# THE MALDIVIAN TUNA FISHERY AND INDO-PACIFIC OCEAN VARIABILITY

R. Charles Anderson

*Marine Research Centre, H. Whitewaves, Malé, Republic of Maldives*

## ABSTRACT

*Maldivian tuna catches are affected by changes in oceanographic conditions, including those associated with ENSO events and with decadal-scale oscillations. Three types of variability are considered here. (1). On inter-annual time scales, catch rates of skipjack tuna tend to go down during El Niño events, while catch rates of yellowfin tuna, frigate tuna and kawakawa tend to go up. The opposite is seen during La Niña events. (2). Over decadal scales, skipjack catches were higher and yellowfin tuna catches were lower than average during 1970-72 and 1985-92, but the opposite was seen during 1973-84 and 1993-98. This is interpreted as evidence for a decadal-scale oscillation in Indian Ocean oceanographic conditions, with a period of about 20 years. (3). Over still longer periods, frigate tuna catches have decreased while kawakawa catches have increased. This is interpreted as possible evidence for a decadal-scale oscillation in Indian Ocean oceanographic conditions, with a period of perhaps 60 years or longer. The lack of understanding of Indian Ocean variability is a hindrance to a full understanding of Indian Ocean tuna dynamics.*

## INTRODUCTION

Of all the fishes, the tunas are among the most supremely adapted to the oceanic environment, and the most responsive to its variations (Sharp and Dizon, 1978). An understanding of the changes in the distribution and abundance of tunas therefore requires an understanding of ocean variability.

The Indian Ocean is the least studied of the major oceans. In particular, there are few, if any, long time series of high quality, wide-scale oceanographic data. As a result it is difficult to assess ocean variability on inter-annual and decadal time scales within the Indian Ocean.

The Maldives has a major traditional tuna fishery, which has been in existence for centuries. The main fishing gear used is livebait pole and line. The main species caught is skipjack tuna (*Katsuwonus pelamis*), with yellowfin tuna (*Thunnus albacares*) being the second most important species. Significant quantities of frigate tuna (*Auxis thazard*) and kawakawa (*Euthynnus affinis*) are also taken. Total tuna catches in recent years have been of the order of 90,000 t. Some catch and effort data have been collected since 1959, and a detailed catch and effort data time series is available from 1970.

The Maldivian data provide a unique time series of information on apparent abundance of surface tunas in the Indian Ocean. Analysis of this time series has provided some important insights into the role of Indo-Pacific Ocean variability on Indian Ocean tuna resource availability, but has also highlighted significant gaps in our understanding.

## MATERIALS AND METHODS

A time series of detailed catch and effort data is available from the Maldivian tuna fishery from 1970. Catch (in numbers of tuna) is available by species, by month, by atoll and by major vessel type. A summary of annual catches by pole and line vessels (*masdhonis*) is given in Table 1. Fishing effort (in numbers of days fished) is available by month, by atoll and by major vessel type. Catch per unit effort (CPUE) is calculated in kg per day (Table 2 and Figs. 1-4). During the period 1970-98 there have been major changes in the fishing power of the main fleet component (the pole and line *masdhonis*) associated with:

- mechanization of the previously sailing fleet during the period 1975-84, and
- subsequent increase in fishing power of the mechanized fleet.

In order to minimize the effect of these changes on interpretation of CPUE data, fishing effort has been standardized (Table 2), following the methodology of Anderson Waheed and Adam (1998: 32). Note that even after standardization, the use of pole and line CPUE data as indices of tuna abundance is not without problems (Anderson et al., 1998: 29). Nevertheless, the underlying data are believed to be mostly sound, and to give a reasonable measure of local apparent abundance of tuna (Anderson and Hafiz, 1996; Anderson et al., 1998).

## RESULTS AND DISCUSSION

### El Niño-Southern Oscillation Events

In the Indian Ocean region, Walker (1924) first identified the atmospheric perturbations that are now known to be associated with El Niño-Southern Oscillation (ENSO) events. More recently, Cadet (1985) and Tourre and White (1997) have reviewed changes in oceanographic conditions in the Indian Ocean associated with the development of ENSO events.

