ANALYSIS OF THE CATCHES BY WEIGHT CATEGORY OF YELLOWFIN TUNA (THUNNUS ALBACARES) UNDERTAKEN BY THE PURSE SEINE FLEETS IN THE INDIAN OCEAN FROM 1991 TO 2000

by

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ABSTRACT

This document analyses the origin of yellowfin catches, by commercial weight category, obtained for the entire purse seine tuna fishing fleet in the Indian Ocean from 1991 to 2000. The catches have been analysed by year, month, fishing area and type of association (free school or floating object), with a view to obtaining a deeper knowledge of the fishery and, especially, to determining the areas, seasons and types of association provided by the largest catches in the intermediate commercial category (C2 from 10 to 30 Kg), traditionally the least abundant in the catches of this species by purse seine in the Atlantic and Indian Oceans.

The C2 category of yellowfin tuna was the least caught (17%) by purse seine between 1991 and 2000. The largest quantities were caught during the months of July, August and September (36.4% of the annual total), while in fishing area no. 7, C2 yellowfin catches were higher than the other two categories (40.6%). The origin of most of the C2 YFT catches (55.2%) has been associated with floating objects. Catches in this weight category were maintained at around 3 t per positive set throughout the entire period, and the highest catch rate was obtained in the months of June, July and August (around 5 t per set). The fishing area with the highest catch rate was no. 7 (9 t per positive set) and the catch rate per set over floating objects was 2.2 t per set and 3.4 t over free schools.

Key words: *Indian Ocean. Yellowfin tuna. Purse seiner. Catches. Fishing effort. Fishing areas. Fads. Sizes distribution. Catch by size.*

INTRODUCTION

Catches of yellowfin tuna (*Thunnus albacares*) undertaken by purse seine fleets in the Atlantic and Indian Oceans are distinguished by presenting a typically bimodal size distribution, with a component composed of specimens between 35 and 75 cm LF (length to the furca) (from 1 to 9 kg) and another between 95 and 150 (>18 kg) cm LF, with a manifest absence of specimens between 75 and 95 cm LF (9 to 18 Kg). In the east Pacific Ocean (EPO), this discontinuity in size distribution does not exist, owing to the fact that, in addition to the catch of this species in free schools and associated with floating objects, a yellowfin fishery is practised in association with dolphins, and an important component of the catches undertaken in this association are the yellowfins that comprise between 75 and 95 cm LF. Given that the fishery over dolphins is only practised in the EPO, this might be an explanation for the absence of these sizes in the purse seine catches in the other two oceans.

The present study attempts to identify the periods, areas and type of association in which the largest catches of category 2 yellowfin (10 to 30 kg) are undertaken in the Indian Ocean, with a view to a better understanding of the space and time distribution of this species and the different age components in the purse seine catches.

MATERIAL AND METHODS

The original data correspond to the information gathered from fishing logs used by the purse seine tuna fishing fleets of Spain, France and other fleets (Seychelles, Panama, etc), which operated in the Indian Ocean from 1991 to 2000.

The current data processing system used for obtaining catches by species and size distribution of the purse seine fleets in the Atlantic and Indian Oceans (Pallarés and Petit, 1998; Pianet et all, 2000), in the case of the yellowfin, takes three or two strata into account, depending on the individual weights of the specimens caught that come close to the commercialisation criteria of catches for this species, those categories are: category 1 < 10 kg (C1), category 2 10 – 30 kg (C2) and category 3 > 30 kg (C3) or for two categories: C1 < 10 kg and C2 > 10 kg. In this analysis we have considered three categories.

Two large groups have been considered as association types for the yellowfin sets: objects and free schools. Included in the first group, along with natural objects and floating objects with or without buoys, are the catches associated with the whale shark and those caught under the tuna fishing boat itself; whereas catches carried out over sea mammals (essentially whales) and the data of sets recuperated with bird localisation rates have been included along with those obtained in free schools. Nevertheless, some years reflect important yellowfin catches whose origin is unknown and no association has been assigned to these years.

The space strata used are the areas utilised in the current data processing system (Pallarés and Petit, 1998). The delimitation of the areas and their numerical equivalent are shown in Figure 1.

The annual and monthly strata have been used as time strata.

The number of positive sets undertaken has been considered as fishing effort data, a positive set being understood to result in a tuna catch, though no yellowfin is present.

The relation between the catch in t of each category and number of positive sets undertaken in each stratum has been considered as the catch data per fishing effort unit.

RESULTS

Catches

Annual

The yellowfin catches undertaken with purse seine in the Indian Ocean have been around 123,000 t on average in the last ten years (1990 – 1999) (Anon., 2001). In the present study, a slightly different historical series is used (1991 – 2000). The catches analysed, proceeding from fishing logs in the period common to both series (1991 – 1999), imply an average coverage of 85.1%, with variations, according to the years, ranging between 80.5% and 88.9% (Figure 2).

The total annual yellowfin catches by weight category undertaken by purse seine in the Indian Ocean for the period 1991 – 2000 are shown in Figure 3.

The catches analysed were around 108,000 t on average, with a minimum of 89,000 t in 1998 and a maximum of 131,000 t in 2000.

Figure 4 shows the monthly evolution of the composition of the yellowfin catches by commercial weight category from 1991 to 2000.

The period under consideration reveals that catches of adult yellowfin (C3) were dominant until 1996 and that, after this time, catches of young yellowfin (C1) became dominant. In the last year, this has returned to the initial standard. As for the C2 yellowfin, these were caught in a similar or even higher ratio than C1 in the first three years, but after 1994 this became the commercial category with the fewest catches.

The average composition of yellowfin catches by commercial category was: 32 % for C1, 17% C2 and 51% C3. The yellowfin C2 varied between 9.1% (1994) and 24.4% (1995) in catches of this species.

Monthly

The months of December, January and February provide the most important yellowfin catches. In Figure 5, the average monthly yellowfin catches are given by weight category. These catches show the following standard: C1 is the dominant category in the months of September, October and November (39% of the annual total of YFT C1), C2 in July, August and September (47% of the annual total of YFT C2) and C3 in the months of December, January and February (47% of the annual total of this category).

Although the C2 yellowfin is caught all year round, it is observed that July, August and September are the months that present the highest ratios of this weight category, which indicates 36% of the total C2 catches for the last ten years on the whole.

Fishing Areas

The origin of 1,080,000 t of yellowfin caught by purse seiners in the Indian Ocean in the period 1991-2000 has been analysed. Figure 6 depicts the yellowfin catches by category and area. For the period under consideration, 82% of the catches of this species was obtained in areas 1, 2, and 3. The smallest yellowfin (C1) essentially originates from area 1 (47% of the catches) and nearly 70% originates from zones 1 and 2 combined.

Figure 7 reveals the composition in percentages of the different categories of yellowfin obtained in each area. For C2 yellowfin, the most important is 7, for C1 areas 1 and 4 and for C3, in particular, area 3.

In the case of category 2 yellowfin, the most important catches were undertaken in areas 2 (35% of the total catches in this category in the last 10 years) and 1 (30%). Therefore, 65% of the C2 YFT caught in the last ten years has been obtained from both these areas combined.

In any case, the area that presents a higher ratio of C2 yellowfin is known to be the Arabian Sea (7), with 41% of yellowfin proceeding from this category, although the total catches of the species in this area in the last ten years have not reached 1% of the total undertaken in the fishery. Practically the only catches of C2 YFT in this area were undertaken between May and September 1996, this being a year when the fishing effort was carried out in this area in these months.

The largest yellowfin (C3) were caught particularly in areas 3 (39%) and 2 (35%), which implies that 74% of the yellowfin weigh in at over 30 kg.

Figures 8, 9 and 10 show the percentages of catches from each yellowfin category by area for the period 1991-2000.

Type of association

Figures 11, 12, and 13 show the annual catches of yellowfin for categories C1, C2 and C3, respectively, obtained by type of association from 1991 to 2000.

Purse seine yellowfin catches in the Indian Ocean during the period 1991-2000 were obtained over floating objects (46.4%), free schools (28.4%) and unknown (25.2%).

Catches over floating objects were composed of 61% of C1, 20.3% of C2 and 18.6% of C3. To the contrary, the catches in free schools contained 80% yellowfin C3, 14.3% of C2 and only 5.8% of small yellowfin.

The origin of the C2 yellowfin catches is mostly from shoals associated with floating objects (Figure 9).

Figures 14 and 15 show the space and time distribution of catches in the different yellowfin categories obtained during the period 1991-2000, month by month, and in several areas for the associations as a whole (floating objects and free schools).

Fishing Effort

The fishing effort used rose to 73,196 positive sets, with a minimum in 1991 (5,493 sets) and a maximum in 1997 (8,509 sets), with 8,131 sets carried out in 2000.

