Received: 1 June 2015

Indian Ocean albacore stock: review of its fishery, biological data and results of its 2014 stock assessment

By Dr Alain Fonteneau[1], IRD Emeritus scientist, UMR MARBEC

Summary

This paper makes first a review of the albacore biological and fishery data that have been used in the IOTC 2014 stock assessment. It also examines the results of the SS3 models and their correspondence with these input data. There is a severe weakness of biological data for albacore in the IO, and most basic parameters are purely hypothetical. A lower natural mortality at age estimated by the Lorenzen method is considered as being more realistic than the level used by the WG. Changes in fisheries are showing that historical Gillnet fisheries were catching medium size albacore, not the very small albacore assumed by the IOTC. The albacore habitat and its core area has been identified and discussed. Major changes in the species targeting have been observed in this area since the mid eighties. It has been concluded that changes in target species are possibly the main causes of the steady decline of the albacore CPUES since 1986. These changes have not been corrected in the today GLM albacore CPUEs. It is shown that sizes caught by the albacore fisheries have been permanently large and stable, being close to the optimal yield per recruit. The stability of total catches and of total albacore effort (and of fishing mortality estimated by SS3) since the late sixties would indicate that there was no critical changes occurring in the fisheries & stock status during the last 30 years. It is concluded that the major decline in the LL CPUE was probably the main & artificial cause producing the major decline of the SS3 modelled biomass. Improved alternate modelling based on improved data, especially improved LL GLM CPUEs, should be done again in order to evaluate better the today real condition of the albacore stock in the IO.

[1] Fonteneau Alain : Alain.fonteneau@ird.fr

Received: 1 June 2015

1- Introduction

The IOTC reports on the albacore stocks are not showing in a comprehensive way the biology of this species and the nature and changes in the various fisheries that have been exploiting them since the late 50ies. The first goal of this work will be to revisit these basic parameters of the subsequent stock assessment work, first reviewing the albacore biology and the fisheries data.

The SC report on the albacore stock in 2014 is estimating that the albacore stock was increasingly and heavily exploited during recent years, and the Kobe plot trajectory of this stock approved by the IOTC scientific Committee in 2014 is showing a rather strange trajectory (figure 1).

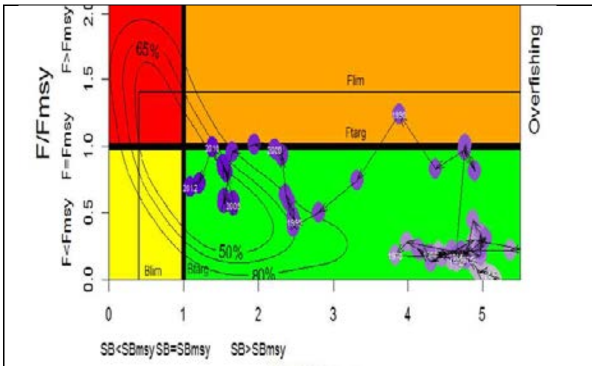


Figure 1: Kobe plot showing the history of exploitation of the Indian Ocean albacore stock as estimated by the SS3 model accepted by the SC (Median trajectory).

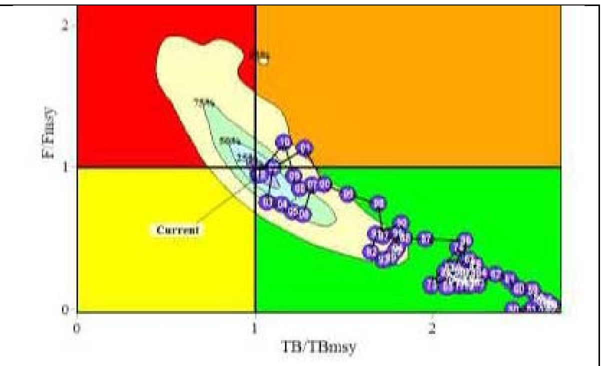


Figure 2: Kobe plot showing the history of exploitation of the Indian Ocean albacore stock as estimated by the ASPIC model

- Between 1985 and 1990: showing a fast and major increase of the estimated Fishing mortality, but without a decline of the SB/SBMSY ratio
- Between 1990 and today: showing a marked decline of the biomass, but without major increase of the Fishing mortality relative to FMSY

On the opposite, the trajectory estimated by the ASPIC production model (Matsumoto et al 2014, an. IOTC 2014), that has not been used in the final SC report (see figure 2) because of several problems, would at least appear to be a “logical one” in term of stock assessment: increasing exploitation rates producing a declining biomass.

These SS3 results have been approved by the IOTC scientific committee scientists, but without real questioning, and they appear to be somehow questionable. This paper will examine how much the biological and fishery data concerning this stock are consistent with the today figure 1 Kobe plot and its underlying components. This paper will for instance examine the various changes that have been observed in the various albacore fisheries during the 60 years period of its exploitation (this albacore stock was virgin in 1952, see figure 10). This paper will also examine & discuss the SS3 assumptions and results, and the potential errors or bias faced by these results. The additional goals of this paper will be:

- to propose recommendations allowing to improve future stock assessment diagnosis of this stock,
- to propose methods allowing more safety in the process of the scientific diagnosis and the approval of the tuna stock assessment results, especially when they have been produced by the complex statistical models that are used today.

These recommendations will be in the annex 1

2- Material and methods

The basic materials used in this paper are the IOTC statistical data:

- biological parameters used in the assessment
- total yearly catches by species, by country and gear
- catches and efforts of the various fleets and gear by 5° and month,
- Size data from the various albacore fisheries, observed or estimated by the IOTC secretariat for the 2014 albacore WG.

In addition, the other material used in this paper were the method, data and results of the albacore WG, as they have been described and published by the IOTC in various scientific documents related to this WG (see the literature). In addition, some detailed results from two selected runs of the SS3 model have been obtained from the authors of the SS3 2014 stock assessment (Sharma et al 2014) allowing to better examine the main basic parameters estimated by the SS3 model.

3- Basic facts and observations on the albacore stock and fisheries

3-1- Albacore main biological characteristics

3-2-1-Overall

While in the Atlantic and in the Pacific (N & S) the biology of albacore has been actively studied by multiple generations of scientists, in the past and today, there has been very few & limited studies on the biology of Indian Ocean albacore. In such context of highly limited biological knowledge, most of the IO albacore biological characteristics have been "imported" from other oceans, and the validity of these hypothesis remains widely unknown. Surprisingly the IOTC reports (albacore and SC reports) are not very strong in their recommendation concerning the urgent need to conduct more active biological studies on albacore.

3-1-2- Stock structure

It has been assumed, as in previous IOTC work, that there was a unique & isolated albacore stock fished in the southern Indian Ocean. This hypothesis may be a valid one, at least temporarily. It is clear in the IO that there is no potential mixing between 2 northern and southern stocks, as in the Atlantic and the Pacific. However, the hypothesis of a potential mixing between the south Atlantic and IO albacore stocks remain entire, because South African waters do not appear to be an environmental barrier limiting the potential exchange of albacore between these 2 oceans. This question is well shown by the geographical distribution of albacore catches that are more or less continuous between the 2 oceans, see figure 3.

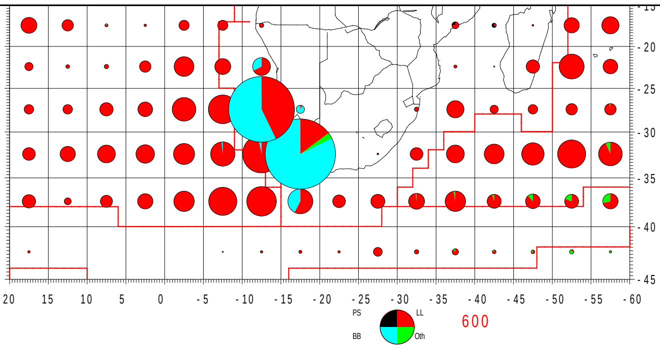


Figure 3: Average albacore catches by gear during the 1967-2013 period and Longhurst areas

Further research should be conducted on this potentially important matter and this important pending question should have a higher priority than in the recommendations by the 2014 albacore WG: for instance making an explicit research recommending to develop an ICCAT-IOTC tagging programme targeting medium size albacore caught in the South Atlantic and south IO.

3-1-3- albacore growth

The albacore growth is clearly slow in all oceans, from a recruitment size at 40 cm and reaching a maximum size of about 50 kg/130 cm after a long duration estimated between 12 to 20 years. However, few studies are available in the IO on the albacore growth, and the albacore growth estimated in the Northern Pacific by Wells et al 2013 has been used in the IO. The albacore growth estimated in the Atlantic (Santiago and Arrizabalaga 2005) would appear to be similar, but showing a higher asymptotic size (124.1 cm in the N Pacific and 127.1 cm in the N Atlantic).

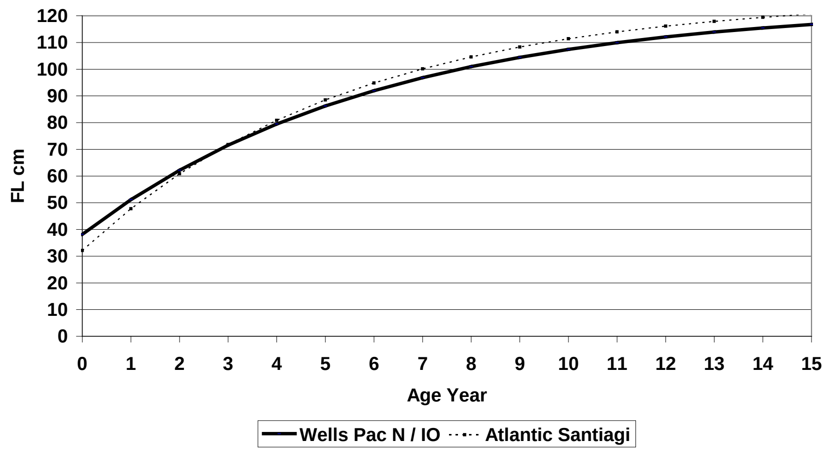


Figure 4: Von Bertalanffy growth curve estimated in the North Pacific by Wells et al 2013 and in the North Atlantic by Santiago and Arrizabalaga 2005.

Furthermore, several age reading studies have been showing for albacore a differential growth between male and female (Williams et al 2012): larger L infinity being estimated for male, but this differential growth by sex was not kept in the IO because of its complexity and because of the lack of data (No CAS[2] by sex available).

[2] CAS : catch at size

Received: 1 June 2015

3-1-4- Albacore sex ratio at size & its implications?

There was no data available in the Indian Ocean on sex ratio at size, and unfortunately this important question was not really visible in the albacore WG report. There is in fact a quasi universal observation done in the N & S Pacific as well as in the north Atlantic that the proportion of adult males increases to a level where no females are found (Alonso *et al.* 2005), and there are few or no females larger than 110 cm FL in most of the fisheries in the Atlantic and Pacific oceans (Bard 1981, Chen *et al.* 2010). Similar lack of large females in the adult catches has been also observed for other tuna species such as YFT & BET. However, this common decline in the proportion of female appears to be variable between the origin of the various samples available, see figure 5 and 6.

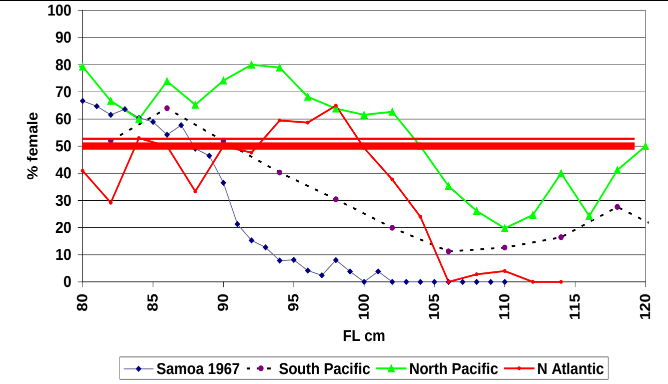


Figure 5: Sex ratio at size that have been observed for albacore in the N & S Pacific and in the North Atlantic oceans

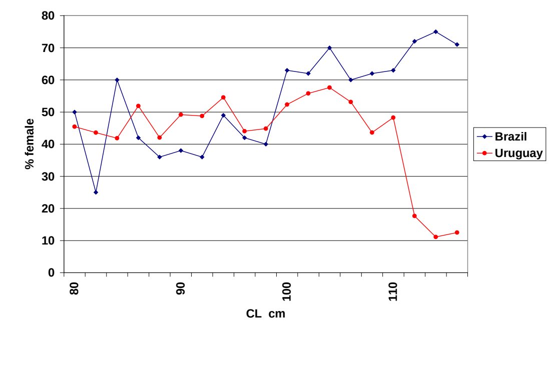


Figure 6: Sex ratio at size observed in the south western Atlantic: south Brazil & Uruguay

Furthermore, it should be noted that some local but very interesting anomalies have been repeatedly observed in the South western Atlantic off Uruguay & Brazil during the seventies and today (see figure 6). In these peculiar areas, sex ratios close to 50/50, or even a dominance of female have been observed even at the largest sizes (Zavala Camin 1978, Pons & al 2011) have been observed at sizes below 1,10 m or over in Brazil. These local sex ratio at size, repeatedly observed in the SW Atlantic, would strongly indicate that at least for this south Atlantic stock, natural mortality and growth of albacore could be similar for adult male and female.

