The Indian Ocean yellowfin stock and fisheries in 2003: overview and discussion of the present situation

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1- Introduction:

It has been noticed that yellowfin catches taken by purse seiners in the Indian Ocean during 2003 were extremely high. After several years of slowly increasing catches, there was in 2003 a sudden jump in the yellowfin catches (taken at large sizes), at levels over 200.000 tons (figure 1 and 2). On the opposite, catches of the other target species, such as skipjack and bigeye, were maintained during 2003 at their average levels. Now the pending scientific questions are:

(1) To identify the reasons explaining this record 2003 high catches (basically, are they due to a high biomass or to a high catchability of an "average" stock? And if so, why this high catchability was observed in 2003?),

(2) To examine if this trend of high catches was also observed (or not) for other fisheries (longliners and artisanal ones) during 2003, and if these high catches were also observed during the beginning of 2004,

(3) To evaluate through a preliminary stock assessment analysis the consequences of these high catches on the stock status of yellowfin (the final real scale stock assessment being done only when most fishery data will be available, e.g. at the earliest date in 2005). This revised stock assessment incorporating the 2003 data will be very important, because the 2003 yellowfin catches will probably be well above any of the MSY presently estimated by scientists.

This paper will attempt to examine and discuss these various points.

2- The yellowfin fisheries in 2003

2-1- Facts on the 2003 EU purse seine fishery

2-1-1- Introduction:

The 2003 purse seine fishery has been analysed in details, comparing the 2003 data to data of the same fishery during recent years (table 1). This comparison has also been conducted on the EU owned fleet of purse seiners (carrying flags of Spain, France and other countries) independently of the flags. Provisional data concerning the Japanese longline fleet was also available. The 2003 catches were still unknown for various major countries (such as Taiwan, the Ex USSR PS fleet, Maldives, Oman, etc) when this paper was finalized (October

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30^{th} 2004), and the yellowfin catches of these countries was estimated based on a comparison of catch trends with similar fleets (table 1)..

2-1-2- Catches by purse seiners

Levels of total catches taken by species (figure 1) show that skipjack and bigeye catches were at levels similar to the levels observed during previous years, when the 2003 yellowfin catches were at their highest level ever observed in the purse seine fishery, 55% in excess of the previous higher catch observed in 2002. The levels of yearly yellowfin catches by fishing mode (on FADs and on free schools) taken by the sampled fleet of purse seiners are shown on figure 2. This figure shows that the extra catches of yellowfin taken during 2003 were caught predominantly on free schools.

2-1-3- Fishing effort and CPUE by purse seiners

Nominal fishing efforts exerted by the sampled purse seine fleet, expressed in terms of its numbers of sets (on FADs and on free schools) and of its yearly fishing days and total carrying capacity are shown figure 3 and 4. These figures indicate that all these indices of nominal fishing effort exerted by the fleet were quite stable in 2003, and very similar to the levels exerted during recent years. This point is also well shown by the relationship between yearly yellowfin catches by the sampled fleet and its fishing effort (figure 30); the peculiar position of 2003 clearly appears in this figure with a very high yellowfin catch taken by a moderate effort. This 2003 year is clearly outside the catch & effort relationship previously observed for this fishery.

The corresponding CPUEs, in terms of average catch per fishing day, are shown (on FAD and on free schools) on figure 5. This figure shows that the CPUE of FADs was stable in 2003, when the CPUE on free schools has reached in 2003 its record level in the 1982-2003 statistical series. The average catch per set (figure 6) shows that the high CPUE observed in 2003 were primarily due to the high frequency of very large sets (figure 7). It can be noticed that this trend was already visible to a less degree in 2002.

2-1-4- Fishing zones in 2003 and in previous years

The overall fishing zones exploited by the sampled purse seine fishery in 2003 and during previous years (average 1995-2001) are shown on figure 8 and 9, when the yellowfin fishing zones during the same periods and in 2002 are shown on figure 10. The fishing zones during 2003 appears to be non typical, (1) with a lack of any significant fishing activity in the Mozambique Channel during the 2^{nd} quarter (2003 was the first year in the 1983-2003 series during which this lack of fishing in the Mozambique Channel has been observed, figure 11) and (2) with large catches of yellowfin taken on free schools in the area between 5° to 10°S, west of 65°East. Figure 11 also shows that this fishing zone (shown by figure 12) was already exploited during previous years, but it also shows that in 2003 the yellowfin catches taken in this area were much higher and being taken all year round (when this area was fished seasonally during previous years). It should also be noticed that large fractions of these 2003 yellowfin catches have been taken close to the African continental shelf. On the other side, it could also be noted that the total size of the area fished by the purse seine fisheries measured in term of numbers of 1° squares fished (figure 13), were stable and very similar to the sizes of the areas fished during recent years.

2-1-5- Sizes of yellowfin taken in 2003 and in previous years

The sizes of yellowfin taken in 2003 are shown on figure 14 (free schools) and figure 15 (FAD), and compared to the sizes and weight taken by the same fishery during the previous years (figure 16 and 17). The average size of yellowfin taken on free schools was typically high at an average of 35 kg, one of the largest average weight observed in the fishery (figure 17) but similar the averages of the 1982-1983 and 1991-1994 periods. The shape of the 2003 size histogram on free schools (figure 14) appears to be typical of the yellowfin sizes taken by purse seiners in the area, e.g. a typical dominance of large fishes over 80 cm of fork length. It can also be noted that the excess of catches was observed at all large sizes, and not in a peculiar range of sizes or ages. On the contrary, yellowfin sizes taken on FADs are very similar to previous years in term of size distribution (Figures 15 & 16) and average weight (Figure 17).

2-1-6- Conclusion on the 2003 yellowfin purse seine fishery

After at least 12 years of stability in the Indian Ocean purse seine yellowfin fishery (with the exception of the 1998 El Niño anomaly and its effects on the purse seine fishery), 2003 appears to be a marked anomaly in term of its large quantities of large yellowfin taken and because of its peculiar fishing zones (although these fishing zones were located within previously exploited areas). As the purse seine fisheries are a major component of the Indian Ocean yellowfin fisheries (catching an average 44% of yellowfin catches during recent years 1998-2002), this event will necessarily play a significant role in the dynamics of the stock exploitation and status.

2-2- Yellowfin fisheries by longliners

2-2-1- Overall

Purse seiners and longliners are exploiting the same yellowfin stock, at least this is the present IOTC hypothesis. However, the year to year changes of stock catchability (for instance due to environmental anomalies) and to changes of fleet efficiency (for instance the effects of new sonar in the purse seine fishery) are independent for these two fleets. Then the comparison of CPUE obtained during 2003 by these two gears will be of immediate interest in order to check if they show the same or opposite trends.

Good examples of such interesting comparisons were shown by the effects of the *El Niño* anomalies on purse seine and longline CPUE: this comparison shows (figure 28) that the yellowfin longline CPUE was quite insensitive to the most active El Niño observed in the Atlantic (1984) and Indian (1998) oceans. On the opposite, the purse seine yellowfin CPUE were seasonally very low in these two oceans during these major El Niño events: such stability of the longline yellowfin CPUE were in fact better representing the real adult biomass trends, when the purse seine CPUEs were providing a too much pessimistic view of the stock status (because of a temporarily low catchability of the adult stock due to these El Niño events).

The opposite cases of a purse seine anomaly of a “too high” purse seine CPUE, due to a high catchability of the stock, could also be envisaged and the comparison of purse seine and longline 2003 yellowfin CPUE should be done to make this comparison.

2-2-2 Yellowfin Longline fisheries in 2003

Catch and effort data collected on the longline fisheries are available with about 1 year of delay (as large scale longliners tend to remain at sea for long durations); however a provisional but significant estimates of the 2003 Japanese series was obtained from Shimizu scientists (Miyabe com.pers.) allowing to compare at least indicatively the recent trend in this fishery.. This preliminary data set shows that high yellowfin CPUE has been observed in the fishing zone between Seychelles and the African coast. The comparison of yellowfin fishing zones between 2003 and previous years shows (figure 32) that there was a positive anomaly of yellowfin catches in a peculiar area shown by figure 33. In the surrounding areas, a negative anomaly of catch was observed, but at a moderate level. There is no doubt that yellowfin has been the target species of Japanese fleet in this strata, as this species was widely dominant in the local catches (figure 32 b). This "anomalous" area is more or less the area where the purse seine anomaly of catches has been observed during 2003. It was also noticed that in 2003 the Japanese longliners had obtain in this peculiar area very high CPUE all year rouind during 2003 (figure 24), and that their catches in the area have been at the highest level ever observed in the Japanese fishery , figure 35, with the exception of the year 1968, a year with a higher catch!

Then, the conclusion is that it seems that the ***longline*** yellowfin fishery has found and heavily exploited during 2003 in the Western Indian Ocean a large biomass of yellowfin (or a "normal" biomass of yellowfin, but heavily available to longliners) and the result will be the Japanese longline a record high level of its yellowfin catch.(14.800 t. in 2002 versus 20.800 t. in 2003, 2003 YFT catch being the highest one observed for Japanese longliners since 1969).

It was noted concerning the yellowfin longline fisheries that the small South African fleet has obtained during this year very good CPUE and high yellowfin catches: 600 T. versus 150 t. in 2002, 2003 being the highest level ever observed for this small fleet (with a CPUE of 310 kg/1000 hooks, much higher than in 2000 and 2002). Furthermore a similar positive anomaly of yellowfin catches was also observed in South Africa waters for the sardine purse seine fishery and for the hand line fishery (Craig Smith personal communication). It can also be noticed that Chinese longliners have declared their highest yellowfin catches and CPUE in the South Western Indian Ocean during 2003, but the small scale of this fleet and its short history is a limiting factor to allow further interpretation of these high values.

2-3- Yellowfin and artisanal fisheries

It should also be necessary to analyse the CPUEs and catches of large yellowfin taken by the various artisanal fisheries that are targeting this group, for instance in the Maldives, Yemen, Sri Lanka and Oman hand line fisheries, or the performances of the various coastal drift net fisheries catching yellowfin.

Unfortunately it was not possible to obtain any quantitative or qualitative information on the catch trends of yellowfin of most of these fisheries when this paper has been finalized. The only fishery for which at least a figure of total catches was available was the Iranian drift net fishery: this figure shows that record high levels of yellowfin catches were taken by this fishery in 2003: nearly 30.000 t., e.g. the highest level of yellowfin catches ever observed in this fishery. Although it would be necessary to obtain more information upon these catches before getting any firm conclusion (for instance about the size of the fishes taken, the levels of fishing efforts in 2003, or changes in the area fished or fishing mode?), this positive anomaly of yellowfin catches that was also observed in the Arabian Sea should also be noticed in the complex panorama of the 2003 yellowfin fisheries..

- If the average catches and CPUE of these artisanal coastal fisheries scattered in the Indian Ocean have been "average", it would indicate that the high catches by purse seine were due to an increased catchability of the stock to the purse seine fleet.
- On the opposite, if catches/CPUE of these artisanal fisheries are also larger than previously, it would tend to confirm a positive trend in the biomass of the adult stock size, or that the anomalies producing high CPUE in the purse seine fishery have also produced high CPUE in these coastal fisheries.

2-4- Estimates of total yellowfin catches in 2003?

It is still difficult to estimate the 2003 catches as many fisheries, especially artisanal and from large scale longline fleets, have not yet provided to the IOTC their 2003 catches. Based on the data presently submitted to the IOTC, the catches of the missing fisheries were estimated in the hypothesis that they had either a stable catch (small fleets) of a higher catch with an increase similar to an equivalent fleet (see legend of table 1).

Based on this estimation procedure, the total yellowfin catch in the Indian Ocean in 2003 would be around 444.000 t.

The trend of total catches is shown by figure X. This figure shows that 2003 catches are well above the highest levels observed since the beginning of the fishery.

The corresponding Grainger and Garcia indices (rates of increase of catches calculated during the 20 last years in reference with catches taken during the 6 previous years) is shown figure 19, and shows that these rates are at their highest levels observed during the last 10 years, as all these recent rates of increase were either close to zero or negative (this negative rate was a strong indication that the stock was fully exploited and probably overfished during the period, as the effective efforts of most fleets were probably increasing during the same period).

3- Potential explanations for the 2003 high catches of yellowfin

3-1- An increased biomass of large yellowfin during 2003?

3-1-1-The question: Any increased of CPUE such as the one observed in yellowfin during 2003, can be explained, among other hypothesis, by a corresponding increase of stock biomass. This conclusion may be a valid one at constant effective effort when it can be assumed that the catchability factors of the fleet were not increased during the considered year. In the case of the 2003 high catches, as all the “excess” in catches were observed at medium and large sizes, the immediate hypothesis would be that there was in the 2003 yellowfin population one or several large cohorts that have been recruited during the 2000-2002 period, and made available in the adult stock (for the first time) during the year 2003. Upon this point, it should be kept in mind that the adult stock of yellowfin is “constituted” by several cohorts, probably at least 5 cohorts in the range of sizes between 80 and 150 cm (the range of sizes caught in excess during 2003). The potential validity of such hypothesis could be tentatively validated through two simultaneous approaches:

(1) An analysis of juvenile yellowfin CPUE during recent years, for instance since 1999, when these fishes were recruited in the same purse seine fishery. The presence of one or several large cohorts should have produced an increase of the purse seine CPUEs of juvenile yellowfin during this recent period. An index of CPUE of juvenile yellowfin (e.g. fishes less than 5 kg) in the purse seine fishery has been calculated.

(2) An analysis of the longline yellowfin CPUEs in 2003: if there was a real positive anomaly in the abundance of large yellowfin in 2003, such anomaly should have also produced a positive anomaly of their yellowfin CPUEs, at least in the Western Indian Ocean. It is too early to answer this question, but the sample of LL data analysed by the SFA was interesting to analyze and has shown that large CPUE and catches of yellowfin have been observed in the fishery close to the purse seine fishing areas (paragraph 2.2.2). .

3-1-2- Purse seine CPUE of juvenile yellowfin

The input data of the GLM CPUE indices was the nominal CPUE (figure 27a) of small yellowfin (<65cm) by quarter and areas shown figure 12). The 4 “traditional” fishing zones used in most analysis of the purse seine fishery (figure 12: Somalia, West Seychelles, East Seychelles and Mozambique Channel) have been used to do this calculation.

