# THE MALDIVIAN TUNA FISHERY

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## ABSTRACT

*The Republic of Maldives has a major pole and line tuna fishery. The main catch is skipjack tuna (115,300 t in 2002), but significant quantities of yellowfin tuna (21,700 t in 2002) are caught as well. Some juvenile bigeye tuna is also taken, but it is not distinguished from yellowfin in the national statistics; estimated catches over the past decade have been of the order of 500-1200t. During the last few years the average size and fishing power of local pole and line vessels has increased significantly. This has contributed to a major recent increase in tuna catches and catch rates. Analysis of skipjack tagging data has allowed new estimates of skipjack growth and movements. Information on the livebait fishery, interactions with sharks, and socio-economic issues is summarized.*

## 1. INTRODUCTION

The Republic of Maldives has traditionally been a tuna fishing nation. Tuna fishing in the Maldives probably started more than 1000 years ago. Until the 1970s the tuna fishery was the mainstay of the Maldivian economy, providing the major source employment, food and export earnings. The relative importance of the fisheries sector has declined since then, however, due largely to the spectacular growth of the tourism industry. The fisheries sector's contribution to GDP declined from about 30% in the 1970s to less than 10% in 1997-2000.

The largest and most important component of the Maldivian tuna fishery is the livebait pole-and-line (*masdhoni*) fishing fleet. This fleet has undergone major changes over the last three decades, starting in 1974 when the first of the traditional sailing pole and line vessels was mechanized. More recently there has been a significant increase in average size and engine power of these vessels. A second component of the fishery is the trolling (*vadhu dhoni*) fleet. This has almost disappeared over the past 20 years, mainly as a result of socio-economic changes in the country.

The most important component of the tuna catch is skipjack (*Katsuwonus pelamis*), which contributes some 75% to the total tuna catch. Yellowfin tuna (*Thunnus albacares*) is the second most important species, contributing some 13% to the total tuna catch. Other tuna species taken include kawakawa (*Euthynnus affinis*), frigate tuna (*Auxis thazard*) and bigeye tuna (*Thunnus obesus*). Catches of the latter are not distinguished from yellowfin tuna in the national statistics. Total tuna catches have increased dramatically in recent years, to nearly 150,000 t in 2002.

Reviews of the Maldivian tuna fishery are given in MRS (1996), Anderson et al. (1998) and Adam (1999). This paper provides a brief update of the fishery.

## 2. DEVELOPMENTS IN THE FISHERY

The Maldivian tuna fishery has undergone profound changes over the past three decades, and changes are still continuing. They affect all aspects of the fishery, from catching to exports (section 9). Socio-economic changes (section 8) have been particularly important.

### 2.1. Developments in Pole and Line Vessels

In recent years pole and line vessels (*masdhonis*) have undergone enormous changes. The most obvious change is the increase in size, and attendant increase in size of engines. About ten years ago, most *masdhonis* were of the order of 35-45 ft loa (c 11-14 m) with 28-42 hp engines. Today most active *masdhonis* are within the range 40-90 ft (c 13-27 m) with 42-200 hp engines.

The size distribution of registered fishing vessels (*masdhonis*) in 2002 is given in Fig. 1. (Note that the smallest vessels are not engaged in pole and line tuna fishing; they are mostly involved in trolling and reef fishing). The modal size class of the fleet is 50-59 ft (15-18 m) loa. Of particular note is the development of a new class of large *masdhonis*, in excess of 60 ft (18 m) loa. These larger vessels are several times more efficient at catching tunas than the smaller pole and line vessels. Their increased size and engine power allows them to range more widely and quickly in search of bait, tuna and markets; they can carry more bait and tuna; and in addition they attract the very best crews.

Despite these changes in fishing power of the pole and line vessels, fishing effort is still recorded in the national statistics in units of fishing days, without taking any account of the diversity of vessels now in use. In order to make some crude standardization to fishing effort we assume the following (after Anderson et al, 1998):

- Sailing vessels were 0.5 times as effective as mechanized vessels in catching tuna during the period 1970-1977 (inclusive).
- The effective effort of sailing vessels decreased linearly from 0.5 in 1978 to zero in 1985 as they were displaced from the pole and line tuna fishery.
- The fishing power of mechanized pole and line vessels increased by 1% per year from 1985.

Actual and standardized pole and line fishing effort are illustrated in Fig. 3. Note that number of fishermen (Table 2) and number of active pole and line vessels (Table 3), in addition to number of actual days fished by pole and line vessels (Table 2) have all decreased in recent years. In contrast, and pole and line catch has increased in recent years. This is a reflection of the recent concentration of fishing effort into a smaller number of larger, more efficient pole and line fishing vessels (which is not fully captured in the procedure used here for standardizing fishing effort).

### 2.2. Collapse of the Troll Fishery

Trolling boats (*vadhu dhonis*) were a significant component of the Maldivian tuna fishery. They caught mainly kawakawa and frigate tuna, inside and just outside the atolls. Fishing effort, and catches, peaked in the late 1970s and early 1980s, during the period of mechanization of the *masdhonis* fleet. Since then troll fishing effort and catches have plummeted. Indeed, the number of days fished by *vadhu dhonis* in 2002 was just 6% of days fished at the peak of the fishery in 1978 (Table 2). The main reasons for the collapse of the fishery are believed to be socio-economic (see section 8).

### 2.3. The EEZ Fishery

Longline fishing by foreign vessels is permitted under licence in the outer waters of the Maldivian EEZ (75-200 miles offshore). Numbers of vessels operating in the EEZ and reported catches for 1997-2002 are summarized in Table 4, with a more detailed breakdown for 2002 in Table 5. Some data for earlier years are given in Anderson et al. (1996) and Anderson (1996). Note that there is believed to be significant under-reporting by licenced vessels.

## 3. SKIPJACK TUNA

Skipjack tuna is by far the most important fishery species in the Maldives, contributing an average of about 75% to the total tuna catch. In 2002, a record catch of 115,322 t was landed. Virtually all the catch of skipjack is by mechanized pole-and-line vessels. In addition to its quantitative importance, skipjack tuna is the preferred source of protein in the local diet.

### 3.1. Skipjack Catch and Effort Trends

Recorded catches of skipjack tuna and fishing effort for the years 1970-2002 are given in Tables 1 & 2 and Fig. 4. From 1988 to 1993, skipjack catches were remarkably stable at around 58,000 - 60,000 t per year. Since then recorded catches have increased dramatically.

Virtually all skipjack tuna in the Maldives are caught from mechanized pole and line vessels. Standardized pole and line fishing effort increased substantially up to a peak in 1996-1997, but has decreased somewhat since then. This is in complete contrast to skipjack catch, indicating a significant recent increase in CPUE, which is believed to be related to the recent increase in numbers large pole and line vessels in the fleet.

### 3.2 Skipjack CPUE Trends

Standardized skipjack CPUE was relatively stable at about 250-300 kg/day from 1985-1997 (Fig. 5). Since than standardized skipjack CPUE has shown a sharp increase to over 450 kg/day in 2002. This sharp increase is due in part at least to the significant increase in numbers of large masdhonis in the fleet (which can land several tonnes per day). There is a recognized need to quantify these changes in fishing power of the masdhonis fleet in order to obtain a better standardization of pole and line fishing effort in recent years.

Maldives skipjack CPUE trends have been shown to be related large-scale oceanographic variations. For example, during El Nino years skipjack catch rates are depressed while in La Nina years they are elevated.

### 3.3. Skipjack Growth

Estimating growth of skipjack has proved to be problematic. Conventional methods such as modal progression from size-frequency data or hard-part analysis have not yielded satisfactory results, due to skipjack's prolonged spawning and irregular growth (Stéquert and Ramcharrun, 1996; Adam et al., 1996). Tagging data appear to provide the best means of estimating growth, although difficulties in obtaining accurate and representative length increment data are problems that have to be considered when estimating growth parameters.

From tagging carried out in the Maldives in 1993-1995, Adam (1999) estimated the parameters of the von Bertalanffy growth model (Fig. 6) as:

$L_\infty = 64.3$ cm

$K = 0.54$ per year.

More recently, Adam and Kirkwood (submitted) found an alternative model of declining growth rate over size (Schnute, 1981; Francis, 1995) was more appropriate for the same data set (Fig. 7). (In the von Bertalanffy model the growth coefficient is constant over size, whereas in the alternative model growth coefficients vary with size, an additional parameter describing the curvature of the growth rate. Setting this curvature parameter to unity makes the Francis model exactly same as the von Bertalanffy model).