Maldivian tuna catches are profoundly affected by ENSO events. This was noted by Anderson (1987), and has subsequently been reported by several authors (Anderson, 1991, 1993 & 1997; Rochepeau and Hafiz, 1990; Hafiz and Anderson, 1994; MRS, 1996; Anderson et al., 1998). Skipjack catches by pole and line vessels tend to be reduced during El Niño events, while those of the other main tuna species tend to increase (Figs. 1-4 and Table 3). In contrast, during La Niña (anti-El Niño) years, skipjack catch rates tend to increase while those of yellowfin and kawakawa (but not frigate tuna) tend to decrease. For trolling vessels (which catch mainly kawakawa) the same pattern is seen, with high catch rates of kawakawa during El Niño years, and low catch rates during La Niña years (Anderson, Waheed and Scholz, 1998).

The statistical significance of the observed pattern of deviations in catch rates in relation to ENSO events (Table 3, Fig. 5) is assessed assuming that the probability of any year's catch rate being above average is equal to it being below average, i.e. 0.5. In this case the probabilities of having deviations of the expected sign during the ten El Niño and La Niña events of 1970-98 are:

| | | | |
|---|---|---|---|
| Skipjack | 10 'trials' | 9 'successes' | p = 0.011 |
| Yellowfin | 10 'trials' | 8 'successes' | p = 0.055 |
| Frigate tuna | 10 'trials' | 6 'successes' | p = 0.376 |
| Kawakawa | 10 'trials' | 7 'successes' | p = 0.172 |
| All tunas | 40 'trials' | 30 'successes' | p = 0.001 |

The relationships between ENSO events and CPUE deviations of skipjack and of all tunas combined are clearly significant. Frigate tuna does not show the expected relationship: while CPUE deviations are consistently positive during El Niño events, they are not negative during La Niña events. Note also that the events of 1996 and 1997 did not produce consistent CPUE deviations of the expected sign; 6 out of 8 'mismatches' occurred in these two years alone. The reasons for this are unknown. Excluding these two years from the analysis, the probabilities of having deviations of the expected sign during the eight El Niño and La Niña events of 1970-95 are:

| | | | |
|---|---|---|---|
| Skipjack | 8 'trials' | 8 'successes' | p = 0.004 |
| Yellowfin | 8 'trials' | 7 'successes' | p = 0.035 |
| Frigate tuna | 8 'trials' | 6 'successes' | p = 0.145 |
| Kawakawa | 8 'trials' | 7 'successes' | p = 0.035 |
| All tunas | 32 'trials' | 28 'successes' | p = 0.00001 |

The details of the oceanographic changes that influence Maldivian tuna catch rates during ENSO events are not known. During El Niño years, increased atmospheric pressure, sea surface temperatures and upper ocean heat storage, and reduced surface winds occur over large areas of the Indian Ocean (Cadet, 1985; Tourre and White, 1997). It has been suggested that increased sea surface temperatures reduce the availability of skipjack (and of relatively heat-sensitive large skipjack in particular) to the Maldivian surface, i.e. pole and line, fishery (Adam and Anderson, 1998). Elsewhere in the western Indian Ocean, it has been suggested that changes in oceanographic conditions associated with El Niño events promote the survival of yellowfin larvae, leading to increased purse seine catches (Hallier and Marsac, 1991). For the Maldivian pole and line fleet, yellowfin catch rates during prolonged El Niño events tend to be elevated only during the latter part of each event (i.e. in 1973, 1983 and 1994 but not in 1972, 1982 or 1991-93). This observation lends support to the hypothesis that El Niño events promote the survival of yellowfin larvae, and hence recruitment to the fisheries only after an appropriate time lag.

### Decadal-Scale Variation (approx 20-year period)

Over longer (decadal) time scales, cyclical shifts occur in the oceanographic climate regime with associated shifts in biological productivity and species composition. An Indo-Pacific example is the North Pacific Oscillation (Polovina et al., 1994; Trenberth and Hurrell, 1994), which has been shown to have, among other things, a profound impact on north Pacific albacore tuna catches (Au and Cayan, 1998).

