

INDIAN OCEAN YELLOWFIN TUNA STOCK ASSESSMENT

R.C. Anderson and A. Hafiz
Marine Research Section

A scientific workshop on the Stock Assessment of Yellowfin Tuna in the Indian Ocean was held in Colombo in early October 1991. It was organized by the Indo-Pacific Tuna Programme (IPTP) and attended by nearly 40 scientists from countries that fish for yellowfin tuna in the Indian Ocean. The aims of the meeting were to review the status of the yellowfin fishery; to review the current status of knowledge of yellowfin biology; to make some first attempts at assessing the status of the Indian Ocean yellowfin tuna stock; and to make recommendations for further work that will be needed to improve future stock assessments. This report briefly summarizes the major findings of the Workshop, which was attended by both authors.

Review of the Fishery

The Indian Ocean yellowfin tuna fishery currently has three major components:

1. The mainly artisanal fisheries of the coastal countries (including the important pole and line fishery of Maldives). Local fisheries for yellowfin tuna have of course been carried out in the Indian Ocean for hundreds of years. Historically coastal countries accounted for the entire Indian Ocean yellowfin tuna catch, which would probably have been less than 5000 MT per year. Now coastal countries catch over 40,000 MT of yellowfin per year, but this is only about 25% of the total catch.

2. The large scale longline fishery which has been carried out largely by vessels from Japan, Taiwan and Korea. Japan started tuna longlining in the Indian Ocean in 1952, Taiwan in 1954 and Korea in 1966. Longline accounted for the great majority of the yellowfin caught in the 1950's and 1960's. However, its importance declined in the 1970's as some Far Eastern longliners transferred their attention to other species (southern bluefin tuna, albacore and bigeye tuna). In recent years yellowfin catches by longline have increased again to nearly 40,000 MT per year, or over 20% of the total Indian Ocean catch. This is largely the result of the entry of coastal countries (notably India, Indonesia and Oman) into the longline fishery, often in joint-venture operations with Taiwanese companies.

3. The large scale purse seine fishery, based mainly in Seychelles. Most of the purse seine catch is by French and Spanish vessels, but purse seiners are also operated by a number of other countries including Japan, Mauritius and USSR. Although there was some experimental tuna purse seining in the Indian Ocean as early as 1977, the purse seine fishery did not really take off until the entry of French vessels in 1983-84. Since then yellowfin catches by purse seiners have increased spectacularly, now amounting to about 100,000 MT per year, or over 50% of the total Indian Ocean yellowfin catch.

A summary of yellowfin catches for the three major fisheries is graphically illustrated in Fig. 1. Note that all data and figures are from IPTP, unless otherwise stated. An overview of the 1990 yellowfin tuna catch by major fishery and area is given in Fig. 2. It can be clearly seen that the Indian Ocean yellowfin fishery is dominated by purse seiners operating mainly in the equatorial waters of the Western Indian Ocean (designated by horizontal shading in Fig. 2). Artisanal fisheries (white) are only important in the northern part of the Ocean. Longline fisheries (oblique shading) are more widespread, but are more important in the north than in the south. Overall the great majority of the yellowfin catch comes from the Western Indian Ocean.

Review of yellowfin tuna biology

a. Size Distribution

In the Indian Ocean yellowfin tuna can grow to at least 180cm fork length (FL). There is considerable variation in the sizes caught by different gears and in different areas. In general juvenile yellowfin tend to swim near the surface, and so are vulnerable to gears such as pole and line, trolling and gillnet. In contrast adult yellowfin tend to be deep swimming, and so are vulnerable to longline and handline. Modern purse seine nets are very deep and so catch both large and small yellowfin. As is well known to Maldivian fishermen, small yellowfin tend to aggregate under floating objects. Purse seines set on drifting objects (whether natural logs or artificial ones released specifically to aggregate tunas) therefore tend to catch a very large proportion of small yellowfin when compared to sets made on 'free schools'. Fig. 3 presents a summary of length frequency histograms from representative fisheries.

b. Migration

In the Maldives the great majority of yellowfin caught are juveniles of 30-60cm FL. There are two main fisheries for these juveniles : off the west coast in the southwest monsoon season and of the east coast in the northeast monsoon season (Fig. 4). The young yellowfins are moved back and forth in the seasonally oscillating surface currents, so there is also a peak in yellowfin catches off SW India and Sri Lanka in the SW monsoon season. In addition to this east-west movement there is evidence of a net northward movement of juvenile yellowfin in the Central Indian Ocean. This evidence includes the observations that larger fish tend to be found at higher latitudes, and that the majority of the yellowfin tagged during the 1990 Maldivian Tuna Tagging Program and recaptured in the Maldives had moved north.

