A comparative overview of skipjack fisheries and stocks worldwide

Alain Fonteneau

IRD
Victoria, Syechelles

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Summary
This paper develops a comparative analysis of skipjack fisheries and stocks world wide. This study is based on the fishery data collected by the various tuna commissions in the Indian, Atlantic and Pacific oceans, as well as all the scientific data and results upon the biology of this species and on the oceanic environment (sea surface temperature). The trends of the various skipjack fisheries observed world wide are compared (catches by gear and fishing mode, sizes). The geographical distribution of fisheries are compared world wide and analyzed as a function of sea surface temperature. This comparison do allow to better evaluate the biological characteristics of skipjack: growth, natural mortality and movement patterns. The importance of changes in the market value of skipjack is also examined. The paper also compares the status of the various skipjack stocks exploited world wide, as well as the methods used by scientists to estimate these stock status.

Résumé
Cet article fait un bilan comparatif mondial des stocks et pêcheries de listao. Cette étude est basée sur les données halieutiques collectées par les diverses commissions thonières actives dans les océans Atlantique, Indien et Pacifique. Elle utilise aussi les données biologiques collectées sur cette espèce ainsi que certaines données d’environnement (températures de surface). Les tendances des diverses pêcheries de listao sont comparées mondialement (prises par mode de pêche, taille des thons). La distribution géographique des captures de listao en fonction de la température de surface est examinée. Sont aussi évaluées et discutées les caractéristiques biologiques du listao (croissance, mortalité naturelle et déplacements) dans chaque région. L’importance des changements dans la valeur économique du listao et ses effets éventuels sur les pêcheries sont aussi examinés. L’article se termine en analysant l’état des divers stocks de listaos exploités mondialement, de même

1 Fonteneau Alain, IRD scientist, PO Box 570, Victoria, Seychelles
that methods employed by scientists to evaluate the state of these stocks.

1-Introduction

Skipjack (*Katsuwonus pelamis*) inhabits all the warm waters of the Oceans: Pacific, Indian and Atlantic oceans, the genetic heterogeneity between oceans being apparently quite low (Graves and Dizon 1986). The history of skipjack fisheries and the present levels of exploitation of skipjack stocks is quite different in each ocean: while the Eastern Pacific and Atlantic oceans were already quite heavily fished during the early eighties, the Indian and west Pacific oceans skipjack were still quite unexploited by industrial fisheries during the period. The goals of this paper will be to do a comparative analysis of skipjack fisheries and of skipjack stocks in the four major oceanic basins, namely the Eastern and Western Pacific, the Indian and Atlantic oceans. One of the interests of such comparative studies is to better evaluate the basic biological characteristics of skipjack and its reaction to an increasing exploitation worldwide. The Indian Ocean scientists can expect a major scientific input from such a comparison because the level of researches and analysis done on skipjack is much higher in all the other oceans. The final goal of this comparison will be to provide some new positive inputs to the stock assessment work conducted upon skipjack by the IOTC in its June 2003 meeting of the tropical tuna working group.

2- Fishery data

2-1- Data sources

All the fishery data (catches, efforts and sizes) have been built and circulated by the various tuna Commissions and bodies, namely the ICCAT for the Atlantic data, the IOTC for the Indian Ocean, the IATTC for the Eastern Pacific and the SPC for the Western Pacific (the limit between the Eastern and Western Pacific being at 150°W). The FAO data base (“the atlas”) has also been used in some cases; the environmental data are the sea surface temperature taken from the Levitus and Boyer 1994 Atlas and CD ROM. Various tagging and recovery data obtained from various tagging agencies and scientists (namely the IATTC W. Bayliff, the SPC J. Hampton, the ICCAT P. Kebe and Maldives S. Adam. The skip jack catches taken by Japanese longliners world wide by areas were also kindly provided to us by the Shimizu laboratory (Z. Suzuki)

2-2- Catch trends by ocean

Figure 1 shows the trend of total skipjack catches in each of the 4 areas used in this comparison. The most productive area for skipjack has always been the western Pacific Ocean (or WPO) with recent catches over 1.2 million tons, following 30 years of steadily increasing catches. The Indian Ocean is ranking number 2 with catches reaching 0.4 million tons during recent years, and after 20 year of steady increase. In the Eastern Pacific (EPO) and Atlantic oceans skipjack catches have been showing a relatively stable trend during the last 25 years, showing a slow and minor increase rate that is quite similar in the two areas (and also with comparable levels of skipjack catches)