### 3.4. Movement and Fishery Interaction

Skipjack movements and fishery interactions have been studied from tag-attrition models (Bertignac 1994; Adam, 1999). A more recent study uses a two-season two-region advection-diffusion-reaction model in which movement patterns were estimated by seasons and regions (Adam and Sibert, 2002). The fishing and natural mortality rates were assumed to be time-invariant in the model. Fig. 8 shows the movement patterns estimated from the model using the data from the two experiments (1990 and 1993-4) separately and for the combined data sets. There was no consistent pattern observed between the two experiments. Diffusive movement were higher in the second experiment data. In the analysis of combine data, diffusive movements dominate northern region in the southwest monsoon. The higher diffusion suggest skipjack's tendency to remain within close range of the fishery area. Uncertainties in these findings result in part from uneven release of tags in space and time and lack of recoveries immediately outside the Maldivian fishery area.

Earlier analyses, which looked at seasonality of recoveries from overseas fisheries only (Yesaki and Waheed, 1992; Anderson et al., 1996), suggested that skipjack in the central Indian Ocean moved in phase with the surface currents: eastwards during the southwest monsoon and westwards during northeast monsoon.

The rate of emigration of skipjack tuna from Maldivian fishery area out of the EEZ is considered be low. Of the total recoveries, less than 2% were from overseas fisheries. An estimate of the fishery interaction is not possible without information on movement from overseas fishery into the Maldivian fishery. But it is believe that high levels of immigration are probably necessary to maintain the current high levels of skipjack catches in the local fishery. If this is the case, high levels of overseas fishing may well affect the productivity of the Maldivian fishery. Such negative effects are suggested by a decrease in average weight of skipjack landed in the Maldives (Cook, 1995; Scholz et al., 1997). However, there are alternative explanations including: sampling bias; oceanographic variation affecting size-related availability (large skipjack tend to stay deeper waters); and effects of fish aggregating devices. On this last point, small skipjack tend to aggregate on FADs more than larger skipjack, and in the Maldives it is believed that about 45% of skipjack are caught when associated with FADs (Anderson et al., 1996).

### 3.5. Residence Times

A measure of residence time (or persistence) is "half-life", which can be calculated from the estimates of tag-attrition curve coefficients. Technically, half-life is the time required for the population to reduce by half. Using the estimates obtained from the tag-attrition analysis of Adam and Sibert (2002), half-life was estimated at 15-30 days. This suggests that fish available to the local fishery were quickly lost due to fishing mortality, natural mortality and emigration. Half-life estimated by setting the fishing mortality zero increased to 92-230 days, which is suggestive of the high impact of local fishing effort.

## 4. YELLOWFIN TUNA

Yellowfin tuna (*Thunnus albacares*) is the second most important species caught in the Maldives, contributing roughly 13% to the total tuna catch. Catches increased threefold between 1991 and 2002, when a record catch of nearly 22,000 t was landed (Table 1, Fig. 9).

Traditionally, the yellowfin fishery in the Maldives was a pole-and-line fishery. Almost all the catch was of small juvenile yellowfin, 30-60 cm FL. However, over the past decade there have been increasing catches of large yellowfin, 60-160 cm TL. This is a direct result of the development of new markets (both domestic and export) for large yellowfin. The favoured gear for catching large yellowfin is livebait handline. Pole and line is used, particularly in the northern atolls, where many vessels install pulley systems during the main large yellowfin season there (December to March). Longline is also used by a few vessels. Separate catch statistics for small and large yellowfin have been collected since 1992, although they are not normally reported separately. An indication of recent catches by size category is presented in Fig. 9. Note that the large yellowfin contribution to total yellowfin catch doubled form 14% in 1994-99 to 28% in 2000-02. This increase in large yellowfin catches is a major factor in the record landings of total yellowfin in 2002. (High catches of small yellowfin from large pole and line masdhonis is another factor). Much of the most recent increase in total yellowfin catch is due to increased catches of large yellowfin in the vicinity of Malé (centre of domestic markets and infrastructure for exports).

Yellowfin tuna catch per unit effort by pole and line vessels decreased from 1980-1990, but has been increasing since then (Fig.10). Much of this variability has been linked to decadal-scale ocean variability (Anderson and Waheed, 1998). The particularly high value of CPUE in 2002 is also linked to record catches of large yellowfin.

In addition to catches of yellowfin by Maldivian *masdhonis*, catches are made by commercial longliners in the outer waters of the Maldivian EEZ. Catch and effort statistics are for 2002 are summarized in Table 5. Total reported catches by longliners operating in the EEZ are summarized in Table 4 Yellowfin and bigeye catches are reported separately but are lumped during compilation; yellowfin contributed an average of 43% of the catch in earlier years (Anderson, 1996). Note that EEZ longliner catches are believed to be grossly underreported.

## 5. BIGEYE TUNA

Bigeye tuna (*Thunnus obesus*) is taken in small quantities by the Maldivian pole and line fleet. However, catches of this species are not distinguished from those of yellowfin tuna by the fishermen or in the national statistics. Estimated proportions of bigeye in the 'yellowfin' tuna catch are approximately 1% by numbers in the north and centre of the Maldives, and 15% by numbers in the south (Anderson, 1996). Estimates of bigeye tuna catches, calculated following the procedure of Anderson (1996), are presented in Table 6. Recent bigeye catches are of the order of 500-1100 t per year, which is some 4-7% of the total *Thunnus* catch.

Note that these estimates are very crude, since the proportions of bigeye in the *Thunnus* catch are based on limited sampling (Anderson, 1996). In particular there has been little sampling in the centre of the Maldives, and there has been no sampling since 1995 after which the catch of large *Thunnus* has increased significantly. (Note also that bigeye catch have not been deducted from the 'yellowfin' catch estimates presented in Table 1, in part because yellowfin catch estimates are likely to be underreported).

Longline vessels operating in the outer waters of the Maldivian EEZ do distinguish between bigeye and yellowfin, and do report the two species separately (Tables 4 & 5). However, the statistics are not compiled separately, and these vessels, particularly the licensed foreign vessels, are believed to grossly underreport catches. In earlier years bigeye tuna made up an estimated average of 57% of the tuna catch by longliners in the EEZ (Anderson, 1996).

## 6. SHARKS

In 1999, IOTC adopted a proposal for a study of shark and marine mammal predation, within the context of an ecosystem approach to fisheries management (IOTC, 2000). Also in 1999, the FAO Committee on Fisheries (COFI) endorsed a voluntary International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) (FAO, 2000). This arose from earlier concerns that sharks (and the related rays and chimaeras) are particularly vulnerable to fishing pressure and that management was urgently required (e.g. Camhi et al., 1998). The IPOA calls upon all States to produce a Shark Assessment Report (SAR) and, if they have shark fisheries, to develop and implement National Plans of Action for the Conservation and Management of Sharks (NPOA). The IPOA also urges States to ensure effective conservation and management of trans-boundary, straddling, highly migratory and high seas shark stocks. A recent report reviewing implementation of the IPOA-Sharks showed that most countries with shark fisheries in the Indian Ocean, including Maldives, had reported no progress towards development of an SAR or NPOA (Anon, 2002).

Within the Maldives, during an exploratory offshore fishing survey in 1987-88, 15% of a small catch of tunas and billfishes taken by longline were damaged by sharks; no evidence of damage by cetaceans was seen (Anderson and Waheed, 1990). There are no data on damage to tuna catches by commercial tuna longliners currently operating in the Maldivian EEZ.

The pole and line tuna fishery is very selective, and results in little by-catch. However, tuna fishermen do sometimes take juvenile silky sharks, *Carcharhinus falciformis*, by pole and line, by handline and by hand (Anderson and Ahmed, 1993; Anderson and Hafiz, 2002). The interactions of silky sharks and tunas is well known (Au, 1991) and is believed to be of particular importance by Maldivian tuna fishermen (Anderson and Ahmed, 1993). They consistently report that the taking of silky sharks from tuna schools reduces subsequent tuna catches. They also report that catching of oceanic sharks by longline reduces pole and line tuna catches. Large silky sharks are predators of tunas, which presumably school more tightly in the presence of sharks, making themselves more vulnerable to pole and line fisheries. More generally, this relationship hints at the complex interactions between oceanic fishery species, and the need for an ecosystem approach to their management.

A study of the pelagic shark longline fishery from one island in the north of Maldives (H.Dh. Kulhudhuffushi) was carried out during 2000-02 (Anderson, 2002). Fishing was carried out 30-100 nm offshore. The main species caught are listed in Table 7.