It is tentatively suggested that the juvenile yellowfin found off Maldives

and western Sri Lanka continue their northward migration off the west coast of India to the north of the Arabian Sea. High catches of 'intermediate' size yellowfin (i.e. around 100cm FL) are made by longline off NW India, Pakistan and Oman. This migration pattern explains the lack of intermediate size yellowfin in purse seine catches from the equatorial waters of the Western Indian Ocean (Fig. 3). As the intermediate yellowfin grow, it is assumed that they return south to the equatorial waters to breed.

c. Reproduction

Yellowfin seem to mature at about 110-120cm FL, although there is wide variation in the size at first maturity. Gonad studies have shown that the peak of spawning activity occurs during the period November to March. The major spawning area so far identified seems to be the equatorial waters between Seychelles and Chagos (i.e. SW of Maldives). The sex ratio of yellowfin up to about 130cm is evenly balanced between males and females. However, at lengths over 130cm FL males predominate, and at lengths over 180cm FL females are entirely absent. While there are several possible explanations for these observations it is not clear yet which one is correct.

d. Growth

Most scientists agree that yellowfin tuna in the Indian Ocean reach a length of about 120-130cm FL by age 3 years and thereafter continue to grow slowly (Fig. 5). There are, however, considerable differences of opinion as to the growth pattern of small yellowfin. There are two main schools of thought on how fast yellowfin grow between about 40 and 70cm FL. One school maintains that yellowfin of this size grow at a 'slow' rate of about 1.5cm/month, while other, supports a 'fast' rate of about 3.0cm/month (Fig. 5). Evidence for both points of view has come from analysis of length frequency data (i.e. modal progression), which is the only major source of information so far available for growth studies in the Indian Ocean. Looking to growth studies in the Atlantic

and Pacific Oceans does not resolve the issue. While tagging studies have tended to show a 'slow' growth rate for juvenile yellowfin tuna, detailed studies of daily growth rings in otoliths (ear bones) clearly show a 'fast' growth rate. Further detailed studies will be required in the Indian Ocean to resolve this dilemma.

e. Oceanographic factors

As mentioned above (see Fig. 4) the distribution of juvenile yellowfin tuna is affected by the seasonally alternating monsoon currents. Apart from variations in abundance between seasons there are also variations in yellowfin availability between years that can be attributed to oceanographic factors. Fig. 6 illustrates the catch per unit effort (i.e a crude measure of abundance) of yellowfin tuna off the west coast of Maldives in the southwest monsoon (data for Raa, Baa, Ari, Faafu, Dhaalu and G. Dhaalu Atolls for June, July, August, September). The general increase in CPUE up to 1983 can be attributed to mechanization of the pole and line fleet, but the decline since then is more difficult to explain. Nevertheless, there are clearly three peak years: 1973, 1983 and 1987. These correspond to El Nino years (1976 was also an El Nino year, but a weak one). It seems likely that oceanographic changes associated with El Nino may increase the catchability of juvenile yellowfin, perhaps by changing their distribution.

French studies suggest that a low mixing index in the Western Indian Ocean (as occurs during El Nino years) increases larval survival. This in turn leads to greater abundance and higher purse seine catches 18 months later. For example 1988 was a peak year for purse seine yellowfin catches, following the El Nino of 1987.

Stock status

With the data available to the Workshop it was possible to try a number of

different approaches to the stock assessment of Indian Ocean yellowfin tuna. None of the approaches could give a definitive assessment of the stock status, but together they suggest that Indian Ocean yellowfin are not yet being overfished.

a. Catch and effort

Catch per unit effort indices were calculated for five different yellowfin tuna fisheries in the Indian Ocean. These were then standardized and combined to give an overall abundance index for the whole fishery. This showed no clear increase or decrease over the period 1981 - 1990 (Fig. 7). In other words there is no evidence of a change in yellowfin abundance from this data. However, as already noted the Maldivian west coast yellowfin fishery (Mald. 1 in Fig. 7) has shown a decrease in CPUE over this period. It is not clear if this is a true reflection of a similar change in local abundance.

From the standardized CPUE indices it is possible to produce a graphical plot of yellowfin catch against standardized total fishing effort (Fig. 8). This shows that catches have increased more or less proportionally in recent years in line with the enormous increase in fishing effort. There is little clear sign yet of a decrease in catch with increase effort. Because of the limitations of the data, no attempt was made to fit these data to a production model to obtain an estimate of 'maximum sustainable yield'.

b. Catch at age

More sophisticated stock assessment analyses require some knowledge of the age structure of the fish caught. Knowing the amount of yellowfin caught by each country, the length frequency distribution of yellowfin caught by each country, and the growth rate of yellowfin, it is quite straight forward to produce tables of total catch for each year split into age classes. Results of this analysis, using two different growth rates based on the two different hypotheses of

juvenile growth, are summarized in Fig. 9. These graphs show several things:

- the different growth hypotheses in fact make relatively little difference to the results.
- the enormous increase in catches of all ages in recent years is readily apparent.
- during the 1950's and 1960's there were relatively high catches of Age 2 and 3 yellowfin, which can be attributed to the longline fishery.

