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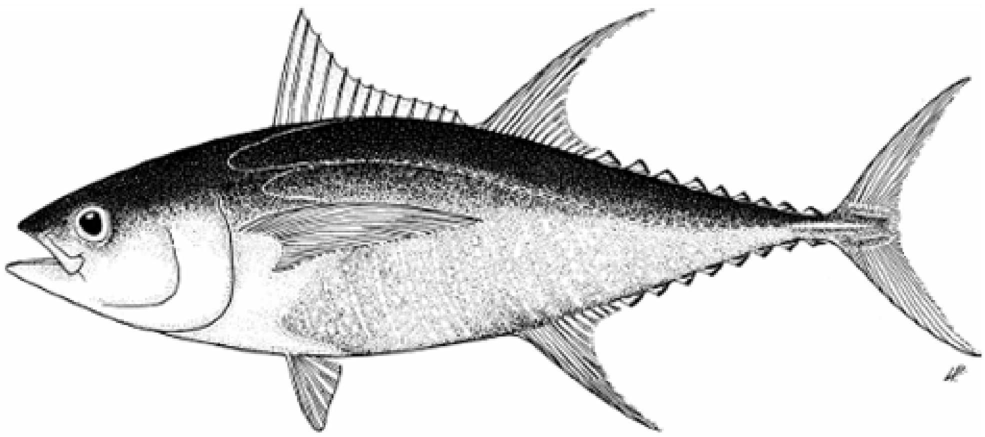
An overview of yellowfin tuna stocks, fisheries and stock status worldwide



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An overview of yellowfin tuna stocks, fisheries and stock status worldwide

By Alain Fonteneau, IRD scientist

(revised version, August 15th 2005)

Summary

This paper makes a comparison of yellowfin stocks worldwide, taking into account the biology of the species as estimated in each ocean and the changes and trends in the yellowfin fisheries observed in each ocean. This paper presents and discusses a wide range of data and figures comparing yellowfin stocks and fisheries in the four « oceans », namely the Atlantic, Indian, Eastern and Western Pacific. It shows an overview of the changes observed in each ocean for the main yellowfin fisheries, longliners and purse seiners: sizes of area fished, CPUE, changes in size distribution and average weigths, etc. The major biological parameters estimated in each ocean by scientists, such as natural mortality at age, spawning, sex ratio and growth are presented and discussed. The methods used to assess yellowfin stocks and the methodological uncertainties in the yellowfin stock assessment are compared and discussed. The conclusion is that it remains difficult to fully understand if the increased catches of yellowfin observed world wide in most oceans should be explained (1) by the effects of increasing fishing zones, (2) by increased fishing effort and/or increased fishing efficiency (3) and/or by increased biological productivity of oceans or by a combination of these parameters. The serious uncertainty in the understanding of the real relationship between the longline and purse seine fisheries are also discussed.

Aknowledgments: *this paper is entirely based on the wide scope of multiple data and informations that have been provided to me by the statistical department or scientists from the various tuna Commissions (ICCAT, IATTC,IOTC) or tuna bodies (SPC). I am giving a full recognition of my gratitude to each of those providing these data, and mainly papa Kebe from the ICCAT, Miguel Herrera from the IOTC, Peter Williams from the SPC and Michael Hinton (and al) from the IATTC.*

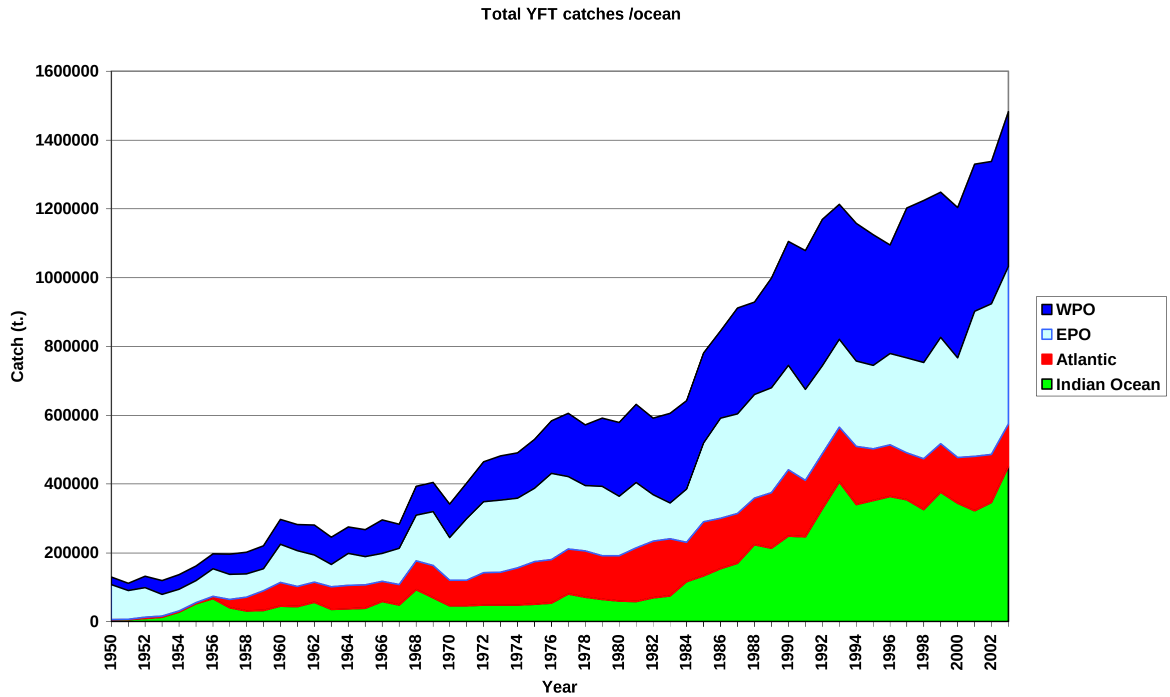
Overview and introduction

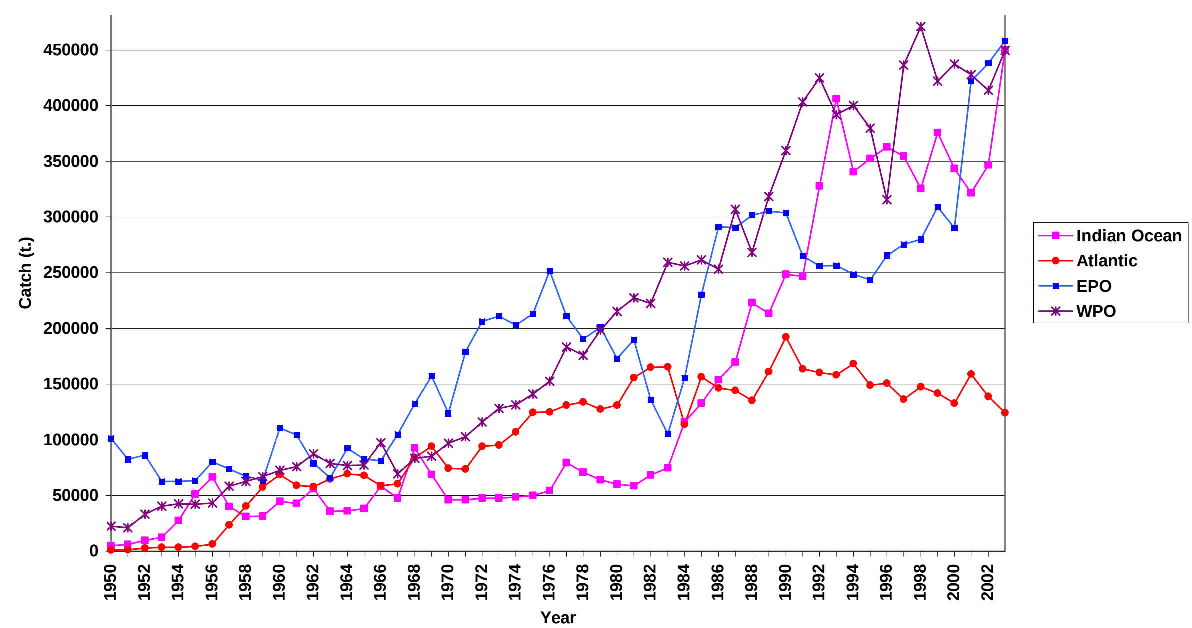
This paper will be presented using a special framework with a series of figures that will show the comparison of the yellowfin fisheries and biological parameters of this species in each of the 4 oceans world wide (Atlantic, Indian ocean, Eastern and Western Pacific). Each of these figures will be followed by a short comment and discussion of the figure. The use of this peculiar framework is to facilitate the use of this comparative document by scientists working in an assessment working group. The following figures are proposed and discussed in this document:

- Trend of yellowfin total catches by ocean and by fisheries (figure 1 to 3).
- Various fishing maps of catches (and some of CPUE) by 10 years period for the longline and purse seine fisheries. The other fisheries, artisanal ones, gill net, sport and others, that are of secondary importance and in general poorly followed will not be shown on these maps. The seasonality of fisheries is shown by quarterly maps (figure 4 to 7).
- The changes in sizes of areas exploited by longliners and by purse seiners (figure 8 and 9)
- The contribution of yellowfin catches in the total catches taken by each gear (figure 10).
- The total yellowfin catches taken by each gear in each ocean by average 5° squares (figure 11 to 12).
- Yellowfin catches associated to FADs in the purse seiners catches (figure 13 to 15)
- Trends of nominal CPUE of in the purse seine and longline fisheries (figure 16 to 18)
- Average sizes taken by each fishery in the various oceans and the corresponding average weight (figure 19 to 23).
- Biological parameters presently estimated are also compared: natural mortality, sex ratio at size, growth parameters and models, sizes at first spawning, catches in each Longhurst ecobiological areas, catches as a function of average sea temperature (surface and at 100m depth) (figure 24 to 29).

The various methods used by scientists to conduct their stock assessment are reviewed and discussed. This discussion will try to evaluate the major problems and uncertainties in the yellowfin stock status faced world wide by tuna scientists. This discussion will incorporate the biological and fishery uncertainties, among them the uncertainty in growth and natural mortality at age, the effects of increasing areas exploited, of increasing fishing powers or of increased biological productivity. The strange lack of visible interactions between most yellowfin surface and longline fisheries will also be discussed, as this question remains a major uncertainty in the assessment of most yellowfin stocks.

Figure 1: Trend of yellowfin fisheries: total catches by ocean

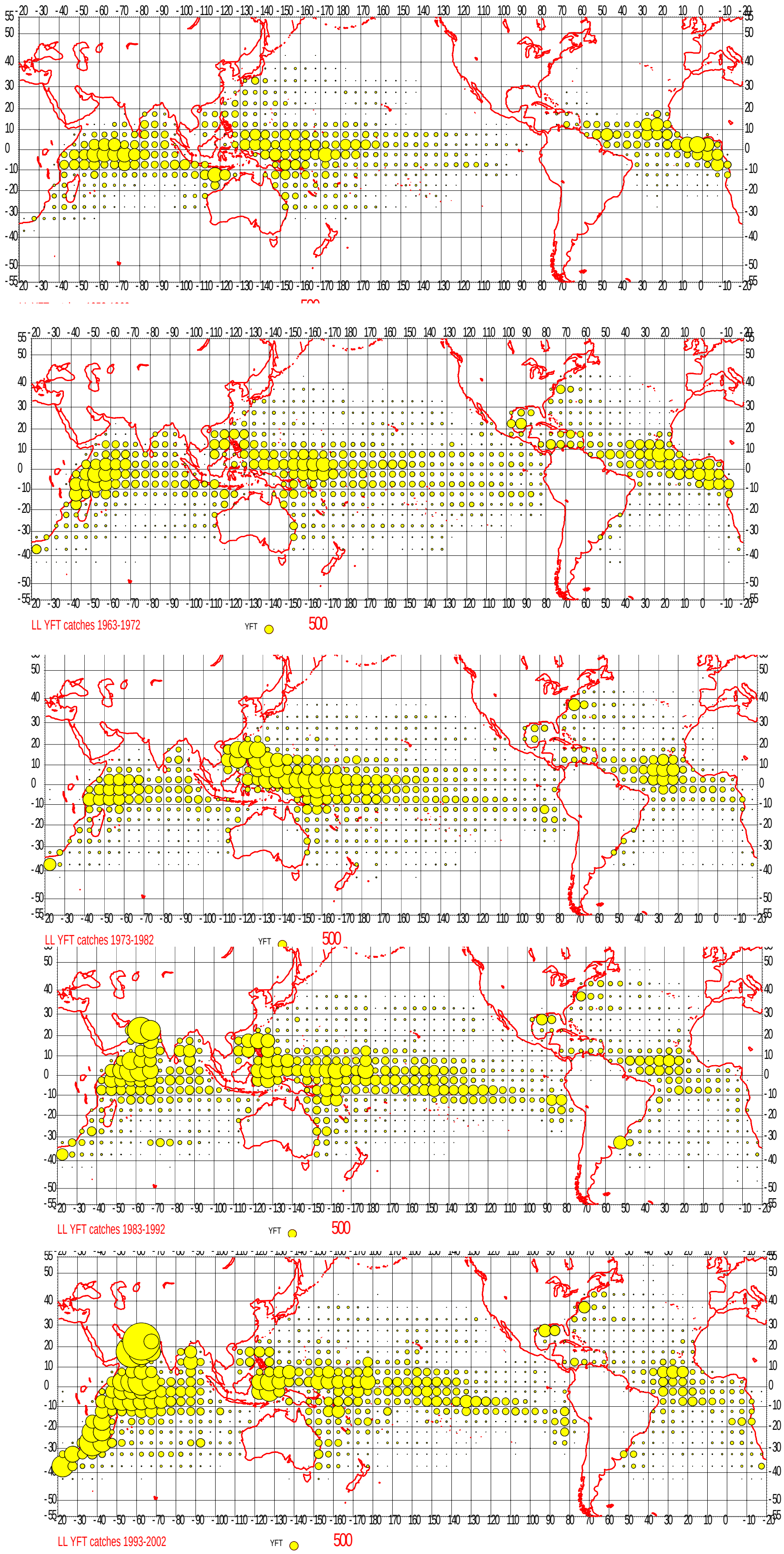




Total catches of yellowfin tuna have been increasing more or less permanently in all oceans with the exception of Atlantic ocean where these catches have been quite stable or slowly declining during the last 20 years. The levels of yellwfin catches taken in the Indian, Eastern and Western Pacific oceans have been similar during recent years in their trends and absolute levels.

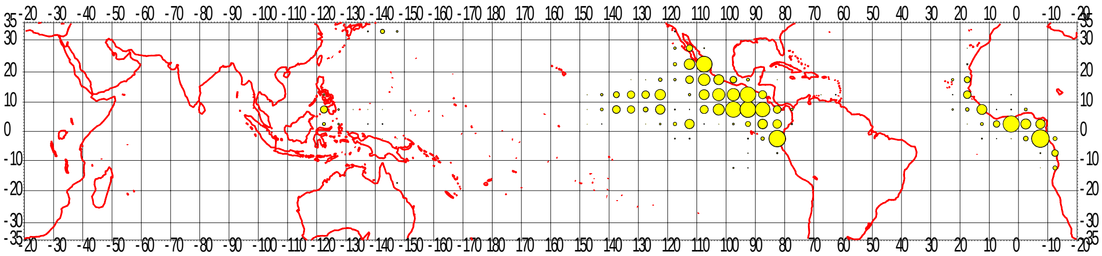
NB: EPO is the Eastern Pacific ocean with a western limit at 150°W, and WPO is the western Pacific ocean, west of this statistical limit.

Figure 2: Yellowfin catches by longline fisheries, by 10 years period

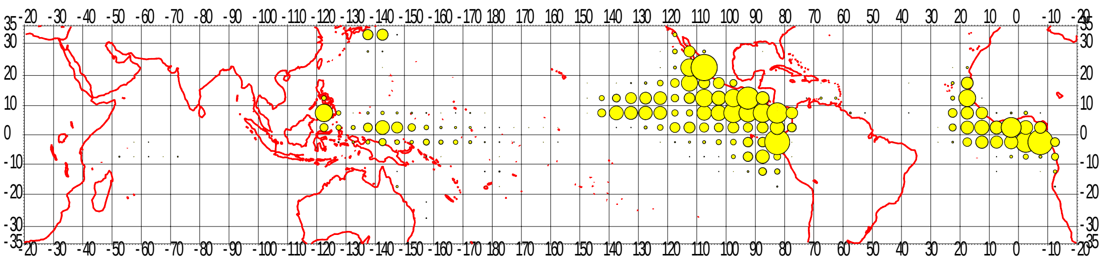


Changes in the yellowfin fishing zones of longliners by 10 years periods show a global stability of fished zones during the entire last half century, most of the present fishing zones being already fished during the mid sixties.

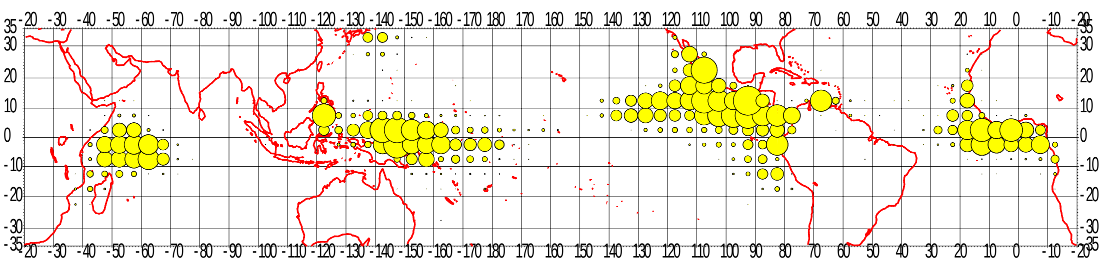
Figure 3: Yellowfin catches by purse seine fisheries, by 10 years period



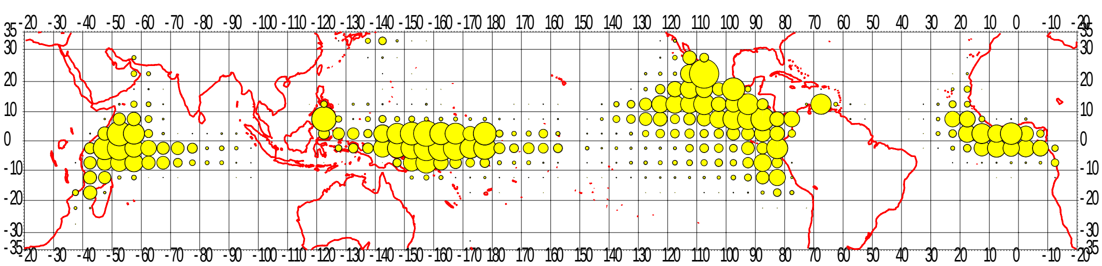
PS YFT catches 1963-1972 YFT 3000



PS YFT catches 1973-1982 YFT 3000



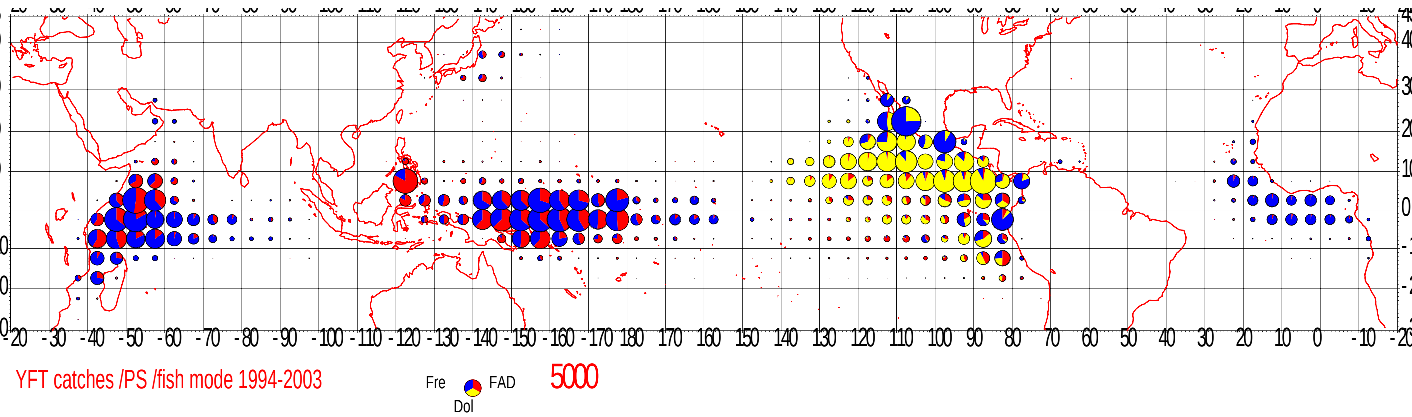
PS YFT catches 1983-1992 YFT 3000

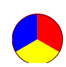


PS YFT catches 1993-2002 YFT 3000

Changes in the yellowfin fishing zones of purse seiners by 10 years periods during the last 40 years do show the wide geographical expansion of fishing zones by this fleet since the early eighties, followed by a stabilty of these fished zones.