Where the seasonal distribution of the fishing effort is concerned, a common standard (Figure 16) can be observed in numbers of positive sets in most years, with annual peaks in March-April and October.

The fishing effort has traditionally been concentrated in areas 1, 2, 3 and 4 (in this order), being insignificant in the remaining areas. Figure 17 shows the distribution of the fishing effort in numbers of positive sets in the different geographical areas of the Indian Ocean.

Where the type of association is concerned, in the period analysed, sets over floating objects have predominated, with percentages higher than 67% of the total sets in all the years (excluding the unknown sets), as shown in Figure 18.

Catch Rates

Figures 19, 20 and 21 show the catch rates of the different categories of YFT in t per positive set, obtained in the different years, months and areas studied.

As for annual catch rates, a slightly upward tendency is observed in C1 yellowfin catches (from 2 t to 6 t per positive set), which is downward for C3 yellowfin (11 t per set in 1991 and 8 t in 2001) and stable for C2 yellowfin (around 4 t per set).

When the seasonal variation is analysed within the year, it can be noticed that C2 yellowfin provide higher catch rates in the months of June and July, C3 presents two annual peaks, in December-January-February and June-July, both around 15 t per set and, finally, the smallest yellowfin reflects the highest catch rates in the months of September-October-November.

As for the catch rate in the different areas and categories, it is observed that C2 yellowfin present the highest levels in area 7 (9 t per set). The largest YFT (C3) present the highest catch rates in areas 5 and 3 with 18 t and 15 t per set, respectively. The smallest yellowfin provide higher catch rates in area 1 (18 t per set) and, in the remaining areas, there are variations in catch rate from between 2 and 5 t per set.

Size distribution

Yellowfin size frequency all gears together were analyze by area and quarter from 1990 to 2000. In this period the size distribution of the catches were completely conditioned by the purse seine catch. For nine of the ten areas considered and for all the quarter size distribution were bimodal. Only area 6 (South Indian Ocean), with a very low effort, presented catches without a juvenile component and seems to be targeted to intermediate sizes.

In order to see the effect of exploitation in each area we compared the average size distribution of the catches in two different periods: recent (1990-200) and historical (before 1990). Figure 22 shows the corresponding average distributions. Figures 23 and 24 show the cumulated size frequencies for the different areas in the periods considered.

Selectivity seems to be changed as a consequence of the exploitation. Areas with historical dominance of intermediate and large sizes present an important juvenile component in the recent period as a result of the purse seine effort increase and specially the development of fishing on floating objets. This change in the size distribution is evident in the main fishery areas.

DISCUSSION

The missing sizes in the yellowfin size distribution taken by purse seiners in both the Indian and Atlantic oceans are clearly a constant and basic characteristic of these fisheries (see figures 22 and 23 showing the average size distribution of yellowfin taken by purse seiners in the two oceans): these fishes are taken primarily, either as early juveniles or as spawners (at sizes larger than 90 cm, e.g. the approximate age at first reproduction in both oceans), but much less at pre adult sizes. This peculiarity which is typical of yellowfin tuna is not observed for another species such as bigeye (primarily because the purse seine is catching only the juveniles of this species).

This bimodal size distribution of the catches can be explained by three types of hypothesis:

Migratory hypothesis: in this case, the medium yellowfin are moving outside the fishing zone of the purse seiners, then producing a decrease of their catch as a function of the size of the migratory fraction of stock. If this hypothesis is the only one valid, it would mean, taking into account the low number of these fishes in the catches, that large fraction of stock would be migrating outside the present fishing zone of purse seiners. This hypothesis is well supported by the large quantities of the missing sizes taken in the NW Indian Ocean, in the Oman and Iran fisheries). Similar situation is also observed in the Atlantic were medium yellowfin are often taken in the western Atlantic, showing later a return to the Eastern Atlantic which is well shown by multiple transatlantic recoveries of medium size yellowfin tagged in the west and recovered one or two years later as spawners in the east Atlantic.

Behavior hypothesis: this point has been poorly studied by scientists, but it is very clear for every skippers of the purse seiners (multiple personal communication) that the "missing sizes" of yellowfin do show a very peculiar behavior: (a) smaller monospecific schools, instead of the large multispecies schools observed at lower sizes, (b) highly mobile schools which are very difficult to catch and (d) and furthermore, these schools seems to be of small sizes (for instance in a range between 5 and 10 tons) which are not of major interest for fishermen. Because of this peculiar behavior, this size of yellowfin tunas are called ***"chicaneurs"*** ("Quibler fishes") by the French fishermen and "recortado" by the Spanish fishermen in the Atlantic and in the Indian oceans were the same behavior has been observed). In this hypothesis, the missing intermediate sizes of yellowfin are possibly still in the fishing zone, but they are not available to purse seiners because of their peculiar schooling behavior.

Two stanza growth hypothesis: it has been hypothesized in the Atlantic by Fonteneau 1981 and other authors such as Gascuel and al 1992 and in the Indian ocean (Marsac 1981) that growth of yellowfin was following a two stanza pattern, with a slow growth of early juveniles, followed by a fast growth in the range of "missing size", e.g. between 60 cm and 1 meter of fork length. This 2 stanza growth pattern is

not yet fully demonstrated for the Indian Ocean yellowfin (even thought such hypothesis is now well accepted world wide), but it is clear that if growth of yellowfin is following such model, there is a much more smaller number of intermediate sizes in the underlying population in comparison with smaller and larger sizes. This would be simply due to the fact that large numbers of slowly growing fishes are accumulated at small and at larger sizes being trapped at their asymptotic juvenile and adult sizes. On the opposite, the transition between small and large yellowfin being very fast, the real numbers of these intermediate sizes would be reduced. This simple arithmetic's of the underlying numbers of fishes at size in the population would be easy to simulate.

It should also be noted that the recent increase of yellowfin catches taken under FADs has not increased significantly the catches of these intermediate sizes (Figure 24). This lack of catches could be due either to the type 1 hypothesis (medium fishes being outside the area) or to the type 2 hypothesis (medium size yellowfin present bot no associated to FADs).

As a conclusion, the rarity of medium size yellowfin in the catches of the Indian ocean purse seine fisheries is a strong fact which would be quite easy to explain by a combination of three hypothesis, migratory, behavioral and growth. The pending final question will be to estimate which weight should be given to each of these 3 components as each of them probably contributes to the scarcity of medium fishes in the catches.

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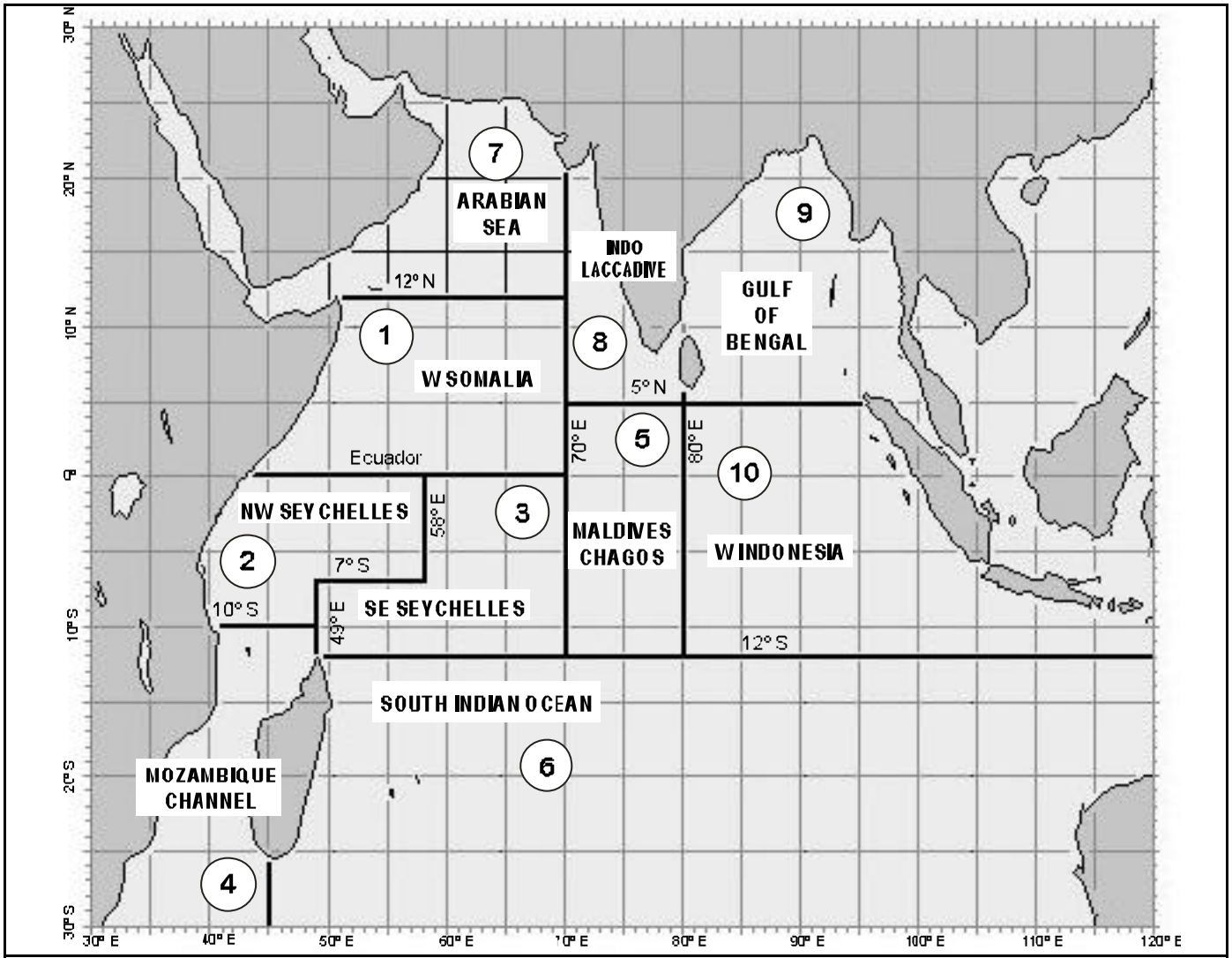


