PROSPECTS FOR THE MANAGEMENT OF FAD FISHERIES IN THE INDIAN OCEAN

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SUMMARY

This paper makes an overview presentation of the Fish Aggregating Device (or FAD) fisheries in the Indian Ocean since the early eighties. A comparison is done between FAD and free school fisheries. Various parameters such as the trends of catches, cpue by country and fishing mode, sizes of tuna taken by species and sizes of the area fished are analysed and discussed. The paper also discusses the prospects of a seasonal moratorium applied to the purse seine fishery in the Somalia area. This moratorium is compared with other management schemes that could also reduce the FAD associated effort and catches. At this stage it remains difficult to evaluate the real biological risks associated with the present use of FADs, but in a precautionary context, some measures limiting the fishing mortality due to FADs should be initiated, even if it will probably be impossible for scientists to model and to predict the short and long term effects of such management schemes.

RÉSUMÉ

Cet article fait tout d'abord une présentation globale de la pêche des senneurs utilisant des Dispositifs de Concentration des Poissons (DCP) dans l'Océan Indien, ceci depuis le début des années 1980. Une comparaison est faite entre les pêcheries à la senne sur DPC et celles sur bancs libres. Divers paramètres importants de ces pêcheries telles que la tendance des prises annuelles, celle des prises par unité d'effort par pays, et par mode de pêche, les tailles de chaque espèce de thons capturés et la surface de la zone de pêche exploité sont examinés. L'article discute aussi des perspectives d'un moratoire qui pourrait être saisonnièrement mis en œuvre pour la pêche à la senne dans la zone Somalie. Ce moratoire est comparé à d'autres mesures de gestion qui pourraient aussi réduire les efforts de pêche et les prises associés aux DCP. Il demeure difficile à ce stade d'évaluer les risques biologiques réels associés à l'usage actuel des DCP, mais il apparaît que dans le contexte de l'approche de précaution il serait souhaitable de limiter l'usage des DCP. Il demeure malheureusement impossible pour les scientifiques de modéliser et de prévoir tant les effets à court terme que ceux à long terme qui résulteraient de ces mesures d'aménagement.

1- INTRODUCTION

The Indian Ocean FAD fishery has been producing during recent years more than 70% of the total purse seiner catches. This is the highest percentage observed world-wide. These high catches are increasingly a source of concern for both fishermen and fishery managers because of the predominantly small fishes taken by this fishing mode. The negative effect of FADs are not yet clearly visible in the Indian Ocean, as yellowfin or bigeye cpue by longliners, as well as recruitment levels of these two species, do not show yet a decline.

This paper will present a comprehensive overview of the Indian Ocean FAD fisheries, in comparison with the free schools fishery. All the main characteristics and trends of these two fishing modes will be compared in detail. Based on these analysis as well as on other analysis done on this topic, the paper will make a global review and discussion about the potential ways that could be recommended to limit the FAD associated catches and the mortality of juvenile yellowfin and bigeye.

2- AN OVERVIEW OF FAD FISHERIES IN THE INDIAN OCEAN

2-1- Overview

This presentation is based on the purse seiner fleet that is well followed by scientists, e.g. the purse seine fleet owned by EU interests. This fleet is primarily fishing under EU flags (France, Spain and Italy), but also under fluctuating third country flags. Despite of these changes of flags, this heterogeneous fleet has been well followed by the EU scientists since the beginning of its activity in 1982. However, it should be noted that a large fleet of ex USSR purse seiners (10 vessels) is also active in the area and fishing on FADs, but not covered by this study (as even total catches taken by this fleet remain unknown)

In the Indian Ocean, about 50% of total catches were already taken on natural logs since the beginning of the purse seine fishery during the 80[ies] (figure 1). This already significant percentage has been widely increased since the early nineties following a massive use of artificial FADs equipped with electronic devices. Natural and artificial FADs are both used and classified as being "FADs" in all

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statistics because the real status of each floating object is not recorded in the present log books. Furthermore it appears that many of the FADs used are natural logs equipped with the same electronic devices used for FADs built by fishermen.

2-2- Trends of FAD associated catches for the various tuna species

Indian Ocean catches on FADs have been permanently increasing during the period for yellowfin, skipjack and bigeye (figure 2 and 3). Skipjack has constantly been the dominant species in the FAD fishery, followed by yellowfin and bigeye (figure 2). The quantities taken on FADs and on free schools were nearly identical and both increasing between 1983 and 1988, but since 1989, the total catches taken on free schools remained fluctuating without trend, During the same period, the total FAD associated catches have shown a permanent and fast increase (figure 2).

However it should be well noted and kept in mind that the percentage of FAD associated catches is quite variable among tuna species:

- High % for skipjack and for bigeye: average 1984-2001= 78% for skipjack and 73% for bigeye (figure 4)
- Significant but lower percentages for yellowfin: an average of 40% of total catches taken on FADs

2-3- FAD associated catches by area

Average catches taken on FADs and on free schools during the period 1995-2001 are obtained in fishing zones that are quite similar (figure 5a and 5b), but it appears that FAD catches are constantly widely dominant in the Somalia area (92%), and most often very important and dominant in the Mozambique channel (67%) (figure 7 and 8). On the opposite, free schools and FAD associated catches are taken in similar quantities in the central area between the Equator and 10°S. The best areas for the free schools fishery are located East and West of the Seychelles Islands. It can also be noted that anchored FADs are also widely used by the Maldivian pole and line fishery since the mid nineties. This fishery catching about 100.000 tons of tunas yearly is one of the biggest and oldest pole and line tuna fishery in the world (active at least since the 11th century?) , while a significant proportion of its catches are now taken on anchored FADs.

The most important fishing zone on FADs is obviously the Somalia area: catches on FADs in this area have shown very high levels and major increases since the mid nineties. This area is quite small, about 400.000 nautical miles^2 (only four 5 degree squares) , but with record catches reaching about 200.000 t. (figure 8). These catches would not be available without the use of FADs, these fishes being too dispersed to be caught efficiently without FADs.

Yellowfin, as well as bigeye tuna, are also significantly and increasingly taken in the same Somalia area between August and November; a wide majority of these catches being taken under FADs (figure 9)

It can be noted that this area is highly productive because of the Somalia upwelling, which is one of the most productive in the world. It can also be noted that catches taken by the FAD fishery are seasonal, with a peak in the Mozambique Channel during the period from March to May, and another catch peak in the Somalia area between August and October (figure 7). This seasonality could facilitate the control of the FAD fishery.

2-4- Sizes of the fish taken under FADs:

Yellowfin

It can be noted that catches of small and large yellowfin taken in association to FADs are equivalent in weight (at least as an average), when large yellowfin are widely dominant in free school catches (figure 10). It can also be noted that the large yellowfin taken under FADs tend to be smaller that large yellowfin taken in free schools (figure 14). A large increase of numbers of small yellowfin taken under FADs has been observed during recent years (see figure 12), when the numbers of large yellowfin taken under FADs appear to be stable or even decreasing during recent years (figure 15). As a consequence, a decline of average weight of yellowfin taken under FAD has been observed during recent years (figure 13).

Bigeye

It can be noted that bigeye taken under FADs are most often quite small, with a stable average weight of about 4.7 kg (without significant quantities of large bigeye, see figure 16 and 17). On the opposite, the bigeye taken on free schools are larger, but these catches are scarce (with a surprising exception, the month of June in the West Seychelles area where large bigeye are often taken significantly in free schools, see figure 9)

Skipjack

Sizes of Skipjack taken under FADs and in free schools are nearly the same (figure 19) and they do not show any apparent temporal trend during the period (figure 20).

2-5- Cpue of FADs and free schools by country

A result obtained in previous statistical analysis of the EU purse seine fleets (ET programme) was that the species composition was statistically identical within each quarterly area strata, independently of the flag of the purse seiner. This statistical result was well founded and significant, but as the spatial and geographical operational patterns of each purse seiner fleet are quite different, the final yearly cpue obtained by each fleet by fishing mode (free or FAD schools) appears to be quite different and fluctuating over time. This heterogeneity of the fleet performances is well shown by figure 18, giving the cpue of yellowfin, skipjack and bigeye tunas for the French and Spanish purse seiners, on free schools and on FAD associated schools (these cpue being calculated dividing the catches of each species and category, by the yearly numbers of fishing days exerted by each fleet). This figure shows that during some periods the cpue on FAD have been equivalent for the French and

Spanish fleet, but with a tendency for the Spanish FAD cpue to be much more higher since 1995 (in relation with supply vessels and/or of larger vessels?). This temporal heterogeneity of the various purse seine fleets should be well kept in mind in the various analysis and management plans.

3- WHAT ARE THE FAD CONCERNS?