Figure 4: Yellowfin catches taken by fishing mode during recent years (1994-2003).

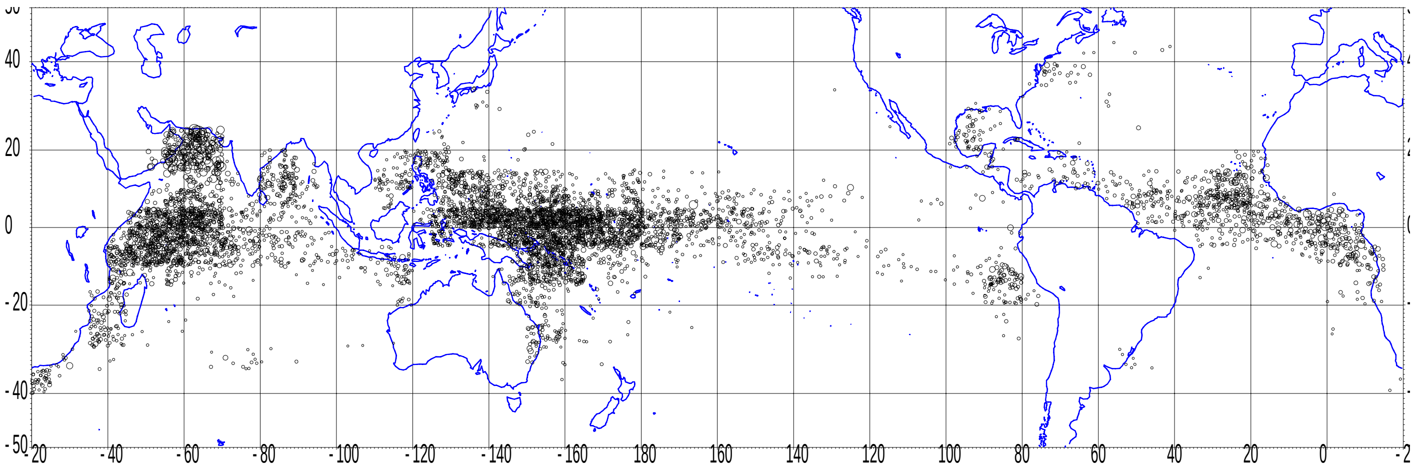


Free schools  FAD

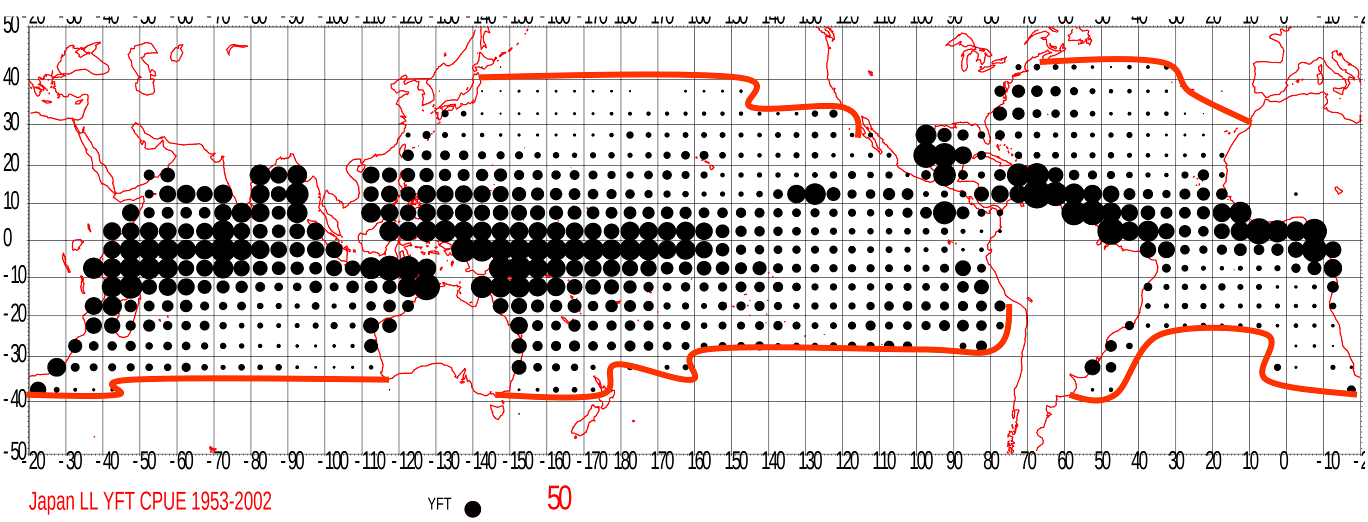
Dolphin

Yellowfin catches taken during recent years (1994-2003) by purse seiners as a function of their fishing modes (FAD, free schools and dolphin schools) show that the dolphin fishery was dominant in the Eastern Pacific, but nearly absent in all other areas, while the FAD associated catches are observed in all oceans, but at a variable degree. In the Atlantic, catches under FADs were limited during recent years following the moratorium on FAD fishing implemented by fishermen and later by the ICCAT .

Figure 5: Geographical distribution of yellowfin tuna: strata of large density and average CPUEs by Japanese longliners

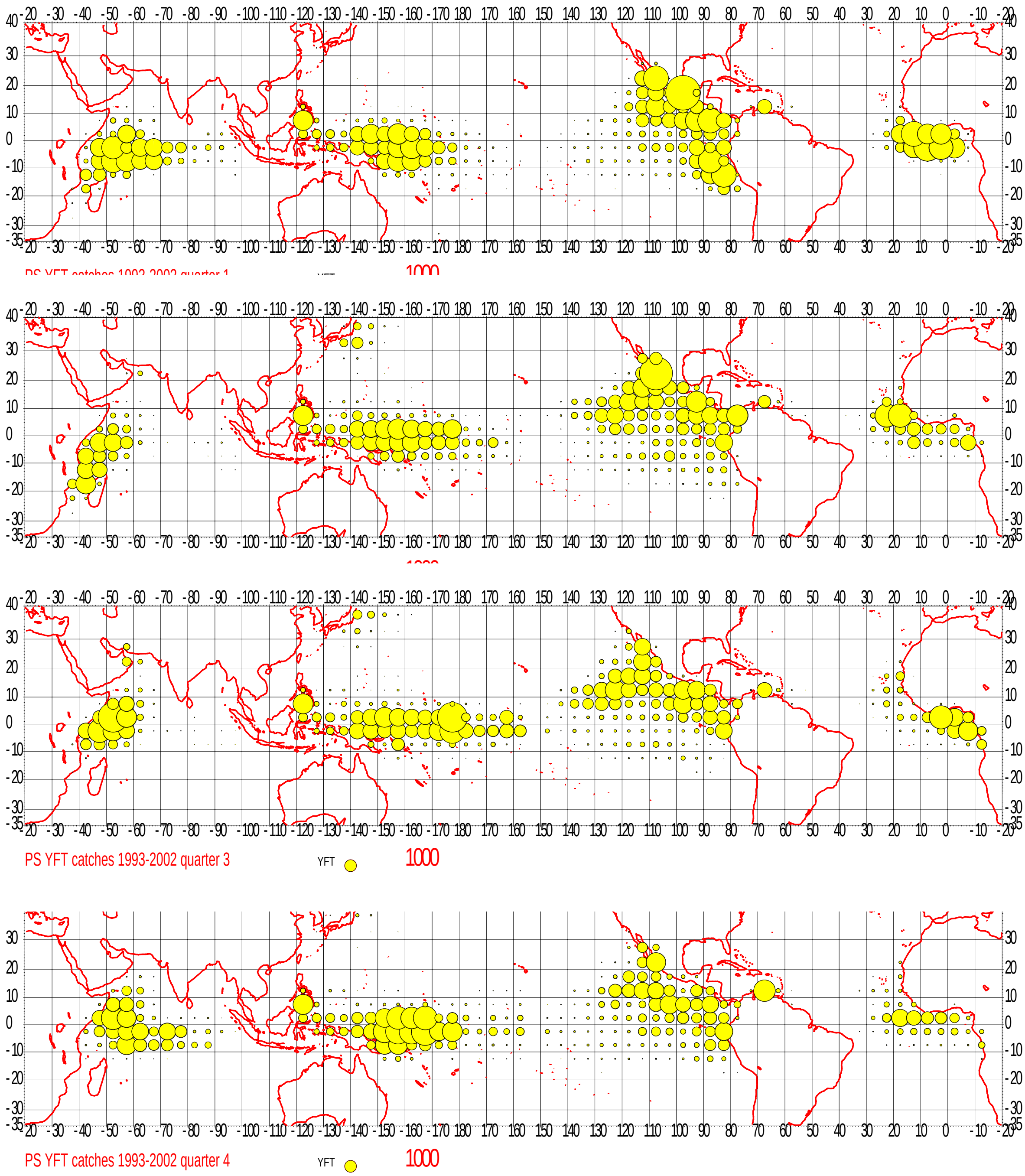


Map of the so-called yellowfin « hot spots» by longline fisheries: each circle corresponds to a large catch of yellowfin (>200 tons) taken during any month in each 5° square during the period 1952-2000 by the combined fleets of longliners (randomly positioned within each 5° square). Such a map is indicative of 5°-month strata where yellowfin tuna have been heavily targetted by longliners at some time during the history of the fishery.



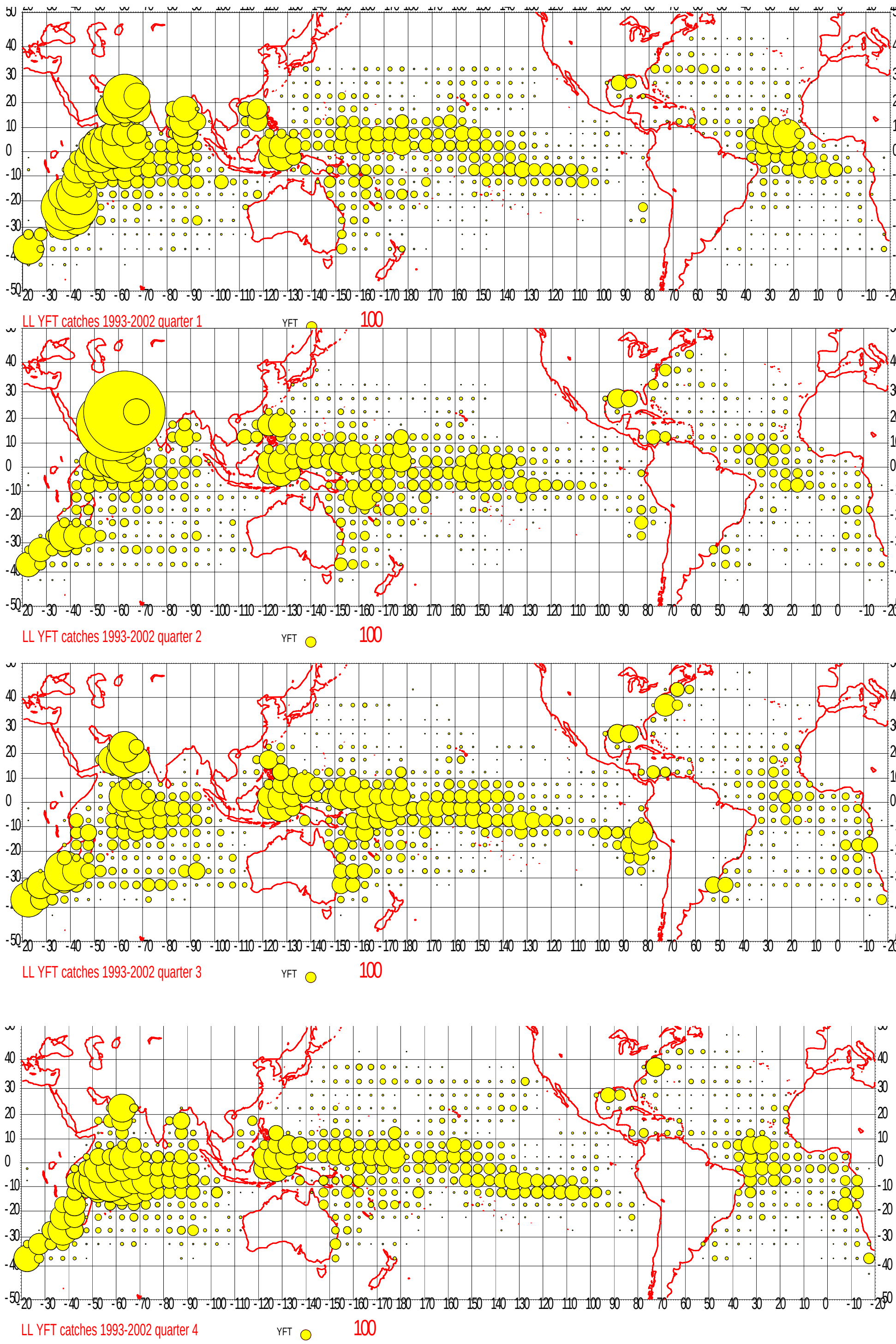
Map showing the average yellowfin nominal CPUE of Japanese longliners during the period 1953-2002. This map shows the 5° area where yellowfin has been abundant during the last 50 years of the fishery. It also shows the biological distribution of the adult yellowfin (lines drawn by hand).

Figure 6: Seasonality of purse seine fisheries: quarterly maps of yellowfin catches during recent years (1993-2002)



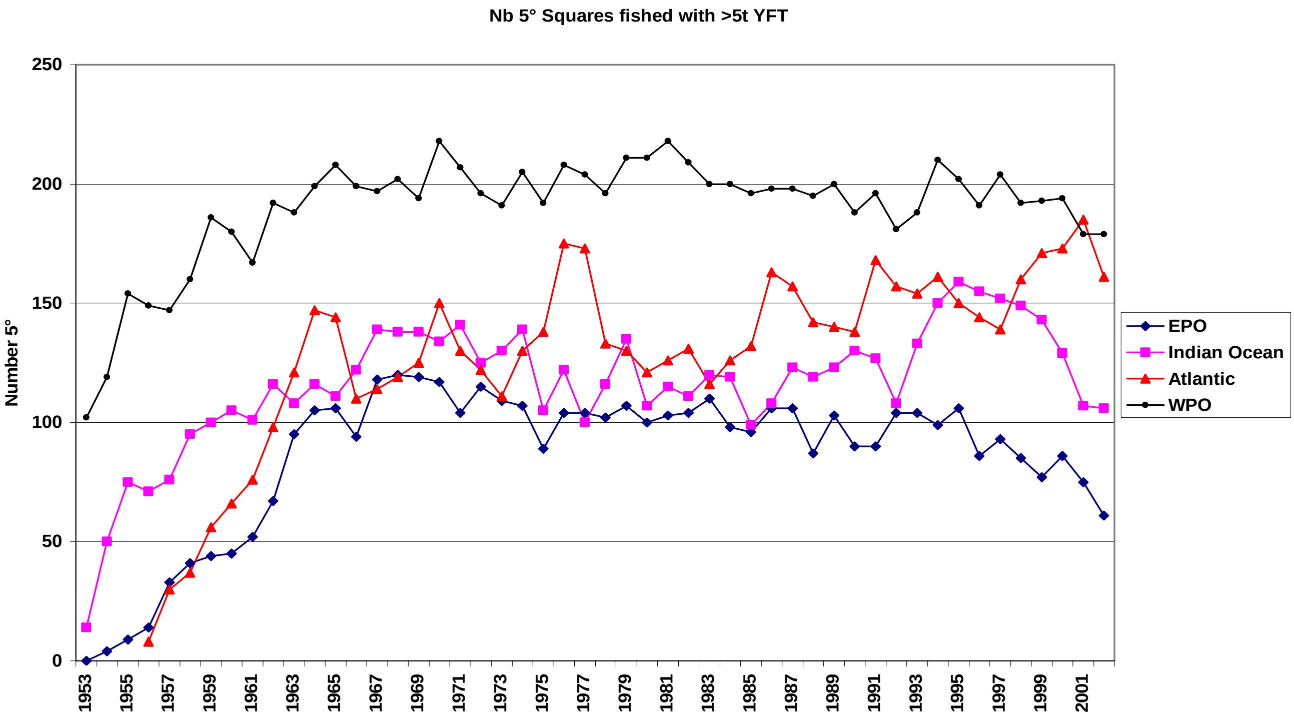
Maps of the average quarterly yellowfin catches by purse seiners during the period 1993-2002, showing that seasoanility in these fisheries is much stronger in the Atlantic and Indian oceans than in the Pacific

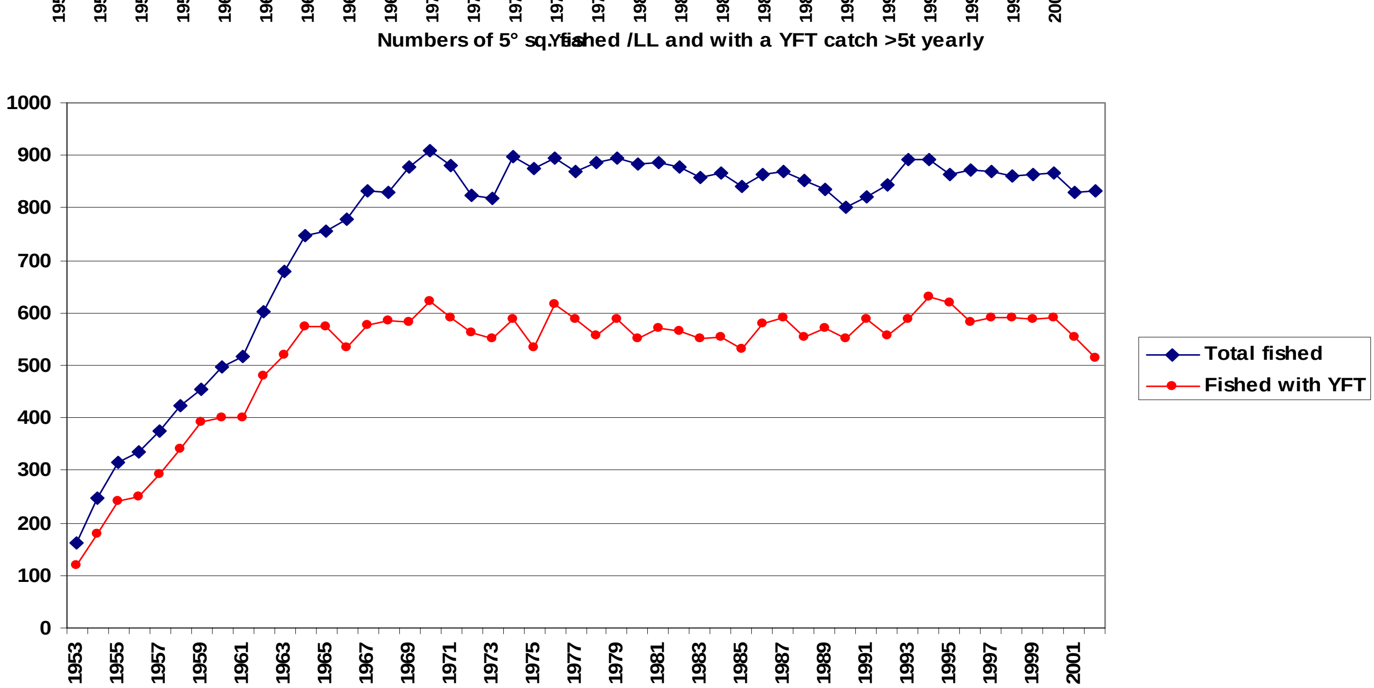
Figure 7: Seasonality of longline fisheries: quarterly maps of yellowfin catches during recent years (1993-2002)



Seasonal fishing zones by longliners show some seasonality in the geographical fishing zones, but often these seasonal patterns can be considered as minor ones, especially in most equatorial fishing zones where yellowfin are permanently fished by longliners.