Figure 1 – Indian Ocean areas: 1 Somalia, 2 NW Seychelles, 3 SE Seychelles, 4 Mozambique Channel, 5 Chagos, 6 South Indian Ocean, 7 Arabian Sea, 8 Indo Laccadive, 9 Gulf of Bengal, 10 West Indonesia.

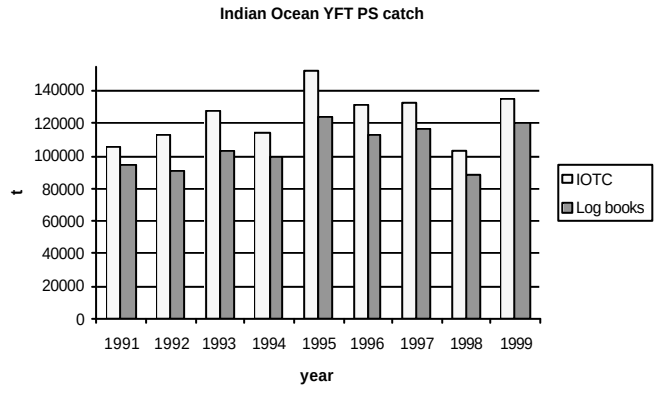


Figure 2. Coverage of fishing logs in relation to the total yellowfin catches in the Indian Ocean for the period 1991 – 1999.

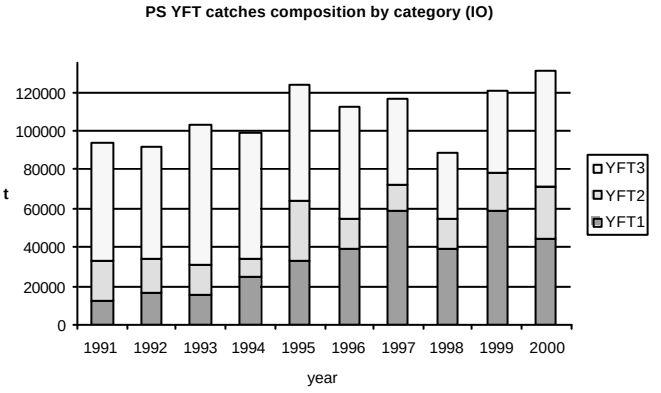


Figure 3.- Yearly purse seine yellowfin catches by category in the Indian Ocean

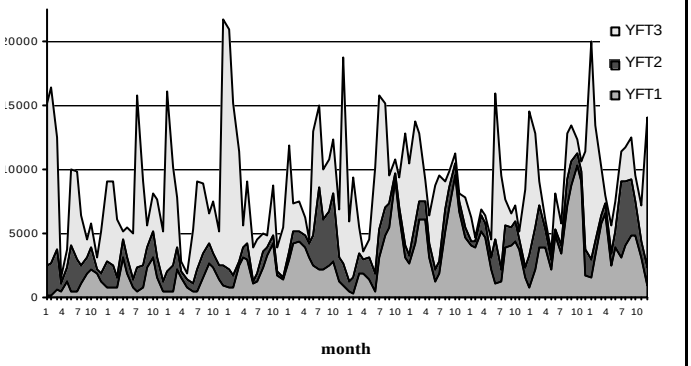


Figure 4. - Purse seine yellowfin catches by category and month in the Indian Ocean (1991 – 2000).

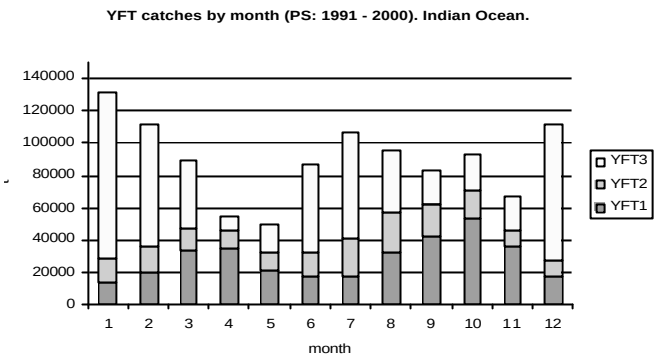


Figure 5. - Purse seine yellowfin catches by month and category in the Indian Ocean (1991 –2000).

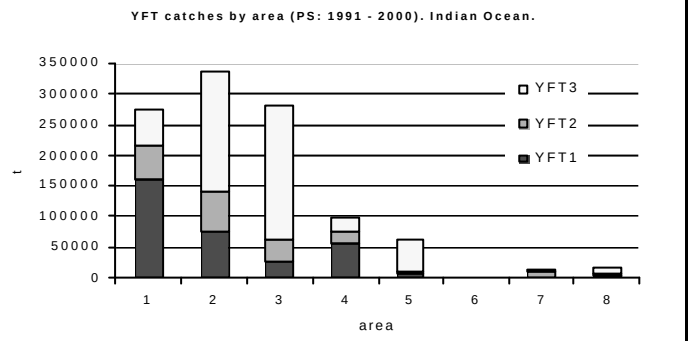


Figure 6. - Yellowfin catches by area and category (1991 – 2000).

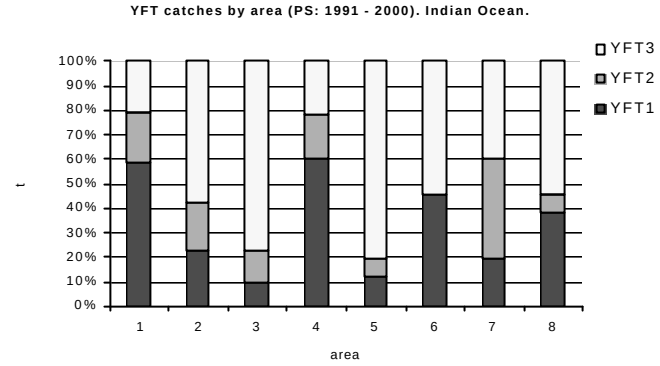


Figure 7. - Percentage of catches by category in each area (1991 – 2000).

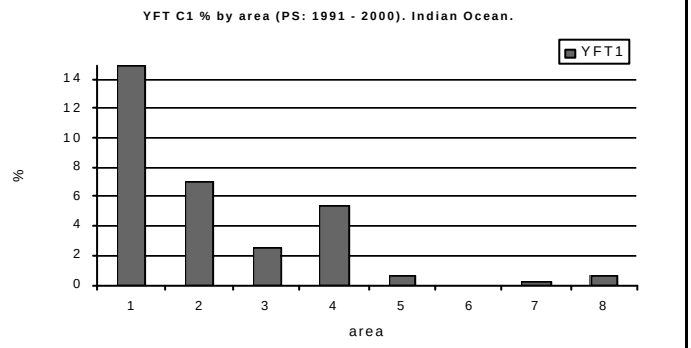


Figure 8.- Category 1 Yellowfin catches (%) by area

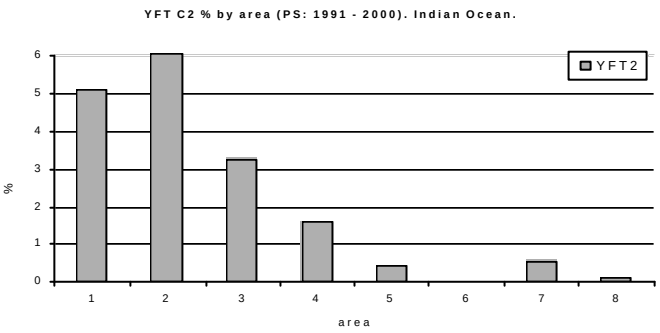


Figure 9. - Category 2 Yellowfin catches (%) by area.

