STATUS OF TUNA RESEARCH AND DATA COLLECTION IN THE MALDIVES

R. Charles Anderson and Ahmed Hafiz

Marine Research Section
Ministry of Fisheries and Agriculture
Malé
Republic of Maldives

INTRODUCTION

The Maldives has had a major tuna fishery for centuries. The great Arab traveler Ibn Battuta gives a clear account of the importance of tuna in the Maldives at the time of his visits in 1343-44 and 1346 (Gray, 1889). There is also some evidence that tuna fishing was an important activity in Maldives before the conversion to Islam in AH548 (AD 1153-4). It seems quite likely, therefore, that the Maldivian tuna fishery has been carried out in a sustainable manner for at least one thousand years. It is only in relatively recent years, with the development of other tuna fisheries within the Indian Ocean, that Maldives has needed to collect data and carry out research on its tuna resources.

TUNA RESEARCH

Within the Maldives, the Ministry of Fisheries and Agriculture (MOFA) has statutory responsibility for the rational and sustainable management of all living marine resources. The Marine Research Section (MRS) of MOFA is responsible for carrying out the research necessary for the Ministry to fulfill that mandate. MRS was formed in 1984 The tuna-related research activities undertaken by MRS have been reported elsewhere, and will be mentioned only briefly here. They include:

- Two tuna-tagging programmes, during which some 17,000 skipjack and yellowfin have been tagged and released (Yesaki and Waheed, 1992; Waheed and Anderson, 1994; Anderson, Adam and Waheed, 1995). In addition to providing information on growth and migration, these tagging programmes have given insights into the population dynamics of skipjack in Maldivian waters (Bertignac, Kleiber and Waheed, 1994; Bertignac, 1994). Recommendations for further tagging studies have been made by Anderson, Adam and Waheed (1995).
- A limited amount of analysis of catch and effort and biological data, notably for yellowfin tuna (e.g. Anderson, 1988b; Adam, 1993; Adam and Anderson, 1995). It is planned to carry out a detailed analysis of all available data for each of the four major tuna species caught in the Maldives (skipjack, yellowfin, frigate tuna and kawakawa) over the next two years.
- Research on the live-bait resources that support the pole and line fishery, including studies of the basic biology of the species involved (Milton *et al.*, 1990a & b); studies of their ecology (Blaber *et al.*, 1990; Anderson and Saleem, 1994); and estimation of catch (Anderson and Hafiz, 1988; Anderson, 1994). There are plans to carry out further research on baitfish, aimed specifically at promoting integrated reef resources management, over the next few years.

The Operations Section of MOFA has been responsible for the successful completion of a fish aggregating device (FAD) research and development programme. Starting in 1981, a design of FAD suitable for Maldivian conditions has been evolved (Naeem, 1988; Naeem and Latheefa, 1994). The latest model FADs typically last for about two years after deployment. Thirty-two sites around the Maldives have been identified as appropriate locations for FADs, taking into account bottom topography, proximity of fishing islands and local tuna abundance. MOFA aims to maintain FADs at all of these sites, with 28-30 FADs in place at any one time.

Lack of trained manpower, and to a lesser extent limited funding, are the main constraints on the development of tuna research activities in the Maldives.

DATA COLLECTION

The Economic Planning and Coordination Section (EPCS) of MOFA is responsible for the collection, compilation and dissemination of Maldivian fishery statistics. Fishery statistics are collected from every inhabited island, of which there are some 200 scattered over 19 administrative atolls. The Maldives has a well-developed system of regional government, with a government office on every inhabited island. It is one of the duties of island officials to record tuna catches. Data sheets are compiled by month in each atoll and returned to Malé. EPCS compiles these records, and also collects catch and effort data directly for Malé market. EPCS produces an annual report of "Basic Fisheries Statistics" (*e.g.* MOFA, 1995), as well as periodic multi-annual summaries. These reports include not only catch and effort statistics, but also export data, collected by Customs and compiled by EPCS. Annual statistics are normally compiled before the middle of the following year, and are reported to interested parties, including the Indo-Pacific Tuna Programme (IPTP), soon afterwards.