Figure 8: Changes in sizes of areas exploited by longliners

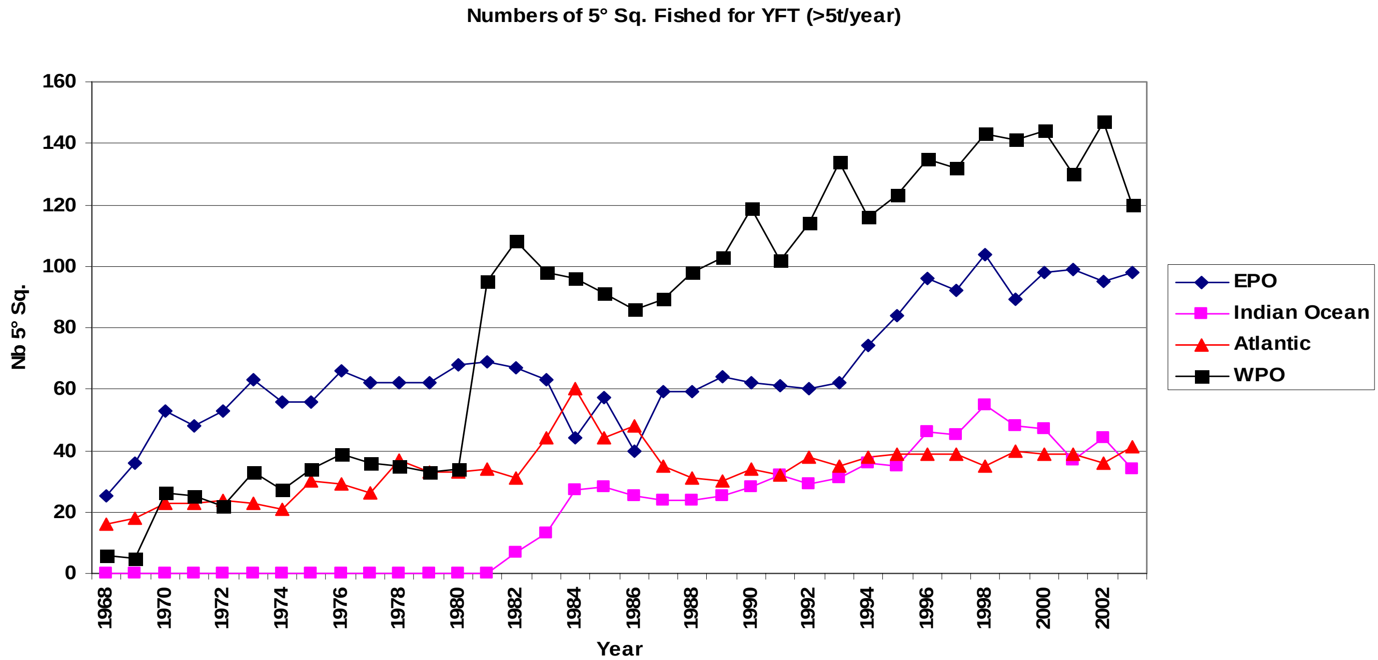


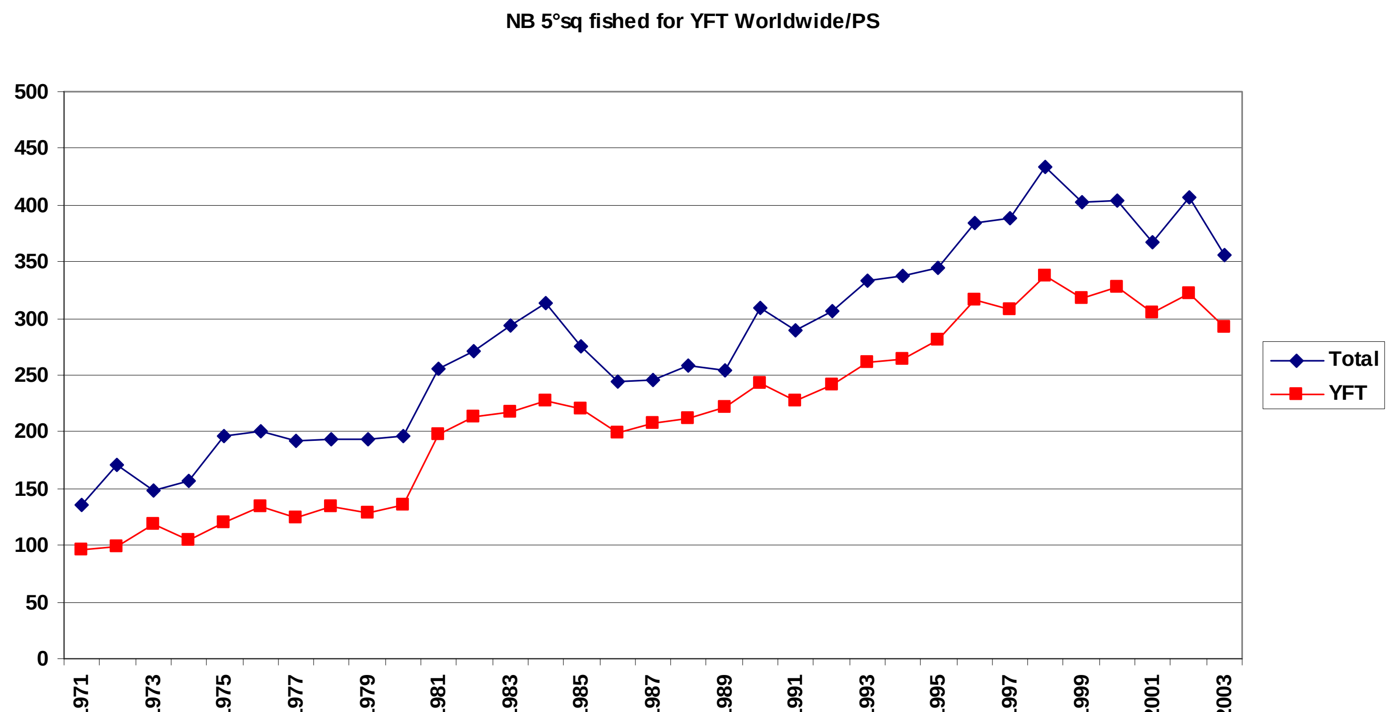


The sizes of the areas fished by longliners (in numbers of 5° squares) have been increasing very quickly during the first 15 years of their exploitation and since, these fished areas have been showing very little year to year variability. Yellowfin was taken in 68% of the areas fished by longliners (last 10 years).

Sizes of the areas with yellowfin catches in each ocean are quite comparable, the Atlantic areas fished with yellowfin catches showing a surprising increase during recent years.

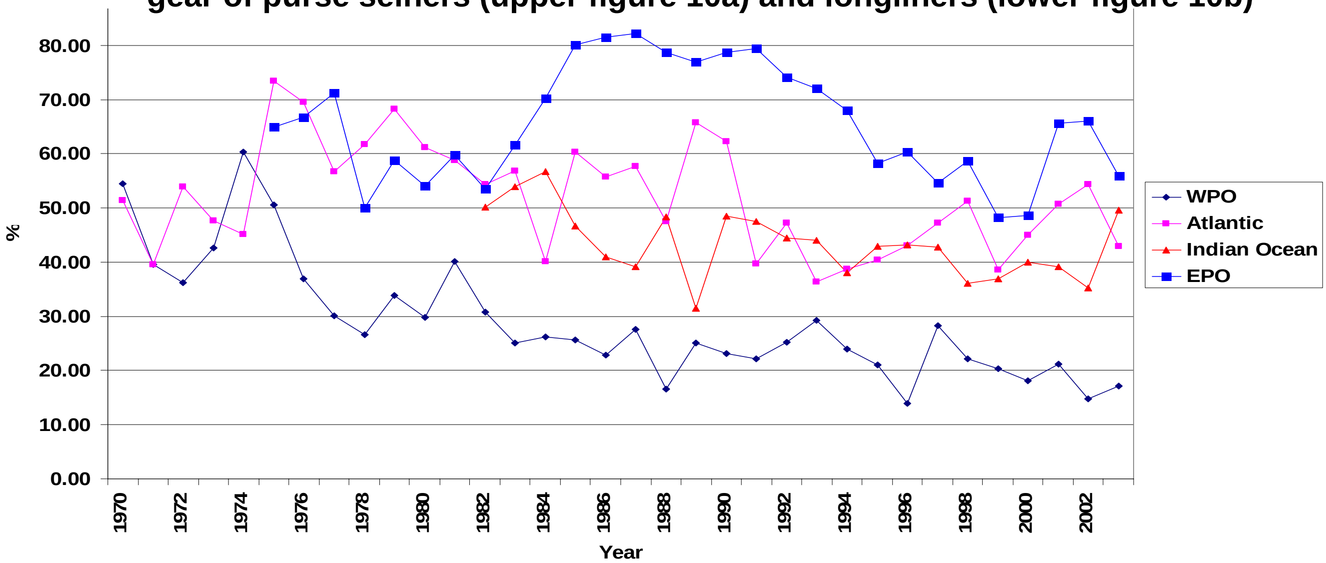
Figure 9: Changes in sizes of areas exploited by purse seiners



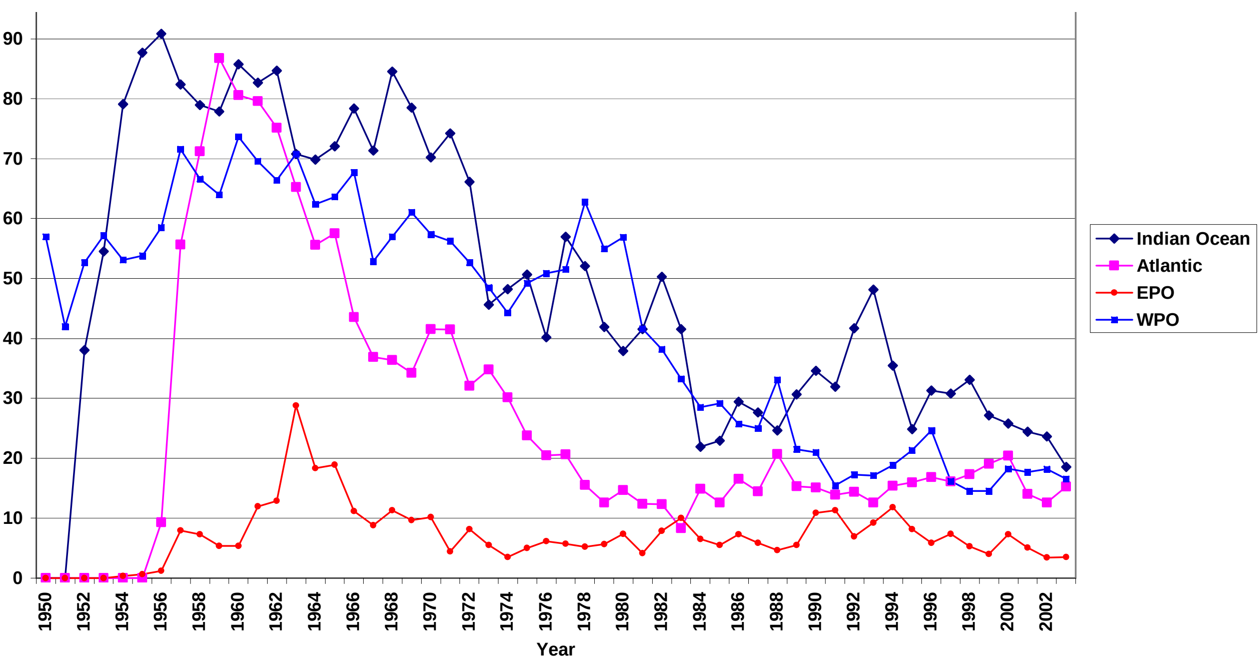


The areas fished by purse seiners with yellowfin catches have been permanently increasing at a world scale and in most oceans (the exception being the Atlantic); a stabilization of the sizes of areas fished by purse seiners has been recently observed in all fishing zones (for instance during their last 8 years of activity). Yellowfin tuna has been caught in most of the 5° area fished by purse seiners (80% of their fished zones world wide)

Figure 10: Contribution of yellowfin catches in the total catches taken by each gear of purse seiners (upper figure 10a) and longliners (lower figure 10b)

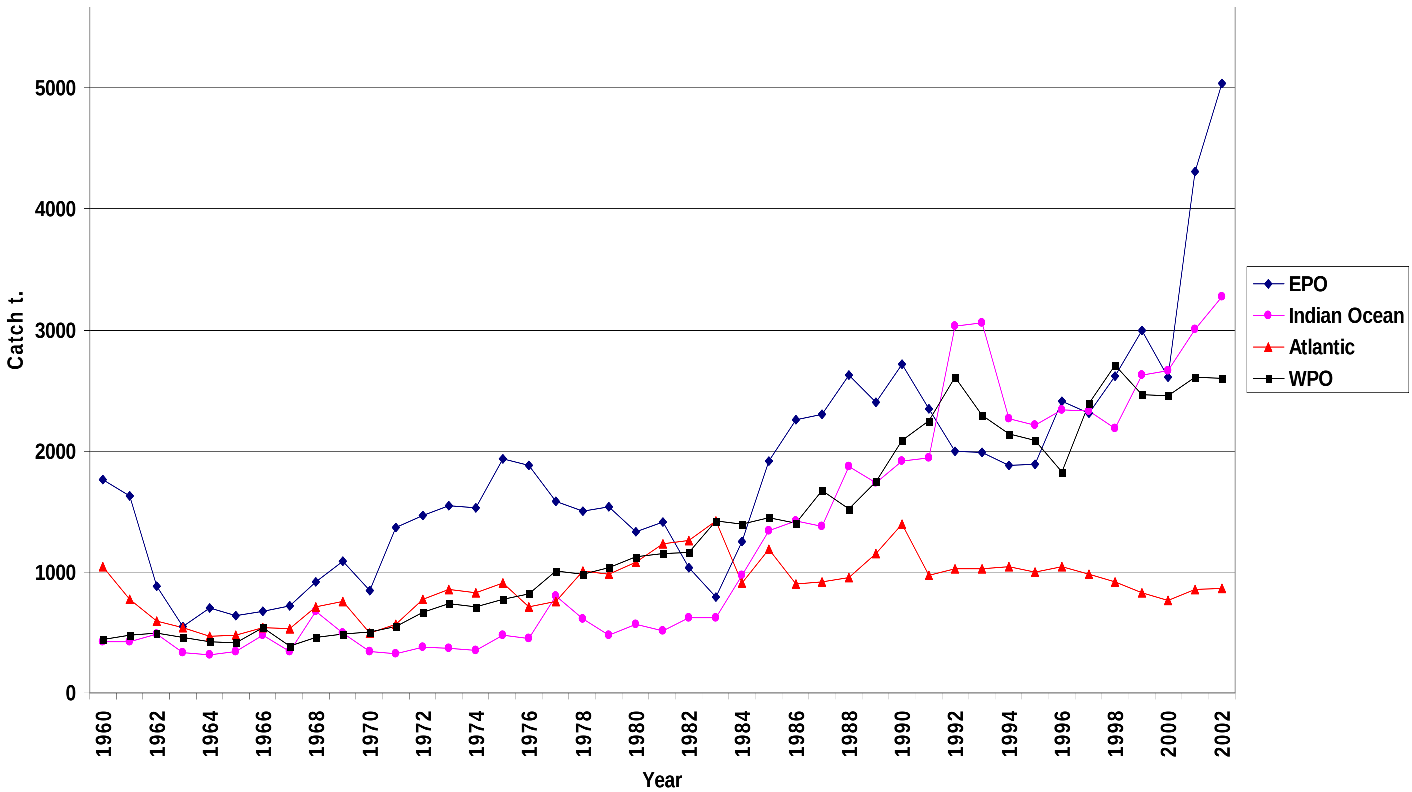


This figure shows the percentage of yellowfin in the total catches taken by purse seiners in each ocean. It shows that yellowfin has always been the dominant species in the Eastern Pacific, being a quite minor species in the Western Pacific (an area dominated by skipjack catches). Indian and Atlantic oceans show an intermediate percentage of yellowfin in the total PS catches.