c. Sequential Population Analysis

Sequential Population Analysis (SPA) is an analytical method that uses catch at age data to estimate fish population size and fishing mortalities. In addition to catch at age data SPA also requires some estimate of natural mortality and recruitment. In the absence of any information on actual recruitment, two possible values were taken to represent relatively low recruitment (60 million new yellowfin per year) and relatively high recruitment (120 million per year). Fig. 10 shows the results of this analysis for the period. During the period 1955-65, the bulk of the young fish caught were taken by the artisanal fisheries, while the older yellowfin were caught exclusively by the longline fishery. Fig. 10 shows a more complex situation during the period 1985-90. Fishing mortalities (i.e. catches) at all ages have increased. Artisanal and longline fisheries continue to catch the same sizes as during the earlier period, but more yellowfin are now taken by artisanal fisheries and fewer by longliners. The new purse seine fishery exploits the full range of sizes, but there are noticeable differences between purse seiners fishing on logs and those fishing on free schools. Because of the lack of information of true recruitment levels it is difficult to take this analysis much further.

d. Yield-per-recruit analysis

Yield-per-recruit (YPR) analysis gives a measure of the productivity one can expect from an exploited stock depending on the level of fishing effort and the type of gear used (which controls the size or age at which fish are first caught). Results for the two periods 1955-65 and 1985-90, assuming two different recruitment rates, are shown in Fig. 11. Note that for each graph the vertical axis is age at first capture in years, and the horizontal axis is relative fishing mortality, with current fishing mortality being 1.0. Age at first capture for yellowfin in the Indian Ocean is about 6 months (i.e. 0.5 years). For the period 1985-90 and a recruitment level of 60 million new yellowfin per year, it can be seen that if fishing mortality is increased, catch will not increase much about the current average level of just over 160,000 MT per year. Infact, the maximum yield would be about 176,000 MT per year. By contrast, if the true recruitment level were 120 million, increasing fishing mortality (i.e. fishing effort) could lead to substantial increases in yellowfin catch, up to a maximum of about 300,000 MT per year. Clearly, this type of analysis also requires more detailed information on recruitment levels.

Recommendations

It was recognized at the Workshop that great improvements have been made in the compilation of catch, effort and size composition data for Indian Ocean yellowfin fisheries. However, gaps in our understanding of key biological and fishery processes presently hinder the analysis of these data. Many recommendations were made in order to improve our understanding these areas. Recommendations of relevance to Maldives include the following:

- continue tagging experiments to better understand yellowfin tuna growth and migration, and fishery interactions.

- further analyse CPUE data to better understand the relationships

between catch rates, fishing power, environmental variation and actual yellowfin abundance.

- carry out length frequency sampling at more sites to better understand the true size composition of the Maldivian yellowfin catch.