As recruitment indexes standardized purse seine small yellowfin catch rates were considered. Standardized cpue were obtained by general linear models (GLM) using the Delta –Lognormal method. In this method two components are considered: the probability that cpue was bigger than zero, P{cpue>0}, and the distribution of the positive values of cpue. Both could be modelled independently to obtain, on one side, an adjustment of the positive cpue probability, and on the other hand, the expected cpue conditioned to obtain a cpue value bigger than zero. Then the Delta-Lognormal model proposed, comprises two lineal generalized using the Bernoulli and Lognormal distributions respectively.

The relative cpue for every year is:

$$CPUE_i = \mu_i \, p_i \, , \; i = 1,2,3.$$

where μ_i is a unit of standardized cpue for the positive catches in every zone, and p is a unit for the standardized proportion of positives.

The model to adjust cpue for positives is:

$$Ln(CPUE) = X\alpha + Z\beta + \varepsilon,$$

where cpue is the observations vector, X is the main factors matrix, α main factors parameter vector, Z is the interactions matrix, β is the interactions parameter vector and ε is the independent error vector identically distributed that follow a $N(0, \sigma^2)$.

On the other side, to estimate the proportion of positives, all the data set was used. A random variable Bernoulli type was created with value 0 or 1, depending if the cpue was nil or positive respectively. Then the average of this variable is calculated in every defined strata for every year, area and quarter and the number of observations existing in every one is calculated.

The probability that the cpue could be positive, could be modelized through a binomial GLM with the logit function as a connection between the explicative variables and the response variable, i.e., the appearance of positive cpue is a Bernoulli random variable with a probability p given by:

$$Log(p/(1-p)) = Z\alpha + Z\beta, \text{ o bien,}$$

$$p = 1/ (1 + exp\{ X\alpha + Z\beta \}),$$

where X is the main factors matrix, α is the main factors parameters vector, Z is the interaction matrix, and β is the interactions parameters vector.
In our analysis we considered four areas: Somalia, Western Seychelles, Eastern Seychelles and Mozambique Channel. Data used correspond to the period 1991-2003. (data from the period 1984-1990 should also be used in the analysis, but unfortunately this file of the early

fishery has not yet been fully standardized[7] in a similar way as the 1991-2003 series, and then it remains difficult to use in the same GLM model)

For the cpue>0 we considered the purse seine catch of fish less than 65 cm divided by the total effort as response variable. As explanatory variables we included year, area and quarter all considered as factors. The final model was:

log(cpuep) ~ year + area + quarter

The model for the proportion of positives was a binomial GLM with the logit function as link,
propor ~ year + area + quarter + area:quarter

Variances explained by both models were 46% and 74% respectively.

The following table 2 shows the ANOVA results.

ANOVA TYPE III SUM OF SQUARES					
Positive CPUE					
	Df	**Sum of Sq**	**Mean Sq**	**F Value**	**Pr(F)**
Year	12	157.9636	13.16363	17.9231	0.0000000
Area	3	115.5485	38.51617	52.44215	0.0000000
quarter	3	20.5911	6.8637	9.34535	0.0000052
Residuals	471	345.9263	0.73445		
Proportion of positive CPUE					
	Df	**Sum of Sq**	**Mean Sq**	**F Value**	**Pr(F)**
Year	12	1.06298	0.088582	2.7147	0.0021521
Area	3	10.23911	3.413035	104.5964	0.0000000
quarter	3	1.71884	0.572947	17.5586	0.0000000
area:quarter	9	5.93904	0.659894	20.2232	0.0000000
Residuals	179	5.84086	0.032631		

Table 2: . ANOVA type III results from the lognormal model of positive cpue and binomial model of the proportion of positive cpue.
The yearly GLM CPUE indices obtained by this model are shown figure 27b.

As a conclusion, this CPUE index do not show any very large year class recruited in the purse seine fishery during recent years (figure 27 a & b). It would then be surprising that one or several large year classes of yellowfin would have been recruited in the adult stock, but without noticing large corresponding CPUE of small yellowfin in the purse seine fishery.

On the other side, it has been noticed that the purse seine fishery has widely increased its catches of small yellowfin since the mid nineties (Shanghai WG report), although its nominal effort was kept stable or decreasing. It was then concluded that these increased

[7] These sizes were processed by 1° and month strata with small size samples and multiple strata substitutions, when the recent series have been processed by large ET areas and quarters, using large samples and few substitutions)

catches of juvenile yellowfin were due to the increased use of FADs (as all these small yellowfin were taken under FADs), and not to increased recruitments. This trend to increase catches of juvenile yellowfin is easily visible on the nominal CPUE of juvenile yellowfin (figure 27a), but not on the GLM**.** If these high catches of juvenile yellowfin after 1995 were due to high recruitment (and not to increased catchabilities), it is clear that these fishes should have produced a progressive significant increase of the adult stock during the late nineties, but this increase was not visible in the purse seine or longline fisheries. The conclusion obtained by the Shanghai WG in 2002 that these higher catches of juvenile yellowfin were due to an increased q due to FADs, remains the best hypothesis.

3-1-3- Why such large biomass of yellowfin tuna could have been observed in 2003?

Although the hypothesis of a sudden "real" increase of the adult biomass in 2003 appears to be quite unrealistic, such increase of biomass could be in relation with three potential factors:

(a) **improved stock productivity:** a wide scale environmental change in the Indian Ocean environment that would be producing an increase of the yellowfin biological productivity (improved biological condition and lower natural mortality): this change could for instance be in relation with the large quantities of a new food available to yellowfin, the *Natosquilla* crustacean. This type of biological natural variability has been often demonstrated for temperate tunas such as bluefin (Ravier et Fromentin 2004) and albacore (observed in both Atlantic and Pacific oceans), but can also be envisaged for tropical tunas.

(b) Great concentration of the yellowfin biomass in a small area, where these tunas have been heavily vulnerable to both purse seine and longline fisheries (and to some artisanal fisheries). This peculiar concentration of yellowfin tuna should have been due to an environmental anomaly, but the environmental causes of this anomaly remain unknown (outside the massive presence of *Natosquilla*).

(c) **A stock productivity underestimated by scientists**: the diagnosis previously done by the IOTC scientists was that the yellowfin stock was fully exploited since the late nineties, with an MSY estimated at about 300.000t. This result has been obtained by various assessment methods. However, there is still the possibility that this estimated MSY was underestimating the real biological productivity of the yellowfin stock. Such bias underestimating the real MSY of a yellowfin stock has in fact been observed for many stock assessment works conducted on yellowfin during the last 40 years in the Pacific, the Atlantic and the Indian Ocean. These underestimated MSY were most of the time easily explained by scientists, at least *a posteriori*, being due to an area effect (increased of zoned fished, and viscosity of the stock) or/and a gear effect (longliners being *de facto* very inefficient to catch the MSY of any yellowfin stock).

3-2- Increased catchability of large yellowfin in 2003

3-2-1- Introduction

This question can easily be stratified into various "explanatory sub-hypothesis" such as the following:

(1)an **environmental anomaly** developed during 2003, for instance a shallow thermocline, that could have temporarily increased the catchability of large yellowfin to the purse seine fleet in given areas, or an environmental anomaly leading to large concentration of the Indian Ocean yellowfin biomass in the south-western Indian Ocean.

(2) An **increased catchability** of large yellowfin due to an anomaly in their **behaviour** (this point being potentially linked with the previous one), and/or

(3) The effect of **new technological factors** introduced during 2003 by the purse seine fleets, such changes **increasing their fishing efficiency** on free schools of large yellowfin.

It should be kept in mind that the high frequency of very large sets observed during 2003 could be linked to each of these three sub-hypothesis, as these large sets could be due either to an environmental anomaly, a change in tuna behaviour and/or to a technological improvement in the purse seine fishery.

3-2-2- New fishing zones in 2003?

It is well known that any significant increase in the size of the exploited fishing zones tend to produce sustainable increases of catches and of stock MSY (Die and al. 1990, Laloe 1989). This is due to the fact that despite of their migratory behaviour, all tuna stocks tend to be "viscous", e.g. they are often showing limited movements instead of the large scale migrations that could be "expected" fur such highly migratory species (Fonteneau and al. 1996). As the movement patterns of most tuna stocks are often quite limited in their geographical scale, when a fishery discovers a new fishing zone, the exploitation of such new zone often tend to produce a sustained increase of catches on the stock (when before these remote & isolated fractions of stocks were *de facto* still cryptic and unproductive). Such potential sustained increase of catch is of course dependent of the stock viscosity and also of the distance between the traditional and new fishing zone.

The analysis of the exploited zone is showing (figure 13) that the size of the area fished by purse seiners has been showing a slow and moderate decline during the last 6 years, the area fished in 2003 being at the lowest level observed during the last 8 years.

However, the map of the yellowfin fishing zones in 2003 compared to the fishing zones exploited during previous years (figure 10), do show that the areas successfully fished for yellowfin during 2003 were **highly non-typical**: large catches of free school of yellowfin have been taken during the entire 2003 year in an area south of Seychelles, between the African coast and west of 65°E, when in the past the yellowfin CPUE and catches were low in this area (Figure 10). It can also be noticed in this map that large quantities of yellowfin have been taken very close to the African coast and close to the African continental shelf. Figure 21 shows the total yearly catches of the sampled purse seiners in this area 5°-10°S, west of 65°E, and this figure shows well the spectacular jump observed about the 2003 yellowfin catches in the area: more than 100.000 t being taken in an area where the highest catches before were under 40.000 t. Catches of skipjack and bigeye were also higher than usual in this area in 2003. Figures 22 and 23 show that these high catches were taken by a "stable" effort but with very high catch rates.

This type of localized areas with high catches and high CPUE may suggest that tunas may have been heavily concentrated in the south west of the Indian Ocean.

It could be envisaged that the exploitation of these rather new East African coastal fishing zones could increase the potential sustainable catches of yellowfin (if these fishes were part of a viscous stock, being permanent residents in these zones suffering a low exploitation rate (these fishes being a component of a cryptic fraction of stock). This hypothesis seems to be quite unrealistic.

The analysis of the catch trends of yellowfin observed in other artisanal fisheries do shows a quite different pattern, with high yellowfin catches being also observed in the Arabian Sea (Iran), in South Africa and around Sri Lanka. These high catches could suggest a high apparent abundance of yellowfin in these areas, but this conclusion would need to be validated (or not) by additional detailed information upon teach of these fisheries.

As a final comment about the yellowfin fishing zones in 2003, it could be said that if large catches have been taken in 2003 by both the purse seine and the longline fisheries in areas where yellowfin was less productive before; however, it appears that these new fishing zones are clearly within the traditional range of these fisheries. In such conditions, it should be considered that the 2003 fishery has been exploiting the same fractions of stock: there is very little hope to consider that such type of "new" 2003 fishing zones could increase the yellowfin catches in a sustainable way (this could be the case for instance if the 2003 fishing zone had been located in remote areas, for instance in the Eastern Indian Ocean). The basic hypothesis now is that there was in 2003 a large biomass of yellowfin that was fully available to all fishing gear in peculiar fishing zones, but probably not a major sudden increase of the 2003 stock biomass.

3-2-3- An environmental anomaly in 2003?

It is well known by fishermen and scientists alike that an anomaly in the physical environment can easily increase or decrease widely the CPUE of any fishing gear, for instance increasing or reducing the efficiency of the purse seiners when a thermocline gets very shallow or very deep. Such anomaly has been a source of deep concern for the Atlantic Ocean purse seine fishery, when in the first quarter of 1984, the Atlantic El Niño reduced the yellowfin CPUE of purse seiners during several months, see figure 28 (when the yellowfin stock was still in a reasonably good condition). However, it should be noticed than during this anomaly the LL CPUE was maintained at a good level, being more representative of the real status of the adult stock.

Similar phenomenon were observed during the Indian Ocean 1998 El Niño, when low CPUE were observed for the purse seine fishery in the Western Indian Ocean, when the LL CPUE in the area were maintained at good levels (see figure 28).

The apparent low biomass of tunas in the Mozambique Channel during the 2nd quarter of 2003 (noticed for the first time since 1983), could be an indication that there was some environmental anomaly in 2003, but such anomaly would need to be identified based on an analysis of the various environmental data, surface and subsurface, available on pelagic waters of the Western Indian Ocean (as the lack of fishing activity in the Mozambique channel could also be due to the good catches obtained simultaneously in the W Seychelles area, see figure 11)

Among the various environmental data of potential interest that could be used in order to identify such anomaly, the thermocline depth (measured by its proxy, depth of the 20° isotherm) has been analysed within 3 sub-areas of the 4-6°S and 40-55°E area in the 2003 fishing zone and in an area where large numbers of bathythermograph have been permanently collected by merchant ships. The overlook of this information[8] do indicate that when the 1983 and 1998 anomalies are clearly visible in each of the 3 selected sub-areas (deep thermocline), there was no visible anomaly in the thermocline depth in any of these zones during the year 2003 (figure 29): during 2003, the thermocline depth appears to be established at an average level.

Further environmental analysis should be conducted on other parameters (such as primary productivity of surface waters) in order to confirm or not this first result. This study should preferably be done at a fine geographical scale in the areas of major concentration of yellowfin catches by both purse seine and LL. It should try to identify all the changes in the ecosystem, from its primary productivity to the various components of the pelagic ecosystem in the critical "anomalous area".

[8] This analysis has been done by Francis Marsac

3-2-4- A behavioural anomaly of large yellowfin in 2003?

Various scientific studies recently conducted by scientists in the area (Potier et al. 2001, Potier et al. 2002, Potier et al. in press), have shown that a major change has been observed during recent years (since 1999) in the trophic chain exploited by tunas in the western Indian Ocean. This major change was in relation with the recent major increase of the biomass of a very small[9] pelagic crustacean, *Natosquilla investigatoris* (figure 23), in shallow waters of the Western Indian Ocean. The time and space extension of this crustacean is not yet clear, but there is no doubts that during the last 25 years (purse seine fishery) this species was very rare until recently, as it was never significantly observed since that year by tuna scientists working in the area, among them Bashmakov et al. 1992 and Roger 1994, who studied tuna feeding in the Indian Ocean. It was noticed from various sources that this species became very abundant during recent years in many areas of the Indian Ocean:

- Around Seychelles: in October 2001, large amount of *Natosquilla sp*. were beached on several islands such as Praslin.
- In Tanzania: Kamukuru and Mgaya (2004) observed in abundance since July 2000; the same species was also noticed in coastal waters and in the stomach contents of yellowfin tuna taken by the Tanzanian sport fishery.
- In Maldives (Charles Anderson personal communication)
- In the Mozambique channel around Europa (July 2002) and Glorieuses Islands (october 2002) (Potier et al, in press)
- Etc….