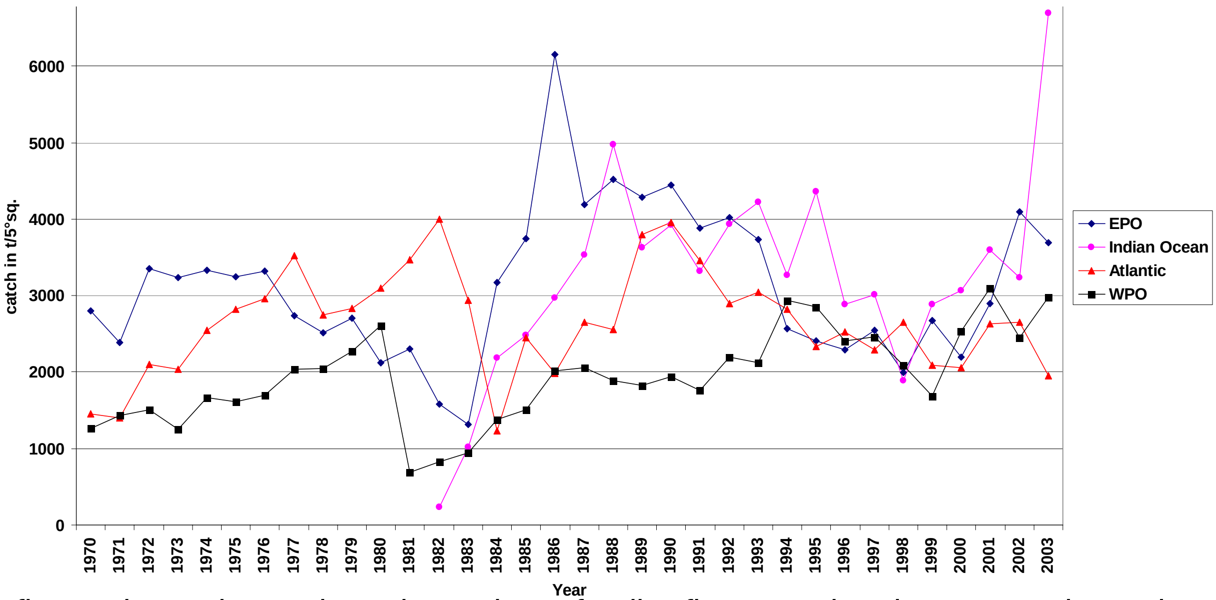
This figure shows the percentage of yellowfin in the total catches by longliners in each ocean. It shows that yellowfin has always been the dominant species in the Indian Ocean, being always a minor species in the Eastern Pacific (an area dominated by bigeye catches). Western Pacific and Atlantic oceans show intermediate percentages of yellowfin in their total catches.

Figure 11: Total yellowfin catches taken in each ocean by average 5° squares

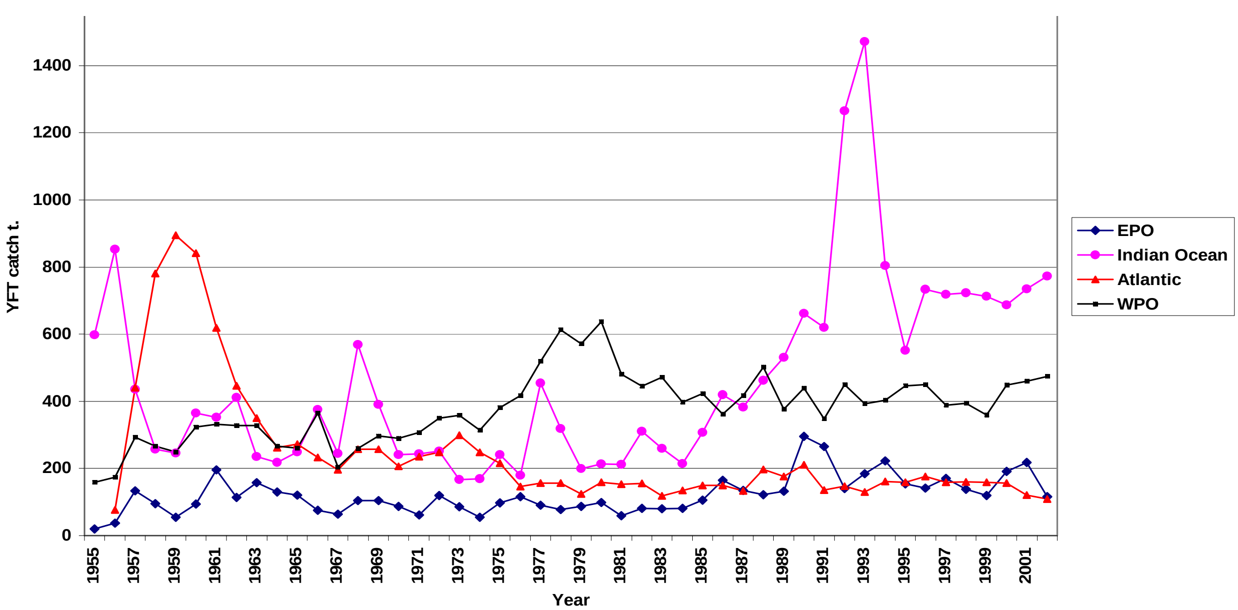


This figure shows the total yearly catches of yellowfin tuna taken in each 5° square (dividing the estimated total catches in each area by the sizes of the fished zones). In the Atlantic, recent yellowfin productivity by 5° square was estimated to be at the lowest level observed world wide and showing a flat trend. On the opposite the yellowfin « productivity » in the other oceans have been permanently increasing (like the total catches)

Figure 12: Average catches of yellowfin taken by 5° square by each gear, purse seiners (upper figure) and longliners (lower figure)

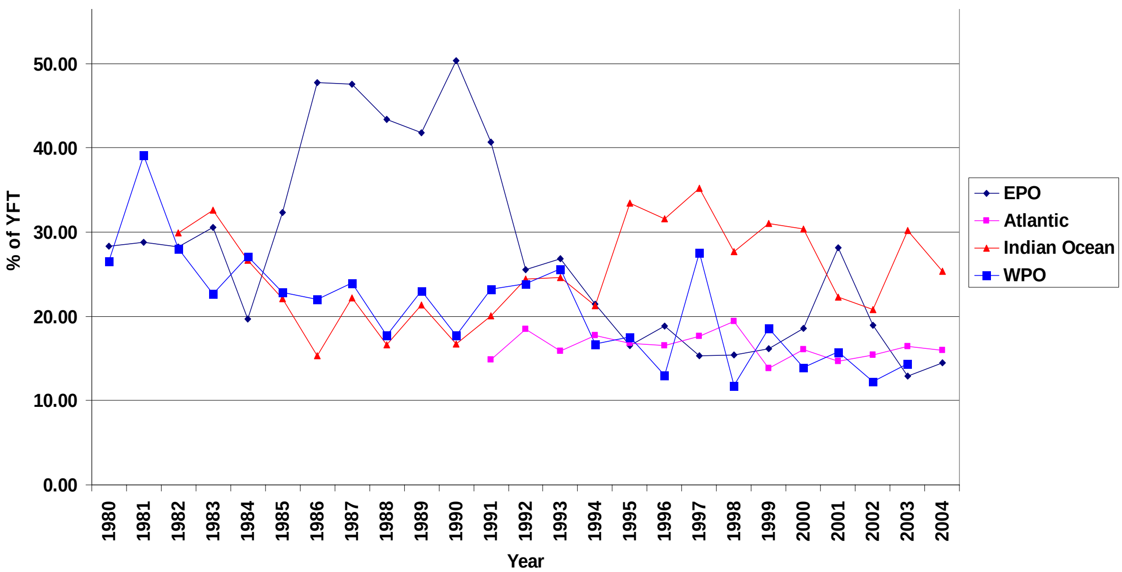


This figure shows the total yearly catches of yellowfin tuna taken by purse seiners in each 5° square fished (dividing the estimated total catches in each area by the sizes of the fished zones). This purse seine yellowfin « productivity » by average 5° areas is estimated to be quite similar during the last 20 years in the 4 « oceans », being a bit lower in the Western Pacific.

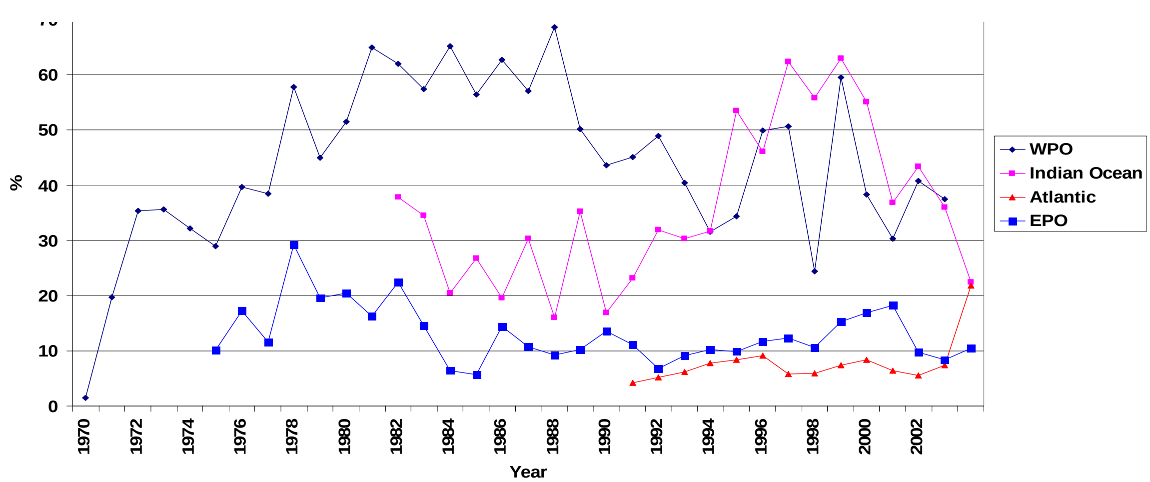


This figure shows the total yearly catches of yellowfin tuna taken by longliners in each 5° square (dividing the estimated total catches in each area by the sizes of the fished zones). During recent years, this longline yellowfin « productivity » by 5° areas is estimated to be larger in the Indian ocean than in the western Pacific, when the same « yellowfin productivity » by 5° square has always been at a flat and low level in the Atlantic and Eastern Pacific.

Figure 13: Yellowfin catches associated to FADs: % of yellowfin in the FAD associated catches (upper figure 13 a) , and contribution of yellowfin FAD associated catches in the yellowfin total catches by purse seiners (lower figure 13 b)

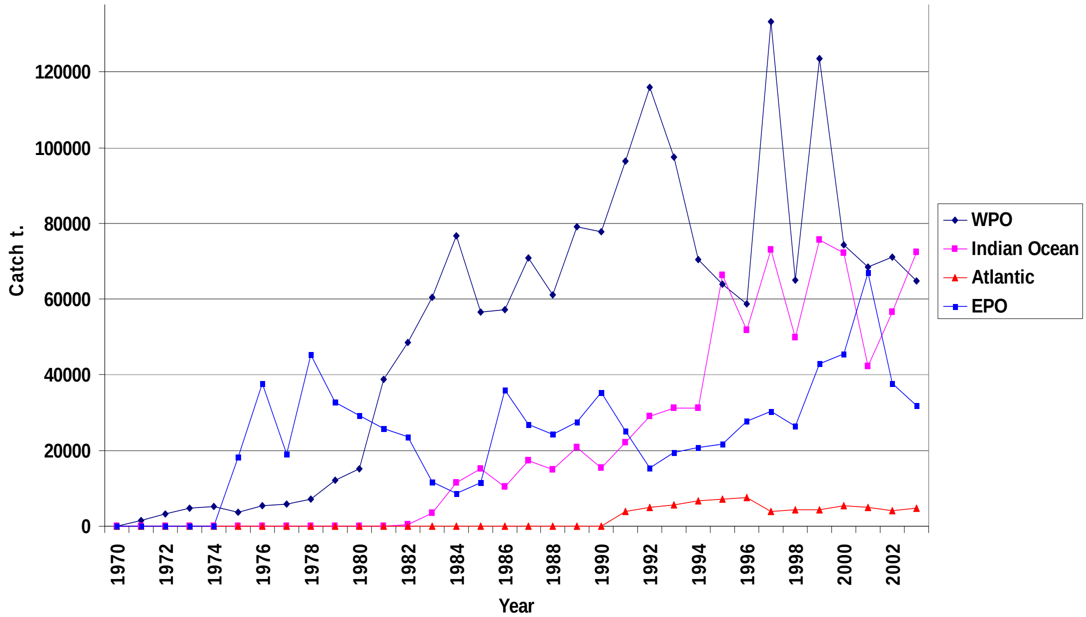


Yellowfin tuna proportion in the FAD associated catches is similar world wide in all oceans, about 15% of total FAD catches, the « anomaly » being the Indian Ocean, an area where since the mid nineties yellowfin is much more important in the FAD associated catches than in other oceans (in a range between 20 and 35% of the total catches by purse seiners).



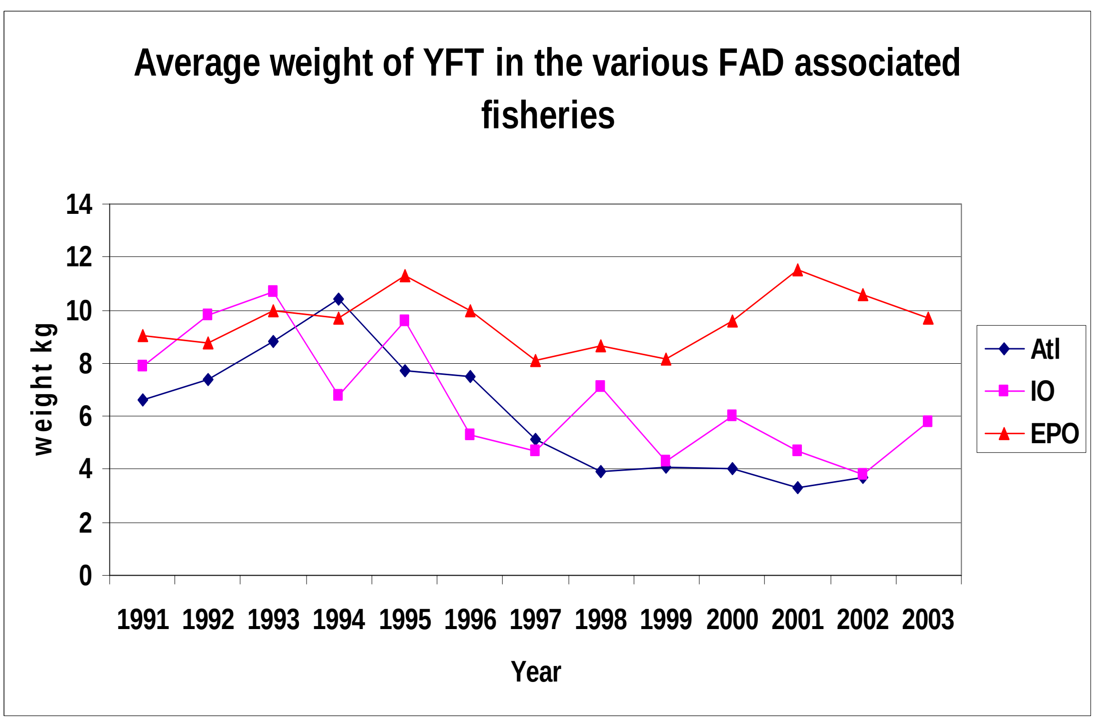
The contribution of FADs yellowfin catches to the total yellowfin catches by purse seiners has been and remains variable between oceans: a low percentage of yellowfin catches being taken on FADs in the Eastern Pacific and in the Atlantic, and as much larger proportion (about 40%, reaching 60% some years) in the Indian and Western Pacific oceans.

Figure 14: Total catches of yellowfin associated to FADs in the various PS fisheries



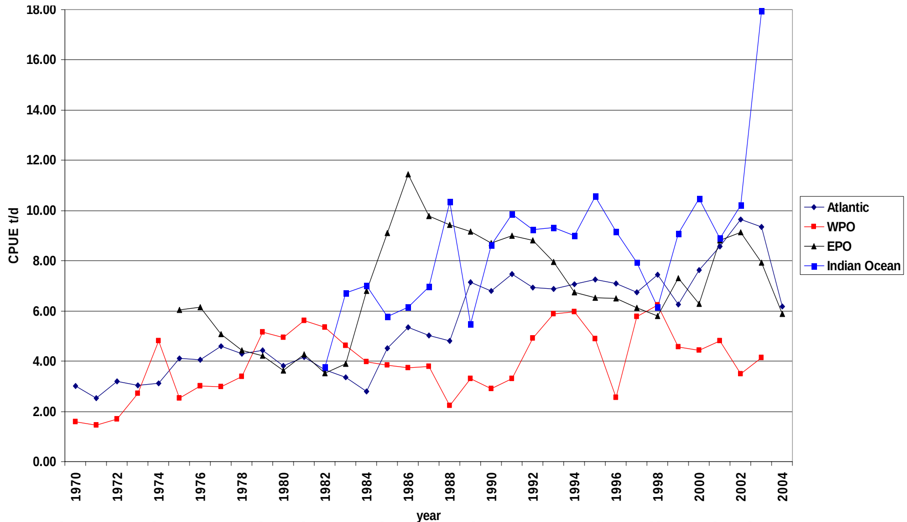
This figure shows the trend of total yellowfin catches estimated to be taken by purse seiners under FADs in each ocean (the Atlantic series being estimated only since 1991)

Figure 15: Average weigth of yellowfin taken by the various FAD fisheries



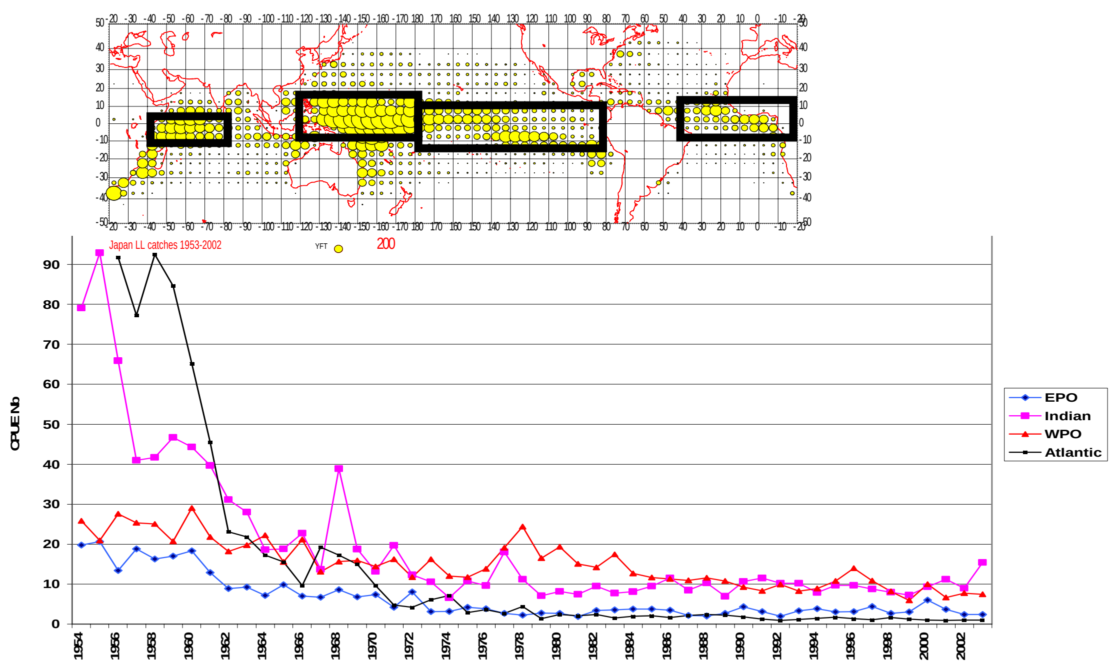
This figure shows the average weight of yellowfin taken under FADs by purse seiners in each ocean. These average weights tend to correspond to the catches of juveniles and small adults in variable proportion. These weights tend to be declining and low in the Atlantic and Indian oceans, and stable and quite higher (8 to 12 kg) in the Eastern Pacific

