YELLOWFIN TUNA (*THUNNUS ALBACARES*) IN THE MALDIVES

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INTRODUCTION

Yellowfin (*Thunnus albacares*) is the second most important species of fish caught in the Maldives, after skipjack tuna (*Katsuwonus pelamis*). Yellowfin catches have increased dramatically in recent years. In 1994 the total Maldives catch of yellowfin was over 13,000 t (Anon, 1995), which was 12.6% of the total national fish landings.

The Maldivian yellowfin fishery is essentially a live-bait pole-and-line fishery. Catches by traditional (but now mechanized) pole-and-line vessels account for over 95% of the total catch. The yellowfin caught are mainly surface-swimming juveniles within the size range of 30-60cm FL. Yellowfin are also caught regularly, but in smaller quantities, by handlining and trolling. These methods generally catch large-size yellowfin of more than 70cm FL. In addition, longliners operating in the waters around the Maldives take deep-swimming adult fish.

The Maldives "yellowfin" catch includes a small number of bigeye tuna (*Thunnus obesus*). No separate statistics are kept for this species, but preliminary studies suggest that bigeye tuna may account about up to 5% of the total yellowfin catch (Anderson and Hafiz, 1991; Anderson, 1995).

This report summarises current knowledge of the biology of yellowfin tuna in the Maldives, and presents new information about the Maldivian yellowfin fishery.

CATCH TRENDS

Recorded catches of yellowfin tuna for the 1970-1994 period are given in Table 1 and Figure 1. Figure 2 illustrates the relative contributions of the main vessel types to annual catches. Pole and line is clearly the most important fishing method for yellowfin tuna in the Maldives. The pole-and-line fleet is a traditional one, but mechanization (which started in 1974-75) effectively transformed the entire fleet from sail to engine power in less than ten years. The contribution of the trolling fleet to the total yellowfin catch is relatively small. Trolling catches peaked at about 590 t/yr (*i.e.,* about 14% of the total yellowfin catch) in 1979-80. Since then they have declined, reflecting the general decline of the whole troll fishery as a result of changing socioeconomic conditions within the Maldives.

During the 1970-1994 period total yellowfin catches have increased substantially, but somewhat erratically (Figure 1). Catches from 1973 to 1982 averaged about 4400 t/yr, and from 1983 to 1990 about 6200 t/yr, but since 1990 they have more than doubled, to a record of 13,126 t in 1994. This is an increase of roughly 2000 t/yr during the 1990-1994 period. Explanations for this dramatic increase include:

1. An increase in crude fishing effort. The number of active pole-and-line fishing vessels increased about 23%, from about 1100 in 1990 to over 1400 in 1994. A more useful index of fishing effort is the number of days fished by mechanised pole-and-line vessels, which increased 13%, from about 198,000 days in 1990 to over 223,000 days in 1994 (see Anderson, Hafiz and Adam (1995) for details of fishing effort statistics).
2. An increase in fishing power of the pole-and-line vessels. In recent years boat owners have tended to build bigger vessels and install larger engines, with the aim of increasing fishing power and attracting better crews. The introduction of mechanical pumps for spraying water during pole-and-line fishing, more frequent use of radios between vessels, greater use of binoculars for spotting seabirds, and an increase in the number of FADs have all increased the effective fishing power of the vessels (Hafiz and Anderson, 1994). These increases are however difficult, if not impossible too quantify.

Figure 1. *Maldives yellowfin catch by vessel type, 1970-1994.*

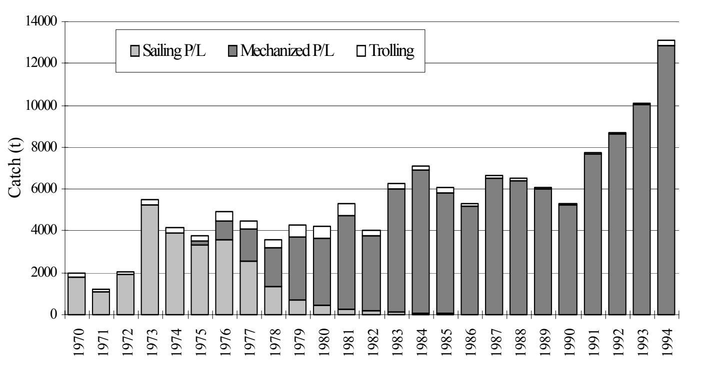


Table 1**. Catches and catch per unit effort (CPUE) of yellowfin tuna for mechanized pole and line vessels, 1979-1994.**

