INTER-ANNUAL VARIATIONS IN LIVEBAIT UTILIZATION IN THE MALDIVES

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INTRODUCTION

Livebait pole and line fishing for tuna is the most important fisheries activity in the Maldives. It has traditionally been the major source of employment, the major and preferred source of animal protein, and the major source of export earnings for the entire country. With the development of tourism, new fisheries, and other economic activities, the relative importance of the tuna fishery has declined over the last two decades. Nevertheless, the fishery remains of crucial importance. In 1994 some 96,800t were caught by pole and line, which was 93% of the total recorded fish catch (MOFA, 1994).

The pole and line fishery in fact comprises two separate fisheries: an offshore one for tunas and an inshore one for livebait. Without livebait there would be no pole and line tuna catch. It is no exaggeration to say that the well being of the Maldives depends on the success of the pole and line tuna fishery, which in turn depends on the availability of livebait. Tuna livebait are thus by far the most important reef fish resource in the Maldives.

The size of the livebait catch has increased enormously in recent years. There is therefore some concern about the status of the livebait resource. One of the first steps needed to obtain an understanding of livebait stock status is an understanding of the nature and scale of natural population fluctuations. Seasonal and regional variations in the utilization of livebait within the Maldives were described by Anderson and Saleem (1994). The aim of this report is to summarize available information on variation in livebait utilization from year to year, and to highlight areas where further study is required.

b. From G.Dh. Thinadhoo in the south of Maldives, where data on livebait utilization have been collected since January 1987. Some months were underrepresented or not sampled at all. Estimates of livebait utilization for months in which less than 18 days sampling were carried out have been raised to the average number of days sampled for that month in all other years for which 18 or more days sampling was carried out. For months in which no sampling was carried out the average bait utilization for that month in other years in which sampling was carried out was substituted. A total of 1986 days sampling was actually carried out during which the livebait utilization of 6292 *masdhonis* was recorded. Correcting for undersampling gives an estimated 7689 days livebait utilization, an increase of about 22% over the actual sample. The corrected sample data are presented in Table 3, and summarized in Figure 2.

The data presented in Tables 2 and 3 are sample data. Sample sizes are relatively stable from year to year, and do not necessarily reflect changes in fishing effort. To allow for this, annual samples from Malé were raised to the total number of mechanized pole and line vessel fishing days recorded at Malé (Table 4). Annual samples from G.Dh. Thinadhoo were raised to the total number of mechanized pole and line fishing vessel days recorded for Gaafu Dhaalu Atoll (Table 4), in the absence of data from just Thinadhoo. The use of Malé fishing effort data will tend to underestimate livebait fishing activity in the area of Malé (as many vessels from other areas fish near Malé), while the use of Gaafu Dhaalu Atoll fishing effort data will overestimate livebait fishing activity near Thinadhoo. Nevertheless, these are the best data available and are believed to give some indication of the true scale of fishing activity in the two areas. For both Malé and Gaafu Dhaalu Atoll, estimated livebait utilization by major varieties is shown graphically in Figures 3 to 9.

In addition to the data from Malé and G.Dh. Thinadhoo, some qualitative information on long term changes in livebait abundance has been collected during interviews with experienced chummers. Interviews have been conducted by the senior author and colleagues from the Marine Research Section (MRS) on over 40 fishing islands throughout the Maldives.

METHODS

Maldivian tuna fishermen carry out single day fishing trips. They normally collect bait first thing in the morning from reefs within the atolls before going offshore for tuna. Thus, numbers of fishing trips (which are recorded by the Ministry of Fisheries and Agriculture, MOFA) are equal to numbers of days livebait utilization. Quantitative information on live bait utilization over a number of years is available from two sources:

a. From Malé market, where the main varieties of livebait (Table 1) used by each *masdhoni* (pole and line vessel) have been recorded regularly since late 1985. Data have been compiled from January 1986 to December 1994 (bound copies of data summaries are maintained at the Marine Research Section, MRS). Sampling has been carried out daily, but some months (notably Januarys) have been underrepresented. This could lead to spurious inter-annual variations, so has been corrected for in the following manner. Estimates of livebait utilization for months in which less than 18 days sampling were carried out have been raised to the average number of days sampled for that month in all other years for which 18 or more days sampling was carried out. A total of 2470 days sampling was actually carried out during which the livebait utilization of 65853 *masdhonis* was recorded. Correcting for undersampling in some months gives an estimated 68454 days livebait utilization, an increase of about 4% over the actual sample. The corrected sample data are presented in Table 2, and summarized in Figure 1.

Table 1. The main livebait varieties used in the Maldives

Local Name	Species	English Name	Family
Rehi	*Spratelloides gracilis*	Silver Sprat	Clupeidae
Hondeli	*Spratelloides delicatulus*	Blue Sprat	Clupeidae
Miyaren	*Encrasicholina heteroloba*	Shorthead Anchovy	Engraulididae
Thaavalha	Various species	Silversides / Hardyheads	Atherinidae
Boadhi	Various species	Cardinalfishes	Apogonidae
Muguraan	Various species	Fusiliers	Caesionidae
Nilamehi	*Chromis viridis*	Blue Damselfish	Pomacentridae
Bureki	*Lepidozygous tapeinosoma*	Fusilier Damselfish	Pomacentridae

TABLE 3. ANNUAL BAIT UTILIZATION FOR G.DH.THINADHOO 1987-1994

(Corrected sample numbers and percentages of days used by masdhonis)