Tuna catch statistics

Traditionally the Maldivian fishery has been a tuna fishery, and the Maldivian fisheries statistical system was developed to record catches of tuna. Other varieties of fish have not been favoured, either for local consumption or for export, and have tended to be ignored. Maldivian "reef fish" catch statistics are therefore not too reliable. Tuna catches are recorded by number, in a total enumeration system. Since it is the custom to count the catch at the end of each day's

fishing, while dividing it among crew and boat owner, this system has proved to be very successful.

The collection of tuna catch statistics started in 1959. The system has been gradually expanded and improved since then. In 1959 only the total tuna catch by pole-and-line vessels was recorded. In 1966 the system was expanded to include trolling vessels and to record the numbers of tunas caught in three categories: large skipjack; small skipjack and yellowfin; kawakawa and frigate tuna. From 1970 the five categories of tunas were recorded separately. Mechanization of the pole-and-line fleet started in 1974-75; from 1979 catches of sailing and mechanized pole-and-line vessels were recorded separately. From 1984 catches of dogtooth tuna were recorded. The majority of yellowfin tuna caught in the Maldives are surface-swimming juveniles taken by pole and line. However, there are also landings of adult yellowfin, taken mainly by handline and troll. From 1992 catches of "large yellowfin" have been recorded separately from "small yellowfin".

Effort data

Since 1959, effort data have been recorded in terms of both number of vessels and numbers of days fished. Because tuna fishing is carried out on day trips, "number of fishing trips" and "number of days fished" are synonymous In line with the catch statistics, the collection of effort statistics was expanded to include trolling vessels in 1966. The numbers of mechanized pole-and-line vessels was recorded from 1974, but numbers of days fished by sailing and mechanized pole-and-line vessels were not recorded separately until 1979. From 1985 the number of pole-and-line vessels actively fishing, in addition to the number registered, has been recorded.

Sources of error

Although there are clear advantages to the well-established total enumeration tuna statistics system, it is not without problems. A detailed review of the system and some of its limitations has recently been provided by Parry and Rasheed (1995). There are three major potential sources of error:

1. Misreporting.
2. The use of inadequate conversion factors.
3. Confusion over the size classification of skipjack tuna.

Misreporting

A large potential source of error is improper reporting. Apart from instances of presumably random error (*e.g.* clerical mistakes), cases of both under-reporting and over-reporting have occurred.

Some over-reporting is believed to have occurred between the mid-1950s and 1981, when prizes were given to top crews or islands in order to encourage fish production. Since 1981 there have been occasional prizes but the awards have tended to be small and are not believed to have influenced catch reporting. In 1984 a registration fee was introduced for transport vessels. In order to qualify for exemption, fishing vessels had to complete 180 days fishing per year. This requirement is believed to have resulted in some over-reporting of fishing effort, and possibly also of catch. In 1990 the exemption requirement was dropped to 120 days fishing per year, and it is believed that this will have minimized over-reporting.

Some under-reporting has probably occurred at all times, for example as a result of fishing skippers or boat owners failing to report catches or trips to their island offices. This may not be as great a problem in Maldives as it might be elsewhere, both because of the nature of Maldivian society and because of the desire of owners to meet the 120 days fishing requirement. Another problem is that less valuable species (notably non-tunas, but also tunas other than skipjack) may be consistently under-reported. It is possible that socioeconomic changes within the Maldives, and the changing pattern of island life, are leading to an increase in under-reporting.

Anderson (1986) suggested that for the period 1970-84 over- and under-reporting may to some extent have tended to cancel out, and that reports of numbers of tunas caught and numbers of days fished may have been accurate to within ±15%. More recently there has been little reason to suspect over-reporting, suggesting that there may have been a net under-reporting of catches. Parry and Rasheed (1995) reviewed the accuracy of 1994 skipjack and yellowfin catch records, matching over 1000 individual pole-and-line trip records in the databases of both MOFA and MIFCO (Maldives Industrial Fisheries Company, see below). They suggested that skipjack catch numbers may be underestimated by about 5% and yellowfin catch numbers by about 15%.