Year	*Catch (t)*	*Effort (days)*	*CPUE (kg/day)*
1979	4,289	79,904	54
1980	4,229	83,134	51
1981	5,284	83,731	63
1982	4,004	97,085	41
1983	6,241	117,172	53
1984	7,124	153,460	46
1985	6,066	162,430	37
1986	5,321	161,910	33
1987	6,668	158,785	42
1988	6,535	184,353	35
1989	6,082	183,944	33
1990	5,280	193,045	27
1991	7,711	198,320	39
1992	8,697	204,808	42
1993	10,110	222,548	45
1994	13,126	223,095	59

Source: Ministry of Fisheries & Agriculture /EPCS.

Table 2. **Maldivian yellowfin tuna catches by vessel type (1970-1994).**

Year	*Sailing P/L vessels*	*Mech. P/l vessels*	*Total P/L vessels*	*Trolling*	*Grand total*
1970	1,799	-	1,799	190	1,989
1971	1,081	-	1,081	146	1,227
1972	1,940	-	1,940	136	2,076
1973	5,234	-	5,234	241	5,475
1974	3,868	-	3,868	260	4,128
1975	3,348	164	3,512	262	3,774
1976	3,569	912	4,481	410	4,891
1977	2,530	1,593	4,123	350	4,473
1978	1,324	1,890	3,214	370	3,584
1979	733	2,959	3,692	597	4,289
1980	471	3,176	3,647	582	4,229
1981	273	4,467	4,740	544	5,284
1982	167	3,603	3,770	234	4,004
1983	112	5,872	5,984	257	6,241
1984	76	6,818	6,894	230	7,124
1985	82	5,715	5,797	269	6,066
1986	22	5,178	5,200	121	5,321
1987	9	6,522	6,531	137	6,668
1988	12	6,366	6,378	157	6,535
1989	6	5,972	5,978	104	6,082
1990	5	5,225	5,230	50	5,280
1991	5	7,649	7,654	57	7,711
1992	11	8,628	8,639	58	8,697
1993	17	10,006	10,023	87	10,110
1994	8	12,859	12,867	259	13,126

Source: Ministry of Fisheries & Agriculture / EPCS

1. A change in catchability and/or abundance of the fish. The abundance and/or catchability of yellowfin and other tuna species is known to be affected by changes in oceanographic conditions, both within the Maldives (Anderson, 1987 & 1993; Hafiz and Anderson, 1994) and within the wider western Indian Ocean (Marsac and Hallier, 1990; Marsac, 1992). It seems possible that oceanographic conditions during 1992-1994 were particularly favourable for yellowfin tuna in Maldivian waters. These points are discussed further below.

TRENDS IN CATCH PER UNIT EFFORT (CPUE)

The Maldivian yellowfin fishery is dominated by mechanized pole-and-line vessels. Annual average catches per unit effort (CPUE) for 1979-1994 for these vessels are given in Table 2 and Figure 3. The best available measure of fishing effort, and the one used here, is the number of fishing days. The problems associated with using fishing days as a measure of pole-and-line fishing effort are well-known (*e.g.,* Anderson, 1993; Hafiz and Anderson, 1994). They include problems of variations in bait availability, seabird abundance, vessel interactions, and others. These difficulties mean that individual annual estimates of Maldivian CPUE may not be too accurate, but the time series is believed to give a very useful picture of major trends.

Annual average yellowfin CPUE decreased from a high of 63 kg/day in 1981 to a low of about 27 kg/day in 1990. This decline has been noted before (Anderson, 1993; Anderson and Hafiz, 1991; Hafiz and Anderson, 1994;