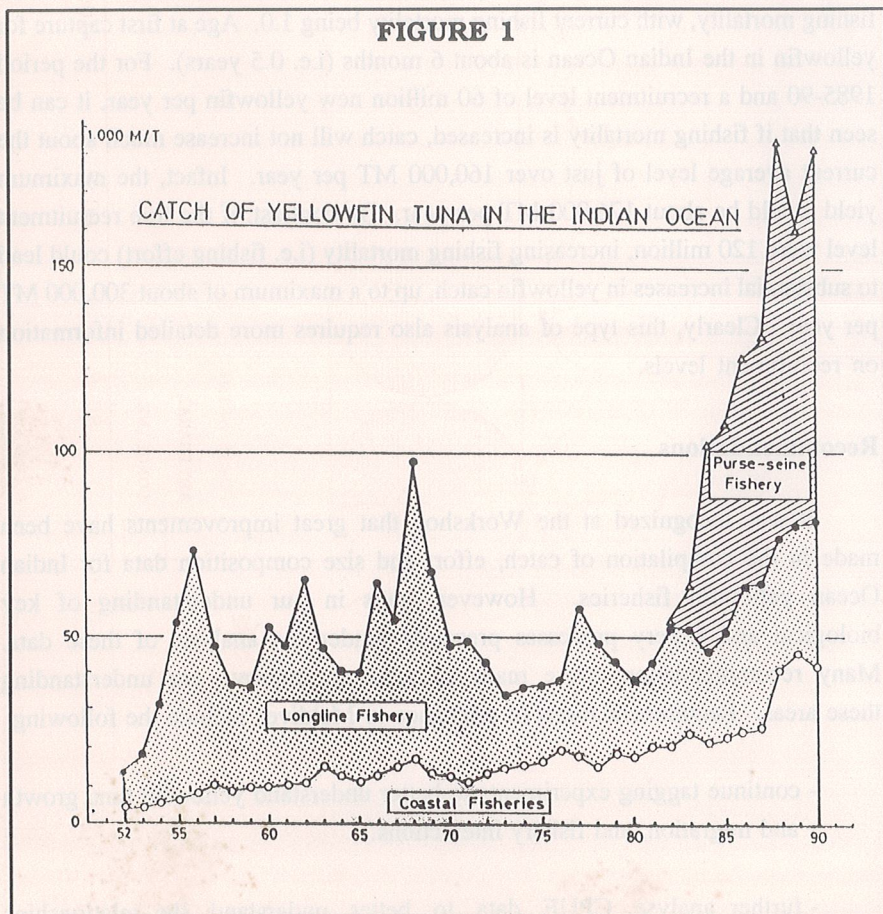


FIGURE 2

1990 YFT CATCH COMPOSITION BY FISHERIES

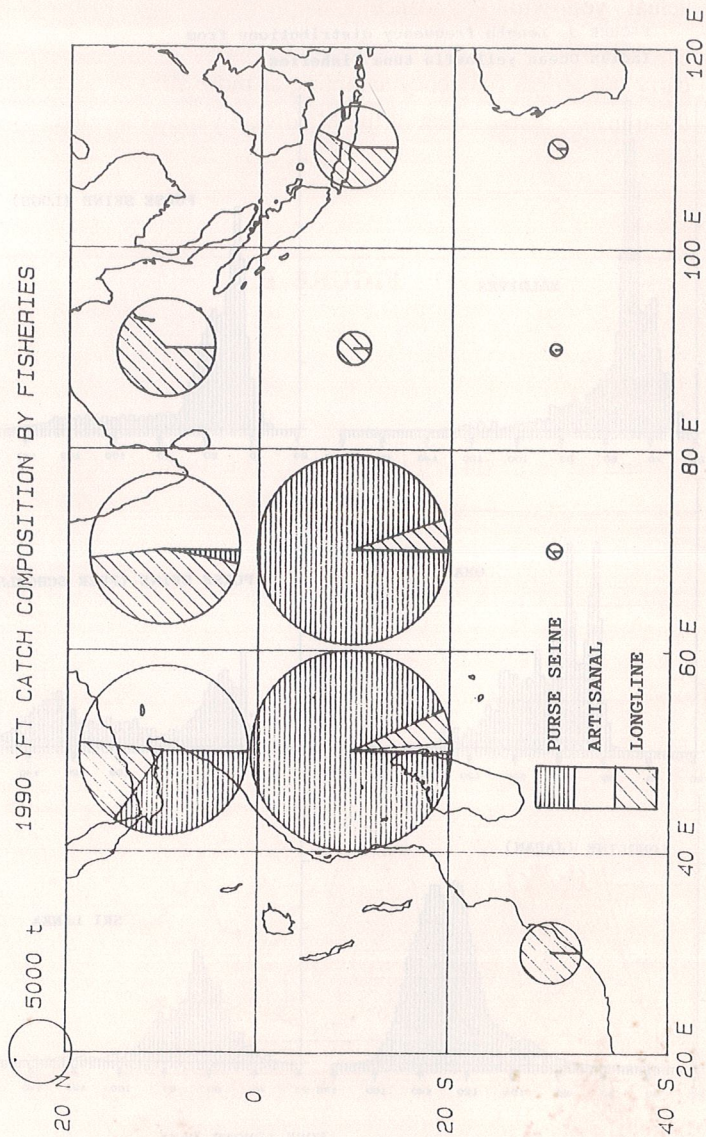


FIGURE 3. Length frequency distributions from
Indian Ocean yellowfin tuna fisheries

