trap design is illustrated in Van der Knaap *et al.* (1991).

Longlines and handlines were normally baited with cut pieces of tuna. Little **tuna** or *latti* (Mal.), *Euthynnus affinis.* was preferred for this, but other tuna species were used according to availability. The other bait popular with the fishermen was bigeye scad or *mushimas* (Mal.), *Selar crumenopthalamus.* Other varieties used as bait on occasion included wahoo, sailfish, jack and barracuda *(kurumas, hibaru, handhi, faru tholhi).* The traps were baited with fish gut.

## 2.3 *Fishing survey*

The aim of the survey was to carry out sufficient fishing in all three target atolls to allow estimation of catch rates, standing stock and (if possible) maximum sustainable yields from each of three major habitats

- the sandy atoll basins;
- the shallow coral reefs and associated areas to a depth of about *50m;* and
- the outer reef slopes between about *50m* and 210m.

Experience from the first phase of the survey in North Male Atoll showed that the longline was the most efficient gear for sampling the atoll basins and outer reef slopes. The longline, it had also been demonstrated, gave consistent results, with crew skill having relatively little effect on catch rates.

Handlines were used to fish on coral reefs to a depth of *40-50m.* The longline could not be used to fish in these shallow coral reef areas because of the greatly increased risk of entanglement on the coral and because numerous small fish (notably triggerfish, surgeonfish, damselfish and wrasses) in this zone soon removed most of the bait. Simple handlines are the fishing gear used by Maldivian fishermen for catching reef fish, and so they were used in the survey to estimate potential commercial catch rates in the target atolls.

Longlining could only be carried out by day because of the difficulties and dangers of navigating at night. Handlining was carried out both by day and by night. However, only one handlining station could be carried out per night.

The survey work was carried out over a total of 23 months, although the bulk of the fishing was carried out over the 12-month period August 1990 to July 1991 (Table 1). The fishing survey can be divided into four phases

- **September 1989-May 1990.** Initial longline survey work in all three atolls.
- **August-November 1990. Longline** survey in all three atolls during the Southwest Monsoon season. Some handlining.
- **February-March 1991. Longline** survey in two atolls during the Northeast Monsoon season. Some handlining.
- **March-July 1991.** Longline survey outside all three atolls, plus N. Maté Atoll. Handlining survey in all three atolls. Comparison of ‘normal’ v. circle hooks on longlines in all three atolls.

**Table** 1

**Summary of fishing effort during the reef fish survey**

| | | | | Numbers of longlines set | | | | | | Hours of fishing | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cruise No. | Target atoll | Daie.s | No. Days | In | Out | Circle | Vertical | Pipe | Total | DHL | NHL | Trolling | No. of Traps |
| 8 | K | 7,09.89 | I | — | I | — | — | — | I | — | — | — | — |
| 11 | A | 22-25.10.89 | 4 | 3 | — | — | — | — | 3 | — | | — | — |
| 20 | L | 9.301289 | 12 | 5 | — | — | — | — | 5 | — | — | — | — |
| 22 | K | I3.0I.90 | l | — | — | — | — | — | -.— | — | — | — | 4 |
| 28 | Sh | 07-15.02.90 | 9 | 4 | — | — | -— | — | 4 | — | — | — | — |
| 37 | A | 07.10.05.90 | 4 | 3 | — | — | — | — | 3 | — | — | — | — |
| 38 | Sb | 21.29.05.90 | 9 | 3 | | — | | — | 3 | — | — | — | — |
| 51 | A | 02.06.08.90 | 5 | 8 | — | — | — | — | 8 | 6 | 8 | 20 | — |
| 56 | L | 21.08-05.09 | 16 | 30 | — | — | — | — | 30 | lb | 99 | 70 | — |
| 58 | Sb | 02-19.10.90 | 18 | 30 | — | — | — | — | 30 | 16 | 47 | 07 | — |
| 59 | A | 28.10-05.11 | 9 | 12 | — | — | — | — | 12 | 2 | I | 16 | — |
| 60 | A | 19-23.11.90 | 5 | 10 | — | — | — | — | 0 | — | I | 29 | — |
| 62 | K | 03.02.91 | I | — | I | — | — | — | I | — | — | — | — |
| 63 | K | 05 .02.91 | I | — | 2 | — | — | — | 2 | — | — | — | — |
| 64 | A | 08-13.02.91 | 6 | 12 | — | — | — | — | 12 | — | 3 | 16 | |
| 65 | Sh | 22.02.05.03 | 12 | 20 | — | — | — | — | 20 | — | 1 | 91 | — |
| 66 | A | 09-11.03.91 | 3 | 8 | 4 | — | — | — | 12 | — | — | 27 | — |
| 67 | K | 14.03.91 | I | — | 3 | — | — | — | 3 | — | — | — | — |
| 69 | K | *07.05.9!* | I | | — | — | — | I | I | — | — | — | — |
| 70 | K | 09.05.9! | 1 | — | — | — | — | 2 | 2 | — | — | — | — |
| 71 | A | 12-23.05.91 | 12 | 5 | 6 | 5 | — | — | 16 | 9! | 79 | 48 | — |
| 72 | Sh | 08-30.06.9! | 23 | 5 | 6 | 5 | — | — | 16 | 111 | 87 | 220 | — |
| 73 | L | 08-20.07.91 | 13 | 5 | 10 | 5 | I | — | 21 | 89 | 59 | 6! | — |
| 74 | A | 21-24.07.9! | 4 | — | — | — | 1 | — | I | 75 | 15 | 22 | — |
| 75 | K | 28.07.91 | 1 | — | 3 | — | — | | 3 | — | — | — | — |
| Subtotals | | | | | | | | | | | | | |
| | Laamu | — | 41 | 40 | 10 | 5 | 1 | — | 56 | lOS | 158 | 13! | — |
| | Alifu | — | 52 | 6! | 10 | 5 | 1 | — | 77 | 174 | 107 | 179 | — |
| | Shaviyani | — | 71 | 62 | 6 | 5 | — | — | 73 | 127 | 135 | 419 | — |
| | Kaafu | — | 8 | — | 10 | — | — | 3 | 13 | — | — | — | 4 |
| TOTAL | | — | I72 | 163 | 36 | 15 | 2 | ·3 | 219 | 406 | 400 | 729 | 4 |

A summary of catch and fishing effort in the three atolls is given in Tables 2-4. Within the atolls, longlines were normally set on the sandy basin floor and not close to the reefs. Longlines were set so that there was a more or less even distribution of fishing effort over the entire atoll basin

## Table 2
## Summary of catch and effort by major fishing gear in Shaviyani Atoll

Numberofcruiscs : 5

Cruise numbers : 22, 38, 58, 65 72

Effort Summary

*Longline inside:* 62 x 150 hook longlines *Longline Outside.* 6 x 150 hook longlines (710 books)

*Day Handline:* 127 hours *Night Handline:* 135 hours *Trolling:* 419 hours

Catch Numbers and Weight Summary

| | *LONGLINE* | | | | *HANDLINE* | | | | *TROLLING* | | *TOTAL* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Inside* | | *Outside* | | *Day* | | *Night* | | | | | |
| | No. | *Kg.* | *No.* | *Kg.* | *No.* | *Kg.* | *No.* | *Kg.* | *!4o.* | *Kg.* | *No.* | *Kg.* |
| Snapper | 180 | 699.20 | 39 | 132.95 | 172 | 194.40 | 184 | 239.50 | 2 | 1.50 | 577 | 1267.55 |
| Emperor | 52 | 106.00 | 4 | 10.85 | 40 | 75.65 | 5 | 18.05 | — | — | 101 | 210.55 |
| Grouper | 49 | 60.35 | 36 | 46.15 | 67 | 83.80 | 35 | 61.35 | — | — | 187 | 251.65 |
| Jack | 3 | 14.70 | 2 | 5.80 | — | — | 23 | 41.65 | 7 | 6.60 | 35 | 68.75 |
| Shark | 149 | 543.95 | — | — | 2 | 7.60 | 4 | 13.30 | | — | 155 | 564.85 |
| Tuna | — | — | — | — | 1 | 1.60 | — | — | 401 | 359.40 | 402 | 361.00 |
| Others | 65 | 80.40 | 1 | 5.70 | 64 | 60.10 | 34 | 34.00 | 2 | 38.30 | 166 | 218.50 |
| **TOTAL** | **498** | 1504.60 | 82 | 201.45 | 346 | 423.15 | 225 | 407.85 | 412 | 405.80 | 1623 | 2942.85 |

## Table 3
## Summary of catch and effort by major fishing gear in Alifu Atoll

Nuznberofcruises : 9

Cruise numbers : II, 37, 51, 59, 60, 64, 66,71,74

Effort Summary

*Longline Inside:* 61 x 150 hook longlines *Long/me Outside:* 10 x 150 hook Ion8lines (1500 hooks)

*Day Handline:* 174 hours *Night Handline:* 107 hours *Trolling:* 178 hours

Catch Numbers and Weight Summary

| | *LONGLINE* | | | | *HANDLINE* | | | | *TROLLING* | | *TOTAL* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *inside* | | *Outside* | | *Day* | | *Night* | | | | | |
| | *No.* | *Kg.* | *No.* | *Kg.* | *No.* | *Kg.* | *No.* | *Kg.* | *No.* | *Kg.* | *No.* | *Kg.* |
| Snapper | 480 | 1507.70 | 28 | 116.60 | 50 | 117.30 | 76 | 81.80 | 1 | 1.00 | 635 | 1824.40 |
| Emperor | 79 | 130.20 | 10 | 23.40 | 38 | 44.80 | 6 | 9.30 | — | — | 133 | 207,70 |
| Grouper | 98 | 131.45 | 20 | 22.95 | 59 | 81.20 | 14 | 25.75 | — | — | 191 | 261.35 |
| Jack | 7 | 22.65 | - | — | 8 | 18.35 | 4 | 20.40 | 1 | 1.30 | 20 | 62.70 |
| Shark | 67 | 203.75 | 2 | 27.40 | 2 | 6.90 | 5 | 22.10 | — | — | 76 | 260.15 |
| Tuna | — | — | — | — | — | — | — | — | 122 | 70.25 | 122 | 70.25 |
| Others | 44 | 125.90 | 6 | 3.80 | 9 | 75.95 | 39 | 26.10 | 2 | 3.70 | 100 | 235.45 |
| **TOTAL** | 775 | 2121.65 | 66 | 194.15 | 166 | 344.50 | 144 | 185.45 | 126 | 76.25 | 1277 | 2922.0 |

## Table 4
## Summary of catch and effort by major fishing gear in Laamu Atoll

Numberofcruises : 3

Cruise numbers : 20, 56, 73

Effort Summary

*Longline Inside:* 40 x 150 hook longlines *Longline Outside:* 10 x 150 hook longlines (1240 hooks)

*Day Handline:* 105 hours *Night Hans/line:* 158 hours *Trolling:* 131 hours

Catd. Numbers aid Weight Summary

| | *LONGLINE* | | | | *HANDLINE* | | | | *TROLLING* | | *TOTAL* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Inside* | | *Outside* | | *Day* | | *Night* | | | | | |
| | *No.* | *Kg.* | *No.* | *Kg.* | *No.* | *Kg.* | *No.* | *Kg.* | *No.* | *Kg.* | *No.* | *Kg.* |
| Snapper | 127 | 291.00 | 47 | 168.95 | 36 | 78.00 | 30 | 72.80 | — | — | 240 | 610.75 |
| Emperor | 33 | 40.95 | 15 | 33.40 | 25 | 31.05 | 5 | 10.50 | — | — | 78 | 115.90 |
| Grouper | 36 | 36.60 | 31 | **49.55** | 38 | 55.05 | 2 | 5.90 | — | — | 107 | 147.10 |
| Jack | 68 | 75.20 | 17 | 65.90 | 8 | 13.55 | 53 | 217.55 | 9 | 10.35 | 155 | 382.55 |
| Shark | 24 | 115.20 | 9 | 49.50 | 1 | 3.00 | 5 | 16.20 | — | — | 39 | 183.90 |
| Tuna | — | — | — | — | 3 | 11.10 | 6 | 73.90 | 42 | 158.50 | 51 | 243.50 |
| Others | 14 | 10.95 | 2 | 3.70 | 19 | 19.10 | 14 | 12.15 | 6 | 23.45 | 55 | 69.35 |
| TOTAL | 302 | 569.90 | 121 | 371.00 | 130 | 210.85 | 115 | 409.00 | 57 | 192.30 | 725 | 1753.05 |



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of each atoll during each seasonal coverage. Outside the atolls, longlines were set parallel to the reef. An attempt•was always made to lay them on a particular depth contour, but currents often caused the line to drop into shallower or deeper water than had been intended. Depths of longlines set outside the atolls were therefore estimated from echosoundmgs taken dunng the lifting ofthe line, while the line was vertical.

In order to compare the fishing efficiencies of 'normal' v. circle hooks, two longlines of standard coiifiguration were rigged. One had 150 normal hooks (Mustad No. 6), the other had 150 similar sized circle hooks. In each of the three target atolls five pairs of longlines *(i.e.,* a total of 30 longlines) Were set. In each case the two longlines were laid parallel to one another, and as close as prevailing conditions allowed (usually about 100m) In order to minimize differences in soaking time, the order of setting the two lines was alternated.

## 2.4 *Catch sampling*

Every fish caught was identified to species, weighed and measured. Species were identified using Fischer and Bianchi (1984). Reference was also made to Allen *(1985),* Carpenter and Allen (1989), Compagno. (1984), Gloerfelt-Tarp and Kailola (1984), and Jones and Kumaran (1980). A lid of the main species caught, giving scientific, English and Dhivehi names is given in the chart on page 11.

A few differences in species names exist between this report and that of Van der Knaap *eta!.* (1991). Following the revision of Lethrinidae by Carpenter and Allen (1989), *Lethrinus elongatus* ie gow known as *L. microdon, L. kallopterus* as *L. erythracanthus,* and *Gymnocranius robinsoni* as *C. grandoculis.* Van der Knaap *et al.* (1991) in fact confused two similar species under the ugme *L. elongatus: L. microdon* and *L. olivaceus* (Hussein Sharcef, pers. comm.). The species of *Gymnocranius* found in the Maldives are not always easy to identify in the field, so they are Iumped together in this report. The so-far unnamed species of *Lethrinus* referred to as *'Lethrinus* pink stripe' by Van der Knaap *etal.* (1991) is referred to as *'Lethrinus* sp.1' here, following Carpenter and Allen (1989). The shark identified as *Carcharhinus wheeleri* by Van der Knaap et *al.* (1991) Is referred to as *C. amblyrhynchus* here.

Weighing was carried out with spring balances. Fish of less than 1kg were weighed to the neajeet 0.05kg, fish of 1-20kg to the nearest 0.1kg, and fish of over 20kg to the nearest 1kg. (It. shouldbe noted that spnng balances are never particularly accurate, especially when used at sea on small bots.) The total, or fork, lengths of all fish were measured to the nearest 1mm with both tape and board,

Further biological sampling was carried out on most (approximately 95 per cent) of the fish caught. Stomach contents, sex and gonad maturity (on a standard five point scale) were recorded. All crabs from stomach contents were preserved for Dr. P. Hogarth, University of York, U.K., who is preparing a checklist of crabs of the Maldives. Samples of unusual fish from stomach contents, and specimens of fish species from survey catches previously unrecorded from the Maldives were preserved for Dr. J.E. Randall, Bishop Museum, Hawaii, who is preparing a checklist of the fish of the Maldives in cooperation with M.R.S.

## 2.5. *Analytical methods*

All catch and biological sampling information was compiled on an IBM-compatible PC using dBase 3+. These data, and those from the first phase of the survey, are maintained at MRS and can be made available for further analysis.

The frequency distribution of catch numbers on longlines was observed to show a roughly PoisSon distribution, and so 95 per cent confidence intervals were approximately estimated by:

95 per cent CI of mean catch (x) = ± 1.96 -/x/n

Note: = 'n' the number of longliness in the sample.

## Major species caught during the Reef Fish Resources Survey

| Scientific name | English name | Dhivehi name |
|---|---|---|
| SNAPPER (Lutjanidae) | | |
| Aphareus rutilans | Rusty jobfish | Fashuvirankarumas |
| Aprion virescens | Green jobfish | Giulhu |
| Lutjanus bohar | Two-spot red snapper | Raiymas |
| Lutfanus gibbus | Humpback red snapper | Ginimas |
| Lutjanus quilcheri | Yellowfin red snapper | — |
| Lutjanus sebae | Emperor red snapper | Maa ginimas |
| Pristipomoides filamentosus | Crimson jobfish | Jambu giulhu |
| Macolor spp. | Black and white snapper | Foniyamas |
| EMPEROR (Lethrinidae) | | |
| ***Gymnocranius*** spp. | Large-eye bream | ***Kandu uniya*** |
| *Lethrinus conchyliatus* | Redaxil emperor | ***Dhon faihu filoihu*** |
| *Lethrinus* ***microdon*** | Smailtooth emperor | ***Filoihu*** |
| *l4ethrinus olh'aceus* | Longface emperor | ***Kashi thun filoihu*** |
| *Lethrinus rubrioperculatus* | Spotcheek emperor | ***Kaihihi*** |
| *Lethrinus xanthochilus* | Yeliowlip emperor | *Faru* ***jiloihu*** |
| GROUPER (Serranidae) | | |
| ***Qephalopholis sonnerati*** | Tomato grouper | ***Veli faana*** |
| ***Epinephelus areolatus*** | Areolate grouper | ***Thijjehi fauna*** |
| *Epinephelus* ***chlorostigma*** | Brownspotted grouper | ***Faana*** |
| *Fpinephelus* ***microdon*** | Camouflage grouper | *Kas* ***faana*** |
| *Yariola* spp. | Lyretail grouper | ***Kandu*** *haa* |
| **JACK** (Carangidae) | | |
| *Alectis ciliaris* | African pompano | *Naruvaa handhi* |
| *Gzrangoides caeruleopinna:us* | Coastal trevally | ***Vah*** *boa handhi* |
| *Cranx ignobilis* | Giant trevally | *Muda handhi* |
| *caranx* ***melampygus*** | Bluefin jack | ***Fani handhi*** |
| *Qzranx sexfasciatus* | Bigeye jack | *Haluvimas* |
| ***Elagat****is* ***bipinnulata*** | Rainbow runner | *Maaniyamas* |
| *Serbia* ***rivoliana*** | Almaco jack | ***Andhun*** *mas* |
| SHARK | | |
| *Carcharhinus albimarginatus* | Silvertip shark | ***Kattafuihi miyaru*** |
| *Carcharhinus* ***amblyrhynchus*** | Greyreef shark | *Vah boa miyaru* |
| *carcharhinus* ***sorrah*** | Spot-tail shark | *Dhon miyaru* |
| *Galeocerdo* ***cuvier*** | Tiger shark | ***Femunu*** |
| *Loxodon* ***macrorhinus*** | Sliteye shark | *Oashi miyaru* |
| *Triaenodon* ***obesus*** | Whitetip reef shark | ***Faana*** *miyaru* |
| TUNA | | |
| *Auris* ***thazard*** | Frigate tuna | ***Raagondi*** |
| *Euthynnus affinis* | Little tuna | ***Latti*** |
| ***Gymnosarda unicolor*** | Dogtooth tuna | ***Woshimas*** |
| *Katsuwonus pelamis* | Skipjack | ***Kaihubilamas*** |
| ***Thunnus*** *aibacares* | Yellowfin tuna | ***Kanneihi*** |
| *Acanthocybium* ***solandri*** | Wahoo | ***Kurumas*** |
| ***Istiophorus platypterus*** | Sailfish | ***Fangandu*** *hibaru* |
| **OTHERS** | | |
| ***Coryphaena hippurus*** | Dolphinfish | *Fiyaia* |
| ***Rhinobatidae*** | Guitarfish | ***Madi miyaru*** |
| *Srgocentron* spp. | Squirrelfish | *Raiverimas* |
| *Sphyraena* spp. | Barracuda | *Faru thou, Maatholl* |

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Abundance of reef fish was estimated from longline catch data using Kulbicki's method (Kulbicki, 1988), which is based on empirical results from New Caledonia. Kulbicki showed that there is a direct relationship between longline catch and fish abundance (estimated by visual census) of the form

$$\text{Log}(D + 1) = 1.94 \log(\text{CPUE} + 1)$$

where CPUE = Catch per unit effort in numbers of fish per 100 hook longline, and

D = Fish density or abundance in numbers of fish per hectare.

Also $B = \mathbf{D} \times$ average weight of fish

where B = Biomass or standing stock in kg of fish per hectare

Kulbicki also estimated approximate 95 per cent confidence limits for D. These are

Upper density limit = $D_{max}$

$$\text{Log}(D_{max} + 1) = 2.07 \text{ Log}(\text{CPUE} + 1)$$

Lower density limit = $D_{min}$

$$\text{Log}(D_{min} + 1) = 1.75 \text{ Log}(\text{CPUE} + 1)$$

It would have been useful to check Kulbicki's formulae, derived in New Caledonia, with underwater observations on longlines set in the Maldives. However, the atoll basins in which the longlines were set were too deep (40-70m) for such observations to be carried out. Estimates of abundance per unit area for each atoll were converted to estimates of biomass per unit area by multiplying by the mean weight of fish caught in each atoll. This approach was used, rather than using Kulbicki's empirical formula for hiomass estimation, because mean weights varied considerably between atolls, and between the Maldives and New Caledonia.

Estimates of reef fish abundance and biomass per unit area were converted to total abundance and biomass by multiplying by the total area under consideration. For each of the three target atolls, areas of the atoll basin, the reef systems and the islands were calculated by two methods: photocopying charts onto graph paper and counting squares; and photocopying charts onto card and cutting out and weighing the different areas. The two approaches gave results within 5 per cent of each other, but the second approach (weighing) was felt to give more reliable results. This technique was therefore used to estimate areas of all the other atolls (Table 5). Total atoll areas were calculated three times by this method, and a mean value taken.