A partial solution to the problem of under-reporting was used by EPCS to correct the 1994 skipjack and yellowfin catch records. Individual fishing vessel records in the MIFCO database (*i.e.* audited records of sales by weight and number) were matched with catch records reported to MOFA. For vessels that reported less to MOFA than they sold to MIFCO, MIFCO weights were used. For other vessels MOFA records and conversion factors were used. This correction procedure is partially responsible for the increase in reported catches of skipjack and yellowfin in 1994.

Conversion factors

A second major potential source of error in Maldivian tuna catch statistics is in the use of conversion factors. Maldivian tuna catch statistics are collected in terms of **numbers** of fish. For most purposes a knowledge of catch **weight** is of more interest, therefore conversion factors are required. The nature and magnitude of the conversion factors used by MOFA have been the source of much controversy over the years (Anderson, 1986; Rochepeau and Hafiz, 1990; Mines, 1992; Wright, 1992; Cook, 1995; Parry and Rasheed, 1995). The most important single problem with the conversion factors used so far is that they have been based on inadequate sampling, both in terms of numbers of fish

measured and in terms of area of coverage. The various conversion factors estimated over the years are listed below:

- The first conversion factor estimates, due to Shiji and Sato (1962), were based on the measurement of only 70 small skipjack at a single location (in Thaa Atoll); the average weights of other species and sizes were guessed. These average weight estimates were used for catch data from 1959-1975.
- Further sampling in 1975 (the details of which have been lost) led to the introduction of revised conversion factors in 1976.
- A third set of conversion factors, again of unknown origin, were used from 1984-87. These included an average weight estimate of 2 kg/pc for dogtooth tuna.
- On the basis of market sampling, Anderson *et al.* (1987) estimated the average weights of tuna species landed at Malé in 1986. Apart from skipjack, yellowfin, frigate tuna and kawakawa, dogtooth tuna average weight was also calculated, at 6.0 kg.
- Further market sampling in 1987 resulted in new average weight estimates for Malé tuna landings (Anderson, 1988a). These average weight estimates have been used as national conversion factors from 1989 to date.
- From 1992 an average weight conversion factor of 20 kg/pc was introduced for large yellowfin, on the basis of information provided to EPCS by MRS.
- Parry and Rasheed (1995) reviewed commercial (MIFCO) purchase records for 1994 to estimate average weights of large skipjack, small skipjack and small yellowfin catches.

The use of fixed species conversion factors from one location for year after year clearly fails to take account of the considerable seasonal, regional and possibly also interannual variations that occur in tuna sizes. The conversion factors currently used by MOFA are the average weights of tunas landed at Malé market in 1987 (as estimated by Anderson, 1988a). In the absence of any national sampling programme these average weight estimates have been used as conversion factors for the entire country.

The use of these conversion factors was recognized as inadequate by Anderson *et al.* (1987; also Anderson, 1988a) and has been criticized by Rochepeau and Hafiz (1990), Wright (1992), Cook (1995) and Parry and Rasheed (1995). While the conversion factors in use at present are undoubtedly inadequate, they are not necessarily biased. For example, in the case of yellowfin tuna, Rochepeau and Hafiz (1990), on the basis of some regional sampling, concluded that the yellowfin conversion factor was underestimated, and that a conversion factor of over 3 kg/pc might be appropriate. In contrast, Parry and Rasheed (1995), on the basis of a detailed analysis of 1994 commercial purchases, concluded that the yellowfin conversion factor in use is too high, and a conversion factor of 2.31 kg/pc was appropriate. The conversion factor problem is well recognized, and MOFA has started a regional tuna length frequency sampling programme to solve it (see below).