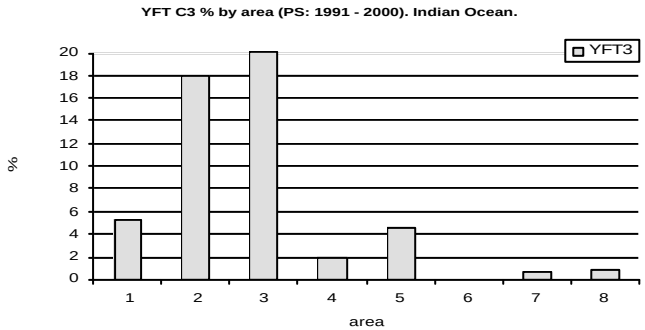


Figure 10.- Category 3 Yellowfin catches (%) by area.

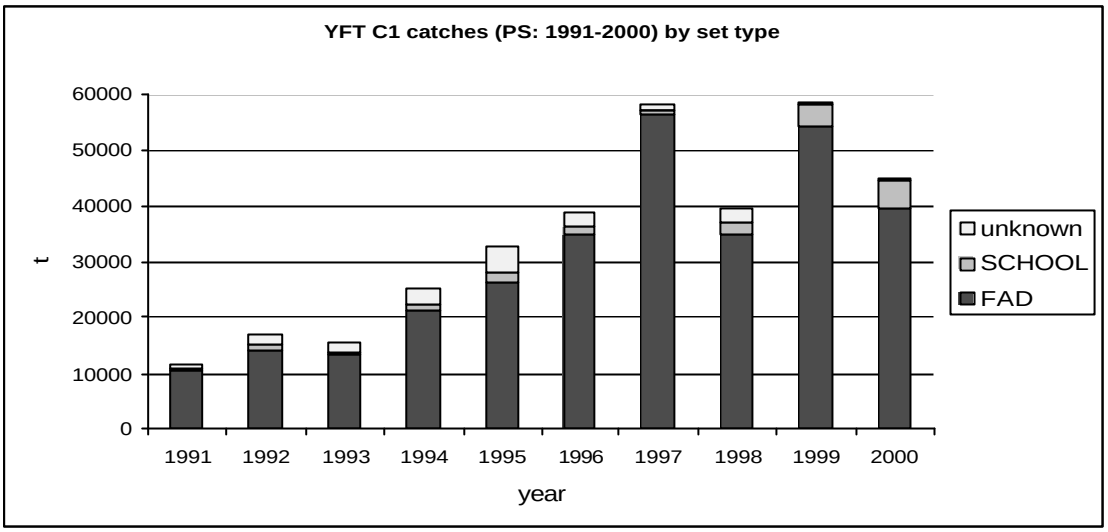


Figure 11. - Yellowfin C1 yearly catches by set type.

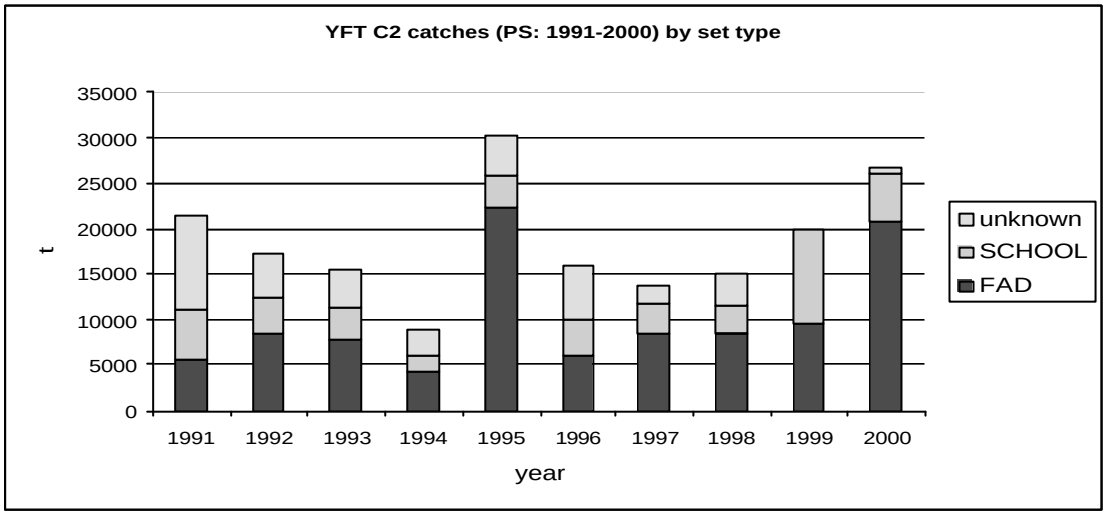


Figure 12. - Yellowfin C2 yearly catches by set type.

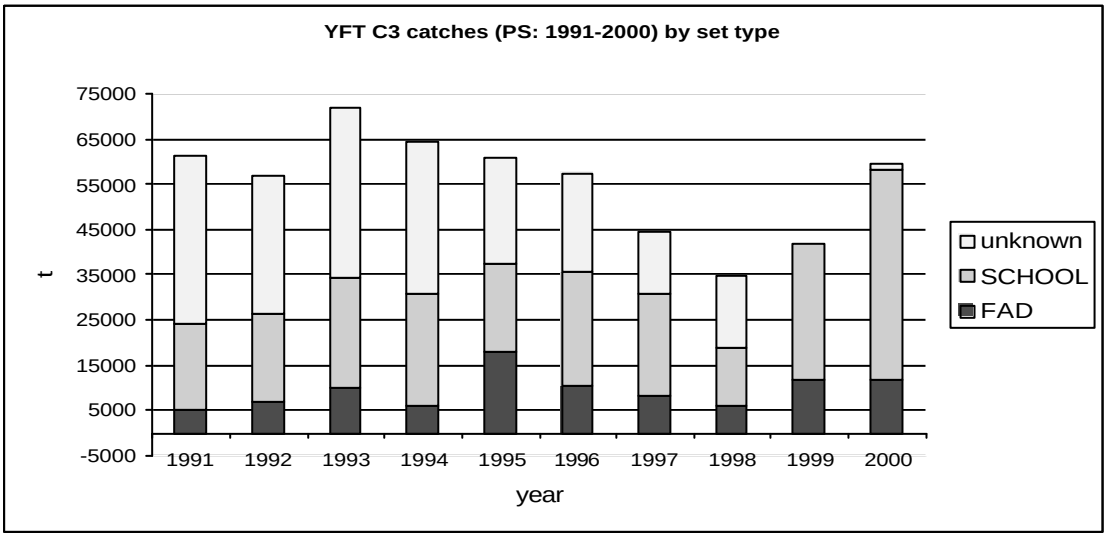


Figure 13. - Yellowfin C3 yearly catches by set type.

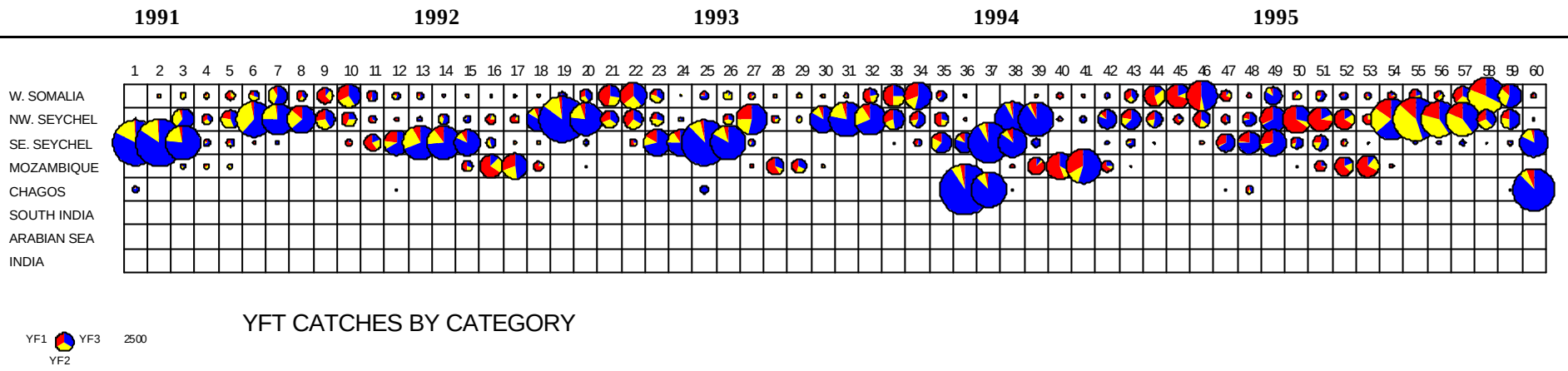


Figure 14.- Indian ocean PS Yellowfin tuna catches by category by month and area (1991-1995)