Table 5

**Approximate sizes of Maldivian Atolls**

| *Geographic Atoll* | *Island area (km²)* | *Reel area (km²)* | *Atoll basin (km²)* | *Total area (km²)* | *Atoll perimeter (km)* |
|---|---|---|---|---|---|
| Ihavandhippolhu | 5 | 55 | 220 | 280 | 70 |
| Thila-Miladunmadulu | 70 | 370 | 3510 | 3950 | 410 |
| Makunudhoo | 2 | 50 | 75 | 127 | 70 |
| Alifushi | 1 | 3 | — | 4 | 10 |
| N. Maalhosmadulu | IS | 180 | 1000 | 1195 | 170 |
| C. Maalhosmadu!u | 2 | 26 | 115 | 143 | 60 |
| s. Maalhosinadulu | 5 | 175 | 770 | 950 | 130 |
| Faadhippolhu | 10 | 90 | 600 | 700 | 120 |
| Goidhoo | 2 | 40 | 65 | 107 | 45 |
| Kaashidhoo | 3 | 5 | — | 8 | 15 |
| Gaafaru | 1 | 20 | 65 | 86 | 40 |
| N. Male | 10 | 270 | 1250 | 1530 | 170 |
| S. Mali | 5 | 120 | 430 | 555 | 100 |
| Thoddoo | 1 | 2 | — | 3 | 10 |
| Rasdhoo | 1 | 19 | 40 | 60 | 30 |
| An | 15 | 385 | 1880 | 2280 | 220 |
| Felidhoo | 2 | 290 | 810 | 1102 | 170 |
| Wattaru | 1 | 24 | 25 | 50 | 30 |
| Mulaku | 12 | 213 | 745 | 970 | 140 |
| N. Nilandhe | 2 | 188 | 420 | 610 | 100 |
| S. Nilandhe | 5 | 175 | 540 | 720 | 110 |
| Kolhumadulu | 10 | 220 | 1450 | 1680 | 160 |
| Haddunmathi | 20 | 180 | 680 | 880 | 130 |
| Huvadhoo | 30 | 365 | 2900 | 3295 | 260 |
| Foa Mulaku | 5 | 5 | — | 10 | 20 |
| Addu | 20 | 50 | 95 | 165 | 60 |
| **TOTAL** | **255** | **3520** | 17685 | 21460 | 2850 |

The US Navy charts were used; these are based on the original Indian Navy /British Admiralty charts but are drawn more clearly. Length of atoll perimeters were estimated from the same charts using a piece of fine string. Each perimeter length was estimated three times and a mean value taken. It should be noted that the charts are based on a survey of 1834-37, and, while accurate enough for many purposes, are far from perfect. Given this, and the crude methods employed to estimate atoll areas and perimeters, it is unlikely that these estimates are accurate to better than $\pm$ 10 per cent. The estimate of small island areas wilt be even less accurate. Much more accurate estimates of reef and atoll areas could be made if satellite imagery data were available.

Estimates of potential yields of reef fish were made from the estimates of standing stock using the modified Gulland formula (Outland, 1971 and 1983)

$$Y_{max} = 0.3(Y_c + MB)$$

where $Y_{max}$ = Rough estimate of maximum sustainable yield (MSY)

$Y_c$ = Current yield (catch) of fish

M = Natural mortality of fish

B = Biomass (standing stock) of fish

Garcia *et al.* (1989) have shown that this formula gives strongly biased results if $Y_c$ is large. However, when $Y_c$ is small (as in the case of the Maldivian reef fishery) it is an unbiased estimator of $Y_{max}$ Nevertheless, this formula gives, at best, only an approximate estimate of MSY, and should strictly be used for single fish species. However, in the absence of other methods this one has to be used, even though the Maldivian reef fishery is a multispecies one.

It should also be noted that the multiplier 0.3 used in the Golland Formula is a conservative value. Some authors recommend a value of about 0.4 *(e.g.* Caddy, 1986; Garcia *et a!.* 1989). Use of 0.3 instead of 0.4 will clearly lead to lower estimates of maximum sustainable yield.

## 3. *FISHING SURVEY RESULTS*

### 3.1. *Longline fishing inside the atolls*

A total of 163 standard 150-hook longlines weuc deployed *to* the thtee target atolls (Table 6). Full catch details are given in Appendix 1. Fishing was carried out dudng both the Southwest and the Northeast Monsoon seasons. Only minor differences between seasons were noted (see Section 5.2).

**Table 6**

**Number of standard 150-hook longlines deployed in the atoll basins of the three target atolls** during **different periods**

| *Period* | *Monsoon* | *Laa,nu* | *Alifu* | *Shaviyani* | *Total* |
|---|---|---|---|---|---|
| 2/89 . 5/90 | NE | 5 | 6 | 7 | 18 |
| 8/90-11/90 | SW | 30 | 30 | 30 | 90 |
| 2/91 - 3/9! | NE | .. | 20 | 20 | 40 |
| 5/91 - 7/9! | SW | 5 | 5 | 5 | 15 |
| TOTAL | | 40 | 6! | 62 | 163 |

In N. Maté Atoll there was no sign of seasonality of longline catches during Phase 1 of the reef fish survey (Van der Knaap *et al,* 1991). As there was no significant seasonal difference in total catch rates, catch records from all fishing periods are combined to give overall catch rates for each atoll (Tables 6 and 7, see page 14). What seasonal variation was noted is detailed in Section *5.2.*

The longlines used were nominally of 150 hooks. Lost hooks were replaced, however, during the course of long trips, but some complete branch lines were lost and not immediately replaced. To account for this, 145 effective hooks per set was used in calculating the catch rates in Table 7. These are presented as catch per 1000 hooks, which is a rough measure of the amount of fishing that could be carried out per day by a small commercial vessel. Overall average catch rates for longlines in the atoll basins were:

| | | |
|---|---|---|
| Shaviyani Atoll | 5.5 + 0.5 fish, | 16.7 + 1.5 kg per 100 hooks |
| Alifu Atoll | 8.8 + 0.6 fish, | 24.0 + 1.7 kg per 100 hooks |
| Laamu Atoll | 5.2 + 0.6 fish, | 9.8 + 1.1 kg per 100 hooks |
| N. Male (Phase I) | | 20.0 kg per 100 hooks |

**Table 7**

**Catch rates by longline of reef fish species and species groups inside the three target atolls**

| | *511.4 VIY4NI* | | *ALIFU* | | *LAA MU* | |
|---|---|---|---|---|---|---|
| | *No, of fish per 1000 hooks* | *kg* | *NO. of fish per 1900 hooks* | *kg* | *No. of fish per ltW4) hooks* | |
| | 20.0 | | 54.2 | 170.5 | 219 | 50.2 |
| *AprOn virescens* | 15.1 | 54,4 | 413 | 24.2 | 8.! | 8.0 |
| *Lu(janss bohar* | 3.7 | 68 | 122 | 43.0 | 6.7 | 3.4 |
| Other ssapner | 1.2 | 6.5 | I) 7 | 3.3 | 7.! | 18.0 |
| EMPEROR | 5.0 | 11.6 | 8,9 | 14.7 | 5.7 | 70 |
| *Le!hrsnas ,nicrodorr* | 3.6 | 8I | 3.7 | 4.6 | 4.7 | 6.4 |
| *Lethrinus robrioperculotas* | 1.2 | | 2.5 | — | 0.3 | |
| Other emperor | 1.0 | 3.7 | 3.2 | 10.1 | 0.7 | 06 |
| GROUPER | 5.4 | 6.7 | 11.0 | 14.9 | 6.5 | 6.3 |
| *Cephalopholis sonnerat,* | 40 | 5.2 | 53 | 5.9 | 0.3 | 11.2 |
| *Epinephelusareolatus* | .0 | 0.6 | 3.4 | 1.8 | 3.4 | .5 |
| *Plectropomusspp* | — | — | 0.2 | 0.7 | 1.4 | 2.3 |
| Other grouper | 0.4 | 0.9 | 2.1 | 6.5 | 1.4 | 2.3 |
| JACK | 0.3 | 1.6 | 0.8 | 2.6 | 11.7 | 13.0 |
| *Alectis ciliaris* | | | —. | — | 1.7 | 6.5 |
| *Carangoides* | | | 0.! | 0.1 | 9.0 | 3.4 |
| Other jack | 0.1 | 1.6 | | 2.5 | | 3.1 |
| SHARK | 1,4 | | 7.6 | 23.0 | 4.2 | 116 |
| *carcharhrnusalbimarginatus* | 2.0 | 9.3 | 1.0 | 4.4 | 0.7 | 4.1 |
| *Loxodonmacrorhinus* | 12.6 | 23.4 | 5.2 | 10.I | 0.9 | 1.5 |
| Other shark | 1.8 | 25.0 | 1.4 | 8.5 | 2.6 | 14.2 |
| OTHERS | 7.4 | 11.7 | 5.0 | 14.2 | 2.4 | 1.9 |
| *Echeneis naucrales* | 5.3 | 4.9 | 2.7 | 2.2 | 1.0 | 0.4 |
| Other specks | 2.1 | 6.8 | 2.3 | 12.0 | 1.4 | 1.5 |
| **TOTAL** | 55.3 | 167.2 | 87.5 | 239.9 | 52.4 | 98.2 |

**Note** All figures rounded to nearest 0.1kg.

The highest catch rates were achieved in Alifu and N. Maté Atolls in the central Maldives. This observation is difficult to explain, since most ecological factors change in a north-south direction, along the Maldivian atoll chain (Darwin, 1842; Gardiner, 1903-6; Woodroffe, 1989). For example, the strength of the monsoonal reversal, the number of openings from the atolls to the ocean, and the frequency of ring reefs, or faros, are all greatest in the north. In contrast, the depths of atoll basins and the length of reefs in atoll rims increase to the south.

Reef fish abundance in atoll basins might have been assumed to. vary similarly along a north-south gradient. This is clearly not the ease. Nor can the abundance of reef fish in atoll basins be related to reef fishing activity. Most reef fishing occurs in N. Maté Atoll and Alifu Atoll. Some occurs



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in Shaviyani Atoll, and virtually none in Laamu Atoll. It is unlikely that reef fishing increases reef fish abundance; it is more likely that reef fishing is preferentially carried out in those atolls with large reef fish resources. If this is the case, it can be considered a fortunate coinilidence that Maté and the tourist resorts (which are the major markets for reef fish in the Maldives) are in atolls rich in reef fish.

One possible explanation for the observed pattern of longline catch rates is that fish abundance in atoll basins is at least partly related to the volume of reefs 1h10 the atoll basins. Certainly, Alifu and N. Male Atolls have numerous internal reefs, while Laalru has relatively few. Shaviyani Atoll does not have many internal reefs, but the few there are, are rather large. Reefs might positively influence the abundance of medium-large carnivorous fish species by providing refuges for the juveniles, and sources of food for the adults.

The high catch rates that were achieved in Alifu Atoll can be largely attributed to the high catches of snapper (notably *Aprion virescens* and *Lutjanus bohar)* in this atoll. In fact, these two species were the most important component of the total longline catch. The contributions of major species *(i.e.*, those that constituted over 5 per cent by weight of total longline catch in any atoll) to longline catches are given in Table 8.

**Table 8**

**Composition of longline catches (percentage by weight) in the atoll basins of four Maldivian atolls**

a. Contribution of major species to longline catches (¾)

| *Species* | *Shaviyani Atoll* | *A!,fu Atoll* | *Laainu Atoll* | *N. Malt (Phase I)* | *Unweighted* ***average*** |
|---|---|---|---|---|---|
| *Aprion virescens* | 33 | 52 | 19 | 19 | 31 |
| *Lutjanusbohar* | 10 | 18 | 14 | 19 | 15 |
| *Luijanus* ***guilcheri*** | — | — | 8 | — | 2 |
| *Lutjanussebae* | 4 | I | 9 | 0 | 4 |
| *Lethrinus rnicrodon* | 5 | 2 | 7 | 6 | 5 |
| *Caracharhinus albirnarginaeus* | 6 | 2 | 4 | 2 | 4 |
| *Carcharhinus sonah* | — | 0 | 8 | 0 | 2 |
| *Loxodon macrorhinus* | 14 | 4 | I | 14 | 8 |
| **TOTAL** (of 8 species) | 72 | 79 | 70 | 60 | 71 |

b. Contribution of major fish groups to longline catches (¾)

| *Family* | *Shaviyani Atoll* | *Alifu Atoll* | *Laamu Atoll* | *Unweighted Average* |
|---|---|---|---|---|
| Snapper (Luljanidae) | 46 | 71 | 51 | 56 |
| Emperor (Lethrinidae) | 7 | 6 | 7 | 7 |
| Grouper (Serranidae) | 4 | 6 | 6 | 5 |
| Jack (Carangidae) | I | I | 13 | 5 |
| Shark | 35 | 10 | 20 | 22 |
| Others | 7 | 6 | 2 | 5 |

The two snapper *(A.virescens* and ***L. bohar)*** plus the small shark *Loxodon macrorhinus* contributed over 50 per cent of longline catch ,weight overall and in every individual atoll, except Laamu Atoll. In fact, reef fish catches from Laamu Atoll, in the south, showed many significant differences from catches in the more northerly atolls. For example

- the overall longline catch rate was much lower;
- three species of snapper ***(L. guilcheri, L. timorensis*** and ***P. multidens)*** made up nearly 10 per cent of the total longline catch, but were never caught in the other atolls;

- the grouper ***C.*** *sonnerafi,* common in the northern atolls, was rare;
- jack contributed a much higher proportion of the catch than in the northern atolls. *A. ciliaris* and *C. caeruleopinnatus* in particular were common, but rare in the north; and
- the small shark, *L. macrorhinus,* was common in the northern atolls (particularly Shaviyani and N. Maté), but rare in Laamu. In contrast *C. sorrah* appeared to be rare in the north and relatively common in Laamu.

These results demonstrate the wisdom of not extrapolating the results of Phase I of the Reef Fish Survey to the whole of the Maldives. However, completion of Phase II still leaves unanswered many questions regarding the reef fish populations of other, unsampled atolls.

## **3.2.** *Comparison of normal v. circle hooks*

It has been noted in other countries that circle hooks tend to catch more fish than normal hooks on longlines and handlines ***(e.g.,*** Anon, 1984). In the Maldives, circle hooks are used on deep vertical longlines to catch spiny dogfish, but have not been used for reef fishing. It was therefore decided to compare the relative efficiencies of the two types of hooks on the reef fish longline. Another reason for this comparison was that Kulbicki's method for estimating reef fish biomass from longline catches (Kulbicki, 1988) uses catch data from longlines with circle hooks.

In order to compare the relative fishing efficiencies of normal and circle hooks, five pairs of longlines with the two hook types were deployed in each of the three target atolls. The catches from the paired normal and circle hook longlines are detailed in Table 9.

**Table 9**

**Comparison of catches by normal hooks and circle hooks**

| | | *Catch by normal hooks* | | *Catch by circle hooks* | |
|---|---|---|---|---|---|
| | | *Nos.* | *WI. (kg)* | *Nos.* | *WI. (kg)* |
| 1. | LAAMU ATOLL | | | | |
| | Snapper | 28 | 72.00 | 19 | 59.40 |
| | Emperor | 2 | 3.50 | 1 | 2.00 |
| | Grouper | 6 | 3.15 | 9 | 5.40 |
| | Jack | 8 | 9.15 | 9 | 6.50 |
| | Shark | 3 | 23.80 | 3 | 18.70 |
| | Others | 1 | 0.55 | — | — |
| | **TOTAL** | **48** | 112.15 | 41 | 92.00 |
| 2. | ALIFU ATOLL | | | | |
| | Snapper | 34 | 125.00 | 40 | 134.00 |
| | Emperor | 4 | 4.50 | 5 | 6.60 |
| | Grouper | 7 | 10.85 | 25 | 35.50 |
| | Jack | 1 | 4.10 | — | — |
| | Shark | 10 | 31.10 | 21 | 45.30 |
| | Others | 1 | 1.10 | — | — |
| | **TOTAL** | 57 | 176.65 | 91 | 221.40 |
| 3. | SHAVIYANI ATOLL | | | | |
| | Snapper | 9 | 42.90 | 9 | 43.35 |
| | Emperor | 6 | 19.10 | 2 | 5.20 |
| | Grouper | 5 | 8.10 | 11 | 12.90 |
| | Jack | — | — | 1 | 7.00 |
| | Shark | 8 | 38.80 | 14 | 60.10 |
| | Others | 4 | 3.80 | 7 | 9.15 |
| | **TOTAL** | **32** | 112.70 | 44 | 137.70 |
| 1.3 | **TOTAL** | | | | |
| | Snapper | 71 | 239.90 | 68 | 236.75 |
| | Emperor | 12 | 27.10 | 8 | 13.80 |
| | Grouper | 8 | 22.10 | 45 | 53.80 |
| | Jack | 9 | 13.25 | 10 | 13.50 |
| | Shark | 21 | 93.70 | 38 | 124.10 |
| | Others | 6 | 5.45 | 7 | 9.15 |
| | **TOTAL** | 137 | 401.50 | 176 | 451.10 |

Note: In each atoll five pairs of longlines, each longline with 150 hooks, were deployed. The figures given above are total catches.



<<

The circle hook longline caught more than the normal hook longline in Alifu and Shaviyani Atolls, but not in Laamu. Overall, the circle hooks caught nearly 30 per cent more fish by numbers and over 10 per cent more fish by weight than the normal hooks. This catch increase is attributable to the far greater effectiveness of circle hooks at catching small grouper and shark. Snapper and jack were caught in almost equal quantities by the two types of hook. Only emperor were caught more frequently by normal hooks than circle hooks, but the differences are small in absolute terms and are not statistically significant.

These results confirm findings from elsewhere that circle hooks tend to catch more fish on longlines than normal hooks. The anomalous results from Laamu Atoll can perhaps be explained by two observations. First, grouper and shark (which were responsible for the bulk of the increase in catches in the other two atolls) were not abundant in Laamu Atoll. Secondly, the Laamu Atoll basin floor, although of smaller size and having few internal reefs, is remarkably uneven. The echosounder revealed that there are two main bottom levels, one at approximately *45-50m* the other at about 60-70m, with relatively steep changes in between. It was noted that when the normal/circle hook longlines were deployed, one longline was often wholly, or partly, at a different level to the other. This was rarely the case in Shaviyani and Alifu Atolls.

## 3.3. *Long/me fishing outside the atolls*

Thirtysix standard, 150-hook longlines were deployed outside Laamu, Alifu, Kaafu and Shaviyani Atolls in depths of 50-210m. More longlining outside the atolls had been planned, but fishing was hindered by echosounder problems, strong currents and bad weather. A summary of fishing effort at different depths (grouped into 30m intervals) outside the different atolls is given in Table 10.

**Table 10**

**Summary of longline fishing effort at different depths on outer atoll reefs from both Phase I and Phase II of the Reef Fish Survey**

**a.** Number of hooks

| Phase | Atoll | 30m | 60m | YOm | 120,n | hOrn | 180rn | 210rn | Total |
|---|---|---|---|---|---|---|---|---|---|
| II | 1. | – | 500 | 140 | – | 450 | 150 | – | 1240 |
| II | A | – | 300 | 600 | – | – | – | 600 | 1500 |
| II | K | | 300 | 300 | – | 300 | 450 | 150 | 1500 |
| II | Sh | | 380 | 300 | - | – | - | 30 | 710 |
| II | SubIolil | – | 1480 | 1340 | – | 750 | 600 | 780 | 4950 |
| I | K | 400 | 600 | 2100 | – | 150 | 150 | – | 3400 |
| I & II | TOTAL | 400 | 2080 | 3440 | – | 900 | 750 | 780 | 8350 |

b. Number of longlines

| Phase | Atoll | 30rn | 60m | 90m | 120m | 150m | I8Oni | 210m | Total |
|---|---|---|---|---|---|---|---|---|---|
| II | L | – | 4 | 1 | – | 3 | 2 | – | 10 |
| II | A | – | 2 | 4 | – | – | – | 4 | 10 |
| II | K | – | 2 | 2 | – | 2 | 3 | 1 | 10 |
| II | Sh | – | 3 | 2 | | – | – | 1 | 6 |
| **II** | **Subtotal** | – | 11 | 9 | – | 5 | 5 | 6 | 36 |
| I | K | 3 | 3 | 12 | – | I | I | – | 20 |
| I & II | TOTAL | 3 | 14 | 21 | – | 6 | 6 | 6 | 56 |

Prior to the deployment of longlines outside the atolls, the reef slope was quickly surveyed by echosounder. A total of 17 outer reef slope sites in four atolls were surveyed to a depth of about 200-250m. All are rather steep. Much of northern and eastern Laamu Atoll in particular, has cliffs dropping from 10-20m straight down to 160-170m or even deeper. However, every reef has a cliff between 100m and 130m. This perhaps relates to the lowering of sea level by 130m during the height of the last glaciation. Longline operations were limited to areas where the reef slope was not too steep. Another limitation was that most longlines were deployed on eastern facing reefs, because most of this work was carried out during the southwest monsoon season.

Longline catches from different depths outside the atolls are presented in Appendix II.

During Phase I of the Reef Fish Survey, 29 longlines were set at various depths outside N. Male Atoll (Van der Knaap *ci al.*, 1991). Some of these longlines were not set parallel to the reef, but data from twenty longlines can be compared with that obtained during this survey. Although there are differences of detail, overall similar species compositions, depth distributions and catch rates were observed. Therefore the two data sets are combined to give a fuller picture of the reef fish resources of the outer atoll slopes. Details of total fishing effort have been given in Table 10. Table 11 summarizes overall catch rates for various species and species groups, by depth, for the two surveys combined.