VARIETIES	1987		1988		1989		1990		1991		1992		1993		1994		TOTAL	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Rehi	390.0	40.2	403.4	42.2	318.0	33.0	265.3	26.5	231.5	24.6	273.5	27.5	395.0	42.0	236.0	25.5	2512.7	32.7
Hondeli	150.3	15.5	144.5	15.1	125.4	13.0	100.1	10.0	98.6	10.5	134.6	13.6	129.1	13.7	95.1	10.3	977.7	12.7
Subtotal Spratelloides	**540.4**	**55.6**	**547.9**	**57.3**	**443.5**	**46.0**	**365.4**	**36.6**	**330.0**	**35.1**	**408.1**	**41.1**	**524.0**	**55.7**	**331.2**	**35.8**	**3490.4**	**45.4**
Muguraan	17.1	1.8	21.8	2.3	32.3	3.3	89.5	9.0	139.9	14.9	181.6	18.3	44.5	4.7	98.1	10.6	624.7	8.1
Mahamana	8.6	0.9	12.0	1.3	77.5	8.0	38.1	3.8	168.8	18.0	186.1	18.7	8.5	0.9	147.0	15.9	646.5	8.4
Kudhien	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal Caesionidae	**25.7**	**2.6**	**33.8**	**3.5**	**109.8**	**11.4**	**127.6**	**12.8**	**308.7**	**32.8**	**367.6**	**37.0**	**53.0**	**5.6**	**245.0**	**26.5**	**1271.2**	**16.5**
Boadhi	19.4	2.0	65.8	6.9	17.4	1.8	139.5	14.0	48.6	5.2	34.5	3.5	174.8	18.6	295.1	31.9	795.1	10.3
Fathaa	1.3	0.1	4.6	0.5	13.3	1.4	1.3	0.1	3.7	0.4	0.6	0.1	0.0	0.0	21.0	2.3	45.7	0.6
Subtotal Apogonidae	**20.7**	**2.1**	**70.4**	**7.4**	**30.6**	**3.2**	**140.8**	**14.1**	**52.3**	**5.6**	**35.1**	**3.5**	**174.8**	**18.6**	**316.1**	**34.2**	**840.7**	**10.9**
Bureki	0.0	0.0	0.0	0.0	5.0	0.5	0.0	0.0	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.1
Nilamehi	6.3	0.6	1.7	0.2	0.5	0.1	0.7	0.1	0.3	0.0	4.2	0.4	0.0	0.0	0.0	0.0	13.6	0.2
Subtotal Pomacentridae	**6.3**	**0.6**	**1.7**	**0.2**	**5.5**	**0.6**	**0.7**	**0.1**	**1.0**	**0.1**	**4.2**	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**19.3**	**0.3**
Thaavalha	53.0	5.5	105.3	11.0	12.1	1.3	74.5	7.5	25.7	2.7	30.2	3.0	2.5	0.3	11.8	1.3	315.0	4.1
Hithiboa	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	3.0	0.3	0.0	0.0	0.0	0.0	4.6	0.1
Bobuboa	0.2	0.0	1.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0
Subtotal Atherinidae	**54.2**	**5.6**	**106.3**	**11.1**	**12.1**	**1.3**	**74.5**	**7.5**	**26.4**	**2.8**	**33.2**	**3.3**	**2.5**	**0.3**	**11.8**	**1.3**	**321.0**	**4.2**
Miyaren	305.6	31.5	188.9	19.8	358.3	37.2	289.8	29.0	206.4	21.9	132.2	13.3	186.1	19.8	17.5	1.9	1684.8	21.9
Mushimas	17.1	1.8	6.5	0.7	4.7	0.5	0.2	0.0	11.7	1.2	12.6	1.3	0.5	0.1	3.0	0.3	56.3	0.7
Hikaa	1.5	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0
Vaalagali	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.1
Subtotal Other	**324.2**	**33.4**	**195.4**	**20.5**	**363.0**	**37.6**	**290.3**	**29.0**	**222.1**	**23.6**	**144.8**	**14.6**	**186.6**	**19.8**	**20.5**	**2.2**	**1746.8**	**22.7**
TOTAL	**971**	**100**	**955**	**100**	**964**	**100**	**999**	**100**	**941**	**100**	**993**	**100**	**941**	**100**	**924**	**100**	**7689**	**100**

TABLE 2. ANNUAL BAIT UTILIZATION FOR K.MALE' 1986 -1994

(Corrected sample numbers and percentages of days used by masdhonis)

VARIETIES	1986		1987		1988		1989		1990		1991		1992		1993		1994		TOTAL	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Rehi	2447.0	33.4	1471.0	18.8	4226.6	51.1	3969.5	49.2	3640.3	49.2	3173.6	44.2	2790.0	39.1	3581.1	44.8	3804.5	52.2	29103.6	42.5
Hondeli	86.0	1.2	68.0	0.9	14.0	0.2	2.0	0.0	1.0	0.0	6.5	0.1	6.0	0.1	12.0	0.2	9.5	0.1	205.0	0.3
Subtotal Spratelloides	**2533.0**	**34.6**	**1539.0**	**19.7**	**4240.6**	**51.3**	**3971.5**	**49.2**	**3641.3**	**49.2**	**3180.1**	**44.3**	**2796.0**	**39.2**	**3593.1**	**45.0**	**3814.0**	**52.3**	**29308.6**	**42.8**
Muguraan	3494.5	47.8	5131.5	65.6	3487.6	42.2	3765.5	46.7	3424.0	46.3	3598.6	50.2	3776.5	53.0	1761.7	22.0	876.5	12.0	29316.4	42.8
Kudhien	0.0	0.0	25.0	0.3	13.0	0.2	30.0	0.4	14.0	0.2	14.0	0.2	0.0	0.0	2.0	0.0	3.0	0.0	101.0	0.1
Subtotal Caesionidae	**3494.5**	**47.8**	**5156.5**	**65.9**	**3500.6**	**42.4**	**3795.5**	**47.0**	**3438.0**	**46.5**	**3612.6**	**50.4**	**3776.5**	**53.0**	**1763.7**	**22.1**	**879.5**	**12.1**	**29417.4**	**43.0**
Boadhi	733.5	10.0	845.5	10.8	473.9	5.7	271.5	3.4	300.2	4.1	333.3	4.6	554.5	7.8	2531.2	31.7	2597.5	35.6	8641.1	12.6
Fathaa	90.0	1.2	15.0	0.2	4.0	0.0	0.0	0.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	112.0	0.2
Subtotal Apogonidae	**823.5**	**11.3**	**860.5**	**11.0**	**477.9**	**5.8**	**271.5**	**3.4**	**301.2**	**4.1**	**335.3**	**4.7**	**554.5**	**7.8**	**2531.2**	**31.7**	**2597.5**	**35.6**	**8753.1**	**12.8**
Bureki	393.0	5.4	120.0	1.5	2.5	0.0	3.0	0.0	7.5	0.1	0.0	0.0	0.0	0.0	16.5	0.2	0.0	0.0	542.5	0.8
Nilamehi	23.0	0.3	63.0	0.8	15.4	0.2	2.0	0.0	1.0	0.0	40.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0	145.3	0.2
Subtotal Pomacentridae	**416.0**	**5.7**	**183.0**	**2.3**	**17.9**	**0.2**	**5.0**	**0.1**	**8.5**	**0.1**	**40.9**	**0.6**	**0.0**	**0.0**	**16.5**	**0.2**	**0.0**	**0.0**	**687.8**	**1.0**
Thaavalha	9.0	0.1	24.0	0.3	6.0	0.1	2.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	43.0	0.1
Keravalha	3.0	0.0	5.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0
Hithiboa	8.0	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	0.0
Subtotal Atherinidae	**20.0**	**0.3**	**30.0**	**0.4**	**6.0**	**0.1**	**2.0**	**0.0**	**1.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.0**	**0.0**	**60.0**	**0.1**
Miyaren	9.0	0.1	2.0	0.0	17.0	0.2	23.5	0.3	6.0	0.1	4.0	0.1	0.0	0.0	88.5	1.1	0.0	0.0	150.0	0.2
Mushimas	13.0	0.2	46.0	0.6	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63.0	0.1
Rimmas	6.0	0.1	7.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	0.0
Hikaa	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Subtotal Other	**29.0**	**0.4**	**55.0**	**0.7**	**21.0**	**0.3**	**23.5**	**0.3**	**6.0**	**0.1**	**4.0**	**0.1**	**0.0**	**0.0**	**88.5**	**1.1**	**0.0**	**0.0**	**227.0**	**0.3**
TOTAL	**7316**	**100**	**7824**	**100**	**8264**	**100**	**8069**	**100**	**7396**	**100**	**7173**	**100**	**7127**	**100**	**7993**	**100**	**7292**	**100**	**68454**	**100**