Nowadays, FAD fisheries are increasingly a source of concern in the Indian Ocean as well as in the other oceans. The massive use of FADs by purse seiners is at the origin of three types of additive concerns: (1) too many small tunas taken under FADs, (2) too many discards with FAD associated schools, and (3) negative impact of FADs acting for tunas as a potential "**biological trap**".

3-1- What changes in yield per recruit due to the FAD fishery?

FADs allow to catch large quantities of skipjack, but small yellowfin and small bigeye are also increasingly taken under FADs, probably reducing the yield per recruit of the yellowfin and bigeye stocks. These yield per recruit calculations are often done in order to evaluate the negative impact of the FAD fisheries: this type of calculation is highly dependent of the fishing and natural mortalities at age estimated for each species, especially at young ages. Unfortunately, these natural mortalities remain poorly known in the Indian Ocean: natural mortality of juvenile yellowfin and bigeye is probably much higher than for the adult (Hampton 2000), but this high level remains entirely hypothetical, due to the lack of results obtained by a large scale tagging program. Subsequently, fishing mortalities at age also remain widely unknown in the Indian Ocean for both yellowfin and bigeye, primarily because the exact status of these two stocks are still poorly evaluated by the IOTC scientists (lack of data and of biological parameters). If the present F at age are well estimated by the IOTC scientists, it would appear that F on juvenile bigeye and yellowfin are still quite low, and that very little benefit can be expected from a reduction of juvenile catches (Pallares et al 2003).

3-2- Discards on FADs

Discards of by-catches are most often larger on FAD schools than on free schools. This fact has been well and constantly observed world wide (see Alverson at al 1994, Edwards E. and P. Perkins 1997, Bailey et al 1996), and confirmed in the Indian Ocean by Romanov 2000 and by Stretta et al. 1996. These discards can be estimated in a range between 2.5 to 5% of FAD tuna catches based on the Stretta et al data set, but these percentages are possibly underestimated because of the low rate of observed sets in the Indian Ocean. Species discarded are typically small tunas, mahi mahi, sharks, wahoo, rainbow runner, billfishes, triggerfish, etc. These discards seems to be quite dependent of the time and area strata fished, but they remain poorly followed in the Indian Ocean due to the lack of permanent observers in any of the purse seine fleets (this uncertainty will be partly solved in 2003 with the new data gathered by the new EU observer scheme)

3-3- Ecological trap hypothesis

The Biological Trap Hypothesis is a working hypothesis that has been first proposed by tuna fishermen and later developed by a team of scientists (from IRD, France, Marsac et al 2000). This hypothesis concerning the association of tunas to artificial fish aggregating devices can be stratified into four hypothetical subsets:

- H1: the aggregation of small tunas under FADs is a fast, strong and long-lasting process
- H2: The large numbers of drifting FADs in the equatorial zone can alter the natural movements of skipjack and juvenile bigeye and yellowfin.
- H3: Subsequently, drifting FADs may affect growth and natural mortality of small tunas when they are associated with FADs.
- H4: This aggregation could also have positive effects, for instance thorough a better schooling: because of a reduced natural mortality faced by tunas associated to FAD? More active spawning for skipjack associated to FADs? This point is still entirely hypothetical and was not incorporated in the formulation of the hypothesis by Marsac et al that FAD could act as biological traps.

These working hypothesis are presently studied by the IRD scientists in the so called THETIS program, in the Indian and Atlantic oceans. If this hypothesis is a valid one, the presence of large numbers of FADs could alter, at least temporarily the biological characteristics of the tuna species and sizes associated to FADs (independently of the fishing activities). If this hypothesis is accepted, it would mean that the biological effects of FADs on tunas would occur in the absence of a fishery when large numbers of FADs are at sea.

This concept of biological trap may appear to be quite strange in the world of fishery science, but it should be kept in mind that the same concept of "ecological trap" has been often used in terrestrial ecology (Schlaepfer et al. 2002). In such a trap, an environment that has been evolutionary favourable for the survival of a population (here the natural logs that tend to be concentrated by convergencies in the rich oceanic areas), could be altered by humans (artificial FADs seeded by fishermen). The animals may be trapped in the new environment introduced by man, leading to poor habitat choices and reduced potential survival. This new and important ecological concept could well be applied to oceanic areas and the massive use of FADs, at least as a working hypothesis that should be tested by an *ad hoc* research programme.

4- WHAT MANAGEMENT PROSPECTS FOR THE INDIAN OCEAN FADS FISHERIES?

Various management plans could be envisaged and implemented to limit the use of FADs by purse seiners and to reduce the FAD associated catches. These measures would target only the purse seine fisheries and drifting FADs and not the use of anchored FADs by the Maldivian fisheries (a pole and line fishery with a much higher percentage of skipjack and without by-catches)

The following management schemes could be envisaged. For each of them, the pros and cons should be well identified and discussed by scientists.

- Moratorium: an area & season closed to FAD fishing, controlled by VMS or/and by observers
- Ban of all supply vessels,
- Permanently closed area: a Marine Protected Area (controled by VMS) selected because of its importance in the FAD fishery (as discussed by Fonteneau 2001)
- Skipjack yearly quota, similar to the quota developed by some tuna boats owners in the late 2000 and early 2001.
- Seasonal closure of the purse seine fishery, for instance during the main fishing season on FADs; this closure could be managed either with a complete ban of all fishing activities during a given period (such closure may be very difficult to manage), of to increase the duration of all landings during the main season of FAD fishing (much more easy to manage)
- Quota on the numbers of FADs used or/and limitation of their electronical equipment.

Table 1 describes and discuss briefly these potential management schemes. It appears that various potential management schemes could be implemented to reduce the impact of FAD and to limit its peculiar fishing pressure, but none of these solutions appears to be simple and easy to be efficiently implemented. Among the potential management measures a seasonal moratorium of the FAD fishing in a given area remains an interesting option that would be worth to be further studied.

5- SOMALIA MORATORIUM PROSPECTS

Several months of moratorium in the Somalia area during the period August to November would probably widely reduce catches taken on FADs, for skipjack, yellowfin and bigeye. This quite obvious result was widely confirmed by all the calculations done by the IOTC tropical tunas WG in 2001. Such a moratorium should thus significantly reduce the catches of small yellowfin and small bigeye (as it was observed for the Atlantic moratorium). However, the direct and indirect consequences of such a moratorium will be highly dependent of multiple unknown parameters. Among them, the unknown new «behaviour» of the purse seine fleet during this moratorium: it is fairly difficult or impossible, for both scientists and fishermen, to predict what would be the new fishing behaviour and the new cpue and catches by species of the purse seine fleet during such potential closure of the Somalia area. Furthermore, the long term effect of such management would be highly dependent of juvenile natural mortality.

This moratorium should of course be controlled by the IOTC and its fishing nations. Unless an efficient control of the moratorium, e.g. covering all purse seine fleets including its IUU vessels, the prospects of such a moratorium would become very weak. This control could be developed using either a VMS control, or on-board inspectors (national or international). The first method, VMS, would be clearly the less expansive one to run, and probably the more reliable one (assuming that the technology implemented cannot be falsified in order to provide false positions). This use of a control by VMS would imply that the Somalia area would be entirely closed to all purse seine fishing. Such a ban could easily be recommended, taking into account the low rate of free schools found in the area. On the other side, it can probably be considered that inspectors are always very expensive and often not entirely reliable.

Such a moratorium would probably also produce a significant and irreversible loss of skipjack catches, because the present intensive use of FADs is probably the only way to efficiently catch the present large levels of skipjack catches with a quite small purse seine fleet. For yellowfin and bigeye stocks, the first analysis tend to indicate that the subsequent changes in the yield per recruit and the long term effects on the stock biomass would tend to be quite minor for each of these two species. All the consequences of the moratorium are highly dependent of the natural mortalities assumed in the models for small yellowfin and small bigeye: when relatively large natural mortality are hypothesised, relatively low levels of fishing mortalities are most often calculated for juvenile yellowfin and bigeye (WPTT 2001 and 2002). As an arithmetic consequence, the potential gains due to a reduction of these low F on juvenile tend to produce only minor potential gains in the yield per recruit for yellowfin and bigeye (and always large skipjack losses). This calculation is simply based upon the hypothesis that the fishing mortality at these young ages is very low (large population), there would be very little potential to reduce it. Another factor explaining why its is “difficult” to obtain very positive results in terms of yield per recruit from most moratorium on FADs, is simply due to the fact that this fishing mortality due to FADs is exerted during a very short period (during one year approximately), while the adult fisheries are exploiting the same resource during several years and most often at a higher rate.