Maldivian tuna catches show clear cyclical shifts. This was first reported by Anderson (1993), who noted that over periods of several years skipjack catches tended to go down while those of yellowfin, frigate tuna and kawakawa tended to go up, and vice versa. More specifically, periods of *consistently* high skipjack and low yellowfin catches alternate with periods of *consistently* low skipjack and high yellowfin catches. The apparent abundance of these two major species during different periods may be summarized as follows:

| | |
|---|---|
| 1970-72 | high skipjack and low yellowfin abundance |
| 1973-84 | low skipjack and high yellowfin abundance |
| 1985-92 | high skipjack and low yellowfin abundance |
| 1993-98 | low skipjack and high yellowfin abundance |

Note that the data series only runs from 1970 to 1998, therefore there is no information regarding the ‘starting date’ of the first period prior to 1970, or, so far, on the ‘ending date’ of the last period. Note also that this signal is very strong, and is apparent in the data for both skipjack and yellowfin, and in both catch (Table 1) and CPUE data (Figs. 1, 2 & 6). In order to highlight the nature of the cycle, Fig. 6 shows 3 year running means of normalized standardized pole and line catch rates for skipjack and yellowfin.

The significance of the observed pattern is assessed using ‘runs tests’, the results of which are summarized in Table 4. Every case is significant, i.e. the probability of getting so few runs is less than that expected by chance alone. Furhtermore, in the comparison of skipjack and yellowfin catch rates, there are only 6 years out of 29 in which skipjack and yellowfin catch rates are both above or both below the mean. The probability of this happening by chance alone is just 0.0012 (i.e. about 1 in 800).

It is known that tunas are highly adapted to their oceanic environment, and it is assumed that many aspects of their population variability can be explained by ocean variability. Some aspects of Maldivian skipjack and yellowfin tuna catch variability can be explained in terms of *known* ocean variability (i.e. in relation to ENSO events). In particular, skipjack and yellowfin tuna responses to ENSO events are out-of-phase (i.e. skipjack catch rates tend to go down while yellowfin tuna catch rates go up and vice versa). It is demonstrated here that Maldivian skipjack and yellowfin tuna catches show consistent, but out-of-phase, changes in apparent abundance on decadal time scales. It is therefore suggested that decadal-scale variations in skipjack and yellowfin catches are related to decadal-scale oceanographic variations in the tropical Indian Ocean, with a period of about 20 years.

The nature of the proposed decadal-scale oceanographic variations is as yet unknown. However, the timing of shifts in apparent abundance of skipjack and yellowfin in Maldivian waters corresponds rather closely to changes in the North Pacific Oscillation. A major climate shift in the North Pacific started in about 1976 and lasted about 12 years, ending in about 1988 (Polovina et al., 1994; Trenberth and Hurrell, 1994). The Maldivian tuna data suggest a climate shift in the central Indian Ocean starting in about 1973, lasting about 12 years and ending in about 1985. This is suggestive of a link between the two oceans. The apparent lag of 3 years between the presumed event in the Indian Ocean and that observed in the North Pacific suggests that these decadal-scale events may be propagated from the Indian Ocean to the Pacific Ocean and not vice versa. A possible route for such propagation is via the Indonesian Throughflow (Godfrey, Hirst and Wilkin, 1993; Allan, Lindesay and Reason, 1995). Alternatively (or additionally) the apparently correlated events in the North Pacific and in the Maldives may both be linked though a third agency, for example the eastward propagating Antarctic Circumpolar Wave in the Southern Ocean (White and Peterson, 1996). This has been shown to be strongly correlated with ENSO events and the Indian Monsoons (Yuan, Cane and Martinson, 1996). At present, however, the nature of any teleconnection between decadal-scale events in the tropical Indian Ocean and the North Pacific Oscillation is just speculation. Nevertheless, the prospect of being able to forecast events in the North Pacific by 3 years must make this an important area for further research.