Fig. 1 Annual average livebait composition, K.Male'

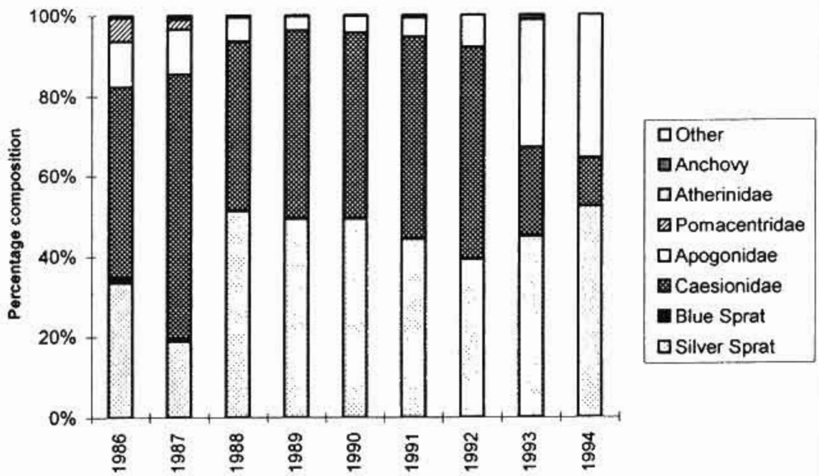


Fig. 2 Annual average livebait composition, G.Dh.Thinadhoo

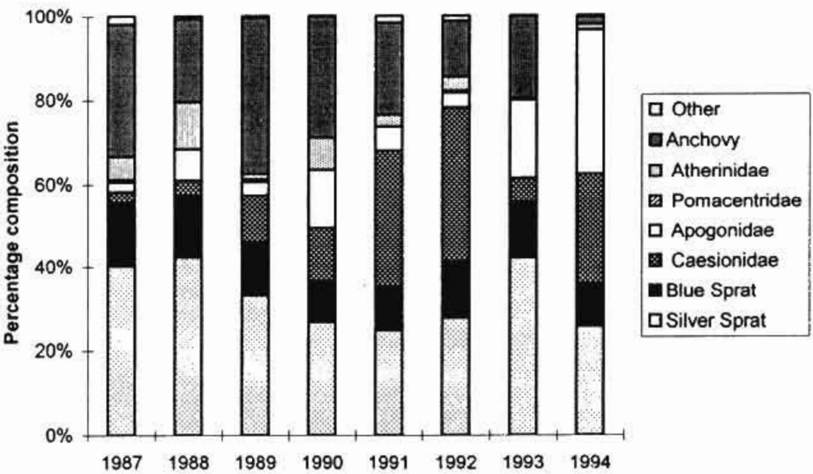


Table 4. Livebait pole and line fishing effort, 1984-1994.

Source: MOFA/EPCS

Year	Number of days fishing by mechanized *masdhonis*		
	Malé	G.Dh.Atoll	Maldives
1984	10,951	7,218	153,460
1985	11,976	10,354	162,430
1986	11,350	10,757	161,910
1987	10,752	11,829	158,785
1988	10,812	12,119	184,353
1989	9,046	11,746	183,944
1990	9,125	11,179	193,045
1991	10,874	11,093	198,320
1992	10,208	8,429	204,808
1993	11,658	9,864	222,548
1994	9,147	8,663	223,095

It must be stressed that data on livebait utilization may provide a rather poor index of livebait abundance, for a number of reasons. First, only the one or two bait species caught in the greatest quantity each day are recorded; as a result minor bait species tend to be underreported. Secondly, if there is a choice, fishermen will have a preference for which bait they want to catch; as a result the abundance of less-favoured livebait species will tend to be underestimated. Thirdly, livebait utilization is recorded in units of days used not weight used, and there is no record of time spent baiting; as a result the extent of variations in bait utilization will tend to be underestimated. Fourth, hardy varieties such as Fusiliers and Cardinalfishes can be kept for use on more than one day; as a result records of utilization for these varieties will tend to overestimate catch. Despite these problems, and until better information becomes available, data on livebait utilization remain the best source of insights into the year to year fluctuations in livebait abundance.

It should also be noted that even the use of actual catch data would be subject to difficulties of interpretation. There is a finite demand for livebait determined by the level of tuna fishing activity. As a result, livebait utilization may reflect tuna fishing effort as much as livebait abundance. Because of this percentages are used to follow trends in livebait utilization (i.e. in Figures 1 and 2), even though this too is not without problems. For example, if the percentage of one livebait variety increases, the percentage of the others must decrease, even if in absolute numbers their utilization has increased. These difficulties should be bourne in mind when attempting to interpret trends in livebait utilization.

The Blue Sprat (*hondeli*) is a minor livebait species in the north and centre of the Maldives, but is of major significance in the south (Anderson and Saleem, 1994), where it makes up some 12% of the livebait catch (Anderson, 1994). At G.Dh. Thinadhoo, annual Blue Sprat utilization in recent years has varied in percentage terms between 10% and 15.5% (Fig. 2). As with Silver Sprat, there is only a suggestion of a decline in Blue Sprat percentage utilization, while in terms of numbers of days used there had been a marked decline, from an estimated average of about 1830 *masdhoni* trips in Gaafu Dhaalu Atoll during 1987-88 to a low of 890 trips in 1994 (Fig. 4).