6- CONCLUSION

The intensive use of FADs allowed a large increase of tuna catches in the Indian Ocean during recent years, but in the new world of precautionary management (an. FAO 1996), there is now an increasing need to control and to limit this fishing mode, this need being reinforced by the unknown risk of interactions between fisheries catching small or large tunas. This concern is especially strong in the Indian Ocean where biological knowledge is still quite weak and where FAD fisheries are highly developed. This political pressure in favour of a preemptive precautionary limitation of FADs has been actively developed by longline fisheries that are catching large yellowfin and large bigeye at optimal sizes (in term of yield per recruit) and at a very high value (sashimi market).

The research policy in the Indian Ocean will now be to develop large scale studies centered on a wide tagging programme: this is because such researches are the only ones that will allow scientists to reduce the uncertainties on the potential effects of FADs. However, as the results of these investigations will need 5 to 10 years before being fully available, there is a need to take pre-emptive action limiting an excess in the use of FADs before the end of the tagging programme.

However, it is also clear that the purse seine fleets are now widely «prisoners» of this very efficient fishing mode. Taking into account the present very low value of tunas taken by purse seiners, especially skipjack, there is a serious danger that many purse seiners, including various recent large vessels, would go out of business if a drastic limitation of the use of FADS is implemented. In this context, only a strong political will by IOTC fishing countries, members and non members of the IOTC could circumvent these difficulties. One of the more visible difficulties being the IUU ex-Russian fleet of purse seiners (10 vessels?: not followed by any statistics), that will not comply with any IOTC regulation and worse, that will make a full use of any type of closure of fishing area or season.

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Table 1: Various management measures that could be envisaged to reduce fishing mortality on FADs

Management measure envisaged	Comment	Pros	cons
Size limit	Such a measure has been commonly taken by various fishing agencies; used for tunas by the ICCAT	This simple measure could be attractive for fishery managers in order to reduce landings of undersized yellowfin and bigeye tunas.	But because of the mixture of species and sizes in the FAD fishery, this measure is not realistic. Such a measure cannot be used for a tuna PS fishery.
Ban of all supply vessels,	Supply vessels are important only for some Spanish vessels	Such a ban would significantly reduce F on FAD: possibly 20 to 40%?	It may be discriminatory against some components of the PS fleet; possibly difficult to apply in legal terms.
Permanently closed area: a Marine Protected Area selected because of its importance in the FAD fishery (controled by VMS)	Such a measure has never been envisaged by any tuna Commission	quite easy to control if all PS are equipped with VMS monitoring and followed by the IOTC (or by a neutral agengy)	IUU vessels may escape to this control, at least temporarily, unless aditionnal measures are taken against their product.
Skipjack yearly quota, taken at least for the PS fisheries	Such measure was recommended in 2001 by various Tuna boat order associations in order to improve the SKJ market prices	Such a quota would limit FAD catches because SKJ is the dominant species under FADs	The multipsecific nature of the FAD fishery may produce negative results, such as massive discards of SKJ. It would be difficult to control such quota in real time.
Seasonal closure of an area for the purse seine fishery during the main fishing season on FADs , controlled by VMS or/and by observers	Tthis spatio temporal moratorium has been applied in the Atlantic: it was a feasible management scheme that produced major changes in the PS fishery.	If the area is closed to any type of fishing, the measure would be quite easy to control if all PS are equipped with VMS monitoring and followed by the IOTC (or by a neutral agengy); inspectors may also be used to control the closure (cf ICCAT)	IUU vessels may escape this control, at least temporarily, unless additional measures are taken against their landings. Such problems may ruin the system. In the Atlantic, the yield per recruit moratorium long term effects remain very difficult to identify.
Quota on the numbers of FADs used or/and limitation of their electronical equipment.	These limitations should potentially reduce the fishing mortality due to FADs; it should be kept in mind that the numbers of FADs are widely different among PS, some vessels being built to fish with FADs and using very large numbers of these FADs. The FAD equipments as well as their effects on FAD efficiency remains poorly studied & poorly followed by scientists	Such a measure could be attractive for fishery managers and the IOTC	But as the number of FADs used by PS are still unknown and nearly impossible to control, this measure would not be realistic; it would be discrimanatory against some vessels. The management of FADs by supply vessels may complicate this statistics.
Limitation of PS fishing effort: monthly closures, or temporary freezing of fishing activity after each landing	This type of limitation has been commonly used by fishery commissions, including for tunas (IATTC)	This closure is quite simple to develop and to apply. The expected decrease of fishing mortality tends to be proportional to the partial F obtained during the closed period.	The complete seasonal closure may be a cause of serious economical problems for fishermen and the tuna industries (ports, canneries, etc)

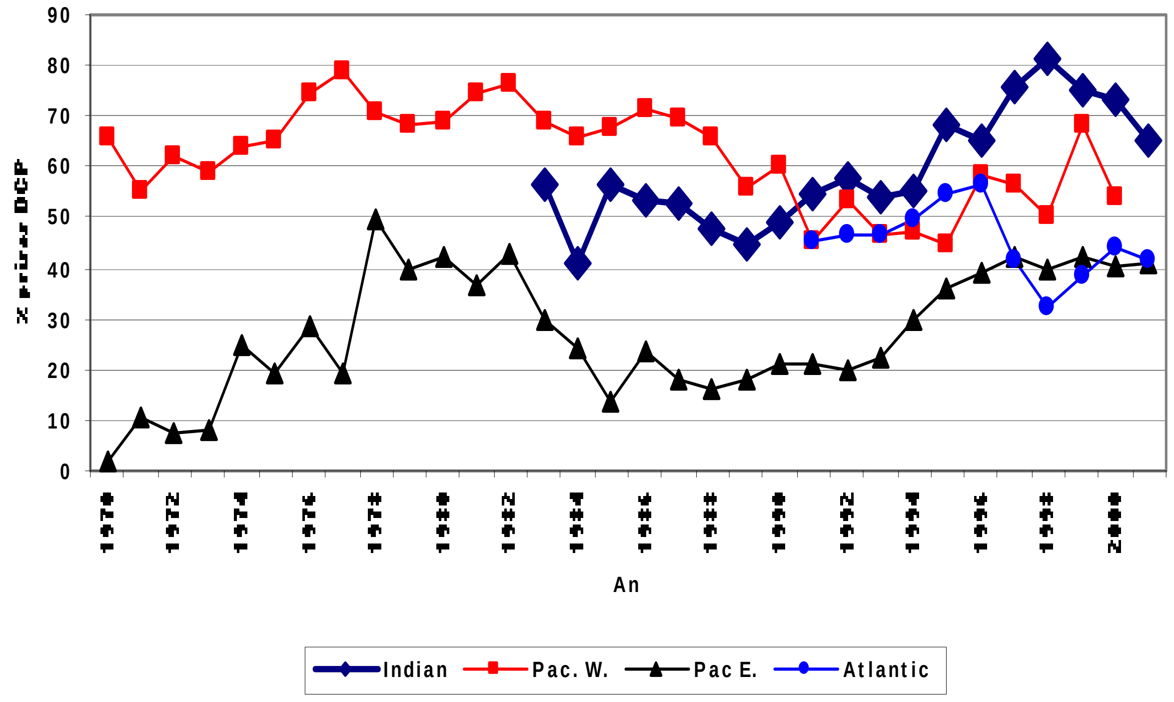


Figure 1: Estimates of tuna catches associated to FAD taken by purse seiners in the various oceans (in %)

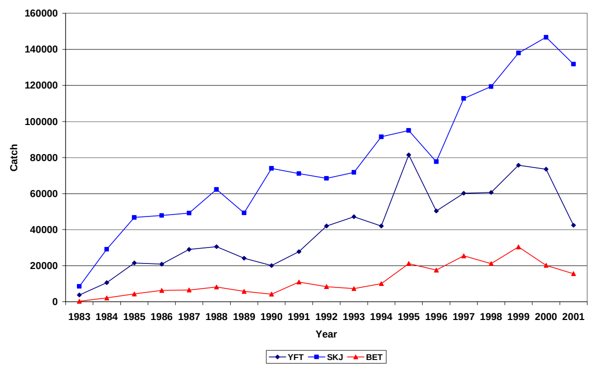


Figure 2: Yearly catches by species taken by purse seiners in the Indian Ocean FAD fishery