**Table 11**

**Catch rates by longline on the outer atoll reef at different depths (Data both Phase I & II)**

| *Depth* (mi | *30* | | *60* | | *90* | | *120* | | *150* | | *180* | | *210* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *No. of Fish per 1000 hooks* | *Ag* | *No of Fish per 1000 hooks* | *Kg* | *No. of Fish per 1000 hooks* | *Kg* | *No. offish per 1000 hooks* | *Kg* | *No. of Fish per 1000 hooks* | *Kg* | *No. of Fish per 1000 hooks* | *Kg* | *No, p1 Fo'h per 1000 hooks* | *Ag* |
| SNAPPER | 2.6 | 9.2 | 30.4 | 116.4 | 38,2 | 118.2 | | — | 30.0 | 105.2 | 18.6 | 22.6 | 3.8 | 5.8 |
| *Aphareus rutilans* | — | — | 9.2 | 48.2 | 5.2 | 19.6 | | — | 5.6 | 32.2 | 4.0 | 16.6 | 1.2 | 4.4 |
| *Aprion virescens* | 2.6 | 92 | 2.8 | 5.0 | 8.4 | 23.2 | | — | 2.2 | 13.8 | — | — | | — |
| *Eselis coruscans* | — | — | — | — | — | — | | — | 4.4 | 19.2 | — | — | — | — |
| *Lutjanus hohar* | — | — | 15.0 | 61.2 | 19.2 | 71.4 | | — | 2.2 | 2.4 | — | — | — | — |
| Other *Luijanus* | — | — | 2.4 | 3.6 | 1.4 | 0.6 | | — | — | — | — | — | — | |
| *Paracaesio* spp. | — | — | 1.0 | 0.4 | 0,6 | 0.2 | | — | 3.4 | 1.6 | — | — | — | |
| *Pristipomoides* | — | — | — | — | 32 | 3.2 | | — | 3.4 | 14.0 | — | — | — | — |
| Other *Pristipomoides* | — | — | — | — | 02 | — | | — | 8.8 | 2.0 | 14.6 | 6.0 | 2.6 | .4 |
| EMPEROR | 10.0 | 7.8 | 18.2 | 26.4 | 23.2 | 41.2 | — | — | 1.2 | 2.6 | | — | — | — |
| *Gysnnocranius* spp. | 2.6 | 0.6 | 1.4 | 0.6 | 2.0 | 2.8 | — | — | — | — | | — | — | — |
| *Leihrinus* spp. | 7.4 | 7.2 | 15.8 | 23.0 | 9.8 | 18.6 | — | — | — | — | | — | — | — |
| *Wattsia* | — | — | 1.0 | 2.8 | 11.4 | 19.8 | — | — | 1.2 | 2.6 | | — | — | — |
| GROUPER | 2.6 | 2.2 | 15.6 | 21.4 | 39.2 | 41.4 | | — | 33.4 | 134.8 | | — | — | — |
| *Cephalopholisspp.* | — | — | 1.0 | 0.6 | 2.6 | 2.4 | | — | — | — | | — | — | — |
| *Epinephe/us areolatus* | | . - | 0.4 | 0.4 | 16.8 | 98 | | — | — | — | | — | — | |
| *Epwepheluschlorost,gma* | — | — | 1.4 | 3.4 | 3.8 | 6.8 | | — | 11.2 | 12.6 | | — | — | — |
| *Epinephelus miliaris* | — | — | 2.8 | 4.6 | 12.0 | 13.4 | | — | 6.6 | 6.8 | | — | — | — |
| Deepwater *Epinephelus* * | — | — | — | — | 1.8 | 5.8 | | — | 14.4 | 113.2 | | — | — | — |
| Other *Epinephelus* | — | — | 2.8 | 5.4 | 0.8 | 1.2 | | — | 1.2 | 2.2 | | — | — | — |
| *Plectropomus* spp | — | — | 0.4 | 1.2 | 0.6 | 1.4 | | — | — | — | | — | — | — |
| *Variola* spp. | 2.6 | 2.2 | 6.8 | 5.8 | 0.8 | 0.6 | | — | — | — | | — | — | — |
| JACK | 2.6 | 2.6 | 2.0 | 5.6 | 3.6 | 10.6 | | — | 14.4 | 61.2 | 2.6 | 8.2 | | |
| *Caranxlugubris* | — | — | 1.0 | 3.6 | 1.2 | 2.4 | | — | 7.8 | 21.2 | — | — | — | — |
| Other *Caranx* | — | — | — | — | 0.6 | 3.0 | | — | — | — | — | — | — | — |
| *Seriola rivoliana* | — | — | — | — | 1.8 | 5.2 | | — | 6.6 | 40.0 | 2.6 | 8.2 | — | — |
| Other jack | 2.6 | 2.6 | 1.0 | 2.0 | — | — | | — | — | — | — | — | — | — |
| SHARK | — | — | 3.8 | 16.2 | 4.4 | 26.8 | | — | 2.4 | 15.0 | 2.6 | 4.0 | | |
| *Carrharhinus albimarginalus* | — | — | 2.0 | 7.2 | 4.4 | 26.8 | — | — | — | — | — | — | — | |
| *Carcharhinus amb/yrhynchus* | — | — | 1.4 | 6.4 | — | — | — | — | 1.2 | 10.6 | — | — | — | |
| *Mustelusmosis* | — | — | — | — | — | — | — | — | 1.2 | 4.4 | 2.6 | 4.0 | — | |
| *Triaenodon obesus* | — | — | 0.4 | 2.6 | — | | | | | | | | | |
| OTHERS | — | — | 2.4 | 2.6 | 1.4 | 3.0 | | — | 6.6 | 5.6 | 6.6 | 2.8 | 6.4 | 3.6 |
| **TOTAL** | 17.8 | 21.8 | 72.4 | 188.6 | 110.0 | 241.2 | | — | 88.0 | 324.4 | 30.4 | 37.6 | 10.2 | 9.4 |

* *E. epislicus*, *E. morrhua* and *E. seplernfasciatus*.

Highest catch rates outside the atoll were achieved just above and just below the main cliff. Combining data from both phases of the Reef Fish Survey, the average catches of commercial species *(i.e.,* excluding the 'Others' category of Tables 11 and 12) per 150-hook longline by depth were

| | | |
|---|---|---|
| 30 m | 2.6 fish, | 3.3 kg per 150 hook longline |
| 60 m | 10.5 fish, | 27.9 kg per 150 hook longline |
| 90 m | 16.3 fish, | 35.7 kg per 150 hook longline |
| 120 m | Cliff | |
| 150 m | 12.2 fish, | 47.8 kg per 150 hook longline |
| 180 m | 3.6 fish, | 5.3 kg per 150 hook longline |
| 210 m | 0.6 fish, | 0.8 kg per 150 hook longline |

The high catch weight at lSOm is affected by data from one Phase I longline, which caught five large grouper *(Epinephelus septemfasciatus)* weighing a total of 75kg. Removal of these exceptional fish gives an average catch weight of *35.3* kg per 150 hook longline at 150 m.

Catch rates dropped sharply in both shallower and deeper water. Catches at 180m and below are believed to reflect the relatively low abundance of fish at these depths. However, at shallow depths *(i.e.* 30 m), diving observations and handline catches show that commercial fish are relatively abundant. The main reason for low longline catches in shallow waters appears to be the presence of large numbers of small fish, such as triggerfish and wrasses, which nibble the bait, leaving the hooks bare.

Although there are insufficient data to give precise depth distributions for different species, some generalizations can be made. Many species of commercial value were not found deeper than 100 m, including emperor ***(Gymnocranius*** and *Lethrinus),* some grouper *(Cephalopholis, Plectropomus* and *Variola)* and most jack. In contrast, several other potentially valuable species were only caught in deeper waters. These include the snapper *Aphareus rutilans, Etelis coruscans,* and *Pristipomoides* spp; and several grouper *Epinephelus morrhua, E. poecilonotus* and *E. septemfasciatus.* The jack ***Caranx lugubris*** and *Seriola rivoliana* are sometimes caught inside the atolls, but they are much commoner on the deep outer slope.

## **3.4.** *Handlining*

### 3.4.1. DAY HANDLINING

A total of 406 hours of day handlining was carried out in the three atolls, resulting in a total catch of 642 fish, weighing nearly 1000 kg. A complete list of day handlining catches is given in Appendix III A summary of catch rates is given in Table 12. Average catch rates and fish weights were

| | *No. fish/h* | *kg/h* | *kg,fish* |
|---|---|---|---|
| Shaviyani | 2.7 | 3.3 | 1.2 |
| Alifu | 1.0 | 2.0 | 2.0 |
| Laamu | 1.2 | 2.0 | 1.7 |
| **Average** (Phase II) | 1.6 | 2.4 | 1.5 |
| N. Male (Phase I) | | 1.2 | |

**Table 12**

**Catch rates of major species and species groups by day handlining**

| | *SHA VIYANI* | | *ALIFU* | | *LAAMU* | | *TOTAL* | |
|---|---|---|---|---|---|---|---|---|
| | *No/hr* | *kg/hr* | *No/hr* | *kg/hr* | *No/hr* | *kg/hr* | *No/hr* | *kg/hr* |
| SNAPPER | .35 | 1.53 | 0.29 | 0.67 | 0.34 | 0.74 | 0.64 | 0.96 |
| *Aprion virescens* | 0.96 | 1.27 | 0.22 | 0.53 | 0.29 | 0.60 | 0.47 | 0.78 |
| *Lutjanusbohar* | 0.05 | OIl | 0.06 | 0.14 | 0.03 | OIl | 0.05 | 0.12 |
| Other snapper | 0.35 | 0.15 | 0.01 | 0.00 | 0.02 | 0.03 | 0.11 | 0.06 |
| EMPEROR | 0.31 | 0.60 | 0.22 | 0.26 | 0.24 | 0.30 | 0.25 | 0.37 |
| GROUPER | 0.53 | 0.66 | 0.34 | 0.47 | 0.36 | 0.52 | 0.40 | 0.54 |
| JACK | — | — | 0.05 | 0.11 | 0.08 | 0.13 | 0.04 | 0.08 |
| SHARK | 0.04 | 0.06 | 0.01 | 0.04 | 0.01 | 0.03 | 0.01 | 0.04 |
| TUNA | 0.01 | 0.01 | — | — | 0.03 | 0.11 | 0.0! | 0.03 |
| OTHERS | 0.50 | 0.47 | 0.05 | 0.44 | 0.18 | 0.18 | 0.23 | 0.38 |
| **TOTAL** | 2.74 | 3.33 | 0.96 | 1.99 | 1.24 | 2.0I | 1.58 | 2.46 |

Note All figures rounded to nearest 0.01.

Day handlining caught a particularly wide variety of species. The most important individual species was *Aprion virescens,* which made up 32 per cent of the catch by weight. Other major species were *Lutjanus bohar, Lethrinus microdon, Epinephelus microdon* and *Ablennes hians,* which, together, made up 22 per cent of the catch by weight. A single large specimen of guitarfish, *madimiyaru* (Mal.) — *Rhinobatos,* caught in An Atoll weighed 70kg, and by itself constituted 7 per cent of the total day handline catch.

Day handlining catches were extremely variable from day to day within each atcll. In addition, handlining was often carried out on an opportunistic basis, between other activities, and so fishing was not always carried out in ideal locations. For these reasons handline catch rates are not thought to be particularly good indices of reef fish abundance.

### 3.4.2. NIGHT HANDLINING

A total of 400 hours of night handlining was carried out in the three atolls, resulting in a total catch of 544 fish weighing just over 1000kg. A complete list of night handlining catches is given in Appendix IV. A summary of catch rates is given in Table 13. Average catch rates and fish weights were:

| | ***No. fish/h*** | ***kg/h*** | ***kg/fish*** |
|---|---|---|---|
| Shaviyani | 2.1 | 3.0 | 1.4 |
| Alifu | 1.3 | 1.7 | 1.3 |
| Laamu | 0.7 | 2.6 | 3.7 |
| Average (Phase II) | 1.4 | 2.4 | 1.7 |
| N. Male (Phase 1) | | 1.5 | |

**Table 13**

**Catch rates of major species and species groups by night handlining**

| | *SHA V1YANJ* | | *ALIFU* | | *LAAMU* | | *TOTAL* | |
|---|---|---|---|---|---|---|---|---|
| | *No/hr* | *kg/hr* | *No/hr* | *kg/hr* | *No/hr* | *kg/hr* | *No/hr* | *kg/hr* |
| SNAPPER | 1.37 | 1.77 | 0.71 | 0.77 | 0.19 | 0.46 | 0.73 | 0.98 |
| *Lutjanus bohar* | 0.93 | 1.43 | 0.38 | 0.56 | 0.15 | 0.38 | 0.47 | 0.78 |
| *Lutjanusgibbus* | 0.41 | 0.28 | 0.28 | 0.17 | 0.01 | 0.01 | 0.22 | 0.14 |
| Other snapper | 0.03 | 0.06 | 0.05 | 0.04 | 0.03 | 0.07 | 0.04 | 0.06 |
| EMPEROR | 0.04 | 0.13 | 0.06 | 0.09 | 0.03 | 0.07 | 0.04 | 0.09 |
| GROUPER | 0.26 | 0.46 | 0.13 | 0.24 | 0.01 | 0.04 | 0.13 | 0.23 |
| JACK | 0.17 | 0.31 | 0.04 | 0.20 | 0.34 | 1.38 | 0,20 | 0.70 |
| *Caranxsexfasciatus* | 0.17 | 0.3! | 0.02 | 0.07 | 0.23 | 0.86 | 0.15 | 0.46 |
| Other jack | — | — | 0.02 | 0.I3 | 0.11 | 0.52 | 0.05 | 0.24 |
| **SHARK** | 0.03 | 0.10 | 0.05 | 0.21 | 0.03 | 0.10 | 0.04 | 0.13 |
| TUNA | — | — | — | — | 0.04 | 0.47 | 0.02 | 0.18 |
| OTHERS | 0.25 | 0.24 | 0.37 | 0.24 | 0.09 | 0.08 | 0.22 | 0.17 |
| *Sargoceniron spiniferum* | 0.10 | 0.11 | 0.05 | 0.04 | 0.02 | 0.0! | 0.06 | 0.05 |
| *Sphyraenaspp,* | 0.13 | 0.10 | 0.27 | 0.14 | 0.01 | 0.03 | 0.12 | 0.08 |
| Other species | 0.03 | 0.03 | 0.05 | 0.06 | 0.06 | 0.04 | 0.04 | 0.04 |
| **TOTAL** | 2.12 | 3.01 | 1.36 | 1.75 | 0.73 | 2.60 | 1.38 | 2.48 |

**Note** All figures rounded to nearest 0.01.

<<

It is difficult to compare catch rates between atolls, since those within the atolls varied so much. Catch rates varied between 0 and the following maxima

| | *No. fish/h* | *kg/h* |
|---|---|---|
| Shaviyani | 7.6 | 9.4 |
| Alifu | 2.3 | *5.6* |
| Laamu | 2.2 | 7.0 |

Very high catch rates were achieved at a few places only. In Shaviyani, one small reef just southeast of Kilisfaru gave the very high catch rates noted above. The catch was composed mainly of small *Lutj anus bohar* (see Figure 8). In Laamu Atoll, night handlining in the vicinity of the freezer vessel mooring off Maamendhoo gave good catches of large fish, notably tuna and jack.

In general, small snapper (particularly *L. gibbus* and juvenile *L. bohar)* made up about half the night handlining catches. However, the importance of *L. bohar* and *L. gibbus* decreased from north to south. In Laamu, in the south, jack were of far greater significance than in Shaviyani or Alifu. *Caranx sexfasciatus* was the most important jack in night handline catches.

### 3.4.3. COMMERCIAL HANDLINING CATCH RATES

During this survey, handlining was generally carried out in atolls about which the crew did not have detailed local knowledge. In addition, it was sometimes necessary to carry out handlining in less than ideal locations between other activities. As a result, the catch rates obtained during this survey for day handlining (2.0-3.3 kg/h) and night handlining (1.7-3.0 kg/h) should be considered as minimum rates for a commercial fishery.

In N. Male Atoll, average handline catch rates of *5-6* kg/h have been recorded for the commercial reef fishery (Brown *et al.* 1989; Van der Knaap *et al.)* In Dhaalu Atoll, average handline catch rates of about 10 kg/h have been recorded from day handlining (Brown *etal.,* 1989). But it should be noted that the commercial reef fisheries do, in fact, take significant quantities of pelagic fish, and so their catch rates probably overestimate reef fish abundance. Average commercial catch rates for demersal reef fish will, therefore, be of the order of *3-5* kg/h.

## *3.5. Trolling*

Trolling was carried out while travelling to and from target atolls, and while travelling between reef fishing stations within atolls, A total of 729 hours of trolling was recorded and a summary of catches is presented in Table 14.

**Table 14**

**Summary of trolling catch rates**

| | *SHAVJYAN!* | | *ALIFU* | | *LAAMU* | | *TOTAL* | |
|---|---|---|---|---|---|---|---|---|
| | *No./100hrs* | *kg/100hrs* | *No,/100hrs* | *kg/100hrs* | *No./100hrs* | *kg/100hrs* | *No,/100hrs* | *kg/100hrs* |
| *Aprion virescens* (Green jobfish) | 0.5 | 0.4 | 0.6 | 0.6 | – | – | 0.4 | 0.3 |
| *Elagatis bipinnulata* (Rainbow runner) | 1.7 | 1.6 | 0.6 | 0.7 | 6.9 | 7.9 | 2.3 | 2.5 |
| *Auxis lhazard* (Frigate tuna) | 23.6 | 14.2 | 25.3 | 10.7 | – | – | 19.7 | 10.8 |
| *Euthynnus afjinis* (Little tuna) | 62.1 | 43.7 | 42.7 | 24.8 | 16.8 | 14.0 | 49.2 | 33.8 |
| *Gymnosarda unicolor* (Dogtooth tuna) | 0.2 | 3.2 | – | – | 3.1 | 33.1 | 0.7 | 7.8 |
| *Katsuwonus pdamis* (Skipjack tuna) | 7.2 | 15.1 | | – | 0.8 | 0.3 | 4.3 | 8.7 |
| *Thunnus albacares* (Yellowfin tuna) | 1.9 | 6.2 | – | – | 1.5 | 11.3 | 1.4 | 5.6 |
| *Acanihocybium solandri* (Wahoo) | 0.7 | 3.4 | 0.6 | 3.8 | 9.9 | 62.3 | 2.3 | 14.1 |
| *istiophorus platyplerus* (Sailfish) | 0.2 | 7.8 | – | – | – | – | 0.1 | 4.5 |
| *Coryphaena hippurzss* (Dolphinfish) | – | – | 1.1 | 2.1 | 3.1 | 10.6 | 0.8 | 2.4 |
| *Sphyraena barracuda* (Great barracuda) | 0.2 | 1.3 | – | – | 1.5 | 7.3 | 0.4 | 2.0 |
| **TOTAL** | 98.3 | 96.9 | 70.9 | 42.7 | 43.6 | 146.8 | 81.6 | 92.5 |



<<

A total of 595 fish weighing 674 kg were caught, *i.e.* an average of 0.82 fish and 0.93 kg/h. Catch rates varied greatly, with much higher catch rates being achieved on a few occasions.

While trolling inside Shaviyani Atoll in June 1991 on schools of small frigate and little tuna, average catch rates of 3.6 kg/h were achieved. While travelling along outer atoll reefs trolling the *mas vadhu* for large pelagics, catch rates of 5.8 and *7.5* kg/h were achieved on two days during trips to Laamu Atoll.

Because catch rates and species composition varied greatly, depending on fishing position *(i.e.* inside atoll, near outer reefs, or offshore), most of the differences in troll catches between atolls (Table 14) are probably not significant. However, the decline in catches of frigate and little tuna from north to south does reflect the situation in the commercial troll fishery (Anderson and Hafiz, 1985).

A single specimen of the bullet tuna *Auxis rochei* was caught in Alifu Atoll on May 16, 1991. It was 28cm fork length and has been included in Table 14 under *A. thazard.*

## 3.6. *Other fishing methods*

Trials were conducted with two types of 'vertical' longline, but the trials were not successful. A 12-hook longline similar to that used by Maldivian fishermen for catching deep water spiny dogfish was tried twice. The lines were deployed in approximately 400m, south of L. Hithadhoo, and in 250m, east of A. Ellaidhoo. There was no catch on either occasion. It is thought that the lines were not set in deep enough water. The aim of these trials was to identify the species involved in this fishery and to make preliminary estimates of catch rates. Unfortunately there was insufficient time for further trials.

A vertical stick longline or trotline (Figure 4) similar to one successfully employed in deepwater snapper fisheries in the Pacific (Lewis, 1989) was used on three occasions outside Male Atoll. The first line was set unbaited in shallow water to check deployment. The line was then set in 90m and 60m. Total catch was only 3.5 kg. Further experimentation may have led to better results, but as was the case with the spiny dogfish longline there was insufficient time for further trials. The relatively high cost of manufacturing this line (to buy all the components new in Male would cost over US $ 1000) would not make it an attractive proposition to Maldivian fishermen.

Fish traps were deployed on one occasion. During the first phase of the Reef Fish Survey, a total of 572 trap, fishing operations were carried out, but all these were inside N. Male Atoll (Van der Knaap *er a!.* 1991). During the Second Phase one set of four traps was set in about 180 - 200m outside N. Male Atoll. No fish were caught, but one trap was hauled up containing a number of small crabs while another contained a deepwater spiny lobster, *Puerulus sewelli.* This species was previously caught in traps, in about 200m, between An and Rasdhoo Atolls, and outside Baa Atoll during the *FridtjofNansen* survey (Stromme, 1983). Since this species is potentially of commercial interest, further trials with more suitable lobster traps were planned. Unfortunately, these could not be carried out owing to the lack of personnel, particularly a gear technologist.

# *4. STOCK ASSESSMENT*

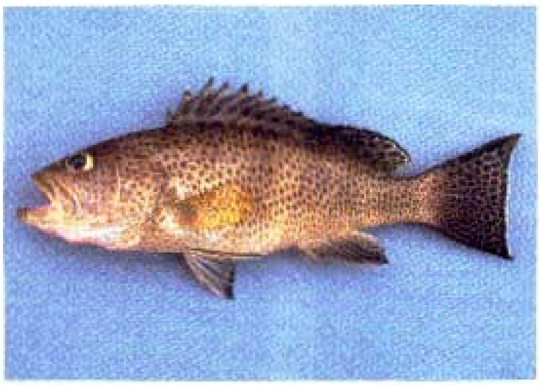
## 4.1. *Models available*

Since the l950s, a number of fish stock assessment models have been developed that can give (relatively) accurate estimates of the size (biomass) of fish stocks and of potential yields or allowable catches. These models usually rely on fairly detailed information on the fishery *(i.e.* long time-series

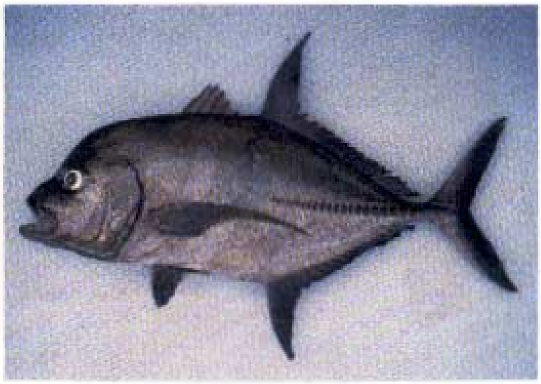
*These were some of the species offish caught by the* LV. Farumas *during the ReefFish Resources Survey in the Maldives, Phase II*

Aprion virescens — *a common snapper*

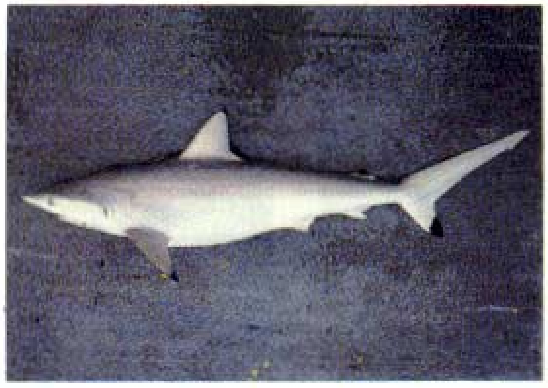
Lutjanus bohar — *another common snapper*



Epinephelus areolatus
— *a common 'plate-size' grouper*



Caranx lugubris — *a deep waterjack*



Carcharhinus sorrah — *the spot-tail shark — caught in Laamu Atoll*

Satyrichthys — *deep water armoured gournards — caught in 180 m*

<<

1

7

1 *Repairing the longline aboard the* Farumas.