Figure 16: Nominal CPUE of yellowfin tuna in the various purse seine fisheries



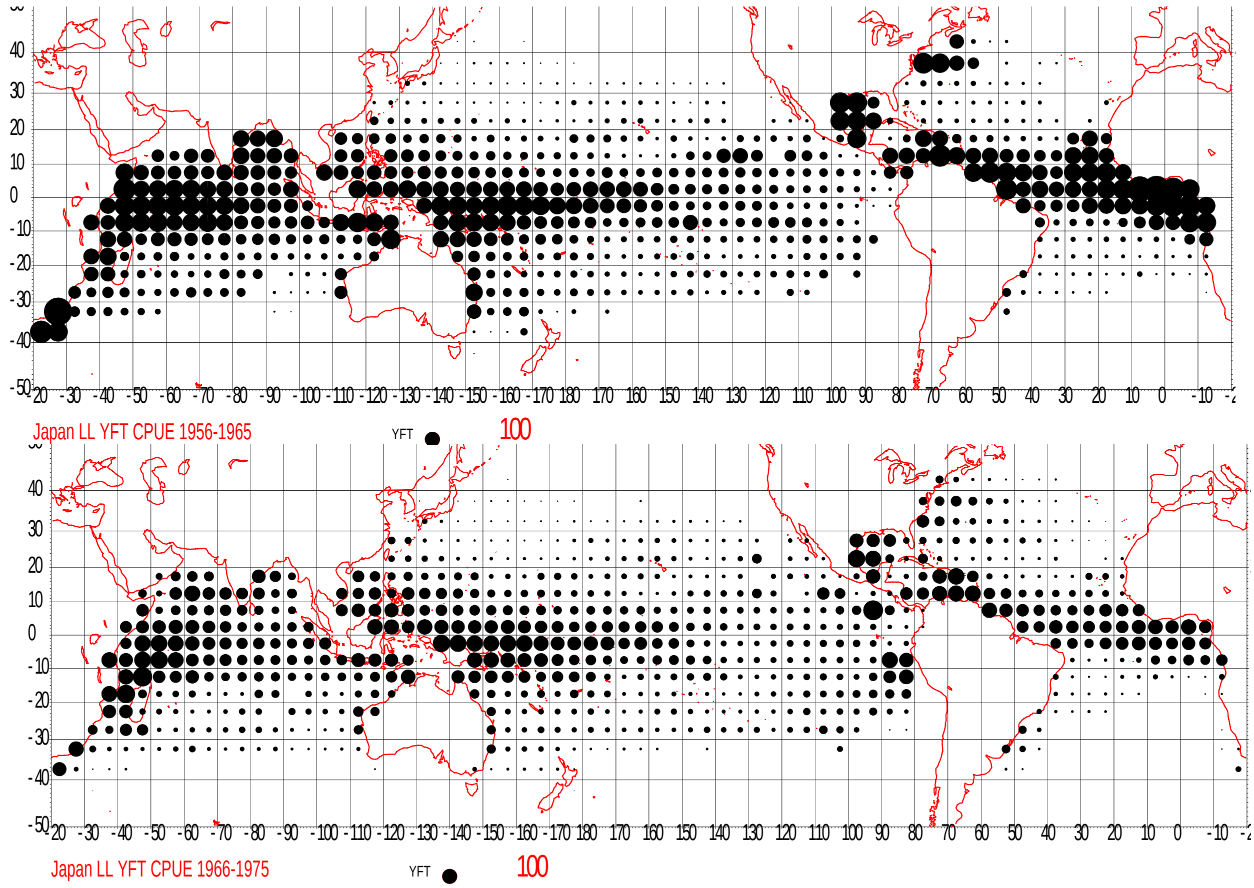
This figure shows the nominal yearly catch rates of yellowfin by purse seine fleets in each ocean; it shows that the higest CPUE have been observed during recent years in the Indian Ocean and the lowest in the Western Pacific, the CPUE in the Atlantic and Eastern PAcific being at similar levels. During this entire period, there is a clear increase of CPUE, probably in relation with increased fishing powers and fishing capacity of most purse seine fleets. 2003 CPUE in the Indian Ocean was at a record high level.

Figure 17: Nominal CPUE of yellowfin tuna in the various longline fisheries, as calculated in the core area of the yellowfin geographical distribution (Japan longliners)



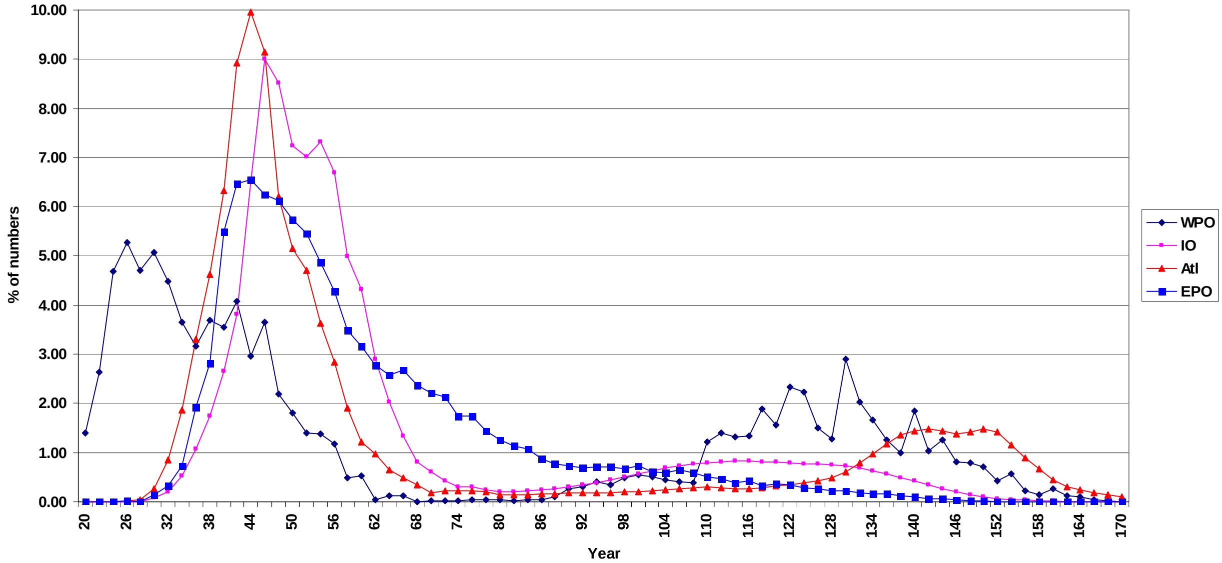
This figure shows the nominal Yellowfin CPUE of Japanese longliners in the 4 major equatorial fishing zones shown on the same page. The trends of the CPUE are very similar in the 4 oceans, with a major fast early decline followed by a flat trend. This early decline of CPUE has been observed at a lower degree in the Western equatorial Pacific, an area that was already more heavily exploited than other oceans in the early fifties.

Figure 18: Average yearly CPUEs of yellowfin for Japanese Longliners, by 5° squares, during the early period 1956-1965 and the subsequent 10 years period (1966-1975)



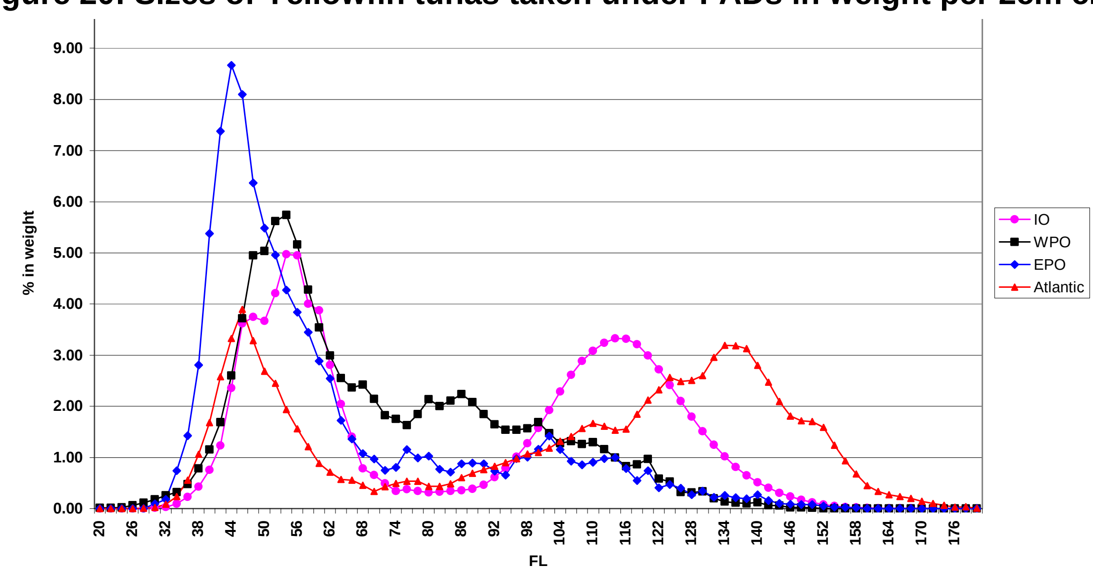
Maps showing the nominal average Yellowfin CPUE of Japanese longliners during two periods of 10 years (1956-65 and 1966-75) of their initial fishing activities (widely targeting yellowfin tuna in the early time of the longline fisheries). These maps show the areas where the highest CPUEs were observed at the beginning of the fisheries and the areas where the early declines were the more spectacular.

Figure 19: Yellowfin average sizes (in weight per 2cm classes) taken by PS fisheries in various oceans



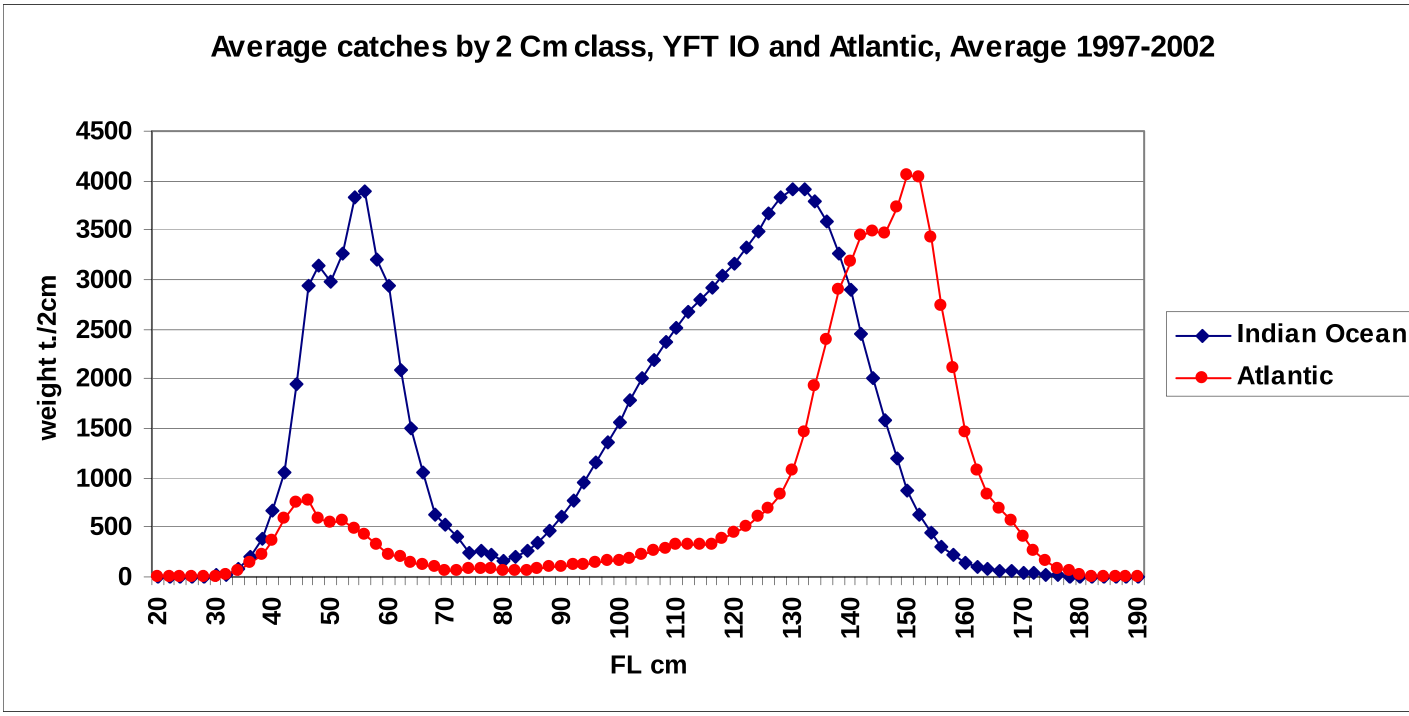
The average sizes of yellowfin taken by purse seiners are quite similar world wide; they are most often bimodal, catching juvenile and spawners, with an exception in the Easten Pacific where sizes taken are unimodal, and with a lower proportion of very large fishes taken. Large quantities of very small yellowfin are commonly caught by the PS fisheries in the Philippines (av. weight<1kg).

Figure 20: Sizes of Yellowfin tunas taken under FADs in weight per 2cm classes)



Sizes of yellowfin taken by purse seiners under FADs are similar world wide with a mixture of small and of medium-large yellowfin (very large fished being very seldom caught under FADs). These large yellowin tend to be quite rare in the Eastern Pacific, when very small yellowfin are seldom caught under FAds in the Western Pacific ocean.

Figure 21: Average sizes of yellowfin tuna taken by purse seiners in the Atlantic and in the Indian oceans (in weight per 2cm classes)



Both fisheries show the curious and typical bimodality of their size structure:

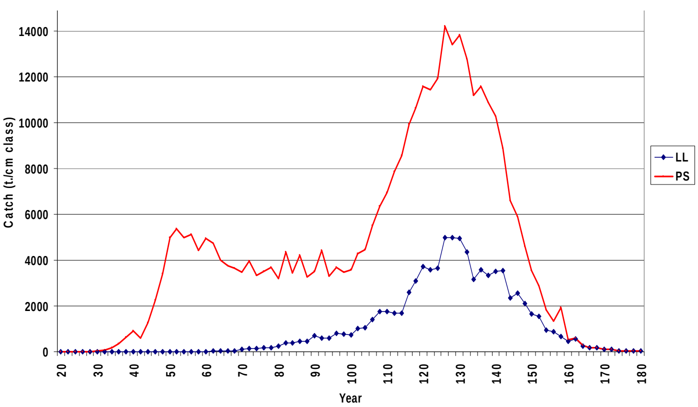
➢*Modes of small fishes do show the same size selectivity with recruitment taking place at about 50cm with a typical mode in a range between 45 and 65 cm*

➢*In both oceans, medium size yellowfin are seldom caugth by purse seine fisheries. Various additive reasons can explain this lack of medium size fishes, among others: (1) fast growth of these fishes (if yellowfin are growing slowly at small sizes and later accelerating their growth between 65 and 95 cm, then these fishes are obvioulsy less abundant in the stock than fishes at smaller sizes), (2) migration of medium sizes yellowfin outside the main fishing zones, (3) low catchability of medium fishes (because they tend to be less schooling and more mobile than smaller and larger yellowfin).*

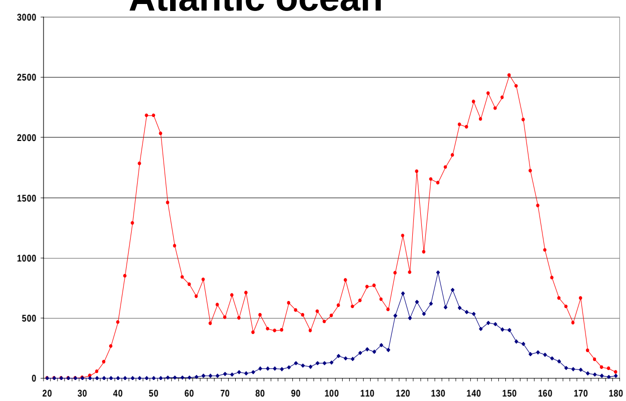
➢*Modes of large fishes tend to be unimodal in both oceans, the Atlantic yellowfin being much larger (mode at 150 cm) than in the Indian Ocean (mode at 125 cm). The reasons explaining such basic difference have not been clearly identified by the scientists.*

Figure 22: Average sizes of yellowfin tuna taken by purse seiners and by longliners in each ocean (recent 5 or 10 years), in weight.

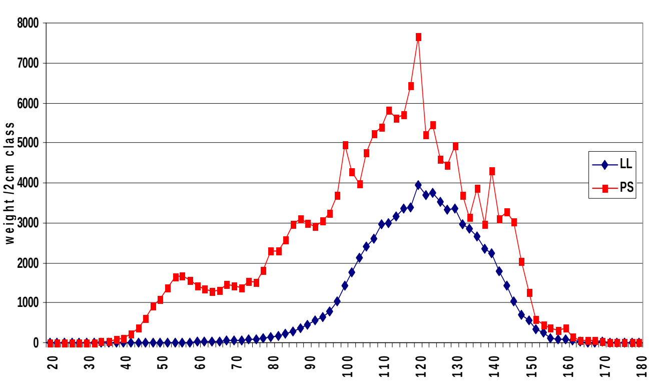
Indian ocean



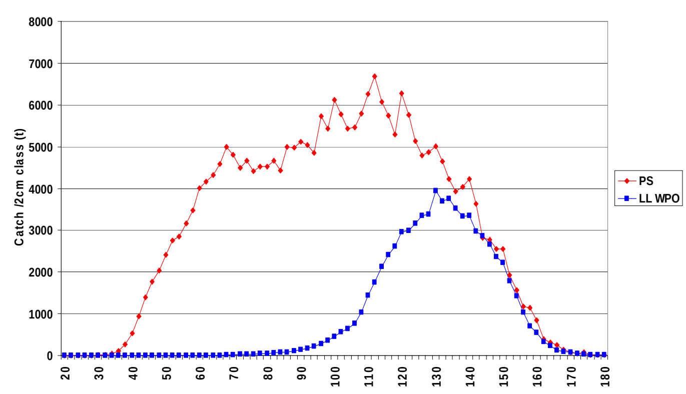
Atlantic ocean



Western Pacific

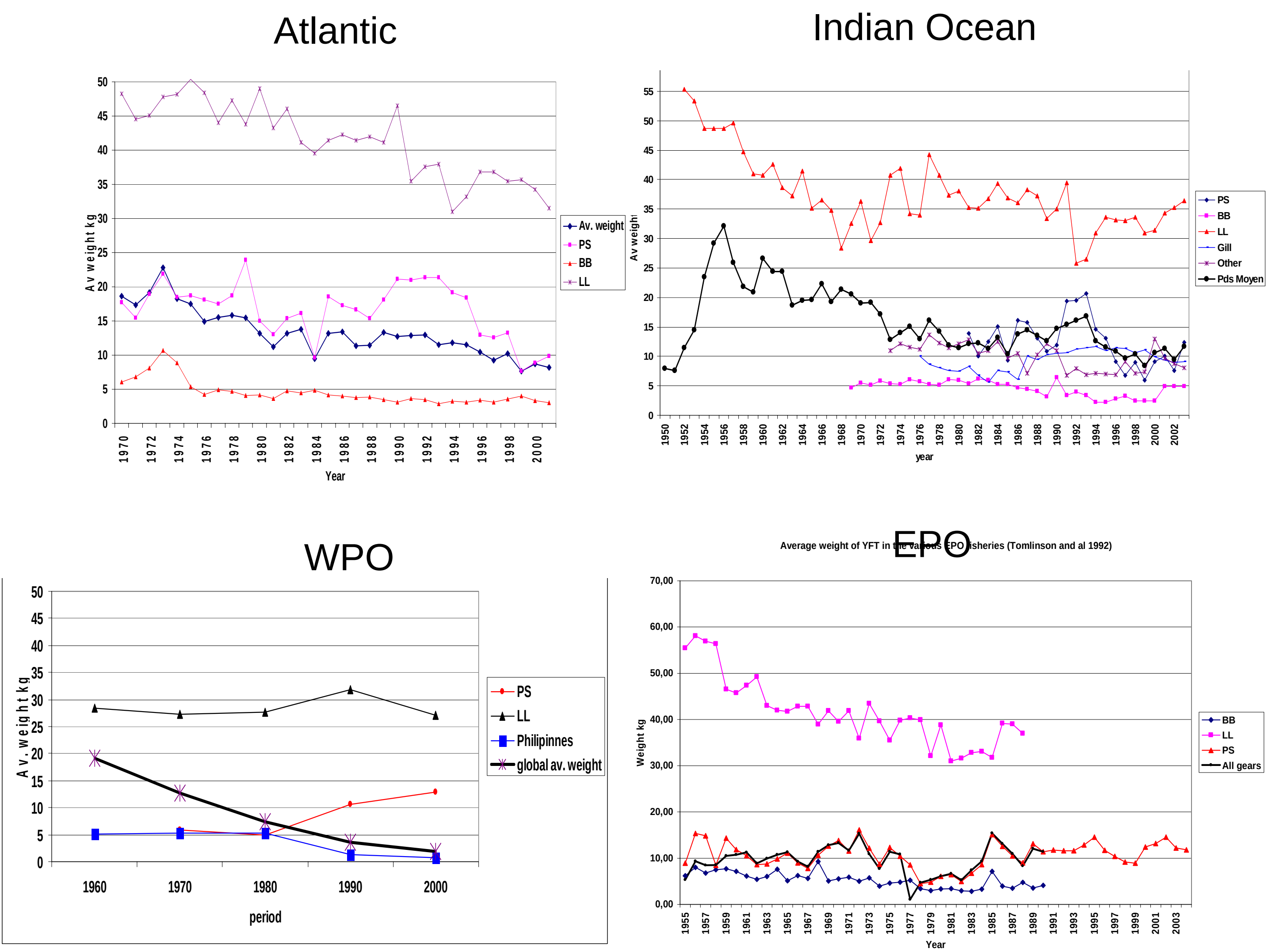


Eastern Pacific



This figure shows that the size patterns are quite similar in the various oceans:
-> Sizes taken in the Atlantic being larger for both gears, and especially for purse seiners where the modal sizes of large fishes are at 150 cm (in weight and only at 130 cm for the Indian Ocean).
-> Catches of very small yellowfin tend to be lower in the Indian Ocean than in in the Atlantic.
-> Minimal and maximum sizes taken by the two gears are the same in each fishing zone.