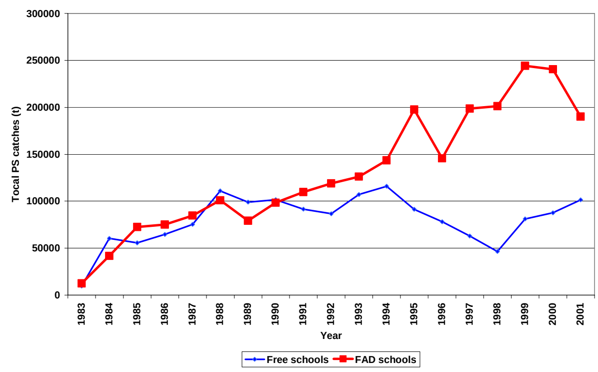
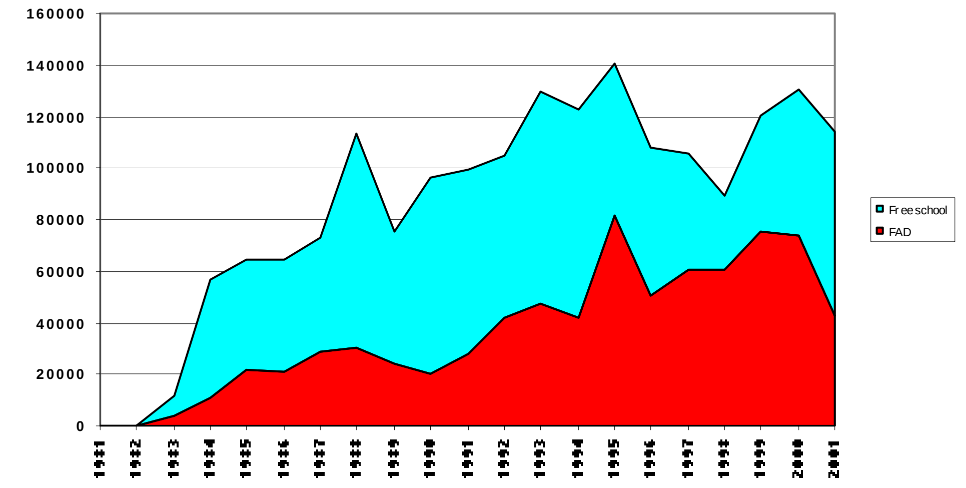
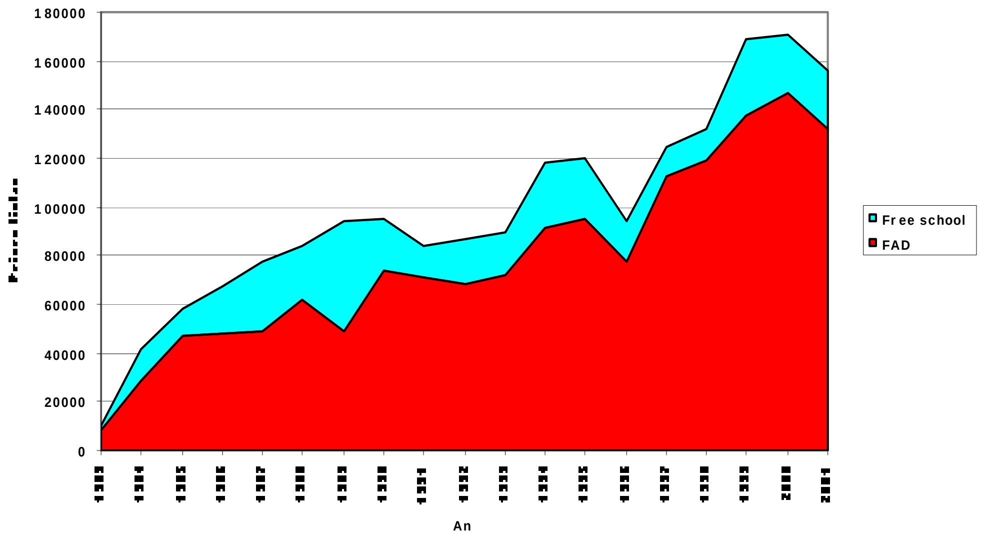


Figure 3: Total yearly catches taken by purse seiners under free schools and under FADs



YELLOWFIN



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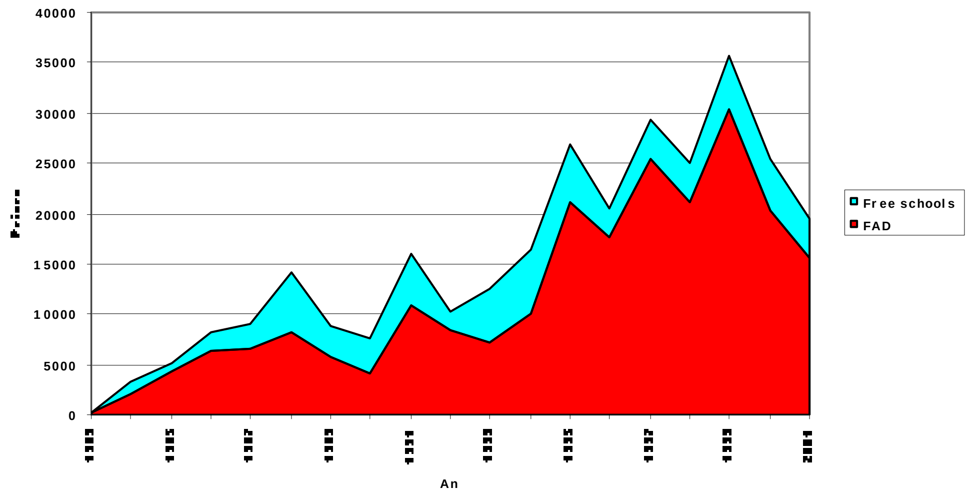
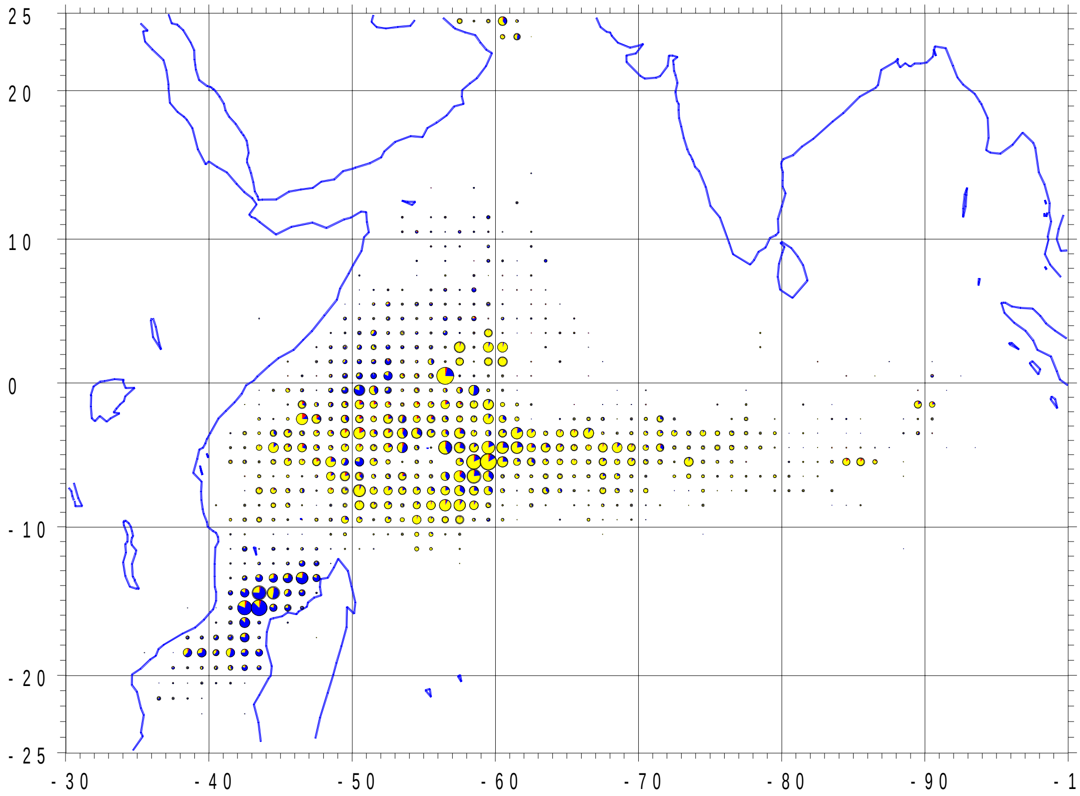


BIGEYE

Figure 4: Total yearly catches of yellowfin, skipjack and bigeye taken by Indian Ocean purse seiners under FADs and on free schools