2 *Baiting the lingline.*

3 *Ready to set the longline*

4 *Hauling in the longilne.*

5 *Landing a nurse shark.*

6 *Unhooking a shark aboard the* Farumas;

7 *Measuring the catch.*

<<

2

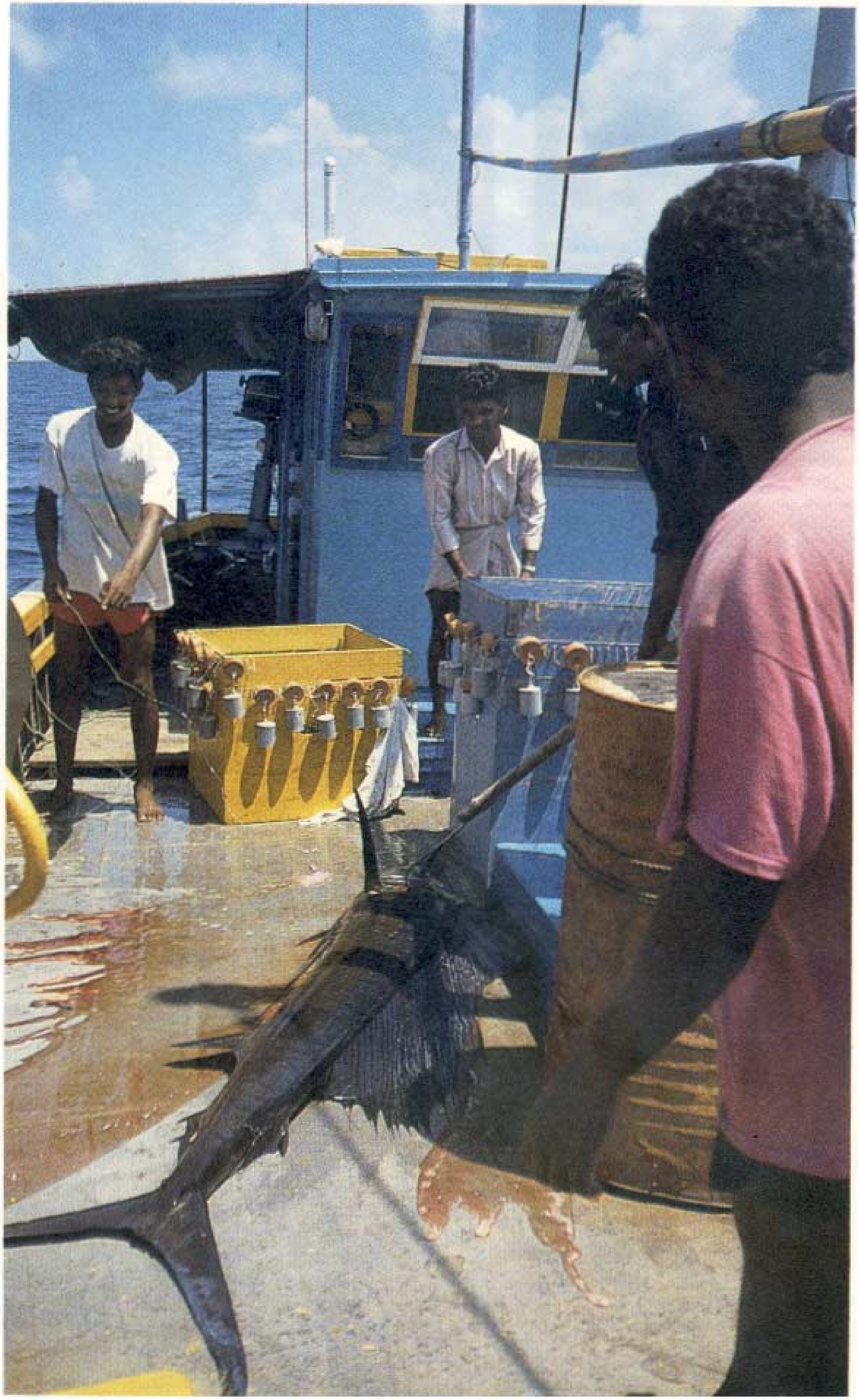
3

4

6

5

<<



*A sailfish aboard the* Farumas, *after capture on the troll line.*



<<

of catch and effort data) and/or the stocks being fished (notably details of population age structure). Such information is not available for the Maldivian reef fish fishery.

Although 'reef fish' catches are included in the official Maldivian fishery statistics, this category actually includes a large proportion of pelagic species *(e.g.* rainbow runner, *Elagatis bipinnulata),* much of which is the by-catch of the pole-and-line fishery. The true catch of demersal reef fishes is unknown but would certainly be less than 5000t per year and probably less than 3000t per year (see Section 1.2). Another problem is that there is no estimate of reef fishing effort. There is also virtually nothing known about the population-age structure of Maldivian reef fish, a problem which is compounded by the fact that the reef fishery is a multispecies one.

Because of these problems, attempts at reef fish stock assessment in the Maldives will have to rely on data from research surveys. As confirmed during the first phase of the Reef Fish Survey (Van der Knaap *eta!,* 1991), the best methods of sampling these reef fish is by handline and longline. However, there are at present very few methods for relating hook-and-line catch data to stock abundance. The methods available include

a. The Leslie-Delvry removal method (Ricker, 1975) which estimates population numbers from the linear regression of catch per unit effort against cumulative catch. Extrapolation to zero catch per unit effort gives the original population size.

b. The Rickard method (Eggers *et al.,* 1982) which estimates the area fished by bailed hooks on longlines with different hook spacings. Population size is estimated from the regression of catch per hook against hook spacing.

c. The Kulbicki method cKulbicki, 1988) which uses visual censuses to relate longline catch to fish abundance.

A number of factors (including the relatively large size of the target atolls; the great variability of longline catches; the multispecies nature of the catches; the fact that many of the species caught were large and active; and the limited survey time available) prevented trials of the Leslie and Rickard methods. However, Kulbicki's method was used to estimate standing stocks of both the atoll basins and the outer reef slopes using the results of the longline surveys in the target atolls. Given the problems of applying Kulbicki's empirical results to the Maldivian situation, it is to be regretted that it was not possible to make any independent estimates of standing stocks. If the opportunity were to arise in the future it might be possible to estimate the standing stock of the deep slope resources of a' small atoll using the Leslie method, or the standing stock of a common atoll basin species *(e.g. Aprion virescens)* using the Rickard method.

Estimates of standing stock can be converted to estimates of potential maximum sustainable yield using Gulland's (1971, 1983) formula. This approach cannot be used for the shallow reef areas (less than 50m), where longlining could not be carried out. For these areas, estimates of potential commercial reef fish yields are made by analogy with well studied coral reef areas in the Pacific, where yields have been calculated. This approach is also used for the deep slope fish stocks, and allows a useful comparison with the results from Kulbicki's method.

In the case of the atoll basins and shallow reef areas, estimates of yields are made initially in terms of weight of fish per unit area. These can be multiplied up to total yields for the whole country, given the total areas involved. In the case of the outer reef slope, the deepwater reef fish habitat can be thought of as a narrow band running around the perimeter of the atolls. Most deepwater reef fish are found between about 60m and ISOm. As the outer reef slope is very steep, this band may be little more than lOOm wide in many places. It is therefore useful to think in terms of yields per km of atoll perimeter. Studies of deepwater reef fish resources from Pacific countries have tended to discuss yields per km of 200m depth contour (isobath). Atoll perimeter, rather than 200m isobath, is used here for four reasons

- The on1y available charts do not give the 200m depth contour;
- The outer reef slopes are steep and the difference in length of the two measures is likely to be relatively small;

- What difference there is will tend to be an underestimate, thus leading to conservative stock size estimates; and
- The greatest concentration of deepwater reef fish in the Maldives is found shallower than 200m, mainly in the range 60-l5Om.

Stock assessments are made separately for three major reef fish habitats: atoll basins, shallow reef areas, and deep reef slopes.

## 4.2. *Atoll basins*

Kulbicki (1988) observed a direct relationship between reef fish abundance and longline catches in the S W lagoon of New Caledonia. Use of his empirical formula allows a first approximation of reef fish abundance in the comparable atoll basin lagoons of the Maldives. However, direct application of Kulbicki's formula must only be considered as a very rough method for making first approximations of reef fish abundance. This is because there are potentially significant differences between the two studies, notably in the species fished, and between the longline used by Kulbicki and in this study.

Kulbicki's model is based on underwater observations that demonstrated the behaviour of individual fish species with respect to the longline; it then uses this information to relate CPUE to abundance. Five species made up 50.8 per cent of the longline catch in the New Caledonjan study (Kulbicki and Grandperrin, 1988). Only one individual of one of those species *(Diagramma pictu,n)* was caught by longline during this survey. However, Kulbicki did suggest that reef fish families tend to behave consistently with respect to the longline. In the New Caledonian study the four families, Serranidae (grouper), Lethrinidae (emperor), Lutjanidae (snapper) and Carangidae (jack) made up 65 per cent of the catch by weight (Kulbicki and Grandperrin, 1988). During Phase I of the Maldivian Reef Fish Survey in N. Male Atoll the same four families made up 63 per cent of the longline catch (Van der Knaap ***et a!.*** 1991). During Phase II of the survey, these four families made up 74 per cent of the total longline catch by weight in the three target atolls. This similarity suggests that Kulbicki's model can be applied in the Maldives, but the differences in species composition that do exist suggest that the results should be interpreted with due caution

There are a number of differences in design between the longline used by Kulbicki (1988) and that used during this survey. Some of these may have significant effects on catch rates and, thus, on the applicability of Kulbicki's method to results from this survey. Circle hooks were used on the longline in Kulbicki's survey, whereas 'normal' hooks were used in this survey. As discussed above, circle hooks catch more than 'normal' hooks. However, the trials conducted during this survey, to compare the two types of hook, allow corrections to be made for this difference in technique.

A second, more intractable, problem is that the distance between the hooks on Kulbicki's longline was 2.8m, whereas the average distance between hooks on the longline used here was nearly 6m (Sm between hooks, plus sinkers placed every five hooks). This has two effects : it increases the area covered by the longline and it decreases the 'overlap' of fishing area of each hook (Eggers ***et*** *a!.* 1982). Thus, the 150-hook longline used in this survey probably caught more than would a longline identical in all respects except for having inter-hook spacings reduced to 2.8m. The problem is to estimate the size of this difference. Hamley and Skud (1978) recorded an 18 per cent increase in halibut catches in the N.E. Pacific when hook spacing on longlines was increased from 2.74m to 5.49m. It is possible that there would be less effect with the more numerous and more active species fished during this survey. However, in view of the uncertainties involved, and in order to provide more conservative estimates of reef fish density and biomass, it is assumed, as a first crude approximation, that the increase in longline catch relative to Kulbicki's longline catch due to wide hook spacing is offset by the decrease in catch resulting from the use of 'normal', rather than circle, hooks. Therefore, catch rate estimates obtained from this survey are used directly in Kulbicki's model.

Other differences in the longlines used that might have affected catch rates include differences in bait (mainly tuna in this survey v. mainly squid used by Kulbicki) and differences in hook size (mainly no. 6 v. nos. 8-10). The larger hook size used in this survey may partly explain the larger mean sizes of fish caught in the Maldives compared with those taken by Kulbicki in New Caledonia. However, the very low level of reef fishing activity in the Maldives may also explain this difference.

For the three atolls studied, plus N. Male Atoll (Phase I results), estimates of commercial reef fish biomass *(i.e.* excluding 'Others' category in Table 6) in the atoll basins using Kulbicki's method are as follows

| | *Shaviyani* | *Alifu* | *Laamu* | *N. Male* |
|---|---|---|---|---|
| CPUE (No. commercial fish/100 hooks) | 4.8±0.5 | 8.3±0.6 | 5.0±0.6 | 5.1±0.7 |
| Density (No. fish/ha) | 29.2 | 74.9 | 31.4 | 32.1 |
| 95% confidence limits of density | 17-43 | 42-114 | 18-49 | 18-51 |
| Mean fish weight (kg) | 3.29 | 2.76 | 1.94 | 2.05 |
| Biomass ($t/km^2$) | 9.61 | 20.66 | 6.08 | 6.58 |
| 95% confidence limits of biomass | 5.80-14.37 | 11.77-31.41 | 3.50-9.53 | 3.70-10.55 |

The biomass estimates for the atoll basins of Shaviyani, Laamu and N. Male Atolls are all in broad agreement. However, the mean estimate of commercial reef fish biomass in the Alifu atoll basin (20 t/km2) is two to three times greater than the biomass estimates for the other atolls. This might reflect the true abundance of reef fish in Alifu Atoll, or it might be that the lower limit of the biomass estimate (i.e. 11 t/km2) is nearer the true value.

In order to convert biomass estimates from individual atolls into a total biomass estimate for the **whole country,** it is assumed that the estimates for Shaviyani, N. Male and Laamu are representative of northern, central and southern atolls respectively. Alifu Atoll is treated as a special case. The total biomass, or standing stock, of commercial reef fishes in the atoll basins of the Maldives is estimated as follows

| | *Area(km2) (Table 17)* | *Total Biomass (t)* | *95% confidence limits of biomass (t)* |
|---|---|---|---|
| Northern atolls | 6,355 | 61,100 | 36,800 - 91,300 |
| Alifu atoll | 1,880 | 38,800 | 22,100 - 59,000 |
| Central atolls | 4,325 | 28,400 | 16,000 - 45,600 |
| Southern atolls | 5,125 | 31,200 | 17,900 - 48,800 |
| **TOTAL** | 17,685 | 159,500 | 92,800 - 244,700 |

THUS : Mean biomass estimate = 160,000 t
Upper biomass estimate = 240,000 t
Lower biomass estimate = 90,000

From these biomass estimates it is possible to estimate potential maximum sustainable yields. To do this it is assumed that the current catch of demersal reef fish species from the atoll basins of the Maldives is of the order of 500t per year. It is also assumed, following Van der Knaap *et al.* (1991) that M=0.5 (although this assumption can be queried on several gr'ounds and the variance of this estimate may be substantial). Thus, the mean estimate of maximum annual sustainable yield of reef fish from the atoll basins is given by

$$Y_{max} = 0.3\ (500 + 0.5 \times 16{,}000)$$
$$= 24{,}000$$

Upper limit of $Y_{max}$ = 36,000 t

Lower limit of $Y_{max}$ = 13,500t

## 4.3. *Shallow reef areas*

The handline results presented above (Section 3.4) give information on the species composition and minimum catch rates that can be expected from a commercial reef fishery. However, it is at present not possible to use this data to make an assessment of the size of the stocks of reef fish in this area.

The only approach available is to make use of estimates of reef fish yields from coral reef areas in other countries. These are generally in the range of 3-6 t/$km^2$ per year (Marshall, 1979; Marten and Polovina, 1982; Munro, 1977 and 1984). Estimates of yields of the order of 20t/$km^2$ per year (Alcala and Luchavez, 1981; Gaizin, 1987; data of Wass 1982 analyzed by Munro 1984) appear to have been based on calculations of coral reef area alone, and do not include lagoons or other less productive areas. These estimates are, therefore, considered too high for use here, where the area of the 'shallow coral reef ecosystem' calculated from naval charts includes many shallow lagoon areas.

The estimates of 3-6 t/k$m^2$ have mainly been calculated for small-scale subsistence fisheries that take large quantities of small species that are not considered to be 'commercial fish' in the Maldives. For example, the reef fishery at Apo Island in the Philippines, studied by Alcala and Luchavez (1981), catches a wide variety of species, but only a third of the catch would be considered to be of commercial value in the Maldives *(i.e.* the medium to large fish which can be caught by handline). Blaber *eta!.* (1990) present results of experimental gillnetting in the Maldives mainly on upper reef slopes, which show that 38 per cent of the catch by weight was of 'commercial' species. As a first approximation it is assumed that one-third of the biomass utilized by subsistence fisheries in other countries would be of species of interest to a commercial reef fishery in Maldives.

Therefore, the potential yield of the coral reef systems of the Maldives to a depth of 50-60m is estimated to be of the order of 1-2 t/ $km^2$ per year. The total area of such reefs is estimated to be roughly 3,500 $km^2$ The total potential yield of reef fish from this area is, therefore, estimated to be

$$Y_{max} = 3{,}500 - 7{,}000 \text{ t per year}$$

## 4.4. *Deep reef slopes*

Both the approaches used above are available for making a crude stock assessment of the reef fish resources of the deep, outer reef slopes of the atolls. First, the longline catch rates obtained during the Reef Fish Survey can be analyzed with Kulbicki's model. Secondly, estimated sustainable yields from deep slope snapper fisheries in the Pacific can be applied.

### 4.4.1. KULBICKI'S METHOD

Kulbicki's empirical formula was developed for a soft-bottom fishery in New Caledonia. Its application to results from a soft-bottom fishery in the Maldives is not without problems (Section 4.2). Its application to results from a hard-bottom fishery is potentially even more problematic. Nevertheless, its use may at least allow an order-of-magnitude estimation of potential yields.

The main fishing zone outside the atolls is at depths between about 60m and lSOm (Table 11). Within this zone, the average catch rate was 8.7 fish per 100 hook longline. The average weight of the fish caught was 2.54 kg. Applying Kulbicki's formula

| | | |
|---|---|---|
| Log (Density + 1) | = | 1.94 Log (CPUE + 1) |
| | = | 1.94 Log (8.7 +1) |
| Density | = | 80.3 fish/ha |
| 95% Confidence Limits | = | 52.7-117.5 fish/ha |
| Biomass | = | 80.3 x ***2.54*** kg/fish |
| | = | 204.0 kg/ha |
| *95%* Confidence Limits | = | 133.9-298.5 kg/ha |

If it is assumed that the deep reef fish stocks occupy a band approximately 100m wide around the perimeter of the atolls, then

| | | |
|---|---|---|
| Biomass | = | 204.0 x 10 kg/km of reef slope |
| | = | 2.04 t/krn of reef slope |
| 95% Confidence Limits | = | 1.34 - 2.99 t/km of reef slope |

Since the total length of the perimeters of all the atolls is estimated at 2,850 km

| | | |
|---|---|---|
| Total Biomass | = | 2.04 x 2,850 |
| | = | 5,8001 |
| 95% Confidence Limits | = | 3,800-8,500 |

**An estimate of the potential MSY can be made using Gulland's formula. This requires an estimate** of M (coefficient of natural mortality). Estimates of mortality rates from the Pacific of deepwater snapper and jack, both found in the Maldives, are available and are of the order of 0.5 (Polovina **and Ralston, 1986). For the deepwater grouper** *E. morrhua*, **M has been estimated at 0.21 (Langi** and Langi, 1987). As a first approximation an 'average' M value of 0.3 - 0.4 will be used. It is further assumed that the current catch of deepwater reef fish is effectively zero. Thus

| | | |
|---|---|---|
| $Y_{max}$ | = | 0.3 (0 + **0.35 x** 5,800) |
| | = | 600t |
| Lower est. of $Y_{max}$ | = | 0.3 (0 + 0.3 x 3,800) |
| | = | 340t |
| Upper est. of $Y_{max}$ | = | 0.3 (0 + 0.4 x *8,500)* |
| | | 1,000t |

## 4.4.2. ANALOGY WITH PACIFIC FISHERIES

The annual sustainable yield of bottom fish has been estimated at 115-154 kg/km of the 200m isobath in Hawaii (Ralston and Polovina, 1982, Polovina, 1984) and in the Marianas (Polovina and Ralston, 1986). The main concentration of deepwater snapper and grouper seems to be somewhat shallower in the Maldives than in the Pacific, but the species composition is comparable. Using sustainable yield data from the Pacific is, therefore, probably valid for a first approximation. The lengths of the perimeters of all the Maldivian atolls total 2,850 km. Therefore the total sustainable yield of deepwater reef fish is estimated to be

| | | |
|---|---|---|
| $Y_{max}$ | = | 330 - 440 t per year. |

## 4.4.3. COMPARISON OF THE TWO METHODS

Given the crude nature of the two methods used to estimate sustainable yields of deep slope reef fishes, it is encouraging that the results obtained overlap

| | | |
|---|---|---|
| **MSY estimated by Kulbicki's method** | = | 600(340-1,000) t/yr |
| MSY estimated by analogy with the Pacific | = | 330-440 t/yr |

The highest catches on the outer slopes of Maldivian atolls were obtained at 60-150m depths. This is shallower than the 200m average fishing depth in the Pacific studies. It is, therefore, possible that the depth zone under consideration in the Maldives is more productive than that in the Pacific. Also, some 'shallow water' species (notably *Lutjanus bohar)* are occurring in the 'deep water' catches. Therefore, the higher of the two MSY estimates may be nearer the true figure. As a first approximation it is, therefore, estimated that

$$Y_{max} \text{ of deep slope reef fish resources} = 400\text{-}600t/yr$$

## *4.5. Total stock assessment*

Estimates of potential yields of reef fish from the three major areas of the Maldivian atolls have been made, as follows

| | *Estimate of annual maximum yield (t)* | | |
|---|---|---|---|
| | *Mean* | *Lower* | *Upper* |
| **Atoll basins** | 24,000 | 13,500 | 36,000 |
| Reef areas | 5,250 | 3,500 | 7,000 |
| **Deep reef slopes** | 500 | 400 | 600 |
| **TOTAL** | 30,000 | 17,000 | 43,000 |

The total annual yield of commercially valuable reef fish species is, thus, estimated at roughly 30,000 t ± 13,000 **t.**

This estimate of potential yield (of the order of 30,000t) is much greater than current catches of demersal reef fish (unknown, but less than 5,000 t per year). The reef fish resources of the Maldives would, therefore, seem to be underfished. The presence of many large and **old fish in both survey** and commercial catches reinforces this interpretation. While an increase in reef fishing activity is, therefore, possible, and may be seen as desirable (particularly if a high value export market can be developed), the following points should be borne in mind

- The estimate of maximum potential yield applies to the country as a whole. The logistical difficulties of operating a high-value, export-oriented fishery in the outer atolls would be **considerable. Therefore, any such fishery is likely to develop within reach of Hulhule International Airport. The central area of Maldives already has the highest level of reef** fishing in the country, to supply Male **market and the tourist resorts.** This area may therefore suffer overfishing of the most valuable species and/or conflicts between users, while in other areas the reef fish resources may remain relatively untouched.
- **A particular source** of conflict may be between resorts and fishermen. Many tourists visit Maldives specifically to dive or snorkel and observe the abundant fish life. Spearfishing **(which is banned in** Maldives) in particular and overfishing in general has reduced the fish life, and particularly the large species, on coral reefs in many other tropical countries. An **expanding** reef fishery might not help tourism.
- The deepwater snapper resource, which was identified as being of potential export value by Elsy (1989), appears to be rather small and very thinly spread around the country.
- The reef fish resources of the atoll basins appear to be considerable, and at present little **utilized. As noted by Kulbicki (1988), tropical soft bottom fisheries in non-trawlable areas** may offer considerable scope for development. The atoll basins have the advantage of being 'out of sight', as far as diving tourists are concerned. However, many of the fish species **caught here are also caught by handlining on reefs.**

It should also be emphasized again that the estimate of potential yield is rather crude, so due caution **should be exercised in using it. In particular, if the Maldivian reef fishery were to be expanded,** it would be necessary to carefully monitor developments and gather detailed information on catch, fishing effort, and population parameters of major species in order to allow a more accurate assessment of stocks.