Figure 2. *Percentage yellowfin catch by vessel type, 1970-1994*

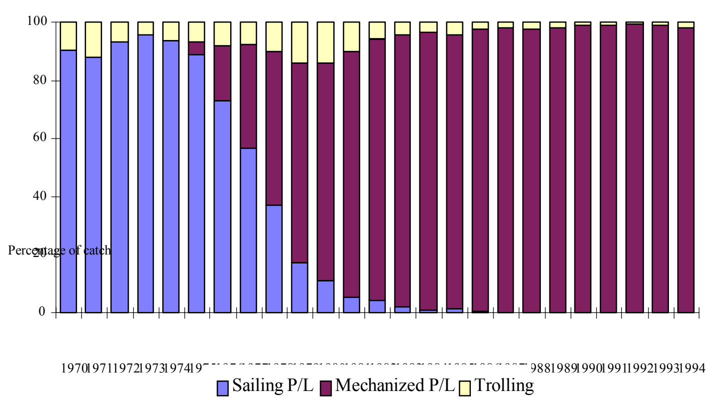


Table3. **Indices of Maldivian yellowfin CPUE (kg/mech. P/L vessel day) for two seasonal yellowfin fisheries, 1970-1994. Data source: Ministry of Fisheries and Agriculture.**

A: North East Monsoon.
Location: Kaafu, Malé town and Lhaviyani
Months: Dec, Jan, Feb and March

Year	*Catch (t)*	*Effort (d)*	*CPUE*
1969-70	132	3,967	33
1970-71	68	4,558	15
1971-72	147	4,682	31
1972-73	430	6,227	69
1973-74	327	6,555	50
1974-75	776	5,674	137
1975-76	296	5,954	50
1976-77	688	5,787	119
1977-78	418	6,255	67
1978-79	278	4,045	69
1979-80	396	6,807	58
1980-81	539	7,037	77
1981-82	186	6,463	29
1982-83	517	7,947	65
1983-84	1,234	12,373	100
1984-85	1,108	11,183	99
1985-86	1,516	11,571	131
1986-87	1,165	11,219	104
1987-88	984	11,800	83
1988-89	571	12,360	46
1989-90	261	8,164	32
1990-91	952	11,416	83
1991-92	892	10,705	83
1992-93	1,228	12,545	98
1993-94	1,818	12,544	145

B: South West Monsoon
Location: Raa and Baa Atolls
Months: June, July Aug and Sept.

Year	*Catch (t)*	*Effort(d)*	*CPUE*
1970	827	6,345	130
1971	376	4,976	76
1972	1022	5,535	185
1973	1814	6,671	272
1974	1294	5,555	233
1975	1644	12,393	133
1976	1909	11,420	167
1977	1358	9,336	145
1978	1131	9,079	125
1979	1075	6,449	167
1980	1378	6,313	218
1981	1160	5,047	230
1982	1898	5,897	322
1983	2175	6,706	324
1984	1527	8,805	173
1985	1591	7,820	203
1986	1053	8,804	120
1987	2226	8,244	270
1988	1062	7,513	141
1989	917	10,403	88
1990	550	12,483	44
1991	778	9,597	81
1992	994	10,048	99
1993	1183	12,807	92
1994	1438	13,115	110

Note: To standardize sailing pole and line vessel effort to "number of mechanized pole and line vessels days" it was assumed that sailing vessels caught half the yellowfin caught by mechanized vessels. For the years 1970-1978 sailing vessel effort was halved. For the years since 1979 sailing vessels effort was small and has been ignored. Also note that data for Dec. 1969 have not been included.

IPTP, 1992; Nishida, 1991). Possible reasons for this decline are noted by IPTP (1992, p. 49).

Since 1990 the annual average yellowfin CPUE has more than doubled, rising steadily from about 27 kg/day in 1990 to 59 kg/day in 1994. Part of this increase can be explained by an increase in fishing power of the pole-and-line vessels, as noted above. Although the change in vessel fishing power has not been quantified, it seems unlikely that it could account for more than about 10-20% of the increase in yellowfin CPUE over the last 5 years. The most likely explanation for the remaining increase in Maldivian yellowfin catch and CPUE is changes in the oceanographic conditions in the Indian Ocean, discussed below.

The Maldivian pole-and-line fishery for yellowfin is highly seasonal. Peak catches are made off the west coast of the Maldives during the southwest monsoon (June to October), and off the east coast during the northeast monsoon (December to April) (Adam, 1993; Anderson, 1985 &1988; Hafiz and Anderson, 1991; Rochepeau and Hafiz, 1990). Particularly high catches are made off Raa and Baa Atolls during the southwest monsoon, and off Kaafu and Lhaviyani Atolls during the northeast monsoon. As simple indices of CPUE for these two seasonal fisheries, pole-and-line catches and effort have been compiled for the following two areas and time periods:

1. Southwest monsoon fishery:

- Raa and Baa Atolls, for June, July, August and September.

2. Northeast monsoon fishery:

- Lhaviyani and Kaafu Atolls and Malé town, for December January, February and March.