### Decadal-Scale Variation (approx 60-year period or longer)

If skipjack and yellowfin tuna can in some respects be considered to form a complimentary pair, then frigate tuna and kawakawa may perhaps be considered to form a second species pair. Both are relatively small species and both are relatively neritic. In addition, Maldivian fishermen consider them to be similar, often referring to them jointly as *latti-raagondi*.

During the period 1970-98, frigate tuna catch rates by pole and line vessels have tended to decrease, while kawakawa catch rates have tended to increase (Figs. 3 & 4). The relative importance of the two species can be visualized by comparing normalized pole and line catch rates (Fig. 7). These figures suggest that there has been a shift in the relative importance of the two species:

1970s high frigate tuna and low kawakawa catches

1980s average frigate tuna and kawakawa catches

1990s low frigate tuna and high kawakawa catches

The reason(s) for this apparent shift in the relative abundance of frigate tuna and kawakawa is not known. One possibility is that there has been a frigate/kawakawa regime shift comparable to the pilchard/sardine regime shifts seen in temperate waters. This would imply that these species are responding to variations in oceanographic conditions on even longer time scales than the decadal-scale variability discussed in the previous section. If this is the case the data available might be taken to represent perhaps one half of one cycle or less, suggesting a cycle period of about 50-60 years or more. This timescale is consistent with some studies from the North Pacific (Minobe, 1996; Mantua et al., 1997). However, with so few data available from the Maldives, and no known oceanographic evidence to support such a cycle in the tropical Indian Ocean it is premature to speculate further.

### Global Warming

It is likely that changes in oceanographic conditions in the Indian Ocean associated with global warming will have profound effects on tuna distribution and abundance (Sharp, 1992). SST and Southern Oscillation Index data show evidence of changes consistent with global warming over the time period under consideration here. The medium- and long-term implications of these changes for Indian Ocean tuna resources is unknown. It may be pertinent to note that deviations of skipjack and yellowfin catch rates in relation to both ENSO events and the proposed 20-year cycle have decreased over the period 1970-98 (Figs. 5 & 6). Whether this is related to the net decrease in the Southern Oscillation Index over the same time period, to long-period (60 year or more) decadal-scale variations (section above), or is a manifestation of global warming, is unknown.

## CONCLUSIONS

Maldivian tuna catches, and by extension Indian Ocean tuna stocks, are affected by ENSO events, decadal-scale ocean variations, and (probably) other long term ocean variability including changes associated with global warming. Attempts to model tuna population dynamics which fail to take account of such variability are likely to prove of limited value. And yet at present our understanding of 'normal' oceanographic conditions in the central Indian Ocean, let alone variations from the norm, is limited.

As one example, the Maldivian skipjack resource supports a fishery of national importance. Skipjack tuna contributes some 68% to the country's total fish catch. The skipjack fishery is of such great importance to the Maldivian economy that a collapse of the fishery would be a national disaster. Over recent years there have been a number of signs that the fishery may not be in good condition, with declines in catch rates and average sizes (Adam and Anderson, 1996 & 1998). These changes might be the result of a negative impact of the western Indian Ocean purse seine fishery on the Maldivian fishery (Adam and Anderson, 1996 & 1998). However, 'natural' variations in catch rates of ±20% and more appear to occur as a result of variations in both ENSO conditions and decadal cycle state. At present our understanding of Indian Ocean skipjack population dynamics and of the oceanography of the tropical Indian Ocean is insufficient to distinguish between 'natural' and fisheries-related declines in Maldivian skipjack catch rates of 50%. This should be a cause for utmost concern.

## ACKNOWLEDGEMENTS

I am most grateful to the Economic Planning and Coordination Section of the Ministry of Fisheries, Agriculture and Marine Resources, and in particular Mr. Hassan Rasheed, for supplying Maldivian tuna fisheries data over many years. Mr. Shiham Adam has been most helpful in providing discussion and advice.

## REFERENCES

ADAM M.S. AND R.C.ANDERSON 1996: Skipjack tuna (*Katsuwonus pelamis*) in the Maldives. pp.232-238. In: A.A.Anganuzzi, K.A.Stobberup and N.J.Webb (eds) Proceedings of the Sixth Expert Consultation on Indian Ocean Tunas, Colombo, Sri Lanka, September 1995. IPTP, Colombo. 373pp.