Fusiliers

After Sprats, Fusiliers (*muguraan*) are the most important component of the Maldivian livebait fishery, making up an estimated 37% of the total catch (Anderson, 1994). At Malé, annual Fusilier utilization during 1986-94 varied between about 12% and 66% of all *masdhoni* trips, averaging 43% (Fig. 1). Fusilier utilization at Malé has declined from a high of about 6250 *masdhoni* trips per year in 1986-87, to a low of about 1850 *masdhoni* trips per year in 1993-94 (Fig. 5).

At G.Dh. Thinadhoo, annual Fusilier utilization during 1987-94 varied in percentage terms between about 3% and 33% (mean 17%), with an increase from 1987-91 and a dip in 1993 (Fig. 2). The number of days on which Fusiliers were used in Gaafu Dhaalu Atoll increased from an estimated 300 in 1987 to about 3650 in 1991 (Fig. 5). Fusilier utilization declined to only 550 days in 1993, but increased again in 1994 (Fig. 5).

Over the sampling period Fusilier utilization has tended to decrease at Malé and increase at G.Dh. Thinadhoo, but at both locations 1991 and 1992 were years of greater than average Fusilier utilization.

Cardinalfishes

Cardinalfishes (*boadhi*) are the third most important component of the Maldivian livebait fishery, making up an estimated average of about 10% of the total catch (Anderson, 1994). At both Malé and G.Dh. Thinadhoo, 1993

RESULTS

Sprats

The Silver Sprat (*rehi*) is the single most important species in the Maldivian livebait fishery (Anderson and Hafiz, 1988; Anderson, 1994). At Malé, annual Silver Sprat utilization during 1986-94 varied between about 19% and 52% of all *masdhoni* trips, averaging 42% (see Figs. 1 and 3). Silver Sprat utilization was relatively low in 1986-87 (average about 2900 *masdhoni* trips per year) compared to 1988-94 (average about 4750 *masdhoni* trips per year).

At G.Dh. Thinadhoo, annual Silver Sprat utilization during 1987-94 varied in percentage terms between 25% and 42% of *masdhoni* trips (mean 33%). There was no clear trend in percentage utilization, although there is a suggestion of a decline (Fig. 2). However, there was a clear decline in the number of days Silver Sprats were used in Gaafu Dhaalu Atoll over the sampling period (Fig. 3). During 1987-88 Silver Sprat utilization in Gaafu Dhaalu Atoll amounted to an estimated average of about 4950 *masdhoni* trips per year, compared to 2900 in 1992-94.