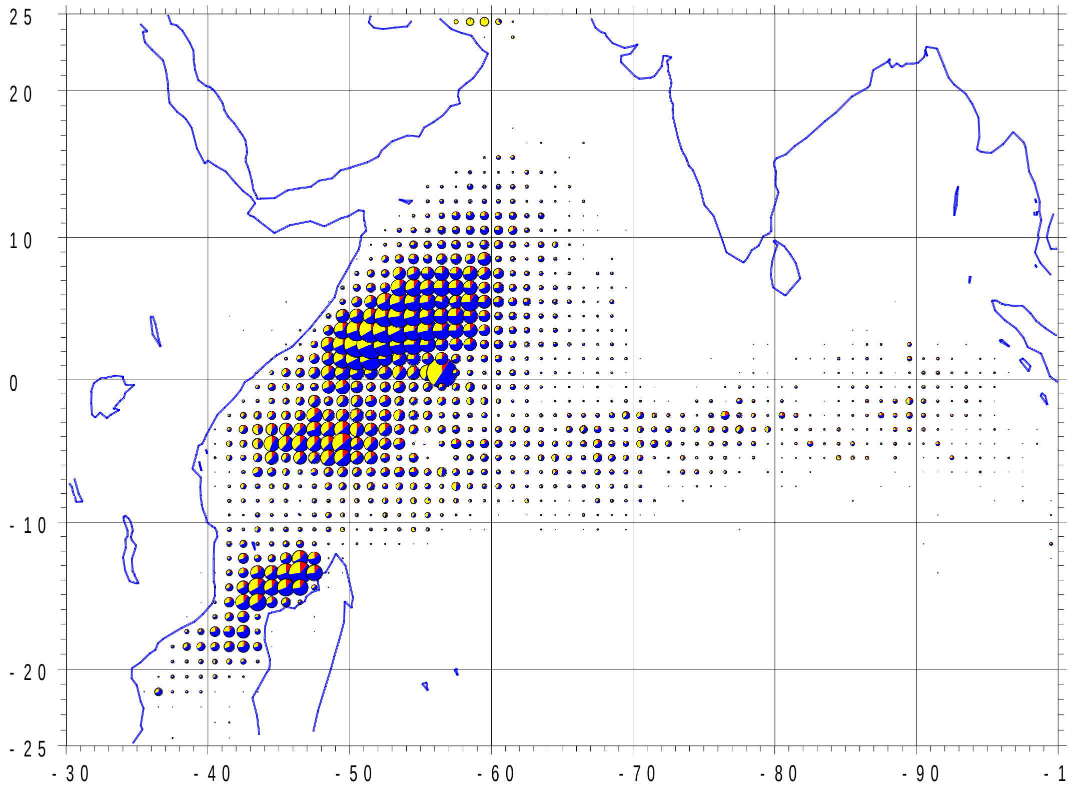


Figure 5: Average catches taken by purse seiners by 1° squares on free schools and on FAD associated schools

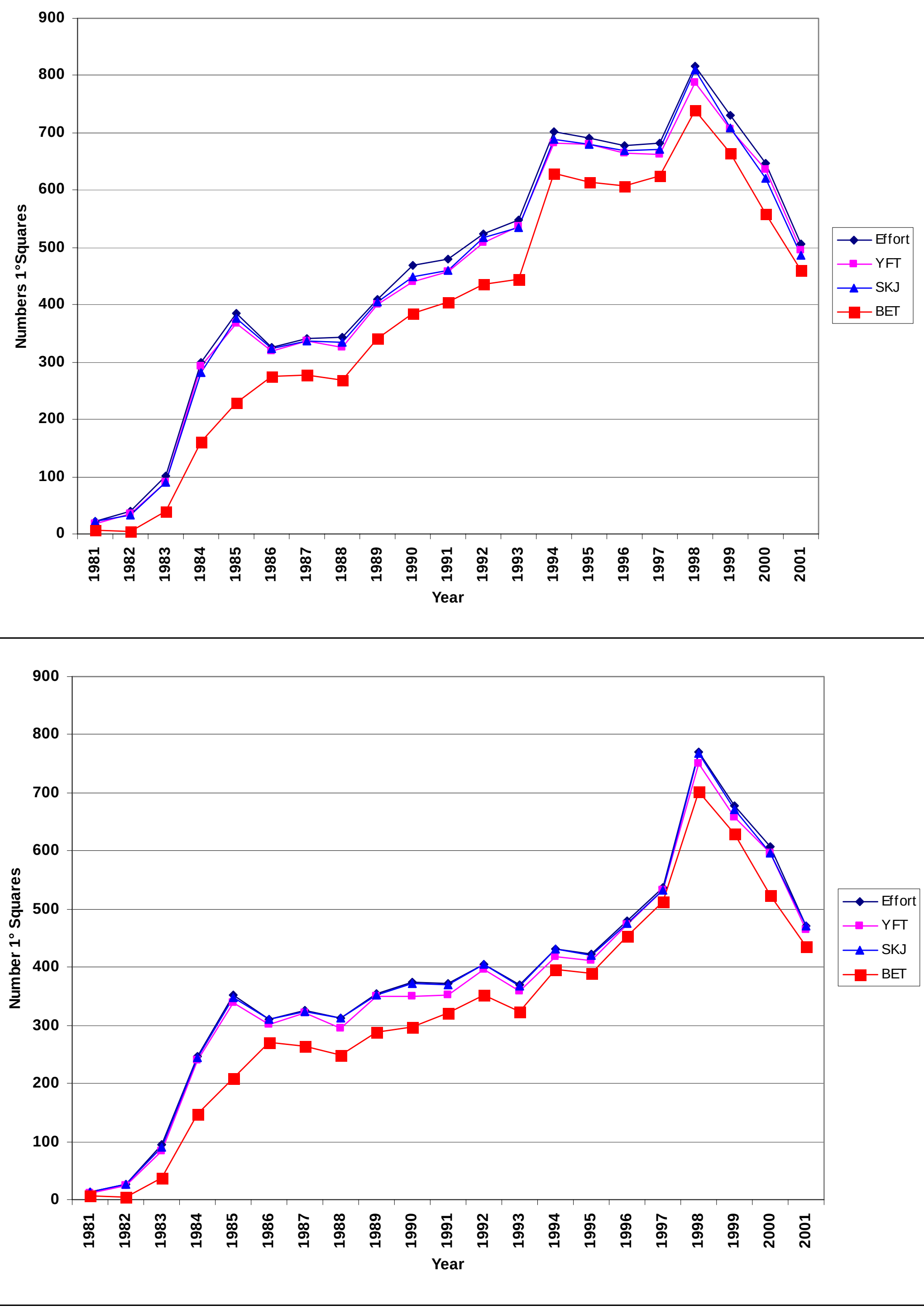


Figure 6: Size of the fishing zone positively fished (in numbers of 1° squares) for the Indian Ocean purse seine fishery as a whole, and for the FAD associated fishery.