Although there is no catch and effort data series for this shark fishery, several findings suggest that stocks of offshore oceanic sharks are being overexploited:

- 1. Fishermen and buyers consistently report falling catch rates (by about 50% over the past 5 years). As a direct result there is no new investment in the fishery and many boats and fishermen have dropped out of the fishery.
- 2. Fishermen and buyers state that very large silky sharks are no longer caught, and average sizes of sharks being landed have declined in recent years.
- 3. Fishermen and boat owners report having to fish further and further offshore to obtain reasonable catches.

It is conceivable that these changes are the result of localized stock depletion. However, localized stock depletion is most likely to occur in coastal shark stocks and seems unlikely in offshore stocks that are believed to be highly migratory. The conclusion must therefore be that the stocks of offshore oceanic sharks are being heavily exploited and probably overexploited on a regional or ocean-wide scale.

Kulhudhufushi shark fishermen by themselves are certainly incapable of making such a significant impact on such enormous stocks. However, many other nations are exploiting oceanic sharks throughout the Indian Ocean. In nearly all cases no catch data are available. Nevertheless, it is clear that oceanic shark catches from the Indian Ocean have been substantial during recent years. For example, Bonfil (1994) estimated that distant water longline fleets operating in the Indian Ocean may have caught about 2,000,000 oceanic sharks (i.e. about 75,000t) per year in 1987-89. In other oceans it is known that pelagic shark stocks have been substantially reduced in recent years (Camhi et al, 1998; Baum et al. 2003). Note also that the reported decrease in catch rates over the past 5 years will not accurately reflect the much greater reduction in biomass that has undoubtedly occurred over the past 40 years or so.

## 7. LIVEBAIT

### 7.1. Livebait Fishery

Some 90% of the Maldivian tuna catch is taken by the pole and line fishery, which in fact comprises two separate fisheries: an offshore one for tunas and an inshore one for livebait. The existence of abundant livebait resources is therefore vital to the prosecution of the Maldivian tuna fishery. Reviews of the baitfishery are provided by Anderson and Hafiz (1988) and Anderson (1997a).

Traditionally, livebait are normally caught first thing in the morning, adjacent to reefs inside the atolls. A simple liftnet is used. Livebait fishing at night using lights was not traditionally practiced in the Maldives, but it became established in Addu Atoll, apparently in the 1970s. It subsequently spread to other southern atolls in the mid-1990s and is now widespread through most of the country (Anderson, 1997b; Anderson, Waheed and Nadheeh, 1997).

The national catch of livebait was roughly estimated at just over 10,000 t per year in 1996 (Anderson, 1997a). The major livebait species, together with rough estimates of their contribution to the daytime livebait catch are listed in Table 8.

MRC has been carrying out a national survey of night baitfishing, but the results have not yet been finalized. However, approximate species composition of night baitfishing catches is available from a preliminary study carried out in the southern atolls in 1997 (Table 9).

### 7.2. Potential Livebait Supplies for Indian Ocean Tagging

Under Maldivian law, only Maldivian fishermen are allowed to fish commercially within the atolls and waters out to 75 miles offshore. This is to protect local fish stocks and the interests of local fishermen. Stocks of livebait that are exploited for the pole and line tuna fishery are recognized as being particularly important. As a result, it is unlikely that permission would be given for a foreign vessel to collect livebait in the Maldives. If livebait were required from the Maldives in support of a regional tagging programme, it might be necessary to purchase the bait from local fishermen. Many Maldivian vessels now fish for bait at night using lights; the species most frequently taken (Table 9 are relatively fragile, and not suitable for holding in bait tanks for any length of time. Hardier species (fusiliers and cardinalfishes) are taken in daytime, but not always in large quantities.

For tagging near the Maldivian atolls, use of normal pole and line vessels (as in previous Maldivian tagging programmes) is possible. For fishing further offshore (say in the range 50-60 miles offshore) large modern Maldivian pole and line vessels could be used. It should also be possible to charter large pole and line vessels to tag in the Chagos (providing permission were obtained from BIOT authorities).

## 8. SOCIO-ECONOMIC ISSUES

The Maldivian tuna fishery has probably been in existence for over 1000 years, and changed little for several centuries, right up until the beginning of the 1970s. Technological changes since then have been dramatic, but they are at least equalled in importance by changes in socio-economic conditions and expectations in the Maldives.

Historically, i.e., pre-1960, fishing was the only major employer and over 15% of the entire population were fishermen. Today less than 5% of the population are fishermen. This dramatic decline is caused in part by the spectacular growth of employment opportunities in other sectors, notably tourism. But it is also in part a reflection of the reluctance of young men to enter the fisheries sector. Young men do not want to become fishermen for a number of reasons including: increased expectations following school education; low perceived social status of fishermen; and the hard physical work involved in fishing. Low income is not a major factor since many fishermen earn good incomes, but most young men would rather work in relatively poorly paid office jobs. Although there are certainly counter-examples, most young men have no intention of ever becoming fishermen.

One clear indication of the reluctance of young men to enter the fishery is the increasing average age of active fishermen. In a survey conducted on the island of Kulhudhuffushi in June 2002, information was collected on the ages of (shark) fishermen (Anderson, 2002). The average age of active fishermen was estimated to be 47 (range 32 to 62 years). This trend will clearly have a major impact on the fisheries sector in the next few decades.

Nationally, the lack of young men entering the tuna fishery has already led to a shortage of fishermen. As a result boat owners have been finding it increasingly difficult to recruit and keep competent crew for their vessels. This has had and is having a number of impacts on the tuna fishery:

- 1. It is believed to have been a major factor in the collapse of the troll fishery since the 1980s (Table 2).
- 2. It is now a major factor in the recent decline in the number of active pole and line vessels (Table 3).
- 3. It has led to changes in the traditional share system, with owners now taking a smaller share in order to pay more to masterfishermen.
- 4. It is the major factor behind the recent boom in construction of very large and fast pole and line vessels, since boat owners now have to compete to attract crews with the best boats.

These changes in the fishery deserve detailed study. In the medium to long-term, they may have a greater impact on total Maldivian tuna catch than any variation in tuna abundance and availability. They may also have major negative impacts on national food supply and export earnings, as well as on the profitability of major fisheries infrastructure investments. Furthermore, the socio-economic impact of these changes on the island communities is likely to be profound and not always beneficial.

A more recent development has been a change in government policy encouraging private sector investment in the post harvest components of the tuna fishery. For example there has been increased private sector production and export of smoke-dried tuna (traditional ‘Maldive fish’);

increased private sector involvement in export of fresh or chilled yellowfin; and most recently the privatisation of part of the largely state-owned fish collection, processing and exporting company, MIFCO. It is too early to assess the impact of all of these changes on production, but the recent increase in catches of large yellowfin can in part at least be attributed to private sector involvement.

## 9. FISHERY EXPORTS

The major fishery export from the Maldives has been the "Maldive fish" (smoke dried tuna), which was primarily exported to the Sri Lanka. This long-established market collapsed in the 1970s due to the foreign exchange shortages there and alternative export products were sought. The export of frozen and canned tuna followed soon after, with other products following more recently. For many years tuna exports were largely under government control, but private sector investment has been encouraged in recent years. A summary of recent tuna exports is presented in Tables 10 & 11, and Fig. 11.

## 10. DATA COLLECTION

The data collection system of the Maldives is based on total enumeration of the catch. Traditionally the catch is shared among the crew so the total number caught is always known. For the purposes of estimating the total weight the numbers are multiplied by the average weights (conversion factors) of the species. The system was specifically designed to record tuna catch, and did so with considerable success for many years.

However, within the last two decades, the country's socio-economic condition has improved tremendously, and the tuna catch reporting system is deteriorating. Today island communities are much larger and mobile. Also the fishing fleet is more heterogeneous, resulting in differences in fishery characteristics across the atolls. The catch is no longer landed or shared directly. It is often sold fresh to government or private collection facilities. The fishermen no longer respect the voluntary reporting system; both the fishermen and the island office staff are far busier then 20 years ago. Under-reporting and use of inappropriate conversion factors has further degraded the quality and reliability of the tuna catch effort data.

The most recent reviews of data collection are given by Parry and Rasheed (1995) and Anderson and Hafiz (1996). A regional catch sampling programme produced regional and seasonal conversion factors for major tuna varieties (Scholz et al. 1997). With recent changes of government policy in the fishery sector particularly relating to privatisation, fishery statistics are increasingly being used for policy evaluation and fishery management purposes. The government is therefore renewing its commitment to improving the fishery data collection system. Currently a review of the existing system is being initiated which should lead to the formulation of a project to strengthen the fishery data reporting system.