This crustacean has also been recently and often noted by all tuna skippers and by various scientists (Potier et al). It should also be noticed that this *Natosquilla* tend to live in shallow waters and in dense concentration. All skippers have frequently noticed that large concentrations of tunas, of large and small sizes, were often feeding in shallow waters upon this crustacean. It can be noticed that these *Natosquilla* are often eaten by large size yellowfin (sizes>1m) despite of the very small sizes of these individual (<10g) (Potier et al. in press), as well as by a variety of fishes and birds. The potential consequences of such peculiar feeding behaviour could be that these tunas concentrated in these shallow waters upon the schools of *Natosquilla* may become more vulnerable to purse seiners (being easily seen and easily caught). An additional hypothesis could also be that these shallow concentrations of *Natosquilla* could create tuna schools much larger that the usual ones, in relation with their unusual feeding (skippers have often described a peculiar feeding frenzy of these new feeding concentrations).

However, it is puzzling that this abundance of *Natosquilla* has apparently not produced any similar effect on juvenile yellowfin and bigeye and on skipjack, when all stomach contents analysis and observations at sea by skippers and scientist demonstrate that all these fishes were also feeding predominantly on *Natosquilla*. Their predominantly shallow distribution, their large abundance and density, their small size and their accessibility to predators (swimming very slowly) make them the perfect preys for all these small tunas. It is possible that skippers did not took profit of such a high potential catchability of juvenile yellowfin and bigeye and skipjack, because they were targeting their fishing effort to the more profitable large yellowfin.

It should however be noticed that this hypothesis would possibly in contradiction with the high catches of yellowfin by LL in 2003 in the same area: such shallow massive feeding of tunas should tend to reduce the catchability to the longline gear, as this gear is fishing in deeper waters (about 100m?) and as only the feeding tunas can be caught on the hooks: it has been noticed in Tanzania by Kamukuru and Mgaya, 2003 that large quantities of *Natosquilla*

[9] The average weight of a *Natosquilla* is less than 10 gram !

may tend to reduce the tuna catchability to hand line and pole and line gears, as tunas could be already fed by these easy to catch preys and as deep tunas may be more concentrated in shallow waters.

3-2-5- A sudden increased efficiency of the purse seine fleet in 2003?

Introduction

It has been well shown that the Indian Ocean purse seine fleet has been permanently increasing its fishing power since the beginning of this fishery in 1982 (results of the European Union ESTHER program, and analysis of the Shanghai IOTC 2002 WG). Most of the technological progresses tend to be introduced in the fishing vessels in a progressive way, but some of major ones have been introduced very quickly within a short period of time. Such changes tend to produce, at least temporarily, an increase of catches (in the same way as a fast increase of nominal fishing effort):

- When the targeted stock is not yet fully exploited, this increase of catches can be sustainable, then producing a higher level of sustainable catches (like an increase in nominal fishing effort on a moderately exploited stock).
- On the opposite, when the stock is already fully exploited or size-overfished (probably the present status of the yellowfin stock in the IO?), this higher 2003 catch due to the new technological progress and/or to a behavioural anomaly of adult yellowfin, will not be sustainable in the long run (these high catches being well in excess of the MSY, then worsening the already fully exploited status of the stock).

Technological changes in the purse seine fishery

It has been noticed that during the period 2002 and beginning of 2003, most of the studied purse seiners have been equipped by new highly efficient long distance sonars. These new sonars are made by Norwegian (SIMRAD SP90) and Japanese (FURUNO) companies and they are both working in a range of frequencies between 20 and 30 Khz . Their theoretical maximum distance is within a range of about 7 to 8 km, but in practice they can identify a tuna school in a range between 3 to 4 km (when sonar previously used was reaching a distance less than 1 km). These sonars are now permanently used:

(1) in the purse seine **searching activities**, this sonar becomes an additional tool allowing to locate sub-surface or deep tuna schools that would not have been visible on the surface (for instance in the absence of bird flocks).

(2) in the **follow up of tuna schools** associated to FADs: the new sonar do allow a comprehensive evaluation of the tuna biomass scattered in the vicinity of the FADs; when an invisible biomass of tunas has been identified in sub-surface waters, this acoustic survey do allow to wait around the FADs and later to set upon it.

(3) When the purse seine is deployed upon a mobile free school, this new high performance sonar allows a more efficient follow up of the school behaviour during the **setting operation**, then potentially improving the success rates of setting operations. However, it can be noted that the success rate of free schools sets (as estimated from the log book data) in 2003 was an average one (57%) (compared to the 57% estimated in 2001 and 59% in 2002), and then this improvement of the success rate in the setting of the net cannot be identified by the analysis of success rate, keeping in mind that there is still the possibility that the new sonar do allow to more efficiently and entirely catch the larger schools increasing the catch per set (Figure 6).

There is no yet any scientific study of the potential quantitative effects of this new sonar on the efficiency of the purse seine fleet, but there is very little doubt that these new sonar tend to (significantly?) increase the purse seine efficiency, improving both the efficiency of the **searching** activities as well as the efficiency of **setting** the purse seine. However it can be noted that these effects of the new sonar will be difficult to analyse, as even if the date of introduction of this new equipment is well known for every purse seiners, the entire purse seine fleet, Spanish and French, did acquire this equipment within a very short period of time.

The widely positive effects of the new sonar are now unanimously recognized by all the Indian Ocean tuna skippers, and these are considered as being a major progress conditioning their fishing efficiency (Spanish and French alike). Then it can be concluded that the use of the new sonar during 2003 did play a positive role to determine the high yellowfin catch rates obtained in 2003 by purse seiners in the Indian Ocean and the high frequency of very large sets.

New sonar in the Atlantic fisheries

However, it can be noticed that the other EU purse seine fleet that was simultaneously fishing in the Atlantic Ocean had also introduced the same sonar technology during the same period. The comparison of the 2003 catch rates obtained by these two fleets in the two oceans shows a very different result in the Atlantic, where it appears that the 2003 purse seine CPUEs were stable for both free and FAD associated schools in 2002 and 2003, when the number of sets was increased by 33% (e.g. the much average smaller sets). This result would tend to indicate either that (1) the effect of these sonar are different in each ocean and less effective in the Atlantic (for instance in relation with stock biomass, the environment or school behaviour), or (2) that the quantitative effects of the new sonar would tend to be minor ones in both oceans (the high 2003 Indian Ocean CPUE being then explained by other factors such as the *Natosquilla* hypothesis). There is also some potential positive interaction between the increase detection facilities offered by the new sonar and the effects of *Natosquilla*. In such case of interaction, the benefit of efficiency due to these sonar would have been lower without the *Natosquilla* effects (The Atlantic case).

3-2-6- Conclusion on the causes explaining the 2003 catch anomaly

It remains difficult due to the limited statistical information available to precisely conclude on the causes explaining the 2003 positive catch anomaly of large yellowfin by purse seiners. At this stage, the preliminary conclusion would be that this high 2003 catch is probably due to an **increased catchability of the stock and not to an increased biomass** (or to an increased biological productivity of the stock). This temporary increase of catchability seems to be due to a combination of a technological factor (such as the new long range sonar recently installed on the purse seine fleet), and a behavioural factor of yellowfin tuna, as its feeding behaviour on *Natosquilla* may be increasing the vulnerability of the stock to the purse seiners. The same atypical fishing zones observed for the purse seine and longline fisheries in 2003 could be in relation with large concentration and large availability of yellowfin tuna in a peculiar and rather small area of the South Western Indian Ocean. It should also be kept in mind that the great numbers of very large sets observed in 2003 have clearly contributed to the record high catches by purse seiners during this year, and they can also be explained by a combination of behavioural effects (*Natosquilla*) and technological effect (new sonar).

4- Overview upon present yellowfin stock status and prospects in 2004

4-1- Introduction

Recent stock assessment analysis done by scientists within the IOTC framework have concluded that the Indian Ocean was already fully exploited and possibly overfished, at least in the Western Indian Ocean, the area where most of the yellowfin catches are taken (IOTC Shanghai WG in 2002). This diagnosis can be simply summarized by the trend of total catches of yellowfin during recent years in the Indian Ocean: it appears that these catches have been slowly declining during the last 10 years (figure 18), despite of the steady increase of effective or/and nominal fishing efforts developed during this period by multiple fleets (purse seine, artisanal and longline, each of these three components being significant in the Indian Ocean yellowfin fisheries). It should be noticed that the new set of catch data recently released by the IOTC has been showing significant increase of total catches (by artisanal fisheries) since the last IOTC stock assessment; it appears that the trends of this new series are very similar to the old ones, then probably confirming the present stock status. This basic conclusion is also well expressed in term of the Grainger and Garcia index showing on the new catches series the decline of the rates of catch increases observed in the area during recent years (figure 19), in opposition with their spectacular jump upwards in 2003. This analysis of stock status conducted in 2002 by the IOTC Shanghai WG (Figure 25) did estimated that after a long period of slow decline during the period 1950-1982 (during which the stock was still moderately exploited primarily by longline fisheries), and that since the early eighties the stock biomass has shown a quite significant decline due to its increased exploitation by the various gears.

4-2- Changes in stock size and/or in its exploitation rate?

It will be necessary to redo a comprehensive updated analysis of the yellowfin stock status based on the complete fishery data (using catches, effort and sizes data from all major fisheries), but there is no doubt that this new analysis will be facing the same structural uncertainties as the present overview. Basically the model used and accepted as the best one, will need to choose among the various hypothesis presented in the paper, mainly choosing between:

(1) The **constant fleet efficiency** hypothesis, then accepting and **increased stock biomass** in 2003 due either to increased recruitments or to increased biological productivity of the yellowfin stock.

(2) the **increased catchability** hypothesis, where this increased q can be due to a combination of technological factors (such as new sonar), changes in fish behaviour (for instance in relation with their new feeding on *Natosquilla* concentrations) and changes in the stock geographical distribution, the stock being more heavily concentrated and suffering a higher catchability to all gears because of its concentration.

(3) or a combination of these sets of factors.

At this stage, it should be considered that **if the hypothesis (2) is valid**, e.g. very large catches due primarily to increased efficiency or to an increased vulnerability of the stock, the status of the yellowfin stock could become very quickly a source of serious concern: if the stock was really fully exploited since the late nineties, the sudden increase of 50% of yellowfin catches by purse seiners do correspond to a corresponding increase of their effective fishing effort: this increase would be for instance equivalent to the arrival of about 30 new vessels targeting yellowfin that would be added to the present fleet of 60 purse seiners. Further analysis are needed to evaluate the trend of the adult stock, but there is no doubt that if the previous IOTC analysis were correct, the Indian Ocean yellowfin stock would be very soon in deep trouble of being severely overfished, especially if the high catches are maintained in 2004 (a realistic hypothesis).

4-3- Stock and fisheries prospects for 2004 onwards

Landing data of yellowfin taken by purse seiners during the first months of 2004 were also analysed in order to check if the 2003 catch anomaly was also observed in 2004. It appears that the landing of yellowfin during the first month by French purse seiners were also very high, being in October 2004 at a level about 20% higher than the 2003 yellowfin catches (but with a 20% lower skipjack catch). The yellowfin catches by Spanish purse seiners were also very good during at least the first 8 months of the year 2004, with a level of total yellowfin catches 21% higher than the record 2003 catches,. As a conclusion the total catches by purse seiners during the year 2004 will probably be larger than the record 2003 levels.

There is also some qualitative information that these high catches of yellowfin were also observed in South Africa in 2004.

5- Conclusion

After about 10 years of a remarkable stability, the situation of the Indian Ocean yellowfin fisheries and stock have been showing major and fast changes since the end of 2002. The reasons of these changes and their future consequences on the sustainable exploitation of the yellowfin stock are still highly questionable, primarily due to the lack of data and lack of a subsequent comprehensive stock assessment. There is no doubt at this stage that the present situation should be a source of serious concern for scientists, fishermen and the IOTC managers. There is no doubt that an in depth and comprehensive updated analysis of the stock status should urgently be conducted on this stock as soon as possible when a majority of the 2003 catch effort and size data will be available to the IOTC. This new assessment should also analyze with great care the potential environmental anomalies that could have been developed in the South Western Indian Ocean area during recent years and especially in 2003 (as such anomaly could change the catchability of the stock or its biological productivity)

It should also be kept in mind by the IOTC scientists, that in the concept of a precautionary approach, the very large and still widely unexplained 2003 catches of yellowfin could well lead the IOTC Scientific Committee and Commission to new management recommendations: The real present status of yellowfin stock is still unclear, but after this analysis of available data, there is a high probability that the new catches will not be sustainable. In this uncertain but risky scenario, a precautionary management should well be promoted in order to reduce the yellowfin catches, and then the risks of stock overfishing (even if these risks are still quantitatively unknown).