Figure 23: Average weight of yellowfin taken in each ocean by each gear and by the combined fisheries

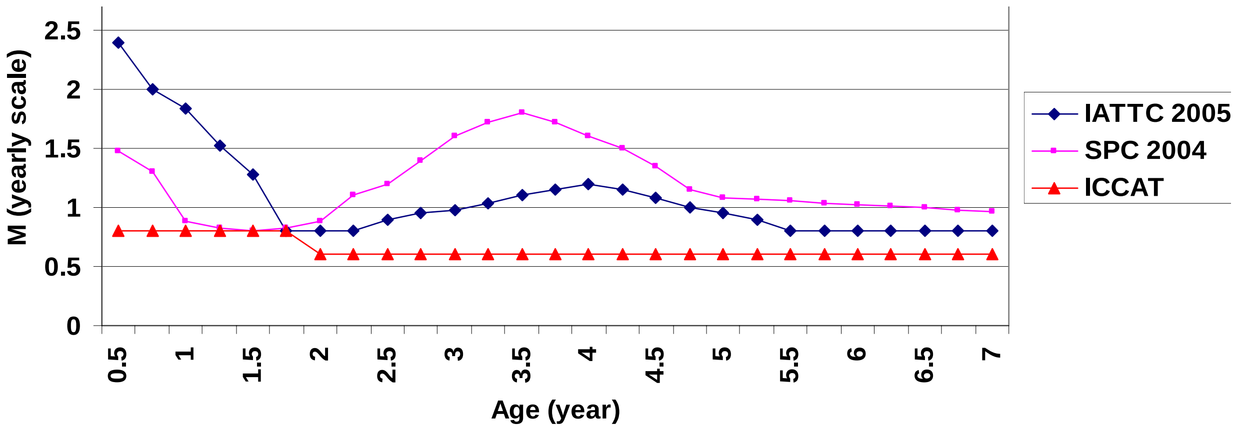


These average weights show, worldwide, a clear and significant decline, on one side for the longliners catching large fishes (especially during their early historical phase), and on the other side for the yellowfin fisheries as a whole combining all gears. This decline of the average weight is at least indirectly in relation with the increasing fishing pressure exerted on most of these stocks. The Eastern Pacific has been the only area with stable weight caught during the entire fishery (dminated by purse seine catches)

Such average figures of yearly weights are clearly interesting basic indices that should always be made available to both scientists and managers of tuna stocks, but unfortunately they remain quite difficult to obtain in many areas

Biological parameters:

Figure 24: Natural mortality recently estimated for yellowfin tuna in each ocean



The ICCAT vector of M at age, also used by the IOTC, was chosen 30 years ago by the ICCAT SCRS, as being the best scientific working hypothesis used to run the first ICCAT VPA. Its level was chosen independently of any real biological base, and without being based on tagging recovery results.

Since that historical time, the multiple results obtained from tagging have produced for yellowfin good statistical estimates of M at age in a wide range of sizes. It should be kept in mind that the present estimates of Mi by these statistical models remains quite weak, as it was well demonstrated by a 2004 sensivity analysis (Labelle 2004)

Furthermore, the progress in the knowledge of the underlying « biological laws » of natural mortality of fishes as a function of their age have been widely progressing, allowing to easily demonstrate that a very small yellowfin of 1/2kg should suffer a much higher M than a fish of 6 kg (Hampton 2000, Fonteneau and Pallares 2004) when this constant M is accepted in the ICCAT Mi).(keeping in mind the good point that these very small yellowfin are seldom caught in the Indian Ocean)

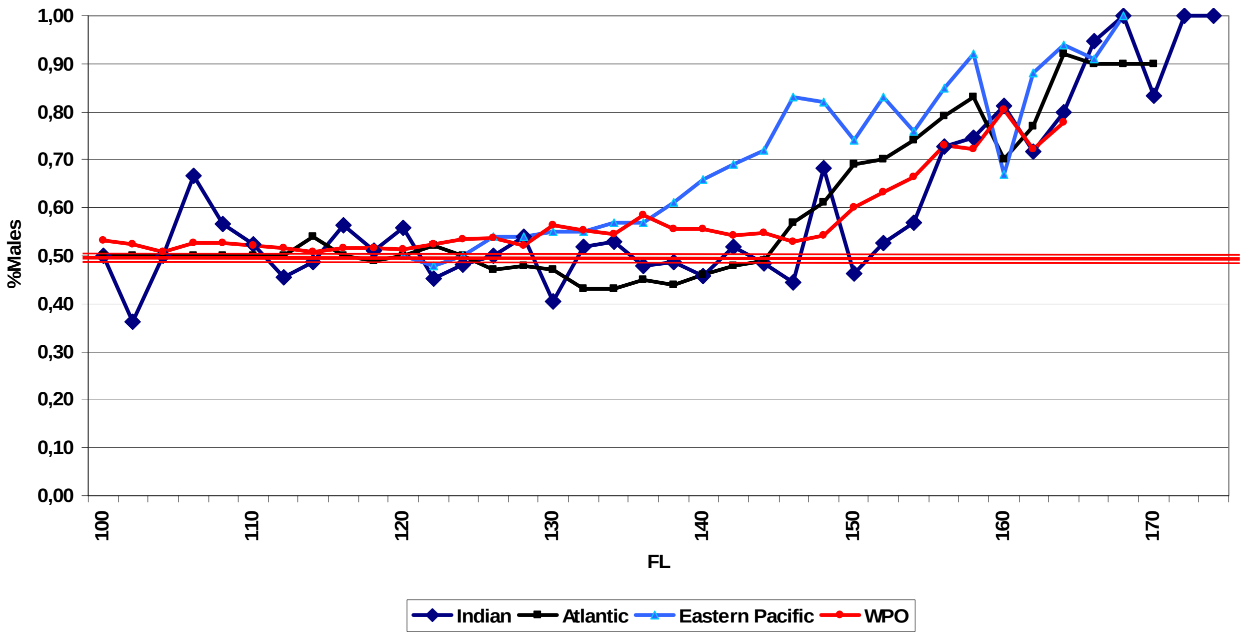
*The estimates of Mi presently obtained by the SPC and the IATTC and used in their stock assessment are very different from the ICCAT « guessed Mi »: the ICCAT average level of Mi **(0.64)** is much lower than in the Eastern (1.09) (Hoyle and Maunder 2005) and Western Pacific (1.20) (Hampton et al. 2004)*

The greatest differences are observed at small sizes, for instance for yellowfin less than 1 year , young ages for which Mi is estimated to be 2.74 times higher in the Western Pacific, and 75% higher in the Eastern Pacific. Furthermore, the fishery data and the lack of clear interaction between the large scale Philipinnes fisheries (average weiht=800g) and the traditional longline and purse seine fisheries confirm the universal biological rule that M is probably much higher at these very small ages and sizes.

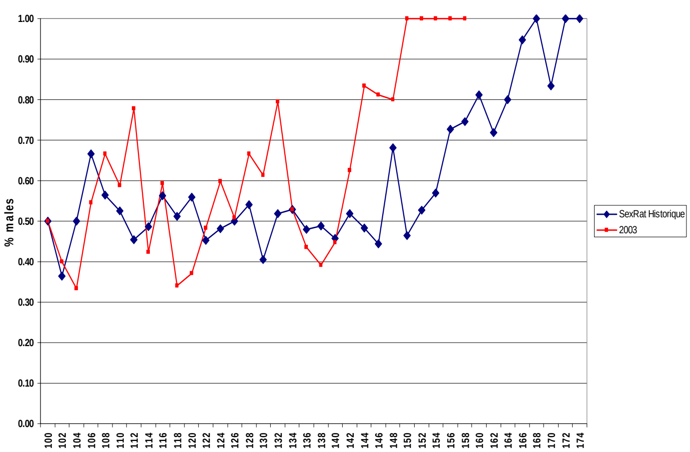
Both the IATTC and the SPC Mi show a peak of M at medium sizes corresponding to spawning (spawning at about 90 cm); such higher M would explain the low frequency of females at large sizes in most yellowfin fisheries.

However, there is a serious concern for various tuna biologists that the high average Mi estimated in the Pacific Ocean could be far to high for a large tuna as YFT (as an adult yellowfin is far to be an anchovy, being a large fish with few predators and high survival potential in pelagic ecosystems).

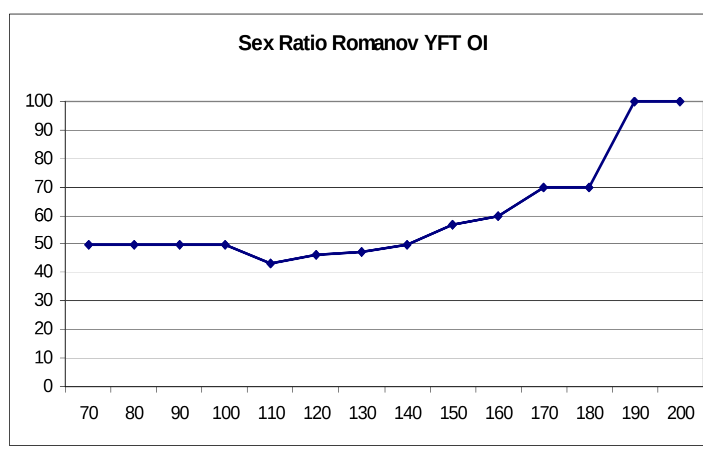
Figure 25: Average sex ratio at size of yellowfin observed on purse seiners in various fisheries and oceans



The proportion of the two sexes as a function of fish length sizes appears to be very similar in every ocean (Schaefer 1998, Albaret 1976, Williams com.pers., Hassani and Stequert 1991)
Sex ratio at size of yellowfin shows a similar identical percentages of males and females at sizes lower than 1.35 m. Males are increasigly dominant at sizes greater than 1,40m, reaching levels close or over 80% of males at 1,60 m in every oceans.

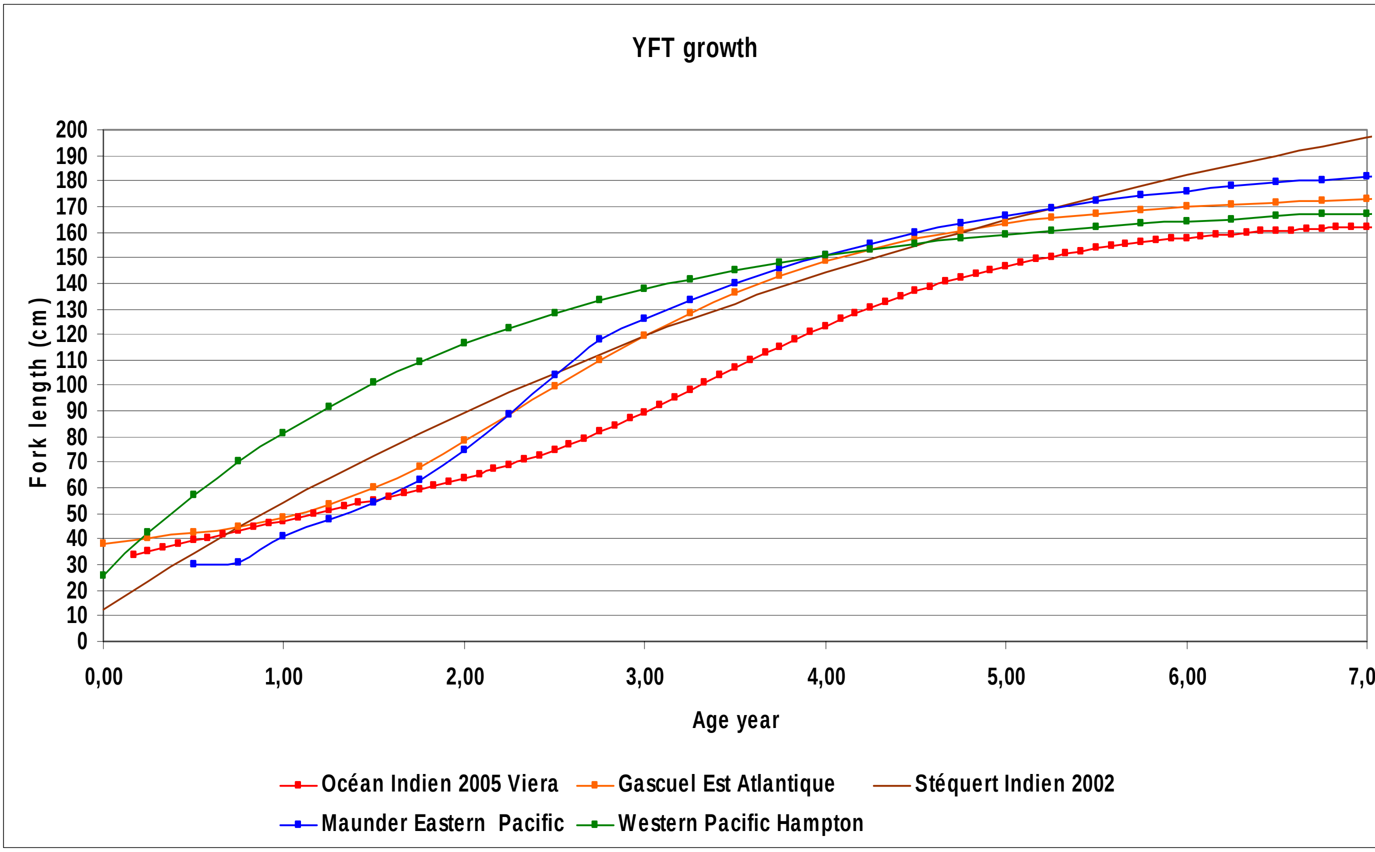


Recent sex ratio sampling conducted in Seychelles by IRD could indicate that the inversion of sex in the catches could nowadays take place at smaller sizes than before: starting at 1,30m and reaching 100% of males at 150 cm.



Historical sex ratio at size collected by Timochina and Romanov 1992 were similar to the Hassani and Stequert 1991 data (left figure). This Romanov sample was obtained on very large yellowfin (over 1,80m)taken by longliners.

Figure 26: Comparison between the various growth models used in each area for yellowfin.

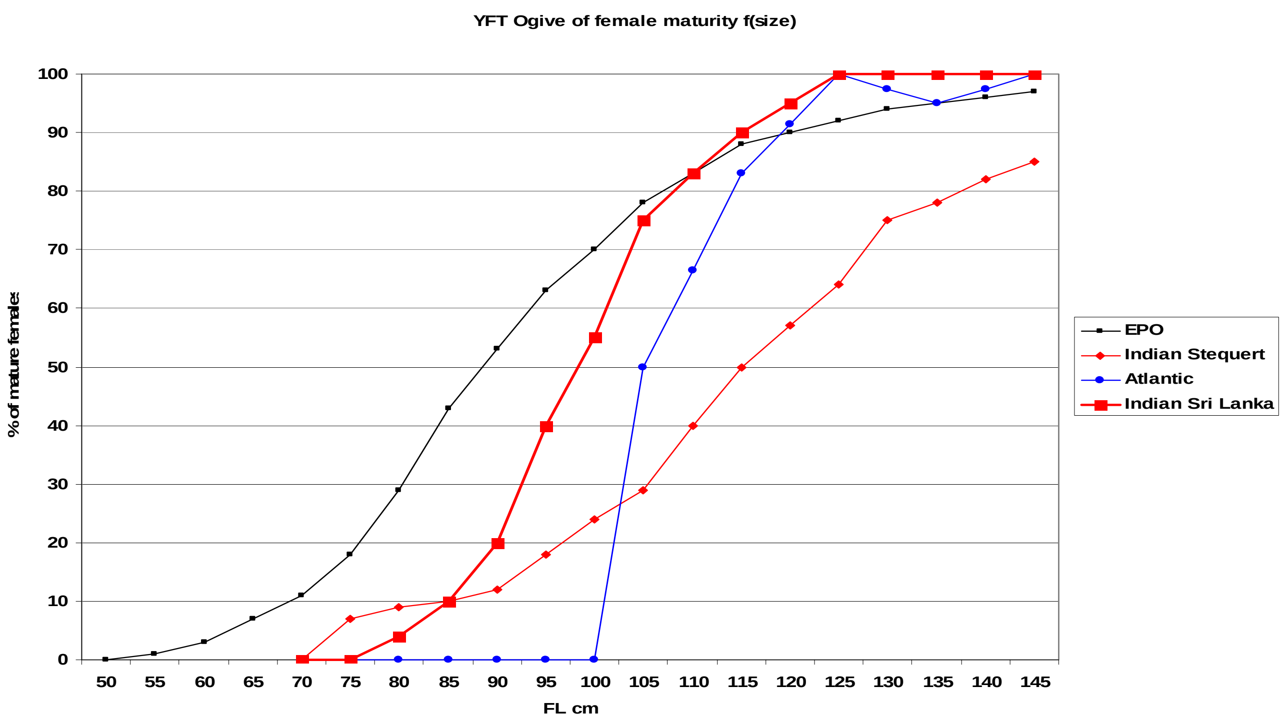


Yellowfin growth has been studied by various methods in each ocean: modal progressions, age readings and appaprent growth of tagged/recovered fishes. The estimated growth in each ocean are quite different, especially the juvenile stages, which may be showing a slow or a fast growth depending on areas and methods used in growth analysis. A two stanza growth model (Nedler or Gascuel et al 1992) seems to be more realistic, being well supported by ecological factors and by multiple sources of data (and knowing that yellowfin recruited at 30 or 40 cm are very young fishes with an absolute age <6 months). Growth rates of medium size fishes (larger than 60 cm) tend to be very similar in most models (Figure taken from Viera 2005). Growth estimated from recoveries of tagged fishes tend to be slower than growth estimated form age readings (Hampton and al 2004)

The potential differential growth between males and females remains a pending question: such differencial growth has never been shown by age reading presently done, but the possibility that male yellowfin would have a larger asymptotic size than females remains an open hypothesis. The best way to solve this basic uncertainty would be to obtain the information of sex on all the large yellowfin tagged and recovered.