## 11. FAD PROGRAMME

Fish aggregating devices (FADs) are now an important part of the Maldives tuna pole-and-line fishery. A national FAD deployment programme started in 1981. After trials, a design suitable for the Maldives was evolved that has become the local standard (Naeem, 1988). FADs of this design last for an average of about 2 years in Maldivian waters. FADs are now maintained at 44 sites by a dedicated FAD deployment team of the Ministry of Fisheries, Agriculture and Marine Resources. Some 44% of skipjack tagged in Maldives in 1993-95 were recaptured near FADs (Anderson et al., 1996). It is assumed that this was a reasonable first estimate of total skipjack catch near FADs.

Experiments are currently underway to develop FADs for attracting livebait. These bait FADs are deployed inside atolls basins. They use underwater lights (powered by batteries and solar panels) to attract bait at night. It is anticipated that these bait FADs will become a significant factor in the livebait fishery.

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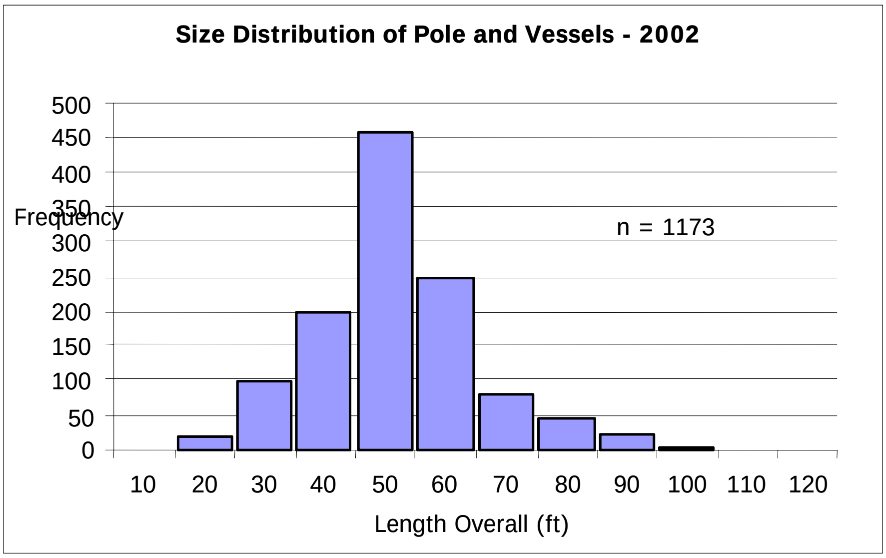

*Figure 1: Length distribution of masdhoni fleet of the Maldives, 2002.*
*Source: MOFAMR*

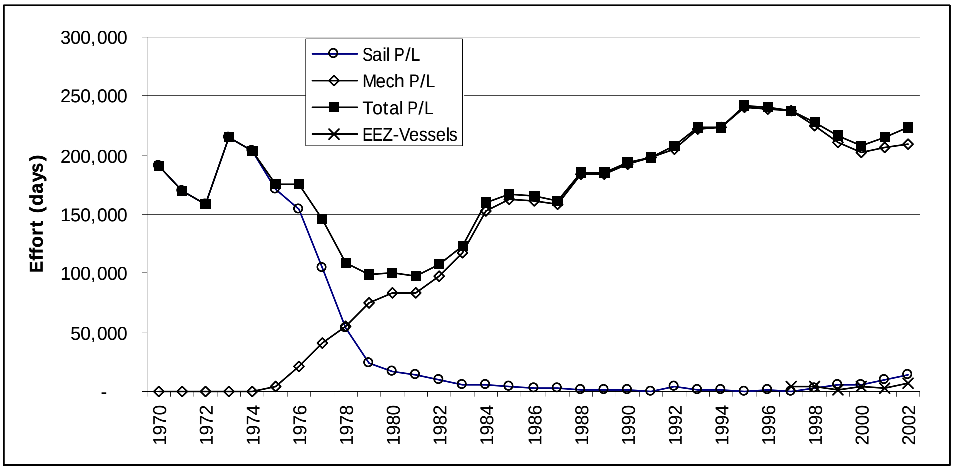

*Figure 2: Annual FISHING EFFORT of the Maldivian pole and line fleet (1970-2002). Also shown are the number of longline days for the EEZ vessels (1997-2002).Source: MOFAMR / Statistics and Database Management Section.*

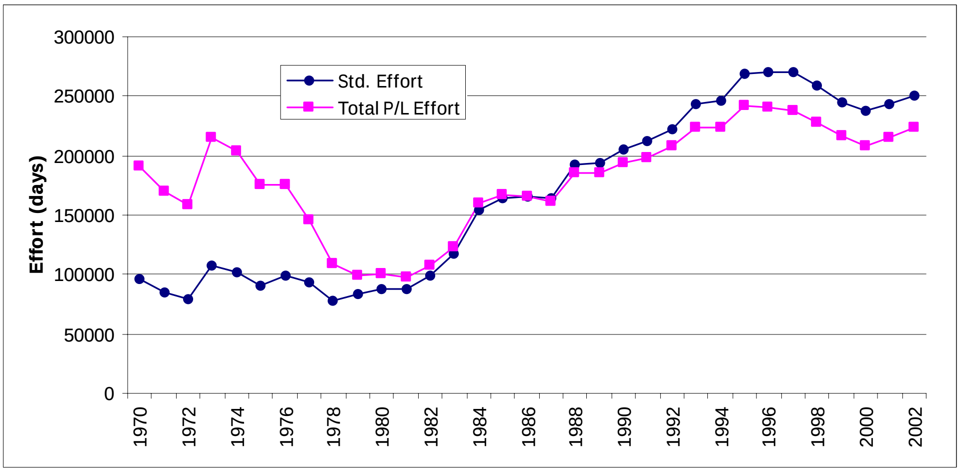

*Figure 3: Actual and standardized FISHING EFFORT of the Maldivian pole and line fleet (1970-2002).*
*Note: Method of standardization outlined in text. Original data source: MOFAMR / Statistics and Database Management Section.*

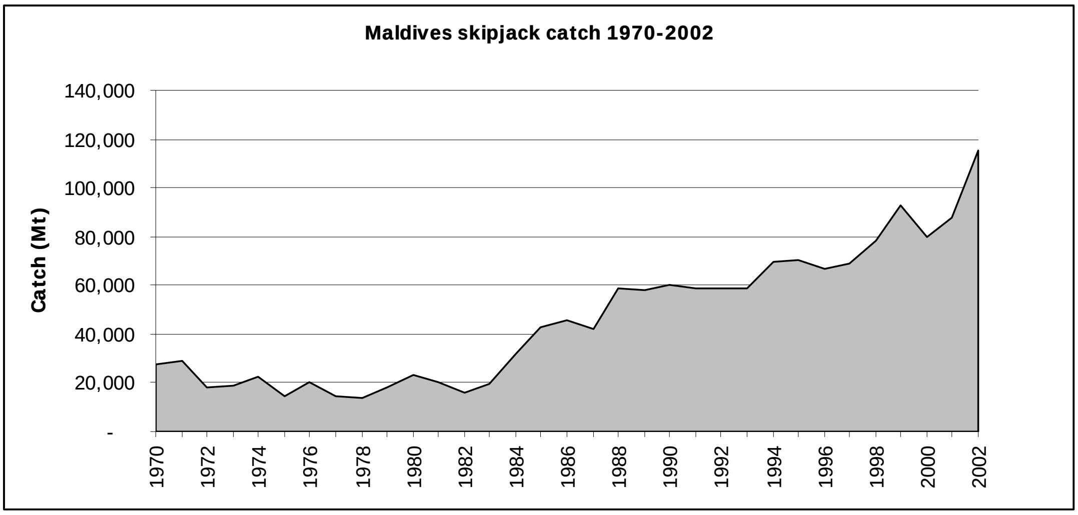

*Figure 4: Recorded catch of SKIPJACK in the Maldives. 1970-2002.*
*Source: MOFAR / Statistics and Database Management Services.*