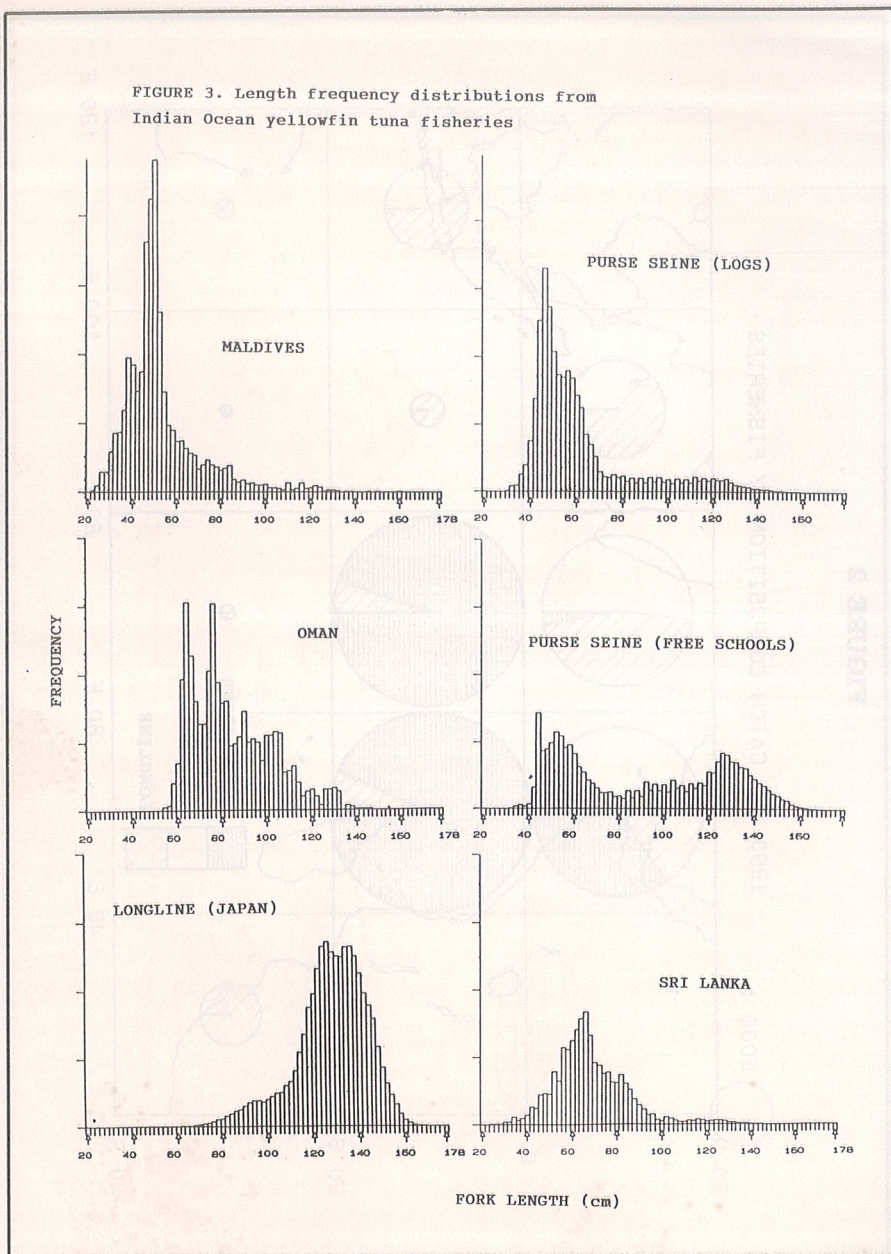


FIGURE 4. Schematic representation of main Central Indian Ocean fishing zones for juvenile yellowfin tuna during the two monsoons (shaded) and hypothetical directions of movement.

Source: Anderson R.C. (1988) IPTP Coll. Vol. Work. Docs. Vol. 3: 28-39

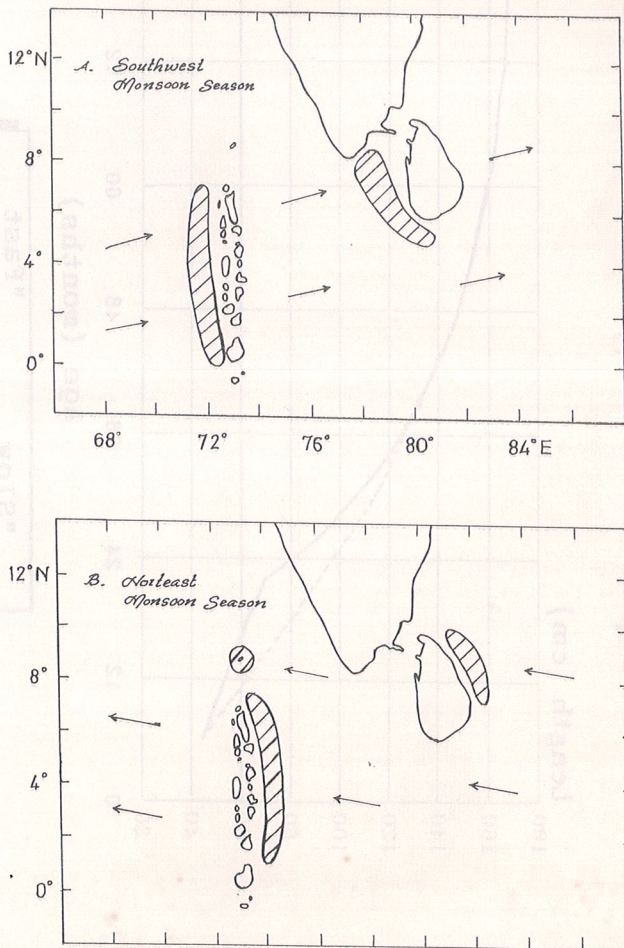


FIGURE 5

Comparison of growth curves

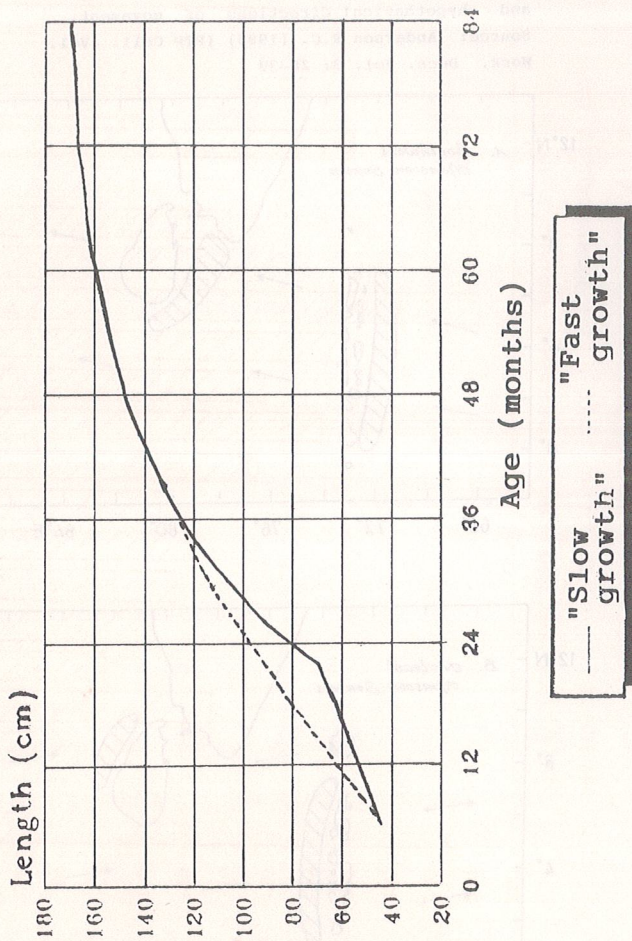


FIG. 6. Catch rates of juvenile yellowfin by masdhonis operating off the west coast of Maldives during the southwest monsoon season