# 5. *BIOLOGICAL FINDINGS*

## *5.1. Species composition*

The Maldivian reef fishery, in common with most other tropical coastal fisheries, is a multispecies one. During the first phase of the reef fish survey, nearly 200 species of fish were caught (Van der Knaap, 1989). That included catches from extensive ttials with fish traps. During this second phase of the reef fish survey, over 130 species of fish were caught. Fifteen of these are believed to constitute new records for the Maldives, Details of most of the species caught by major gear are given in Appendices I—lV, hut a summary is given below

| | Lox gline | | Handline | | Troll | Total |
|---|---|---|---|---|---|---|
| | Inside | Outside | Day | Sight | | |
| Snapper | 7 | 4 | 6 | 8 | 1 | 18 |
| Emperor | 9 | 7 | 10 | 6 | — | 12 |
| Grouper | 13 | 15 | 8 | 14 | — | 28 |
| Jack | 8 | 5 | 4 | 7 | l | 10 |
| Shark | 2 | 4 | 2 | 5 | — | 14 |
| Tuna | . | — | 2 | 3 | 8 | 8 |
| Others | 20 | 9 | 6 | 4 | 2 | 40 |
| **TOTAL** | 69 | 54 | 58 | 57 | 12 | 130 |

Two species of shark were caught that do not appear in the Appendices. These are the silky shark — *Carcharhinusfalciformis* — (a small one was caught on a circle hook longline in Shaviyani Atoll, near a channel to the open sea) and the oceanic white tip shark *Carcharhinus longimanus* — (one was caught on a longline set in 210m depth between An and Rasdhoo; it was believed to have been caught while the line was being hauled and was not included as part of the longline catch). One specimen of the bullet tuna, *Auxis rochei,* caught while trsslling in Alifu Atoll is included in the text tables under *A. thazard.* Three species of stingray were caught, but were not landed and so are not included in the catch statistics.

Despite this diversity, relatively few species made up the majority of the reef fish catch. The contributions of major species *(i.e.* those that made up at least 2 per cent of the total catch weight of at least one gear) are listed in Table 15.

**Table 15**

**Contributions of major reef fish species to the catches of four major fishing gear (%)**

| | Inside longline | Outside longline | Day handlining | Night handlining |
|---|---|---|---|---|
| SNAPPER | | | | |
| *Aphareus rutilan.s* | — | 20.3 | 0.3 | — |
| *Apr/on lirescens* | 404 | 4.5 | 32.4 | 1.2 |
| *Lutjanusbohar* | 3.6 | 15.3 | 5 | |
| *Lutjanus gibbus* | - | 0.6 | 1.7 | 5.8 |
| *Lwjanus sebue* | 3.1 | 0.5 | | 0.2 |
| EMPEROR | | | | |
| *Lethrinus microdon* | 3.6 | ɪ | 5.3 | 0.4 |
| *Lethrinus oliuaceus* | 1.4 | 39 | 3.2 | 0.7 |
| *Lethrsnus xanthochilus* | 0.4 | — | 3,4 | 0.6 |
| GROUPER | | | | |
| *cephalopholis sonneraO* | 2.4 | 0.9 | 2.2 | — |
| *Epinephelusareolarus* | 0.7 | 2.6 | 0.! | — |
| *Epmephelus chiorostigma* | — | 4.6 | — | — |
| *Epinephelusmicrodon* | 0.3 | 1.2 | 6.4 | 4.2 |
| *Epinephelus mi/ions* | — | 4.2 | 0.6 | — |
| *P/eetropomuspessulifenus* | 0.3 | 0.3 | 3.8 | 0.2 |
| *Variola/outi* | 0.1 | 0.4 | 2.9 | 0.7 |
| JACK | | | | |
| Caranx | 0.4 | 1.2 | — | 7.4 |
| *Caranx lugubnis* | — | 3.0 | — | 0.6 |
| Caranxsexfasciatus | 0.1 | 0.1 | — | 18.3 |
| *Seniola rivoliana* | 0.3 | 5.9 | 13 | — |
| SHARK | | | | |
| *Carcharhinusalbimarginatus* | 3.5 | 2.9 | 0.3 | 1.1 |
| *Carcharhinus amblyrhynchus* | 0.9 | 2.6 | 1.5 | 1.3 |
| *Loxodon macrorhinus* | 7.4 | — | — | — |
| *Stegosoma var/urn* | 3.4 | | | — |
| OTHERS | | | | |
| *Thunnus albacares* | — | — | — | 6.5 |
| *Ablenneshians* | 0.1 | — | 5.1 | — |
| *Rhinobatidae* | 1.7 | — | 7.1 | — |
| *Sargocentron spiniferum* | — | — | 0.3 | 2.2 |
| *Sphyraenaforsteni* | — | — | — | 2.3 |
| **TOTAL** (of these species) | 85.1 | 86.7 | 83.0 | 84.9 |

Note : Percentages are calculated from the total weights of catches from all three atolls combined.

Only about a dozen species made up about 80 per cent of the catch of each gear. Two snapper, *Aprion virescens* and *Lutjanus bohar,* were particularly abundant, between them making up at least *30-55* per cent of the catch of each gear. It is noticeable, however, that while *Lutjanus bohar* dominated catches by night handline and longlines set outside the atolls, *Aprion virescens* dominated day handline catches and those of longlines set inside the atolls. Several species showed clear diurnal differences in catch rates.. Apart from *Lutjanus hohar,* such species as *Lutjanus gibbus, Caranx ignobilis, Caranx sexfasciatus, Sargocentron spiniferum* and *Sphvraenafosteri* were caught far more frequently by night than by day.

## *5.2. Regional variation*

The Reef Fish Survey was conducted in N. Male Atoll during Phase 1, and in Shaviyani, Alifu and Laamu Atolls during Phase II. Relatively little longlining was carried out outside each atoll (and longlines were not set in every depth stratum outside each atoll), so meaningful comparisons of the outer slope fish fauna of the different atolls cannot he made. However, catch data from day handlining, night handlining and longlining within the atoll basins are available for comparisons of species composition between atolls.

Comparison of these catch data shows that Laamu Atoll, in the south, has a rather different reef fish fauna than the more northerly atolls surveyed. Catches from Shaviyani, Alifu and North Male did show some differences (See Tables 6, 8, 13, 14), but these are solely due to changes in relative abundance of shared species. In contrast, Laamu Atoll catches contain a number of species that were not found in the other atolls, Indeed, the first day's fishing in Laamu Atoll in August 1990 produced five species that were previously unrecorded from the Maldives.

The differences in atoll basin fish fauna, as sampled by the longline, have already been noted in Section 3.1. Handline catches showed similar differences (Section 3.4). The major differences between reef fish catches from Laamu Atoll and these from the three more northern atolls may be summarized as follows

**Snapper** Two species of snapper *(Luijanus guilcheri* and *Lutjanu.s timorensis)* were taken in appreciable quantities in Laamu Atoll, but not at all in the more northern atolls. *Pristi-*pomoides multiclens was not rare in Laamu Atoll, hut was taken only once elsewhere (by deep longline outside North Male Atoll). Catch rates of the common snapper, *Aprion virescens, Lutjanus bohar* and *Luijanus gibbus* tended to be lower in Laamu than in the more northern atolls.

**Emperor** : Overall catch rates did not differ significantly between atolls, but there was a suggestion that *Lethrinus microdon* was more common and *Lethrinus rubrioperculatus* was less common in Laamu than in the north.

**Grouper** : No species of grouper were caught in Laamu Atoll alone. Because of the relatively low catch rates of the many species taken, it is difficult to make comparisons between atolls. In general, however, coral grouper *(Plectropomus* spp.) appear to be more common in Laamu than in the north. In contrast, the tomato grouper, *Cephalopholis* was rare in Laamu, but common in the northern atolls.

**Jack** : Jack contributed a much higher proportion of the catch in Laamu Atoll than in the northern atolls. In particular, *Alectis ciliaris* and *Carangoides caeruleopinnatus* were common in longline catches in Laamu Atoll, but rare in the north. *Caranx sexfasciatus* was caught more commonly by night handlining in Laamu than in the north, but this might simply be the result of the differences in the types of fishing locations *(i.e.* sampling error).

**Shark** : **The small** shark *Loxodon macrorhinus* was common in the northern atolls (particularly in Shaviyani and North Male), but rare in Laamu. In contrast, *Carcharhinus sorrah* appeared to be rare in the north and relatively common in Laamu. The blacktip shark *Carcharhinus limbatus* was only caught in Laamu Atoll.

It is clear from these observations that there are both absolute and relative differences in the fish fauna of Laamu Atoll, compared to that of Shaviyani, Alifu and North Male Atolls. What is not clear is the extent to which the fish fauna of Laamu Atoll is representative of that of the southern Maldives as a whole, and, if it is, the extent of overlap or otherwise of the 'northern' and 'southern' fish fauna. As mentioned in Section 3.1, many ecological factors vary in a north-south direction along the Maldivian atoll chain. It is perhaps to be expected that the composition of the fish fauna too might change in a similar way (although, as noted in Section 3.1, total reef fish abundance in the atoll basins does not appear to vary along a north-south gradient).

Brown *et a!.* (1989) note that jack and *Plectropomus* spp. were more common in commercial handline catches in Dhaalu Atoll than in Male. In this respect, Dhaalu and Laamu Atolls are similar. However, Brown *et a!.* (1989) give no indication that the several distinctive species found in Laamu Atoll *(e.g. Lutjanus gui!cheri, Lutjanus timorensis, Carcharhinus limbatus)* were also found in Dhaalu. It is possible that these species are only found regularly in those southern atolls with deep atoll basins and long atoll rim reefs *(i.e.* Thaa, Laamu and Huvadhu and possibly also Addu).

## *5.3 Seasonal variation*

Most of the handline fishing carried out during this survey, and most of the longline fishing in Laamu Atoll, was carried out during the Southwest Monsoon season. It is therefore not possible to discuss seasonal variation in these cases. However, in both Shaviyani and Alifu Atolls, longlining was carried out in both seasons (Table 5). Note that fishing was not carried out in every month in each atoll, so comparisons have to be made by season, not by month. In both Alifu and Shaviyani Atolls, catch rates and species composition during August to November 1990 (Southwest Monsoon season) were very similar to those in February to March 1991 (Northeast Monsoon season). Mean longline catch rates (± 95% confidence intervals) were

| | *Alifu Atoll* | *Shaviyani Atoll* |
|---|---|---|
| Mean no. fish/set | | |
| NE season | 13.3 ± 1.6 fish | 7.9 ± 1.2 fish |
| SW season | 13.5 ± 1.3 fish | 9.3 ±1.1 fish |
| Mean weight/set | | |
| NE season | 37.0 + 2.7 kg | 27.7 ± 2.3 kg |
| SW season | 35.3 ± 2.1 kg | 25.4 ± 1.8 kg |
| No. longline sets | | |
| NE season | 20 | 20 |
| **SW season** | 30 | 30 |

Although the differences are not significant, both atolls did show a small increase in numbers and decrease in weight of.fish caught per longline in the Southwest Monsoon season compared to the Northeast season. These differences can be largely explained by the seasonal differences in catch rates and mean weight of *Aprion virescens.*

| | ***APRION VIRESCENS*** | | ***LOXODON MACRORHINUS*** | |
|---|---|---|---|---|
| | *Catch rate (No/set)* | *Av. weight (kg/fish)* | *Catch rate (No/set)* | *Ay. weight (kg/fish)* |
| **SHAVIYANI** | | | | |
| NE season | 1.4 ± *0.5* | 3.9 | 1.2 + 0.4 | 2.0 |
| SW season | 2.8 ±0.6 | 3.5 | 2.3 + 0.5 | 1.8 |
| **ALIFU** | | | | |
| NE season | 4.5 ±0.8 | 3.1 | 1.2 + **0.4** | **2.0** |
| **SW season** | **7.1** ±0.9 | 2.9 | 0.4 + 0.2 | 1.9 |

In both atolls, *A. virescens* appears to be more abundant and of smaller average size during the Southwest Monsoon season than in the Northeast season. This might perhaps partly reflect recruitment and growth within the atolls (See Section 5.4, below).

The shark *L. macrorhinus* also showed significant seasonal variations in catch rate, but these were not consistent between atolls. In Shaviyani, the highest catch rate was during the Southwest seasOn, while in Alifu Atoll the highest longline catch rate was in the Northeast season.

The emperor *Lethrinus microdon* showed highest catch rates in both atolls during the NE season. However, the differences between seasons, although consistent, were not statistically significant.

During Phase I of the survey (Van der Knaap *et a!.,* 1991), no significant differences in catch rate or species composition were noted between seasons. It was, however, noted that longline catches of snapper and emperor were highest during August-October *(i.e.* the Southwest season). Van der Knaap *et al.* (1991) actually noted more seasonal variation in the distribution of the reef fishermen than of reef fish. They noted that at Male reef fishermen tended to go for more pelagic species during the Northeast season.

It is perhaps not surprising that there are no significant differences in overall reef fish abundance between seasons, since most of the species caught live for several years and probably do not migrate between atolls. There may, however, be seasonal shifts within atolls. In Alifu Atoll, total longline catch rates were highest in the north of the atoll during the Southwest season and highest in the south during the Northeast season. Van der Knaap *et al.* (1991) noted high longline catch rates on the west side of North Male Atoll during August-October.

## *5.4. Size composition*

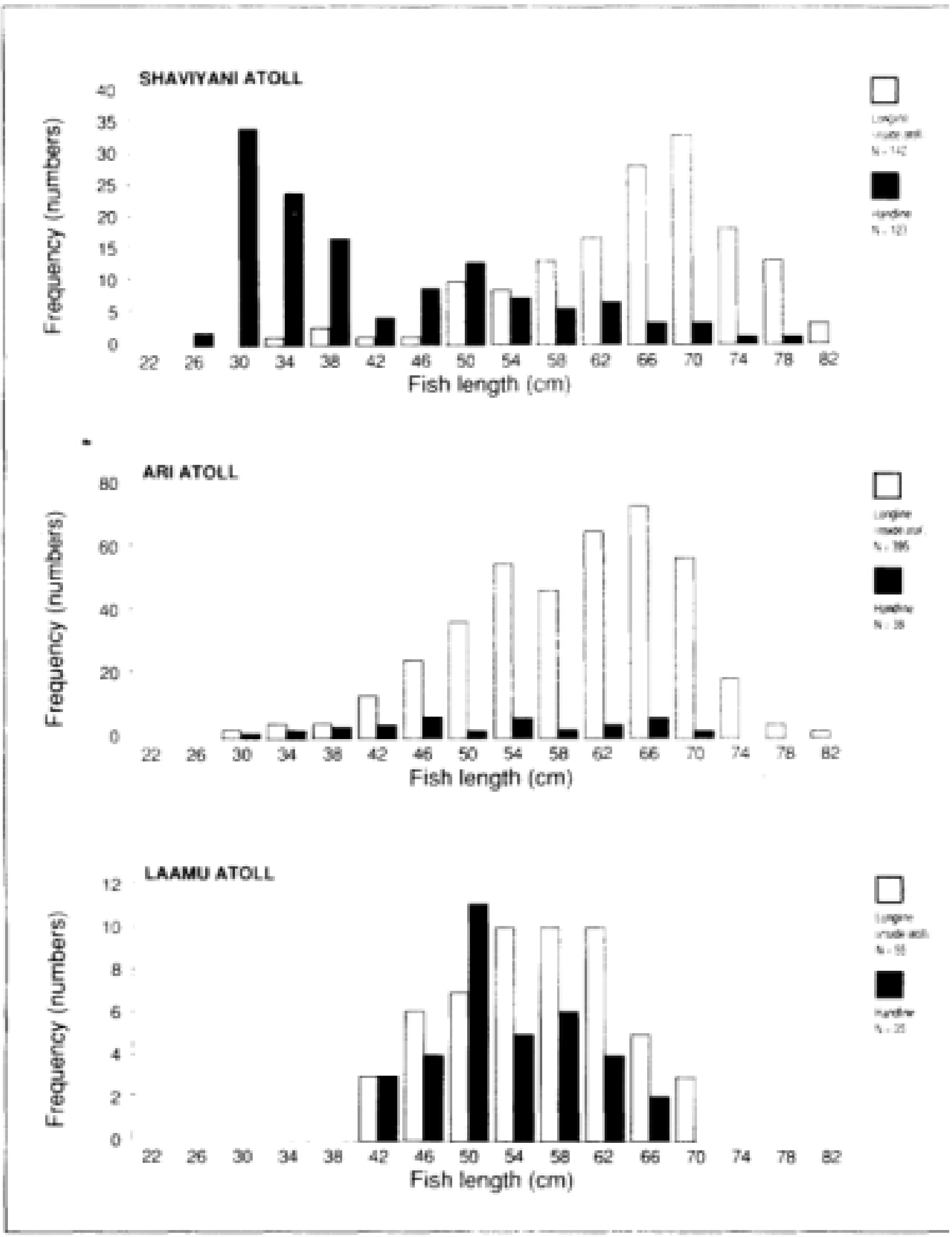
As noted by Van der Knaap *era!.* (1991), the longline tends to catch larger fish than the handline, although this does not hold for all species. A summary of the mean weights of some major species by gear is given below

| | *MEAN WEIGHTS (in kg)* | | | |
|---|---|---|---|---|
| | Longline inside azolls | Longline outside atolls | Day handline | Night handline |
| *Aprion virescens* | 3.1 | 3.0 | 1.7 | 2.4 |
| *Lutjanusbohar* | 3.4 | 4.1 | 2.5 | 1.7 |
| *Lethrinus microdon* | 1.7 | 1.4 | 1.6 | 1.3 |
| *Ceph.sonnerati* | 1.2 | 1.0 | 1.3 | — |
| *Epinephelus microdon* | 1.8 | 2.2 | 2.1 | 2.2 |
| **MEAN OF ALL FISH** | 2.7 | 2.4 | 1.5 | 1.8 |

More detailed information can be obtained from analysis of length frequency data, which include information from circle hook longline catches. These catches were not included in Appendix I. There may, therefore, be some discrepancies between the numbers given in the Appendices and the numbers used to create the length frequency histograms.

## *LENGTH FREQUENCY DATA*

**Fig 6. Aprion virescens**




The snapper *Apr/on virescens* was caught most commonly by longlines inside the atolls and by day handline. Figure 6 presents the size frequency distribution of the catches of *A. virescens* by these two gear in the three target atolls. Although there is considerable overlap in the sizes caught, the longline clearly tends to catch larger fish than the handline. There is no evidence for growth overfishing in any atoll, including Alifu Atoll (the most heavily fished of the three atolls): survey catches from this atoll showed a considerable proportion of large fish. As noted in Section 5.3, the size of *A. virescens* caught by longline in the Southwest season tended to be slightly smaller on average than those caught in Northeast season.

**Fig 7. Aprion virescens (Shaviyani Atoll)**

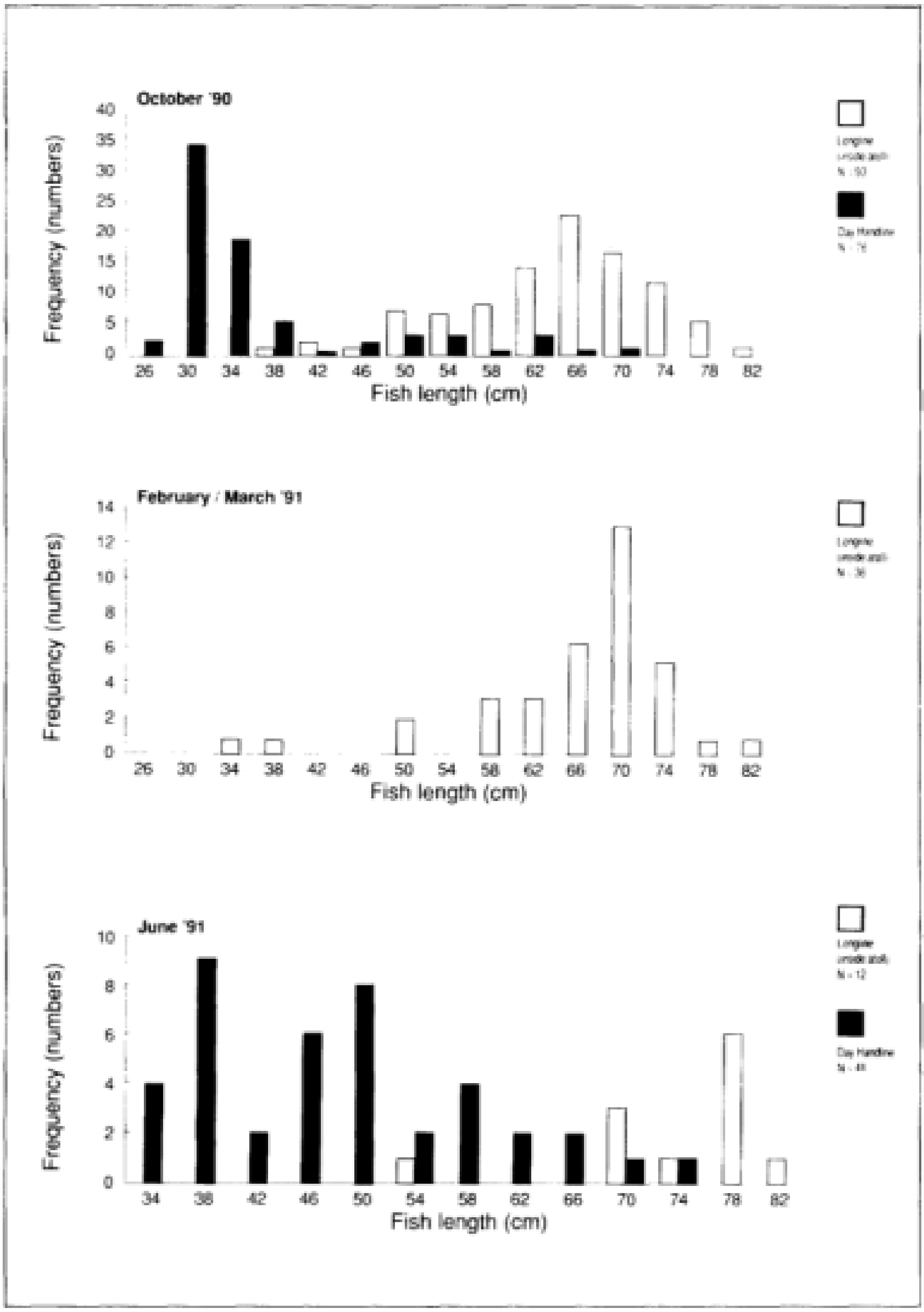



Figure 7 illustrates the size frequency distributions of *A. virescens* caught during three trips to Shaviyani Atoll. Note that no handlining was carried out during the second trip. The modal size of *A. virescens* caught by longline during the first trip (in the SW season) is about 65 cm, while that of *A. virescens* caught during the second trip (during the NE season) is about 70cm. From simple analysis of modal progression it is possible to suggest that these larger fish grew at about 1.5 cm/mo, whereas those between about 30 and 50cm might have grown at about 2.3 cm/mo.