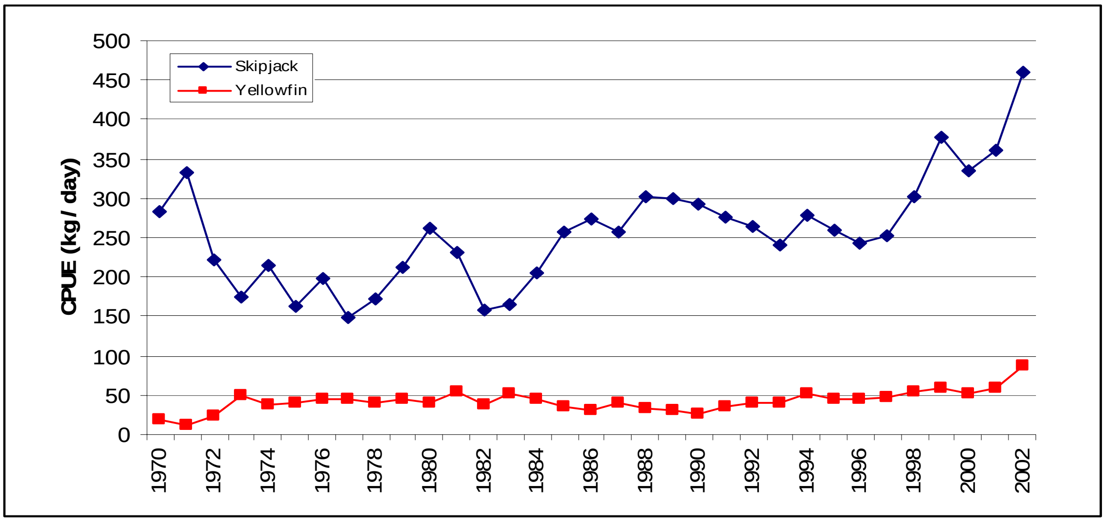

*Figure 5: Adjusted pole-and-line CPUE for skipjack (stars) and yellowfin (crosses), 1970-2002.*
*Source: MOFMAR, Statistics and Database Management Services.*

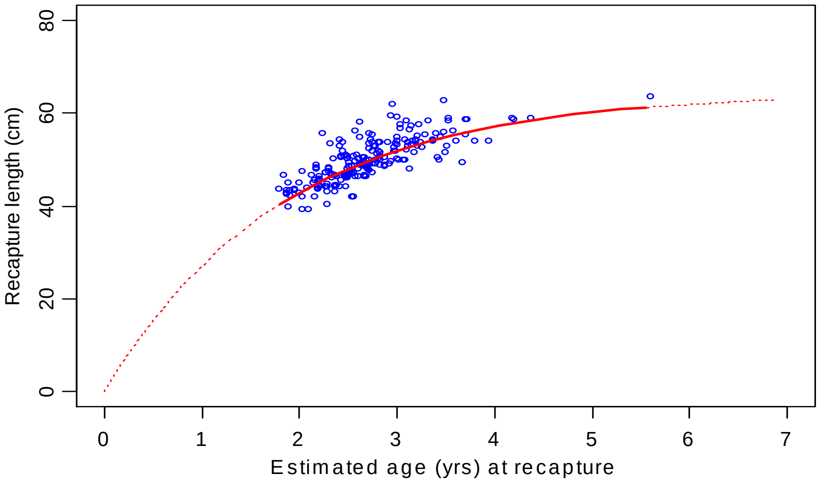

*Figure 6: Observed recapture lengths of SKIPJACK TUNA against the model (von Bertallanfy) predicated relative age. The model predicted values are shown in smoothed lines; continuous curve for the data range (40-64 cm FL) and dotted line predicted curve (Modified from Adam 1999)*

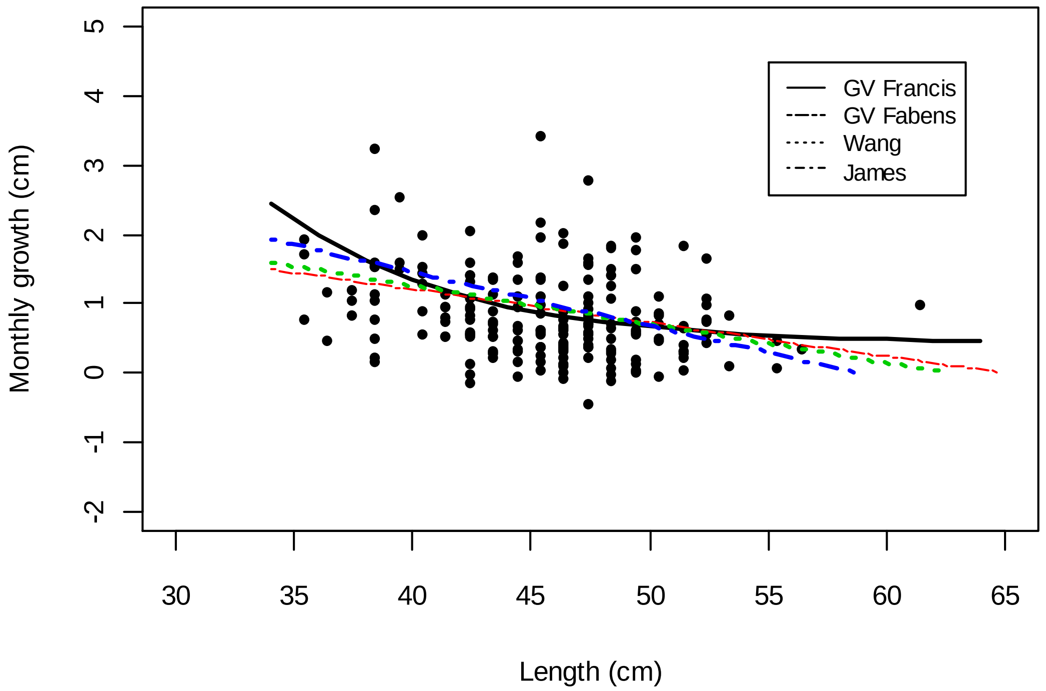

*Figure 7: Monthly growth rates against release length of tagged SKIPJACK tuna in the Maldives, showing predicted relationships for 4 growth models. The models are GV Francis (Francis model with Generalized Variance error structure), and three variations on the von Bertallanfy growth model: GV Fabens (Fabens model with Generalized Variance error structure), Wang (Wang's approximation method of taking into account of release age) and James (James's method of using unbiased estimating functions). Francis' model was found to provide the best fit (based on AIC, Akaike Information Criterion) over other models (Adam and Kirkwood, submitted)*

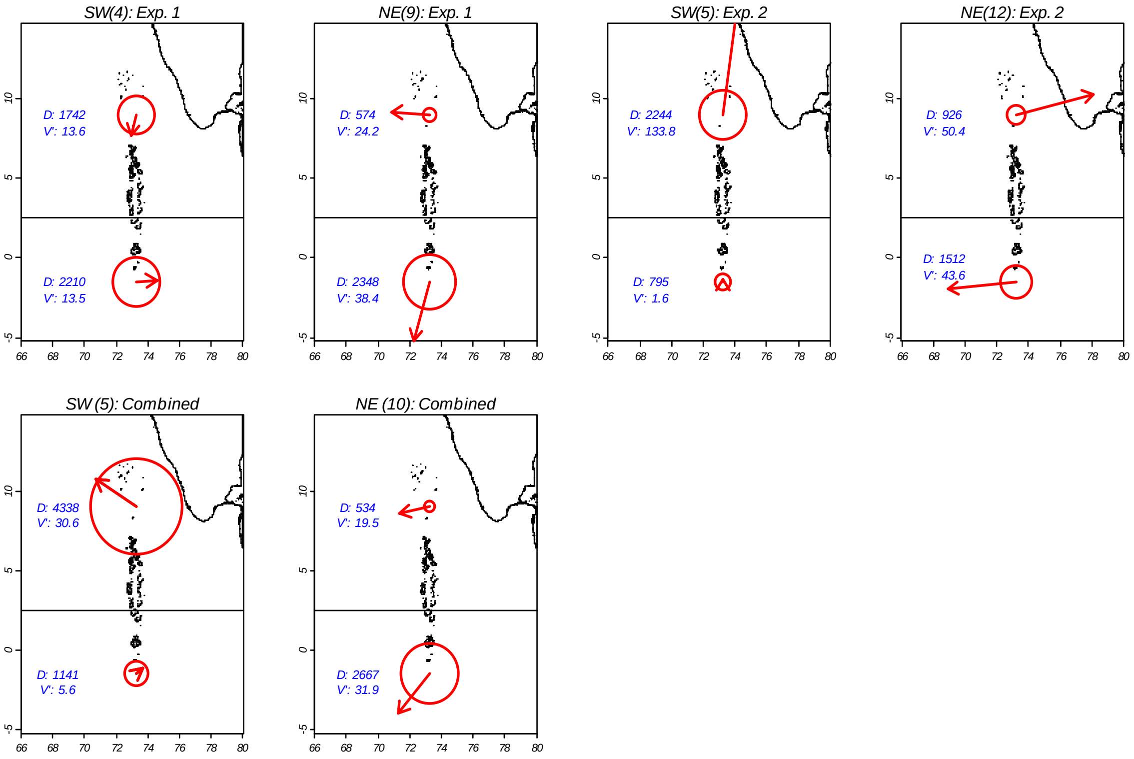

*Figure 8: Movement patterns of SKIPJACK TUNA as estimated from a two-region two-season model. Circles are diffusion; D (sq. nautical miles per month), while arrows are directional vectors, V (nautical miles/month). SW is the southwest monsoon and NE northeast monsoon season. Numbers in parenthesis indicate season starting months Note V and D are not drawn relative to geographic scale. Note also the centres of diffusion and advection in the southern and northern regions do NOT represent centres of fish release. (Adapted from Adam and Sibert, 2002).*