Fig. 3 Silver Sprat utilization

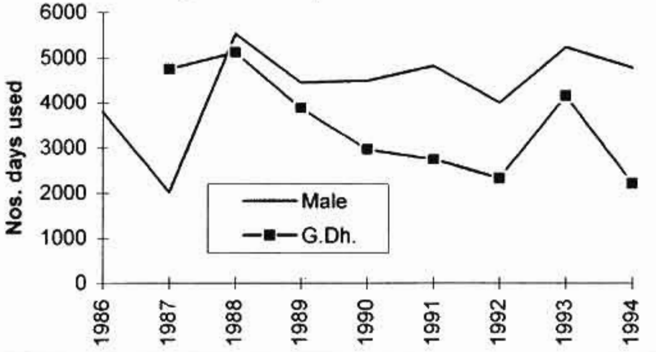


Fig. 4 Blue Sprat utilization

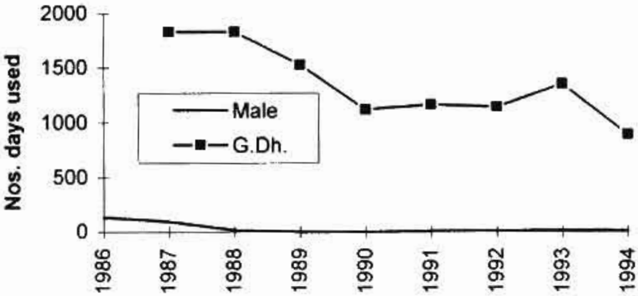


Fig. 5 Fusilier utilization

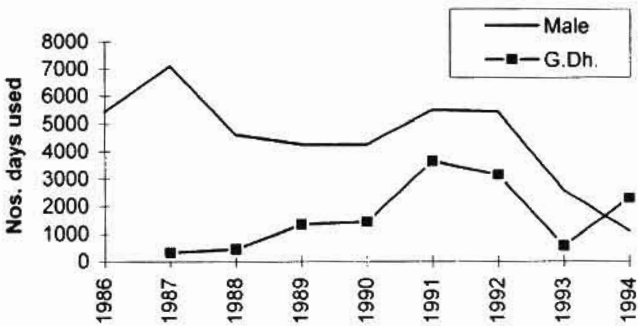


Fig. 6 Cardinalfish utilization

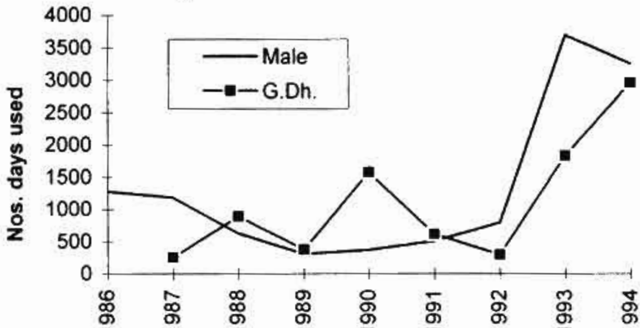


Fig. 7 Anchovy utilization

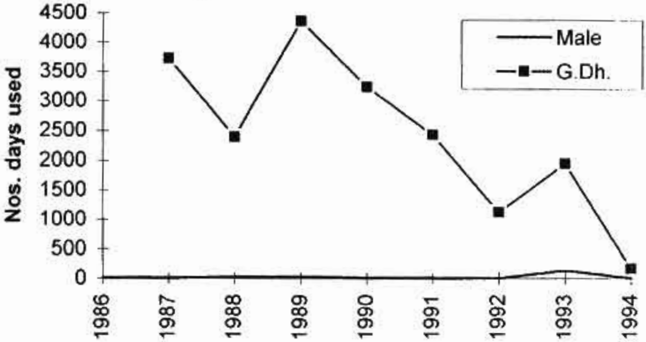


Fig. 8 Damselfish utilization

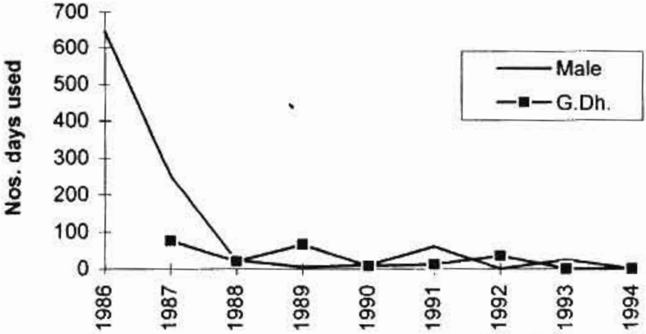
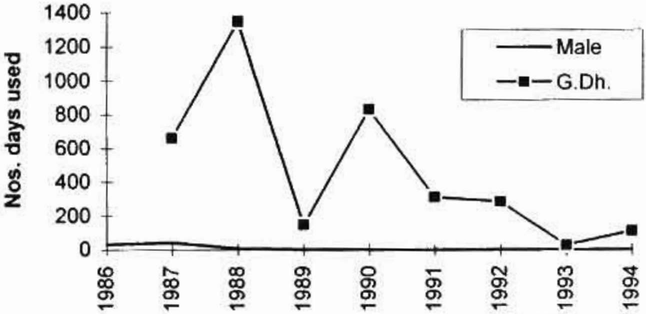


Fig. 9 Silverside utilization



varied considerably from year to year (Fig. 9), between 0.3% and 11% of the total livebait utilization. Estimated Silverside utilization for Gaafu Dhaalu Atoll peaked at nearly 1400 *masdhoni* trips in 1988 and has declined erratically since then.

DISCUSSION

Overall Trends

For the Maldives as a whole there has been a major increase in livebait catches in recent years. The total annual catches of livebait have been roughly estimated for three different time periods by Anderson and Hafiz (1988) and Anderson (1994) as follows:

1978-1981	3000 - 3500 t
1985-1987	5800 ± 1300 t
1993	11100 ± 2800 t

This increase can largely be explained by the steady increase in fishing effort over the last 15 years (Anderson et al., 1995). The period 1978-81 marked the low point of pole and line fishing effort, and therefore of livebait utilization, during the transition from an entirely sailing fleet to an essentially mechanized one. There also appears to have been an increase in the quantity of livebait used per day. This is due to an increase in average size and associated fishing power of pole and line vessels in recent years.

Whatever the overall trend in total livebait utilization in recent years, the results presented above show that utilization and presumably also abundance of some components of the livebait catch have been increasing over the sampling period while others have been decreasing. Utilization of one bait variety often doubles or halves from one year to the next, and may change by an order of magnitude over two years. Explaining these inter-annual variations in livebait utilization is not easy, although there are many possible factors that could cause them, including:

- Changes in fishing effort, causing direct changes in catch, and possibly, at high levels of effort, overfishing.
- Changes in baitfishing methods and in the behaviour of fishermen.

and 1994 were record years for Cardinalfish utilization (Figs. 1, 2 and 6). At Malé, Cardinalfishes were used on an average of 3475 days fishing (34% of trips) in 1993-94, compared to an average of 720 days (7% of trips) in previous years. In Gaafu Dhaalu Atoll, Cardinalfishes were used on an estimated average of 2400 days fishing (26% of trips) in 1993-94, compared to an average of 670 days (6% of trips) in previous years.

Anchovies

Anchovies are a very minor component of the livebait catch in northern and central Maldives, but a significant component in the south (Anderson and Saleem, 1994), where they make up an average of about 20% of the total livebait catch (Anderson, 1994). At G.Dh. Thinadhoo, annual Anchovy utilization in recent years has varied greatly, between 2% and 37% (Fig.2). In Gaafu Dhaalu Atoll estimated Anchovy utilization actually peaked in 1989, at 37% of *masdhoni* trips, and appears to have declined over the sampling period, from an annual average of about 3500 *masdhoni* trips (29% of trips) in 1987-89 to about 1080 trips (12%) in 1992-94 (Fig 7).

Damselfishes

Damselfishes (*nilamehi* and *bureki*) are a minor component of Maldivian livebait catches, accounting for only about 1% of the total catch (Anderson, 1994). At both Malé and G.Dh. Thinadhoo, Damselfish utilization, although always very low, appears to have declined over the sampling period (Fig. 8). At Malé, during 1986-88 Damselfish accounted for some 2.6% of livebait utilization, compared to only 0.1% during 1992-94. At G.Dh. Thinadhoo, during 1987-89 Damselfish accounted for some 0.5% of livebait utilization, compared to 0.1% during 1992-94.

Silversides

Silversides (*thaavalha*) are a minor component of Maldivian livebait catches, accounting for just over 1% of the total on average (Anderson, 1994). At Malé, Silverside utilization was particularly low, averaging only 0.1% of total *masdhoni* trips during 1986-94. At G.Dh. Thinadhoo, Silverside utilization has degradation, below). Most fishermen interviewed in 1995 said that Cardinalfish were particularly abundant in 1993-94 and that high catches reflected this. The extent to which these developments influenced recent catches of Cardinalfish requires further investigation. It should be noted that Anderson (1994) used livebait utilization data averaged over a number of years to estimate 1993 livebait catches. This has almost certainly resulted in an underestimation of Cardinalfish catch for 1993, and consequently an overestimation for other varieties.

A few bait species, notably *Chromis viridis* (Adam, 1995) but also some other Damselfishes and Cardinalfishes, are taken by aquarium fish collectors for export. Some Silver Sprats and Fusiliers are used for human consumption in the Maldives. Both aquarium fish exports and baitfish consumption have increased in recent years. However, the quantities involved in these activities are still small and are not believed to have a significant impact on the baitfishery.

Many Maldivian tuna fishermen believe that reef fishing, and in particular shark netting and grouper catching, are detrimental to the livebait fishery. The fishermen say that the presence of predatory fishes causes livebait to aggregate in tight schools and inhibits them from moving widely over the reefs. This makes the catching of livebait easy. The increase in reef fishing activity in recent years, and in particular the rapid development of the grouper fishery (MRS, 1994; Shakeel, 1994) might therefore have had a deleterious effect on the catches of some livebait species. It is, however, difficult to quantify these possible changes, and impossible to gauge their effects on livebait utilization.