The frequent lack of large female observed in the albacore catches could be explained by a combination of 3 main causes:

1) **Differential growth** of male & female: male having a larger average asymptotic size (as it has been shown by various age readings of hard parts)
2) **Differential natural mortality** of male & female: spawning females showing a higher natural mortality because they are investing more energy in their spawning, as it was well estimated by various authors such as Bard 1982 in the Atlantic and Hoyle 2013 in the south Pacific.
3) **Lower catchability of adult female** albacore in most of the LL fisheries: for instance if female albacore are deeper or shallower, being more scattered in peculiar areas of lower CPUEs and of lower fishing efforts. This 3rd hypothesis has been seldom used, but it should also be kept in mind.

For instance, the 50/50 sex ratio observed south off Brazil and Uruguay would be in support of this 3rd hypothesis, eliminating at least for this stock, the hypothesis that female albacore are showing higher asymptotic sizes and/or higher natural mortality. This 3rd hypothesis could also be a valid factor contributing to explain, at least to some extent, the world wide decline of large females in most of the albacore catches.

Received: 1 June 2015

Furthermore, it should also be noted that in the IO albacore fisheries a large proportion of the catches are caught at large size: 70% of the 1993-2012 CAS in weight were caught at sizes over 90 cm, i.e. in the size range of potentially vanishing females. As a consequence, it should be of key importance in the Indian Ocean:

a) to estimate well the albacore sex ratio at size of the IO albacore catches, this sampling being done in as many areas as possible. The recommendation by the 2014 albacore WG giving a "moderate" priority to obtain such a fundamental parameter was clearly too weak! Such sex ratio at size data should have the highest and most urgent priority in the Indian Ocean, as this result is quite easy to obtain based on observer data on the longline catches or on sampling in canneries on the purse seine catches. These results could widely condition the stock assessment work and its results..
b) to explain this sex ratio at size by a proper combination of the 3 hypothesis summarized before; the today rule of a 50/50 sex ratio at all sizes, same growth and same natural mortality and same catchability of male of female is more easy to handle in the stock assessment, but it may be widely biased, for instance in order to allow to estimate the sizes of the albacore spawning stock.
c) to incorporate these basic biological rules selected as being the more realistic ones in a future base case stock assessment model.

3-1-5- Albacore natural mortality at age

It has been accepted based on age reading and on recoveries in other oceans that albacore was probably showing a longevity over 12-15 years or more, then natural mortality of albacore stocks is always assumed to be quite low, but a wide range of potential levels of M have been hypothesized in a range between 0.2 and 0.5. The SS3 model has been running on this range of potential M.

The logical hypothesis that spawner albacore females are suffering a higher rate of natural mortality has been also often envisaged by scientists as this hypothesis would appear to be more realistic in biological terms. The Lorenzen method (Lorenzen 1996) is an efficient way to estimate such natural mortality at size based on a given VB growth curve (see figure 7). This calculation has been done based on the growth curve used in the IO assessment, and the following curve of natural mortality at age was obtained.

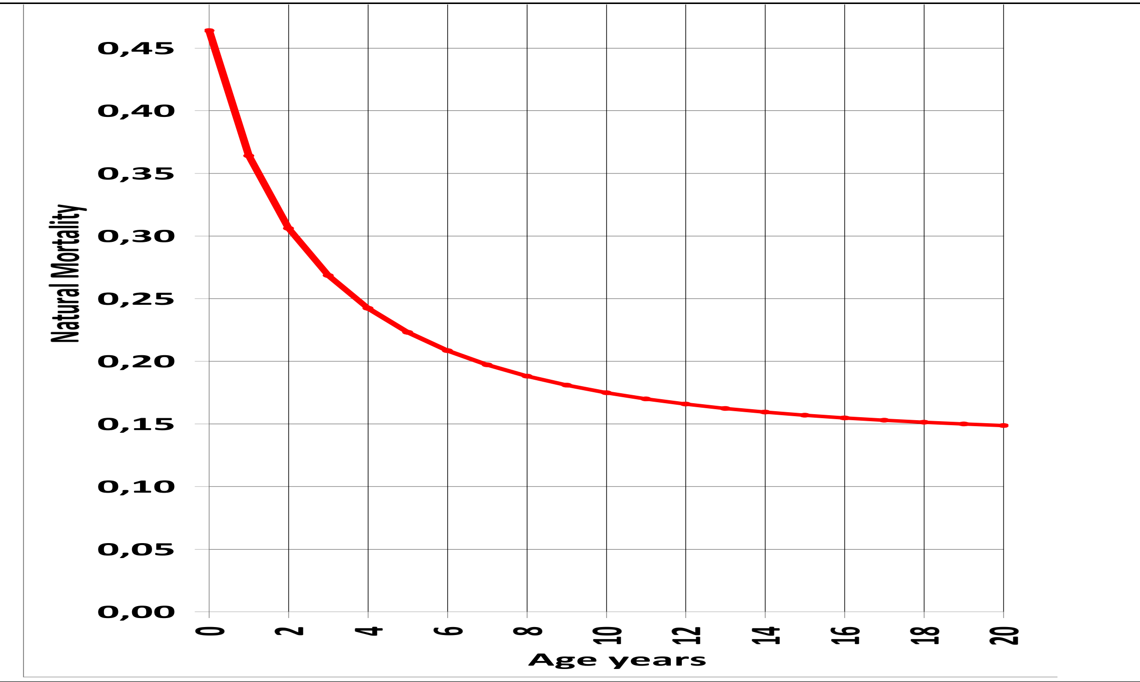


Figure 7: Natural mortality by age estimated by the Lorenzen method based on the growth curve used in the N Pacific and Indian ocean.

This estimated natural mortality is estimated at levels over 2 between age 0 and 6 (0.45 at age zero), but its yearly level for adult albacore between ages 6 and 20 years is estimated at low level between 0.2 and 0.15. At least, this curve appears to be much more realistic in biological terms, than the flat M assumed between birth and death often assumed in the albacore stock assessment: natural mortality of a 2 kg albacore should be much higher than natural mortality of a 40 kg albacore.

The assumed M is a key stone parameter in all stock assessment, possibly sometimes the most important one in many stock assessment analysis. It is always interesting in the discussion and choice of a Natural mortality of a studied species to simply simulate the biomass at age of a cohort under the assumed growth and length weight relationship of the species. Such basic simulation has been conducted for 5 natural mortalities envisaged for albacore, between 0.22 and 0.5, and for the Lorenzen natural mortality at age, see figure 8.

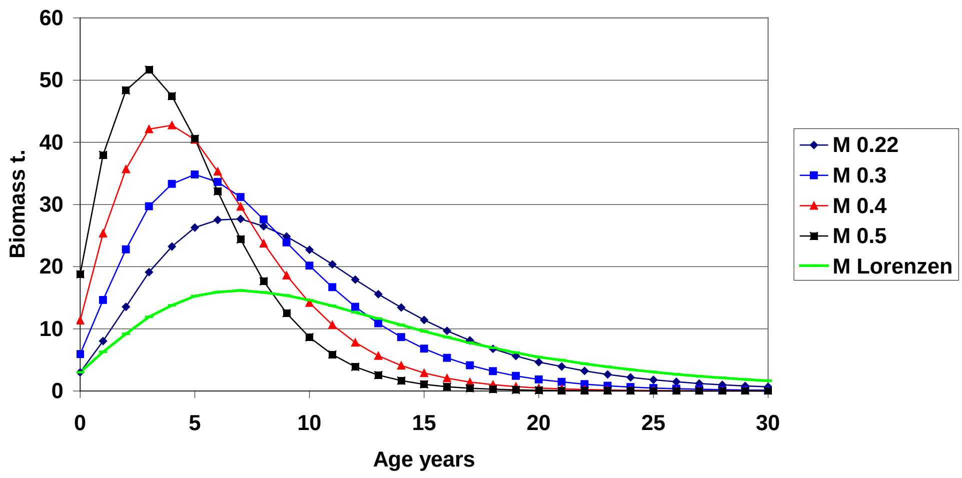


Figure 8: Simulated biomass at age of a virgin albacore cohort (10 millions of individuals) as a function of an assumed average natural mortality M between 0.22 and 0.5, and for the Lorenzen natural mortality at age (see figure 7)

Maximum biomass of a virgin cohort is observed at older ages assuming a low M (8 years at M=0.22 and 4 years at M=0.4). In the hypothesis of a very low M, for instance M=0.22 (as it was recommended in the 2014 WG report), an important fraction of the cohort biomass is reaching ages over 12 years (32 % of the virgin biomass), while at M=0.5 this percentage of age 12+ virgin biomass is only of 3 %.

In all the hypothesis of a low M, typical of albacore stocks, for instance between 0.22 and 0.5 or in the Lorenzen pattern of Mi, there are many cohorts in the adult stock and there is very little potential to observe significant year to year fluctuations of the adult biomass under any realistic variability of yearly recruitments and of yearly F. This conclusion is strongly confirmed by all simulations conducted on all albacore adult stocks in these range of natural mortality. This low variance of the year to year variability of simulated albacore stocks biomass is in deep contradiction with the observed “yoyo CPUEs” and with the brutal major decline of CPUEs observed for Taiwan in the late eighties: this CPUEs cannot be representative of the real adult stock biomass! It should also be kept in mind that natural mortality may also be dependent of the sex, as it was discussed by Hoyle 2008, see figure 9.

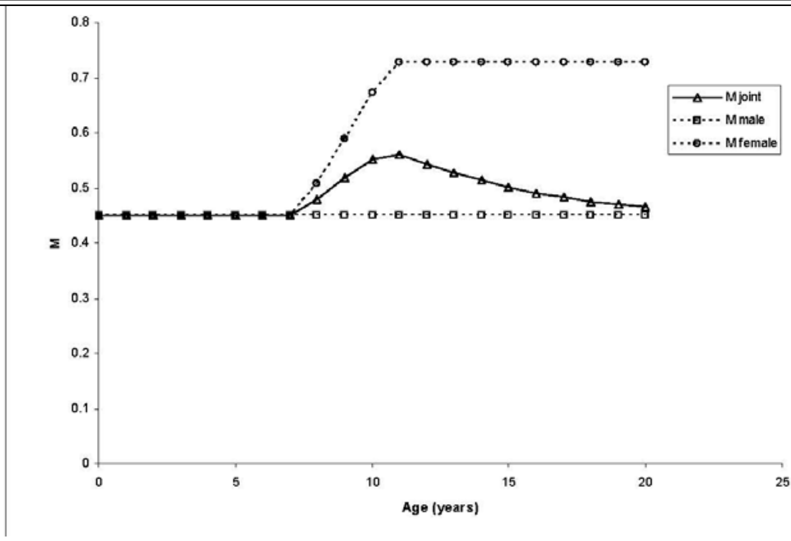


Figure 9: Example of natural mortality at age pattern proposed for albacore in the south Pacific by Hoyle 2008.

An improved biological knowledge of albacore spawning, of the growth by sex and of the observed differential sex ratio at size would help to clarify this serious biological uncertainty.

As for most tuna species, the level and pattern of Mi remains widely uncertain for albacore, but based on the estimated great longevity of the albacore stocks, low level of M close to 0.2 or 0.3 are probably more realistic. Furthermore the natural mortality level and pattern that are estimated by the Lorenzen method would appear to be quite realistic and it should be kept in future stock assessment.

3-1-6- Age at first spawning

Sizes at first spawning are more or less the same for all the albacore stocks and positioned at about 90 cm, i.e. at an age of 6 years based on the North Pacific growth presently assumed in the IO. This size corresponds either to the sizes where the percentage of female starts its decline, but the decline of female in the catches has been also observed at larger sizes over 1 meter.

3-2- Albacore fisheries

3-2-1- Yearly catches by gear

The albacore fisheries have been showing 60 years of slowly but steadily increasing albacore catches, these yearly catches showing moderate fluctuations; quite similar levels of yearly average catches have been landed during recent years since the late nineties. Following a period of stable low catches at a 17500 tons level during the 1961-1985 period, there was a peak of high average catches observed during the 1986-1991 period (average catches of 31000 tons) primarily because of the large catches by the gillnet fisheries.

Received: 1 June 2015

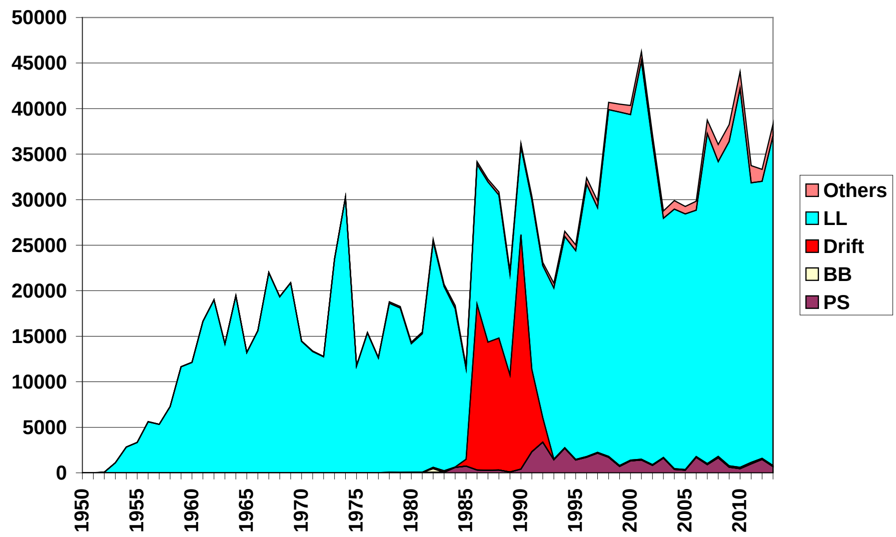


Figure 10: Yearly catches of albacore by gear in the Indian Ocean

Gillnet fisheries declared an average of 15400 tons during this period 1986-1991, while the LL fisheries caught similar level of catches (an average of 14700 tons) during this period. This period was followed between 1997-2003 by a period of increased fishing efforts and of increased catches. The albacore catches by purse seiners have been always very low (an average of 1150 t. yearly since 1984), but these catches have been very well documented (catch, effort and sizes). It should be noted that unfortunately an increasing proportion of the albacore catches have been observed during recent years without any detailed statistics (C/E or sizes): by Indonesian & Taiwanese albacore fisheries. Large amount of albacore were caught by these ghost fisheries: 26 % of the albacore catches were caught by Indonesia during the last 7 years & 32% by the poorly documented Taiwanese ice LL. A massive move has been observed for the Taiwan fleet between its traditional LL freezers fishery (large vessels), and its today LL fishery dominated by small ice LL. The today fishing zones of these 2 fleets and the catches by species being quite distinct for these 2 segments of the Taiwanese fleet (figure 11 and 12).