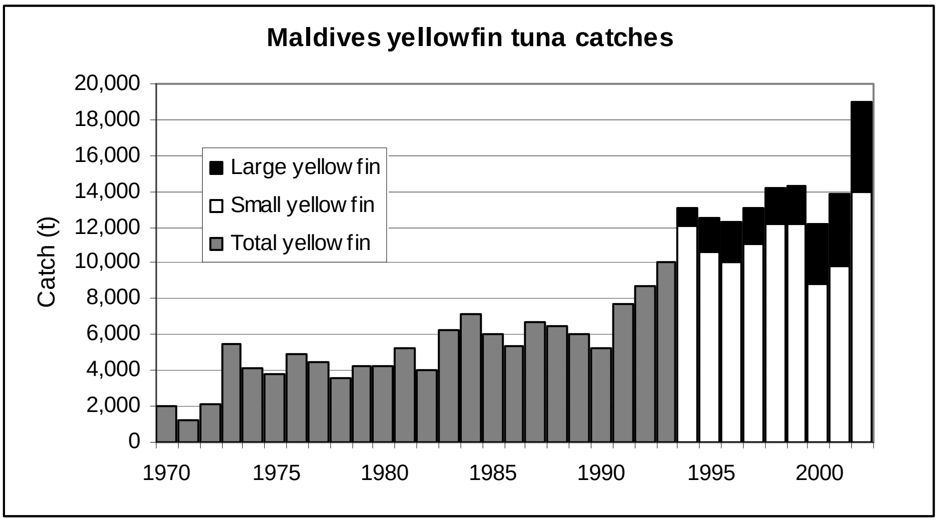

*Figure 9: Recorded catch of YELLOWFIN in the Maldives. 1970-2002. Also shown are catches from the EEZ (longline fishery)*
*Source: MOFAMR / Statistics and Database Management Services*

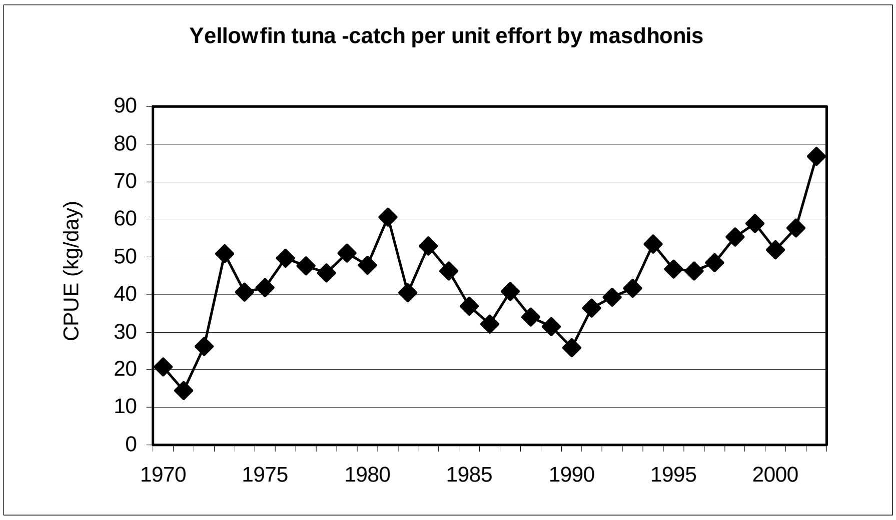

*Fig. 10: YELLOWFIN tuna catch per unit effort by pole and line vessels*
*Original data source: MOFAMR, compile by MRC*

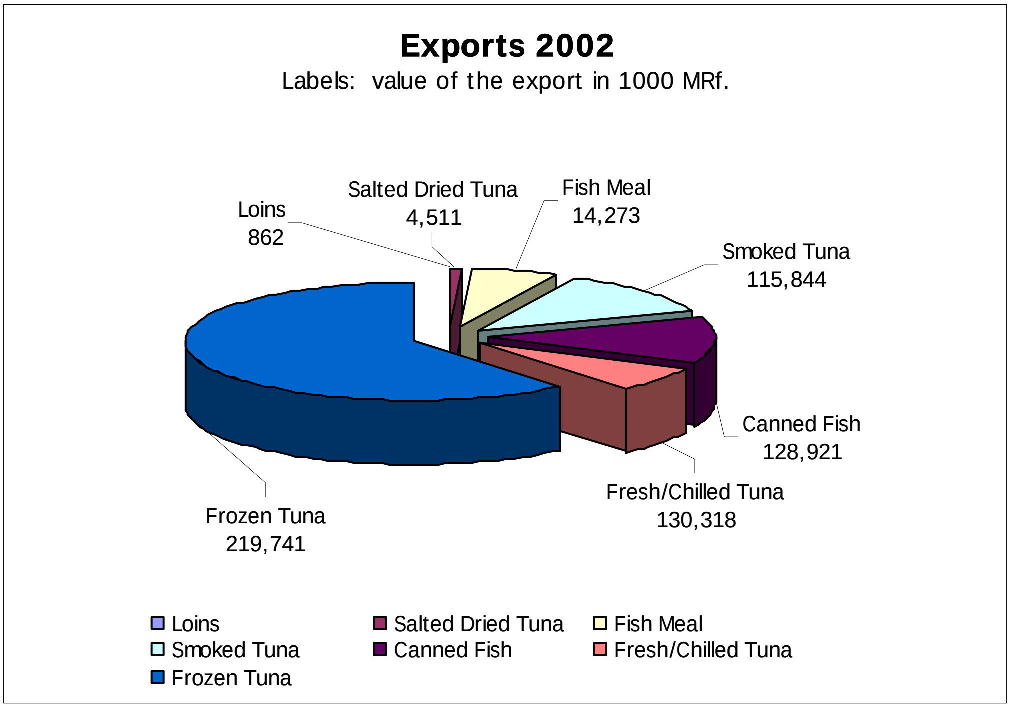

*Figure 11: Values of tuna exports from the Maldives, 2002*

*Source: Customs data compiled by MOFMAR / Statistics and Database Management Services*