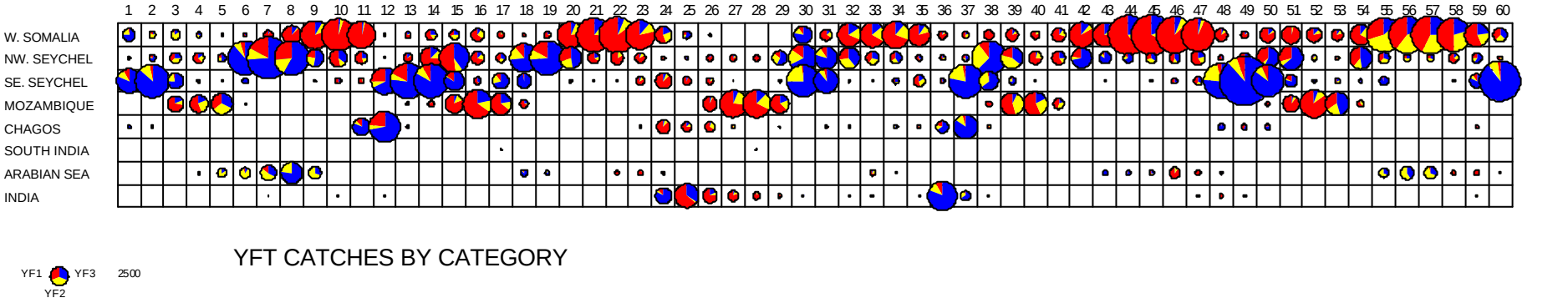


Figure 15.- Indian ocean PS Yellowfin tuna catches by category by month and area (1996-2000).

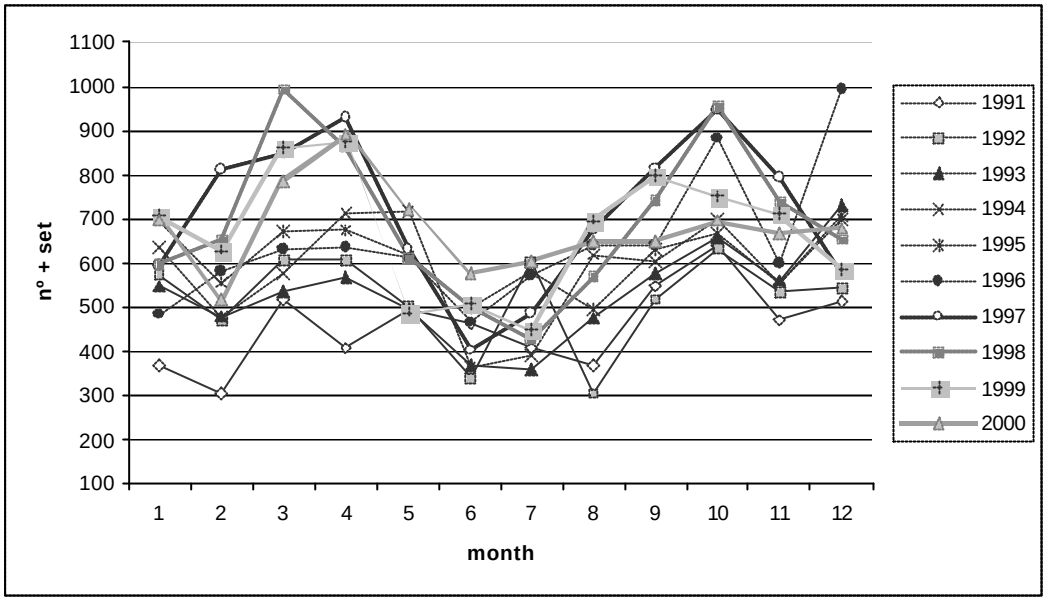


Figure 16. - Number positive sets by month and year

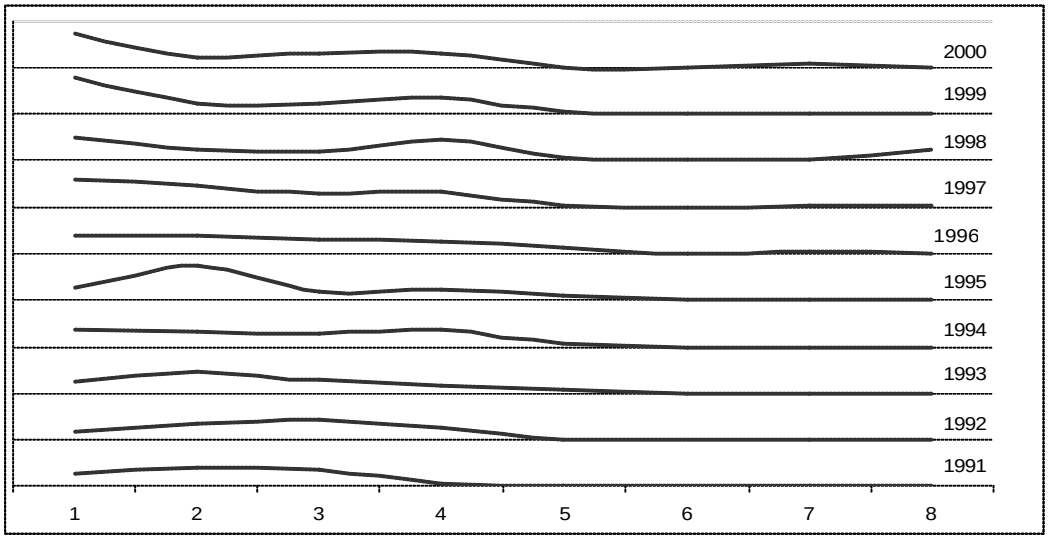


Figure 17. - Number positive sets by area and year.

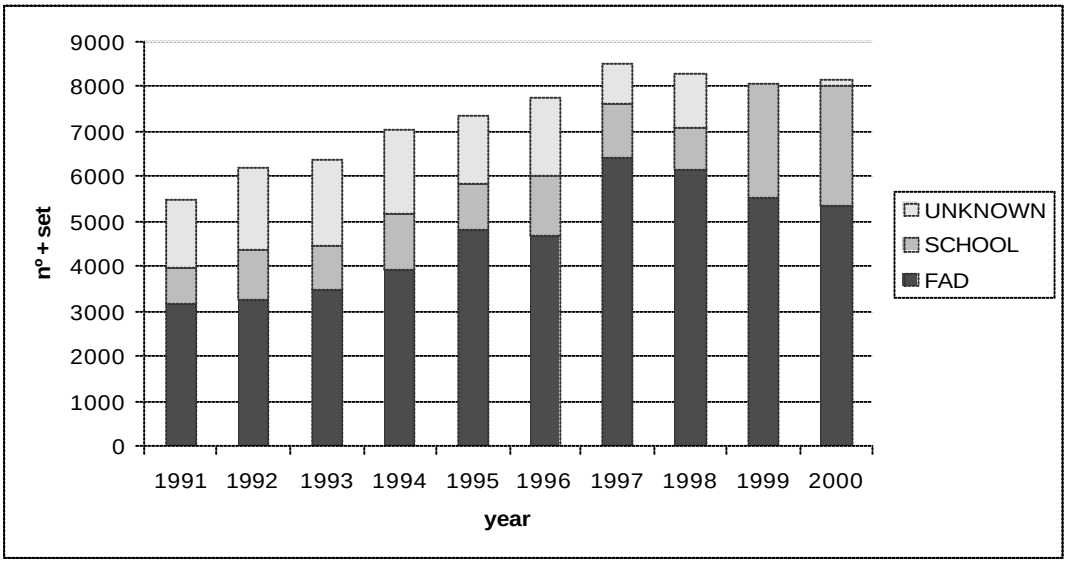


Figure 18. - Number of annual sets by set type.