ADAM M.S. AND R.C.ANDERSON 1998: Skipjack tuna (*Katsuwonus pelamis*). pp.47-77. In: R.C.Anderson, Z.Waheed and M.S.Adam. The tuna fishery resources of the Maldives. Maldives Marine Research Bulletin 3: 180pp.

ALLAN R.J., J.A.LINDESAY AND C.J.C.REASON 1995: Multidecadal variability in the climate system over the Indian Ocean region during the Austral summer. J. Climate 8: 1853-1873.

ANDERSON R.C. 1987: Small tunas, seerfishes and billfishes in the Maldives. pp. 38-45. In: Report of Workshop on Small Tuna, Seerfish and Billfish in the Indian Ocean. Colombo, Sri Lanka, December 1987. IPTP/87/GEN/13: 123pp.

ANDERSON R.C. 1993: Oceanographic variations and Maldivian tuna catches. Rasain 13: 215-224.

ANDERSON R.C. AND A.HAFIZ 1996: Status of tuna research and data collection in the Maldives. pp.361-367. In: A.A.Anganuzzi, K.A.Stobberup and N.J.Webb (eds) Proceedings of the Sixth Expert Consultation on Indian Ocean Tunas, Colombo, Sri Lanka, September 1995. IPTP, Colombo. 373pp.

ANDERSON R.C., Z.WAHEED AND M.S.ADAM 1998: The tuna fishery resources of the Maldives. Maldives Marine Research Bulletin 3: 180pp.

ANDERSON R.C., Z.WAHEED AND O.SCHOLZ 1998: Kawakawa (*Euthynnus affinis*). pp.127-144. In: R.C.Anderson, Z.Waheed and M.S.Adam. The tuna fishery resources of the Maldives. Maldives Marine Research Bulletin 3: 180pp.

AU D.W. AND D.R.CAYAN 1998: North Pacific albacore catches and decadal-scale climatic shifts. Tuna Newsletter (U.S. National Marine Fisheries Service) 130: 5-8.

CADET D.L. 1985: The southern oscillation over the Indian Ocean. Journal of Climatology 5: 189-212.

GODFREY J.S., A.C.HIRST AND J.WILKIN 1993: Why does the Indonesian through-flow appear to originate in the North Pacific? J. Phys. Oceanogr. 23: 1087-1098.

HAFIZ A. AND R.C.ANDERSON 1994: The Maldivian tuna fishery – an update. pp. 30-33. In: J.D.Ardill (ed) Proceedings of the Fifth Expert Consultation on Indian Ocean Tunas, Mahé, Seychelles, October 1993. IPTP, Colombo. 275pp.

HALLIER J.P. AND F.MARSAC 1991: The recent drop in yellowfin catches by the western Indian Ocean purse seine fishery: overfishing or oceanographic changes? IPTP Coll. Vol. Work. Docs. 4: 66-83.

MANTUA N.J., S.R.HARE, Y.ZHANG, J.M.WALLACE AND R.C.FRANCIS 1997: A Pacific interdecadal oscillation with impacts on salmon production. Bull. Amer. Meteor. Soc. 78: 1069-1079.

MINOBE S. 1996: Climate variability with periodicity of 50-70 years over the North Pacific and North America. Geophys. Res. Lett. 24: 683-686.

MRS 1996: The Maldivian tuna fishery: a collection of tuna resource research papers. Maldives Marine Research Bulletin 2: 176pp.

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.

ROCHEPEAU S. AND A.HAFIZ 1990: Analysis of Maldivian tuna fisheries data 1970-1988. IPTP/90/WP/22: 56pp.

SHARP G.D. 1992: Climate change, the Indian Ocean tuna fishery, and empiricism. pp.377-416. In: M.H.Glantz and L.Feingold (eds) Climate variability, climate change and fishery. Cambridge University Press.

SHARP G.D. AND A.E.DIZON (EDS) 1978: The physiological ecology of tunas. Academic Press, San Francisco.