*Table 1: Recorded tuna catches (t) in the Maldives by species, 1970-2002.*

*Source: MOFAMR, Statistics and Database Management Services.*

| Year | Skipjack | Yellowfin | Frigate | Kawakawa | Dogtooth | Total |
|---|---|---|---|---|---|---|
| 1970 | 27,684 | 1,989 | 3,023 | 644 | n/a | 33,340 |
| 1971 | 28,709 | 1,227 | 3,015 | 473 | n/a | 33,424 |
| 1972 | 17,971 | 2,076 | 3,186 | 596 | n/a | 23,829 |
| 1973 | 19,195 | 5,475 | 6,626 | 1,088 | n/a | 32,384 |
| 1974 | 22,160 | 4,128 | 6,006 | 830 | n/a | 33,124 |
| 1975 | 14,858 | 3,774 | 4,057 | 415 | n/a | 23,104 |
| 1976 | 20,092 | 4,891 | 2,707 | 953 | n/a | 28,643 |
| 1977 | 14,342 | 4,473 | 3,080 | 927 | n/a | 22,822 |
| 1978 | 13,824 | 3,584 | 1,661 | 768 | n/a | 19,837 |
| 1979 | 18,136 | 4,289 | 1,701 | 721 | n/a | 24,847 |
| 1980 | 23,561 | 4,229 | 1,595 | 1,063 | n/a | 30,448 |
| 1981 | 20,617 | 5,284 | 1,606 | 1,274 | n/a | 28,781 |
| 1982 | 15,881 | 4,005 | 2,061 | 1,887 | n/a | 23,834 |
| 1983 | 19,701 | 6,241 | 3,540 | 2,087 | n/a | 31,569 |
| 1984 | 32,048 | 7,124 | 3,105 | 1,714 | 376 | 44,367 |
| 1985 | 42,602 | 6,066 | 2,824 | 2,177 | 182 | 53,851 |
| 1986 | 45,445 | 5,321 | 1,778 | 1,071 | 136 | 53,751 |
| 1987 | 42,111 | 6,668 | 1,921 | 1,232 | 105 | 52,037 |
| 1988 | 58,546 | 6,535 | 1,629 | 1,257 | 84 | 68,051 |
| 1989 | 58,145 | 6,082 | 2,146 | 1,322 | 108 | 67,803 |
| 1990 | 59,899 | 5,279 | 3,013 | 1,891 | 281 | 70,363 |
| 1991 | 58,898 | 7,711 | 2,582 | 1,677 | 234 | 71,102 |
| 1992 | 58,577 | 8,697 | 3,389 | 2,451 | 337 | 73,451 |
| 1993 | 58,740 | 10,110 | 5,456 | 3,569 | 628 | 78,503 |
| 1994 | 69,411 | 13,126 | 4,019 | 2,656 | 387 | 89,599 |
| 1995 | 70,372 | 12,504 | 3,938 | 2,694 | 439 | 89,947 |
| 1996 | 66,502 | 12,440 | 6,485 | 3,789 | 624 | 89,840 |
| 1997 | 69,015 | 13,029 | 2,488 | 2,088 | 490 | 89,840 |
| 1998 | 78,409 | 14,170 | 4,217 | 3,624 | 470 | 103,885 |
| 1999 | 92,887 | 14,268 | 3,402 | 1,692 | 426 | 113,486 |
| 2000 | 79,682 | 12,185 | 3,990 | 1,897 | 451 | 101,727 |
| 2001 | 88,044 | 14,579 | 3,981 | 2,148 | 647 | 110,068 |
| 2002 | 115,322 | 21,729 | 4,187 | 2,242 | 789 | 147,826 |

*Table 2: Annual fishing effort (no. boat days) by vessel type, and number of fishermen, 1970-2002. P/L = pole and line*

*Source: MOFAMR, Statistics and Database Management Services.*

| Year | Sail P/L | Mech P/L | Total P/L | Std P/L | Trolling | No. Fishers |
|---|---|---|---|---|---|---|
| 1970 | 191,421 | - | 191,421 | 95,711 | 104,482 | 17,094 |
| 1971 | 169,237 | - | 169,237 | 84,619 | 67,378 | 18,075 |
| 1972 | 158,544 | - | 158,544 | 79,272 | 76,136 | 18,535 |
| 1973 | 215,278 | - | 215,278 | 107,639 | 90,461 | 18,807 |
| 1974 | 203,362 | - | 203,362 | 101,681 | 93,504 | 19,362 |
| 1975 | 171,808 | 4,200 | 176,008 | 90,104 | 90,100 | 19,666 |
| 1976 | 153,539 | 21,800 | 175,339 | 98,570 | 135,031 | 21,381 |
| 1977 | 104,943 | 41,300 | 146,243 | 93,772 | 157,948 | 21,594 |
| 1978 | 53,739 | 54,800 | 108,539 | 78,311 | 176,878 | 22,683 |
| 1979 | 24,615 | 74,904 | 99,519 | 84,135 | 132,903 | 23,924 |
| 1980 | 16,877 | 83,134 | 100,011 | 88,408 | 136,934 | 24,330 |
| 1981 | 13,852 | 83,731 | 97,583 | 87,194 | 130,362 | 22,301 |
| 1982 | 10,036 | 97,085 | 107,121 | 98,967 | 132,342 | 21,727 |
| 1983 | 6,339 | 117,172 | 123,511 | 117,964 | 118,639 | 22,262 |
| 1984 | 6,220 | 153,460 | 159,680 | 153,849 | 108,314 | 21,028 |
| 1985 | 4,681 | 162,430 | 167,111 | 164,054 | 110,061 | 19,671 |
| 1986 | 3,354 | 161,910 | 165,264 | 165,148 | 79,139 | 22,245 |
| 1987 | 2,355 | 158,785 | 161,140 | 163,549 | 69,380 | 22,387 |
| 1988 | 1,242 | 184,353 | 185,595 | 191,727 | 51,460 | 21,880 |
| 1989 | 911 | 183,944 | 184,855 | 193,141 | 39,725 | 22,025 |
| 1990 | 1,317 | 193,045 | 194,362 | 204,628 | 37,933 | 21,725 |
| 1991 | 424 | 198,320 | 198,744 | 212,202 | 35,814 | 21,432 |
| 1992 | 3,602 | 204,808 | 208,410 | 221,193 | 28,137 | 21,195 |
| 1993 | 1,057 | 222,548 | 223,605 | 242,577 | 34,507 | 19,995 |
| 1994 | 1,138 | 223,095 | 224,233 | 245,405 | 31,687 | 22,268 |
| 1995 | 623 | 240,858 | 241,481 | 267,352 | 30,826 | 21,932 |
| 1996 | 731 | 239,787 | 240,518 | 268,561 | 30,431 | 22,109 |
| 1997 | 580 | 237,661 | 238,241 | 268,557 | 32,106 | 22,463 |
| 1998 | 3,020 | 224,751 | 227,771 | 256,216 | 24,436 | 21,998 |
| 1999 | 6,050 | 210,816 | 216,866 | 242,438 | 18,323 | 22,098 |
| 2000 | 6,048 | 202,195 | 208,243 | 234,546 | 17,513 | 19,108 |
| 2001 | 9,508 | 205,897 | 215,405 | 240,899 | 14,273 | 16,816 |
| 2002 | 13,776 | 209,839 | 223,615 | 247,610 | 10,463 | 14,355 |

*Table 3: Numbers of active masdhonis (pole and line fishing vessels) operating in the Maldives, 1985-2002.*

*Source: MOFAMR, Statistics and Database Management Services.*

| Year | Sail P/L | Mech P/L | Total P/L |
|---|---|---|---|
| 1985 | 43 | 988 | 1031 |
| 1986 | 32 | 1009 | 1041 |
| 1987 | 21 | 1044 | 1065 |
| 1988 | 16 | 1096 | 1112 |
| 1989 | 14 | 1114 | 1128 |
| 1990 | 11 | 1151 | 1162 |
| 1991 | 6 | 1252 | 1258 |
| 1992 | 38 | 1347 | 1385 |
| 1993 | 15 | 1434 | 1449 |
| 1994 | 42 | 1410 | 1452 |
| 1995 | 8 | 1407 | 1415 |
| 1996 | 13 | 1397 | 1410 |
| 1997 | 9 | 1328 | 1337 |
| 1998 | 30 | 1271 | 1301 |
| 1999 | 52 | 1206 | 1258 |
| 2000 | 41 | 1137 | 1178 |
| 2001 | 66 | 1128 | 1194 |
| 2002 | 90 | 1102 | 1192 |

*Table 4. EEZ fishery catch and fishing effort, 1997-2002 (Source: MOFAMR)*

| | Tuna catch (t) | No. longliners | No. fishing days |
|---|---|---|---|
| 1997 | 5,990 | 48 | 4,523 |
| 1998 | 2,994 | 46 | 3,990 |
| 1999 | 811 | 32 | 1,453 |
| 2000 | 3,521 | 49 | 4,445 |
| 2001 | 667 | 20 | 3,372 |
| 2002 | 3,556 | 43 | 7,497 |

*Table 5: Catch and effort data for longline vessels operating in the Maldivian EEZ, 2002. Source: MOFAMR, Statistics and Database Management Services.*

| | Maldivian Vessels | Foreign Vessels | Total |
|---|---|---|---|
| **CATCH (t)** | | | |
| Bigeye Tuna | 60.1 t | 1618.9 t | 1678.9 t |
| Yellowfin Tuna | 7.1 t | 1869.9 t | 1877.1 t |
| Others | 8.1 t | 532.3 t | 543.4 t |
| TOTAL | 75.2 t | 4024.1 t | 4099.4 t |
| | | | |
| **FISHING EFFORT** | | | |
| No. vessels | 4 | 39 | 43 |
| No. fishing days | 260 | 7237 | 7497 |