2-3- Catches by gear and fishing mode

Purse seine is the major gear catching skipjack tunas: a wide majority of skipjack catches is taken world wide by this gear (EPO 99%, Atlantic 60%, Indian 50%, WPO 80%). A majority of these skipjack catches are taken under Fish
Aggregating Devices (natural or artificial, most often drifting) see figure 5. This percentage of FAD associated skipjack is highest in the Indian Ocean (average of 83% during the last 10 years), and lowest in the WPO (average of 63% during the last 10 years). Percentages of FAD associated skipjack are also high in the EPO (67%) and in the Atlantic (63%), but in this ocean this percentage has been lowered by the seasonal moratorium on FAD fishing developed in the Atlantic since 1997. However, various other gears are also catching this species:

- Drifnet and other artisanal gears are active in the Indian Ocean and represent about 27% of recent skipjack catches (period 1992-2001), but, they are not significant in all other areas.
- Pole and live baitboat vessels are also active worldwide in the skipjack fisheries, catching about 21% and 40% respectively of recent total skipjack catches in the Indian and Atlantic Ocean. This gear is also active to catch significant quantities of skipjack in the WPO, and its catches have been reaching stable levels of about 250,000 tons of skipjack during the last 30 years. Baitboat catches in the EPO have always been negligible.
- Longliners are also catching some minor quantities of skipjack, most often at large sizes. These catches are not significant in terms of quantities taken, but these fishes are large adults taken in deep waters and they are interesting to show the geographical distribution and ecology of large skipjack. The average cpue of skipjack obtained by Japanese longliners during the period 1960-1995 are indicative of the distribution of these large and deep adult skipjack (figure 3) It can be noticed that these large skipjack are taken in an area wider than the area where the surface fisheries are active. It can also be noticed that skipjack is very seldom caught in all the areas where extremely low rate of oxygen are observed at 100 m (for instance in the equatorial EPO or the Arabian sea). The typology of this skipjack fishery by longliners has been well analyzed by Marcille and Suzuki 1974.

2-4- Fishing zones, sizes of area fished and catches by area

The main fishing zones of skipjack are given on figure 2. This figure well show the relative importance of the two western basins of the Pacific and Indian oceans, and the lower levels of productivity observed during recent years in the EPO and Atlantic oceans. The fact that a majority of skipjack catches are taken in equatorial waters, with various exceptions of significant fisheries active at more temperate latitudes is also apparent from this map. The size of the areas fished in each of these oceanic basins is given by figure 7 in terms of numbers of 5° squares fished (with a catch >50 tons) and by figure 8 in terms of the surface fished expressed in 1000 nautical miles². These two figures shows that the WPO is by far the largest area fished for skipjack (more than 10 Million nautical miles² fished), followed by the EPO with more than 7 Million nautical miles² fished during recent years (since 1995 following the westward expansion of the FAD fishery). The area fished in the Indian and Atlantic Oceans are similar, about 4 Million nautical miles². Based on the data concerning total catches and sizes of the area fished in each ocean, it is easy and interesting to calculate the average catches per fished area. This result is given in figure 9. The highest catch per area fished has been taken since the early nineties in the WPO (about 100t/1000 sq. miles), followed by the Indian ocean (about 75t), the Atlantic (about 40t) and the EPO (about 20t). It can also be noted that until the early nineties this productivity per area was similar in the Indian ocean and the WPO.

2-5- Sizes of skipjack taken in each ocean
The average sizes of skipjack taken in each ocean by the major gear, purse seiners, are given in weight in figure 11. Skipjack taken during recent years in the Indian and Atlantic oceans tend to be much smaller (respective average weight of 2.1 and 2.9 kg) than skipjack taken in the Western and Eastern Pacific (respective average weight 4.1 and 4.0 kg). It is also quite striking to notice the great similarities between the histograms of sizes taken, on one side in the Atlantic and Indian oceans, and on the other side in the Eastern and Western Pacific. The similarities between the Indian and Atlantic oceans are possibly in relation with similarities in the growth patterns observed in the two oceans (the Atlantic showing lower sizes because of its higher exploitation rates?). It can be noted that sizes of skipjack taken in free schools and in FAD associated schools tend to be very similar, in the Indian and Atlantic Oceans as well as the WPO: the free schools skipjack tend to be larger in free schools than in FAD associated schools, but this difference tends to be a minor one (see figure 12). This situation is different from the case observed world wide for yellowfin where FAD associated fishes are always much smaller.