TOURRE Y.M. AND W.B.WHITE 1997: Evolution of the ENSO signal over the Indo-Pacific domain. J. Phys. Oceanogr. 27: 683-696.

TRENBERTH K.E. AND J.W.HURRELL 1994: Decadal atmosphere-ocean variations in the Pacific. Climate Dynamics 9: 303-319.

WALKER G.T. 1924: Correlation in seasonal variations in weather, IX: A further study of world weather. Mem. Indian Meteor. Dept. 24: 275. [Not seen: cited by Cadet, 1985].

WHITE W.B. AND R.G.PETERSON 1996: An Antarctic circumpolar wave in surface pressure, wind, temperature, and sea-ice extent. Nature 380: 699-702.

YUAN X., M.A.CANE AND D.G.MARTINSON 1996: Climate Variations: Cycling around the South Pole. Nature 380: 673-674.

*Table 1. Catches (t) of major tuna species by Maldivian pole and line vessels*

| **Year** | **Skipjack** | **Yellowfin** | **Frigate** | **Kawakawa** | **Total Tuna** |
|---|---|---|---|---|---|
| 1970 | 27,068 | 1,799 | 2,775 | 242 | 31,884 |
| 1971 | 28,200 | 1,081 | 2,849 | 220 | 32,350 |
| 1972 | 17,634 | 1,940 | 3,004 | 253 | 22,831 |
| 1973 | 18,761 | 5,234 | 6,440 | 574 | 31,009 |
| 1974 | 21,760 | 3,868 | 5,804 | 397 | 31,829 |
| 1975 | 14,601 | 3,512 | 3,894 | 147 | 22,154 |
| 1976 | 19,603 | 4,481 | 2,419 | 191 | 26,694 |
| 1977 | 14,032 | 4,123 | 2,816 | 160 | 21,131 |
| 1978 | 13,549 | 3,214 | 1,455 | 133 | 18,351 |
| 1979 | 17,798 | 3,692 | 1,429 | 173 | 23,092 |
| 1980 | 23,074 | 3,647 | 1,291 | 295 | 28,307 |
| 1981 | 20,198 | 4,740 | 1,297 | 403 | 26,638 |
| 1982 | 15,694 | 3,770 | 1,830 | 843 | 22,137 |
| 1983 | 19,491 | 5,984 | 3,189 | 993 | 29,657 |
| 1984 | 31,593 | 6,894 | 2,767 | 695 | 42,069 |
| 1985 | 42,170 | 5,797 | 2,141 | 910 | 51,018 |
| 1986 | 45,268 | 5,200 | 1,439 | 499 | 52,406 |
| 1987 | 41,872 | 6,531 | 1,605 | 566 | 50,574 |
| 1988 | 58,108 | 6,378 | 1,387 | 701 | 66,574 |
| 1989 | 57,806 | 5,978 | 1,949 | 824 | 66,557 |
| 1990 | 59,771 | 5,230 | 2,781 | 1,253 | 69,035 |
| 1991 | 58,761 | 7,654 | 2,423 | 1,248 | 70,086 |
| 1992 | 58,362 | 8,639 | 3,252 | 2,063 | 72,316 |
| 1993 | 58,559 | 10,023 | 5,250 | 3,081 | 76,913 |
| 1994 | 68,519 | 12,867 | 3,767 | 2,228 | 87,382 |
| 1995 | 69,453 | 12,340 | 3,723 | 2,285 | 87,869 |
| 1996 | 65,870 | 12,286 | 6,237 | 3,367 | 87,760 |
| 1997 | 68,183 | 12,847 | 2,417 | 1,865 | 85,312 |
| 1998 | 77,796 | 13,923 | 4,039 | 3,051 | 98,809 |

