IOTC-2016-WPTT18-INFO2_Rev1
Received: 26 November 2016

Fishery indicators suggest symptoms of overfishing for the Indian Ocean skipjack stock

By Alain Fonteneau[1] and Francis Marsac[2]

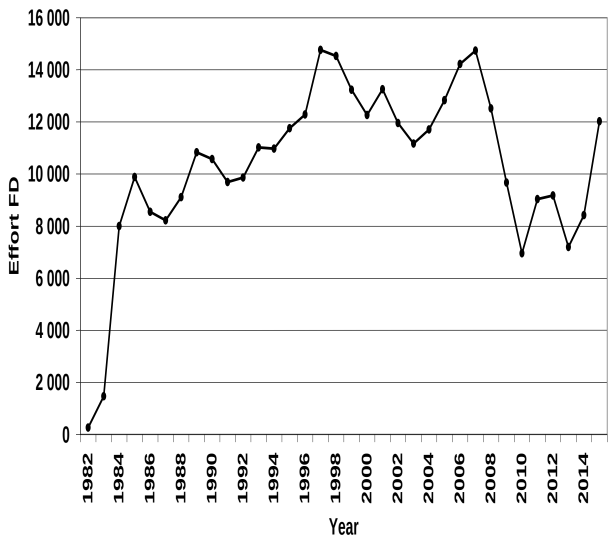
Summary

This paper is making an overview of various parameters of the SKJ fisheries active in the Indian Ocean, mainly for purse seiners. This analysis is showing that during recent years a major increase in the FAD fishing effort targeting SKJ was developed by purse seiners, for instance by seeding larger quantities of FADs equipped with new geolocation devices and underwater sensors However, this increased efforts did not produced the expected increase of SKJ catches, and various negative trends have been observed in the fisheries: declining SKJ catches for purse seiners and baitboats, vanishing SKJ in free schools, serious decline of SKJ catch per FAD sets, declining percentages of SKJ in FAD catches, quite low average weight of SKJ during the period. These fishery indicators are in contradiction with the last stock assessment in 2014, whereas they could be clear and strong symptoms of a SKJ stock overfishing in the Western Indian Ocean. Further studies of the SKJ stock status should be conducted by the IOTC, and this analysis should try to incorporate a wide range of fishery parameters for instance on species composition, on catch per set, supply vessels, numbers of FADs, etc.

1- Changes & trends in fishing power directed to FADs

On one side, the nominal fishing effort of purse seiners active in the western Indian Ocean (Fig 1a,) expressed in terms of numbers of fishing days, has been declining during 2009-2014, a period when nominal fishing efforts were at their lowest level observed since the late eighties. However, it should also be noted that the 2015 fishing effort was back to the high level of nominal effort observed in the 1994-2008 period. The same comment can be done on the carrying capacity developed by this fleet (Fig 1b).

[1] Retired IRD scientist, alain.fonteneau@ird.fr
[2] IRD, UMR Marbec, Sète, France francis.marsac@ird.fr



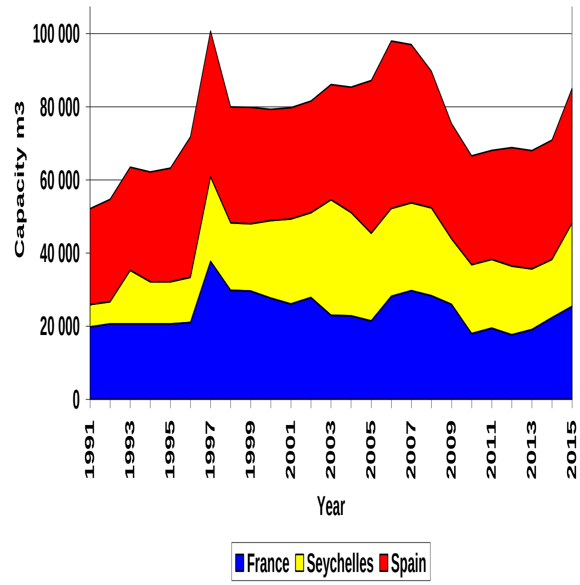


Figure 1a: Number of fishing days exerted yearly by the EU and Seychelles PS fleets

Figure 1b: Yearly carrying capacity developed by the EU and Seychelles PS fleets

A comparison of the SKJ fishery data during 2 recent periods, 2000-2009 and 2010-2015, is clearly showing that the fishing pressure exerted by the PS fleet has been widely increasing during recent years, and especially the fishing pressure targeting FADs (impacting SKJ, its dominant species). Among the main parameters that have been contributing to this large increase of fishing power and more efficient targeting on FADs, the following ones have been identified:

1) **Age of the PS fleet**: the EU & Seychelles PS fleets active in the IO has been permanently modernized and renewed, the average age of the PS being maintained at a about a young age of 15 years (based on SFA data).