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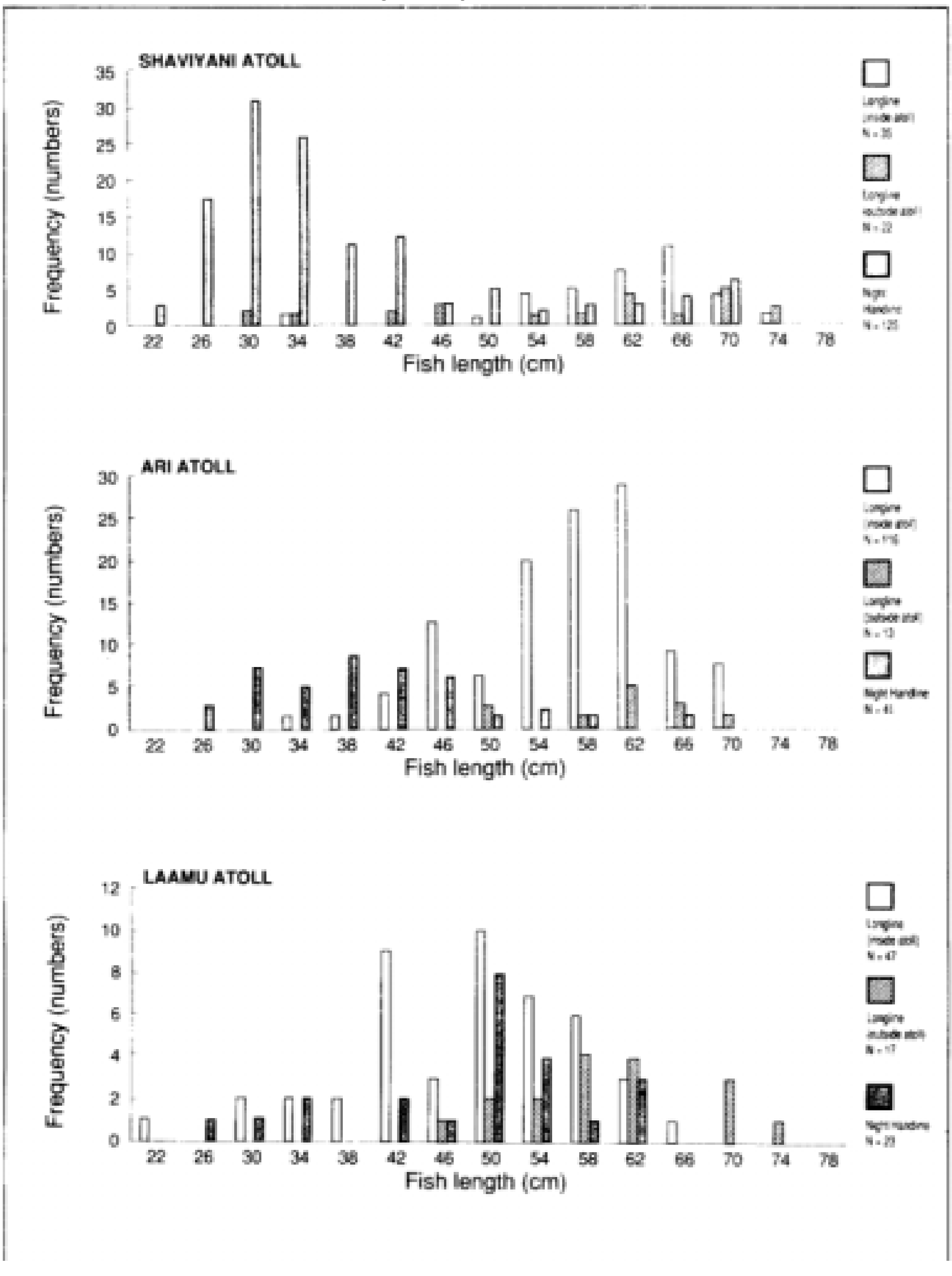
**Fig 8. Lutjanus bohar**




The red snapper *Lutjanus bohar* was caught mainly by longline (both inside and outside the atolls) and by night handline. Figure 8 illustrates the length frequency distributions of *L. bohar* catches by gear for the three target atolls. In general, smaller fish were caught by handline than by longline. The longlines set outside the atoll tended to catch larger fish than the longlines set inside the atoll. **These findings suggest that larger and older fish tend to be found deeper than smaller** fish. The size distributions of *L. bohar* are similar **to those recorded in N. Male Atoll by** Van der Knaap *et a!.* (1991 : Figure 12). As was **the case with** *A. virescens,* the presence of a significant proportion of large and old fish (including ones with worn teeth and scales) in the longline catches suggests that the stocks of *L. bohar* are not overfished.



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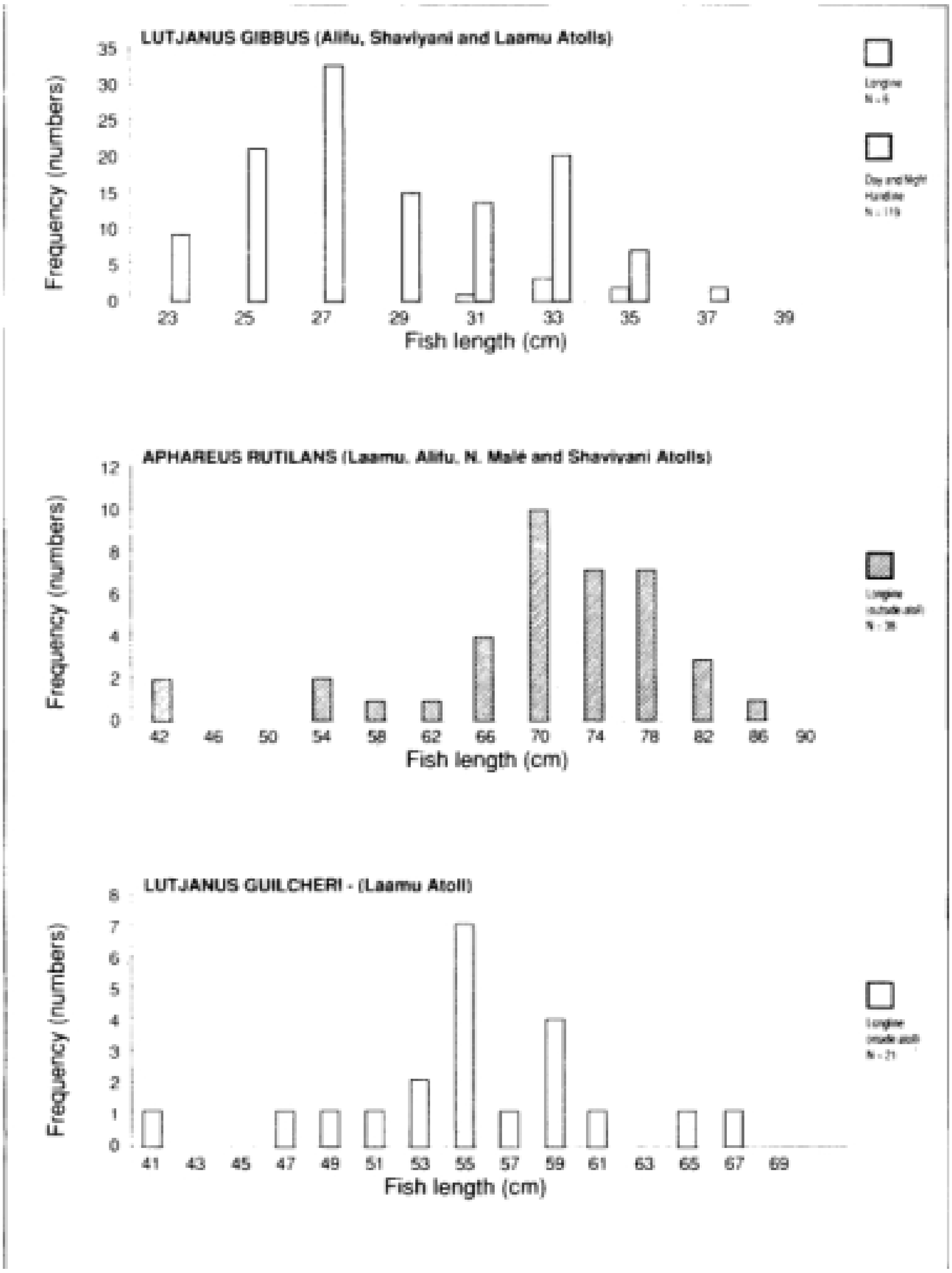
**Fig 9. Snapper**




The humpback red snapper *Lutjanusgibbus* is caught mainly by night handlining. Some specimens were caught by day handlining, but these were all taken late in the day, just before sunset. Figure 9 illustrates the length frequency distribution of *L.gibbus* handline catches. There were no significant differences between atolls or seasons, so all data has been combined. The bimodal length frequency distribution observed is very similar to that recorded in N. Male Atoll by Van der Knaap *et al.,* (1991: Figure 12). Two other snapper were caught in significant quantities, but only in specific areas. *Aphareus rutilans* was caught almost entirely by longline outside the atolls, while *Lutfanus guilcheri* was caught exclusively by longline inside Laamu Atoll. Length frequency histograms are presented in Figure 9.



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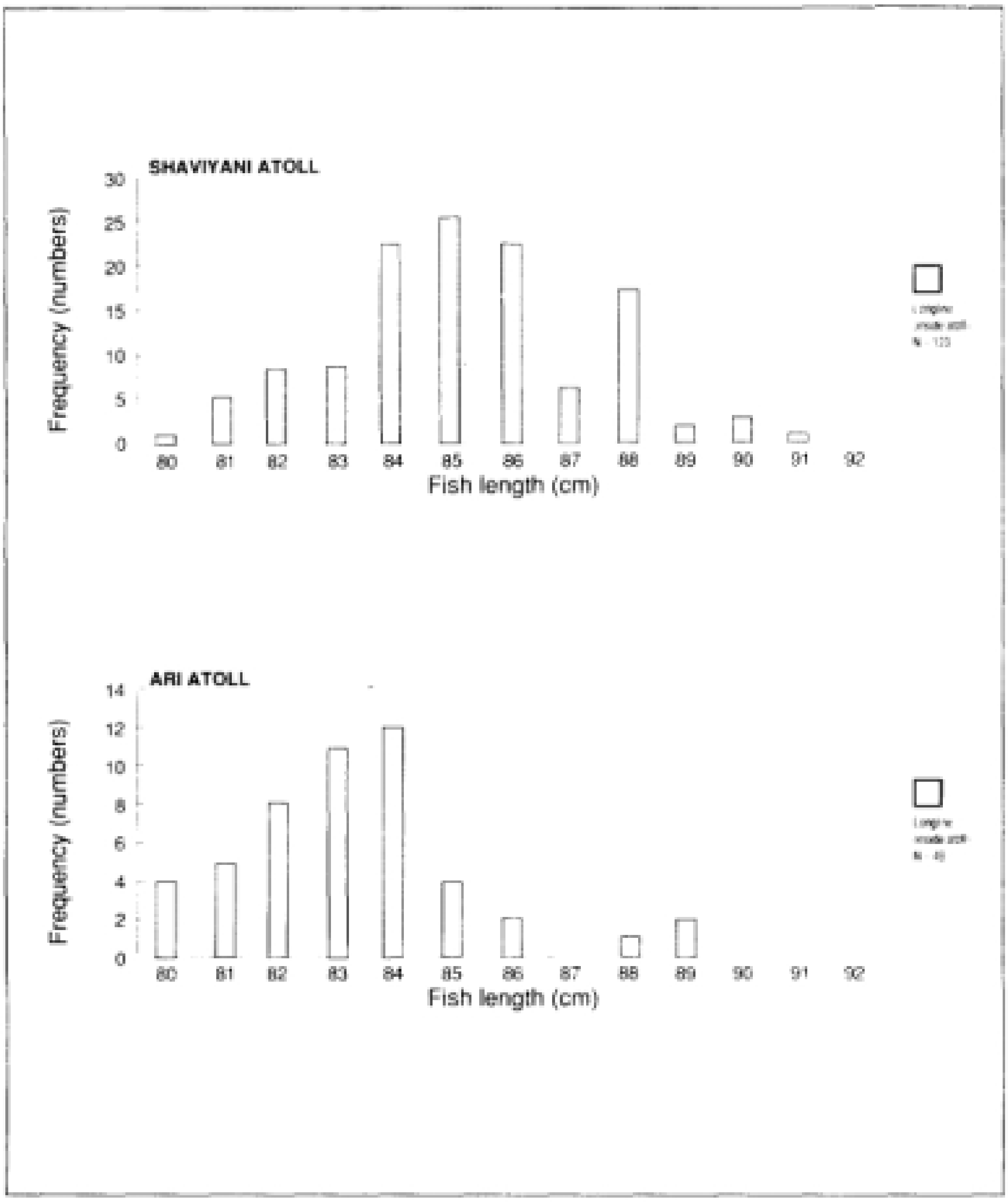
**Fig 10. Loxodon macrorhinus**




The commonest shark caught was *Loxodon macrorhinus.* This species was caught exclusively by longline inside the atoll basins. Remarkably, only males were taken, and all of them were adults. The reasons for this sexual selectivity are not known. *L. macrorhinus* catches show unimodal, size frequency distributions (Figure 10). There are small differences in modal lengths between atolls. In Alifu Atoll, the modal length was about 83cm, in Shaviyani Atoll 85cm and in N. Male Atoll about 88cm (Van der Knaap *et al.,* 1991: Figure 12; note that the lengths given in their figure are lower caudal lobe to snout; their 70cm mode is equivalent to about 88cm TL). In Laamu Atoll, only five *L. macrorhinus* were caught; their mean length was 83 cm. It is not clear if these differences between atolls have any biological significance. However, the largest sizes were found in the atolls where *L. macrorhinus* appears to be most abundant. It is possible that the biological and physical parameters that affect population size also affect growth rate and/or maximum size. The distribution of *L. macrorhinus* in longline catches was not random, but highly clumped. If *L. macrorhinus* exhibits cooperative hunting behaviour, this might partly explain an apparent correlation between population size and growth or maximum size.



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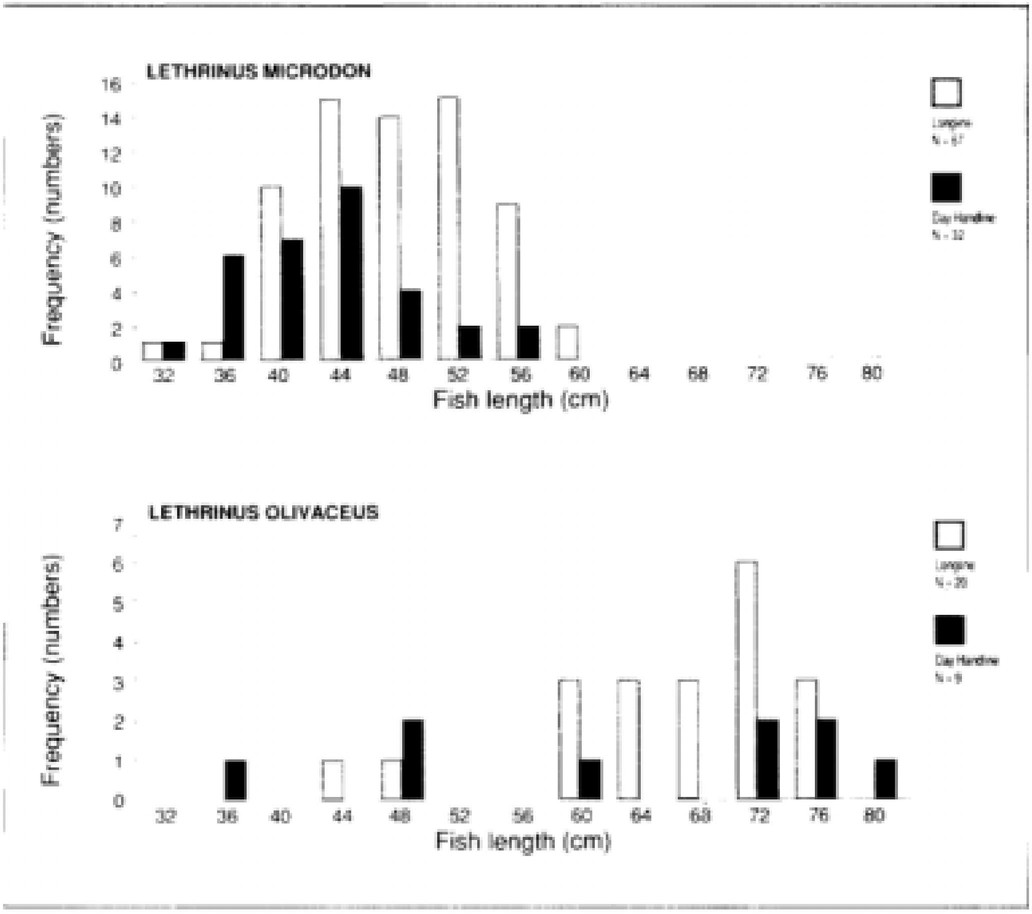
**Fig 11. Emperor**




The emperor *Lethrinus microdon* was caught mainly by day handline and longline inside the atolls. Only three fish were caught by night handline; their lengths are combined with day handline caught fish in Figure 11. The sizes of *L. microdon* caught by longline in Shaviyani Atoll were larger than those taken in Alifu and Laarnu Atolls *(584cm* FL v. 45.8cm FL). However, the numbers involved are small (21 v, 34) and there was considerable overlap of size ranges, so all available data are combined in Figure 11. The longline outside the atolls tended to catch smaller fish than the longline inside the atolls (mean fork length: 41.9cm v *50.6cm).* However, as only ten fish were caught by longline outside the atolls, all longline catch data are combined in Figure 11. Note that the longline caught larger fish on average than the handline, although there is an almost complete overlap in the sizes caught. Note also that the largest *L. microdon* caught was 58cm FL. Van der Knaap *etal.,* (1991: Figure 12) present a length frequency histogram for *Lethrinus elongatus* (a synonym of *L. micmdon)* which suggests a maximum length of 71cm. However, as noted above, Van der Knaap *etal.* (1991) mistakenly combined the two similar looking emperor species *L. microdon* and *L. olivaceus* under the name of *L. elongatus. L. olivaceus* is a large species. The maximum size recorded during this survey was 78cm FL (Figure 11). Combining the length frequency histograms of L. *microdon* and *L. olivaceus* would give a histogram very similar to that of *'L. elongatus'* presented by Van der Knaap *et al.,* (1991).

The tomato grouper *Cephalopholis sonnerati* was caught in larger numbers than any other grouper. It was caught mainly by longline inside the atolls and by day handline. Differences in size frequencies between atolls were not observed, nor were the differences in sizes between fish caught by longline inside and outside the atolls. Figure 12 presents length frequency histograms for *C. sonnerati* catches by day handline and longline. It is noticeable that in contrast to the snapper *A. virescens* and *L. bohar, C. sonnerati* tends to be caught more frequently in small sizes by the longline than by handline.



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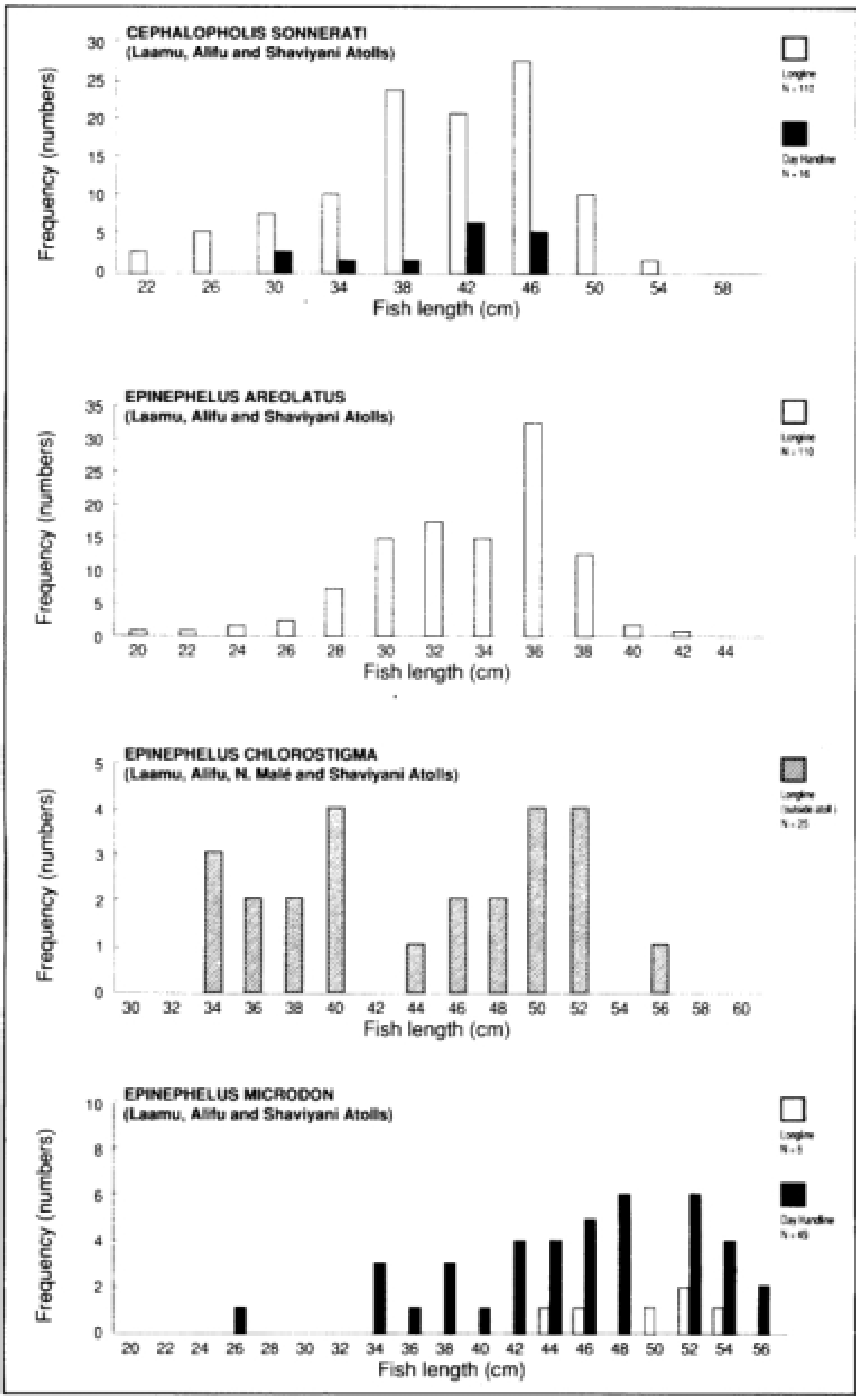
**Fig 12. Grouper**



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The second most common grouper caught was *Epinephelus areolatus.* This was taken almost exclusively by longline, both inside and outside the atolls. There were no differences in sizes caught between atolls, or between inside and outside the atolls. A length frequency histogram of longline catches of *E. areolatus* is presented in Figure 12. *E. areolatus* is a small species, most fish being between about 29-39cm FL. *E. areolatus* was patchily distributed, being rather common at some localities outside the atolls. This species might be able to support a small specialised fishery for 'plate-sized' grouper.