2-6- The economy of skipjack fisheries
Skipjack tuna is the major tuna species used by the canneries, nearly all the skipjack catches being used in the canning industry, and skipjack being seldom used as a fresh fish. The value of skipjack has been widely fluctuating during the last 30 years, being sold at high prices during some periods, or at a very low price during others (fluctuating in a 1 to 4 range of value, after taking into account the correction for inflation). These price changes tend to be parallel world wide on all the markets, for instance showing similar heights during the mid seventies when skipjack was precious to reduce the rate of mercury in tuna cans, or similar lows in 2000 when the world skipjack market was depressed because of its overproduction. These wide changes in relative market value may have been an important factor conditioning the targeting of skipjack by purse seine fleets. It should be useful to incorporate the landing values of skipjack (and also of yellowfin) in some biological analysis as this parameter may widely explain some changes in the catch rates and in the targeting of skipjack tunas by the various purse seine fisheries.

3- Skipjack biology
3-1- Relationship between skipjack catches and its environment
The geographical distribution of skipjack catches world wide confirms that this species is typically a warm water species that is predominantly taken in the warm ecosystems: either the equatorial ecosystems, or their warm coastal derivatives such as the Kuroshio, the Agulhas and the Brazil currents (figure 2). Skipjack tuna are seldom caught and they are probably rare in the mid oceanic gyres. A majority of skipjack catches are taken world wide in warm waters at SST over 24° C (an average of 85%), a small percentage being caught in more temperate waters in a range between 18 and 24°C at lower latitude (for instance in New Zealand, Azores and the south of Brazil). It has been well demonstrated in the Pacific ocean that skipjack populations are widely driven and mobile at an oceanic scale as a function of the large scale anomalies (El Niño) (Lehodey 1997). This type of environmental effects may also occur in other oceans, taking into account the fact that these anomalies are probably less important outside the Pacific Ocean.

3-2- Skipjack spawning
It has been shown world wide that skipjack tunas are spawning very early in their life, at small sizes of 40 to 45 cm (in all oceans). Spawning takes place at an early age of about 1 year; skipjack tunas show a life span of several years, probably less than 5 years (FISHBASE gives an estimate of 4.5 years based upon T₀, k and L), but the real longevity of the exploited stock remains unknown. The spawning appears to take place on an opportunistic basis when these fishes are inhabiting warm waters (for instance warmer than 24°C. These warm waters cover wide areas in each ocean: these average areas have been estimated based on the quarterly SST given by 5° square in the Levitus atlas; the areas estimated are the following (in million nautical miles²):

- Indian Ocean: 10.8
- Atlantic: 10.6
- EPO: 8.9
- WPO: 17.1

For instance, it has been shown by Stequert and Ramcharrun 1996 that skipjack tunas in the Indian Ocean do show a permanent spawning activity, with two spawning peaks during the northwest monsoon (November to March) and during the South East monsoon (June to August). Such spawning tends to produce a continuous recruitment; subsequently the modal structure of size distribution corresponding to identified cohorts are seldom observed for skipjack. When such modal progressions have been identified (as in Marcille and Stequert 1976), this observation is probably in relation with a local recruitment of a fraction of a viscous stock that is resident in a given area during several months. Taking into account the histogram of skipjack sizes taken world wide by fisheries (figure 11), it can be noted that fisheries are predominantly exploiting the adults (spawners) and seldom the juvenile skipjack; this is a positive factor to ensure a better conservation of the spawning stock.

3-3- Skipjack growth

Skipjack growth has been quite well studied by various scientists in each ocean. Various methods have been used to study the growth, but the most convincing results were probably obtained from tagging programs done in each ocean, since modal progressions of sizes taken are rarely apparent for skipjack and otolith daily or yearly rings are most often poorly related to age. The Von Bertalanffy models has been most often used to model skipjack growth, allowing to estimate the 2 parameters k and L used in this model. One of the problems commonly faced in the comparison of these 2 growth parameters obtained in each ocean is due to the statistical relationship between k and L. The likelihood surface of these 2 parameters tend to show a “banana shape”. All the points in this “banana of uncertainty” are statistically very close. It is then quite difficult or impossible to compare a given set of k and L parameters, unless the shape of the banana uncertainty has been fully identified. The comparison of skipjack growth between oceans can only be done comparing positions and shapes of bananas, not single k and L points.