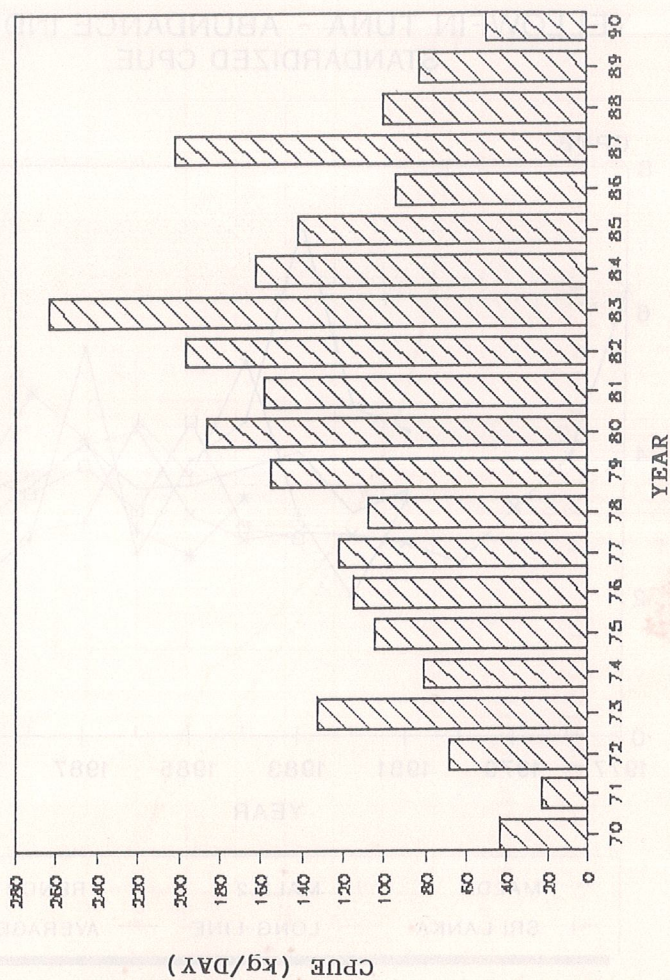
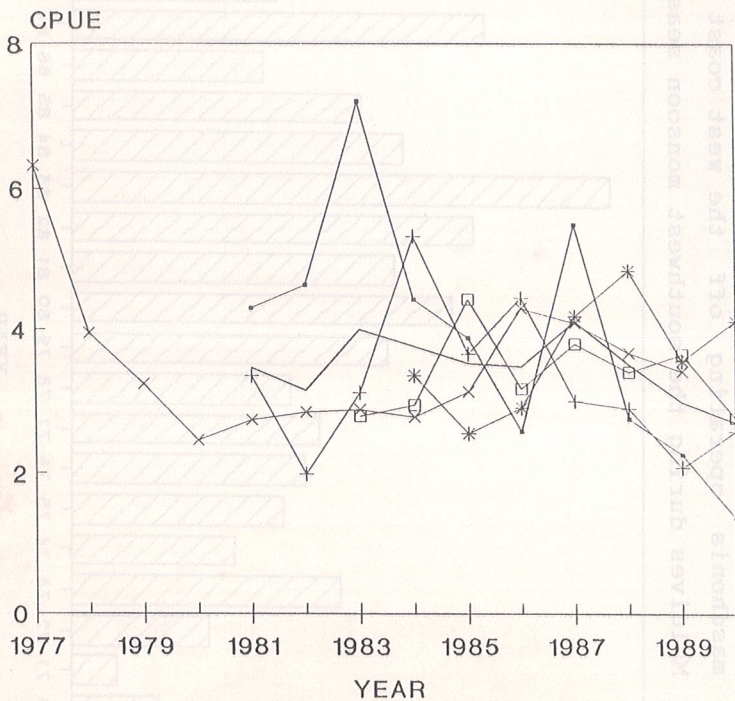