*Table 6: Estimated Maldivian BIGEYE TUNA catches (excluding EEZ catches)*

*Note: Bigeye tuna catches are estimated from Thunnus ('yellowfin') catch numbers following Anderson (1996) ie using different proportions in the north and centre of the Maldives (HA to Dh Atolls) and in the south (Th to S Atolls).*

*Original data source: MOFAMR. 2000 & 2001 data and estimates are provisional and will be revised.*

| | **Total *Thunnus* catch (t)** | | | **Estimated Bigeye catch (t)** | | | **%** |
|---|---|---|---|---|---|---|---|
| **Year** | **North** | **South** | **Total** | **North** | **South** | **Total** | **Bigeye** |
| 1970 | 1,530 | 459 | 1,989 | 8 | 73 | 81 | 4.1 |
| 1971 | 940 | 287 | 1,227 | 5 | 45 | 51 | 4.2 |
| 1972 | 1,770 | 306 | 2,076 | 10 | 48 | 58 | 2.8 |
| 1973 | 4,822 | 653 | 5,475 | 27 | 103 | 130 | 2.4 |
| 1974 | 3,462 | 666 | 4,128 | 19 | 105 | 124 | 3.0 |
| 1975 | 3,257 | 517 | 3,774 | 18 | 82 | 100 | 2.6 |
| 1976 | 4,135 | 756 | 4,891 | 23 | 119 | 142 | 2.9 |
| 1977 | 3,584 | 889 | 4,473 | 20 | 140 | 160 | 3.6 |
| 1978 | 2,935 | 649 | 3,584 | 16 | 103 | 119 | 3.3 |
| 1979 | 3,579 | 710 | 4,289 | 20 | 112 | 132 | 3.1 |
| 1980 | 3,696 | 533 | 4,229 | 20 | 84 | 105 | 2.5 |
| 1981 | 3,965 | 1,319 | 5,284 | 22 | 208 | 230 | 4.4 |
| 1982 | 3,505 | 500 | 4,004 | 19 | 79 | 98 | 2.4 |
| 1983 | 5,383 | 858 | 6,241 | 30 | 136 | 165 | 2.6 |
| 1984 | 4,965 | 2,159 | 7,124 | 27 | 341 | 368 | 5.2 |
| 1985 | 4,208 | 1,858 | 6,066 | 23 | 294 | 317 | 5.2 |
| 1986 | 4,113 | 1,208 | 5,321 | 23 | 191 | 213 | 4.0 |
| 1987 | 4,824 | 1,846 | 6,670 | 27 | 291 | 318 | 4.8 |
| 1988 | 4,691 | 1,844 | 6,535 | 26 | 291 | 317 | 4.9 |
| 1989 | 4,296 | 1,786 | 6,082 | 24 | 282 | 306 | 5.0 |
| 1990 | 3,544 | 1,735 | 5,280 | 19 | 274 | 294 | 5.6 |
| 1991 | 4,817 | 2,894 | 7,711 | 26 | 457 | 484 | 6.3 |
| 1992 | 6,469 | 2,228 | 8,697 | 36 | 352 | 388 | 4.5 |
| 1993 | 7,163 | 2,947 | 10,110 | 39 | 466 | 505 | 5.0 |
| 1994 | 10,281 | 2,845 | 13,126 | 57 | 450 | 506 | 3.9 |
| 1995 | 9,851 | 2,653 | 12,504 | 54 | 419 | 473 | 3.8 |
| 1996 | 8,758 | 3,682 | 12,440 | 48 | 582 | 630 | 5.1 |
| 1997 | 9,923 | 3,105 | 13,029 | 55 | 491 | 546 | 4.2 |
| 1998 | 11,201 | 2,969 | 14,170 | 53 | 531 | 584 | 4.1 |
| 1999 | 9,694 | 4,575 | 14,268 | 43 | 963 | 1,007 | 7.1 |
| 2000 | 9,478 | 2,707 | 12,185 | 37 | 523 | 560 | 4.6 |
| 2001 | 9,232 | 4,666 | 13,897 | 34 | 889 | 923 | 6.6 |
| 2002 | 13,280 | 5,736 | 19,016 | 51 | 1097 | 1148 | 6.0 |

*Table 7. Shark species sampled from longline landings in northern Maldives, 2000-02*

*Source: Anderson, 2002*

| **Species** | | **Numbers** | **Percentage** |
|---|---|---|---|
| Silky Shark | Carcharhinus falciformis | 612 | 84.4 |
| Oceanic Whitetip | *Carcharhinus longimanus* | 27 | 3.7 |
| Blue Shark | *Prionace glauca* | 25 | 3.4 |
| Longfin Mako | *Isurus paucus* | 22 | 3.0 |
| Silvertip Shark | *Carcharhinus albimarginatus* | 15 | 2.1 |
| Others | | 24 | 3.3 |
| Total | | 725 | 100 |

*Table 8: Approximate species composition of Maldivian* ***daytime*** *livebait catches*

*Source: Anderson, 1997a*

| **English name** | **Species** | **Maldivian name** | **Percentage** |
|---|---|---|---|
| Silver sprat | *Spratelloides gracilis* | *Rehi* | 38 ± 10 % |
| Fusiliers | Various Caesionids | *Muguraan* | 37 ± 9 % |
| Cardinalfishes | Various Apogonids | *Boadhi & fatha* | 10 ± 3 % |
| Anchovy | *Encrasicholina heteroloba* | *Miyaren* | 7 ± 2 % |
| Blue sprat | *Spratelloides delicatulus* | *Hondeli* | 5 ± 1 % |
| Others | Various species | *Nilamehi, bureki, gumbalha* | 2 ± 2 % |

*Table9: Approximate species composition of Maldivian* ***night-time*** *livebait catches*

*Note: from two samples totaling 138 vessels. Source : Anderson et al., 1997*

| **English name** | **Species** | **Maldivian name** | **Percentage** |
|---|---|---|---|
| Silver sprat | *Spratelloides gracilis* | *Rehi* | 50-90 % |
| Blue sprat | *Spratelloides delicatulus* | *Hondeli* | 3-38 % |
| Anchovy | *Encrasicholina heteroloba* | *Miyaren* | 4-12 % |
| Others | Various species | | 0-3 % |

*Table 10: Export quantities (t) of tunas and tuna products from the Maldives, 1997-2002.*

*Note: Weights are actual export weights, not live weights*

*Source: Customs data compiled by MOFAMR / Statistics and Database Management Services.*

| **Commodity** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
|---|---|---|---|---|---|---|
| Canned | 6,826 | 6,726 | 4,564 | 7,676 | 7,212 | 5,728 |
| Frozen | 13,279 | 12,607 | 21,095 | 9,925 | 13,282 | 28,100 |
| Fish Meal | 2,440 | 2,080 | 2,690 | 2,080 | 2,123 | 2,770 |
| Smoked | 3,868 | 5,684 | 5,281 | 5,674 | 6,067 | 5,815 |
| Salted Dried | 1,483 | 1,189 | 1,137 | 140 | 97 | 382 |
| Fresh/chilled | 2,968 | 2,344 | 584 | 3,994 | 1,198 | 3,090 |
| Loins | NA | NA | NA | 72 | 8 | 10 |
| Others | NA | NA | NA | NA | 41 | NA |

*Table 11: Export values ('000 MRf) of tunas and tuna products from the Maldives, 1997-2002.*

*Note: US$ 1 = MRf 11.72 in 2001*

*Source: Customs data compiled by MOFAMR / Statistics and Database Management Services.*

| **Commodity** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
|---|---|---|---|---|---|---|
| Canned | 192,260 | 196,807 | 101,501 | 127,070 | 120,163 | 128,921 |
| Frozen | 132,754 | 200,239 | 146,333 | 53,760 | 88,702 | 219,740 |
| Fish Meal | 16,944 | 15,609 | 15,819 | 9,479 | 10,878 | 14,272 |
| Smoke dried | 79,064 | 108,260 | 105,491 | 127,856 | 136,291 | 115,843 |
| Salt dried | 14,572 | 13,704 | 8,922 | 422 | 1,063 | 4,510 |
| Fresh/chilled | 120,253 | 72,038 | 13,417 | 62,202 | 64,415 | 130,317 |
| Loins | NA | NA | NA | 1,959 | 429 | 861 |
| Others | NA | NA | NA | NA | 594 | NA |
| Total | 555,847 | 606,657 | 391,483 | 382,748 | 422,535 | 614,464 |