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Table 1: Total catches of yellowfin by country during recent years and best estimates of 2003 catches

Country	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Taiwan,China	34062	23117	27850	18374	23416	17686	17367	18860	27747	*40136*
Korea	3999	2692	4019	4161	2576	1013	1138	1533	341	2143
South Africa	8	33		34	157	167	208	101	156	**753**
Philippines					623	619	339	324	346	1639
Yemen	881	873	875	915	893	893	893	892	892	3569
Seychelles	10	6	67	2880	7453	9954	11899	13422	17147	34739
France	35819	39635	35577	31227	22382	30799	37694	31377	35111	**63281**
China		156	550	808	477	2469	2488	1850	1363	2307
Iran	27162	27175	30235	22079	21534	27085	15743	20153	24045	37722
Spain	43149	65143	59431	60986	38588	51919	49512	47894	53812	**79368**
Japan	15057	12779	16726	18216	18753	16166	16430	14582	14652	**21195**
Sri Lanka	23181	20369	24846	30422	29674	36731	33390	27824	29967	33518
Indonesia	27049	32343	48007	49081	49378	59291	39846	36815	34838	38123
France-Reunion	492	402	643	636	609	534	656	610	544	586
Mauritius	1918	1803	742	1176	1473	1250	739	685	670	694
NEI-Other	19676	19319	16741	21898	20283	25827	27051	19444	19051	18862
Pakistan	4604	5140	5747	4049	4019	9533	5543	3994	3289	3102
Australia	651	268	109	307	278	484	397	1016	335	218
France-Territories		115	191	207	433	328	461	3608	1684	261
Maldives	12621	12031	11811	12489	13566	13261	11625	13656	20593	20593
NEI-Fresh Tuna	23471	16527	16695	22109	15906	12781	12456	6867	6598	*9544*
NEI-Ex-Soviet Union	5836	16338	13174	10175	5305	11768	10949	9764	6816	*12285*
Oman	19212	21428	11636	9873	11338	7402	7146	6306	5301	5301
NEI-Deep-freezing	9654	6706	11554	5570	10865	8584	7081	4400	3439	*4974*
Comoros	5880	5880	5789	5569	5569	5437	5874	5437	5437	5437
India	1555	1579	1635	1829	1568	1822	1925	1797	1830	1830
others	16731	9184	4081	4351	652	681	1413	1453	1495	1586
Total	**332679**	**341043**	**348732**	**339422**	**307768**	**354483**	**320261**	**294667**	**317501**	**443767**

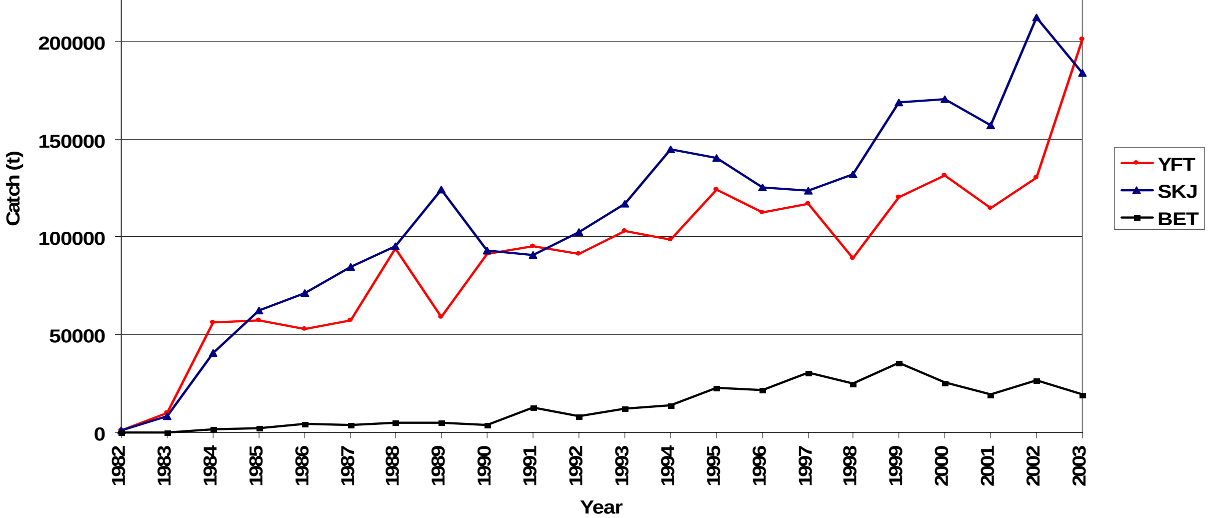


Figure 1: Catches by species taken by the sampled purse seine fishery

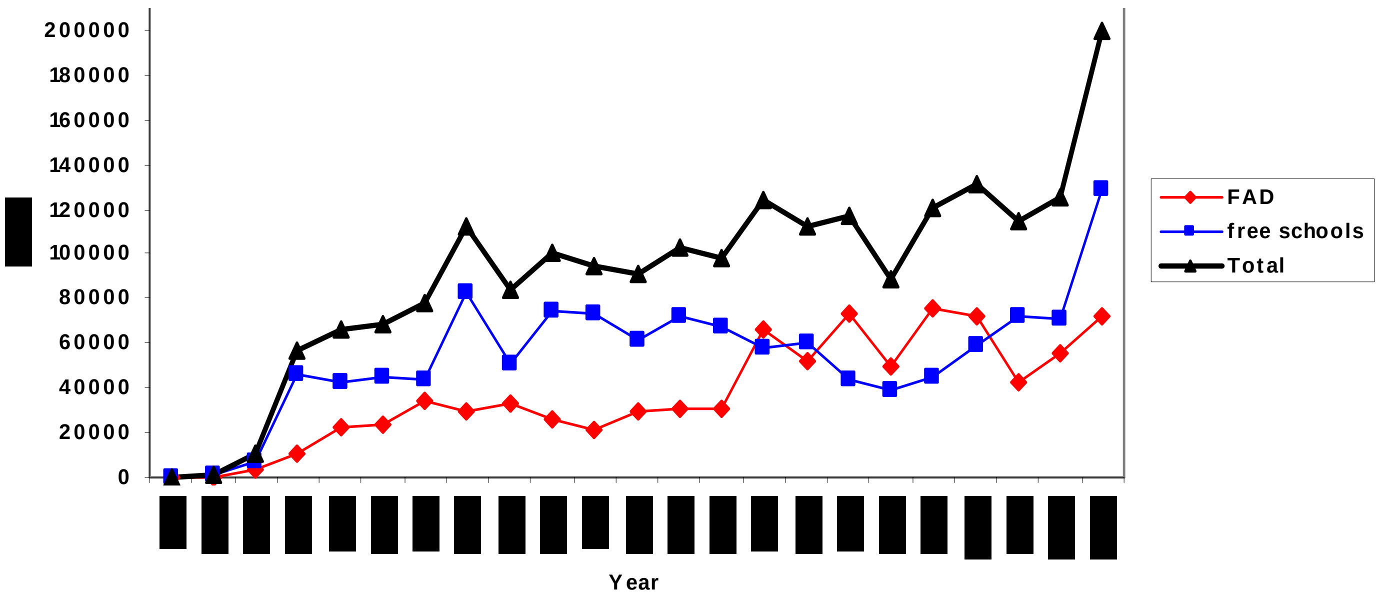


Figure 2: Catches of yellowfin taken on FAD, on free schools and total, by the studied fishery.

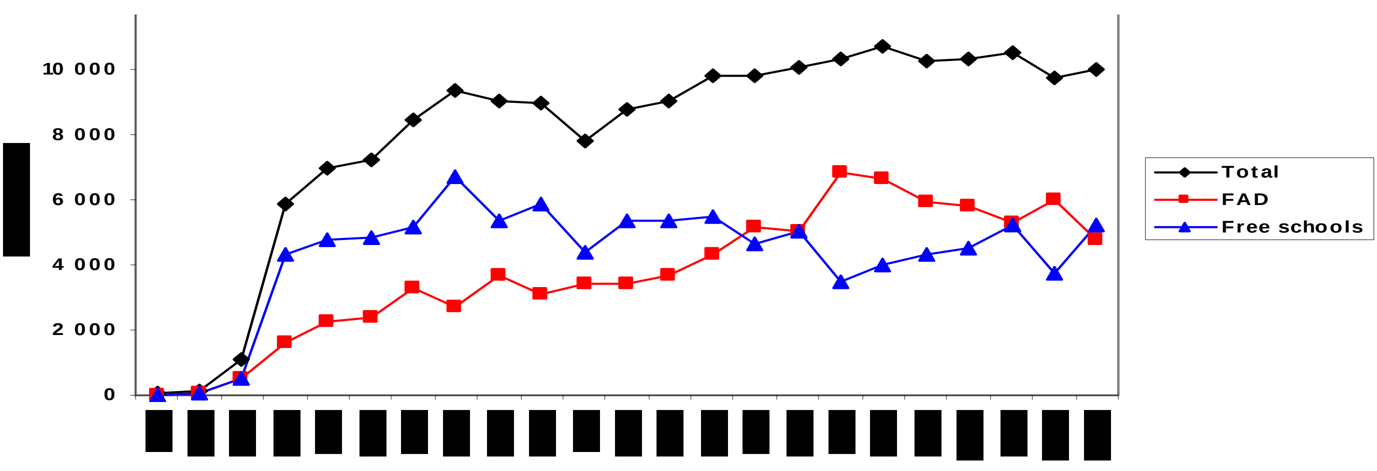


Figure 3: Numbers of sets by the PS fishery on FADs, on free schools, and total.

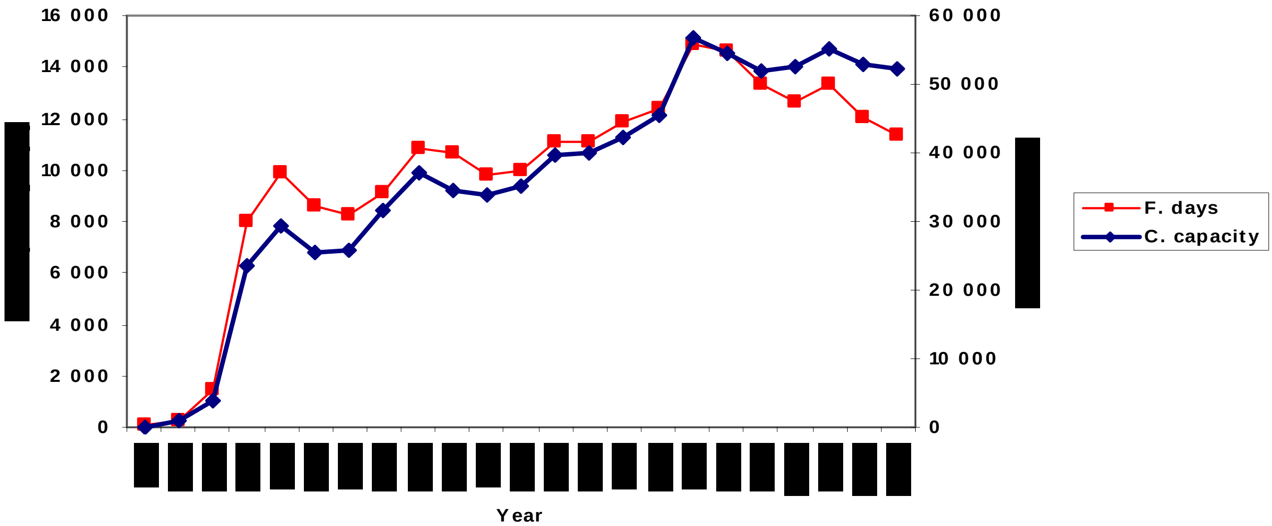


Figure 4: Fishing effort by the sampled PS fishery expressed in term of its carrying capacity and of fishing days

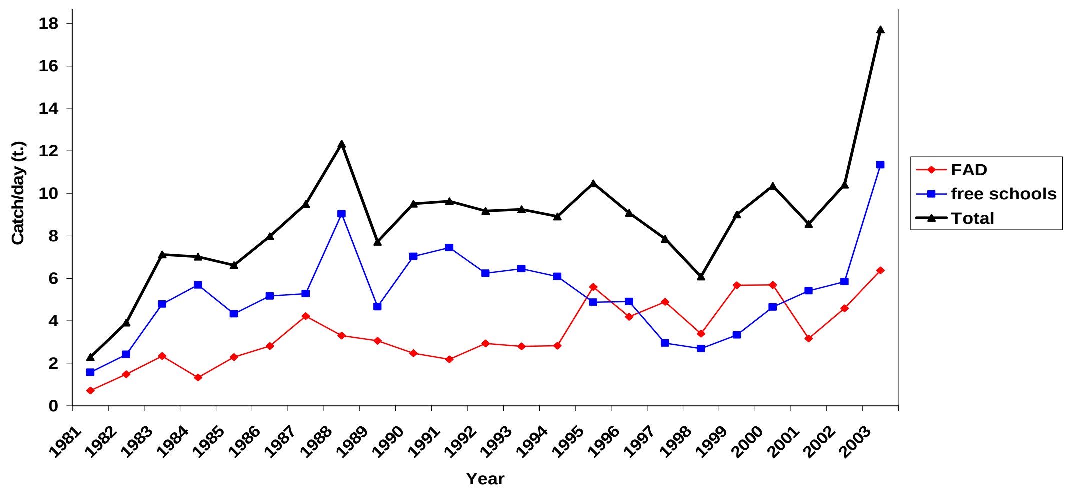


Figure 5: Yearly CPUE (catch / fishing day) in the FAD, in the free school fishery and in the average PS fishery.

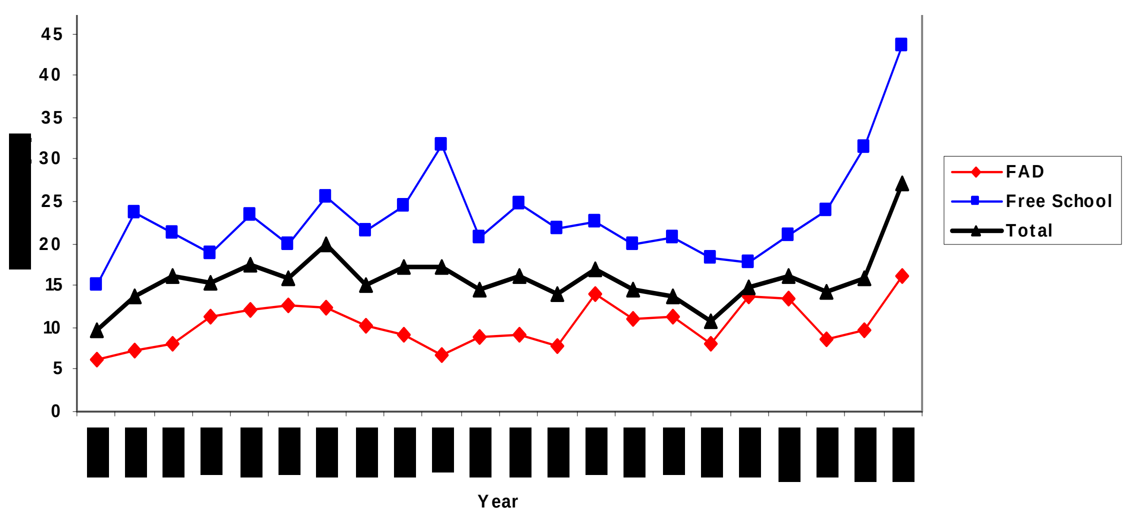


Figure 6: Average yearly catches per set in the sampled PS fishery, on FAD and free schools, and total