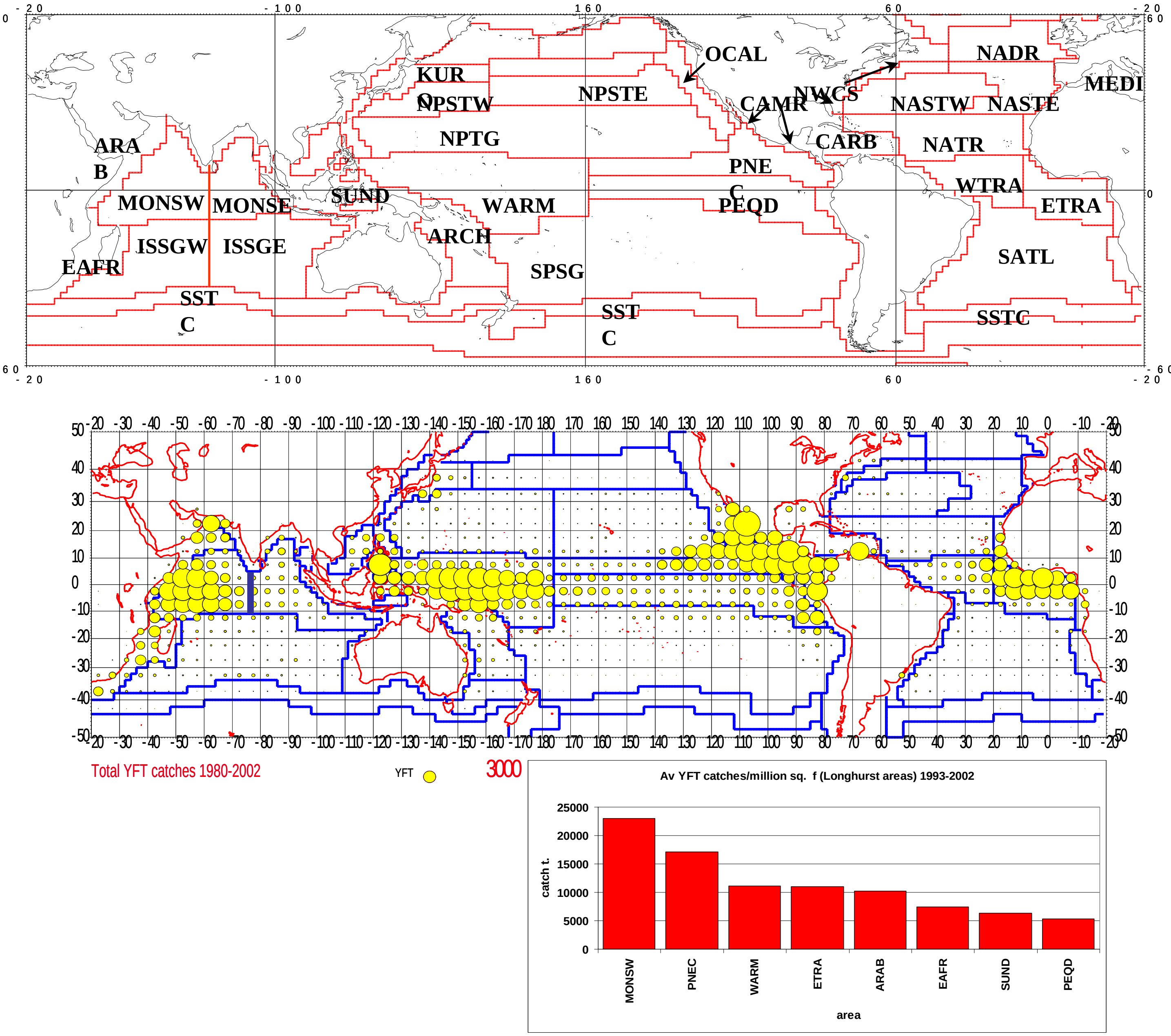
Spawning:

Figure 27: Sizes at 1st spawning estimated for yellowfin in various oceans



First spawning of yellowfin appears to significantly (50% of mature females) take place in every ocean at sizes smaller than one meter, e.g. at ages between 2 and 3 years. The observation by Hassani and Stequert 1991 showing a late spawning at sizes over 1,15 m and a limited sexual activity of females over 1,20m in the Indian Ocean are probably biased (compared to other studies, especially the Sri Lankan study by ????) .

Figure 28: Yellowfin tuna and Longhurst ecobiological areas

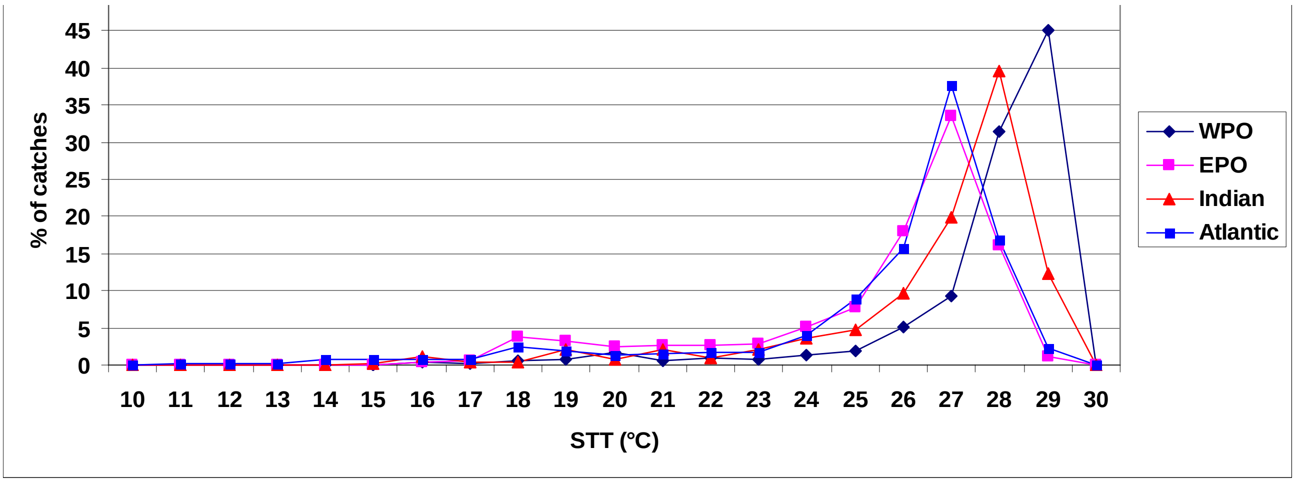


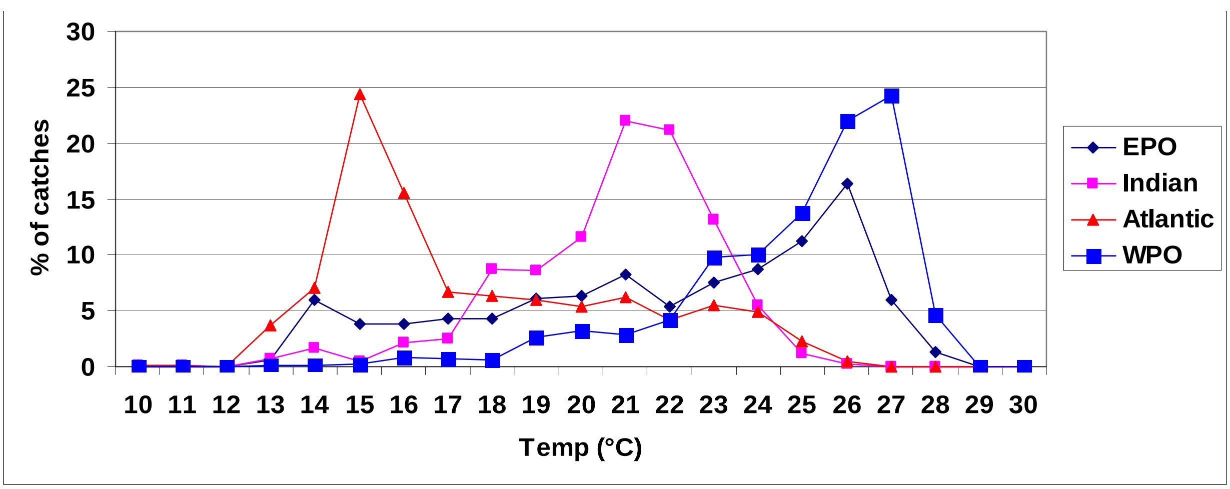
Yellowfin tunas are primarily caught in warm equatorial ecosystems

The estimated average catches of yellowfin per unit area (millions nautic. Square, period 1993-2002) are the highest in:

1) *the Western Indian Ocean Monsoon area (possibly overestimated),*
2) *the Eastern Pacific Equatorial Divergence ,*
3) *the warm Pool and the Eastern tropical Atlantic*
4) *the Arabian sea.*

Figure 29: Yellowfin catches taken in each ocean by longliners (period 1993-2002) as a function of average sea surface temperature (upper figure) and of temperature at 100m depth, the fishing depth estimated for regular longlining (lower figure).

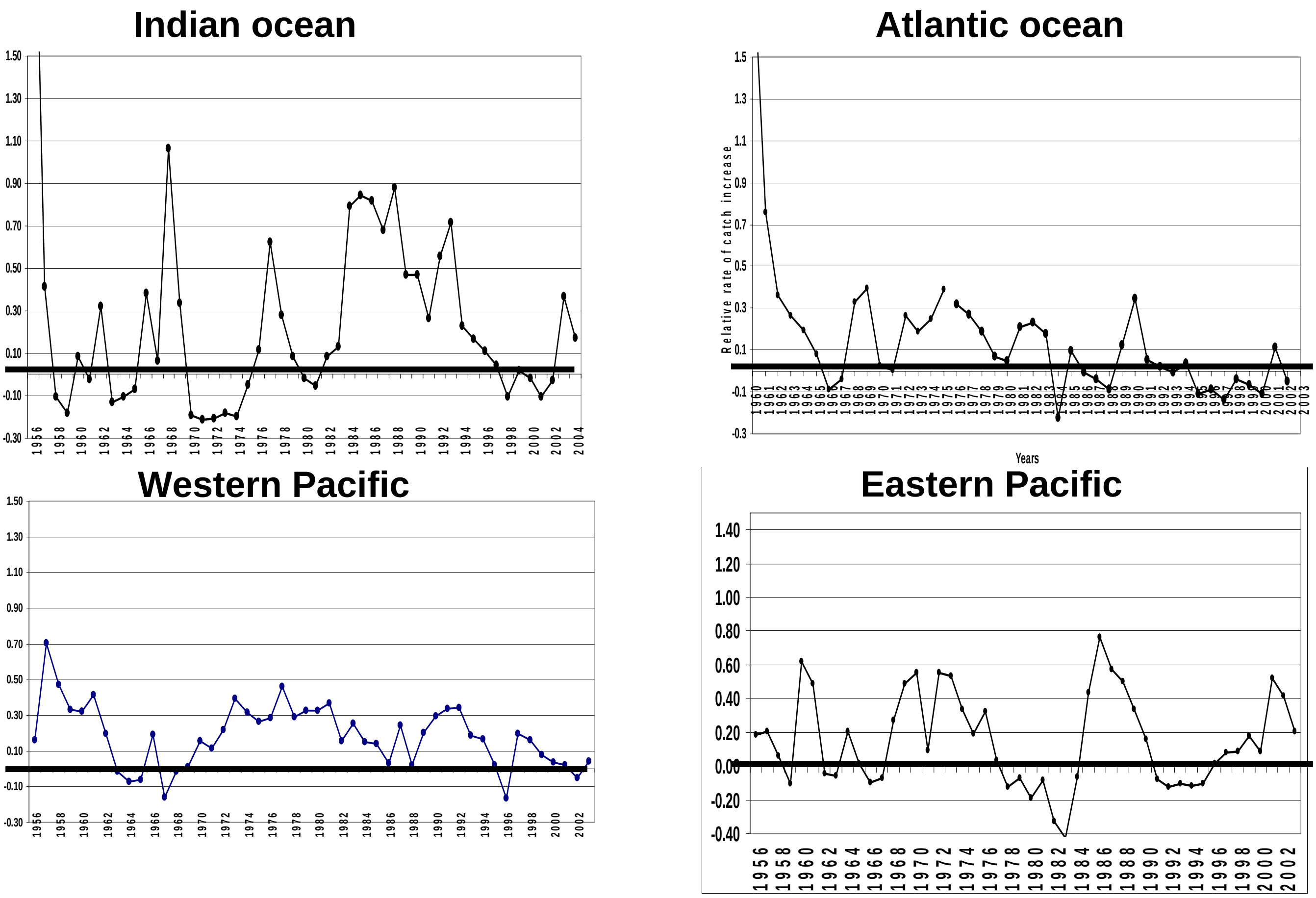




Most yellowfin are caught world wide in oceanographical conditions showing warm sea surface temperatures (only 6% of total yellowfin catches being taken associated to SST <20°C)

Patterns of yellowfin catches as a function of SST are very similar in the various oceans. However, the patterns of water temperature at a 100m depth (approximately the average depth at which regular longlines are operating) in the fishing zones where yellowfin are caught by longliners are quite different between oceans: depth at 100 m being widely over 22° in the Pacific, colder in the Indian ocean and much colder in the Atlantic ocean.

Figure 30: Analysis of total catches trends by the Grainger & Garcia index,



➢*This simple index putting in relation relative change in the total catches versus total catches taken during the 6 previous years (approximate duration of exploitated life of yellowfin) are very easily calculated. When fishing efforts are permanently increasing (this was most often the case for yellowfin fisheries) and when total catches are well known, the trend and level of such a simple index tend to indicate the stock status, as several consecutive years of negative indices tend to correspond to overfished stocks (increasing efforts producing stable or declining catches).*

✓*negative indices may be partly due to stock management measures (eastern Pacific) or to a decline in the effective fishing effort (Atlantic during recent years?)*

✓*positive indices may correspond to an effort in excess of MFY effort (following an effort increasing very quickly), this bias being worse for a long living species with large accumulated biomass. This potential bias tends to be worse when a fishery catching juveniles was developped, allowing to reduce yield per recruit, but only after several years and after a period equal to the life term of the exploited species.*

➢*These simple indices provide interesting results for the four yellowfin stocks, keeping in mind that the interpretation of such simple index should be precautionary as:*

➢*Such a basic simple index based on catch trends should always be given and precautionarily discussed by scientists in comparison with the results of more complex models.*

Yellowfin stock assessment problems and uncertainties in the yellowfin stock status

Production models: yellowfin stock status tend to be easily and well estimated by **simple production models** (preferrably exponential models for tuna stocks) when there is a good measure of the effective effort exerted on the stock (Eastern Pacific: Schaefer, Tomlinson, Atlantic: ICCAT SCRS reports).

Most of these assessments of yellowfin stocks have **underestimated the real potential catches** during the early phases of the fisheries, when only a given fraction of the stocks were exploited. This problem was easily and well explained by increases in fishing zones (Die and al 1990, Laloe 1989) in relation with the structural viscosity (Mac Call) that is now increasingly accepted for most tuna stocks. Although yellowfin is clearly an highly migratory species, most of its movement patterns are probably limmited in their geographical scales and distances covered by the fishes.

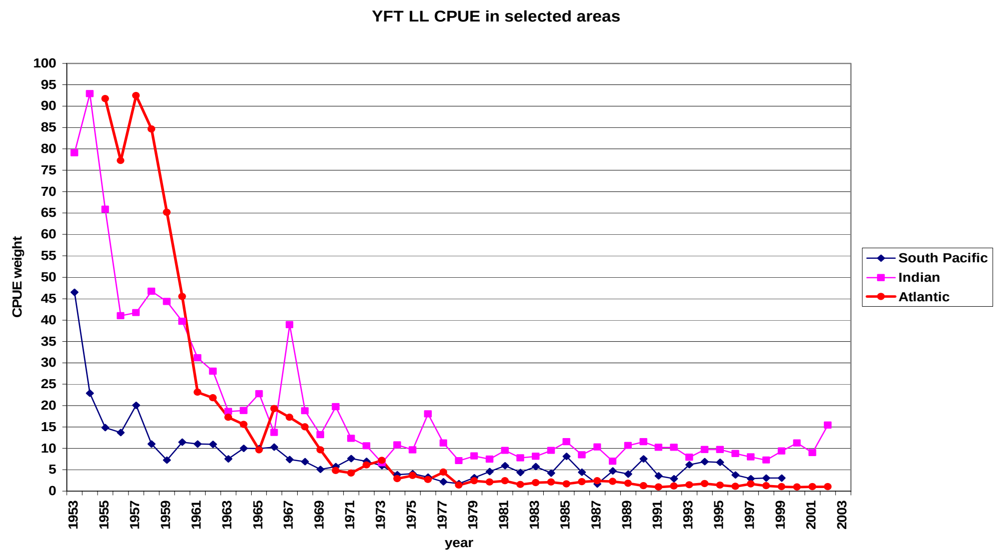
Sequential Population Analysis have also been widely used (under various models and hypothesis) for many years for various yellowfin stocks and with consistent results: in the Eastern Pacific (Tomlinson), in the Atlantic and in the Indian Ocean. They need a good catch at age table (then good statistics at size and good knowledge of growth), good biological data (natural mortality at age). They also face the same potential geographical bias as production models in their handling. The analysis of past performances of these SPA done by Fonteneau et al. 1996 have concluded that many of these analysis tend to evaluate, not the real sizes of the stock, but only their « minimal » levels at the given time of the analysis.

Statistical models (A-SCALA and MF-CL) have been successfully used used during recent years by the IATTC and the SPC scientists. Their results tend to incorporate all the data and knowledge upon fishes and fisheries, but their results are facing most of the difficulties of other simple models, see thereafter. The real uncertaities in their results remain quite wide, probably much larger than estimated by the models (as many of the real uncertainties are not incorporated in these models). These models probably face the same difficulty that they may tend to estimate only the minimal stocks at a given time, and not necessarily the real stock sizes.