The complete time series for both fisheries are presented in Table 3 and Figures4a and 4b. Note that fishing effort in these time series has been standardized to “number of days fished by mechanized pole-and-line vessels”. This has been done for years prior to 1979 by assuming that sailing vessels caught half the yellowfin that mechanized vessels did, following Anderson (1985).

Historically, the southwest monsoon fishery has always been more important than the northeast monsoon fishery. The average CPUE for the southwest monsoon fishery during the 1970-1994 period was 165 kg of yellowfin per mechanized pole-and-line vessel day. For the northeast monsoon fishery the average CPUE was 81 kg/day. Both fisheries show similar recent trends in CPUE: a rapid decline from 1983/85-1990, and an increase since 1990. While there are a number of possible explanations for this

Table 4. **Average lengths and size ranges (cm) of yellowfin tuna samples in Maldives during 1994.**

Sample number	*Sample location*	*Mean*	*Mode*	*Median*	*Size range 5-95%*	*Smallest*	*Largest*	*Total in sample*
1	H.Dh. Kulhudhufushi	46	48	47	33-57	25	82	11,730
2	R. Alifushi	46		47	30-60	20	84	10,063
3	K. Malé*	53	44	45	31-112	22	164	2,749
4	M. Maduvvari	44	47	47	33-51	29	154	2,269
5	Dh. Kudahuvadhoo	39	38	39	31-49	23	66	9,984
6	L. Maamendhoo	47	46	47	37-53	20	118	6,826
7	G. A.Villingili	43	43	44	32-55	17	87	12,283
8	G.Dh. Thinadhoo	47	47	47	35-58	20	98	18,563
	TOTAL							74,467

*Malé sample includes catches from hand line and trolling

pattern of changes, the most likely is believed to be changes in oceanographic conditions, which are discussed below.

Since 1990, CPUE in the southwest monsoon fishery has increased only slowly. In contrast the increase in CPUE in the northeast monsoon fishery has been very rapid. During 1970-1990 the southwest monsoon fishery CPUE was greater than that of the northeast monsoon fishery in 20 out of 21 years. During 1991-1994 the northeast monsoon fishery CPUE was greater than that of the southwest monsoon fishery in three out of four years. One possible explanation for this change is the increasing catch of yellowfin tuna by other nations in the western Indian Ocean, adversely affecting recruitment to the southwest monsoon fishery in the Maldives.

OCEANOGRAPHIC VARIATIONS AND YELLOWFIN CATCHES

As noted by Marsac (1992), a traditional approach to population dynamics based on an assumption of environmental stability is no longer tenable. In the Maldives the abundance of juvenile yellowfin is known to be affected by variations in oceanographic conditions of at least three types:

Seasonal variations. As mentioned above, the fishery for juvenile yellowfin tunas in the Maldives is highly seasonal. In fact there are essentially two fisheries, one off the west coast during the southwest monsoon and one off the east coast during the northeast monsoon (Adam, 1993; Anderson, 1985 & 1988; Anderson and Hafiz, 1991; Rochepeau and Hafiz, 1990). In both seasons the juvenile yellowfin are strongly associated with drifting objects.

Medium-term variations. As noted above, there have been medium-term trends in yellowfin CPUE in recent years. Since the same pattern of variation in CPUE is seen in Maldivian frigate tuna (*Auxis thazard*) and kawakawa (*Euthynnus affinis*), while the opposite pattern is seen in skipjack, these trends are believed to be related in some way to medium-term variations in oceanographic conditions (Anderson, 1993; Hafiz and Anderson, 1994).

Variations associated with ENSO events. Maldivian yellowfin CPUE increases during El Niño years (Anderson, 1987 & 1993; Hafiz and Anderson, 1994; Rochepeau and Hafiz, 1990). Note the elevated yellowfin CPUEs during the El Niño years of 1972-73 (Figures 1 and 4a), 1976 (Figures 1 and 4b), 1982-83 (Figure 4b), 1987 (Figures 1, 3, and 4b), and 1992-94 (Figures 1, 3, and 4a). In the western Indian Ocean, ENSO events are characterized by high sea-surface temperatures, low wind mixing, and strong vertical gradients in the thermocline. These conditions appear to promote yellowfin larval survival (Marsac and Hallier, 1990; Marsac, 1992) and hence presumably also recruitment to the Maldivian fishery.