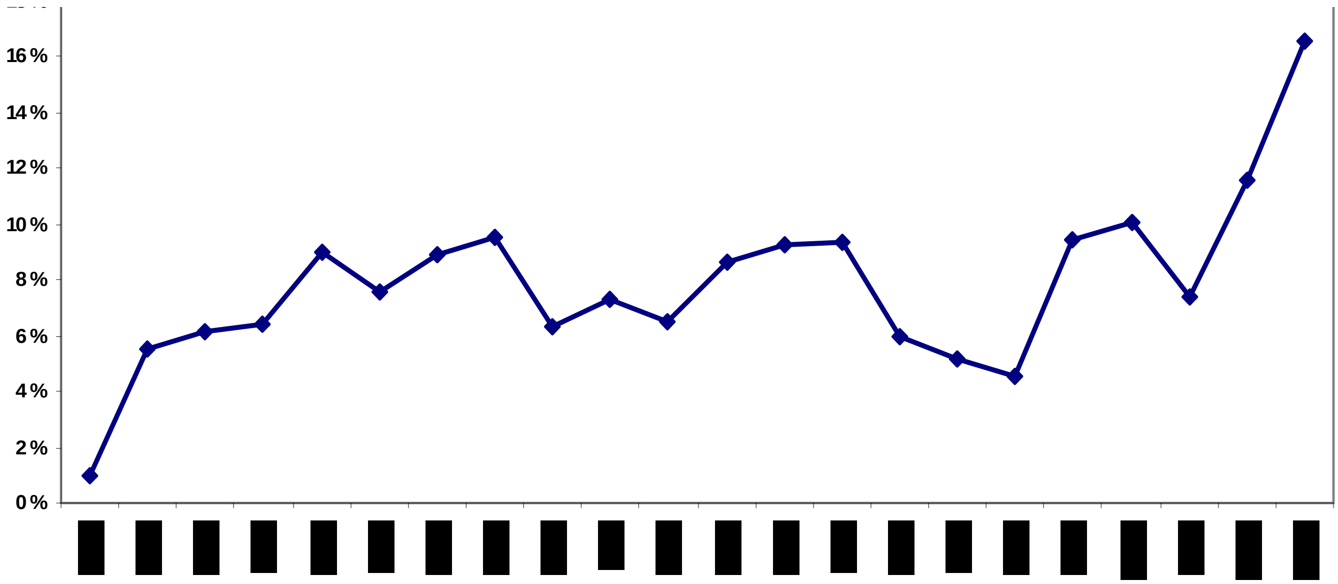


Figure 7 : Average yearly percentages of large sets (>100tons) in the PS fishery

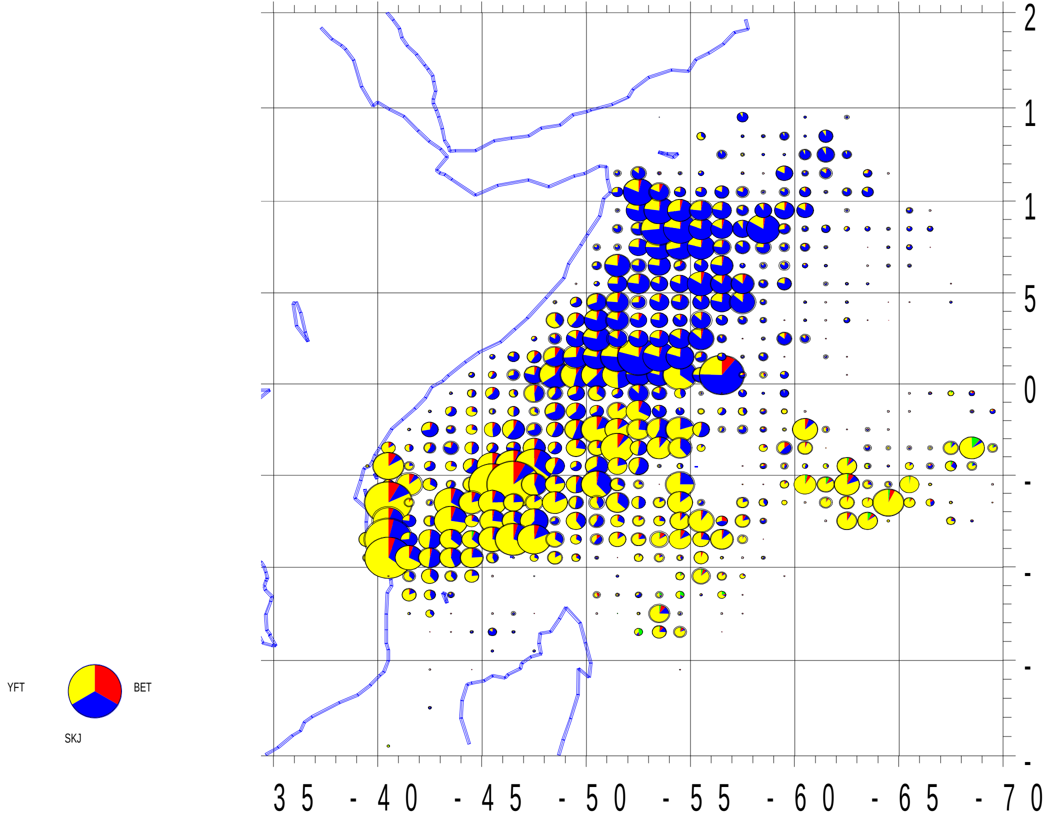


Figure 8 : Fishing zones of the sampled PS fishery during 2003 for the 3 species, yellowfin, skipjack and bigeye

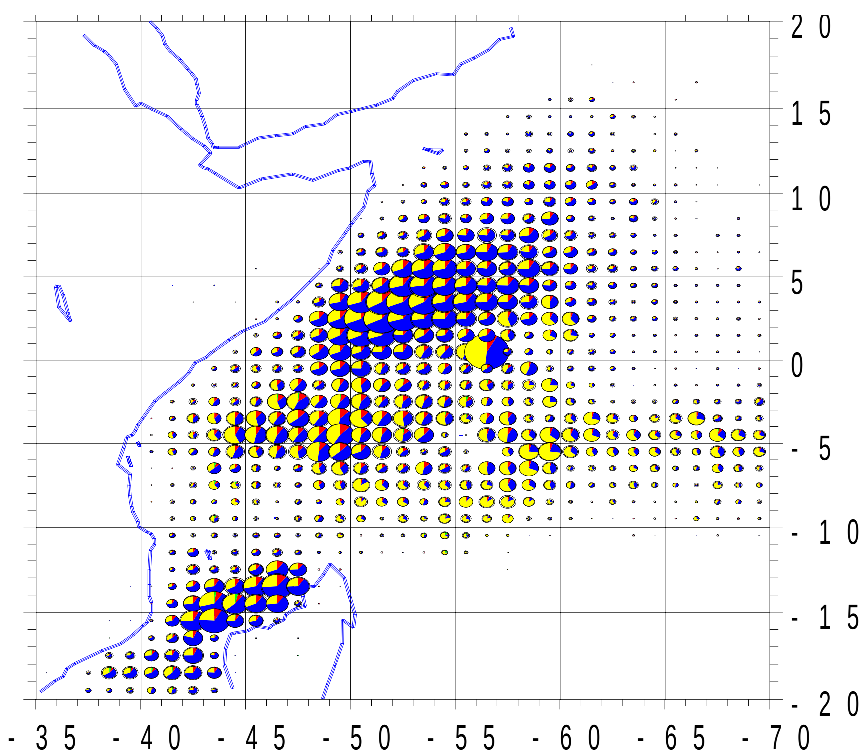


Figure 9: Fishing zones of the sampled PS fishery duringthe average period 1995-2001 for the 3 species, yellowfin, skipjack and bigeye

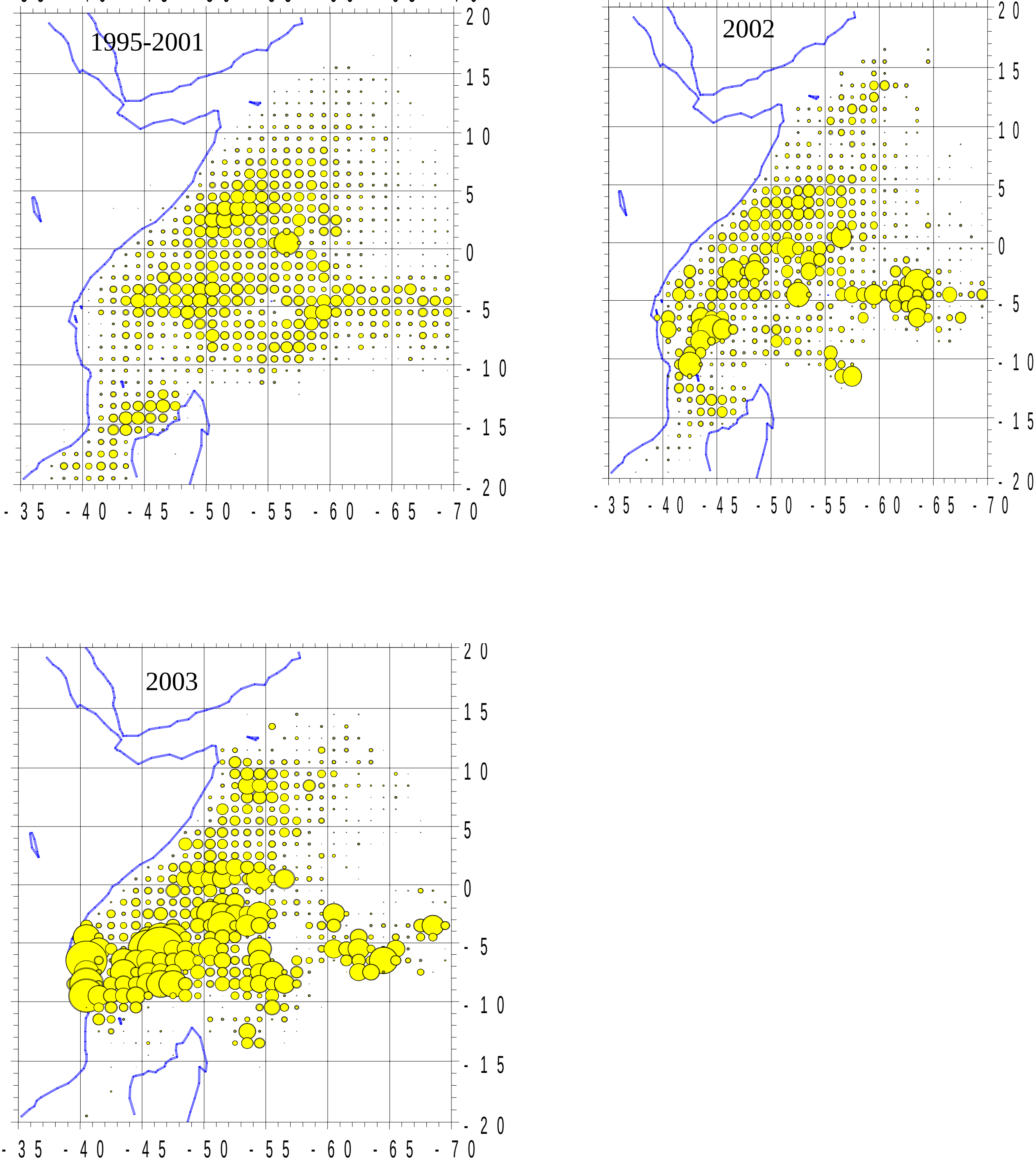


Figure 10 : Maps of the yellowfin PS catches in the sampled fishery during the average years 1995-2001, during 2002 and 2003.

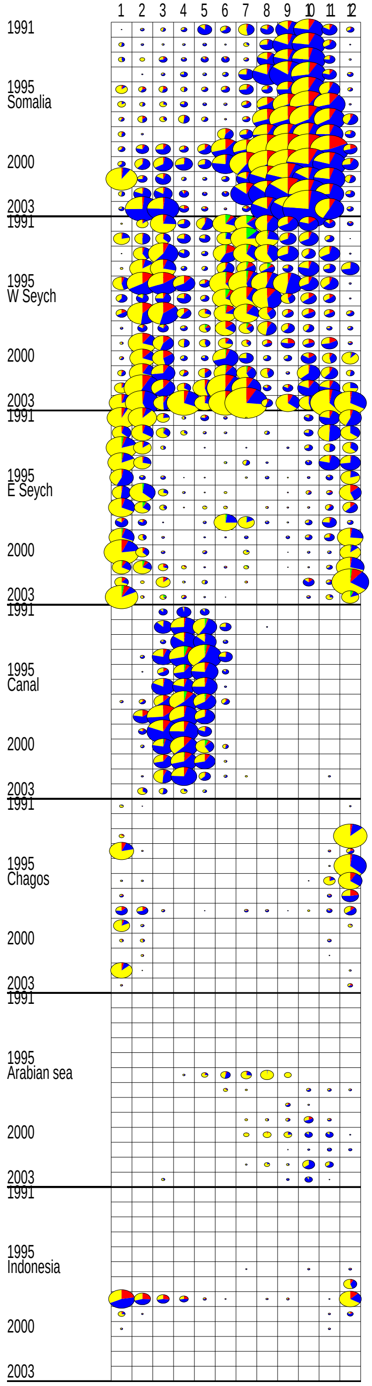


Figure 11 : Pie Diagram showing the monthly catches by the sampled PS fishery in each area

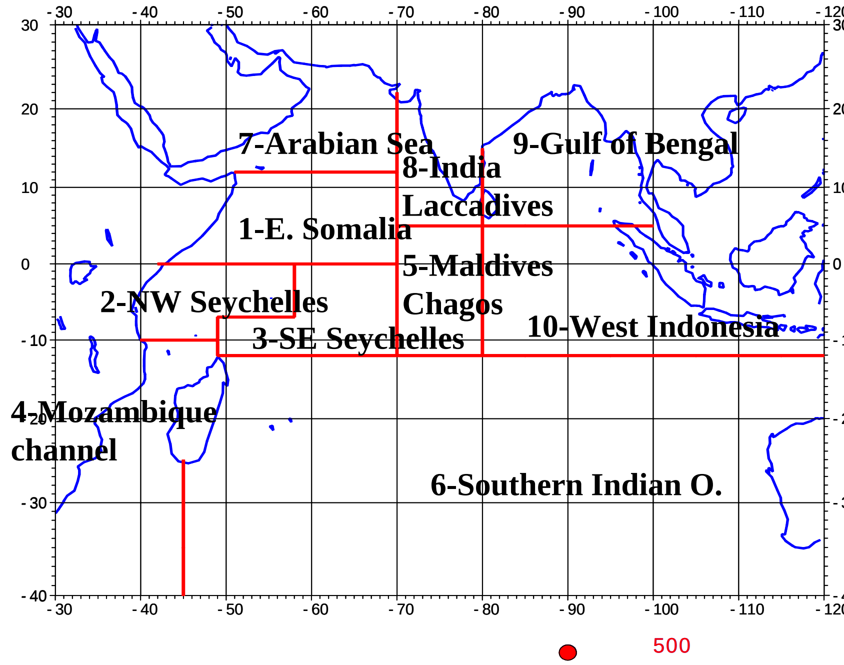
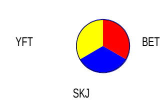


Figure 12: Map showing the areas used to show the monthly catches by species taken by PS.