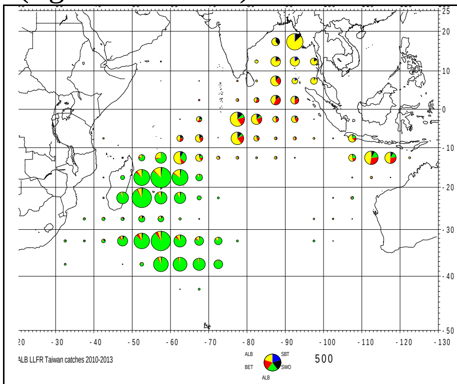


Figure 11: Average catches by species of the Taiwanese ice LL longline fleet during the 2010-2013 period

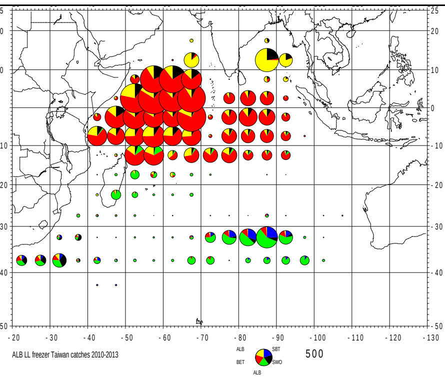


Figure 12: Average catches by species of the Taiwanese freezer LL longline fleet during the 2010-2013 period

While the ice LL being a gear solely targeting albacore in the core albacore southern IO areas and with a very poor statistical coverage, the traditional freezing LL are targeting today a wider range of target species & in much wider areas. The effects of this basic change are difficult to handle, especially because of the very limited coverage of the catch and effort data available now for the ice LL fleet.

3-2-2- Sizes of the albacore catches

Average weight of albacore caught by albacore fisheries: the yearly average weights of albacore landed by the combined albacore fisheries are shown by figure 13.

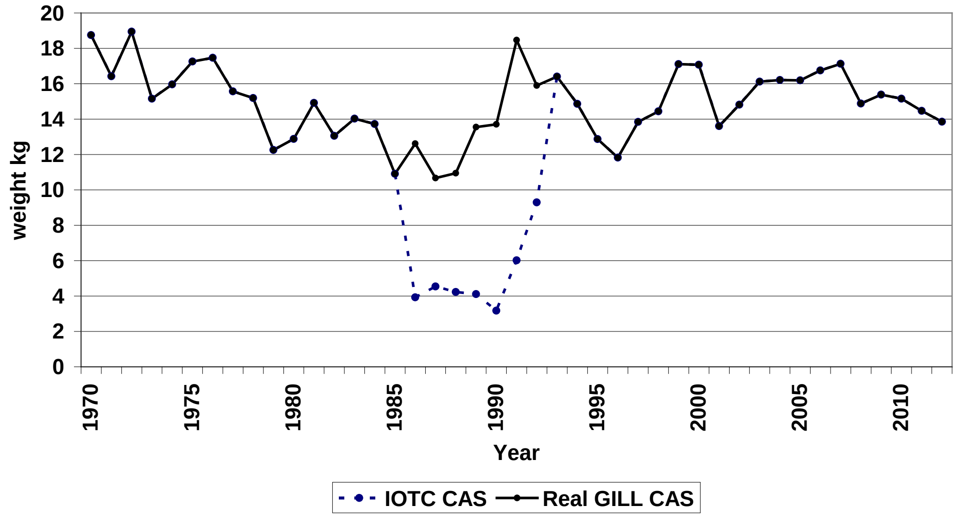


Figure 13: Average weight of albacore caught by albacore fisheries: estimated by the IOTC with wrong Gillnet sizes, and based on real Taiwanese size data

Sizes caught by the Longline fisheries

Optimal catch at size of albacore IO dominated by LL catches: an average weight 1993-2012 estimated by the IOTC at 15kg. This average weight of 15kg is probably close to the optimum albacore sizes (while in the N Pac & N Atl albacore fisheries the average sizes of the albacore catches are well under 10kg, and well under this optimum Y/R size)

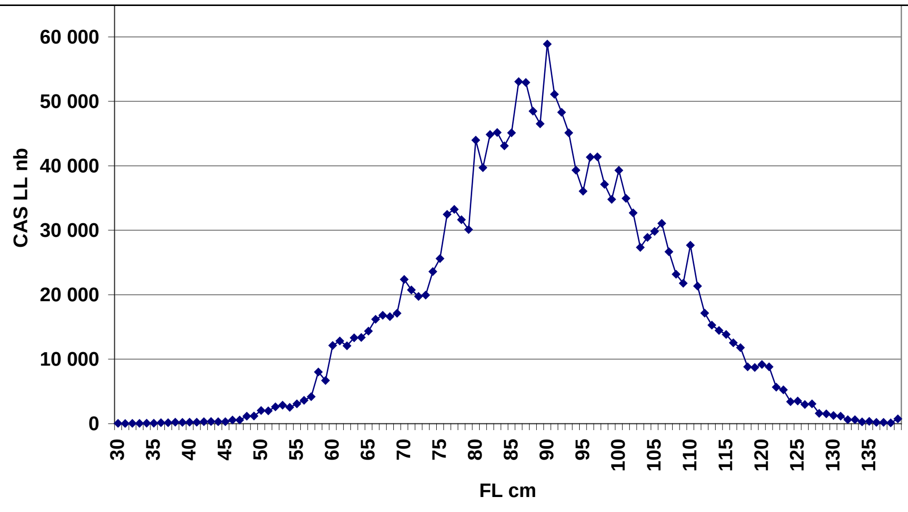


Figure 14: Albacore average CAS caught by the LL fleets during the 1993-2012 period (IOTC CAS data)

Sizes caught by the Gillnet historical fisheries

Sizes caught during the 1986-1992 period by this major historical fishery remain some how questionable. On one side, it has been assumed by the IOTC secretariat in its albacore CAS matrix, based on a strata substitution with another ocean & fishery, that these albacore were caught at a very small size: an average weight of only **2.4** kg during the 1986-1991 period. As a consequence, the average weight of the combined albacore fisheries was very low during the 1986-1991 period, at an average weight of only **4.3 kg**, see figure 15.

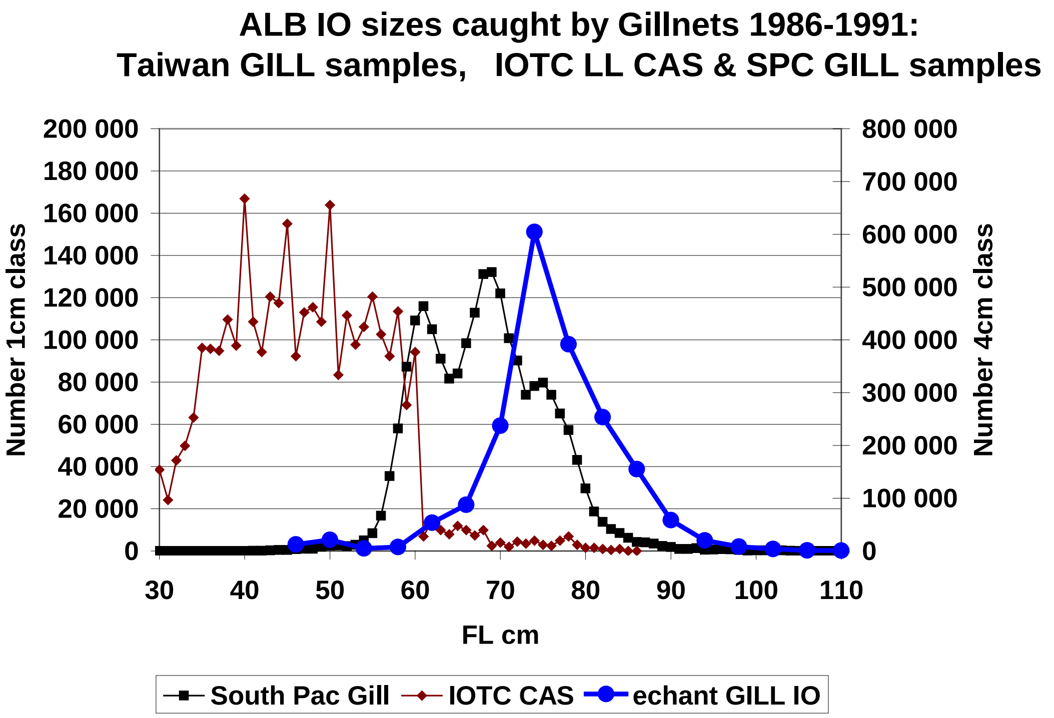


Figure 15: Average sizes (1986-1991 period) of albacore caught by Gillnets fisheries in 3 data set: submitted by Taiwan in 1993, estimated by IOTC and from SPC south Pacific)

This IOTC CAS and its corresponding CAA table was use in the unsuccessful attempt by Japanese scientists to run sequential population analysis based on the ASPM model (Nishida et al 2014). However it would appear that all the SS3 runs have been conducted assuming that sizes caught by the historical gillnet fisheries were identical to the sizes caught by the south Pacific fisheries, then at a much larger average weight of **6.9 kg**. It should also be noticed that while there are no size data available today for this fishery in the IOTC data base, significant numbers of size data have been submitted by Taiwanese scientists to the IPTP in 1992 (Lee and Liu 1993). These sizes are quite similar to the sizes caught in the South Pacific, but showing a larger average weight: **9.3 kg** vs 6.9 kg (lower than the average weigh of the LL fishery estimated during the same period at **16.0** kg) The average catch at size of the average gillnet fisheries during the average period 1986-1991 are shown by figure 15. As this fishery was of major importance in the history of the albacore fisheries, this point should be clarified by the IOTC, in contact with Taiwanese scientists, as soon as possible. It should be assumed that during the 1986-1992 period there was no significant decline in the average weight and of the yield per recruit of the albacore fisheries.

Received: 1 June 2015

Catch at size of LL and PS by latitudinal areas

An important point to note in the albacore fisheries in that the albacore caught in warm waters (spawning strata) are showing larger sizes that fishes caught in temperate areas. Furthermore it should also be noted that the modal sizes caught by LL and by PS in the equatorial areas are very similar, but LL catching more of the smaller albacore in a size range between 85 and 95 cm (figure 16)

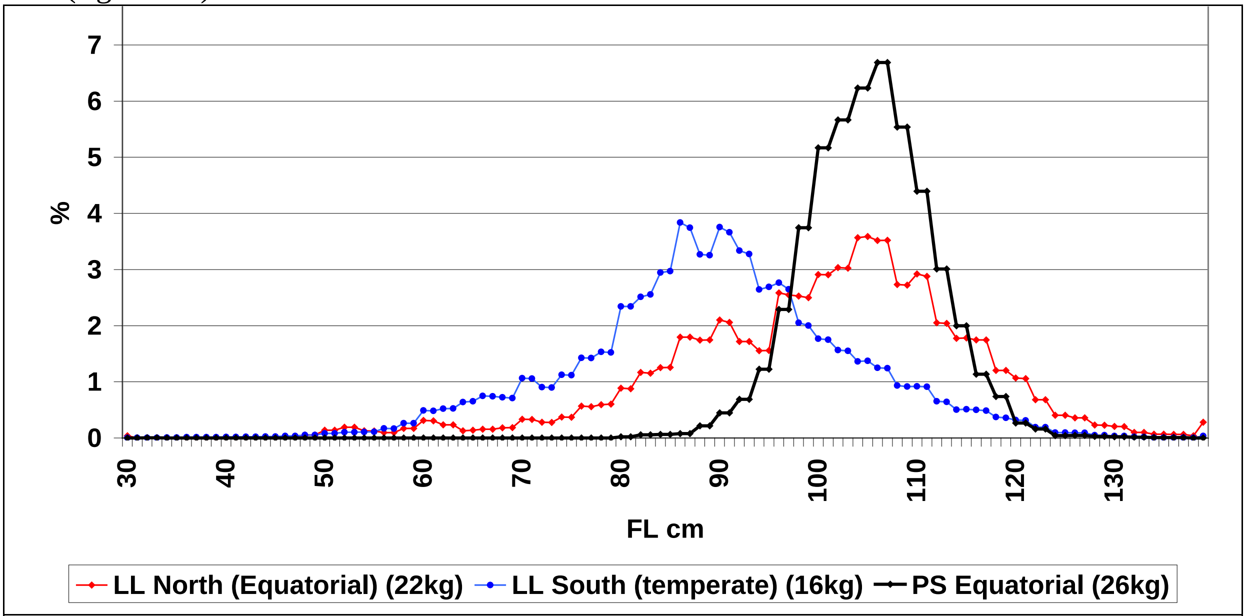


Figure 16: Average sizes of albacore caught in the equatorial and temperate waters by LL and by PS (1990-2012)

Average catch at age by the albacore fisheries has been tentatively estimated by the IOTC based on slicing of the CAS and using the North Pacific albacore growth curve proposed by Wells 2012. The average yearly catches by age estimated by a slicing method and based on the growth curve (1993-2012 period) are shown by gear figure 17.