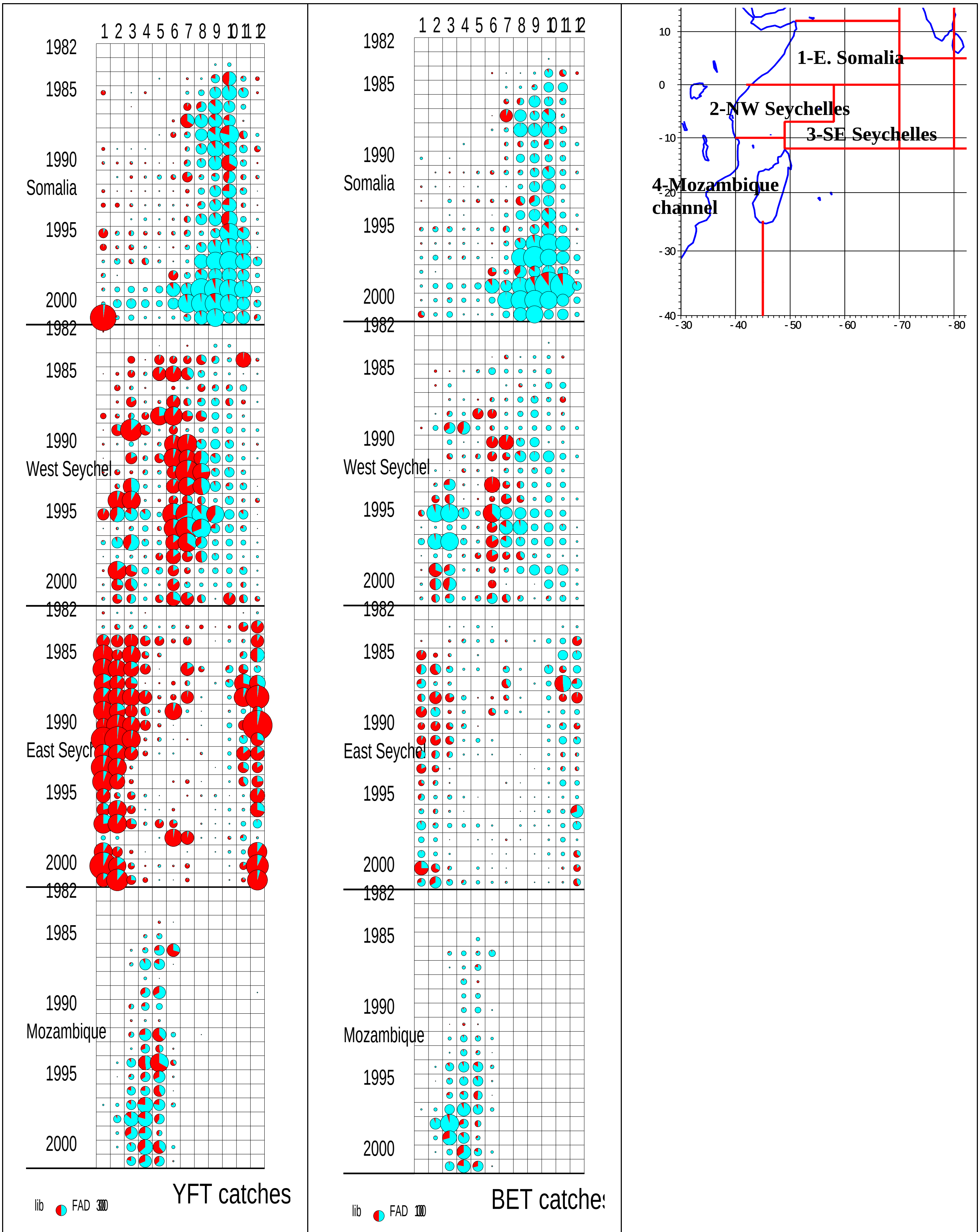


Figure 9: Monthly catches of yellowfin (left) and of bigeye (right) taken by area under FADs (grey) and on free schools (dark) by Indian Ocean purse seiners

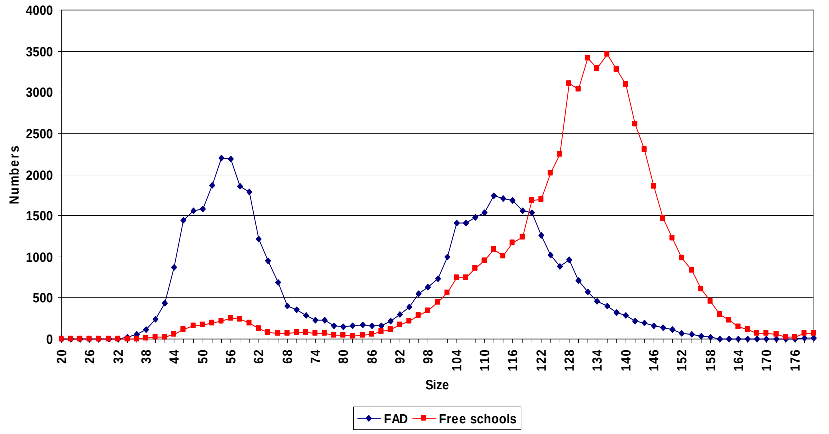


Figure 10: Average size distribution (1991-2001) of yellowfin taken under free schools and on FADs (expressed in weight and %)

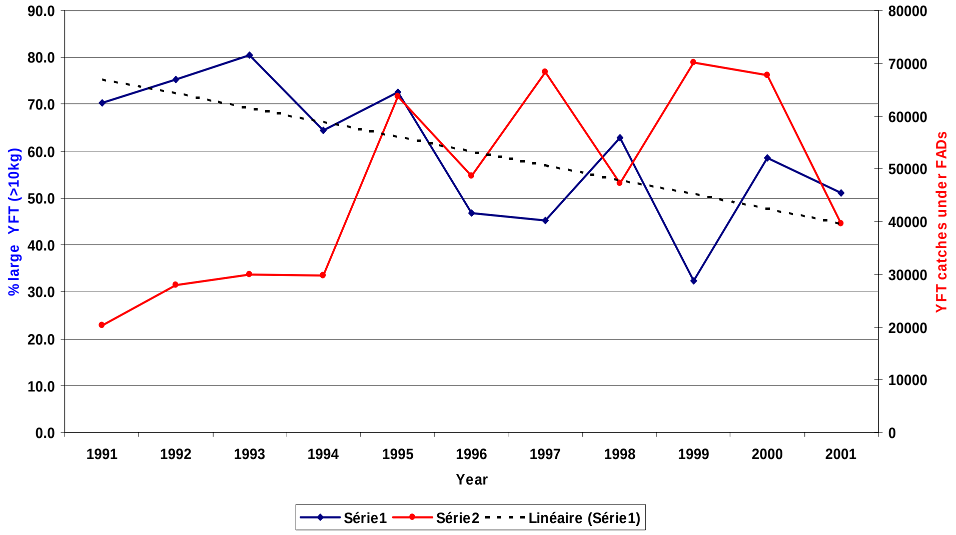


Figure 11: Catches of yellowfin tunas taken under FADs expressed in weight and in % of he total yellowfin catches.

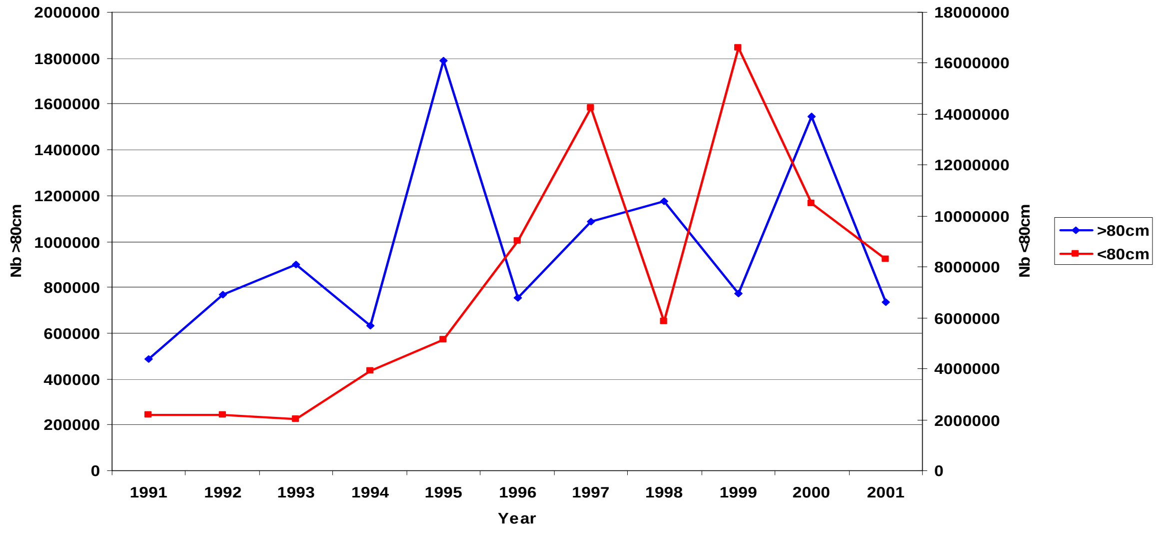


Figure 12: Numbers of small (<80cm) and of large (>80cm) yellowfin tunas taken under FADs by the purse seine fishery

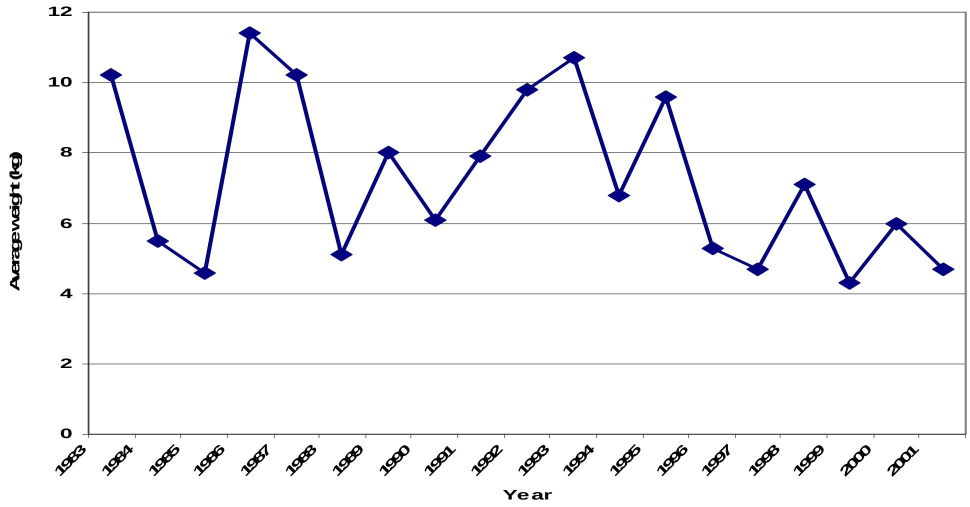
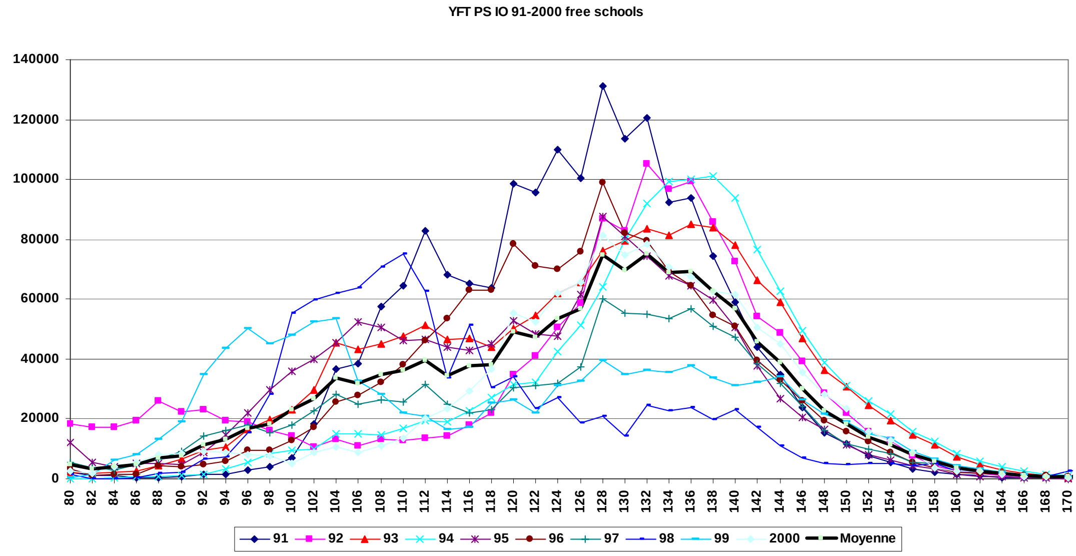