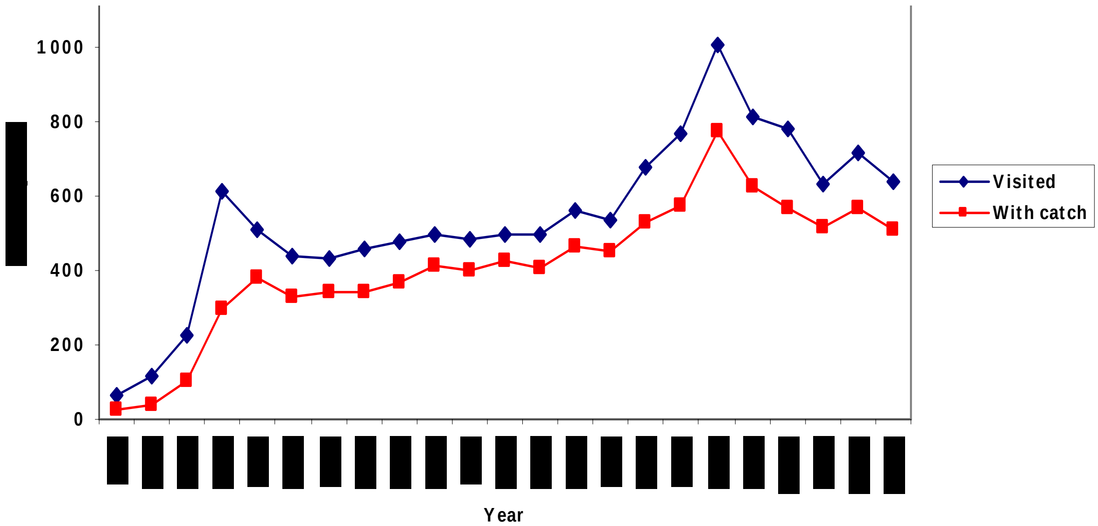


Figure 13: Size of the fished area, yearly, measured by the numbers of 1° squares visited by the PS fishery, and with a tuna catch.

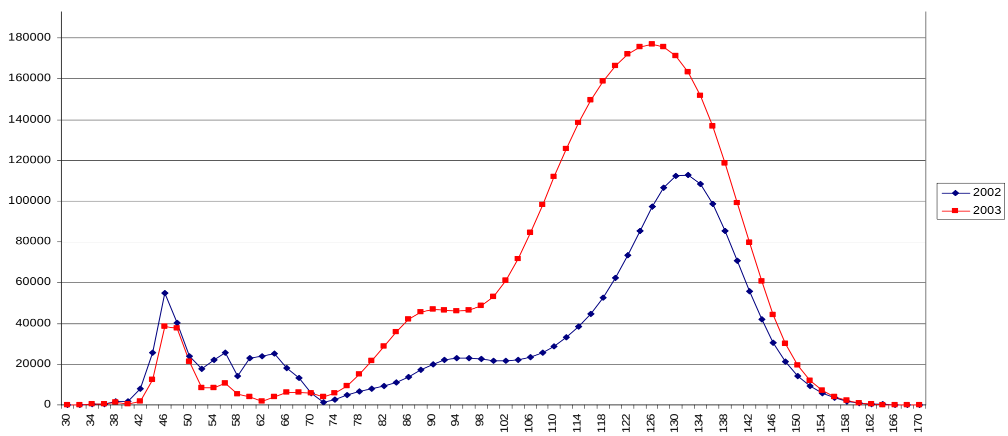


Figure 14 : Yearly size distribution of yellowfin, in weight (kg), taken by PS in 2002 and 2003 on free schools

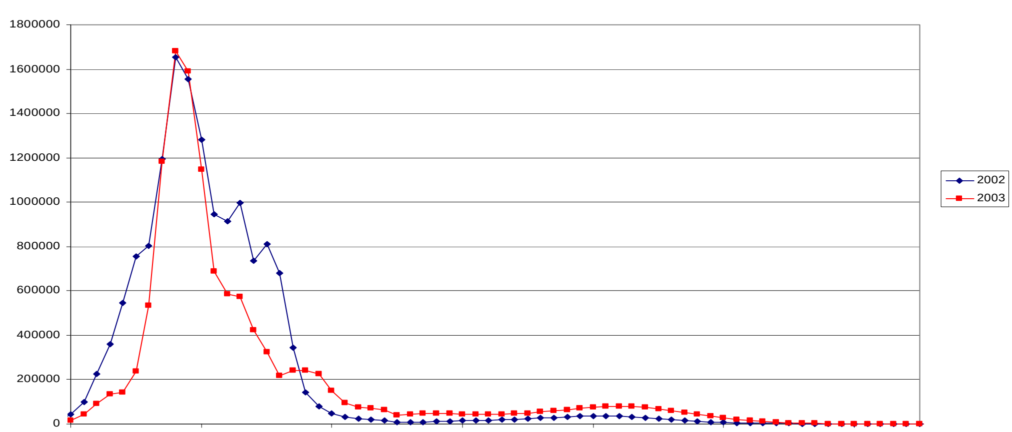


Figure15: Yearly size distribution of yellowfin, in weight (kg), taken by PS in 2002 and 2003 on FAD schools

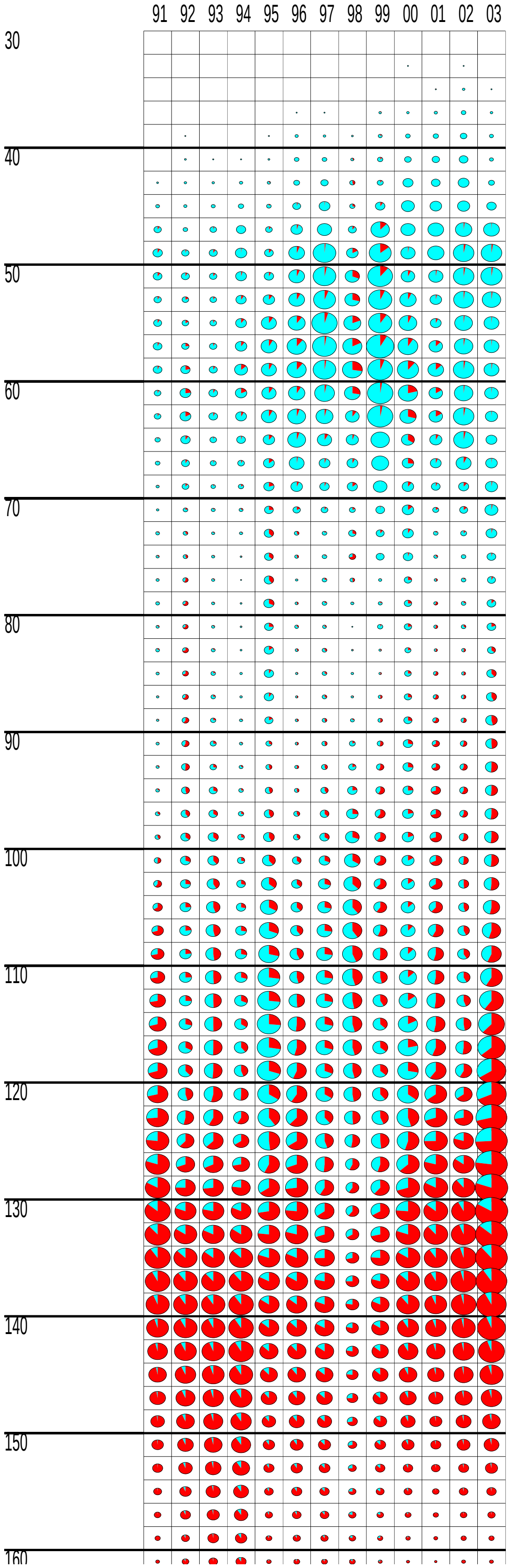


Figure 16: Catches of yellowfin by size, in weight, taken by PS on FADs (blue) and on free schools (red)

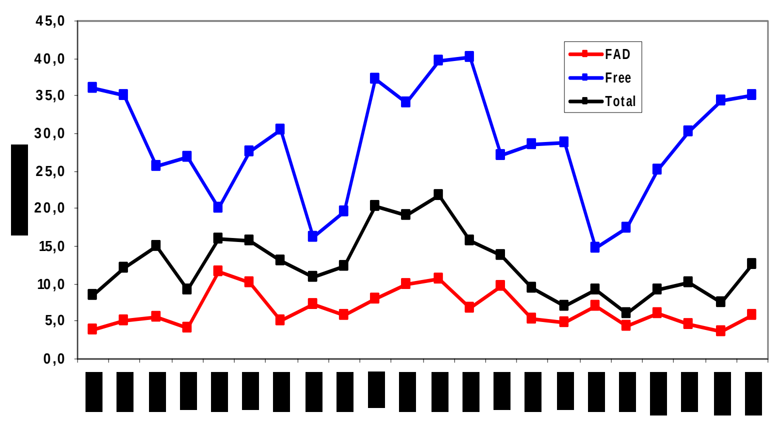


Figure 17: Average weight of yellowfin taken by the PS fishery under FADs and in free schools.

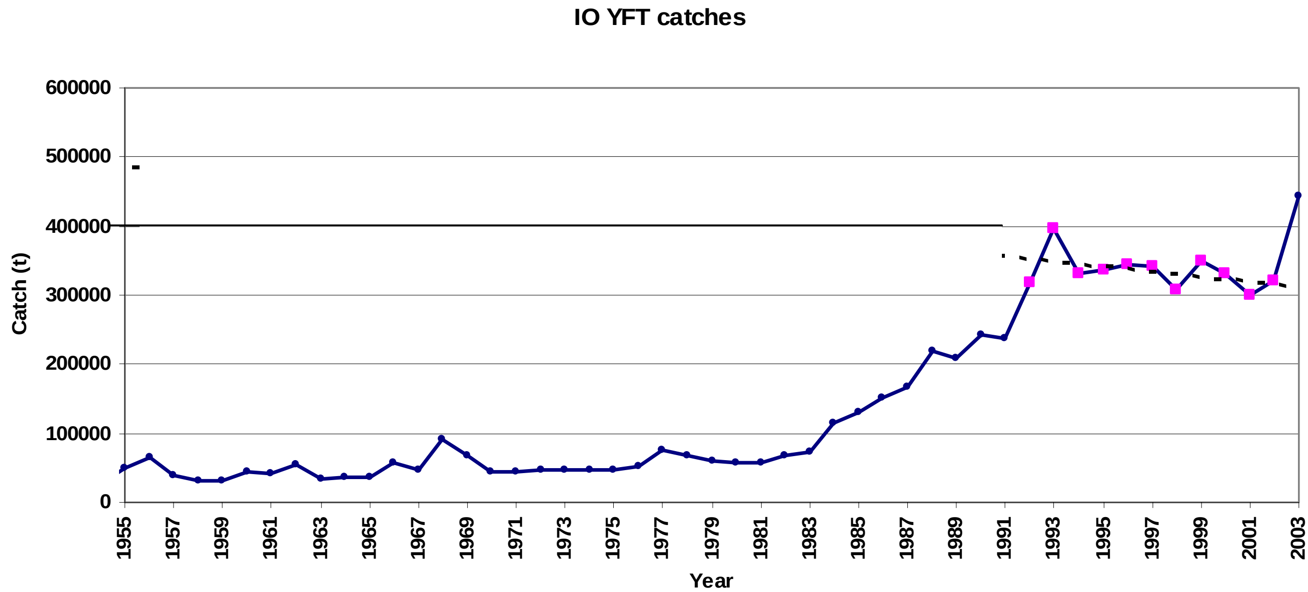


Figure 18: Total yearly yellowfin catches in the Indian Ocean between 1950 and 2003, and linear trend of the 1992-2002 catches (2003 catches are estimated)

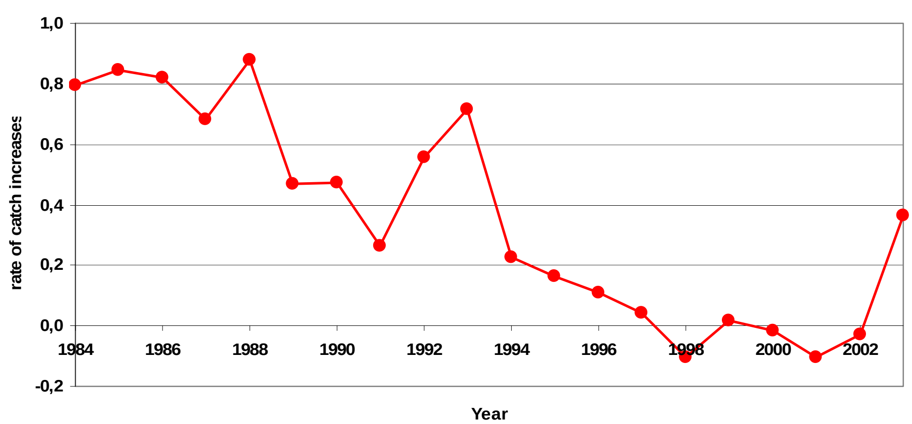


Figure 19: Rate of increase of yellowfin catches (Grainger and Garcia index) in the Indian Ocean (2003 being estimated)

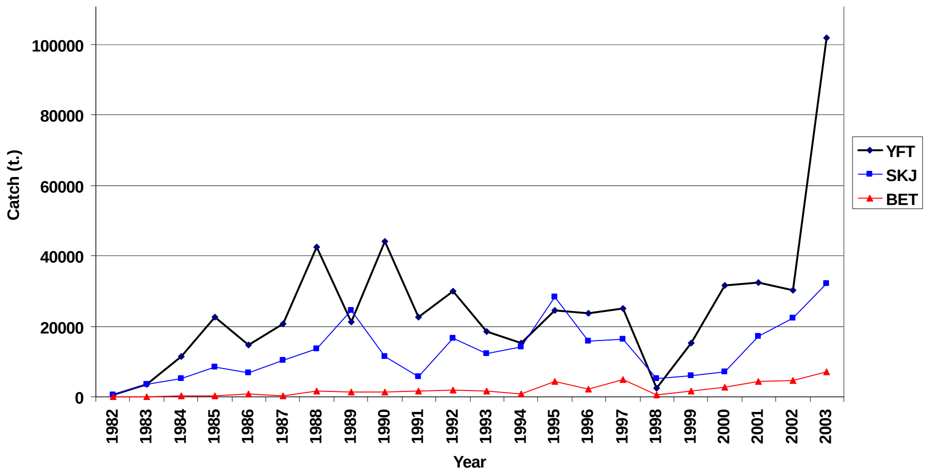


Figure 20 : Tuna catches by species taken yearly by purse seiners in the 5° to 10°S, west of 65°E area.