*Table 2. Standardized catch rates (kg/day) of major tuna species and standardized fishing effort (days fished) by Maldivian pole and line vessels*

| Year | Skipjack | Yellowfin | Frigate | Kawakawa | Std Effort |
|---|---|---|---|---|---|
| 1970 | 283 | 19 | 29 | 3 | 95,711 |
| 1971 | 333 | 13 | 34 | 3 | 84,619 |
| 1972 | 222 | 24 | 38 | 3 | 79,272 |
| 1973 | 174 | 49 | 60 | 5 | 107,639 |
| 1974 | 214 | 38 | 57 | 4 | 101,681 |
| 1975 | 162 | 39 | 43 | 2 | 90,104 |
| 1976 | 199 | 45 | 25 | 2 | 98,570 |
| 1977 | 150 | 44 | 30 | 2 | 93,772 |
| 1978 | 173 | 41 | 19 | 2 | 78,311 |
| 1979 | 212 | 44 | 17 | 2 | 84,135 |
| 1980 | 261 | 41 | 15 | 3 | 88,408 |
| 1981 | 232 | 54 | 15 | 5 | 87,194 |
| 1982 | 159 | 38 | 18 | 9 | 98,967 |
| 1983 | 165 | 51 | 27 | 8 | 117,964 |
| 1984 | 206 | 45 | 18 | 5 | 153,849 |
| 1985 | 257 | 35 | 13 | 6 | 164,054 |
| 1986 | 274 | 31 | 9 | 3 | 165,148 |
| 1987 | 256 | 40 | 10 | 3 | 163,549 |
| 1988 | 303 | 33 | 7 | 4 | 191,727 |
| 1989 | 299 | 31 | 10 | 4 | 193,141 |
| 1990 | 292 | 26 | 14 | 6 | 204,628 |
| 1991 | 277 | 36 | 11 | 6 | 212,202 |
| 1992 | 264 | 39 | 15 | 9 | 221,193 |
| 1993 | 241 | 41 | 22 | 13 | 242,577 |
| 1994 | 279 | 52 | 15 | 9 | 245,405 |
| 1995 | 260 | 46 | 14 | 9 | 267,352 |
| 1996 | 245 | 46 | 23 | 13 | 268,561 |
| 1997 | 254 | 48 | 9 | 7 | 268,557 |
| 1998 | 304 | 54 | 16 | 12 | 256,216 |

(Note: Catch rates in years listed compared with average of catch rates in year before and after)

*Table 3. Changes in Maldivian tuna catch rates (by standardized pole and line vessels) during ENSO events in comparison with 'normal' years.*

| ENSO events | Skipjack | Yellowfin | Frigate | Kawakawa |
|---|---|---|---|---|
| El Niño | | | | |
| 1972-73 | - 28% | + 44% | + 8% | + 31% |
| 1977 | - 20% | + 2% | + 39% | - 6% |
| 1982-83 | - 26% | - 10% | + 39% | + 85% |
| 1987 | - 11% | + 23% | + 23% | + 4% |
| 1991-94 | - 4% | + 18% | + 15% | + 26% |
| 1997 | - 7% | - 4% | - 54% | - 43% |
| All, 1970-98 | -11% | + 11% | +11% | + 44% |
| La Niña | | | | |
| 1971 | + 32% | - 41% | + 1% | - 9% |
| 1974-75 | + 1% | - 18% | + 19% | - 24% |
| 1988-89 | + 10% | - 2% | - 26% | - 17% |
| 1996 | - 5% | - 3% | + 103% | + 62% |
| All, 1970-98 | +11% | - 19% | + 46% | - 16% |

*Table. 4. Summary of results of Runs Tests on time series of skipjack and yellowfin tuna catch and CPUE data*

| Species | Data series (1970-98) | Median value | Number of runs | Significance |
|---|---|---|---|---|
| Skipjack | % in total tuna catch | 78% | 9 | p<0.05 |
| Skipjack | Standardized pole and line CPUE | 254 kg/day | 9 | p<0.05 |
| Yellowfin | % in total tuna catch | 14% | 8 | p<0.01 |
| Yellowfin | Standardized pole and line CPUE | 41 kg/day | 8 | p<0.01 |
| SKJ & YFT | Pole and line catch ratio | 5.6kg SKJ : 1kg YFT | 8 | p<0.01 |
| SKJ & YFT | Pole and line CPUE ratio | [Normalized data] | 6 | p<0.001 |