FIGURE 7

YELLOWFIN TUNA - ABUNDANCE INDICES STANDARDIZED CPUE



-●- MALD.1 -+ MALD.2 -* FRENCH P.S.
 -□- SRI LANKA -x LONG-LINE — AVERAGE

FIGURE 8

CATCH VS EFFORT PLOT

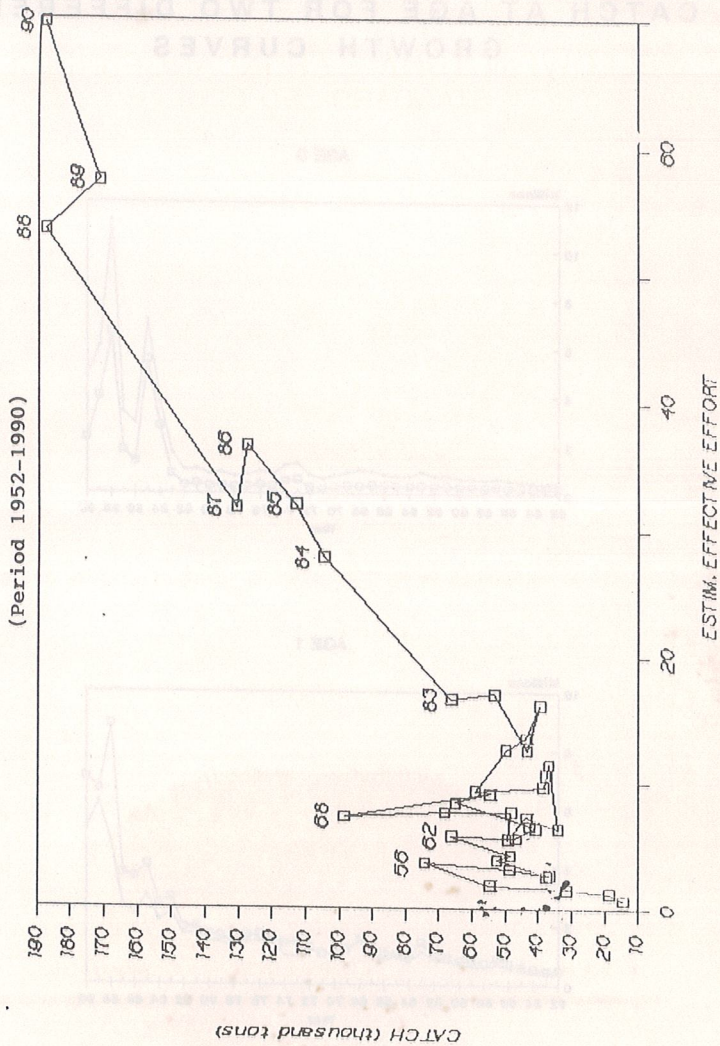
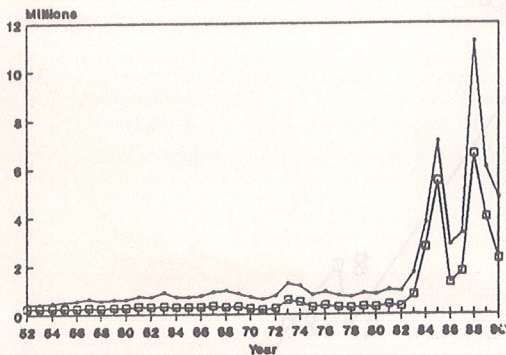
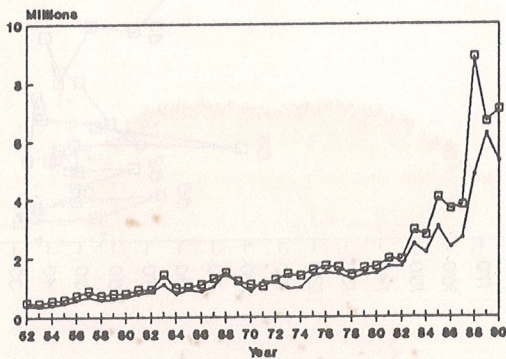


FIGURE 9
CATCH AT AGE FOR TWO DIFFERENT
GROWTH CURVES

AGE 0



AGE 1



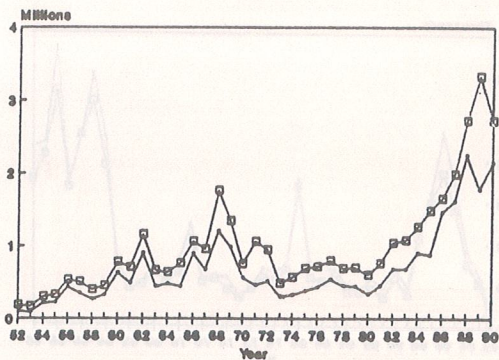
□ FAST GROWTH

● SLOW GROWTH

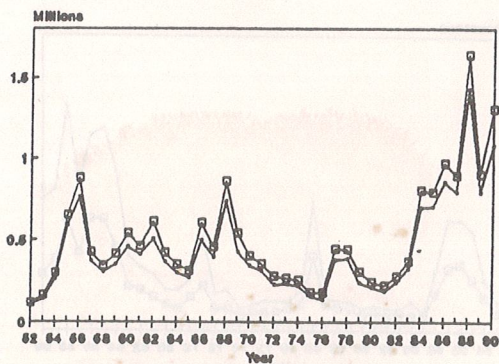
FIGURE 9 Continued.