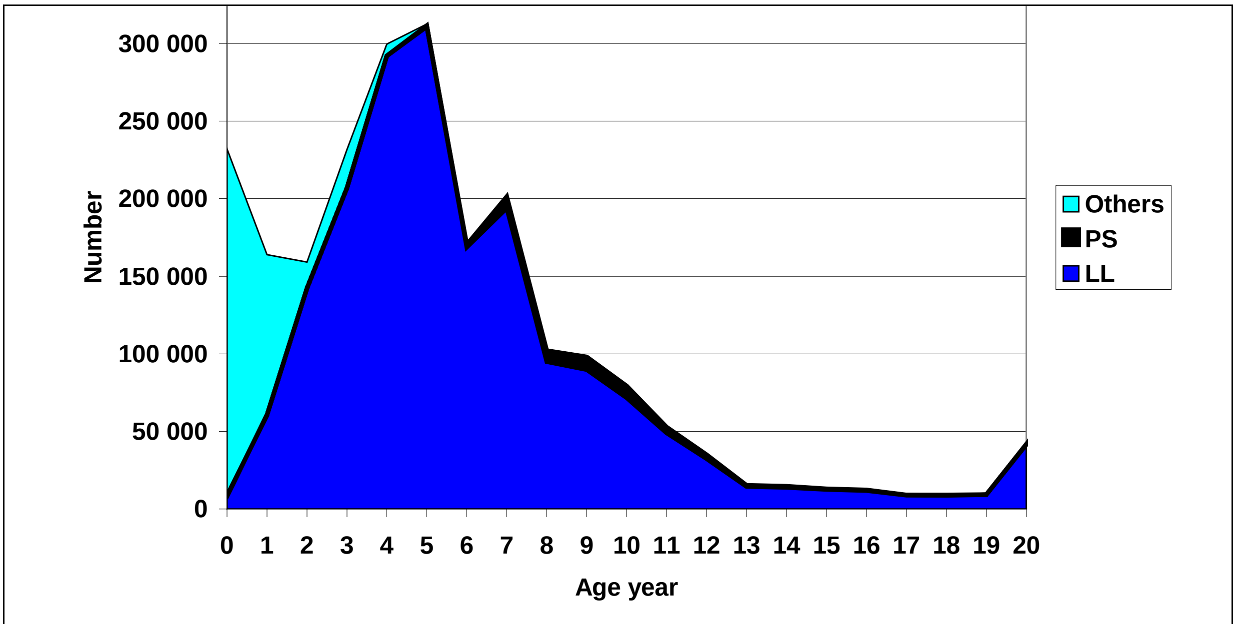


Figure 17: Average catch at age for the albacore catches, by gear, during the 1993-2012 period as estimated by the IOTC (Average weight=16 kg)

This figure is showing that catches during the 5 first years of exploitation (ages 0 to 4) are estimated to be lower than at subsequent ages (then corresponding to a much lower fishing mortality). These estimated yearly catch at age are later showing a declining trend between ages 5 and 13, followed by a plateau of the older albacore catch at older ages. Older ages in the estimated catch at age table are reaching 20 years, but these estimated catches of very old albacore are widely uncertain as they are not based on data: being dependent of the growth curve and of the inter individual variability of their asymptotic sizes, 2 parameters that are unknown in the Indian Ocean. However, if these significant catches of very old albacore, for instance caught at ages over 12 or 15 years, would be indicative of a very low total mortality and of a low natural mortality: under a natural mortality of 0.4 or 0.3 and a significant fishing mortality, there would be very few or no survivors at ages over 12 years.

3-2-3- Albacore catches by area and core fishing zones

It is essential to carefully analyze the fishing zone where the species has been fished (targeted and as a by catch) as these areas are the basis of the areas that will be selected for the calculation of CPUEs and also to choose the areas later used in the stock assessment model. Furthermore these fishing zones should preferably be put in relation with the environmental conditions, for instance with the Longhurst areas, as these areas are somehow explaining the geographical distribution of the species.

The first basic figure is the average catches of LL by 5° squares observed during the history of the fishery in relation with the Longhurst areas, see figure 18.

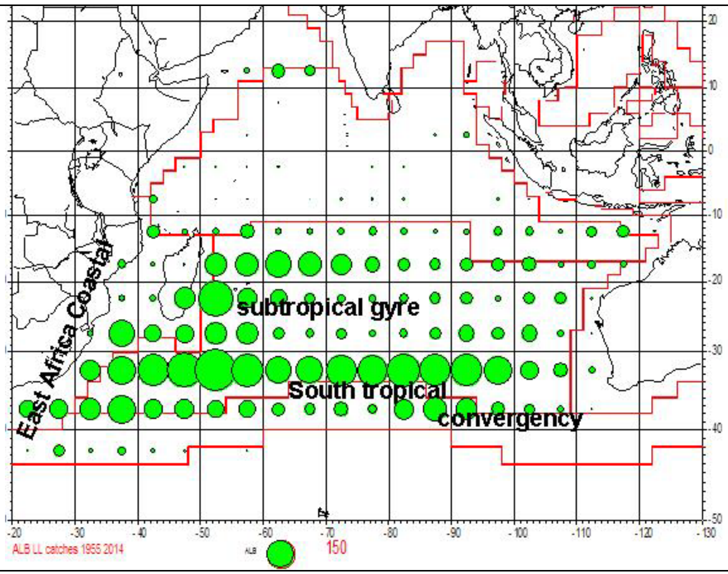


Figure 18: Total average albacore catches during the 1950-2013 period and Longhurst areas

In addition to this map, it is also informative to examine the average catches by gear during the period the driftnet fishery: figure 19 is showing the average catches of albacore caught by gear during the period 1986-1991.

Received: 1 June 2015

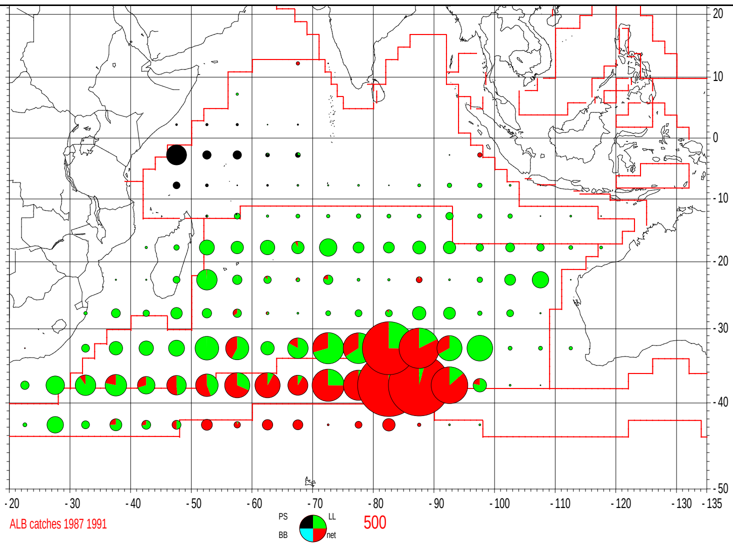


Figure 19: Average catches of albacore by gear during the 1987-1991 period

It is also interesting to identify the albacore “core areas” where albacore is the dominant species and that has been often targeted by LL fisheries. The simple method proposed by Fonteneau 2010 was used to identify this albacore core area: simply selecting all the 5°-month strata when & where the albacore catches were dominant in weight. The map showing the average geographical distribution of these fishing efforts with dominant albacore catches is shown figure 20.

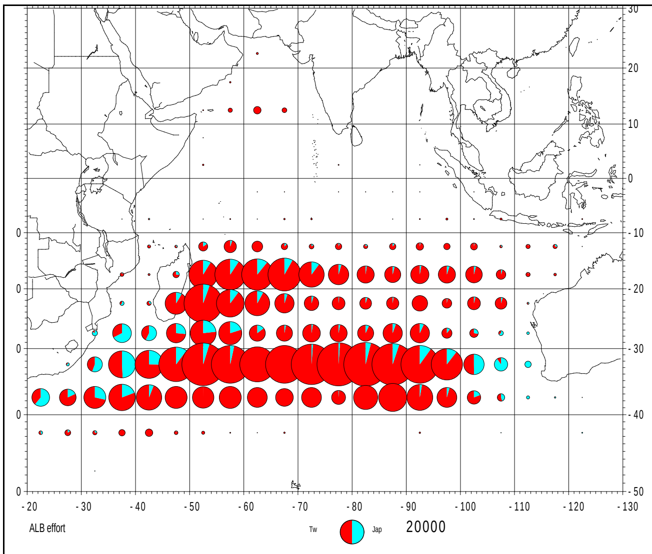
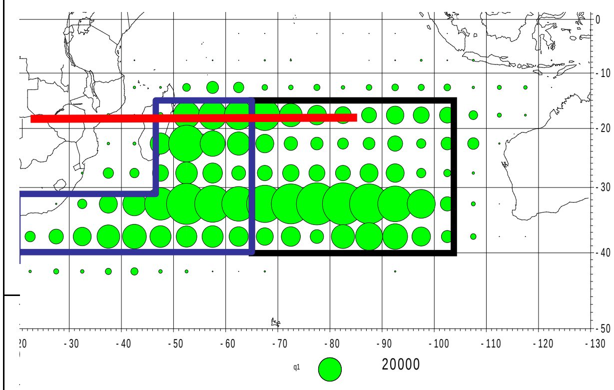


Figure 20: Albacore core areas, based on the average fishing effort exerted in 5°month strata with dominant albacore catches in weight by Japanese and by Taiwanese longliners during the 1967-2013 period.

The albacore stock is clearly a stock mainly fished in oceanic waters and mainly targeted in peculiar areas south of 15°S in the Longhurst subtropical gyre, in the south tropical convergency and in the Eastern Africa coastal area from Longhurst 1995. In the historical fisheries before 1986, and since 1992 after the moratorium of driftnet fisheries, Indian Ocean albacore is on of the few tuna stock predominantly caught by LL: 95% of its total catches. Taiwanese LL fisheries are by far the dominant country in this albacore fishery, catching 60%

Received: 1 June 2015

of the total albacore catches during the 1970-2013 period (very few tuna fisheries showing such a dominance of a given flag). The albacore fishing zones targeted by LL are quite easy to identify, simply based on the dominance (in weight) of albacore catches (by 5° & month) against the combined catches of all other species (as proposed by Fonteneau 2010). These core area showing dominant catches of albacore during the period 1967-2013 are shown by figure 21: showing well the core albacore areas that can be potentially stratified in 2 E & W sub areas. Furthermore the area that have been targeted for albacore by Taiwanese & Japanese LL appear to be quite similar see figure 20. Based on our analysis of the fishery and environmental data, we consider that the albacore LL CPUEs should preferably by calculated in the 2 areas shown by figure 21.



In each of these 2 areas we calculated the average nominal CPUEs of Taiwanese and Japanese LL (each yearly CPUE being calculated as the average of the monthly CPUE in the area). These yearly nominal CPUEs are shown by figure 22, as well as the Taiwanese GLM CPUEs (average of the 2 zones).

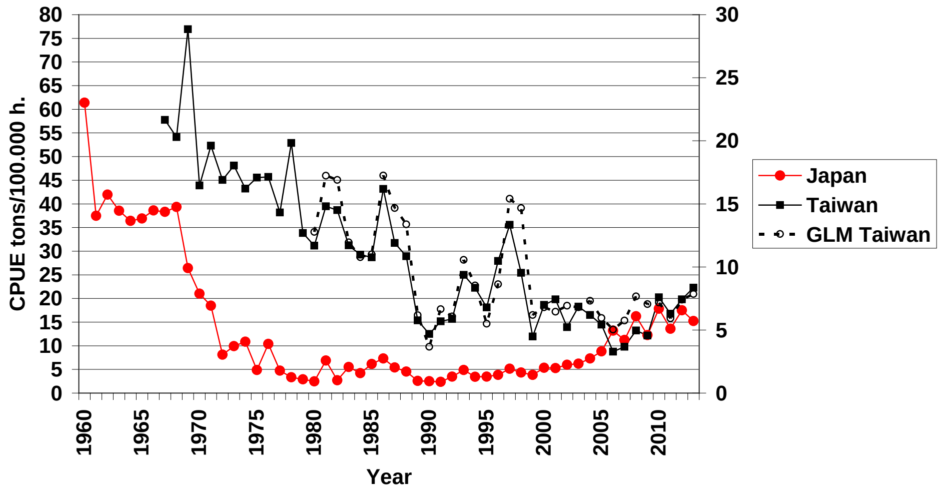


Figure 22: Three types of albacore CPUEs: Japanese and Taiwanese longliners CPUEs in the core area, and standardized GLM PUEs proposed by Taiwanese scientists.