This comparison has been tentatively done, based on the analysis of apparent growth rates of recovered tagged skipjack observed in the Atlantic, Indian Ocean

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2 With the exception of the Marcille and Stequert 1976 growth study based on modal progression and in which the growth parameters can be well compared with the Maldivian growth obtained from tagging, see figure 10;
(Maldives), EPO (IATTC) and WPO (SPC). This statistical analysis\(^3\) is still very provisional and preliminary, but its results indicate that skipjack growth are probably very similar in the Indian and Atlantic oceans, but significantly different in the EPO and WPO (figure 10). This statistical conclusion can easily be confirmed visually with a simple plot of the growth curves estimated in each ocean, and of the apparent growth of recovered skipjack (figure 13, done using the PLOTREC software, Fonteneau and Nordstrom 2000).

It should also be noted that a characteristic of skipjack growth that has been well demonstrated in the Eastern and Western Pacific (Maunder 2001) as well as in the Atlantic (Bard et Antoine 1986) is its spatial variability: in the same ocean, skipjack growth appears to be highly variable as a function of the time and area strata, for instance comparing equatorial and northern and southern tropical areas. It is not clear how much these geographical differences in growth correspond to sub populations or more probably to growth patterns that are typical of each ecosystem as a function of its environment (temperature and food available). As a conclusion, there is probably a potential risk when extrapolating the Maldivian growth curve to the Indian Ocean skipjack stock, as this growth may not be valid in other areas (it can be noted that the Marcille and Stequert 1976 growth obtained in the Mozambique Channel was compatible with the present figures obtained in the Maldives (see figure 10).

3-4- Skipjack movements and migrations

Skipjack is typically a tuna species showing a limited scale of movements. The best knowledge upon skipjack movements has been obtained from tagging results (using dart tags). Similar results where obtained from tagging in all oceans (Pacific, Indian and Atlantic) concerning distances traveled by skipjack: even for skipjack at sea during several month, most of the skipjacks were recovered world wide in a range of less than 1500 nautical miles. This majority of short distance recoveries has also been observed for the Maldivian skipjack recoveries. Transoceanic migrations have very seldom been observed for skipjack. The conclusion is that the skipjack population probably is quite “viscous” (Mac Call 1990) showing in the ocean various fraction of stocks that can mix genetically with the other skipjack of the oceanic population, but which are quite sedentary and isolated in terms of their low mixing rates with the other skipjack fractions of stock. Based on this result, Hilborn and Sibert 1986 made the quite controversial but probably realistic recommendation that skipjack stocks could well be managed at the level of large EEZ.

In the Indian Ocean, taking into account the quite large distances that are all over 1000 nautical miles between the various skipjack fisheries (see figure 4), there is a high probability that these fractions of the population may correspond to quite isolated fractions of stocks. This could well lead the IOTC to do its stock assessment analysis and its management recommendations for skipjack at a regional scale and not at the level of the entire Indian Ocean. Concerning these movements of skipjack, there is also the pending question to know if the present massive seeding of artificial FADs in given areas may or may not alter the “natural” movement patterns of these fishes.

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\(^3\) These preliminary calculations were conducted by Alejandro Anganuzzi from the IOTC, using all the recovery data kindly provided to us by the various tuna Commissions (IATTC, ICCAT ad SPC), and by S. Adam from Maldives. It is planned to finalize this comparative work with scientists from these bodies and to submit a paper on this topic to a fishery Journal.
It is clear that these movement patterns of skipjack and their geographical scales and speed, will widely condition the potential interaction between the various fisheries (for instance between the purse seine fishery operating in the Western Indian Ocean and the Maldivian fishery)

3-5- Skipjack natural mortality

This parameter is essential to evaluate stock status and potential competition between subsequent fisheries. It has always been estimated that skipjack natural mortality was quite high or very high: a stock showing very large levels of recruitment (always accounted in hundred of millions) and a short life span (max age apparently less than 4 or 5 years) must have a very high natural mortality. This basic arithmetic rule has been widely confirmed by all skipjack tagging done world wide: all the skipjack recoveries show large attrition rates, and natural mortality estimated from these attrition rates tend to be high or very high.

Furthermore, it seems that skipjack M is not constant over time, but U shaped: showing 2 maxima for juvenile and for aging skipjack (Maunder, Hampton). This U shape growth tend to be a universal rule in ecology (already analyzed and well justified in 1825 by Gompertz!). Its very strong and universal basis is that small juvenile are always more fragile that adults and highly vulnerable to predation (including by their parents); on the other side, the old individuals are increasingly suffering the damage of aging and senescence (imagine an old skipjack suffering from arthritis!).