Large skipjack (kg/pc)	*Small skipjack (kg/pc)*	*Yellowfin (kg/pc)*	*Kawakawa (kg/pc)*	*Frigate tuna (kg/pc)*	*Source*
7.00	1.96	1.96	1.00	1.00	Shiji & Sato (1962)
6.18	2.12	2.12	0.95	0.95	? (1975)
5.87	2.01	2.12	0.95	0.95	??
5.90	2.20	2.60	1.40	0.60	Anderson *et al.* (1987)
5.70	2.10	2.60	1.10	0.60	Anderson (1988a)
6.70	2.42	2.31	-	-	Parry & Rasheed (1995)

Skipjack Average Weight

The inadequacy of the conversion factors currently used in the Maldives applies to all tuna species, but there is a particular problem with the use of conversion factors for skipjack tuna. This is of special significance since skipjack contributes something of the order of 70% to the total recorded catch. Therefore errors in the conversion factors used for skipjack may have significant effects on the estimates of total catch.

Traditionally, Maldivians have classified skipjack into two size classes: small (*mas*) and large (*godhaa*). A large skipjack is one which when carried by the tail will have its snout touching the ground. The broadly bimodal size distribution of skipjack catches in the Maldives is believed to provide a biological basis for this division (Anderson *et al.*, 1987; Hafiz and Anderson, 1988).

MOFA uses two separate conversion factors for skipjack (5.7 kg and 2.1 kg), based on these two traditional size categories. There is considerable overlap between the two categories, but the dividing line is approximately 55-60 cm fork length, which corresponds to about 4 kg.

In recent years about one-third of the skipjack catch has been purchased for export by the Government (*i.e.* by freezer or collector vessels, or the Felivaru cannery). These purchases have for the most part been according to two different size categories: 1.5-2 kg, and above 2 kg. Many fishermen who sold their fish to one of the Government agencies reported their daily catches according to the details on their sales receipts. As a result the numbers of "large" skipjack being reported has increased. Since MOFA continues to use the traditional skipjack conversion factors for all reported catches this is believed to have led to errors in the estimation of the total weight of skipjack caught.

Rochepeau and Hafiz (1990) noted that there had been an increase in the proportion of large skipjack in the Maldivian catch during the 1980s. They suggested that this was the result of increasing misreporting of "large" and "small" skipjack, resulting in skipjack catch being overestimated. They used the proportion of large skipjack in 1979-82 catches to estimate annual catches for 1984-88. T hey concluded that for those years skipjack catch could have been overestimated by 6-11%. It should be noted, however, that these estimates did not take account of possible under-reporting, nor of the extent to which other factors may have caused a real increase in large skipjack catches.

Mines (1992) stated that the discrepancy between MOFA and commercial conversion factors resulted in tuna catch being overestimated. Using export data and estimates of local consumption, he calculated total fish catches for the years 1984-90. These estimates were up to nearly 30% lower than MOFA catch figures. It should be noted, however, that Maldivian fish consumption estimates are notoriously inaccurate and are not a good basis for calculations of this type.

Parry and Rasheed (1995) reviewed MOFA data for 1994 and identified several atolls in which the proportion of large to small skipjack was very much higher than the national average. They suggested that in these atolls the bulk of reporting may be according to the commercial conversion factors rather than the traditional MOFA ones, and that for these atolls the conversion process should be altered accordingly.

A number of other solutions to this problem have been suggested, but all have their limitations:

1. After the problem first became apparent in 1988, MOFA added a new box to the fish catch recording forms which are completed on every island. The island official filling the form was supposed to indicate in the box whether he was recording the two sizes of skipjack according to the traditional division or according to the modern commercial division. This scheme does not work because the island officials do not tick the box.
2. MIFCO purchases up to about one-third of all skipjack caught in Maldives. Numbers and weight are recorded, so the average weight of a very substantial sample is available, and could be used for the entire catch. The problem with this approach is that MIFCO does not buy the smallest fish, so their sample is biased. The extent of the bias has been reduced since December 1993, when MIFCO started buying skipjack of less than 1.5 kg. However, some bias remains because MIFCO prefers to buy large fish rather than small fish. Therefore, when catch exceeds purchasing/holding capacity, the average weight of the fish purchased by MIFCO will be greater than that of the fish caught. This bias is not easy to estimate because it will vary according to catch and purchasing capacity. In addition, fishermen will tend to keep the least valuable (*i.e.* the smallest) fish for their own consumption.
3. It should be possible to combine size-frequency samples for both small and large skipjack to obtain a single size-frequency distribution and hence a single average weight conversion factor. This, however, relies on strictly random sampling or careful stratified random sampling, which in practice are difficult to achieve. Small skipjack are more common than large skipjack, and there is a tendency to over-sample the less common fish. This tendency is exaggerated at Malé market, where fishermen sort their catches by size. Prior to August 1987 skipjack sampling at Malé market was not stratified by size; this led to a considerable overestimation of the occurrence of large skipjack in the catch (Anderson *et al.*, 1987).

This problem is still under review by MRS and EPCS. One possible solution is to use MIFCO conversion factors for all skipjack purchased by MIFCO (matched as far as possible by individual fishing vessel, but otherwise stratified by atoll and by month) and new MOFA/MRS regional and seasonal conversion factors for the remainder of the skipjack catch. There are two difficulties that would arise with this approach. First, when there is an excess of fish MIFCO will tend to buy the larger ones. Therefore fish not sold to MIFCO but returned to the island and reported will be smaller than the average estimated by MOFA conversion factors. This may tend to cause an overestimation of total catch. Secondly, fishermen who sell part of their catch to MIFCO may not report the unsold balance of their catch to MOFA. This will tend to cause an underestimation of total catch. These two opposing biases may tend to cancel out, but this needs further research.

Regional Length-Frequency Sampling Programme

The need for a regional length-frequency sampling programme has long been recognized within MOFA. As a first attempt, office-based, non-fishing field officers were employed on a number of islands by MOFA. Length-frequency sampling was only one of their duties, and an unpopular one at that. The quality and quantity of their length-frequency data returns were inadequate. Therefore, in late 1993 MRS initiated a regional tuna length-frequency sampling programme using active fishing skippers, who are employed to measure their own catches. A total of 13 skippers have been recruited on 7 islands, representing all regions of the country. The skippers were instructed in sampling methodology, and given monthly targets amounting to 2000-3000 tunas, depending on season. They are contacted regularly by post, mail?? and personal visits to ensure that the quality of their work is maintained. In addition to the sampling in the atolls, MRS staff sample landings at Malé market on about 20 days per month.

Although there are some problems with this programme it is proving very successful. The advantages of using active fishing skippers are their access to the fish, the help they have available from their crews, and in most cases their high motivation. The disadvantages of using fishing skippers are their tendency to sample rather few catches (even though total numbers of fish sampled may be high), and the fact that sampling stops when they stop fishing. This programme has been reviewed by Anderson *et al.* (1995). During 1994 a total of over 285,000 tunas were measured. Numbers measured by sampling location and species (to the nearest 100) are listed below:

These data have been compiled by MRS. Two constraints prevented the completion of this work in time to estimate conversion factors for use with the 1994 catch statistics. The first is a shortage of trained manpower at MRS. The second was the lack of adequate tape length-board length and length-weight relationships.

Region	*Atoll*	*Island*	*Skipjack*	*Yellowfin*	*Frigate*	*Kawakawa*	*Total*
NE	H.Dh.	Kulhudhoofushi	31,100	11,700	8,200	500	51,500
NW	R.	Alifushi	15,500	10,000	4,700	1,800	32,100
EC	K.	Malé	12,000	2,800	4,300	2,200	21,400
EC	M.	Maduvveri	18,500	2,300	1,000	13	21,900
WC	Dh.	Kudahuvadhoo	8,700	10,000	1,300	700	20,600
S	L.	Maamendhoo	24,600	6,800	200	0	31,600
SE	G.A.	Villingili	22,500	12,200	4,500	2,900	42,000
SW	G.Dh.	Thinadhoo	39,800	18,600	5,600	200	64,200
Total			172,900	74,400	29,800	8,300	285,400
	Average (of 8 islands)		21,600	9,300	3,700	1,000	35,700