It can be noted that the early Japanese nominal CPUE were at a high & stable level during the early years until 1968 (an early period of albacore targeting in the southern IO for Japanese LL), followed by a period of quick & major CPUE decline. There is no doubt that this decline of the albacore Japanese CPUE in the core albacore areas was simply due to a complete

Received: 1 June 2015

change of target species, and longline fisheries , while a major fleet of Taiwanese LL have been showing a slowly declining nominal CPUE trend, but at quite high level during the 1967-1986 period (5.3 times higher than Japanese LL CPUEs during the period 1970-1985). Later on, a marked decline has been observed for Taiwanese CPUEs since 1986, while Japanese CPUEs have been showing steadily increasing CPUEs during the last 15 years. Nominal CPUEs observed for Japanese and Taiwanese fleets during the last 8 years are nearly identical: 14.6 vs 15.4 tons per 100.000 hooks. There is no doubt that the Japanese CPUEs in the core area do not represent the biomass of the stock because of major changes in the species targeting of the fleet and the value of the Taiwanese CPUEs remains widely questionable.

These areas could be compared with the 2 types of fishing zones used by the albacore 2014 WG: the areas used to calculate the Taiwanese standardized CPUEs (primarily used in the stock assessment) and the 2 areas used in the stock assessment itself (Figure 23).

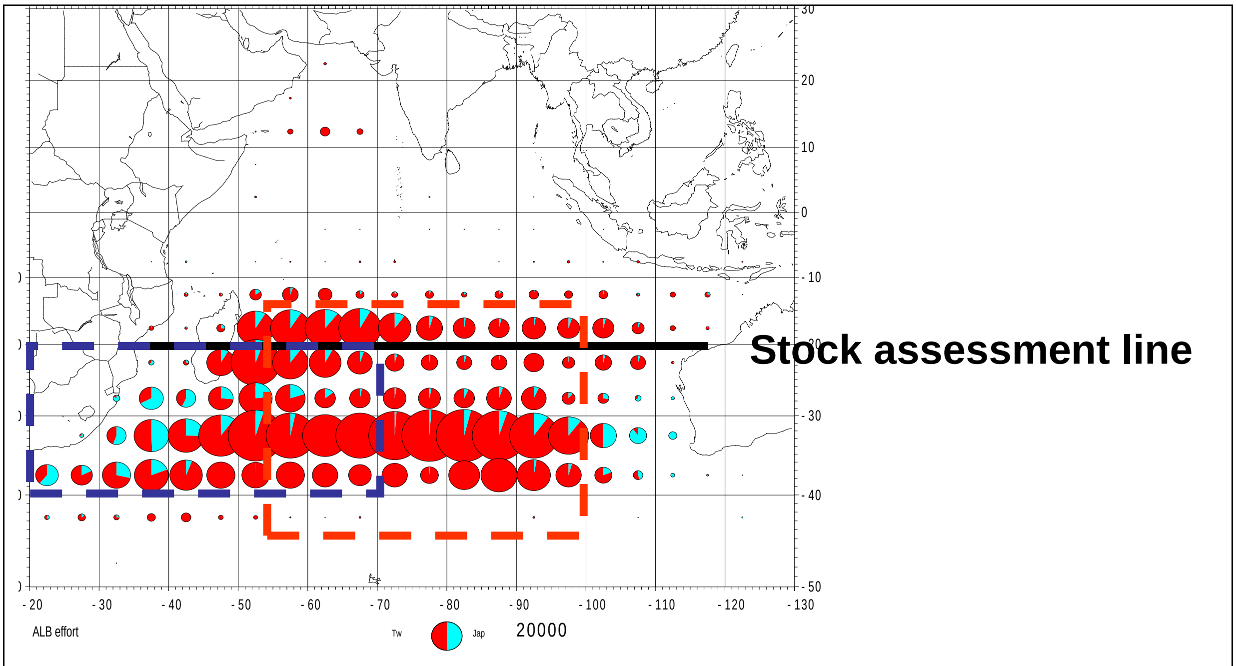


Figure 23: The 2 areas used in the standardization of the 2014 standardized Taiwanese CPUEs and core albacore areas identified based of the albacore targeted efforts of Japanese and Taiwanese longliners.

Comparing the various information presented before, the following comments can be done on these various potential geographical stratifications:

1) The frontier between the 2 areas in the SS3 model appears to be widely questionable, being positioned at 20°N, and leaving the 15°S to 20°S band, an area clearly pertaining to the core albacore area, in the widely heterogeneous northern area dominated by tropical species.
2) The eastern area used in the CPUE calculation contains the area south of 40°S where albacore has never been targeted.
3) The western area used in the CPUE calculation contains the southern area of the Mozambique Channel where albacore has never been caught significantly and it does not incorporate the area between 15° and 20° South were albacore has been actively targeted by LL fisheries

Received: 1 June 2015

On the other side it should also be noted (as it was noted by the albacore WG, An IOTC 2014) that the Taiwanese Nominal and standardized CPUEs are showing nearly exactly trend and same large yearly variability. This similarity should cast major doubts on the efficiency of the GLM standardization of on the validity of these CPUE results. Major additional questions are also faced by these GLM CPUEs, for instance:

- Concerning the major very fast decline of CPUEs observed before & after 1986, when CPUEs are suddenly divided by a factor 2; such brutal decline can never be observed for a biomass of an adult stock of albacore and its 10 cohorts.
- Concerning the very large year to year variability of the GLM CPUEs, for instance being multiplied by a factor 2 between one year to the next.

At this stage, based on the scientific knowledge of the LL fisheries, our strong general feeling will be that these major and fast changes in nominal and GLM CPUEs are probably mainly due to a combination of various factors:

- Primarily to a declining trend in the albacore targeting that has been exerted yearly by each LL fleet, and to the great flexibility of all LL fleet to adjust their species targeting, for instance changing their fishing strata and their fishing depth in order to increase their catches of alternate species such as YFT, BET, SWO & SBT. Furthermore it should also be kept in mind that other species not recorded by the IOTC such as oilfish (*Ruvettus pretiosus*) and escolar (*Lepidocybium flavobrunneum*) would have been increasingly targeted in the Indian Ocean since 2004 2005, then potentially producing an artificial decline of the albacore CPUEs. The change of target species was already well identified 30 years ago by Lee and Liu 1993 in their conclusion that *"the fishing pattern of the Taiwanese longliners has been changing since the mid-1980s. Some longliners have been transferring their target from albacore to yellowfin tunas and bigeye tunas. Therefore, how to find the longline CPUE which can well represent the stock status is a new and important topic for the future"*. There was clearly 2 types of changes in the multispecies targeting of Taiwanese longliners: 1st a change of fishing areas and moving from the temperate albacore areas to the equatorial Bigeye areas and 2nd a change of specific targeting in the traditional albacore fishing zones, for instance significantly targeting swordfih in shallow night settings. This potential change in the species targeting was for instance well shown by the Bard & al 1999 study in the central Pacific: as each of the 3 major target species, yellowfin, bigeye and albacore tend to be living at distinct depth and at distinct thermal preferendum, lonliners can set their lines at given depth in order to target a given mixture of species, see figure 24 from Bard et al 1999.

Received: 1 June 2015

o

.

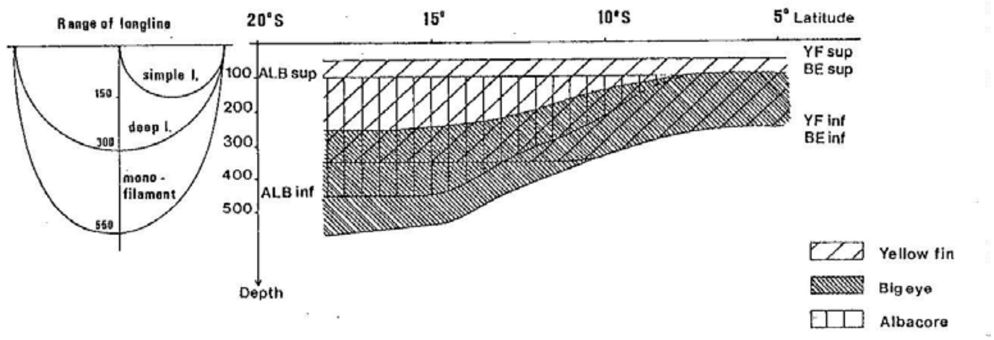


Figure 24: Schematic view of the vertical extension of the 3 main species of tunas in the Polynesian EEZ, and types of longline configuration used to target a given mixture of species.

Furthermore, while such potential change in fishing depth are well identified in GLM standardization models if the HBF configuration of the longline are well known, this basic rule remains widely questionable as it was shown by Bach and Fonteneau 2005 who concluded that HBF configuration would be today a poor indicator of the real fishing depth.

- Secondarily, to changes in the albacore biomass available in the studied core area, as there is no doubt that the biomass of the albacore stock is lower today than 20 years ago, simply because the total albacore catches have been multiplied by 2 during the periods before and after 1986.

As this species tend to be of limited value in the international market (compared with YFT, BET and SBT), it has probably been more or less actively targeted among periods & fleets, depending of the economy and market of each fleet during each period. It should also be kept in mind that the development of the sashimi market in the late seventies, following the implementation of deep freezing longliners, has been widely increasing the pressure on tropical tunas, and decreasing the relative interest of albacore targeting. The best and only proof that the species was heavily targeted during a given period would be the dominance of the albacore catches in value, but unfortunately these yearly values, that are dependent of each fleet, are not available today in the public domain or in the IOTC files. In a first step, it could be concluded that the high percentage of 80 % of albacore in the total catches of Taiwanese LL provides a strong indicator that this species was heavily & primarily targeted by this fleet during the 1967-1985 period (see paragraph 3-2-5), while this albacore targeting has been widely reduced since 1986.

Furthermore it is also interesting to compare the Taiwanese LL CPUEs in the core areas of the southern Atlantic & Indian oceans (figure 25 and 26): while a marked decline has been observed in the Southern IO, there was a quite stable trend of albacore CPUE in the Atlantic.

Received: 1 June 2015

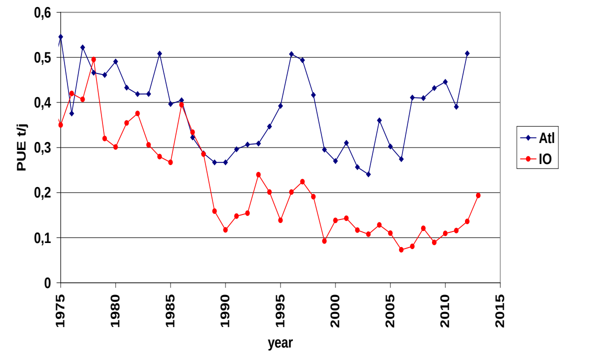


Figure 25: Taiwanese albacore CPUE in the South Atlantic and Indian oceans core albacore areas

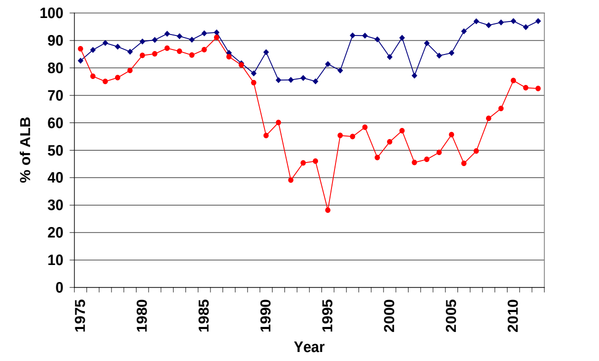


Figure 26: Yearly percentage of albacore in the Taiwanese catches in the South Atlantic and Indian oceans core albacore areas.

On the other side, while the percentage of albacore has been heavily declining in the IO, it has been remaining permanently at a high level in the Atlantic (Figure 26). Knowing that the Taiwanese fishing vessels that are active in the 2 oceans are very similar in term of fishing behaviour, this result would reinforce our hypothesis of a strong link between the albacore multispecies targeting and the % of albacore in the catches, and the corresponding albacore CPUEs.

3-2-4- Albacore habitat and environmental conditions

The core habitat is basically positioned in the south Indian Ocean gyre (cf Longhurst 1995) and secondarily in the South African coastal waters. Catches of adult albacore by LL, dominated by large albacore that are predominantly potential spawners, are positioned in cold waters <25°C (feeding zones) and in warm waters over 25°C (spawning strata) (Figure 27).