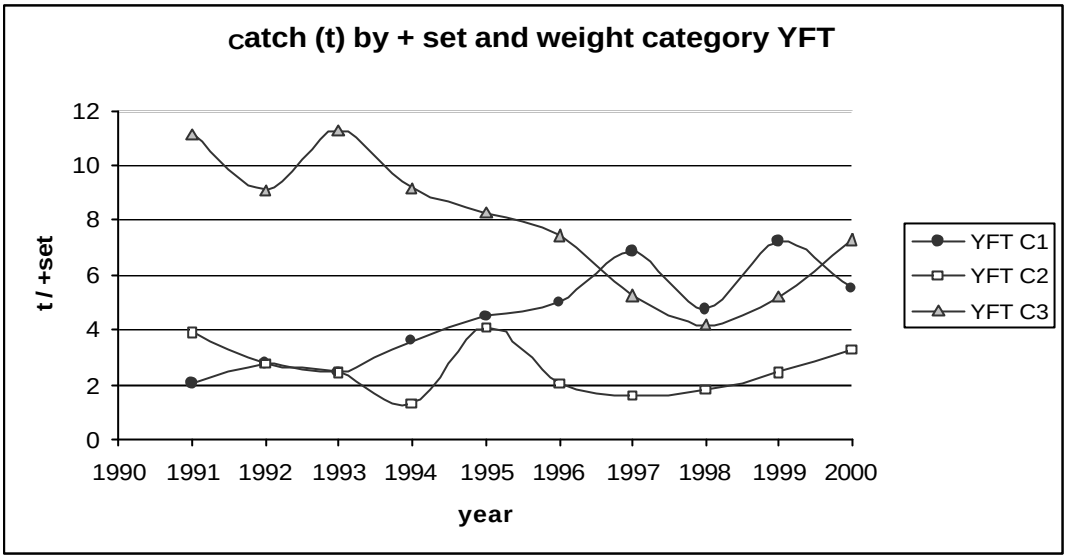


Figure 19. - Catch of yellowfin by set and category from 1990 to 2000.

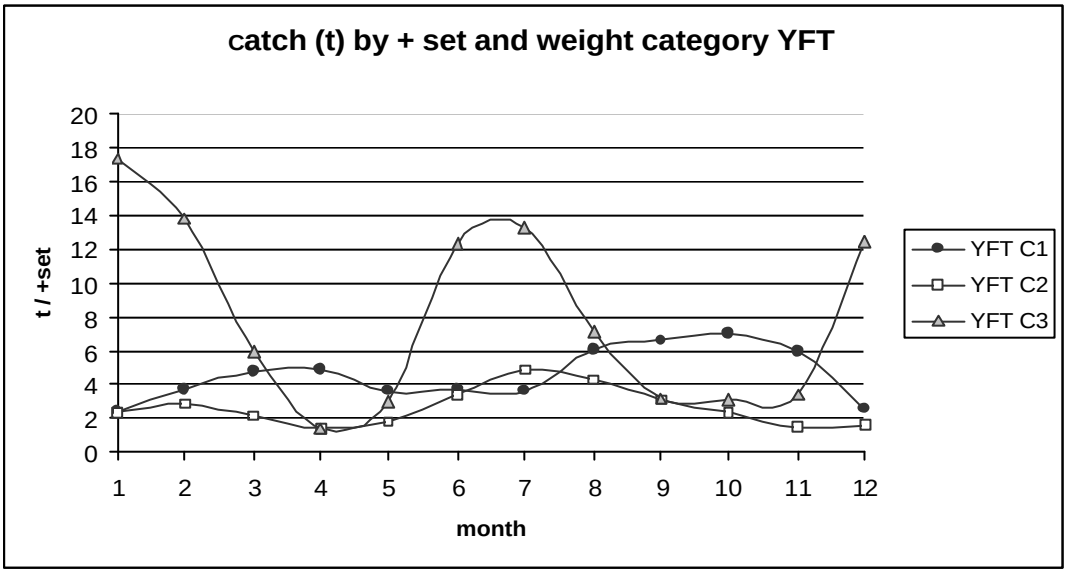


Figure 20. - Catch by set and month of each yellowfin category (1991-2000).

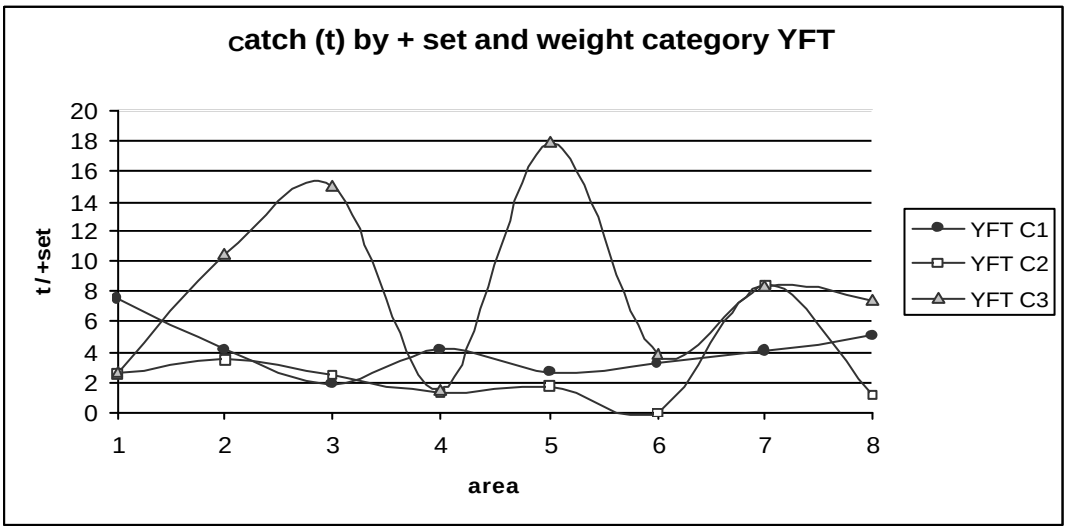
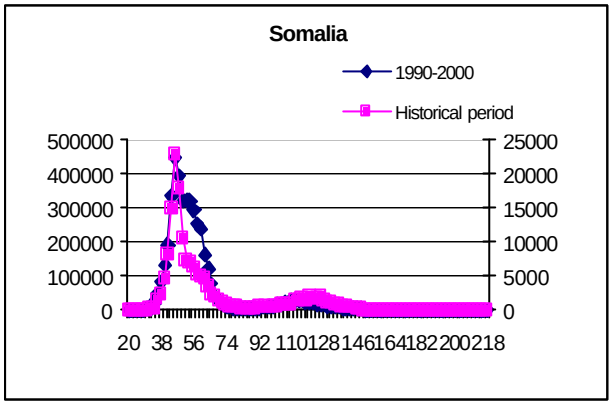


Figure 21. - Catch by set and area of each yellowfin category (1991-2000).