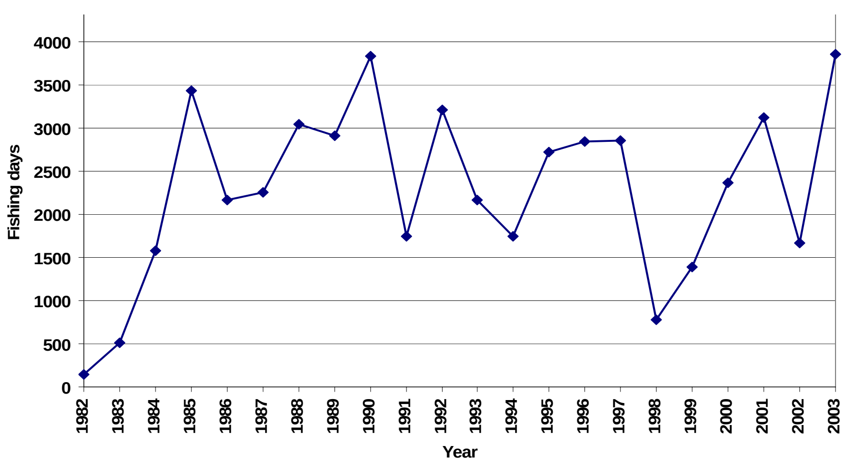


Figure 21 : Fishing effort (fishing days) exerted by purse seiners in the 5° to 10°S, west of 65°E area.

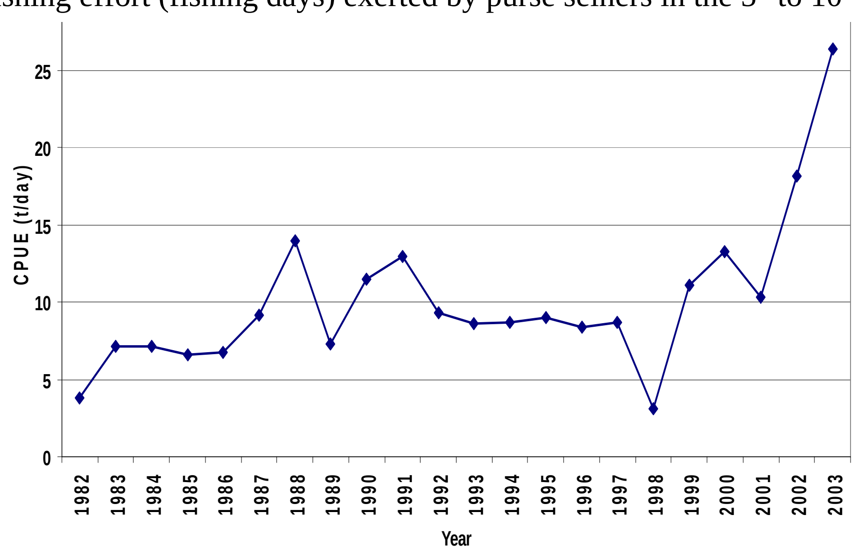


Figure 22: Yellowfin CPUE of purse seiners (yearly catches/efforts) in the 5° to 10°S, west of 65°E area.

Figure 23: *Natosquilla investogatoris*

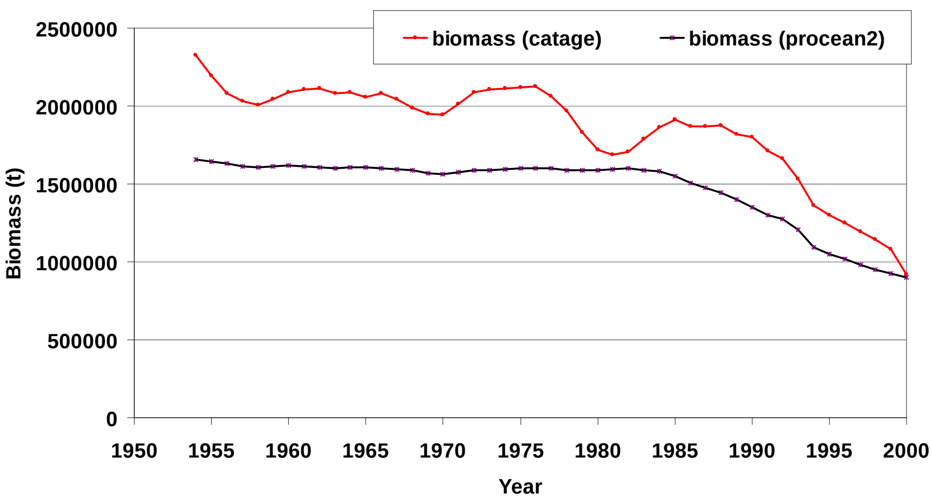


Figure 24: Biomass of the Indian Ocean yellowfin stock estimated in 2002 by the IOTC Shanghai WG.

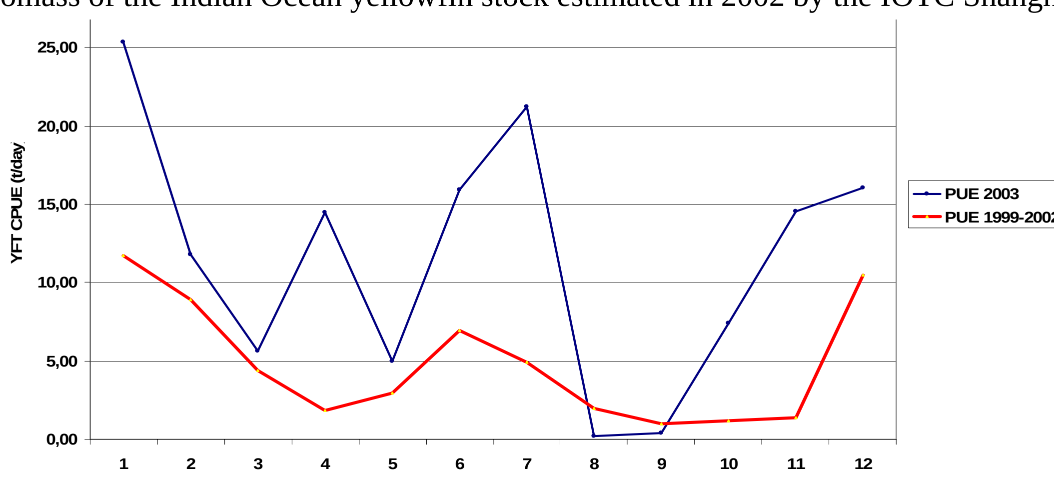


Figure 25 : Monthly CPUE of purse seiners on free schools of yellowfin in 2003 compared to the YFT CPUE during the average period 1999-2002

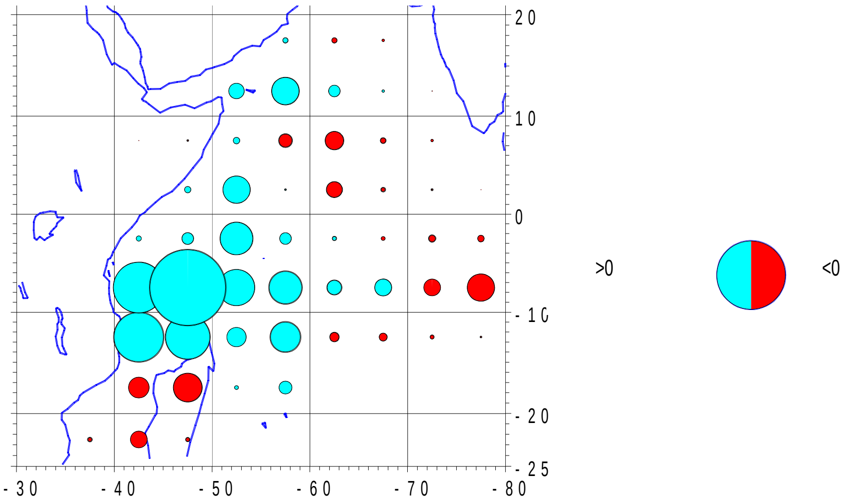
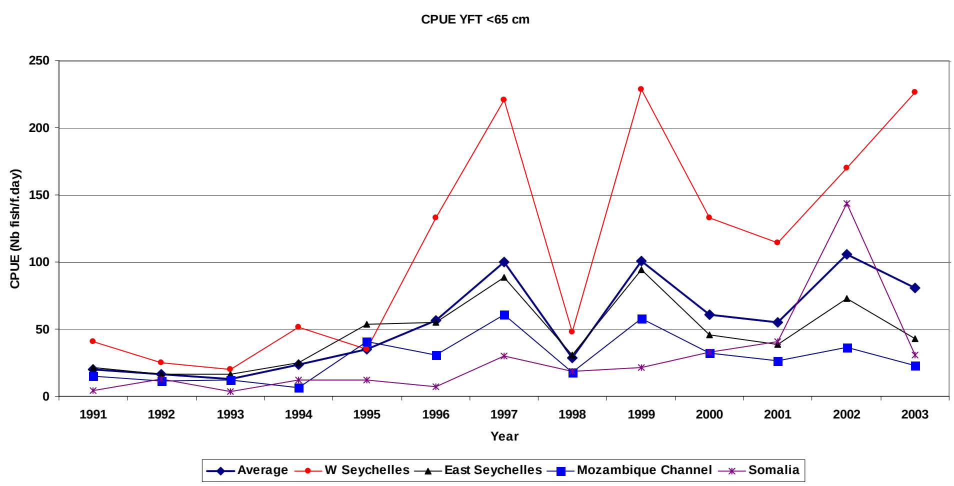


Figure 26: Differential catches of yellowfin by PS in 2003: map of the average yellowfin catches during the year 2003 minus the average catches during the period 1993-2002 (The areas with an excess of 2003 catches are shown in light blue, negative in red//dark)



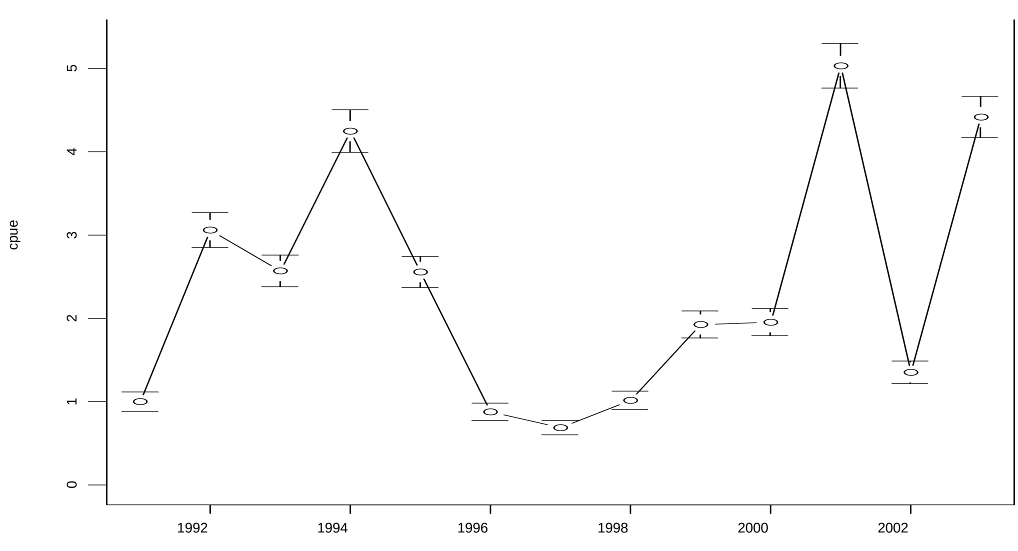


Figure 27: YFT CPUE of small YFT (<65 cm) of the EU purse seiner on free and on FAD associated schools in the Indian Ocean: nominal CPUE (upper fig.) and nominal CPUE (lower)