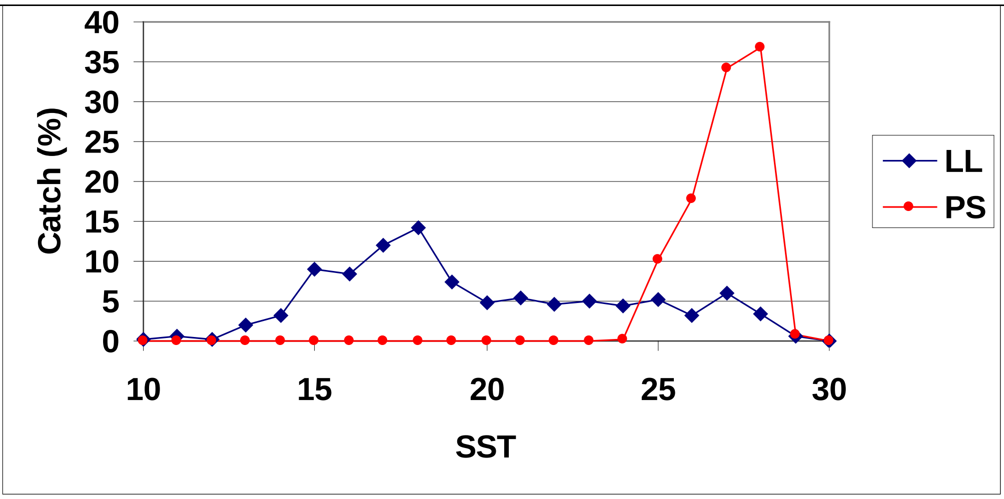


Figure 27: Average catches of albacore as a function of sea surface temperature, by gear (estimated at a 5°-quarter scale)

These strata are showing a consistent geographical position that are probably indicative of the feeding and spawning strata, shown by figure 28 and 29.

Received: 1 June 2015

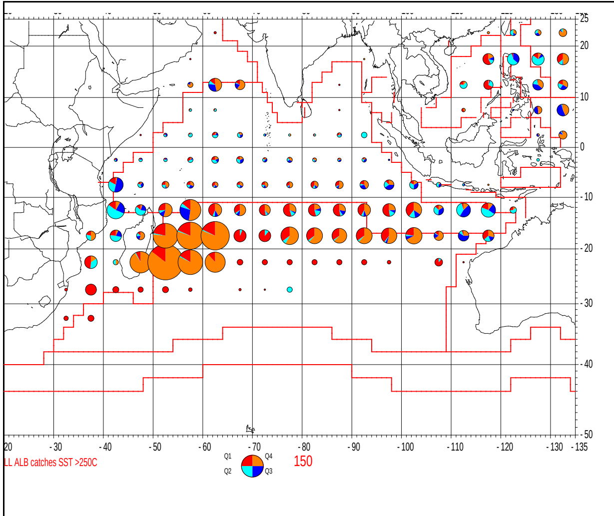


Figure 28: Quarterly catches of albacore by longliners, predominantly large fish, caught in warm SST waters >25°C, potential spawning strata.

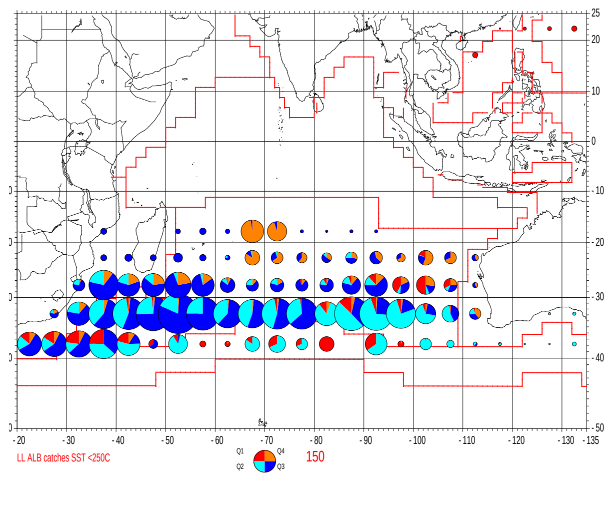


Figure 29: Quarterly catches of albacore by longliners, predominantly large fish, caught in cold SST waters <25°C, potential feeding strata.

Another typical characteristic of albacore fisheries is their dominant positioning in deep waters that are showing high rates of oxygen over 4 ml/l at 200 m, see figure 30, that are typical of the oceanic gyres, while other tuna species such as YFT and BET are commonly caught at much lower rates of oxygen.

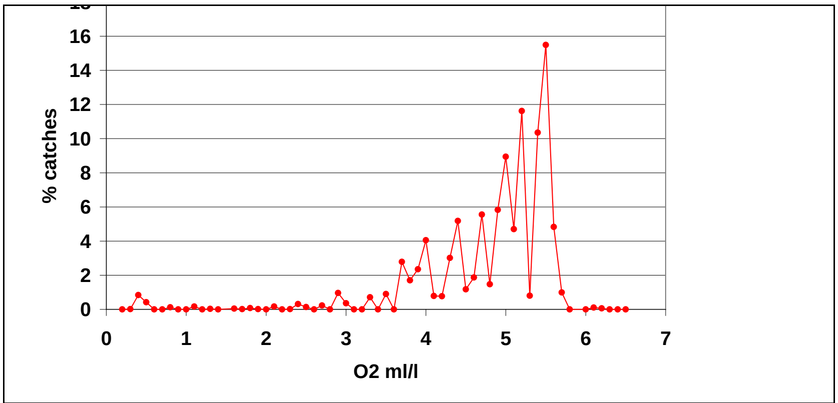


Figure 30: Average catches of albacore during the 1967-2013 period, as a function of oxygen rate at a depth of 200 meters (estimated at a 5°-quarter scale)

Then the geographical configuration of oxygen rate at depth is clearly an important factor conditioning the geographical distribution of a temperate tuna such as albacore. As a consequence, all the LL fishing efforts that are exerted in the equatorial areas or in deep waters with low oxygen rates will never catch significant amount of albacore.

Received: 1 June 2015

3-2-4- Species composition of LL catches in the core albacore area

The analysis of the catch and effort files by 5° squares is showing that major changes of species composition of Taiwanese LL catches have been observed since 1990 in their core albacore area. While albacore has been permanently the dominant species in the catches of Taiwanese LL in the core albacore area during the early 1967-1987 period (figure 31), it appears that a wide range of other species (YFT, BET, SWO & SBT) have been often targeted and caught since the late eighties by this fleet in some part of the the same albacore core area (figure 32). While albacore was in weight and in value the dominant species during the 1967-1988 period in the albacore area (about 70% of the value of the total catches in weight), these albacore catches correspond to only 55 of total catches since 1986, while its average value can be estimated at only about 30% of the total value of the total catches in this strata.

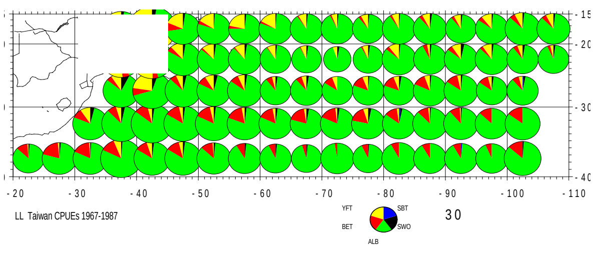


Figure 31: CPUEs of Taiwanese LL by species during the average period 1967-1987

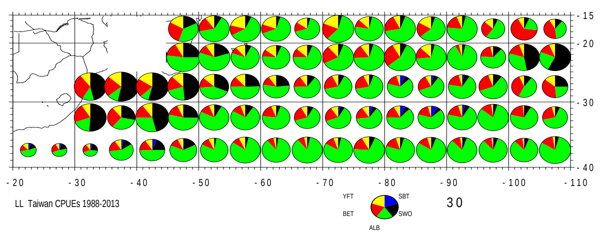


Figure 32: CPUEs of Taiwanese LL by species during the average period 1988-2013

An average fishing map showing the species composition of the average catches by Taiwanese LL during recent years (2010-2013) is showing very well the change observed in the species targeting observed in the albacore core fishing zones (figure 33): while in the central southern Indian Ocean (between 45 & 70°E) albacore tend to be the widely dominant species in the catches of all the 5° squares fished, the south eastern and south western of this core albacore area are showing a wide range of species caught in addition to albacore. Swordfish and tropical tunas being the target species in the west, while southern bluefin and BET are probably the main target species in the Eastern area for Taiwanese LL, because of their high value on the sashimi market (on the opposite most albacore catches are sold to canneries at much lower prices): the value of a large SBT is approximately 10 to 20 times higher than the value of an average albacore!

There should be no doubt that the increased targeting of these alternate species that are of much higher value in the market have produced a decline in the albacore CPUE: the albacore nominal CPUEs as well as the CPUEs standardized by the today method.

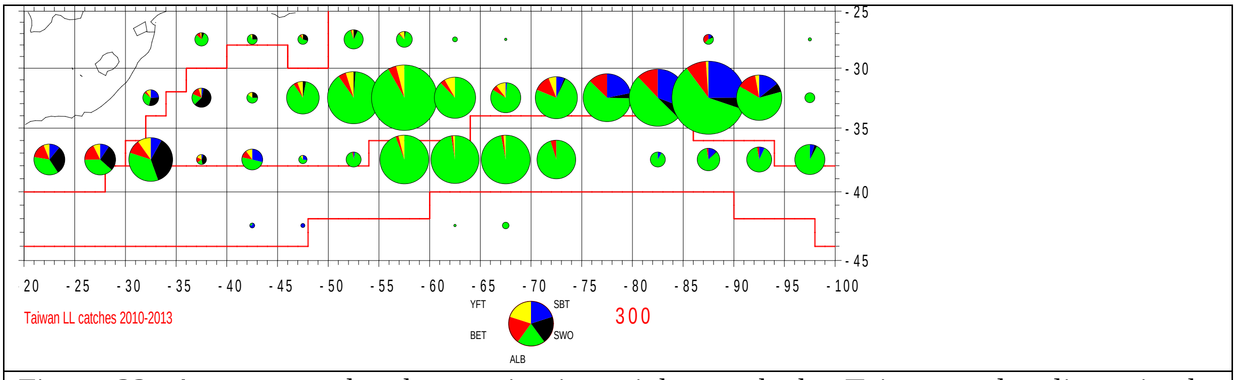


Figure 33: Average catches by species in weight caught by Taiwanese longliners in the southern Indian ocean during recent years, 2012-2013 period.

These major changes in the species composition of the catches may be explained by a combination of 2 factors: (1) a decline in the abundance of albacore, or/and (2) changes in the species targeting. Based on our knowledge of the LL fisheries and of their great capability to modify their species targeting, our favourite hypothesis would be that these change in species composition and the corresponding brutal decline of albacore CPUE observed since 1986 were primarily due to the 2nd reason: changes in the targeting by Taiwanese longliners, and secondarily changes in the stock biomass (due to increased catches). This question is of major importance because all stock assessment models have their biomass mainly driven by these questionable Taiwanese CPUEs based on the hypothesis that CPUE=Biomass.

3-2-5 Nominal and standardized yearly albacore CPUEs

Our nominal albacore CPUEs can be compared with the nominal and with the standardized CPUEs proposed by Taiwanese scientists (Lee et al 2014). These CPUEs of Taiwanese LL are showing distinct trend and levels between the early period 1967-1987 & late period 1988-2013. It should also be noted that the GLM and the nominal CPUEs are nearly identical, both CPUEs showing large fluctuations of CPUEs up&down during the 1980-2000 period: « **YOYO cpues** »… This variability of CPUEs cannot be representative of fluctuations in the stock biomass: such an albacore stock and its 10+ cohorts of adult biomass are showing very little yearly variability.

In such context, it should be concluded that these albacore CPUEs are solely conditioned by changes in the Taiwanese LL fishery and/or by yearly anomalies in the availability of the albacore stock to longliners, and not at all by changes in the stock biomass. They should not be used in any stock assessment model or solely with a light weight.

It should be noted and kept in mind that the albacore CPUE obtained by the 2 fleets in this albacore core area were widely different during most years (as it was shown by figure 22): much lower CPUE of Japanese LL during the 1967-2004 period, as this fishery was targeting other species in this area, but taking note that very similar albacore CPUEs have been observed for the 2 fleets in the core albacore area during recent years (same figure 22), very similar species composition being now observed for the 2 fleets during recent years.

One of the major changes observed in the Taiwanese LL fisheries in the Indian Ocean have been the major decline in the percentage of its albacore catches: the Taiwanese fleet is now targeting a wide range of mixed species (albacore, but also SWO, YFT, BET, SBT & others) while albacore was its main target species until 1986. The decline of Taiwanese albacore CPUEs may also be due to changes in the efficiency of the LL fleet targeting albacore (Eric Chang, personal com.). This potential reduction of efficiency would be due to changes in the fleet targeting albacore: since the late seventies the albacore stock was exploited by a mixture of old traditional LL and by modern deep freezing LL, while during recent years the modern & more efficient longliners have been more and more targeting the higher value deep frozen sashimi species (YFT, BET and SBT), leaving the older traditional LL and their lower & declining efficiency in the lower profile of canned albacore fishery. This change in the LL fleet has been also probably producing a decline in the albacore CPUE of Taiwanese LL. This effect should be easily estimated if the type of the longliners was identified & introduced in a CPUE standardization that should be done at the set by set level

Comparing standardized & nominal albacore Taiwanese CPUEs in the core albacore areas

CPUE standardization used in the assessment was done by Taiwanese scientists at a 5°-month level, not on the set by set basis. The comparison between nominal & standardized CPUEs shows that the standardization of CPUEs had very little or no effect to correct potential bias in the nominal CPUEs: nominal & standardized albacore CPUEs are nearly

identical. While the effects of by-catch rates (of SWO, BET,YFT, SBT) was tentatively incorporated in the Taiwanese GLM, the similarity between nominal & standardized CPUEs is a strong proof that the effect of changes in target species had not been well incorporated in the GLM. The increased catches of additional target species since the late eighties do correspond in fact to major changes in the species targeting, and probably to a major decline of the albacore targeting & catchability, not simply to increased rates of by-catches. As an example, there are no albacore caught in the SWO targeting and most often very few albacore when LL are targeting SBT, and even in the core albacore area !
Recommendation: LL CPUE standardization should only be done on a set by set basis, and based on an *a posteriori* clear identification of the target species of each set

3-2-6. Nominal fishing effort targeting albacore: In&Out the core areas

The total nominal fishing effort exerted in the albacore southern IO areas can be estimated for all LL fleets targeting albacore, based on all the LL fishing efforts declared in the albacore core area, & in a 2nd step these visible efforts in the core albacore area are extrapolated to the total albacore fishing efforts: multiplied by the ratio of albacore total catches/albacore catches of LL with these known effort (with C/E data), see figure 34.