2) **Carrying capacity of purse seiners**: The increasing fishing capacity of the average purse seiner should be noted, reaching in the 2010-2015 period an average carrying capacity of 2000 tons (+ 8% compared to the 2000-2009 period), see fig. 2. This increased carrying capacity is a factor that is indirectly linked with an increased targeting of FADs, because the only way allowing to fill such large size vessels is to target a large number of FADs.

3) **Supply vessels**: Supply vessels are clearly increasing the fishing efficiency of the FAD fishing. A purse seiner assisted by a supply vessel can catch 45% more than a purse seiner operating alone. A support vessels also provide a gain of 20% in terms of fishing sets per day for the associated purse seiner (Maufroy et al, 2015). It should be noted that their numbers have been increasing during recent years, 20 supplies being active in 2016 (figure 2, taken from an. 2016)

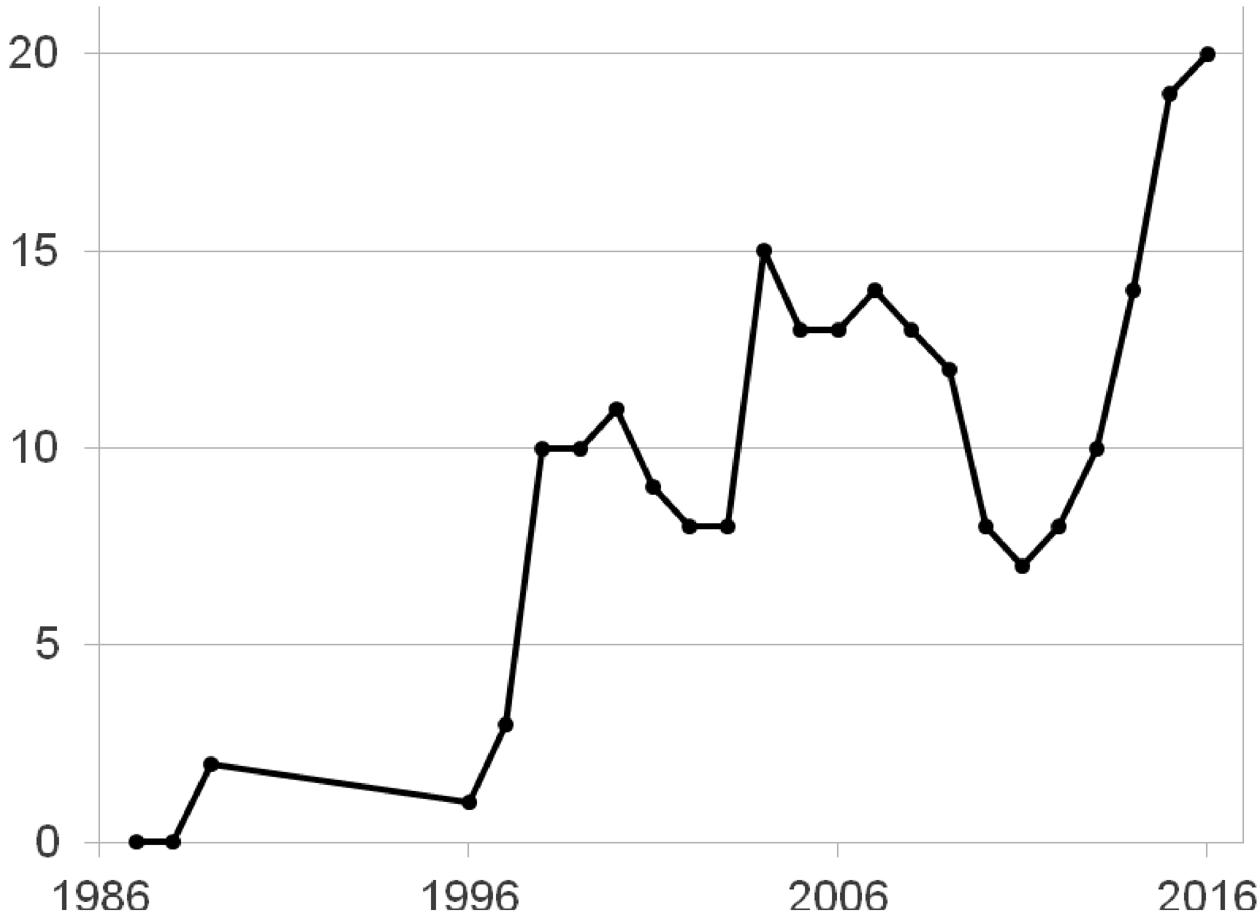