It appears that oceanographic conditions during 1992-1994 were particularly favourable for juvenile yellowfin tuna in Maldivian waters. This is reflected in the high total catch (Figure 1) and national CPUE (Figure 3). However, the relatively low CPUE for juvenile yellowfin off Raa and Baa Atolls during the southwest monsoon is a cause for concern. There is clearly a need for further study of both the effects of oceanographic variability on yellowfin tuna distribution and abundance, and of fisheries interactions, within the Indian Ocean.

THE FISHERY FOR LARGE YELLOWFIN

The great majority of yellowfin landed in the Maldives are surface-swimming juveniles, caught by live-bait pole and line. A traditional trolling and handlining fishery for large yellowfin also exists in the Maldives. The yellowfin caught in this fishery are generally subadults and adults of more than 70cm FL. Large yellowfin are also caught occasionally by pole and line, using double poles. There

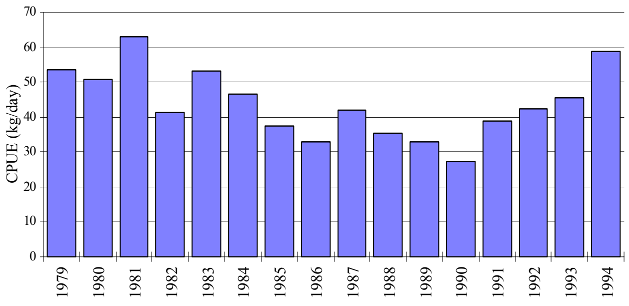


Figure 3. *Mechanized pole and line CPUE for yellowfin tuna, 1979-1994, for the entire Maldives (kg/day)*

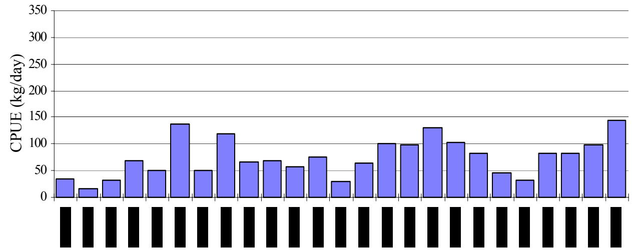


Figure 4a. *CPUE of yellowfin tuna for Lhaviyani, and Kaafu Atolls and Malé town, NE monsoon season (kg/mech. P/L day)*

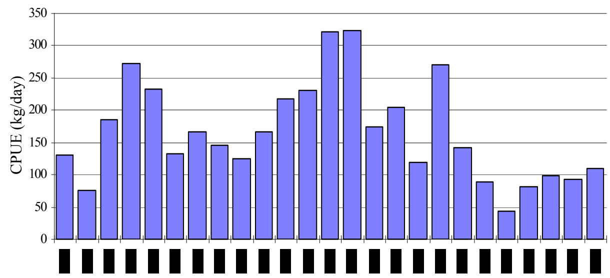


Figure 4b. *CPUE of yellowfin tuna for Raa and Baa Atolls, SW monsoon season (kg/mech. P/L day)*

are a number of well-established local fisheries for large yellowfin, including ones off:

- Haa Alifu Atoll, in the far north, during January-April.
- Malé, in the centre of the country, during March-September.
- Fuvah Mulaku and Addu Atoll, in the far south, during April and November.

The Fuvah Mulaku fishery has been briefly described by Anderson, Adam and Waheed (1993). However, the overall seasonal distribution of large yellowfin tunas within Maldivian waters has not been well documented. A survey has therefore been initiated of all fishing islands in the country, to obtain information from experienced fishermen on the seasonal occurrence of large yellowfin. At present there is considerable business interest in large yellowfin within the Maldives: exports of chilled fish to the Japanese *sashimi* market and of tuna loins to Europe have recently started.

In addition to the "inshore" fishery for large yellowfin, some tuna longlining has been and is being carried out in the outer waters of the Maldivian EEZ (*i.e.* 75-200 miles offshore). Further details are given in Anderson, Hafiz and Adam (1995).