Changes in climatic and oceanographic conditions

It has become increasingly clear in recent years that marine ecosystems in general, and small pelagic fisheries in particular, are greatly influenced by changes in environmental conditions (e.g. Anderson, 1993; Cushing, 1982; Dalzell, 1984 and 1993; Lluch-Belda et al., 1989). For example, the production of tropical clupeoids (Sprats, Sardines and Anchovies) is believed to be strongly influenced by wind and rainfall (Dalzell, 1993). Rainfall may influence livebait catches in a number of ways. For example, increased rainfall may lead to increased coastal productivity via run-off, particularly from high islands or continental land masses. However, at the highest levels of precipitation livebait catch rates may decline (Dalzell, 1993).

- Changes in meteorological and/or oceanographic conditions causing changes in the apparent abundance of livebait.
- Changes in other environmental conditions, notably reef health.
- Changes in the abundance of other livebait species.

Changes in fishing activity

Although national pole and line fishing effort has been increasing in recent years, at Malé fishing effort was roughly stable over the sampling period, while in Gaafu Dhaalu Atoll it declined over the sampling period (Table 4). In Gaafu Dhaalu Atoll, fishing effort declined by approximately 25% from an average of about 12,000 mechanized pole and line vessel days in 1987-88 to about 9,000 days in 1992-94. During this same period, the number of *masdhoni* trips during which Silver Sprats were used declined by about 40%, while Blue Sprat utilization declined by about 50% and Anchovy utilization declined by about 70%. Thus most of the observed decrease in Silver Sprat utilization can be explained by the drop in fishing effort, while for Blue Sprats and particularly for Anchovies additional explanations must be found for their decline.

The livebait fishery is a traditional one dating back hundreds of years. The last two decades have seen a number of improvements in livebait fishing and holding methods (Anderson and Hafiz, 1988). They include the introduction of diving masks and the replacement of small cotton nets with large nylon ones, both of which have undoubtedly influenced livebait catchability and hence utilization. However, these and other improvements were well established by the mid-1980's, i.e. before the data on which this study is based were collected.

One very recent change which may now be beginning to have an effect on livebait catches is the use of SCUBA diving gear by baitfishermen. This practice started within the last couple of years, and is now practised fairly regularly near Malé, but it is apparently still very rare in other atolls. SCUBA diving makes bait caching easier. It is believed that this is particularly the case for Cardinalfishes. It is possible therefore that the introduction of SCUBA diving contributed to the recent jump in Cardinalfish catches at Malé (Fig. 6). However, relatively few *masdhonis* used SCUBA diving gear at Malé during 1993-94 and very few or none at G.Dh. Thinadhoo, so this cannot be the whole explanation for the increase in Cardinalfish catches. One fisherman interviewed in 1995 said that they had only recently adopted the slightly specialized techniques needed to catch Cardinalfishes for livebait (see section on reef

Anderson and Saleem (1994) noted that the occurrence of Anchovies in Meemu Atoll is highly irregular, and may be related in some way to the occurrence of El Niño Southern Oscillation (ENSO) events. ENSO events are already known to affect Maldivian tuna abundance (Anderson, 1993; Anderson et al., 1995). Fishermen on several islands in Meemu Atoll interviewed in 1983-84 (i.e. during or after the 1982-83 ENSO) all said that Anchovies were a major bait. In contrast, fishermen from Meemu interviewed in 1992 (i.e. before the full development of the 1992-94 ENSO events) all said that Anchovies were rarely used. Then during early 1993 Anchovy utilization was recorded from three islands in Meemu Atoll. It therefore seems possible that the occurrence of Anchovies in Meemu Atoll is influenced by oceanographic variations associated with ENSO events. However, variations in apparent abundance of Anchovies (or indeed any other livebait varieties) at Malé and at G.Dh.Thinadhoo show no sign of being associated with ENSO events (which occurred in 1987 and 1992-94). It is possible that the record catches of Cardinalfishes in 1993-94 were influenced by the 1992-94 ENSO event, but this will require a longer time series to confirm.

Anchovies are highly seasonal in occurrence and are used mainly during the intermonsoon periods (Anderson and Saleem, 1994). However, during 1988-89 at G.Dh.Thinadhoo Anchovy utilization remained high from the October-November intermonsoon of 1988 right through to July 1989. This anomaly was the reason for the peak in Anchovy utilization during 1989 (Fig. 7). The cause(s) of this anomaly are unknown, but Anderson and Saleem (1994) suggested that it might be related to some unknown oceanographic perturbation.

Maldivian tuna catches appear to be influenced by medium-term fluctuations in oceanographic conditions (Anderson, 1993). Catch rates of skipjack tuna (*Katsuwonus pelamis*) increased between 1982-83 and 1988 and decreased since then. In contrast, catch rates of yellowfin tuna (*Thunnus albacares*), frigate tuna (*Auxis thazard*) and kawakawa (*Euthynnus affinis*) decreased from the early to the late 1980's, and then increased. The trends of annual livebait utilization (Figs. 3 to 9) appear in many cases to fit this same pattern, with the years 1986-7/8 being ones of either high or low utilization for most varieties. Furthermore, many fishermen interviewed during 1983-87 stated that bait fishing had been better before the mechanization of the *masdhoni* fleet (i.e. before the late 1970's). Some noted specific shifts in species abundance at around that time. These changes were not thought to be a result of

Annual average rainfall records for Malé and S.Gan (the nearest long-term station to G.Dh.Thinadhoo) are presented in Table 5. Graphs showing the relationships between rainfall and utilization of Silver Sprat, Blue Sprat and Anchovy are presented in Figs. 10 to 12. There appears to be a negative correlation between rainfall and Silver Sprat utilization, within the rainfall range sampled. Relationships for Blue Sprats and Anchovies are less clear cut, and could be interpreted to suggest either no relationship between catches and rainfall, or increasing catches with increasing rainfall. The latter interpretation is consistent with results from elsewhere. Dalzell (1984) noted that the production of some species of Anchovies in Papua New Guinea was related to rainfall, with catch rates for *Encrasicholina heteroloba* increasing up to a maximum at about 3000mm rain per year. Ianelli (1988) noted a positive correlation between catch rates of the Blue Sprat and rainfall in Kiribati. It should be noted, however, that these results from Maldives are of a preliminary nature only. All three species are highly seasonal (Anderson and Saleem, 1994); more detailed studies of the relationships between seasonal rainfall and catch rates are needed. Furthermore, rainfall data from much nearer G.Dh.Thinadhoo are now becoming available since the opening of the regional airport at G.Dh.Kaadedhoo. Other environmental factors such as wind stress should also be taken into account in future analyses.