The absolute levels of M estimated by the various tuna bodies are still widely uncertain and highly dependent of the method used. The levels presently used in the stock assessment of skipjack in the EPO, the WPO and the Atlantic are shown by figure 14. It should be kept in mind that in the Pacific these M were estimated by statistical models (MULTIFAN CL 2002 in the WPO and ASCALA 2002 in the EPO), while the ICCAT M was estimated by “crystal ball” guesses done by the ICCAT experts.

It can also be noted indicatively that the average natural mortality estimated by the Pauly method (based on the growth curve and the average temperature of skipjack habitat) would in a range between 1.2 and 1.5.

As a conclusion, if a natural mortality is hypothesized for the Indian Ocean skipjack, it should have a high average level (about 1.2 or 1.5?) and a U shape profile.

4- Skipjack catches variability over time

The year to year variability of skipjack catches is quite different in the various oceans. The variability is quite low in the WPO and IO, the two most productive areas for skipjack (figure 2). The El Niño years (for instance 1983 and 1998) do show large catches during one year (showing during these years an increase of catch of nearly 40%), but in general catches are showing a moderate variability (an average of only 16% of change from one year to the other for the WPO and of 14% for the IO). On the opposite, skipjack catches in the Atlantic and the Eastern Pacific (EPO) show a quite flat trend (figure 1), but much more between years variability, especially in the EPO (yearly variability of 33%), and also, but to less degree, in the Atlantic (variability=25%). This variability of skipjack catches is due to a combination of environmental factors, but also economical factors (see paragraph 2-6). Catches of skipjack are also dependent of the cpue of the other tuna species: when yellowfin catch rate are high, there is less incentive to target skipjack, and the opposite when yellowfin is rare.
There is some consensus among skipjack experts worldwide concerning the fact that skipjack catch rates are probably seldom related with stock biomass, but driven by changes in the catchability of the stocks. These changes of catchability are due to multiple combined causes such as:

- An universal trend to increase the fishing powers of tuna vessels (FADs, bird radars, etc…);
- An environmental variability of the availability of skipjack o the fisheries;
- The economic causes, such as skipjack and YFT prices;

These uncontrolled changes constitute a serious limiting factor in the modeling of this resource, because it is very hard to measure the real fishing pressure exerted on skipjack stocks.

5- Skipjack stocks present levels of exploitation

The analysis done on skipjack stocks indicate that in the EPO and WPO the skipjack stocks are still in good shape and that recent catches are still well under the MSY. These results were obtained by statistical models used in the WPO by the SPC (MULTIFAN-CL, Fournier et al 1998) and in the EPO by the IATTC (ASCALA, Maunder submitted). The exact potential catches on these skipjack stocks are still widely questionable and uncertain, especially in the EPO (cf IATTC report 2002). In the Atlantic, where the stock assessment is done in the hypothesis of two stocks, east and west Atlantic, the situation is less clear: the ICCAT SCRS concluded that there were some indices of local overfishing observed for skipjack in various areas of the Eastern Atlantic (an ICCAT 2000). The typical symptoms of this overfishing were a drastic decline of average weight in some areas of the Eastern Atlantic and steadily declining cpue. Furthermore, the levels of total skipjack catches have also been declining during recent years as a consequence of the moratorium on FADs, but the average weight taken by purse seine fleets remain quite low at only 2 kg. It is not clear if the present catches are lower than the stock MSY, or if these stocks are fully exploited or overfished.

A general conclusion concerning skipjack stocks and their potential overfishing is that skipjack is a species that is difficult to severely overfish because of its biological characteristics. This result was well shown by Fromentin and Fonteneau 2001 comparing by simulation the dynamics and risk of overfishing of skipjack stocks (stable, robust and resilient) and of bluefin stocks (variable and easily overfished to dangerous levels). These self regenerating simulations concluded that skipjack stocks should be much less variable as a function of increased fishing mortality, showing a great resistance to recruitment overfishing. This conclusion is probably valid for all skipjack stocks worldwide because of the similarities in the biological and behavioral characteristics of this species. Another strong and clear characteristic of skipjack resources worldwide is that, because of its short exploited life, the fisheries cannot sustain a dis-equilibrium of their catches during long periods of time (on the opposite bluefin tuna, a species with many year class can produce during several years catches that are well above the equilibrium productivity of the stock). There is then an excess of catches when the fishing mortality has been increased quickly, but within a couple of years, catches will fall towards the equilibrium catches of the stock. This basic characteristics of all skipjack stocks are easily simulated, as it was done by Fonteneau 1986.
6- Conclusion