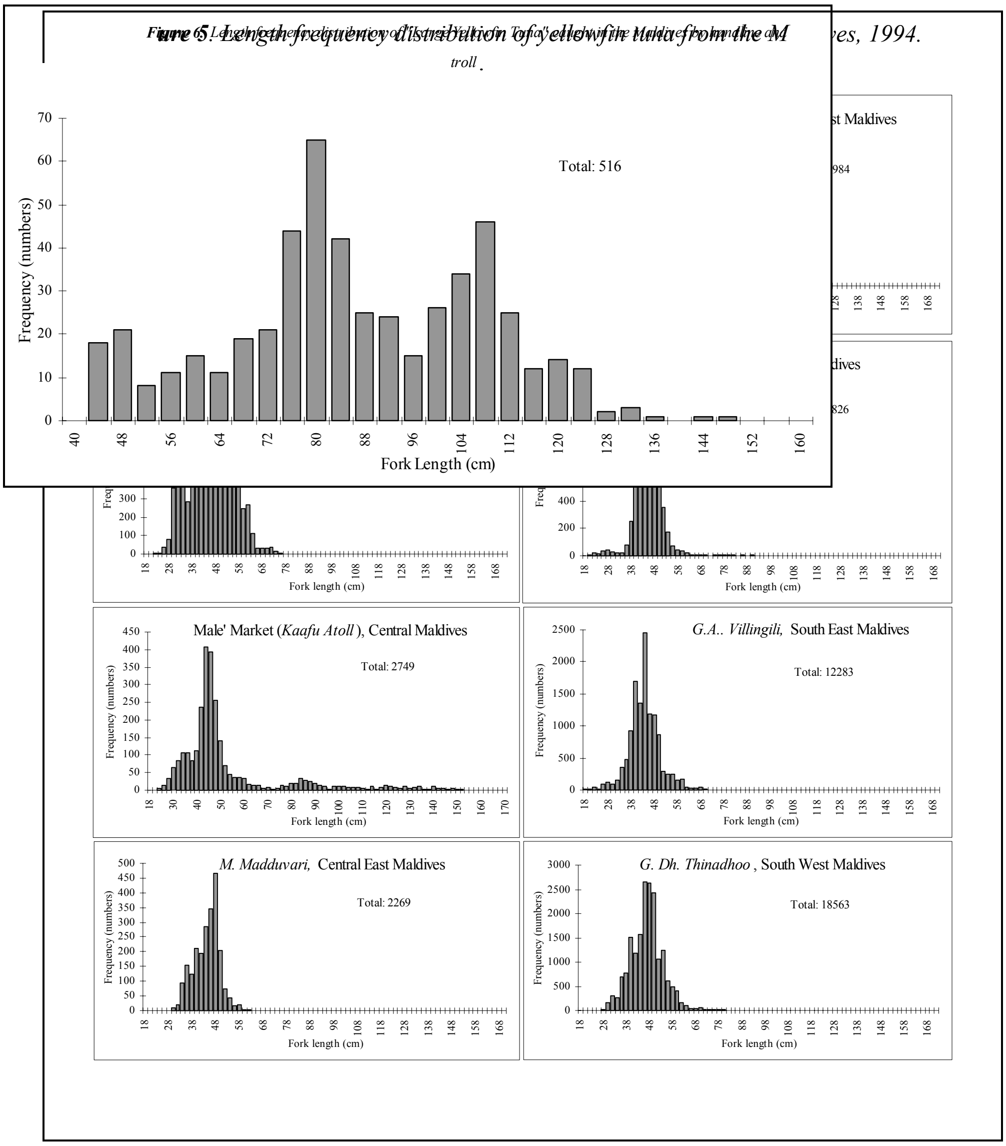
SIZE DISTRIBUTION OF YELLOWFIN CATCHES

In 1993 Maldives initiated a regional tuna length-frequency sampling program. Active pole-and-line skippers were employed to measure their tuna catches at seven islands, representing all regions of the Maldives. In addition, sampling at Malé market, which was initiated in 1983, has continued. 1994 data are summarized in Figure 5 and Table 4. Among over 74,000 yellowfin measured in 1994, the commonest sizes in the pole-and-line fishery were between 38 and 50 cm FL. The great majority of the yellowfin sampled fell within the 30-60cm FL size range. There was no obvious trend in yellowfin size between regions. Yellowfin sampled at one location (Dh. Kudahuvadhoo) were on average smaller than at other locations. The median size of yellowfin sampled there was 39 cm FL, compared with 44-47 cm FL at the other seven sampling locations. As Dh. Kudahuvadhoo is a central location, this observation is difficult to explain; returns for 1995 are currently being compiled and may shed some light on this apparent anomaly.