Figure 13: Average weight of yellowfin taken under FADs yearly by Indian Ocean purse seiners



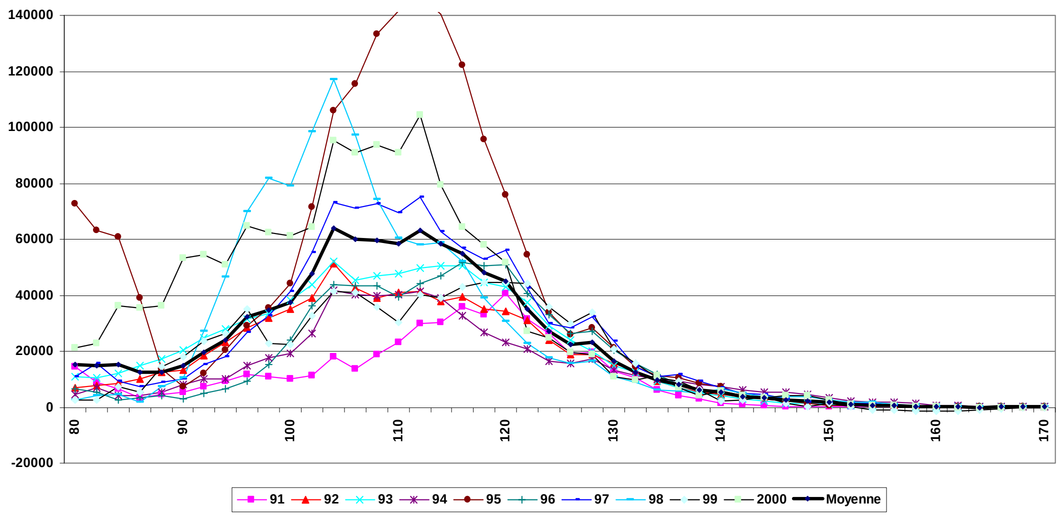


Figure 14: Yearly size distribution of the large yellowfin taken on free schools (upper figure) and under FADs (lower figure)

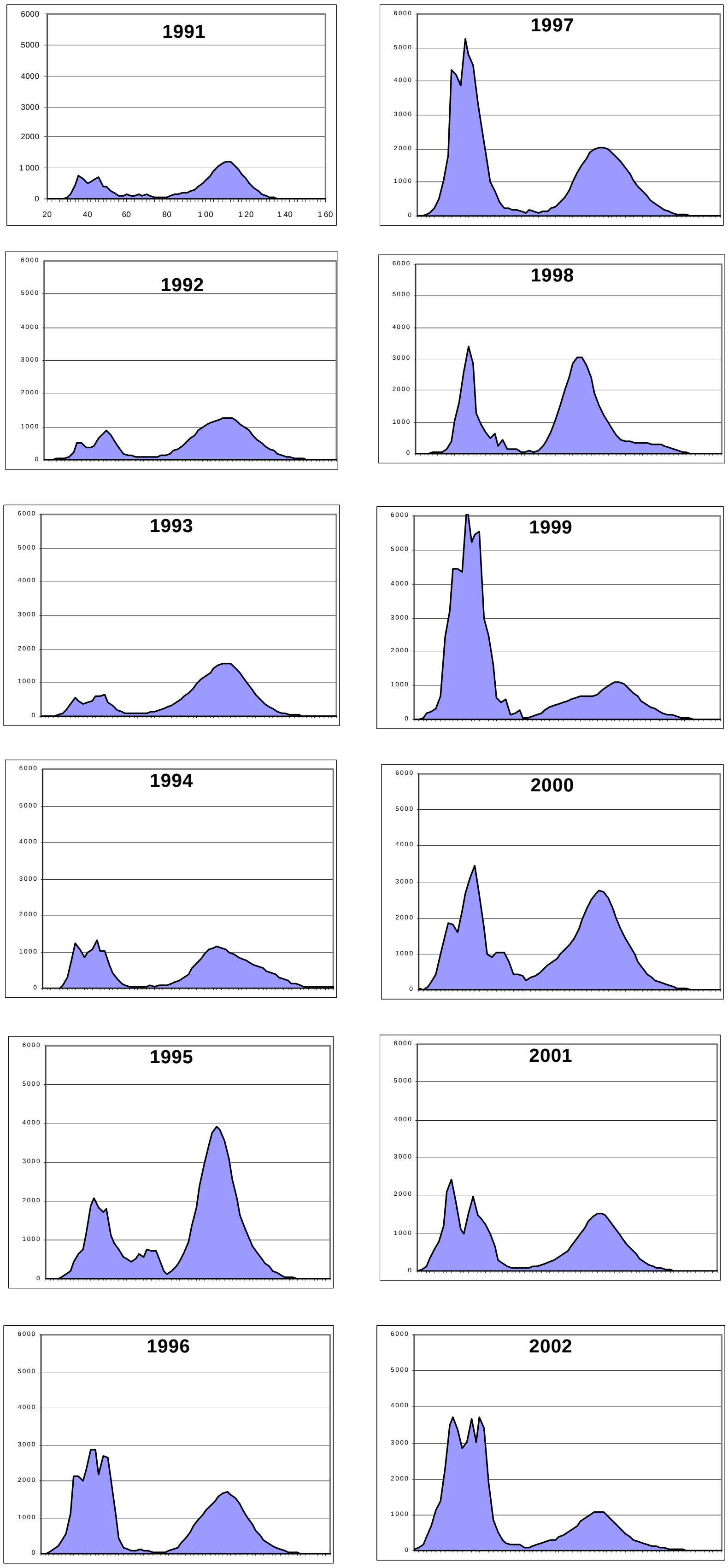


Figure 15: Yearly size distribution of yellowfin tuna taken by purse seiners under FAD (in weight) between 1991 and 2002.