CATCH AT AGE FOR TWO DIFFERENT
GROWTH CURVES

AGE 2



AGE 3



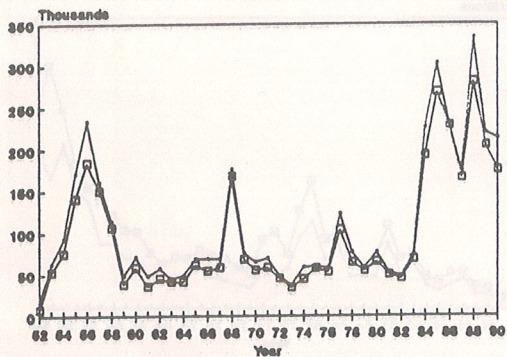
□ FAST GROWTH

● SLOW GROWTH

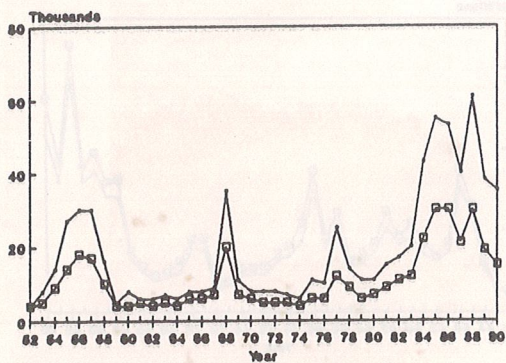
FIGURE 9 Continued.

CATCH AT AGE FOR TWO DIFFERENT
GROWTH CURVES

AGE 4



AGE 5

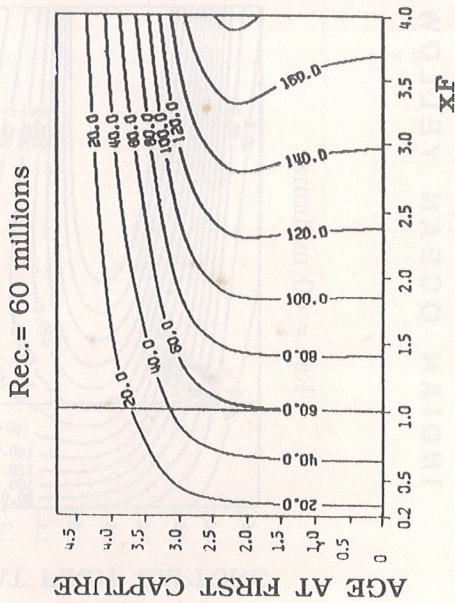
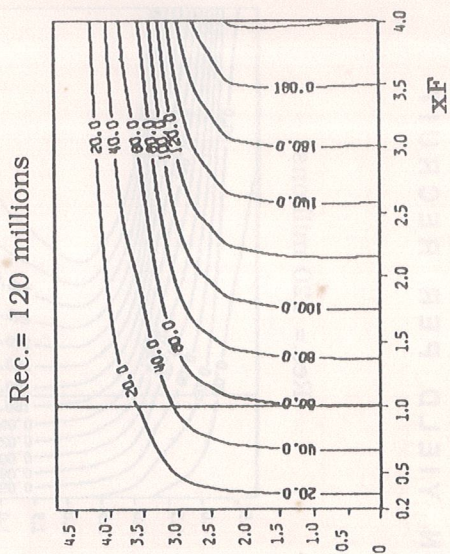


□ FAST GROWTH

● SLOW GROWTH

FIGURE 11

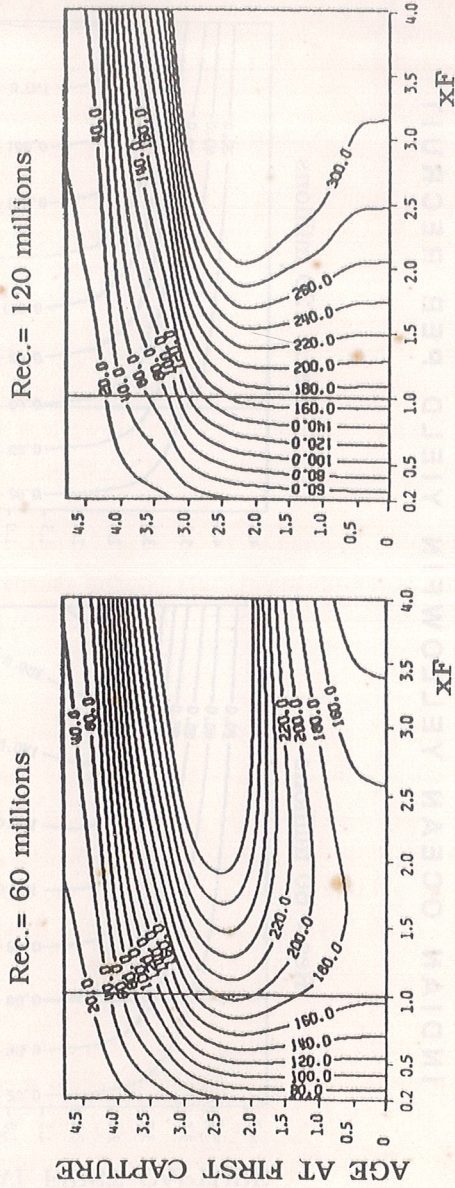
INDIAN OCEAN YELLOWFIN YIELD PER RECRUIT



Year 55 - 65

FIGURE 11 Continued.

INDIAN OCEAN YELLOWFIN YIELD PER RECRUIT



Year 85 - 90