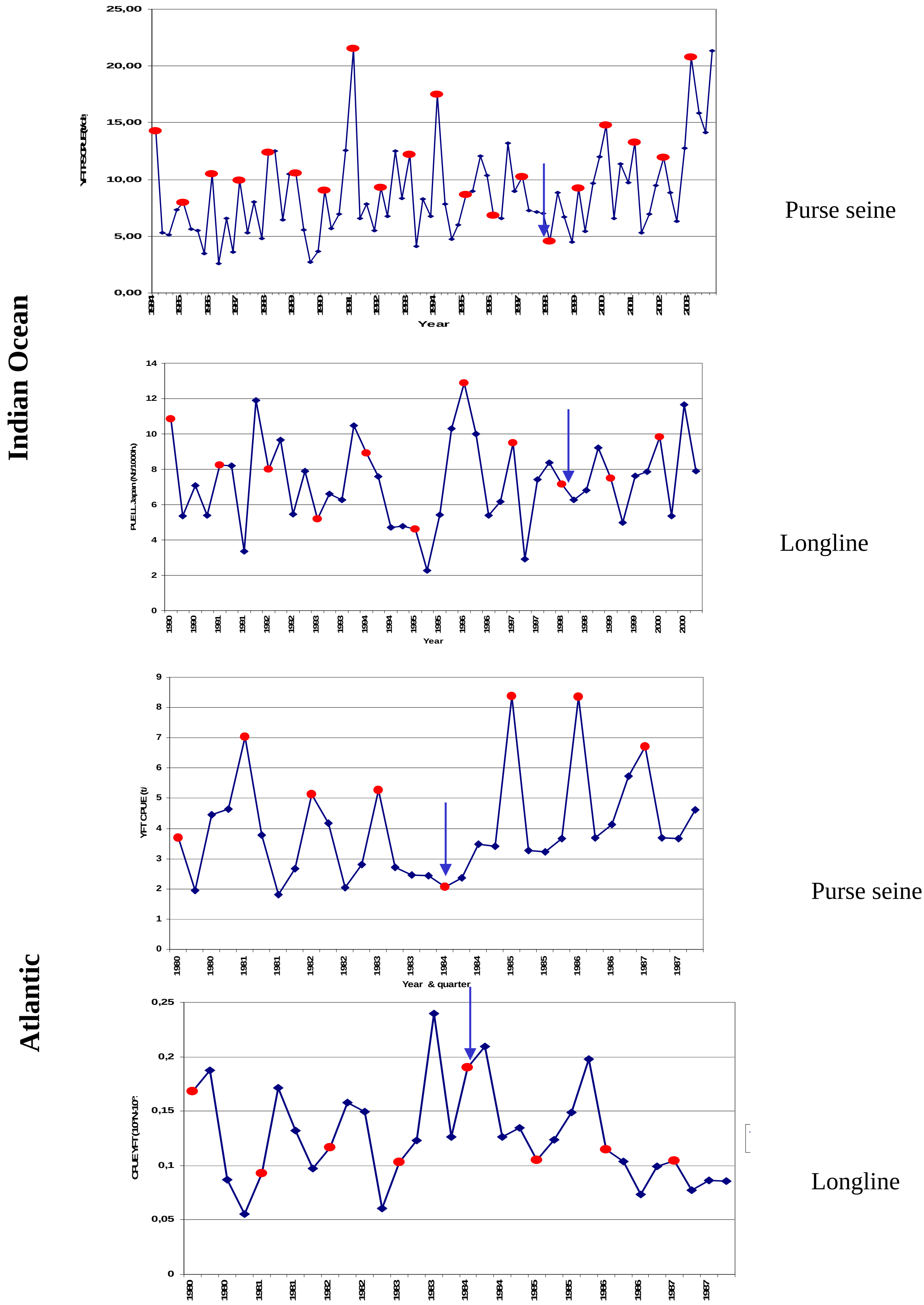
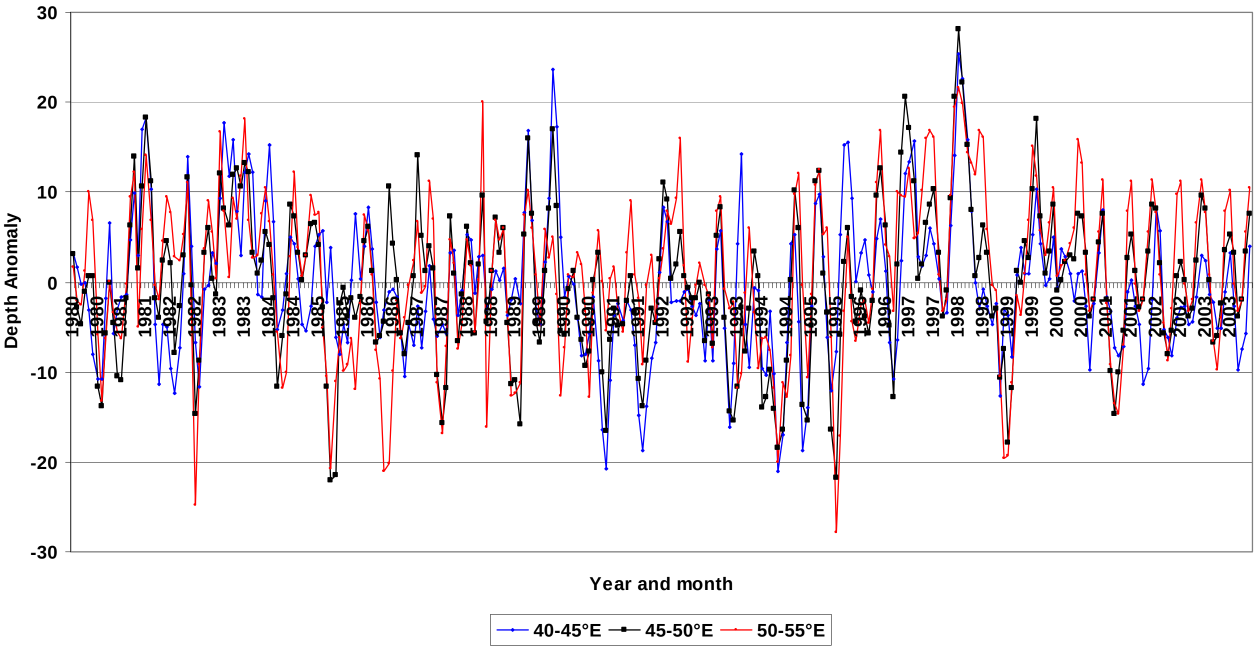


Figure 28: Quarterly yellowfin nominal CPUE in the Atlantic and Indian Oceans in the equatorial areas (10°N-10°S) (LL catches in the Indian Ocean; assuming a stable nominal effort, this figure should be indicative of abundance fluctuations). The levels observed for PS and LL in the Atlantic during the first quarter of 1984, and in the Indian Ocean during the first quater of 1998 should be compared



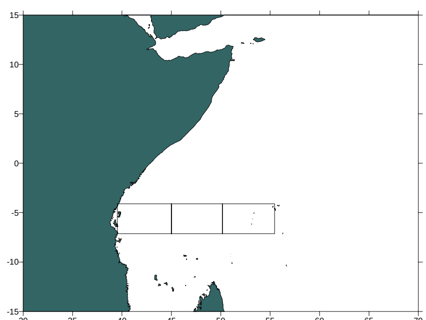


Figure 29: Monthly depth anomaly of the thermocline (measured by its proxy, depth of the 20° isotherm) in 3 selected areas during the period 1980-2003 (the reference period used to calculate this anomaly was the period 1950-2003); the selected area (4-6°S, 45-55°E) and its 3 sub-areas are shown on the bottom figure.

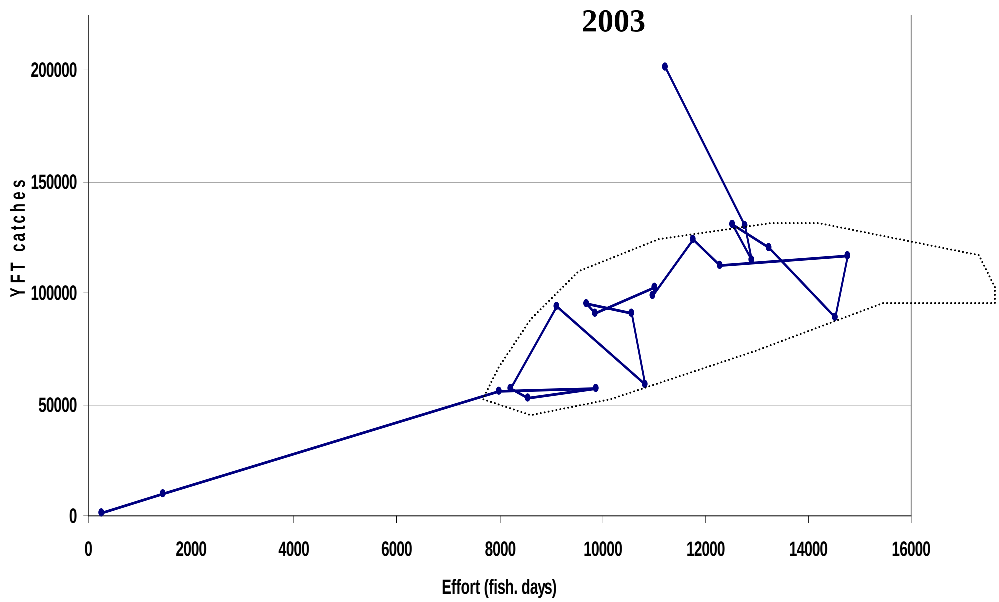


Figure 30: Relationship between yellowfin catches by the fleet of EU purse seiners and their yellowfin catches during the period 1982-2003

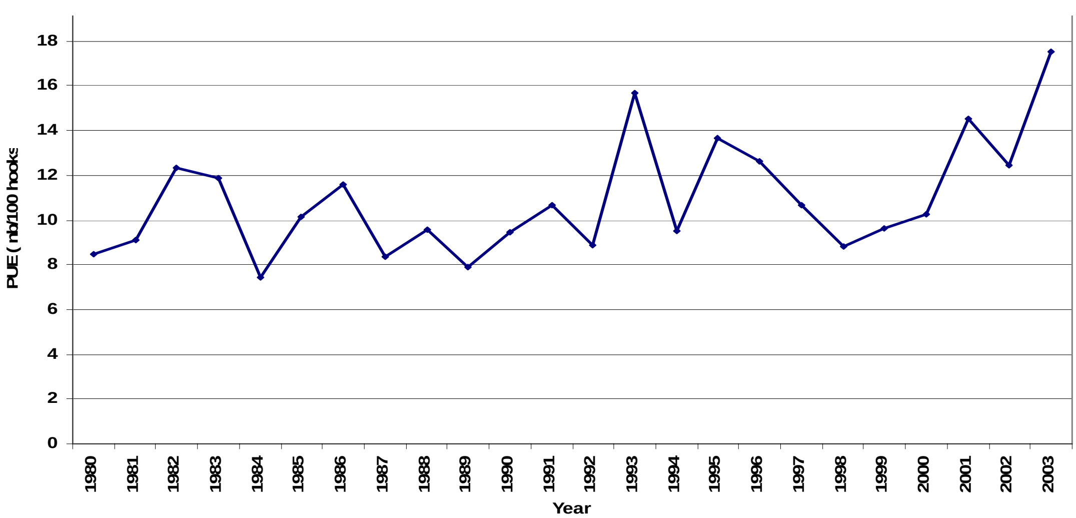


Figure 31: Yellowfin CPUE of Japanese longliners in the South West Indian Ocean (area between 5 and 15°S, west of 65°E); the 2003 CPUE is still provisional

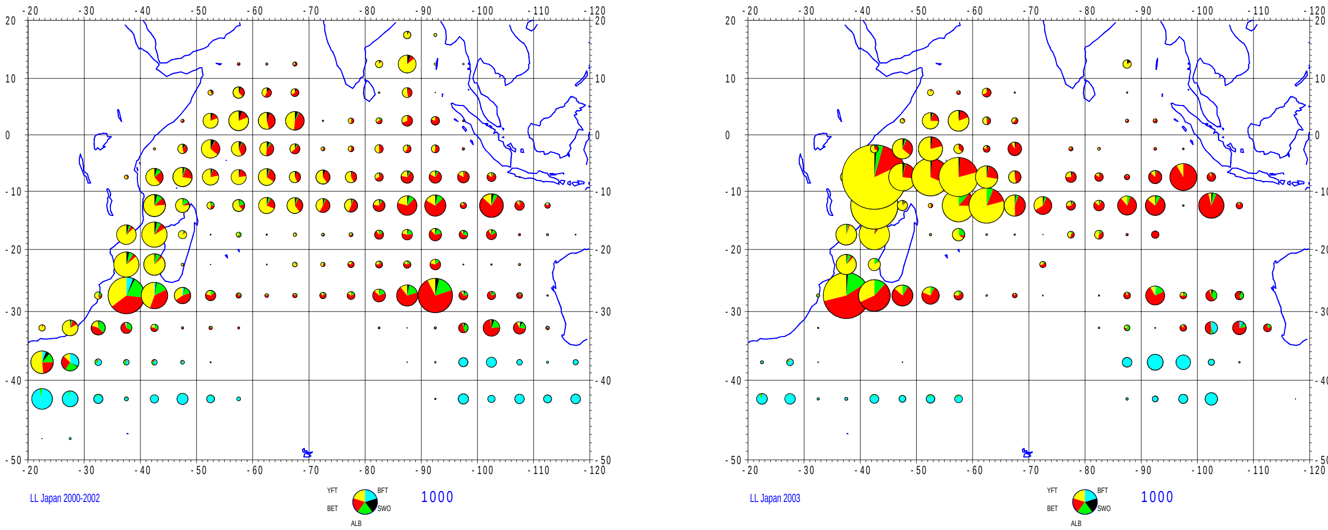


Figure 32: Average catches by species of Japanese longliners during the period 2000-2002 (left), and same figure for 2003 (provisional data, right)

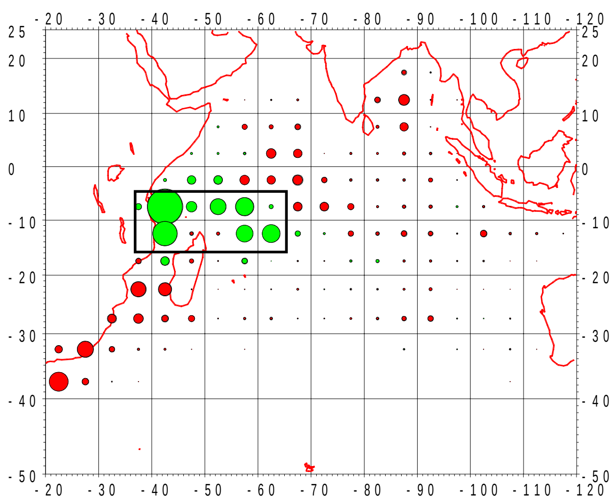


Figure 33: Anomalies of yellowfin catches of Japanese longliners comparing the year 2003 (provisional data, right) and the average period 1998-2002 (green/light being >O).

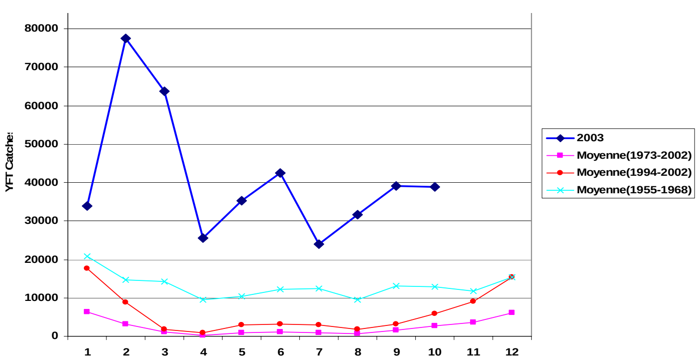


Figure 34: Monthly yellowfin catches taken by Japanese longliners in the SW Indian Ocean (5°S-15°S, W of 65°E) in 2003 and during various average periods

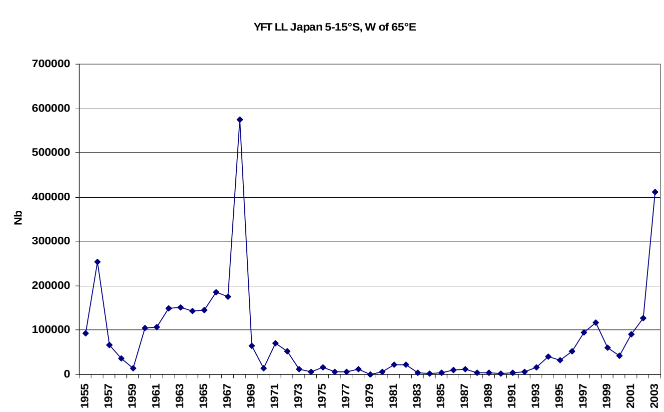


Figure 35: Yearly yellowfin catches taken by Japanese longliners in the SW Indian Ocean (5°S-15°S, W of 65°E)