Table 5. Annual average rainfall at Malé and S. Gan, 1984-1994

Source: Department of Meteorology

Year	Annual Rainfall (mm)	
	Malé	S.Gan
1984	1973	2287
1985	1903	2307
1986	1796	2195
1987	2223	2374
1988	1771	2252
1989	1868	2492
1990	1618	2432
1991	1814	2871
1992	1654	2415
1993	2397	2133
1994	2141	2837

mechanization, just coincident with it. Polovina et al. (1994) have demonstrated that a climate event in the North Pacific which began in the mid-1970's, peaked in the early 1980's, and ended around 1988, had profound effects on the productivity of a range of species in that region. It is possible that a related event in the Indian Ocean at the same time could have affected fisheries production in the Maldives. This requires further investigation.

Over still longer time-scales, there may have been changes in Anchovy abundance associated with long-term fluctuations in oceanographic conditions. Anchovies are currently rare in most of northern and central Maldives (Anderson and Saleem, 1994), but this might not always have been the case. Experienced chummers interviewed on B.Thuladhoo in 1983 said that Anchovies used to be a common bait "about 40 years ago", while on R.Alifushi fishermen interviewed in 1987 noted that Anchovies were commonly used by "earlier generations". Lluch-Belda et al. (1989) reviewed worldwide fluctuations in Anchovy and Sardine stocks. They concluded that "at time-scales of several decades, fluctuations in catches of sardines and anchovies are seemingly dominated by long-term environmental variations which cause large and prolonged changes in abundance and give rise to 'regimes' of sardine or anchovy". It is possible that there has been a shift from an Anchovy 'regime' in the northern Maldives within living memory, as a result of a long-term change in oceanographic conditions.

Changes in reef health

Changes in oceanographic environmental conditions can clearly have a profound influence on livebait abundance. For most, if not all, Maldivian livebait species the coral reefs are also an important part of their environment. It is therefore to be expected that changes in coral reef health might play a role in determining livebait abundance. Climatic and oceanographic conditions undoubtedly influence reef health, but perhaps of more immediate concern to the Maldives are man-made or anthropogenic changes.

Coral mining is widespread in the Maldives, and perhaps the major anthropogenic cause of reef degradation. However, most tuna fishermen do not believe that coral mining affects livebait abundance because most coral mining takes place on reef flats, while most baitfishing takes place on reef slopes. This belief is bourne out by the findings of a detailed study of the effects of coral

Fig. 10 Relationship between Silver Sprat utilization and rainfall, 1986/7-1994

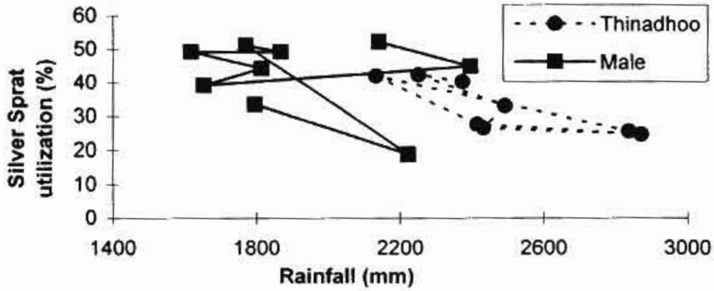


Fig. 11 Relationship between Blue Sprat utilization and rainfall, 1986/7-1994

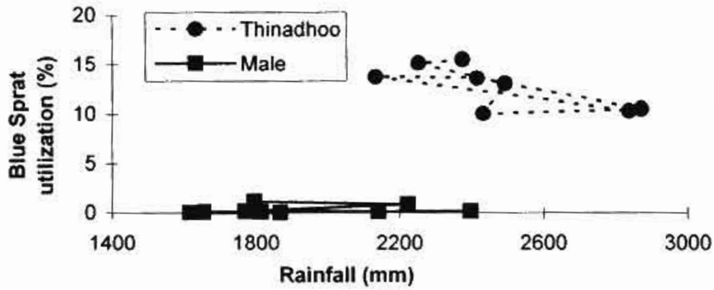
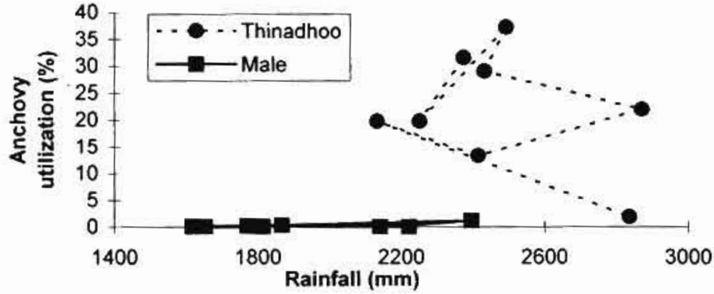


Fig. 12 Relationship between Anchovy utilization and rainfall, 1986/7-1994



abundance, 1993-94 appear to have been bumper years for Cardinalfishes (Fig. 6).

Changes in abundance of other livebait varieties

As mentioned above (see Methods) there is a finite demand for livebait, determined by the level of tuna fishing activity. Therefore, if one livebait variety is particularly abundant and widely used by fishermen, other varieties will be used less even if they are no less abundant then normal. A case in point is the spectacular rise in utilization of Cardinalfishes in 1993-94 (Fig. 6), which must have contributed to the particularly low levels of utilization of Fusiliers, Anchovies and Silversides in those years.

The interpretation of patterns of Silverside utilization can be particularly problematic. Silversides can on occasion be very abundant, but they are not used very often by fishermen as tuna livebait because of their poor chumming ability (Anderson and Saleem, 1994). As a result, data on Silverside utilization are a particularly poor index of Silverside abundance. Silverside utilization may rather provide an index of the scarcity of other more highly favoured livebait varieties. If this is the case, the high level of Silverside utilization in 1988, when fishing effort was highest (Table. 4), might suggest that there was some shortage of preferred livebait species then. The (erratic) decline in Silverside utilization at G.Dh. Thinadhoo (Fig. 9) since 1988 may be an indication that there is no longer a shortage of other, preferred livebait varieties.