Two other grouper taken in significant numbers were *Epinephelus microdon* (taken mainly by handline) and *Epinephelus chlorostigma* (taken exclusively by longline outside the atolls). Length frequency distributions are summarized in Figure 12 (see previous page).

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# APPENDICES

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## Appendix I

**Total numbers and weight (kg) of fish (by species) caught by longline inside the three target atolls.***

| Species | SHAVIYANI Nos. | SHAVIYANI Wt. | ALIFU Nos. | ALIFU Wt. | LAAMU Nos. | LAAMU Wt. | TOTAL Nos. | TOTAL Wt. |
|---|---|---|---|---|---|---|---|---|
| SNAPPER (Lutjanidae) | 180 | 699.2 | 480 | 1507.7 | 127 | 291.0 | 787 | 2497.9 |
| *Aprion virescens* | 136 | 489.5 | 366 | 1098.3 | 47 | 108.8 | 549 | 1696.6 |
| *Lutjanus bohar* | 33 | 151.1 | 108 | 380.2 | 39 | 77.95 | 180 | 609.25 |
| *Lutjanus guilcheri* | — | — | — | — | 20 | 43.35 | 20 | 43.35 |
| *Lutjanus sebae* | 10 | 55.9 | 6 | 29.2 | 12 | 49.45 | 28 | 134.55 |
| *Lutjanus timorensis* | — | — | — | — | 6 | 7.8 | 6 | 7.8 |
| *Macolor niger* | 1 | 2.7 | — | — | — | — | 1 | 2.7 |
| *Pristipomodies multidens* | — | — | — | — | 3 | 3.65 | 3 | 3.65 |
| EMPEROR (Lethrinidae) | 52 | 106.0 | 79 | 130.2 | 33 | 40.95 | 164 | 277.15 |
| *Gymnocranius* spp. | 1 | 1.05 | 11 | 18.4 | — | — | 12 | 19.45 |
| *Lethrinus conchyliatus* | 2 | 2.7 | 1 | 1.5 | 2 | 0.9 | 5 | 5.1 |
| *Lethrinus erythracanthus* | — | — | 2 | 8.9 | 1 | 0.8 | 3 | 9.7 |
| *Lethrinus lentjan* | — | — | — | — | 1 | 1.15 | 1 | 1.15 |
| *Lethrinus microdon* | 32 | 72.7 | 28 | 40.6 | 27 | 37.4 | 87 | 150.7 |
| *Lethrinus olivaceus* | 4 | 20.6 | 8 | 36.6 | — | — | 12 | 57.2 |
| *Lethrinus rubrioperculatus* | 11 | 4.1 | 22 | 11.7 | 2 | 0.7 | 35 | 16.5 |
| *Lethrinus xanthochilus* | 2 | 4.85 | 7 | 12.5 | — | — | 9 | 17.35 |
| GROUPER (Serranidae) | 49 | 60.35 | 98 | 131.45 | 36 | 36.6 | 183 | 228.4 |
| *Cephalopholis miniata* | — | — | — | — | 1 | 0.45 | 1 | 0.45 |
| *Cephalopholis sonnerati* | 36 | 47.1 | 47 | 52.15 | 2 | 1.2 | 85 | 100.45 |
| *Epinephelus areolatus* | 9 | 5.6 | 30 | 15.6 | 20 | 8.65 | 59 | 29.85 |
| *Epinephelus fasciatus* | — | — | 2 | 0.35 | — | — | 2 | 0.35 |
| *Epinephelus flavocaeruleus* | — | — | 1 | 3.2 | — | — | 1 | 3.2 |
| *Epinephelus fuscoguttatus* | — | — | — | — | 1 | 4.75 | 1 | 4.75 |
| *Epinephelus longispinis* | 2 | 2.15 | 1 | 1.1 | — | — | 3 | 3.25 |
| *Epinephelus microdon* | — | — | 5 | 10.6 | 3 | 3.95 | 8 | 14.55 |
| *Epinephelus multinotatus* | 1 | 5.3 | 8 | 39.2 | 1 | 4.2 | 10 | 48.7 |
| *Plectropomus laevis* | — | — | 1 | 5.5 | — | — | 1 | 5.5 |
| *Plectropomus pessuliferus* | — | — | 1 | 1.0 | 8 | 13.4 | 9 | 14.4 |
| *Variola albimarginata* | 1 | 0.2 | 1 | 0.65 | — | — | 2 | 0.85 |
| *Variola louti* | — | — | 1 | 2.1 | — | — | 1 | 2.1 |
| JACK (Carangidae) | 3 | 14.7 | 7 | 22.65 | 68 | 75.2 | 78 | 112.55 |
| *Alectis ciliaris* | — | — | — | — | 10 | 37.7 | 10 | 37.7 |
| *Carangoides caeruloepinnatus* | — | — | 1 | 0.7 | 52 | 19.5 | 53 | 20.2 |
| *Carangoides fulvoguttatus* | — | — | — | — | 3 | 10.3 | 3 | 10.3 |
| *Carangoides orthogrammus* | — | — | — | — | 1 | 2.65 | 1 | 2.65 |
| *Caranx ignobilis* | 3 | 14.7 | 1 | 4.1 | — | — | 4 | 18.8 |
| *Caranx sexfasciatus* | — | — | 1 | 6.1 | — | — | 4 | 6.1 |
| *Elagatis bippinulata* | — | — | — | — | 1 | 3.1 | 1 | 3.1 |
| *Seriola rivoliana* | — | — | 4 | 11.75 | 1 | 1.95 | 5 | 13.7 |
| SHARK | 147 | 519.15 | 67 | 203.75 | 24 | 115.2 | 238 | 838.1 |
| *Carcharhinus albimarginatus* | 18 | 83.95 | 99 | 38.9 | 4 | 24.0 | 31 | 146.85 |
| *Carcharhinus amblyrhynchus* | 6 | 15.95 | 3 | 9.7 | 4 | 12.2 | 31 | 37.85 |
| *Carcharhinus limbatus* | — | — | — | — | 1 | 7.8 | 1 | 7.8 |
| *Carcharhinus melanopterus* | — | — | 1 | 9.2 | — | — | 1 | 9.2 |
| *Carcharhinus sorrah* | — | — | 2 | 5.4 | 8 | 47.85 | 10 | 53.25 |
| *Carcharhinus cuvier* | 4 | 23.5 | 3 | 14.85 | — | — | 7 | 38.35 |
| *Loxodon macrorhinus* | 113 | 210.75 | 46 | 89.7 | 5 | 8.85 | 164 | 309.3 |
| *Nebrius ferrugineus* | 1 | 70.0 | — | — | — | — | 1 | 70.0 |
| *Sphyrna lewini* | — | — | — | — | 2 | 14.5 | 2 | 14.5 |
| *Stegastoma varium* | 5 | 115.0 | 2 | 27.0 | — | — | 7 | 142.0 |
| *Triaenodon obesus* | — | — | 1 | 9.0 | — | — | 1 | 9.0 |
| OTHERS | 67 | 105.2 | 44 | 125.9 | 14 | 10.95 | 125 | 242.05 |
| *Acanthuridae* | 2 | 5.7 | — | — | — | — | 2 | 5.7 |
| *Ablennes hians* | 2 | 2.85 | — | — | 2 | 1.9 | 4 | 4.75 |
| *Balistidae* | 9 | 15.0 | 11 | 28.55 | 1 | 3.6 | 21 | 47.15 |
| *Coryphaena hippurus* | — | — | 1 | 1.85 | — | — | 1 | 1.85 |
| *Diagramma pictum* | — | — | 1 | 3.2 | — | — | 1 | 3.2 |
| *Muraenidae* | 1 | 2.0 | 3 | 4.1 | 1 | 2.2 | 5 | 8.3 |
| *Nemipterus bleekeri* | — | — | — | — | 3 | 0.15 | 3 | 0.15 |
| *Pterois volitans* | 1 | 0.65 | — | — | 1 | 0.85 | 2 | 1.5 |
| *Rachycentridae* | 2 | 9.9 | — | — | — | — | 2 | 9.9 |
| *Remora* | 48 | 44.3 | 24 | 19.8 | 6 | 2.25 | 78 | 66.35 |
| *Rhinobatidae* | 2 | 24.8 | 2 | 45.3 | — | — | 4 | 70.1 |
| *Sphyraenidae* | — | — | 2 | 23.1 | — | — | 2 | 23.1 |
| TOTAL | 498 | 1504.6 | 775 | 2121.65 | 302 | 569.9 | 1575 | 4196.15 |

* **Note :** 62 longlines set in Shaviyani, 61 in Alifu, 40 in Laamu.

## Appendix II

### Total numbers and weight (kg) of fish (by species and depth) caught by longline on outer atoll reef slopes during Phase II of the Reef Fish Survey

| | 60m | | 90m | | 120m | | 150m | | 180m | | 210m | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nos. | Wt. | Nos. | Wt. | Nos. | Wt. | Nos. | Wt. | Nos. | Wt. | Nos. | Wt. |
| SNAPPER (Lutjanidae) | 59 | 234.45 | 50 | 167.1 | — | — | 19 | 57.75 | 12 | 7.45 | 3 | 4.45 |
| *Aprion virescens* | 4 | 7.8 | 8 | 24.6 | — | — | 1 | 7.2 | — | — | — | — |
| *Aphareus rutilans* | 19 | 96.3 | 13 | 50.0 | — | — | 4 | 25.0 | 1 | 2.9 | 1 | 3.4 |
| *Lutjanus bohar* | 29 | 122.05 | 23 | 88.8 | — | — | 2 | 11.1 | — | — | — | — |
| *Lutjanus gibbus* | 4 | 3.5 | 2 | 1.5 | — | — | — | — | — | — | — | — |
| *Lutjanus kasmira* | — | — | 1 | 0.2 | — | — | — | — | — | — | — | |
| *Lutjanus sebae* | 1 | 4.0 | — | — | — | — | — | — | — | — | — | |
| *Paracaesio sordidus* | 1 | 0.45 | — | — | — | — | 3 | 1.5 | — | — | — | — |
| *Paracaesio xanthurus* | 1 | 0.35 | — | — | — | — | — | — | — | — | — | — |
| *Pinjalo lewisi* | — | — | 1 | 0.4 | — | — | — | — | — | — | — | — |
| *Pristipomoides auricilla* | — | — | — | — | — | — | 3 | 2.35 | 6 | 2.5 | 2 | 1.05 |
| *Pristipomides filamentosus* | — | — | 2 | 1.6 | — | — | 1 | 2.1 | — | — | — | — |
| *Pristipomoides multidens* | — | — | — | — | — | — | 2 | 6.0 | — | — | — | — |
| *Pristipomoides sieboldii* | — | — | — | — | — | — | 2 | 1.0 | 5 | 2.05 | — | — |
| *Pristipomoides zonatus* | — | — | — | — | — | — | 1 | 1.5 | — | — | — | — |
| EMPEROR (Lethrinidae) | 18 | 38.35 | 19 | 39.6 | — | — | — | — | — | — | — | — |
| *Gymnocranius grandoculis* | 2 | 1.25 | 3 | 4.5 | — | — | — | — | — | — | — | — |
| *Lethrinus conchyliatus* | 2 | 3.4 | 5 | 6.5 | — | — | — | — | — | — | — | — |
| *Lethrinus microdon* | 5 | 5.25 | 6 | 9.6 | — | — | — | — | — | — | — | — |
| *Lethrinus olivaceus* | 5 | 21.6 | 3 | 12.9 | — | — | — | — | — | — | — | — |
| *Lethrinus rubrioperculatus* | 1 | 0.6 | — | — | — | — | — | — | — | — | — | — |
| *Lethrinus* sp. 1 | 1 | 0.55 | — | — | — | — | — | — | — | — | — | — |
| *Wattsia mossambica* | 2 | 5.7 | 2 | 6.1 | — | — | — | — | — | — | — | — |
| GROUPER (Serranidae) | 30 | 42.4 | 81 | 84.25 | — | — | 21 | 30.2 | — | — | — | — |
| *Cephalopholis aurantia* | — | — | 1 | 0.25 | — | — | — | — | — | — | — | — |
| *Cephalopholis sexmaculata* | 1 | 0.25 | — | — | — | — | — | — | — | — | — | — |
| *Cephalopholis sonnerati* | 1 | 1.1 | 7 | 7.15 | — | — | — | — | — | — | — | — |
| *Epinephelus areolatus* | 1 | 0.7 | 36 | 22.25 | — | — | — | — | — | — | — | — |
| *Epinephelus chlorostigma* | 3 | 7.2 | 12 | 21.9 | — | — | 10 | 11.3 | — | — | — | — |
| *Epinephelus epistictus* | — | — | 2 | 4.0 | — | — | 2 | 6.6 | — | — | — | — |
| *Epinephelus fasciatus* | 1 | 0.2 | — | — | — | — | — | — | — | — | — | — |
| *Epinephelus microdon* | 3 | 6.2 | 1 | 2.6 | — | — | 1 | 2.0 | — | — | — | — |
| *Epinephelus miliaris* | 6 | 9.6 | 17 | 20.65 | — | — | 6 | 6.2 | — | — | — | — |
| *Epinephelus morrhua* | — | — | 1 | 2.6 | — | — | 2 | 4.1 | — | — | — | — |
| *Epinephelus multinotatus* | 1 | 4.0 | — | — | — | — | — | — | — | — | — | — |
| *Epinephelus retouti* | — | — | 1 | 0.8 | — | — | — | — | — | — | — | — |
| *Plectropomus pessuliferus* | 1 | 2.6 | — | — | — | — | — | — | — | — | — | — |
| *Variola albimarginata* | 11 | 7.35 | 3 | 2.05 | — | — | — | — | — | — | — | — |
| *Variola louti* | 1 | 3.2 | — | — | — | — | — | — | — | — | — | — |
| JACK (Carangidae) | 4 | 11.5 | 6 | 19.75 | — | — | 13 | 55.0 | 2 | 6.2 | — | — |
| *Caranx ignobilis* | — | — | 1 | 10.1 | — | — | — | — | — | — | — | — |
| *Caranx lugubris* | 2 | 7.5 | — | — | — | — | 7 | 19.0 | — | — | — | — |
| *Ceranx sexfasciatus* | — | — | 1 | 0.45 | — | — | — | — | — | — | — | — |
| *Elagatis bipinnulata* | 2 | 4.0 | — | — | — | — | — | — | — | — | — | — |
| *Seriola rivoliana* | — | — | 4 | 9.2 | — | — | 6 | 36.0 | '2 | 6.2 | — | — |
| SHARK | 6 | 25.0 | 1 | 13.5 | — | — | 2 | 13.5 | 2 | 3.0 | — | — |
| *Carcharhinus albimarginatus* | 3 | 11.7 | 1 | 13.5 | — | — | — | — | — | — | — | — |
| *Carcharhinus amblyrhynchus* | 3 | 13.3 | — | — | — | — | 1 | 9.5 | — | — | — | — |
| *Mustelus mosis* | — | — | — | — | — | — | 1 | 4.0 | 2 | 3.0 | — | — |
| OTHERS | 5 | 5.4 | 3 | 9.3 | — | — | 2 | 2.9 | 5 | 2.15 | 5 | 2.8 |
| *Congridae* | — | — | — | — | — | — | — | — | — | — | 3 | 1.5 |
| *Echeneis naucrates* | — | — | 1 | 0.5 | — | — | — | — | — | — | — | — |
| *Muraenidae* | 3 | 3.5 | 2 | 8.8 | — | — | 2 | 2.9 | — | — | — | — |
| *Naso vlamingi* | 1 | 1.2 | — | — | — | — | — | — | — | — | — | — |
| *Satyrichthys* | — | — | — | — | — | — | — | — | 4 | 1.9 | 1 | 1.1 |
| *Scorpaenidae* | — | — | — | — | — | — | — | — | 1 | 0.25 | 1 | 0.2 |
| *Sufflamen fraenatus* | 1 | 0.7 | — | — | — | — | — | — | — | — | — | — |
| **TOTAL** | 122 | 357.1 | 160 | 333.5 | — | — | 57 | 159.35 | 21 | 18.8 | 8 | 7.25 |



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## Appendix III

### Total numbers and weight (kg) of fish (by species and atoll) caught by day handlining

| Species | SHAVIYANI Nos. | SHAVIYANI Wt | ALIFU Nos. | ALIFU Wt. | LAAMU Nos. | LAAMU Wt | TOTAL Nos. | TOTAL Wt |
|---|---|---|---|---|---|---|---|---|
| SNAPPER (Lutjanidae) | 172 | 194.4 | 50 | 117.3 | 36 | 78.0 | 258 | 389.7 |
| *Aphareus rutilans* | — | — | — | — | 1 | 2.7 | 1 | 2.7 |
| *Aprion virescens* | 122 | 161.15 | 38 | 92.95 | 31 | 63.3 | 191 | 317.4 |
| *Lutjanus bohar* | 6 | 14.1 | 11 | 23.65 | 3 | 11.6 | 20 | 49.35 |
| *Lutjanus gibbus* | 30 | 15.75 | 1 | 0.7 | 1 | 0.4 | 32 | 16.85 |
| *Lutjanus kasmira* | 13 | 2.5 | — | — | — | — | 13 | 2.5 |
| *Macolor macularis* | 1 | 0.9 | — | — | — | — | 1 | 0.9 |
| EMPEROR (Lethrinidae) | 40 | 75.65 | 38 | 44.8 | 25 | 31.05 | 103 | 151.5 |
| *Gnathodentex aurolineatus* | 2 | 0.1 | — | — | — | — | 2 | 0.1 |
| *Gymnocranius* spp. | — | — | 4 | 5.4 | — | — | 4 | 5.4 |
| *Lethrinus conchyliatus* | 4 | 7.2 | 2 | 3.2 | 1 | 0.9 | 7 | 11.3 |
| *Lethrinus erythracanthus* | — | — | — | — | 1 | 1.7 | 1 | 1.7 |
| *Lethrinus microdon* | 12 | 22.3 | 7 | 10.6 | 13 | 18.8 | 32 | 51.7 |
| *Lethrinus olivaceus* | 7 | 31.5 | — | — | — | — | 7 | 31.5 |
| *Lethrinus rubrioperculatus* | 7 | 2.6 | 8 | 4.6 | 6 | 3.85 | 21 | 11.05 |
| *Lethrinus* sp. 1 | 2 | 0.25 | 9 | 5.4 | — | — | 11 | 5.65 |
| *Lethrinus xanthochilus* | 6 | 11.7 | 8 | 15.6 | 4 | 5.8 | 18 | 33.1 |
| GROUPER (Serranidae) | 67 | 83.8 | 59 | 81.2 | 38 | 55.05 | 164 | 220.05 |
| *Aethaloperca rogaa* | 7 | 6.4 | 2 | 3.2 | 1 | 0.7 | 10 | 10.3 |
| *Anyperodon leucogrammicus* | — | — | 1 | 0.5 | — | — | 1 | 0.5 |
| *Cephalopholis argus* | 3 | 0.75 | 2 | 1.45 | — | — | 5 | 2.2 |
| *Cephalopholis miniata* | 3 | 1.7 | 2 | 1.2 | 5 | 1.95 | 10 | 4.85 |
| *Cephalopholis sonnerati* | 3 | 4.45 | 12 | 15.9 | 1 | 0.7 | 16 | 21.05 |
| *Cephalopholis urodeta* | 5 | 0.7 | 4 | 0.8 | — | — | 9 | 1.5 |
| *Epinephelus areolatus* | — | — | 1 | 0.7 | — | — | 1 | 0.7 |
| *Epinephelus fasciatus* | 4 | 1.05 | — | — | — | — | 4 | 1.05 |
| *Epinephelus feveatus* | — | — | 1 | 0.7 | — | — | 1 | 0.7 |
| *Epinephelus flavocaeruleus* | 1 | 6.0 | 2 | 5.7 | 2 | 7.3 | 5 | 19.0 |
| *Epinephelus microdon* | 13 | 31.6 | 9 | 16.9 | 8 | 14.4 | 30 | 62.9 |
| *Epinephelus miliaris* | 2 | 4.4 | — | — | 1 | 1.2 | 3 | 5.6 |
| *Epinephelus spilotoceps* | 5 | 1.25 | — | — | — | — | 5 | 1.25 |
| *Plectropomus areolatus* | 1 | 2.5 | — | — | 2 | 3.25 | 3 | 5.75 |
| *Plectropomus laevis* | — | — | — | — | 2 | 7.1 | 2 | 7.1 |
| *Plectropomus pessuliferus* | 2 | 6.0 | 9 | 18.1 | 10 | 13.45 | 21 | 37.55 |
| *Variola albimarginata* | 10 | 4.75 | 9 | 4.75 | 1 | 0.4 | 20 | 9.9 |
| *Variola louti* | 8 | 12.25 | 5 | 11.3 | 5 | 4.6 | 18 | 28.15 |
| JACK (Carangidae) | — | — | 8 | 18.35 | 8 | 13.55 | 16 | 31.9 |
| *Carangoides orthogrammus* | — | — | 1 | 2.2 | 3 | 6.8 | 4 | 9.0 |
| *Caranx melampygus* | — | — | 2 | 3.9 | — | — | 2 | 3.9 |
| *Elagatis bipinnulata* | — | — | — | — | 5 | 6.75 | 5 | 6.75 |
| *Seriola rivoliana* | — | — | 5 | 12.25 | — | — | 5 | 12.25 |
| SHARK | 2 | 7.6 | 2 | 6.9 | 1 | 3.0 | 5 | 17.5 |
| *Carcharhinus albimarginatus* | 1 | 3.0 | — | — | — | — | 1 | 3.0 |
| *Carcharhinus amblyrhynchus* | 1 | 4.6 | 2 | 6.9 | 1 | 3.0 | 4 | 14.5 |
| TUNA | 1 | 1.6 | — | — | 3 | 11.1 | 4 | 12.7 |
| *Euthynnus affinis* | 1 | 1.6 | — | — | 2 | 5.8 | 3 | 7.4 |
| *Gymnosarda unicolor* | — | — | — | — | 1 | 5.3 | 1 | 5.3 |
| OTHERS | 64 | 60.1 | 9 | 75.95 | 19 | 19.1 | 92 | 155.15 |
| *Belonidae* | 53 | 50.2 | — | — | 11 | 8.2 | 64 | 58.4 |
| *Balistidae* | 5 | 1.55 | 7 | 4.95 | 5 | 7.5 | 17 | 14.0 |
| *Lagocephalus* sp. | 1 | 2.1 | — | — | — | — | 1 | 2.1 |
| *Naso vlamingi* | 1 | 2.3 | — | — | 2 | 2.9 | 3 | 5.2 |
| *Parupeneus cyclostomus* | — | — | — | — | 1 | 0.5 | 1 | 0.5 |
| *Remora* | 1 | 1.0 | 1 | 1.0 | — | — | 2 | 2.0 |
| *Rhinobatidae* | — | — | 1 | 70.0 | — | — | 1 | 70.0 |
| *Sargocentron spiniferum* | 3 | 2.95 | — | — | — | — | 3 | 2.95 |
| TOTAL | 346 | 423.15 | 166 | 344.5 | 130 | 210.85 | 642 | 978.5 |