This comparative analysis of skipjack stocks exploited in all oceans and studied by various tuna Commissions do confirm the interest for the Indian Ocean scientists to compare the biology and exploitation patterns of skipjack in other oceans. As many of these characteristics are probably similar world wide, the comparative knowledge obtained in other oceans may help to compensate for the present lack of knowledge available concerning the Indian Ocean skipjack. The main lessons obtained by this comparison are that skipjack is clearly a species that is difficult to overfish because of its biological characteristics and habitat. However, because of the limited movement of skipjack resources, there is some potential to obtain situations of local overfishing when local fishing effort and local catches are excessive. This local overfishing tends to be only a localized size overfishing, and should not be harmful for the spawning stock as a whole.
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pelamis) from the Western Indian Ocean. Aquat. Living Resour., Vol 9, n°3, pp 235-245.
Figure 1: Levels and trends of skipjack catches in the various oceans
Figure 2: Average skipjack catches of skipjack during the period 1990-1998 (FAO data)

Figure 3: Average cpue of skipjack taken by Japanese longliners during the period 1960-1995
Figure 4: Average position of the main skipjack fisheries in the Indian Ocean and distances (in nautical miles) between these fisheries
Figure 5: Average percentage of FAD associated skipjack catches observed in the various oceans.

Figure 6: Average distribution of skipjack catches in each ocean as a function of the average sea surface temperature (calculated on the average SST by quarter and 5° squares).
Figure 7: Sizes of the areas successfully fished for skipjack by surface fisheries in each ocean, expressed in numbers of $5^\circ$ squares fished with a catch of at least 50t of skipjack yearly.

Figure 8: Sizes of the areas successfully fished for skipjack by surface fisheries in each ocean, estimated in nautical miles$^2$ fished with a catch of at least 50t of skipjack yearly in each $5^\circ$ square.
Figure 9: Average catches of skipjack taken by surface fisheries per nautical miles$^2$ estimated in each ocean; these values are calculated dividing total catches given by figure 1 and the areas fished by figure 7 (The high level of productivity by area fished at the beginning of the Indian Ocean fishery is easily explained by the fact that fisheries were concentrated in Maldives, a small and rich area).
Figure 10: Growth parameters $k$ and $L_{\infty}$ estimated from tagging and recovery data on skipjack tunas from the various oceans. These « banana » of uncertainty show estimates of $k$ and $L_{\infty}$ that are statistically equivalent (within a statistical range of 95% uncertainty); small circles corresponds with the growth curves used on figure 13 to compare the growth of Maldivian recoveries as a function of various growth curves.

Figure 11: Average size distribution of skipjack taken by the purse seine fisheries in the various oceans.
Figure 12: Average skipjack sizes taken during recent years on FAD and on free schools in the Atlantic, Indian oceans and WPO

**Indian Ocean**

FAD = 2.6 kg  
Free schools = 3.0 kg

**Atlantic**

FAD = 2.0 kg  
Free schools = 2.2 kg

**Western Pacific**

FAD = 3.9 kg  
Free schools = 4.2 kg
Atlantic growth: $k = 0.3$ and $L_{\infty} = 80\text{ cm}$

EPO growth: $k = 0.8$ and $L_{\infty} = 83\text{ cm}$

WPO growth, $k = 1.2$ and $L_{\infty} = 66\text{ cm}$

Indian Ocean growth, $k = 0.55$ and $L_{\infty} = 64\text{ cm}$ (Adam)

Figure 13: Apparent growth over time of maldivian skipjack recoveries plotted against the best estimates of Growth curves estimated by tagging in other oceans: 13a: Atlantic, 13b: EPO, 13c: WPO and 13d: Indian Ocean. The values of $k$ and $L_{\infty}$ used to plot the growth curves are indicated on figure 10.

This figure shows that the Indian Ocean Maldivian recoveries of skipjack are well fitted with the Indian Ocean growth model as well as with the Atlantic one. Its fit is poor with both models used in the EPO and WPO, the IO apparent growth being much slower than in the Pacific ocean.
Figure 14: Natural mortality as age used by various tuna commission for their most recent stock assessment of skipjack