Conclusions and Recommendations

This study demonstrates that there are major inter-annual variations in the species composition of the livebait used in the Maldivian pole and line tuna fishery. It also shows that in most cases these variations cannot be explained. Reef degradation as a result of coral mining may have played a role in the apparent decline in Damselfish utilization as a livebait, while changes in baitfishing methodology may have contributed to the increased utilization of Cardinalfishes in 1993-94. However, it seems likely that climatic and oceanographic variations play the key role in determining livebait abundance. Much further work will be required to confirm this and to elucidate the mining on Maldivian fish communities, which showed that reef slope fishes were not affected by coral mining (Dawson Shepherd et al., 1992). However, reef flat fishes are affected by coral mining, and two livebait species, the Blue Chromis (*nilamehi*) and Fusilier Damselfish (*bureki*), are associated with reef flat corals. As noted above, Damselfish utilization at both Malé and G.Dh. Thinadhoo, although always low, appears to have decreased (Fig. 8). Furthermore, Anderson and Hafiz (1988) suggested that some 140t Damselfishes were used annually as livebait in the Maldives during 1985-87, which was something of the order of 3% of all bait used. Anderson (1994) suggested that some 120t of Damselfishes were used in 1993, which was only about 1% of all livebait used. It is therefore possible that there has been a real decline in the utilization of these species, and further that this decline may be associated with habitat destruction caused by coral mining. However, there are considerable sources of error associated with these estimates, so this interpretation may not be correct.

Baitfishing itself can cause damage to the coral reefs. The collection of some species, notably Cardinalfishes and Damselfishes that are closely associated with the corals, can be particularly destructive. In such cases the net may be spread over the corals with which the livebait are associated. Any livebait remaining under the net may be chased out using poles, or a 'scarer' (such as a palm frond or a steel chain) on the end of a rope. This can result in much coral damage, and in particular branching corals in which livebait shelter may be smashed. In the case of essentially pelagic varieties such as Fusiliers, Sprats and Anchovies the net is generally kept off the bottom, and the livebait are lured into the required position with fish paste, so reef damage is minimal. However, even in these cases there can be anchor damage.

Many tuna fishermen say that the collecting of black coral trees (Dhivehi: *endheri*) reduces the abundance of some varieties of Cardinalfishes which swarm by day among their branches. In earlier times black coral was presumably abundant on Maldivian reefs. However, over the last two decades large quantities were removed, to make jewellery and other souvenirs for tourists. From 1995 a ten year moratorium on the collecting and export of black coral from the Maldives was introduced by the Ministry of Fisheries and Agriculture.

Although reef degradation as a result of baitfishing and black coral collecting might have been expected to have had a particularly bad effect on Cardinalfish

Anderson R.C. and A.Hafiz (1988) The Maldivian livebait fishery. Indo-Pacific Tuna Programme, Colombo. IPTP Coll. Vol. Work. Docs. **3**: 18-26.

Anderson R.C. and M.R.Saleem (1994) Seasonal and regional variation in livebait utilization in the Maldives. Rasain **14**: 162-182.

Anderson R.C., A.Hafiz and M.S.Adam (1995) A review of the Maldivian tuna fishery. Indo-Pacific Tuna Programme, Colombo. IPTP Coll. Vol. Work. Docs. **9**:

Cushing D.H. (1982) Climate and Fisheries. Academic Press. 373pp.

Dalzell P. (1984) The influence of rainfall on catches of Stolephorid anchovies in Papua New Guinea waters. Department of Primary Industry, Fisheries Research and Surveys Branch, Research Report 84 - 04: 18pp.

Dalzell P.J. (1993) Small pelagic fishes. Pp. 97-133. In: A. Wright and L.Hill (eds.) Nearshore marine resources of the south Pacific. Institute of Pacific Studies, Suva, and Forum Fisheries Agency, Honiara. 710pp.

Dawson Shepherd A.R., R.M.Warwick, K.R.Clarke and B.E.Brown (1992) An analysis of fish community responses to coral mining in the Maldives. Environ. Biol. Fish. **33**(4): 367-380.

Ianelli J. (1988) The status of the Kiribati live bait fishery. Workshop on Pacific inshore fisheries resources. Background paper No. 59. South Pacific Commission, Noumea. 20pp. (Not seen in original; cited by Dalzell, 1993).

Lluch-Belda D., R.J.M.Crawford, T.Kawasaki, A.D.MacCall, RH.Parrish, R.A.Schwartzlose and P.E.Smith (1989) World-wide fluctuations of sardine and anchovy stocks: the regime problem. S. Afr. J. mar. Sci. **8**: 195-205.

MOFA (1995) Basic Fishery Statistics 1994. Economic Planning and Coordination Section, Ministry of Fisheries and Agriculture, Malé. 19pp.

MRS (1994) Executive review of the status of Maldivian fishery resources. Unpublished report. Marine Research Section, Ministry of Fisheries and Agriculture, Malé. 25pp.

underlying causative mechanisms relating variations in environmental conditions with those in livebait availability.

The livebait fishery supports the all-important pole and line fishery, and as such is undoubtedly the most important reef fishery in the Maldives. Catches have increased to record levels in recent years. There may therefore soon be a need for some form of management of the Maldivian livebait resources. Activities that would facilitate future management decisions were recommended in MRS (1994) and include:

- Carrying out a full review of the baitfishery.
- Developing a baitfish statistics collection system.
- Improving estimates of livebait catch weights.
- Carrying out further biological studies on major livebait species.
- Carrying out further studies on the effects of environmental variations on livebait availability.
- Carrying out a stock assessment of livebait resources.
- Conducting experimental night baitfishing trials.

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REFERENCES

Adam M.S. (1995) Review of the aquarium fish trade of the Maldives, with proposals for monitoring and regulation. Unpublished report. Marine Research Section, Ministry of Fisheries and Agriculture, Malé. 29pp.

Anderson R.C. (1993) Oceanographic variations and Maldivian tuna catches. Rasain **13**: 215-224.

Anderson R.C. (1994) The size of the Maldivian tuna livebait fishery. Rasain **14**: 203-208.

Polovina J.J., G.T.Mitchum, N.E.Graham, M.P.Craig, E.E.DeMartini and E.N.Flint (1994) Physical and biological consequences of a climate event in the central North Pacific. Fisheries Oceanography **3**(1): 15-21.

Shakeel H. (1994) Grouper fishery: benefits, threats and challenges. Rasain **14**: 183-196.