The regional length-frequency sampling programme concentrates on pole-and-line catches, with the exception of Malé market sampling which covers all gears. As a result, large yellowfin catches are not particularly well represented. Some sampling of large yellowfin catches has been carried out in Haa Alifu, Raa and Baa Atolls in the north and at Fuvah Mulaku in the south. The combined length-frequency distribution of handline catches of large yellowfin from these two locations is presented in Figure 6. Sampling at Malé does not separate pole-and-line and handline catches, so Malé data have been excluded from Figure 6. In both Figure 5c (Malé) and Figure 6 there is a clear mode at 82-84cm FL. The 108cm FL mode in Figure 6 is mainly due to fish from Fuvah Mulaku.

OTHER BIOLOGICAL INFORMATION

Growth. Because the Maldivian yellowfin tuna fishery mainly targets juveniles, it has not been possible to develop growth models for the full size range of yellowfin tuna found in Maldivian waters. Two studies so far have concentrated on growth rates of juveniles. From analysis of length-frequency data, Anderson (1988) estimated a linear growth rate of 2.9±0.4 cm/mo between 30-70cm FL (although growth at half this rate could not be discounted). From tagging data, Yesaki and Waheed (1992) estimated an average growth rate of 2.4 cm/mo at 70cm FL.



...ure 5. Length frequency distribution of yellowfin tuna from the M... ...ves, 1994.

troll .

Migration. Anderson (1988) proposed a model of juvenile yellowfin tuna migration in the central Indian Ocean in which a broad band of young fish in the equatorial waters moves east and west in phase with the seasonally changing monsoon currents. Anderson (1988) and Adam (1992) suggest that intermediate-size fish migrate northwards from the Maldives into the north of the Arabian Sea. Length-frequency data from pole-and-line catches presented here show no evidence of increase in size with latitude within the Maldives. From a tagging study of juvenile yellowfin tuna in Maldives, Yesaki and Waheed (1992) confirmed the east-west movement in phase with the monsoons, but did not present evidence for a net northward movement. It may be therefore that if there is a northward migration it does not start until the yellowfin have grow to a size greater than that at which they are normally taken by pole and line (*i.e.* greater than 60cm FL). For western Indian Ocean yellowfin, a change in body proportions determined by detailed analyses of length-weight relationships has been noted at about 64-68cm FL, and this has been interpreted as reflecting a “turning point in the life of this fish” (Montaudouin, Hallier and Hassani, 1990; Hallier, 1991). Maldeniya and Joseph (1988) demonstrated a northward movement of yellowfin along the west coast of Sri Lanka, mainly on the basis of changes in relative abundance of 60-80cm FL fish.

Regarding adult yellowfin, Morita and Koto (1971) suggested that there is a movement of fish from the equatorial western Indian Ocean, through the southern Maldives and up past Sri Lanka into the Bay of Bengal every year between October and March. The seasonal fishery for large yellowfin at Fuvah Mulaku every November may be targeting these fish (Anderson, Shiham and Waheed, 1993). Some tagging of large yellowfin at Fuvah Mulaku has been carried out (Anderson, Adam and Waheed, 1995), but no overseas recoveries have been received to date.

Stock relationships. Nishida (1992) proposed that there are two major stocks of yellowfin tunas in the Indian Ocean: a western and an eastern stock, with an area of overlap between about 70^{o} - 90^{o}E. If this is the case, it is possible that the juvenile yellowfin caught off the west coast of the Maldives during the southwest monsoon could come from the western stock, while those caught off the east coast of the Maldives during the northeast monsoon could come from the eastern stock. A scatter plot of southwest monsoon fishery CPUE against northeast monsoon fishery CPUE shows no obvious correlation. The same applied when southwest monsoon fishery CPUE was plotted against northeast monsoon fishery CPUE for previous and following years. This finding would tend to support the two-stock hypothesis. If that is the case, the similarity in CPUE trends over the 1970-94 period for the two fisheries, noted above, might still be attributed to large-scale changes in oceanographic conditions affecting local abundance or catchability in Maldivian waters of juvenile yellowfin tunas from different sources.

Length-weight relationship. Anderson *et al*. (1995) have calculated the following length-weight relationship (cm-kg) for Maldivian yellowfin tuna landings, within the size range of 25-145cm FL:

$$W = 0.00002863\ FL^{2.897} \quad (N = 875;\ r = 0.990)$$

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