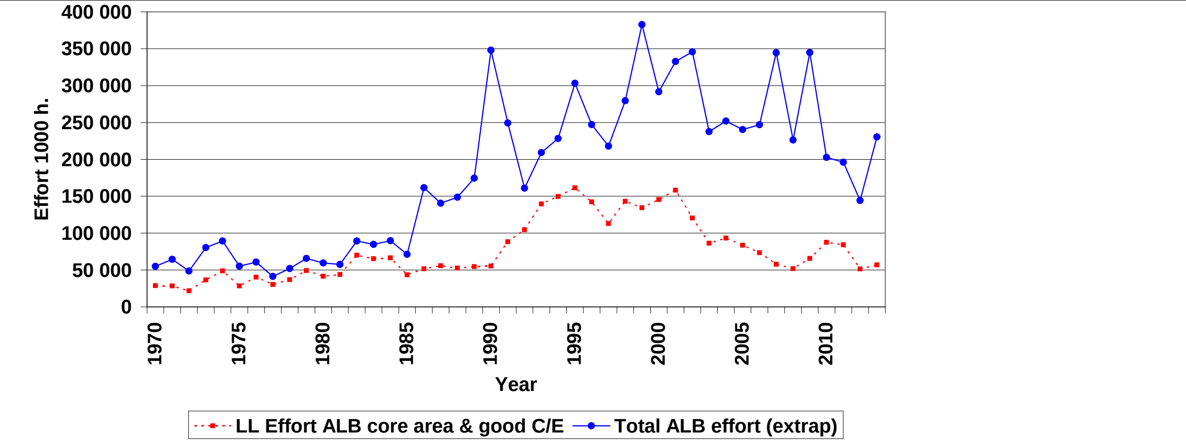


Figure 34: Fishing effort of LL in the core albacore area and estimated total effort targeting albacore (all areas and all fleets)

These estimated nominal albacore fishing efforts remain quite stable since 1990, for instance at levels similar to the fishing effort in the nineties, or even declining during recent years. This result is in agreement with the trend of fishing mortality estimated by the SS3 model (figure 38), but it is somehow in contradiction with the IOTC SC 2014 report statement that:

« *The impacts of piracy in the western Indian Ocean has resulted in the displacement of a substantial portion of longline fishing effort into the traditional albacore fishing areas in the southern and eastern Indian Ocean* ».

This important conclusion would appear to be quite wrong: there is visible move of longliners from the BET/YFT areas (NW Indian Ocean, predominantly deep freezing LL) to the albacore core areas (fishing zones that are clearly much less profitable for oceanic deep freezer longliners) and no major increase of albacore fishing mortality due to piracy in the equatorial western IO. It is also interesting to compare the nominal efforts exerted by the longliners by the main 2 flags, Taiwan & Japan, in the core albacore area (figure 21). This comparison is showing that since 1967 similar levels & trends of nominal fishing efforts have been exerted by Taiwanese & Japanese LL in the core albacore area since 1967, see figure 35.

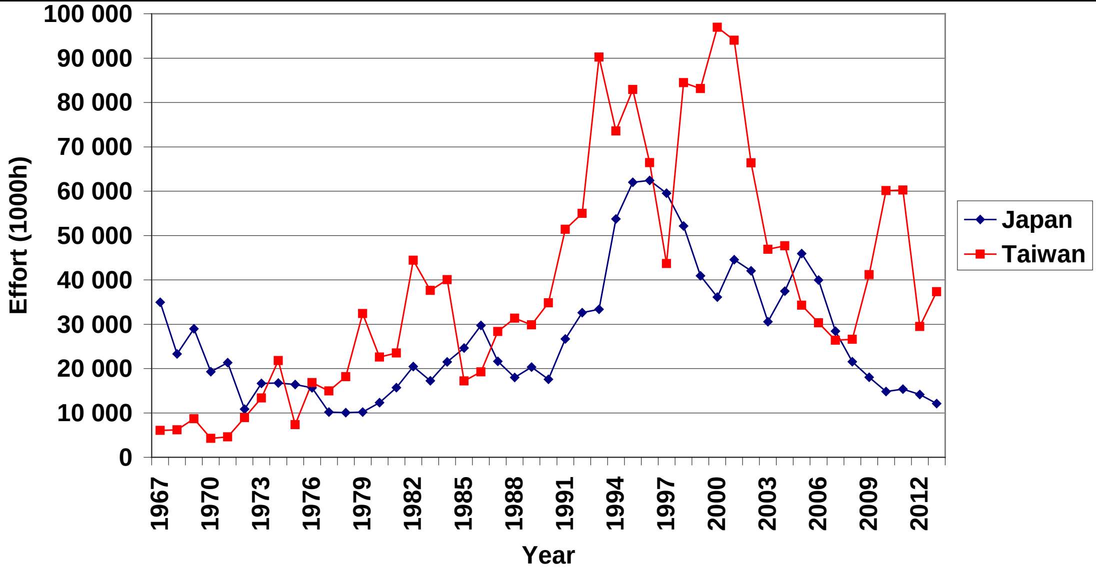


Figure 35: Nominal fishing effort exerted by Japanese and Taiwanese longliners in the core albacore area of the Indian ocean

4- Main results of the 2014 stock assessment results

4-1- Stock assessment results in 2014

These results can be summarized by the following quite pessimistic conclusion of the 2014 diagnosis by the SC:
« Current catches (38,297 t in 2012) are below the current estimated MSY levels from both SS3 & ASPIC models, 47.600 et 34.700t. However, maintaining or increasing effort will likely result in further declines in biomass, productivity and CPUE. The available evidence indicates considerable risk to the stock status at current effort levels ».

Various stock assessment models have been tentatively used by the albacore WG in 2014, but the 2014 executive summary on the status of the albacore stock was primarily or only based on the results of the SS3 model, and these results have been taken from the Hoyle et al. 2014 document. In the SC report and its executive albacore summary, the diagnosis provided by this SS3 model is visible only in its Kobe plot (figure 1) that is summarizing its results in term of the estimated changes in the biomass and fishing mortality relative to their estimated MSY levels. However, these results are presented as a cloud of uncertainty and on its median value, based on multiple runs of the SS3 model, these various models being based on a wide range of real uncertainties in the data and hypothesis. As a consequence, there is not any base case run in these multiple SS3 results: the selected line and selected MSY and F MSY are simply the median of the cloud of uncertainty and then it is impossible to obtain, to show and to examine all the detailed basic results of such base case model: for instance showing the more realistic changes in yearly recruitments, in yearly biomass (total and spawning), of fishing mortality (total and by age), etc..

On the other side, we consider that it is essential to see all these results corresponding to the stock assessment results, are they are essential to understand the results of the best model(s), and also their potential bias and dysfunction: the results of such complex statistical model should not be accepted by scientists as a miraculous black box, simply based on their Kobe plot.

In order to progress in the understanding of the best SS3 results, we have obtained from Simon Hoyle and from Rishi Sharma the detailed results of 2 SS3 models that could be considered as being close to the median (2 models based on an assumed M of 0.22, the value recommended by the IOTC report and of M=0.3). Our discussion of the SS3 results will be done based on these 2 series.

4-2- Estimated yearly recruitments

Moderate decline are estimated for the estimated recruitments: between 15 and 33% comparing the 1950-1985 and 1986-2012 periods in the 2 selected cases.

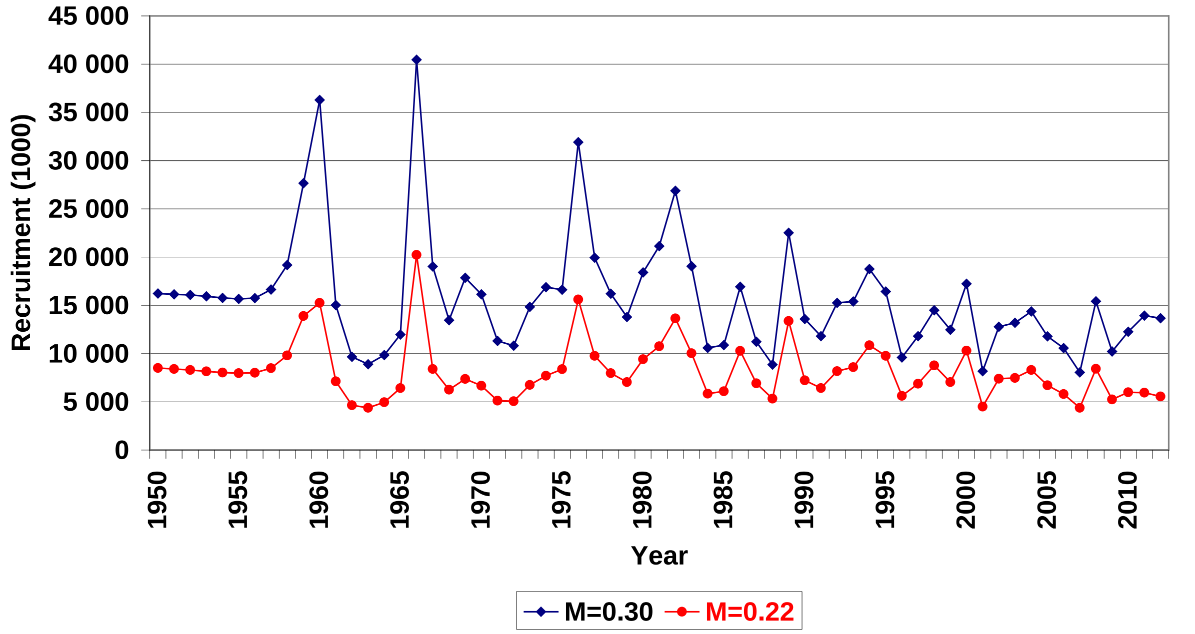


Figure 36: Yearly recruitments estimated by 2 runs of the more realistic SS3 models

There is a surprisingly large variance of the albacore recruitments estimated by SS3 during the early period 1950-1985 of low catches and stable fisheries catching large albacore…. but without size data! It is hard to understand the statistical causes of such variance, but it may be widely due anomalies in the SS3 model?

4-3- Estimated yearly biomass

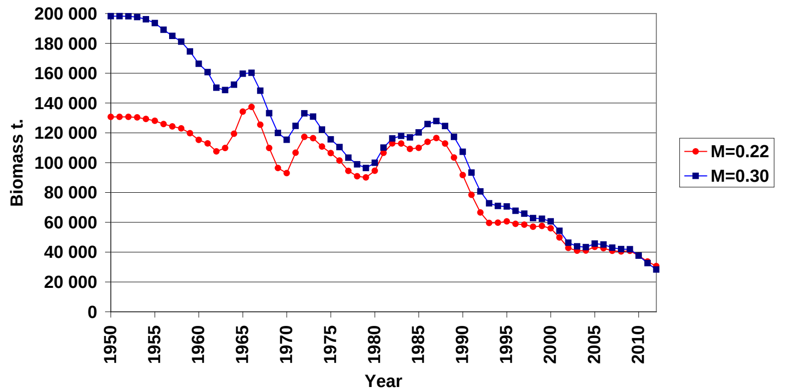


Figure 37: Yearly spawning stock size estimated by 2 runs of the more realistic SS3 models

Received: 1 June 2015

The albacore adult biomass estimated by SS3 and Taiwan LL standardized CPUE (monthly average in 2 E & W core albacore area) is showing a steadily declining SS3 biomass, primarily driven by the Taiwanese CPUEs. Very low adult biomass are estimated by SS3 during recent years: such very low levels close to zero would be a source of worry if they are shown to be realistic ones.

4-4- Estimated yearly Fishing mortality

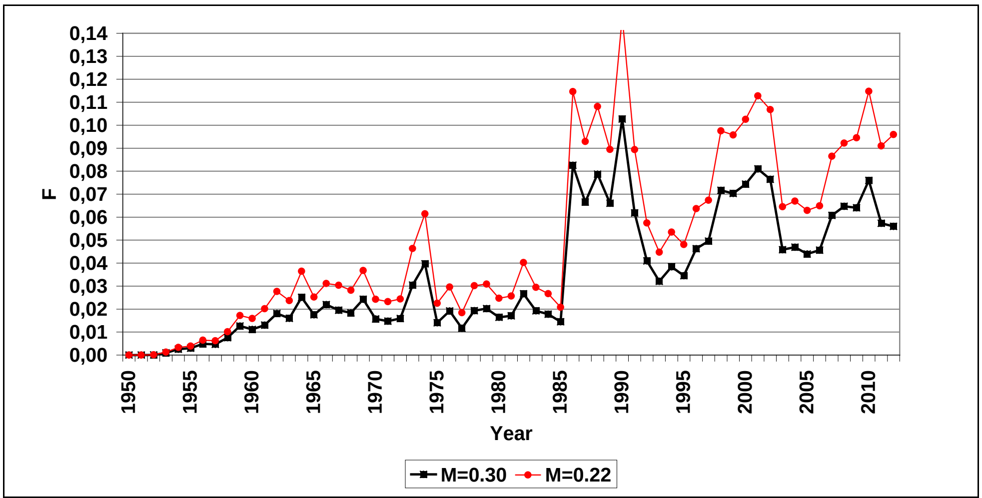


Figure 38: Yearly average fishing mortality (ages 1 to 12) estimated by 2 runs of the more realistic SS3 models

Quite low level of F have been always estimated by SS3: this is a logical result because of the low apparent Z in the catch at size and catch at age table (and because of the low F exerted on juvenile albacore). Increasing F estimated since 1986: a logical increase due to the increasing catches during this period (figure 10) and much higher Fishing mortality estimated by SS3 since 1986, following a 1960-1985 period of very low F. In most results Recent F was estimated to be lower than F MSY, but very close to it, while F in excess of MSY were also estimated in several SS3 runs.