Board-tape and Length-weight Relationships

In almost all cases tunas are measured with measuring boards. However, at Malé market fishermen object to their fish being handled by samplers. As a result the use of measuring boards, which had been in use since 1983, had to be discontinued in February 1986. Tape measures have been used since March 1986. Calipers were used for a trial period in December 1993, but proved unpopular with both samplers and fishermen, and so their use was discontinued. A very few tuna length-frequency samples outside Malé have also been measured with tapes. Tape lengths are usually slightly longer than board lengths, the exact difference depending on fish size, species and degree of curvature (although grossly bent tunas are not measured). To correct for this, tape length-board length conversion tables are being prepared by MRS (Anderson *et al.*, 1995). These should be completed before the end of 1995.

To convert length-frequency data to weight frequency and hence to average weight, length-weight relationships are required for each species. New length-weight relationships for Maldivian tunas are being prepared by MRS (Anderson *et al.*, 1995) and again should be completed before the end of 1995.

Overview of the Tuna Statistics System

In summary, MOFA has a well-established system of total enumeration for tuna catches. There are at present problems with under-reporting, with the confusion over skipjack size reporting, and with the use of inadequate conversion factors. The latter problem will largely be solved once MRS's regional length-frequency sampling programme starts producing regional and seasonal conversion factors for each species in a regular and timely manner. The use of commercial (*i.e.* MIFCO) data, and/or some other sampling scheme, will be necessary to estimate and correct for underreporting. Despite these problems the MOFA system produces tuna catch estimates that are of an accuracy as good or better than that of almost any other country. In particular, despite any minor inaccuracies, the 25-year time

series of Maldivian tuna catch and effort data compiled by species, atoll and month from 1970-94 gives a consistent picture of major trends and forms an invaluable resource for further research.

OTHER AGENCIES

Although MOFA has primary responsibility for the collection of tuna statistics and the carrying out of research on tuna resources, a number of other government agencies do have related responsibilities. These include:

1. The Maldives Industrial Fisheries Company (MIFCO) is a government tuna-exporting agency. MIFCO purchases fresh skipjack and yellowfin from fishermen, for which purpose it maintains an extensive fleet of freezer and collector vessels. This fish is exported either frozen (*e.g.* to Thailand for canning), canned (mainly to Europe from the cannery on Felivaru in Lhaviyani Atoll), or smoke dried (to Sri Lanka). In addition, small quantities have recently been exported to Japan for *sashimi* and to Europe as loins. MIFCO maintains detailed daily records of its fish purchases (*i.e.* total numbers and weight of skipjack and yellowfin by size category purchased from each fishing vessel). Although mainly a fish purchasing agency, MIFCO has carried out offshore longlining since 1993, using a Far Eastern high-seas vessel. Detailed catch records are maintained.
2. 2. The Ministry of Trade and Industries (MTI) is responsible for licencing all foreign-registered fishing vessels operating in Maldivian waters. For the most part this applies to longliners operating in the outer waters of the Maldivian EEZ (*i.e.* 75-200 miles offshore). However, a single foreign big game fishing boat is also registered with MTI. All foreign vessels are supposed to supply complete catch and effort statistics to MTI. These statistics are on the whole of poor quality. They have been compiled by MOFA but have not been reported to IPTP.
3. The State Trading Organization (STO) was the government agency involved with the transshipment of purse-seine catches in Addu Atoll during the 1994-95 Chagos season.
4. The Customs Department is responsible for monitoring and recording all imports and exports. Detailed records are maintained of all fish product exports, by value and weight. These are compiled and summarized on an annual basis by MOFA/EPCS.
5. The National Security Service Coastguard is responsible for fisheries surveillance throughout the Maldivian EEZ.

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