# Appendix IV

## Numbers of fish and weight (kg) of fish (by species and atoll) caught by night handlining

| Species | SHAVIYANI Nos. | SHAVIYANI Wt | ALIFU Nos. | ALIFU Wt. | LAAMU Nos. | LAAMU Wt | TOTAL Nos. | TOTAL Wt |
|---|---|---|---|---|---|---|---|---|
| SNAPPER (Lutjanidae) | 184 | 239.5 | 76 | 81.8 | 30 | 72.8 | 290 | 394.1 |
| *Aprion virescens* | 1 | 1.5 | — | — | 4 | 10.7 | 5 | 12.2 |
| *Lutjanus bohar* | 125 | 193.3 | 41 | 59.85 | 23 | 59.85 | 189 | 313.0 |
| *Lutjanus gibbus* | 55 | 38.25 | 30 | 18.1 | 2 | 1.35 | 87 | 57.7 |
| *Lutjanus kasmira* | 1 | 0.15 | 4 | 0.65 | — | — | 5 | 0.8 |
| *Lutjanus sebae* | 1 | 2.2 | — | — | — | — | 1 | 2.2 |
| *Lutjanus timorensis* | — | — | — | — | 1 | 0.9 | 1 | 0.9 |
| *Macolor macularis* | 1 | 4.1 | — | — | — | — | 1 | 4.1 |
| *Macolor niger* | — | — | 1 | 3.2 | — | — | 1 | 3.2 |
| EMPEROR (Lethrinidae) | 5 | 18.05 | 6 | 9.3 | 5 | 10.5 | 16 | 37.85 |
| *Lethrinus conchyliatus* | 1 | 2.8 | 1 | 1.7 | — | — | 2 | 4.5 |
| *Lethrinus erythracanthus* | 2 | 11.3 | 2 | 3.2 | 1 | 0.85 | 5 | 15.35 |
| *Lethrinus microdon* | — | — | 1 | 1.3 | 2 | 2.7 | 3 | 4.0 |
| *Lethrinus olivaceus* | — | — | 1 | 1.9 | 1 | 5.35 | 2 | 7.25 |
| *Lethrinus rubrioperculatus* | — | — | 1 | 1.2 | — | — | 1 | 1.2 |
| *Lethrinus xanthochilus* | 2 | 3.95 | — | — | 1 | 1.6 | 3 | 5.55 |
| GROUPER (Serranidae) | 35 | 61.35 | 14 | 25.75 | 2 | 5.9 | 51 | 93.0 |
| *Aethaloperca rogaa* | 1 | 1.2 | 1 | 0.9 | — | — | 2 | 2.1 |
| *Anyperodon leucogrammicus* | 1 | 0.5 | 1 | 0.5 | — | — | 2 | 1.0 |
| *Cephalopholis argus* | 1 | 0.4 | — | — | — | — | 1 | 0.4 |
| *Cephalopholis aurantia* | — | — | 1 | 0.1 | — | — | 1 | 0.1 |
| *Cephalopholis miniata* | 2 | 1.1 | 2 | 0.85 | — | — | 4 | 1.95 |
| *Epinephelus fasciatus* | 1 | 0.3 | — | — | — | — | 1 | 0.3 |
| *Epinephelus flavocaeruleus* | — | — | 1 | 5.1 | — | — | 1 | 5.1 |
| *Epinephelus fuscoguttatus* | — | — | 1 | 9.2 | — | — | 1 | 9.2 |
| *Epinephelus malabaricus* | 1 | 2.8 | — | — | — | — | 1 | 2.8 |
| *Epinephelus microdon* | 14 | 33.4 | 3 | 3.05 | 2 | 5.9 | 19 | 42.35 |
| *Epinephelus spilotoceps* | 11 | 4.7 | 1 | 0.25 | — | — | 12 | 4.95 |
| *Plectropomus laevis* | 1 | 13.2 | — | — | — | — | 1 | 13.2 |
| *Plectropomus pessuliferus* | — | — | 1 | 2.4 | — | — | 1 | 2.4 |
| *Variola louti* | 2 | 3.75 | 2 | 3.4 | — | — | 4 | 7.15 |
| JACK (Carangidae) | 23 | 41.65 | 4 | 20.4 | 53 | 217.55 | 80 | 279.6 |
| *Carangoides caeruleopinnatus* | — | — | — | — | 6 | 2.25 | 6 | 2.25 |
| *Carangoides fulvoguttatus* | — | — | — | — | 1 | 3.35 | 1 | 3.35 |
| *Caranx ignobilis* | — | — | 1 | 7.6 | 5 | 66.7 | 6 | 74.3 |
| *Caranx lugubris* | — | — | 1 | 5.8 | — | — | 1 | 5.8 |
| *Caranx melampygus* | — | — | — | — | 2 | 6.6 | 2 | 6.6 |
| *Caranx sexfasciatus* | 23 | 41.65 | 2 | 7.0 | 36 | 135.1 | 61 | 183.75 |
| *Elagatis bipinnulata* | — | — | — | — | 3 | 3.55 | 3 | 3.55 |
| SHARK | 4 | 13.3 | 5 | 22.1 | 5 | 16.2 | 14 | 51.6 |
| *Carcharhinus albimarginatus* | 1 | 2.7 | 2 | 8.1 | — | — | 3 | 10.8 |
| *Carcharhinus amblyrhynchus* | 3 | 10.6 | 1 | 2.9 | — | — | 4 | 13.5 |
| *Carcharhinus limbatus* | — | — | — | — | 3 | 8.7 | 3 | 8.7 |
| *Carcharhinus sorrah* | — | — | — | — | 2 | 7.5 | 2 | 7.5 |
| *Triaenodon obesus* | — | — | 2 | 11.1 | — | — | 2 | 11.1 |
| TUNA | — | — | — | — | 6 | 73.9 | 6 | 73.9 |
| *Euthynnus affinis* | — | — | — | — | 1 | 2.4 | 1 | 2.4 |
| *Gymnosarda unicolor* | — | — | — | — | 1 | 6.0 | 1 | 6.0 |
| *Thunnus albacares* | — | — | — | — | 4 | 65.5 | 4 | 65.5 |
| OTHERS | 34 | 34.0 | 39 | 26.1 | 14 | 12.15 | 87 | 72.25 |
| *Diagramma pictum* | — | — | — | — | 1 | 1.2 | 1 | 1.2 |
| *Muraenidae* | — | — | 2 | 1.5 | — | — | 2 | 1.5 |
| *Myripristis murdjan* | 1 | 0.2 | — | — | — | — | 1 | 0.2 |
| *Naso vlamingi* | — | — | 3 | 5.1 | — | — | 3 | 5.1 |
| *Remora* | — | — | — | — | 6 | 3.55 | 6 | 3.55 |
| *Sargocentron spiniferum* | 14 | 15.45 | 5 | 4.2 | 3 | 2.1 | 22 | 21.75 |
| *Sargocentron violaceum* | 1 | 0.3 | — | — | — | — | 1 | 0.3 |
| *Sphyraena jello* | 1 | 2.3 | 3 | 4.0 | 2 | 4.3 | 6 | 10.6 |
| *Sphyraena forsteri* | 16 | 11.85 | 26 | 11.3 | — | — | 42 | 23.15 |
| *Tylosaurus acus* | — | — | — | — | 2 | 1.0 | 2 | 1.0 |
| *Tylosaurus crocodilus* | 1 | 3.9 | — | — | — | — | 1 | 3.9 |
| **TOTAL** | 285 | 407.85 | 144 | 185.45 | 115 | 409.0 | 544 | 1002.3 |



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# PUBLICATIONS OF THE BAY OF BENGAL PROGRAMME (BOBP)

The BOBP brings Out the following types of publications

Reports (BOBP/REP/...) which describe and analyze completed activities such as seminars, annual meetings of BOBP's Advisory Committee, and subprojects in member-countries for which BOBP inputs have ended.

Working Papers (BOBP/WP/...) which are progress reports that discuss the findings of ongoing BOBP work.

Manuals and Guides (BOBP/MAG/...) which are instructional documents for specific audiences.

Information Documents (BOBP/INF/...) which are bibliographies and descriptive documents on the fisheries of member-countries in the region.

Newsletters (Bay of Bengal News) which are issued quarterly and which Contain illustrated articles and features in non-technical style on BOBP work and related subjects.

Other publications which include books and other miscellaneous reports.

A list of publications from 1986 onwards is given below. A complete list of publications is available on request.

## *Reports* (BOBP/REP/...)

23. *Summary Report of BOBP Fishing Trials and Demersal Resources Studies in Sri Lanka.* (Madras, March 1986.)
24. *Fisherwomen 's Activities in Bangladesh : A Participatory Approach to Development.* P. Natpracha. (Madras, May 1986.)
25. *Attempts to Stimulate Development Activities in Fishing Communities in Adirampattinam, India. P.* Natpracha, V. L. C. Pietersz. (Madras, May 1986.)
26. *Report of the Tenth Meeting of the Advisory Committee.* Male, Maldives. 17-18 February 1986. (Madras, April 1986.)
27. *Activating Fisherwomen for Development through Trained Link Workers in Tamil Nadu, India.* E. Drewes. (Madras, May 1986.)
28. *Small-scale Aquaculture Development Project in South Thailand: Results and Impact.* E. Drewes. (Madras, May 1986.)
29. *Towards Shared Learning: An Approach to Non-formal Adult Education for Marine Fisherfolk of Tamil Nadu, India.* L. S. Saraswathi and P. Natpracha. (Madras, July 1986.)
30. *Summary Report of Fishing Trials with Large-mech Driftnets in Bangladesh.-* (Madras, May 1986.)
31. *In-service Training Programme for Marine Fisheries Extension Officers in Orissa, India.* U. Tietze. (Madras, August 1986.)
32. *Bank Credit for Artisanal Marine Fisherfolk of Orissa, india.* U. Tietze. (Madras, May 1987.)
33. *Non-formal Education for Children of Marine Ficherfolk in Orissa, India.* U. Tietze, Namita Ray. (Madras, December 1987.)
34. *The Coastal Set Bagnel Fishery of Bangladesh — Fishing Trials and Investigations.* S. E. Akerman. (Madras, November 1986.)
35. *Brackishwater Shrimp Culure Demonstration in Bangladesh.* M. Karirn. (Madras, December 1986.)
36. *Hilsa Investigations in Bangladesh,* (Colombo, June 1987.)
37. *High-Opening Bottom Trawling in Tamil Nadu, Gujarat and Orissa, India: A Summary of Effort and Impact.* (Madras, February 1987.)
38. *Report of the Eleventh Meeting of the Advisors' Committee.* Bangkok, Thailand, March 26-28, 1987. (Madras, June 1987.)
39. *Investigations on the Mackerel and Scad Resources of the Malacca Straits.* (Colombo, December 1987.)
40. *Tuna in the Andaman Sea.* (Colombo, December 1987.)
41. *Studies of the Tuna Resource in the EEZs of Sri Lanka and Maldives.* (Colombo, May 1988.)
42. *Report of the Twelfth Meeting of the Advisory Committee.* Bhubaneswar, India, 12-15 January 1988. (Madras, April 1988.)
43. *Report of the Thirteenth Meeting of theAdvisory Committee.* Penang, Malaysia, 26-28 January, 1989. (Madras, March 1989.)
44. *Report of the Fourteenth Meeting of the Advisory Committee.* Medan, Indonesia, 22-25 January, 1990. (Madras, April 1990.)
45. *Report of the Seminar on Gracilaria Production and Utilization in the Bay of Bengal Region.* (Madras, November 1990.)
46. *Evploralory Fishing for Large Pelagic Species in the Maldives.* R.C. Anderson and A. Waheed. (Madras, December 1990.)
47. *Exploratory Fishing for Large Pelagic Species in Sri Lanka.* R. Maldeniya and S.L. Suraweera. (Madras, April 1991.)
48. *Report of the Fifteenth Meeting of the Advisory Co,vimittee.* Colombo, Sri Lanka, 28-30 January, 1991. (Madras, April 1991.)
49. *introduction of New Small Fishing Craft in Kerala.* O Gulbrandsen and M.R. Andersen. (Madras, January 1992)
50. *Report of the Sixteenth Meeting of the Advisory Committee.* Phuket, Thailand, 20-23 January, 1992. (Madras, April 1992.)

## *Working Papers* **(BOBP/WP/...)**

27. *Reducing the Fuel Costs of Small Fishing Boats.* O Gulbrandsen. (Madras, July 1986.)
38. Credit for Fisherfolk: The Experience in Adirampattinam, TamilNadu, India R. S. Anbarasan and O Fernandez. (Madras, March 1986.)
42. *Fish Trap Trials in Sri Lanka.* (Based on a report by T. Hammerman). (Madras, January 1986.)
43. *Demonstration of Simple Hatchery Technology for Prawns in Sri Lanka.* (Madras, June 1986.)
44. *Pivoting Engine Installation for Beachlanding Boats.* A. Overa, R. Ravikumar. (Madras, June 1986.)
45. *Further Development of Beachianding Craft in India and Sri Lanka.* A. Overa, R. Ravikumar, O Gulbrandsen, G. Gowing. (Madras, July 1986.)
46. *Experimental Shrimp Farming in Ponds in Polekurru, Andhra Pradesh, India.* J. A. J. Janssen, T. Radhakrishna Murthy, B. V. Raghavulu, V. Sreekrishna. (Madras, July 1986.)
47. *Growth and Mortality of the Malaysian Cockle* (Anadara granosa) *under Commercial Culture: A na/psis through Length-frequency Data.* Ng Fong Oon. (Madras, July 1986.)
48. *Fishing Trials with High-Opening Bottom Trawls from Chandipur, Orissa, India.* G. Pajot and B. B. Mohapatra. (Madras, October 1986.)
49. *Pen Culture of Shrimp by Fisherfolk: The BOBP Experience in Killai, Tamil Nadu, India. F.* Drewes, G. Rajappan. (Madras, April 1987.)
50. *Experiences with a Manually Operated Net-Braiding Machine in Bangladesh.* B. C. Gillgren, A. Kashem. (Madras, November 1986.)
SI. *Hauling Devices for Beachlanding Craft.* A. Overa, P. A. Hemminghyth. (Madras, August 1986.)
52. *Experimental Culture of Seaweeds* (Gracilaria *Sp.) in Penang, Malaysia.* (Based on a report by M Doty and **J Fisher)** (Madras, August 1987.)
53. *Atlas of Deep Water Demersal Fishery Resources in the Bay of Bengal.* T. Nishida and K. Sivasubramaniam. (Colombo, September 1986.)
54. *Experiences with Fish Aggregating Devices in Sri Lanka.* K.T. Weerasooriya. (Madras, January 1987.)
55. *Study of Income, Indebtedness and Savings among Fisherfolk of Orissa, India.* T Mammo. (Madras, December 1987.)
56. *Fishing Trials with Beachlanding Craft at Uppada, A ndhra Pradesh, India.* L. Nyberg. (Madras, June 1987.)
57. *Identifying Extension Activities for Fisherwomen in Visakhapatnam District, Andhra Prodesh, India.* D. Tempelman. (Madras, August 1987.)
58. *Shrimp Fisheries in the Bay of Bengal.* M. Van der Knaap. (Madras, August 1989.)
59. *Fishery Statistics in the Bay of Bengal.* T. Nishida. (Colombo, August 1988.)
60. *Pen Culture of Shrimp in Chilaw, Sri Lanka.* **D. Reyntjens.** (Madras, April 1989.)
61. *Development of Outrigger Canoes in Sri Lanka.* O Gulbrandsen, (Madras, November 1990.)
62. *Silvi-Pisciculture Project in Sunderbans, West Bengal: A Summary Report of BOBP's assistance.* C.L. Angell, J. Muir, **(Madras, September** 1990.)
63. *Shrimp Seed Collectors of Bangladesh.* (Based on a study by UBINIG.) (Madras, October 1990.)
**64.** *ReefFish Resources Survey in the Maldives.* M. Van der Knaap, Z. Waheed, H. Shareef, M. Rasheed (Madras, April 1991.)
65. *Seaweed* (Gracilaria Edulis) *Farming in Vedalai and Chinnapalam, India.* Ineke Kalkman, Isaac Rajendran, Charles L Angell. (Madras, June 1991).
66. *Improving Marketing Conditions for Women Fish Vendors in Besant Nagar, Madras.* K. Menezes. (Madras, April 1991.)
67. *Design and Trial of Ice Boxes for Use on Fishing Boats in Kakinada, India.* I.J. Clucas. (Madras, April 1991.)
68. *The By-catch from Indian Shrimp Trawlers in the Bay of Bengal: The potential for its improved utilization.* **Ann Gordon. (Madras, August** 1991).
**69.** *Agar and Alginate Production from Seaweed in india.* J .J .W. Coppen, P. Nambiar, (Madras, June 1991.)
70. *The Kattumaram of Kothapatnam-Pallipalem, Andhra Pradesh, India — A survey of the fisheries and fisherfolk.* Dr. **K. Sivasubramaniam. (Madras, December 1991.)**
72. *Giant Clams in the Maldives — A stock assessment and study of their potential culture.* Dr. J. R. Barker. (Madras, December **1991.)**
73. *Small-scale culture of the flat oyster* (Ostrea folium) *in Pulau Langkawi, Kedah, Malaysia,* Devakie Nair and Bjorn Lindeblad. (Madras, November 1991).
76. *A View from the Beach — Understanding the status and needs of fisherfolk in the Meemu, Vaavu and Faafu Atolls of the Republic of Maldives.* The Extension and Projects Section of the Ministry of Fisheries and Agriculture, **The Republic of Maldives. (Madras, June 1991).**
77. *Development of Canoe Fisheries in Sumatera, Indonesia.* O Gulbrandsen and C. Pajot. (Madras, April 1992).



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78. The Fisheries and Fisherfolk of Nias island, Indonesia. A description of thefisheries and a socio-economic appraisal *of the fisherfolk.* Based on reports by G. Pajot and P. Townsley. (Madras, December 1991.)

79. *Review of the Beche De Mer (Sea Cucumber) Fishery in the Maldives* by Leslie Joseph (Madras, April 1992.)

80. *Reef Fish Resources Survey in the Maldives — Phase Two* by R C Anderson, Z Waheed, M Rasheed and A Arif *(Madras.* April 1992)

82 *Cleaner Fishery Harbours in the Bay of Bengal* (Madras, April 1992)

## ***Manuals and Guides*** *(BOBP/MAG/...)*

1. *Towards Shared Learning: Non-formalAdult Educationfor Marine Fisherfolk.* Trainers' Manual. (Madras, June 1985.)
2. *Towards Shared Learning: Non-formalAdult Educationfor Marine Ficherfolk.* Animators' Guide. (Madras, June 1985.)
3. *Fishery Statistics on the Microcomputer: A BASIC Version of Hasseiblad's NORMSEP Program.* D. Pauly, N. David, J. Hertel-Wuiff. (Colornbo, June 1986.)
4. *Separating Mixtures of Normal Distributions: Basic programs for Bhattacharya 's Method and Their Application for Fish Population Analysis.* H. Goonetilleke, K. Sivasubramaniam. (Madras, November 1987.)
5. *Bay of Bengal Fisheries Information System (BOBFINS) : User's Manual.* (Colombo, September 1987.)

10. *Our Fish, Our Wealth.* A guide to fisherfolk on resources management. — in 'comic book' style (English/Tamilll'elugu) Kamala Chandrakant with K. Sivasubramaniam and Rathin Roy. (Madras, December 1991.)

## ***Information Documents*** *(BOBP/INF/...)*

9. *Food and Nutrition Status of Small-Scale Fisherfolk in India's East Coast States : A Desk Review and Resource Investigation.* V. Bhavani. (Madras, April 1986.)
10. *Bibliography on Gracilaria — Production and Utilization in the Bay of Bengal.* (Madras, August 1990.)
11 *Marine Small-Scale Fisheries of West Bengal : An Introduction.* (Madras, November 1990.)
12. *The Fisherfolk of Puttalam, Chilaw, Galle and Marara — A study of the economic status of the fisherfolk of four fisheries districts in Sri Lanka. (Madras, December 1991.)*

## *Newsletters* *(Bay of Bengal News)*

Quarterly

## ***Other Publications***

*Artisanal Marine Fisherfolk of Orissa: Study of their Technology, Economic Status, Social Organization and Cognitive Patterns.* U Tietze. (Madras)

*Studies on Mesh Selectivity and Performance: The New Fish-cum-Prawn Trawl at Pesalal, Sri Lanka.* BOBP/MIS/3. M.S.M. Siddeek. (Madras, September 1986.)

*Motorization of Dinghy Boats in Kasafal, Orissa.* BOBP/MIS/4. S. Johansen and O Gulbrandsen. (Madras, November 1986.)

*Helping Fisherfolk to Help Themselves . A Study in People's Participation.* (Madras, 1990.)

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