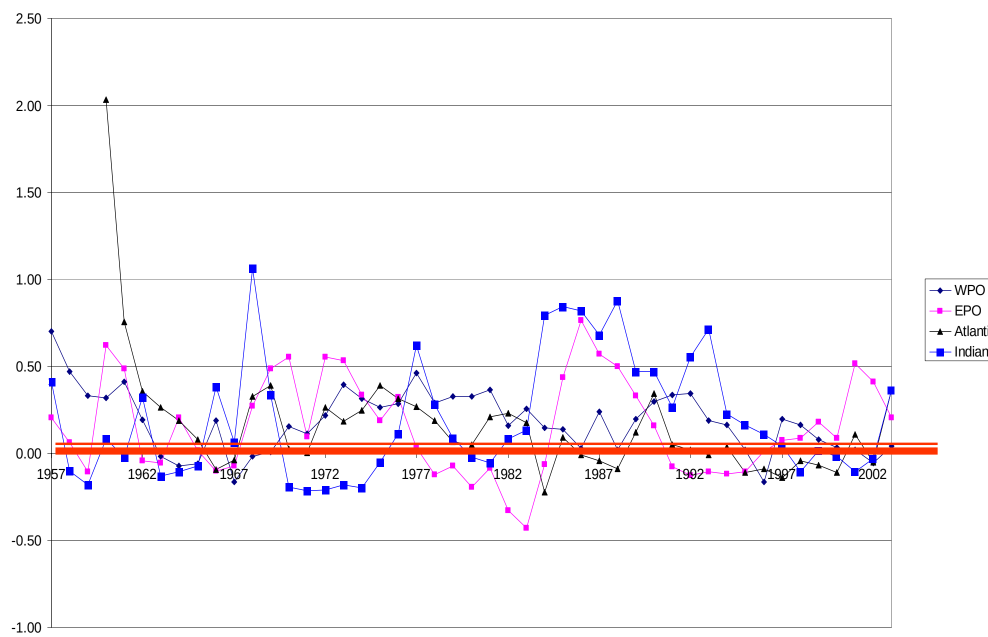
Projections: All the assessment models, global, SPA or analytical, being based on the backward analysis of past fishery data, have been facing major multiple difficulties in their projections. These difficulties are structural (cf Kirkegaard: « **Life can only be understood backwards, but it must be lived forwards** »), but they are also worsened by the fact that the estimates obtained during the most recent years, tend to be the most uncertain, while population sizes and fishing mortality during these recent years play the major role in all the projections (added, of course, to all the biological and fisheries forward uncertainties)

Stock status: early diagnosis obtained from simple basic indicators?

LL **CPU**E trends?



Catch trends
& Grainger-Garcia
index?



Average weight taken
by combined fisheries?

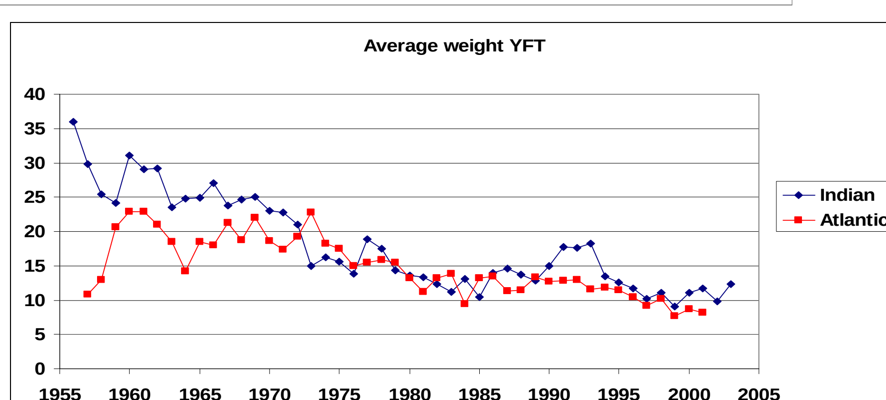
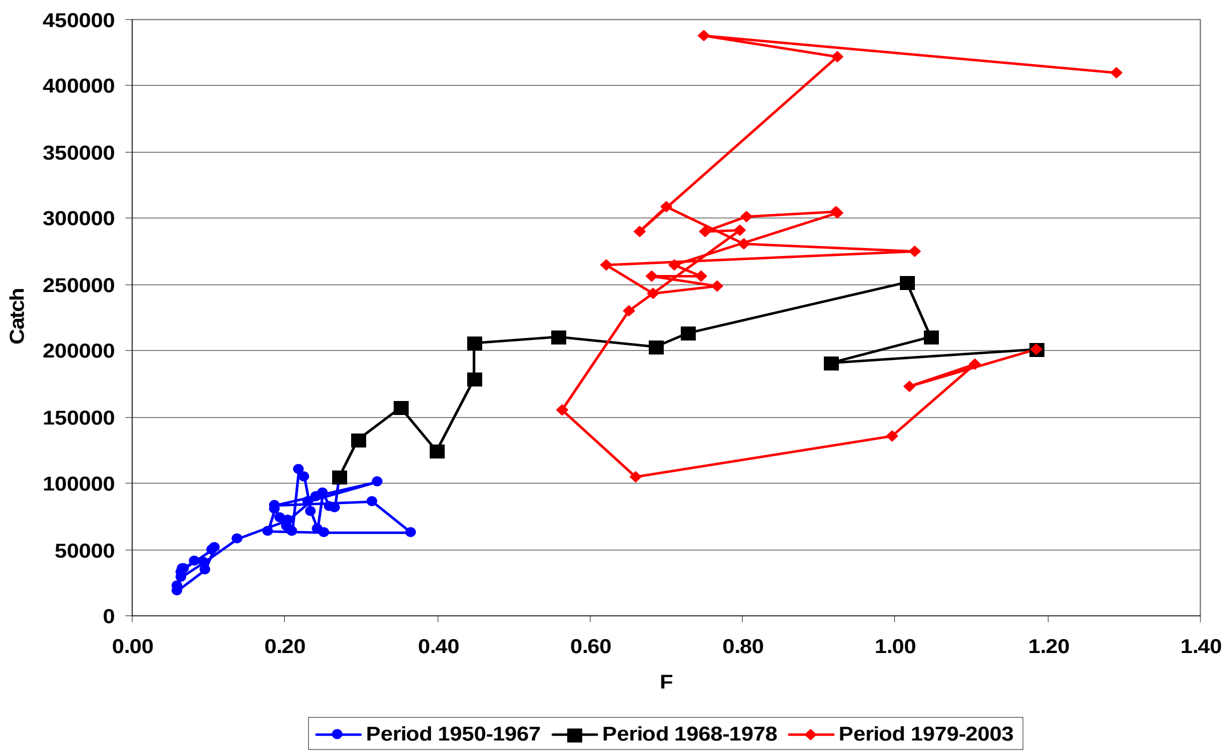


Figure 31: An overview of catch and effort relationship for the yellowfin stock exploited in the Eastern Pacific

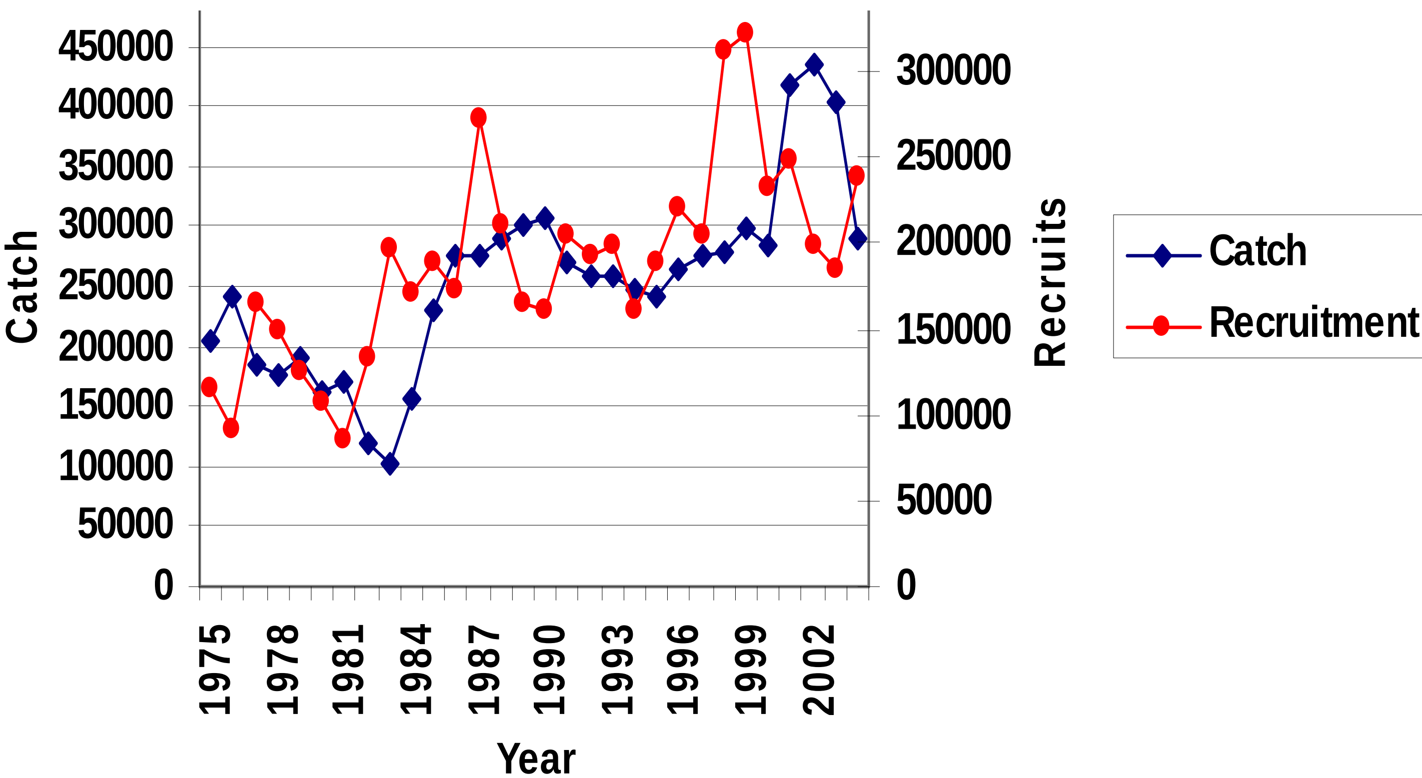


The relationship between total yellowfin catches and estimated fishing mortality (obtained by the A-SCALA model) n the Eastern Pacific tend to show, as in most other oceans, increased levels of catches with moderate or no increase of « apparent » fishing effort or estimated fishing mortality..

Such an increase is probably the consequence of a combination of factors, mainly changes in the size of fishing zone, change in gear technology and gain in efficiency, changes in the environment and in recruitment levels.

In the absence of direct estimates of stock size that could be obtained by scientists independently of fisheries data, it remains very difficult to exactly measure the relative contribution of each of these factors in the observed gain of stock productivity and increasing MSY.

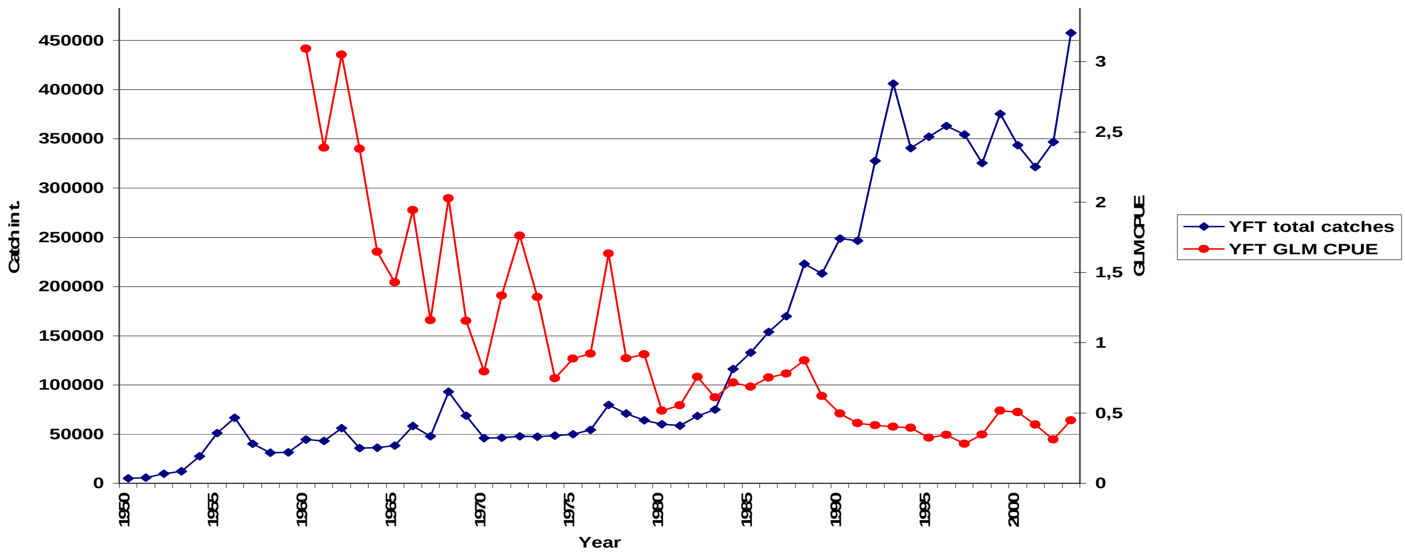
Figure 32: Yearly catches and yearly levels of recruitment estimated (by A-ASCALA) for the Eastern Pacific stock of yellowfin



*This figure shows that the estimated recruitments tend to increase as a function of total catches. This may be a real biological phenomenon of increased recruitment, but this type of analytical bias has been often observed for many sequential population analysis or SPA (cf Fonteneau and al 1996). In this type of problem, the model tend to estimate that at the beginning of the fishery, a period of very low catches, the level of recruitments was very low (and with a very low virgin biomass, as in this « SPA syndrom », **no catch means no biomass**). The same problem could also be faced for a fishery where the effort and catches have been declining for economical reasons: in such a case this « SPA syndrom » will tend to estimate that recruitments have been constantly declining as a function of declining total catches. This type of bias, typical of many stock assessmeent methods, has been commonly observed for tuna and billfish stocks because these assessment are driven de facto by the fishery data (and mainly by the levels of total catches), when in most other coastal stocks assessments, the biomass trends are controlled by scientific results (research boats, never used for tuna stock assessments)*

A strange lack of visible interactions between most yellowfin surface and longline fisheries? The Indian Ocean exemple

Figure 33: Yearly total catches of yellowfin tuna in the Indian ocean and trend of the GLM indice estimated on the Japanese longline fishery in the same area



(1) **Longline CPUE and catch trends**: An observation done for all yellowfin stocks: the early decline of longline CPUE has been observed during periods of low total catches, followed by period of quite stable CPUE when catches have been rocketing to high levels. This figure showing the Indian ocean exemple is typical of situations observed world wide. The lack of decline of adult stock fished by longliners remains strange for various additive reasons:

- It was concluded in 1979 by the Shimizu WG experts (Miyake and Suzuki), based on longline data fr*om the Indian Ocean*, than the fishery was alreading reaching its MSY at about 40000t
- The much larger catches that have been taken later by various surface fisheries, and at much smaller sizes, should have reduced the Yield /recruit of the stock, but they simply increased its MSY, without reducing the longline CPUE(again, the opposite was expected by scientists in 1979)

(2) There is a **lack or recoveries** of surface tagged yellowfin by longliners in the world yellowfin fisheries (Suzuki 1996, Fonteneau 1996): most or all quantitative analysis of yellowfin recoveries tend to conclude that these recoveries are much less abundant in the longline fisheries than expected based upon their total catches of adult yellowfin. This low rate may be due to a poor reporting of tags by these fleets, but the recovery rates seem to be much better for other tuna species taken by the same longline fleets.

This problem is of major importance in most stock assessment done worldwide on yellowfin stocks: such basic uncertainties may hamper many of the results and projections of present models, unless this structural uncertainty be corrected.

An overview of major difficulties and uncertainties faced in most/all yellowfin assessments:

- Behaviour and **trends of yellowfin LL CPUEs** and their relationship with adult stock biomass? It has been concluded that in the long run, the trend of LL CPUEs tend to poorly estimate the trends of adult stocks, even processed by a good GLM: their initial decline tend to be in excess of the stock decline (for a combination of good reasons, still poorly weighted and understood); more recently, they may show the opposite bias, as they seem to often underestimate the decline of stock biomass, showing world wide a strange lack of visible interactions between surface and longline fisheries.
- Subsequently, there is a pending question concerning the **relationship between the shallow and deep yellowfin fractions of stocks**. Do we have a real & complete mixing, or some vertical segregation, between these two fractions of stocks? This strange hypothesis may in fact be realistic, as it would well explain the lack of clear interaction between surface and deep fishing. Such hypothetical vertical stratification can be simulated quite easily, and its results are easily consistent with the observed trends of catch and effort data by purse seiners and longliners.
- Effects of changes of **fished zones as a function of biomass distribution**, and fraction of cryptic biomass in the exploited stocks?: it is nowadays clear that an increased fishing zone tend to increase the potential MSY of the fishery. A coastal fishery cannot overfish a yellowfin stock at its real level of an oceanic wide stock! Potential catches in a coastal yellowfin fisheries are, by nature, limited to levels lower than the MSY.
- **Increasing efficiency** of all tuna fleets: longline, purse seine and others. This increase tends to be most often poorly estimated (or not at all) and not well taken into account by the models or scientists, and they are potentially transformed by most models into artificial increasing recruitment: as an exemple, the increasing recruitments estimated for both the eastern and western Pacific yellowfin stocks may be overerstimated by these increased efficiency of all the tuna fleets.
- What are the **real long term environmental effects** on yellowfin recruitments? The interannual anomalies of recruitment are easily followed and estimated by most analytical models, but the increasing recruitment trends that has been often observed, may be (1) either real ones, due to a long term environmental effect (global warming), ot (2) to serious bias in the models, transforming an increased fishing zone or an increased efficiency of fishing fleets into a « false » increasing trend of recruitment (due to changes in the environmental conditions!)
- Taking into consideration these difficulties, it should be recommended to evaluate stock status not with a given model, but with a wide range of assessment models, and to keep a permanent attention to selected stock and fishery indicators

Conclusion

Yellowfin tuna stocks and fisheries tend to be very similar in the various oceans. The biology of the species, its behaviour and movement patterns during its life cycle are widely conditioned in each ocean by their environmental structure, but there is little doubt that the main biological characteristics of this species are very similar world wide. On the other side, it appears that various of the biological parameters used in each oceans are quite different, many of these differences being more probably due to scientists and methods used in each area, without real links to real biological differences.

In the same way, there is very little or no doubts that all the major tuna fleets, purse seiners and longliners alike, have been showing, during the last 50 years, changes in their fishing technology and fishing efficiency that have been very similar worldwide. As a consequence of these great similarities between the fishes, the environment and the fisheries, most of the stocks have been showing similar behaviour of their main characteristics in all oceans world wide. Some visible differences between oceans are probably real and significant, and thus interesting to study further , but many of the differences are simply due to heterogeneity between scientists and tuna commissions.

There are still major questions and uncertainties faced world wide by yellowfin stock assessments, among others (1) growth and natural mortality as a function of sex, (2) stock structure and stock viscosity, (3) real interactions between surface and deep fractions of stocks, and (4) real relationship in the long run between CPUEs (of the various gears) and stock biomass.

It should be clear for all tuna scientists and commissions that a more active cooperation and a systematic comparative analysis between the various yellowfin stocks exploited world wide during the last half century, should be promoted. Such comparative analysis would be the best or only way to answer the major still pending questions concerning yellowfin stocks and fisheries. This document was a first step in that cooperative direction, but further more active work, based on detailed data and well selected models, should be developed by tuna scientists worldwide working on this species.

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Annex: list of figures and pages in the document