Somalia
1990-2000
Historical period
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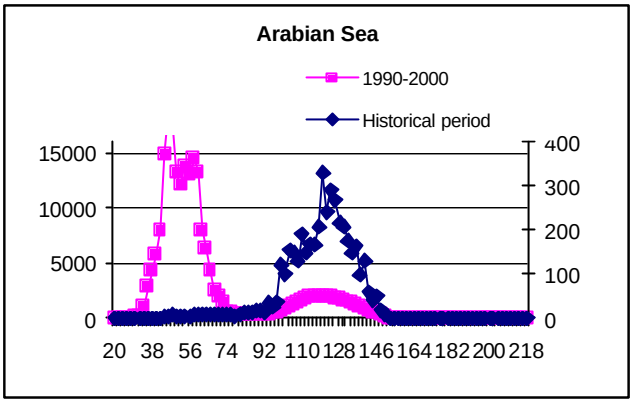
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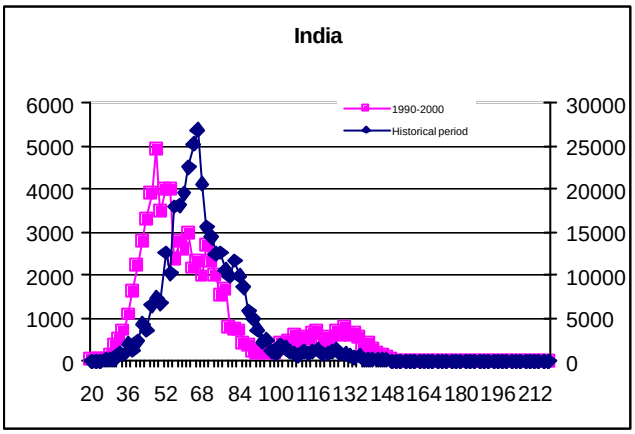
India
1990-2000
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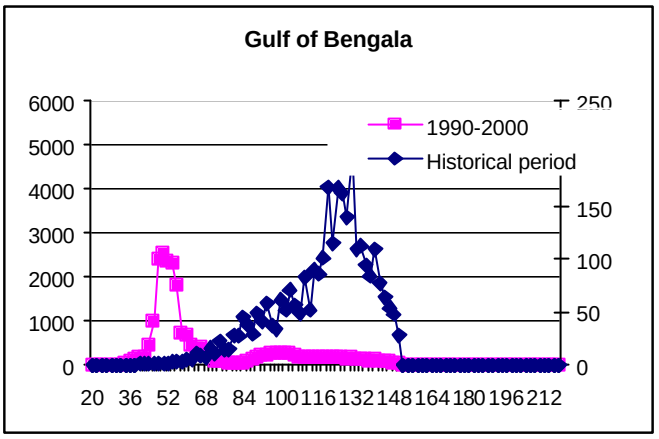
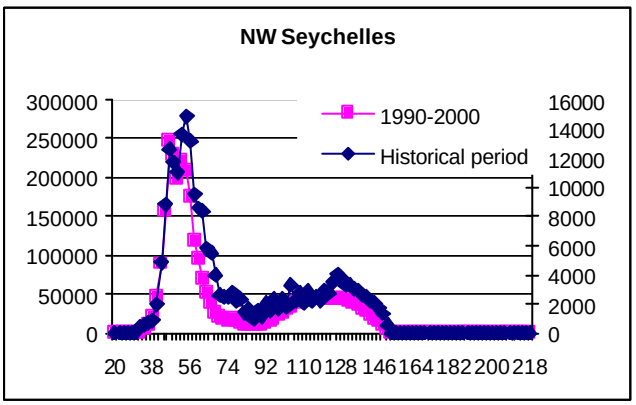
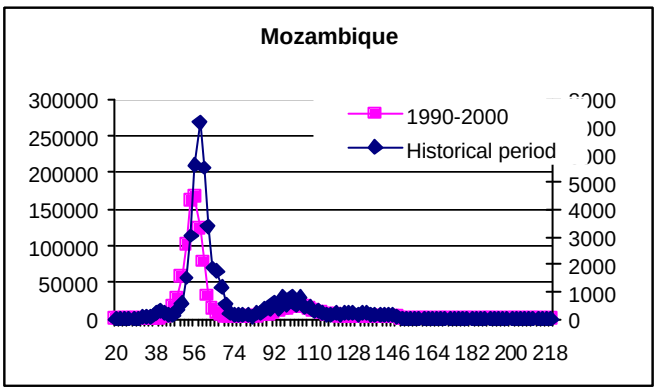
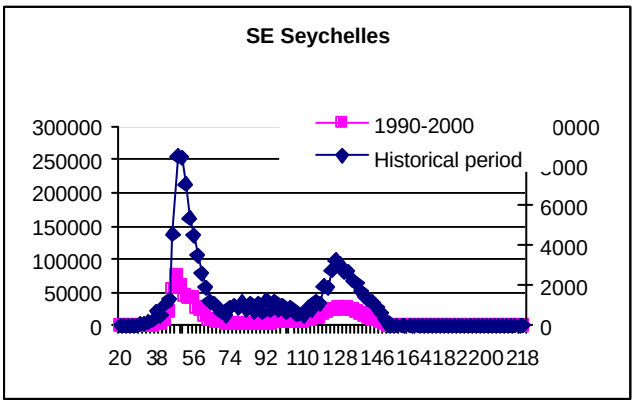
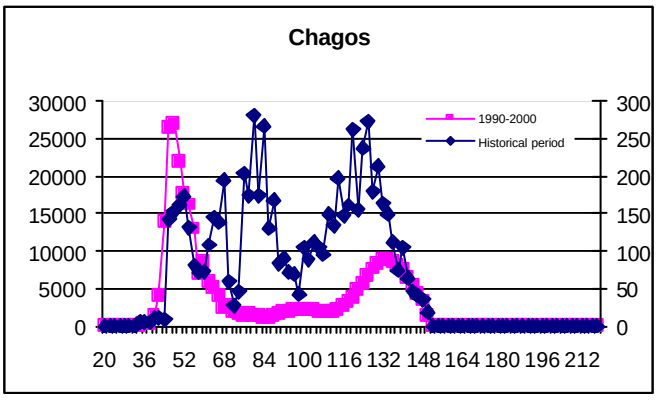
5000
4000
3000
2000
1000
0
30000
25000
20000
15000
10000
5000
0
20 36 52 68 84 100 116 132 148 164 180 196 212

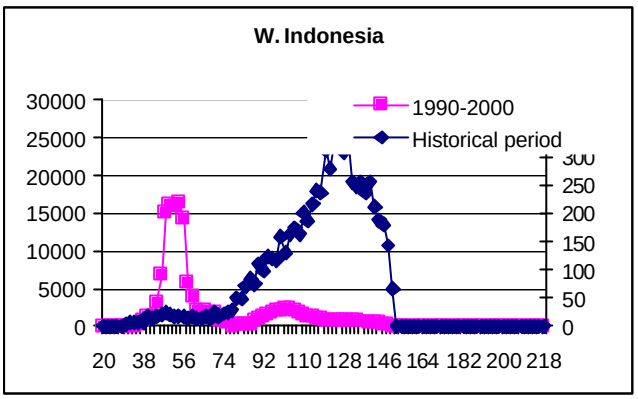

Gulf of Bengala
1990-2000
Historical period
6000
5000
4000
3000
2000
1000
0
250
150
100
50
0
20 36 52 68 84 100 116 132 148 164 180 196 212


NW Seychelles
1990-2000
Historical period
300000
250000
200000
150000
100000
50000
0
16000
14000
12000
10000
8000
6000
4000
2000
0
20 38 56 74 92 110 128 146 164 182 200 218


Mozambique
1990-2000
Historical period
300000
250000
200000
150000
100000
50000
0
5000
4000
3000
2000
1000
0
20 38 56 74 92 110 128 146 164 182 200 218


SE Seychelles
1990-2000
Historical period
300000
250000
200000
150000
100000
50000
0
6000
4000
2000
0
20 38 56 74 92 110 128 146 164 182 200 218


Chagos
1990-2000
Historical period
30000
25000
20000
15000
10000
5000
0
300
250
200
150
100
50
0
20 36 52 68 84 100 116 132 148 164 180 196 212



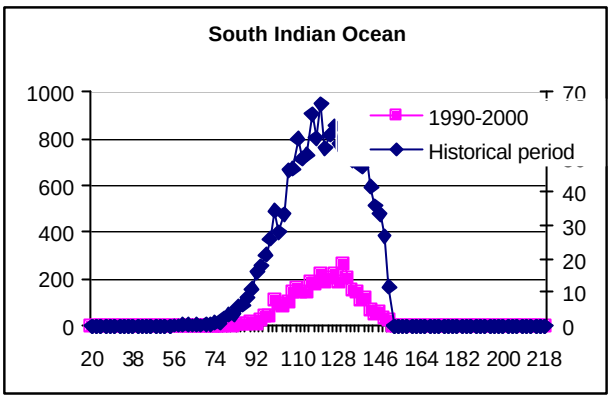
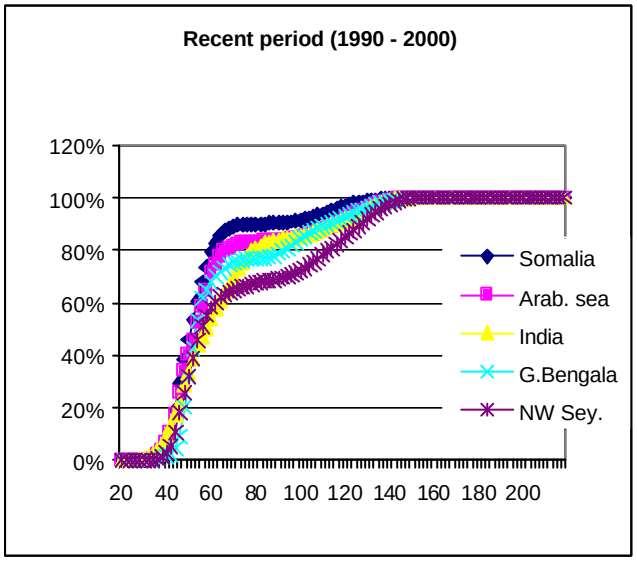


Figure 22. - YFT size distribution by area and two fishing periods (recent and historical).