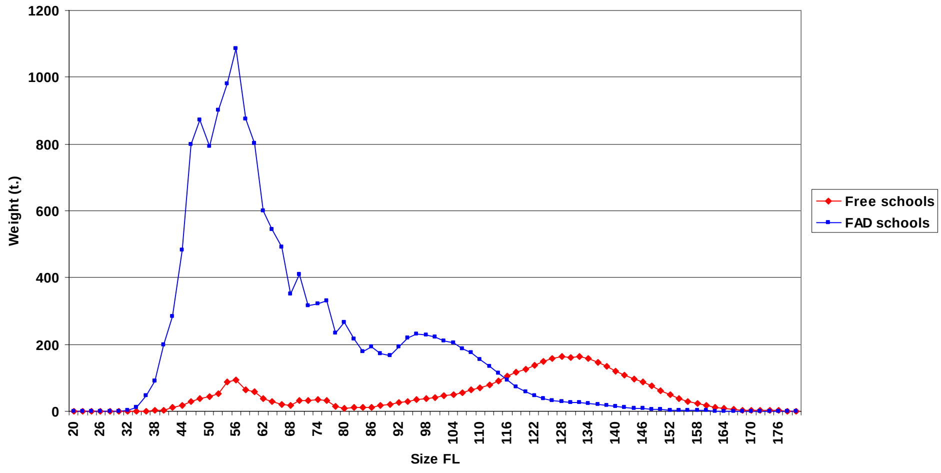


Figure 15: Average size distribution (1991-2001) of bigeye taken under free schools and on FADs (expressed in weight and %)

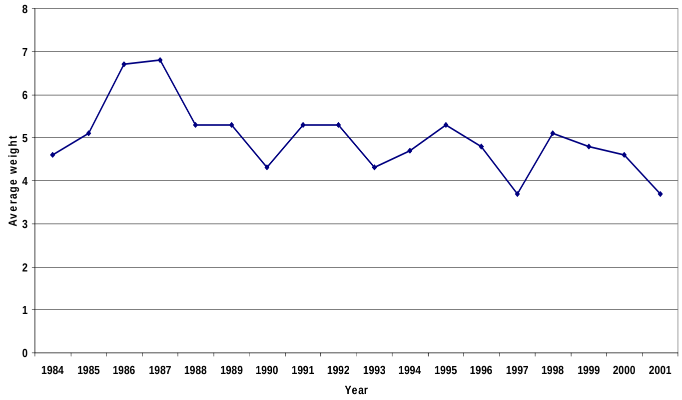


Figure 16: Average weight of bigeye taken yearly under FADs by Indian Ocean purse seiners

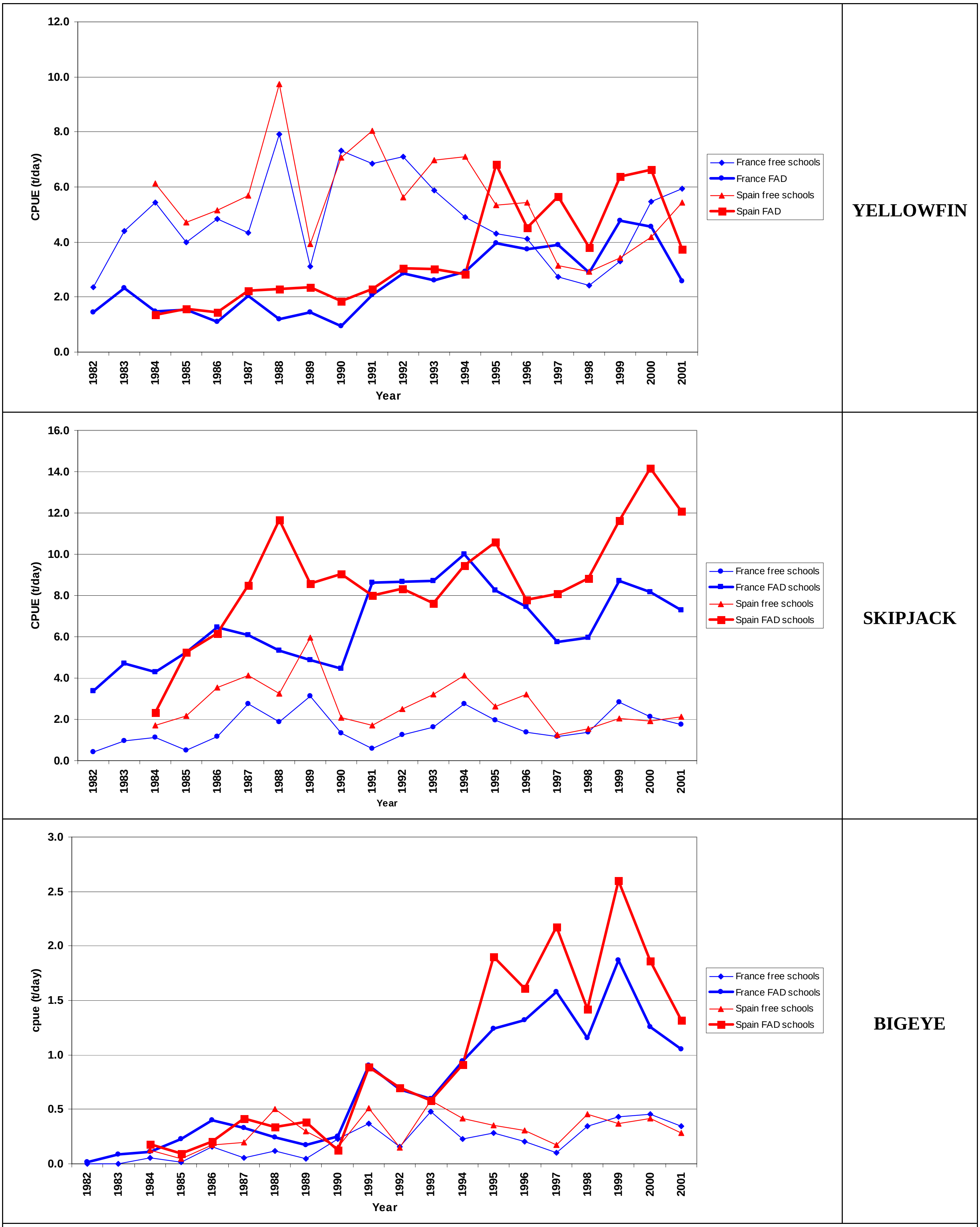


Figure 17: cpue of yellowfin (upper), skipjack (middle) and bigeye tunas (low) for the French and Spanish purse seiners, on free schools and on FA associated scholls. These cpue are calculated dividing the catches of each species and category, by the yearly numbers of fishing days exerted by each fleet.

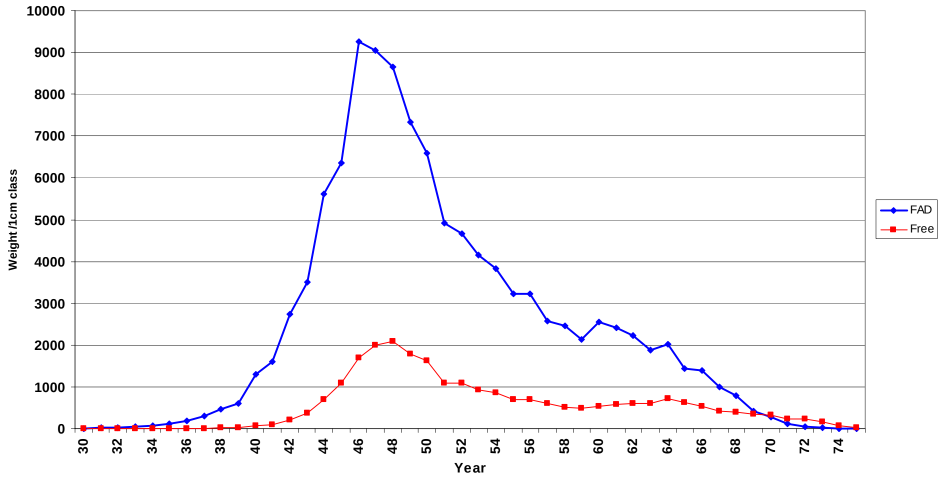


Figure 18: Average size distribution (1991-2001) of skipjack taken under free schools and on FADs (expressed in weight and %)

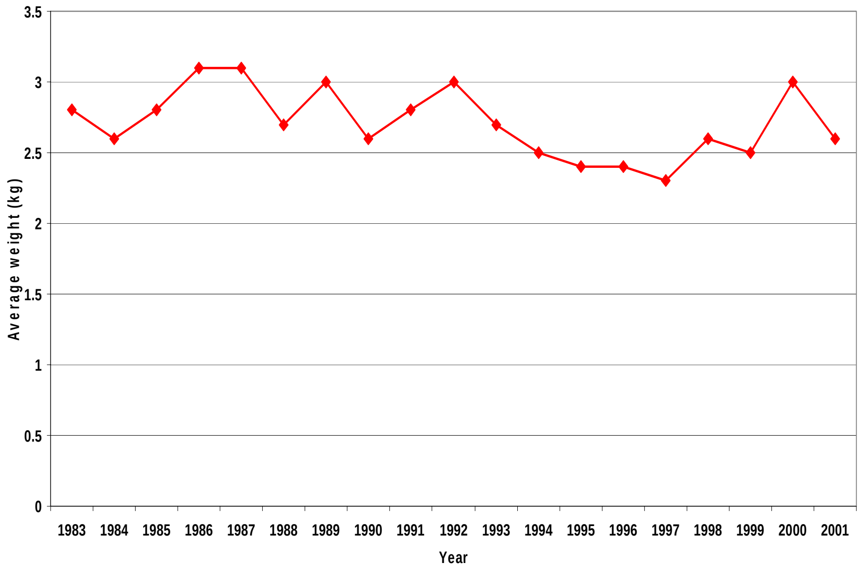


Figure 19: Average weight of skipjack taken yearly under FADs by Indian Ocean purse seiners