5-Discussion

The main results of the albacore stock assessment conducted by the IOTC in 2014 would appear to be widely questionable and possibly wrong because of serious problems as :

Serious problems in the basic IOTC albacore data:

- missing **catch at size of the gillnet fisheries**: the Gillnet fishery and its very large catches during the 1986-1991 period had questionable data in the today analysis (see parag. 3.2.2). The IOTC should recover the Taiwanese sizes submitted to the IPTP 20 years ago, and use this data set in its future analysis. The sizes of the significant catches by the other gears remain totally questionable, and this uncertainty should be fully explored

- errors in the historical Taiwanese data: catch and effort or total catches? These errors have been examined by the IOTC staff in various documents, but not in its most recent review of the albacore data (an IOTC 2014). As a consequence, there are still today major inconsistencies in the Taiwanese data that are used in the albacore stock assessment. These problems are for instance visible during the 1992-1994 period, see table 1.

Received: 1 June 2015

Table 1: Total albacore catches by Taiwan LL as declared by Taiwan to the IOTC and estimated in the catch and effort file in weight for the years 1992-1994.

Year	Total catch	C/E file catches
1992	11 109	19 000
1993	11 968	24 153
1994	14 407	16 874

While the total catches should always be higher that the catch and effort data set (that are based on a sample of log books), this is not the case during this period, and by far: total albacore catches in the catch & effort file of Taiwanese LL being much larger than the declared total catches. Several other problems have been identified in the Taiwanese data that are essential in the analysis of the albacore stock because Taiwanese fleets have been catching more that 50% of the IO albacore catches since 1967.

Recommendation: the basic catch and effort data set of the historical Taiwanese LL fisheries should be carefully validated and corrected as much as possible before the next albacore WG by Taiwanese scientists

Major basic questions in the albacore CPUEs used:

Our analysis would allow to conclude that the major decline of Taiwanese CPUE observed for Taiwanese LL in the late 80^{ies} was probably artificial and not related to a major decline of the adult stock biomass: this a typical bias faced by many Tuna Stock assessement analysis where changes in fisheries that are not well handled by the stock assessment model have been creating false trends in estimated tuna stocks (Fonteneau et al 1998). As a consequence, it could easily be hypothesized that many of the quite pessimistic results obtained by SS3 model may have been widely driven by the artificial decline in the Taiwanese LL albacore. This decline of nominal & of standardized CPUE was real, but probably due to a combination of 3 factors:

- The major change in the targeting of this LL fisheries that have not been corrected by the today CPUE standardisation, There is clearly a deep need to analyze CPUE in a multispecies context, preferably in US dollars and necessarily on a set by set basis, not as today on a 5°-month basis.
  - The massive shift observed for Taiwanese longliners from its traditional LL freezers fishery toward small ice LL poorly followed by statistics.
  - The decline in the deep freezer longliners in the albacore areas

As a consequence, all the results of the today stock assessment driven by this declining adult CPUEs are widely or totally questionable & probably wrong. A major research effort should be developed on the detailed catch and effort Taiwanese data in order to estimate CPUEs that could be representative of albacore densities and biomass in the Indian Ocean.

Similar case of real changes in the LL fisheries that are creating artificial changes in the tuna stocks have been shown worldwide following the discovery and implementation by Japanese vessels of the deep longline between 1978 & 1981: this new more efficient fishing mode has been producing world wide large increase in the BET Japanese standardized CPUEs (that have been most often used in the BET stock assessment), creating in the results of most stock assessment models (as in the IO) an artificial increase of the BET adult biomass. There is no doubt that in reality the adult BET biomass has not been increased by the introduction of deep LL, but that all BET stocks suffered since the late seventies a severe increase of the fishing mortality due to increase the increased efficiency of the deep LL, and decreased adult

Received: 1 June 2015

biomass. The increase of the BET biomass estimated in the late seventies by most/many of the stock assessment models results is clearly artificial.

Natural mortality assumed?

Our overview of this question would tend to conclude that the average level of natural mortality is probably low or very low, for instance close to 0.2, and that it should be higher for juvenile than for adult albacore. The level and trend of natural mortality at age estimated by the Lorenzen method would appear to be realistic and it should preferably be used. The constant level of M or the too high levels of M should not be used in future stock assessment because they are inconsistent with the longevity and the albacore catch at age table.

5- Conclusion

Our conclusion is that the increase of effort targeting albacore during recent years would have been quite moderate and that the steady decline of the albacore CPUEs since the late sixties were mainly by changes in target species, and not by a declining recruitment and a decline of the adult biomass. In such context, the albacore stock is possibly/probably in better shape than it was estimated by the 2014 IOTC WG and SC, possibly a stock not yet reaching its MSY? The albacore stock assessment analysis has been clearly facing in 2014 a well identified basic problem that has been often faced by tuna stock assessments models: artificial changes in the estimated tuna stocks are created by real but uncorrected changes in the fisheries (Fonteneau et al 1998). These vicious changes in the fisheries should be permanently envisaged & tracked by scientists, as they constitute a frequent & serious trap and danger in many tuna stock assessment ! New more realistic CPUEs & new stock assessment analysis are deeply needed to estimate the real stock status: there is a deep need to incorporate in the calculation of specific standardized CPUEs (1) the real changes in the multispecies targeting of the LL fisheries and (2) the type of the longliners active in a well chosen albacore strata: deep freezer, -18°C or ice. Real albacore sizes caught by the historical driftnet fisheries should be incorporated in the analysis. The landing value of each species should also be incorporated in future CPUE analysis, as they have been always conditioning the targeting of all LL fisheries, especially in such longline fishery where the value of each individual caught tend to be highly variable. Comparison between oceans should also be usefully conducted, as they could be very informative to better understand changes in the albacore tuna fisheries, tuna stocks and tuna stock assessment results: the albacore fisheries & albacore stocks appear to be very similar worldwide!

Furthermore, is should also be concluded that well handled MSE simulations or SEAPODYM modelling could probably allow a better understanding of alternate and possibly more realistic of the real dynamics of the albacore stocks & fisheries.

Acknowledgments

Our most sincere acknowledgments are given to Dr Evgueny Romanov for the valuable ideas and comments given to us upon this complex problem of the albacore biology, fisheries and stock assessment work.

Received: 1 June 2015

Cited bibliography

An. IOTC 2014. Review of the statistical data and fishery trends for albacore. 2014–WPTmT05–07, 28p.

An IOTC 2014. Report of the Fifth Session of the IOTC Working Party on Temperate Tunas IOTC–2014–WPTmT05, 53p.

Alonso C, Arrizabalaga H, Restrepo VR. 2005. Contribution of a chapter on Albacore tuna for the revised ICCAT field manual. Collective Volume of Scientific Papers. ICCAT 58(5): 1646-1661

Bach P. and A. Fonteneau 2005. Historical shifts in hooks between floats and potential target species of the Japanese longline fishery in the equatorial Western Indian Ocean. IOTC-2005-SC-INF016[EN], 12p

Bard FX. 1981. Le Thon Germon (*Thunnus alalunga*, Bonnaterre 1788) de l'Océan Atlantique. De la dynamique des populations à la stratégie démographique. Thèse de Doctorat d'Etat. Université Pierre et Marie Curie. Paris XI

Bard F.X., S. Yen, and A. Stein. 1999. Habitat of deep swimming tuna (Thunnus obesus, albacares, alalunga) in Central South Pacific. Col.Vol.Sci.Pap. ICCAT, 49 (3) : 309-317

Chen KS, Crone PR, Hsu CC. 2010. Reproductive biology of albacore *Thunnus alalunga*. Journal of Fish Biology 77(1): 119-136

Fonteneau A., D. Gascuel et P. Pallares 1998. Vingt cinq ans d 'évaluations thonières de l'Atlantique : quelques réflexions méthodologiques. J. Beckett Ed. Actes du symposium ICCAT de Punta Delgada. Rec. Doc. Scient. ICCAT Vol. L(2) ; pp 523-562.

Fonteneau A. 2010. Potential indicators of fishing efforts targeting yellowfin and bigeye tuna exerted by Japanese and Taiwanese longliners in the Indian Ocean. Document IOTC-2010-WPTT-28, 9p.

Hoyle S.D. 2008. Adjusted biological parameters and spawning biomass calculations for albacore tuna in the south Pacific and their implications for stock assessments. WCPFC-SC4-2008/ME-WP-2 , 20p.

Hoyle S.D., R. Sharma & M. Herrera 2014. Stock assessment of albacore tuna in the Indian Ocean for 2014 using Stock Synthesis. Doc. IOTC–2014–WPTmT05–24

Lee Y.C. and H.C. Liu 1995. An updated virtual population analysis of the Indian Ocean albacore stock, 1980-1992. IPTP collective Vol. 9(3): 267-278.

Lee, L.-K., C.-C. Hsu and F.-C. Chang (2014). Albacore (*Thunnus alalunga*) CPUE Trend from Indian Core Albacore Areas based on Taiwanese longline catch and effort statistics dating from 1980 to 2013.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in fish: a comparison of natural ecosystems and aquaculture. J. Fish Biol. 49: 627–647.

Matsumoto T., T. Nishida & T. Kitakado. 2014. Stock and risk assessments of albacore in the Indian Ocean based on ASPIC. 2014. IOTC–2014–WPTmT05–22

Nishida, T., T. Matsumoto and T. Kitakado (2012). Stock and risk assessments on albacore (*Thunnus alalunga*) in the Indian Ocean based on AD Model Builder implemented Age-Structured Production Model (ASPM).

Pons M. and A. Domingo 2012. CATCH, LENGTH AND SEX COMPOSITION OF ALBACORE, *THUNNUS ALALUNGA*, IN THE SOUTHWESTERN ATLANTIC. Collect. Vol. Sci. Pap. ICCAT, 68(2): 529-545

Santiago, J. and H. Arrizabalaga (2005). "An integrated growth study for North Atlantic albacore (*Thunnus alalunga*, Bonn. 1788)." ICES Journal of Marine Science 62(4): 740-749.

Zavala Camin L.A. 1978. Distribucion del Atun blanco (*Thunnus alalunga*) en el sudeste y sur del Brasil 1969-1977. B. Inst. Pesca, Sao Paulo 5(1), 26-39.

Wells, R. J. D., S. Kohin, S. L. H. Teo, O. E. Snodgrass and K. Uosaki (2013). "Age and growth of North Pacific albacore (*Thunnus alalunga*): Implications for stock assessment." Fisheries Research 147: 55-62.

Williams, A.J., Farley, J.H., Hoyle, S.D., Davies, C.R., Nicol, S.J. 2012, Spatial and Sex-specific Variation in Growth of Albacore Tuna (*Thunnus alalunga*) across the South Pacific Ocean. PLoS ONE 7(6)

Received: 1 June 2015

Annex: Main basic recommendation targeting the next stock assessment

The following recommendations could help to avoid the various pending questions that have been identified in the present work but that are not so much visible in the IOTC albacore report.

1) There is a deep and urgent need to conduct more active biological studies on albacore, for instance to evaluate growth by sex, the potential mixing between Atlantic and Indian Ocean stocks, and the sex ratio at size on purse seiners and longliner catches, and in a wide range of fishing areas.
2) A need to summarize and to show better in the albacore WG report the main characteristics of the albacore biology and of the changes in the albacore fisheries (adding figures, tables and discussion)
3) A deep need to correct as much as possible and before the next albacore WG, the basic catch and effort data set of the historical Taiwanese LL fisheries(priority 1992-1994 period) and to fully recover the size data of the historical Gillnet fishery (Taiwanese scientists)
4) A need to do a new stock assessment analysis of the albacore stock based on improved data and improved selected hypothesis (for instance new CPUEs more representative of stock biomass, new CAS and new natural mortality at age).
5) A need to identify in the stock assessment results **a base case model** based on a selected set of best data and hypothesis chosen by the experts, and not solely the median of a wide range of heterogeneous uncertainties, many of them being too wide and widely unrealistic.
6) Stock assessment results: a need to see the basic figures that are showing the main results corresponding to this base case assessment model, for instance yearly recruitments, total & spawning biomass, yearly Fishing mortality, fishing mortality at age, etc. These basic results should not remain cryptic as today in the SC report. They should be **fully visible to the SC scientists** and also visible in the executive summaries, & not solely as today the final Kobe plot. Kobe plots are OK to show a final stock assessment diagnosis, but they cannot show the basic parameters leading to it and allowing to understand this diagnosis.
7) These basic selected and well visible results of the stock assessment model should be carefully examined and potentially discussed by the albacore WG and the SC scientists.