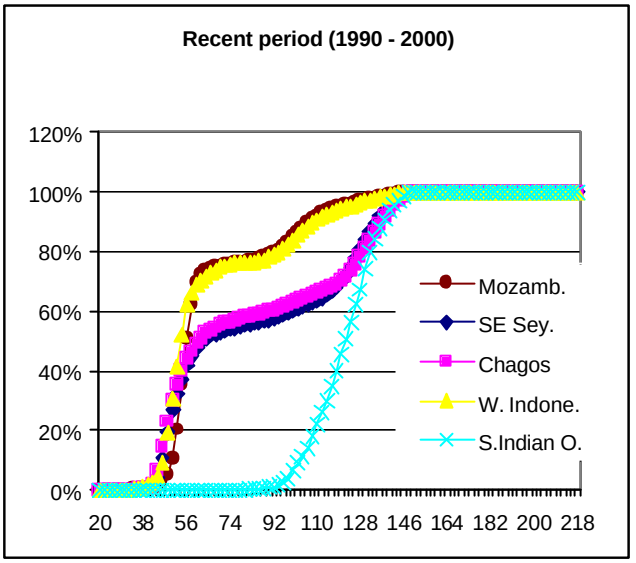
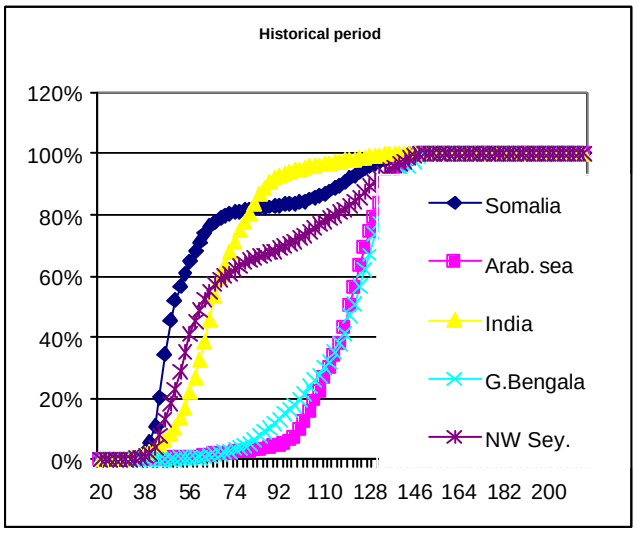


Figure 23.- Cumulative % of YFT size distribution by fishing area (recent period 1990 – 2000)



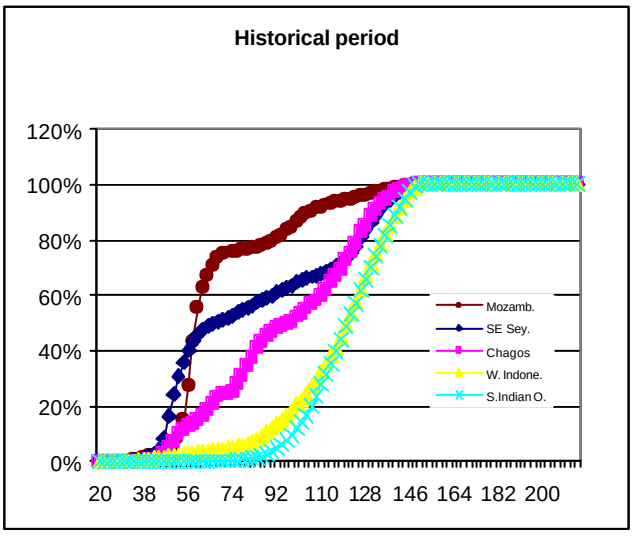


Figure 24.- Cumulative % of YFT size distribution by fishing area (historical period before 1990).

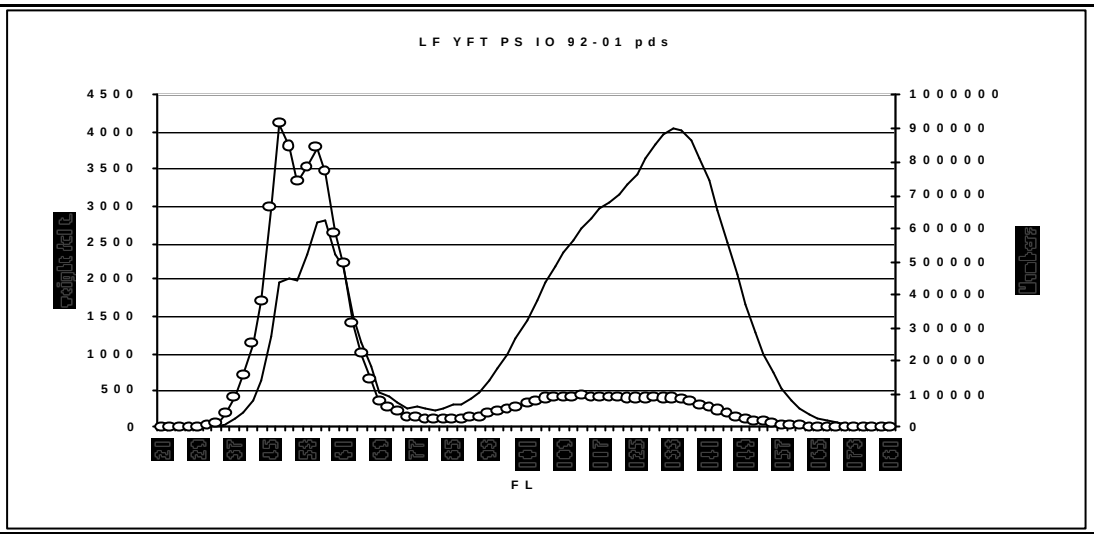


Figure 25.- Average sizes of yellowfin landed by purse seiners in the Indian ocean during the period 1992-2001, in weigh and in number of fishes.

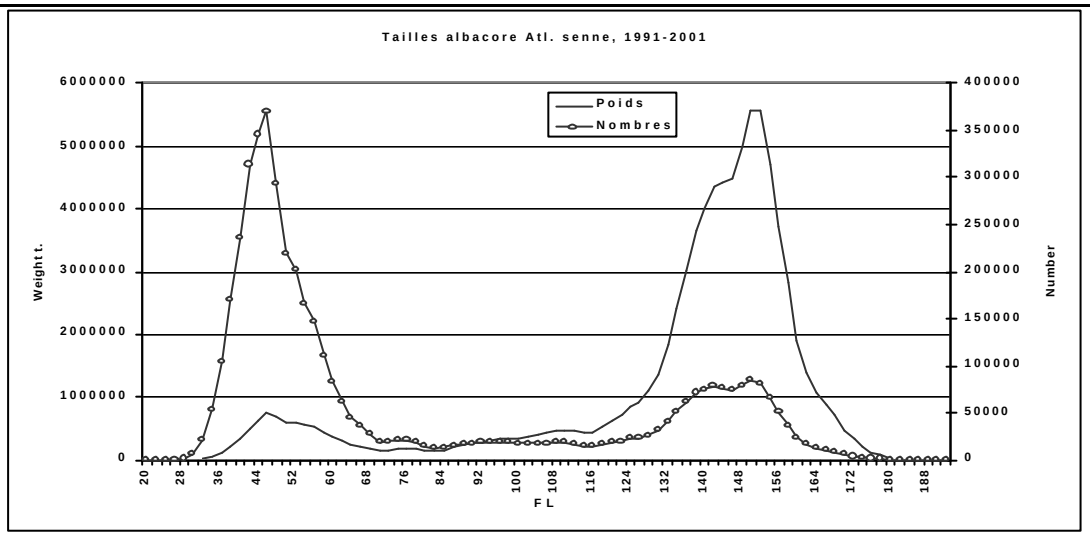


Figure 26.- Average sizes of yellowfin landed by purse seiners in the Atlantic ocean during the period 1992-2001, in weigh and in number of fishes.

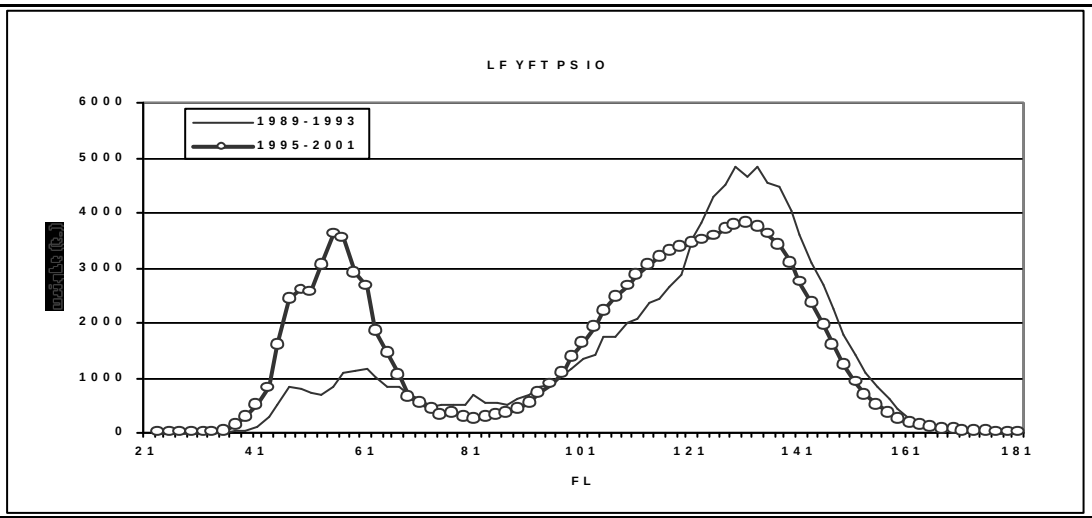


Figure 27.- Average sizes of yellowfin landed by purse seiners in the Indian ocean during the two periods 1989-1993 (before the Massive use of FADs) and 1995-2001, in weigh