Figure 2: Yearly numbers of supply vessels active in the Indian Ocean.

The average age of this fleet of supply vessels was quite young in 2015, only 13 years, several of these supplies vessels being brand new vessels especially built as supply vessels in order to ensure a maximum efficiency of their support in the FAD fishing.

4) **Targeting on FADs**: there is little doubt that an increasing focus on FAD fishing has occurred during recent years. This conclusion is for instance shown by the yearly percentages of FAD associated catches, by flag. All flags have been showing an increase of their FAD catches, this increase being especially spectacular in the recent period 2009-2015, mostly for Spanish & Seychelles PS (both at 86% of FAD catches), and to a lesser degree for French PS, showing 66% of FAD catches during (Fig. 3).

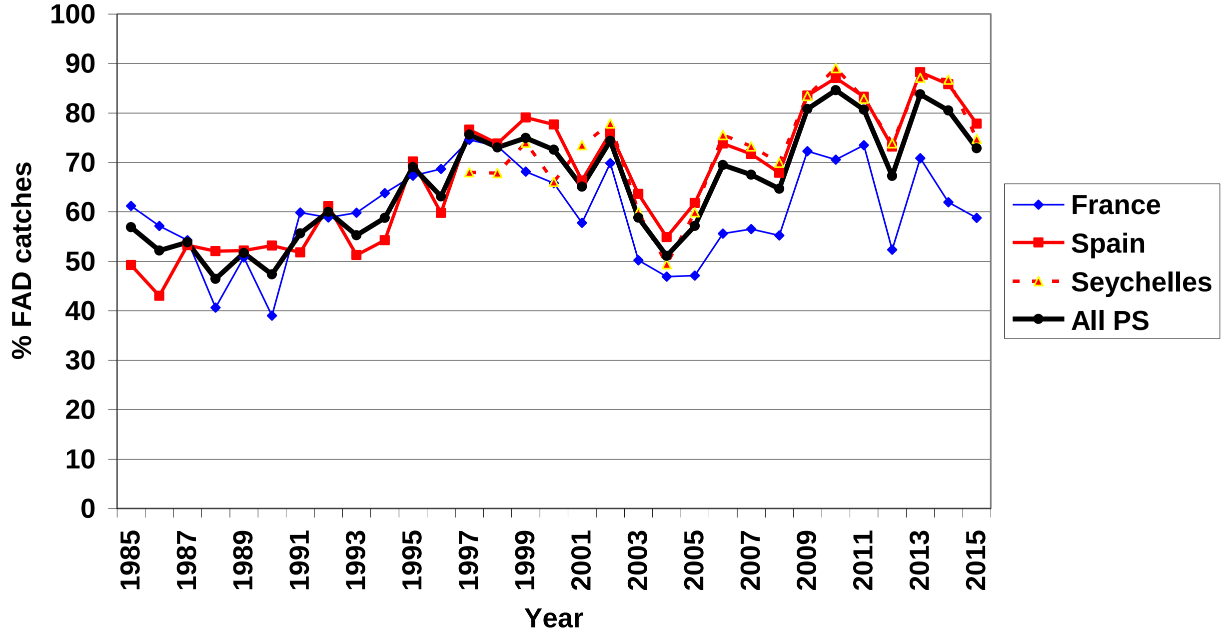


Figure 3 : Yearly percentage of FAD catches by flag and for the entire PS fleet

5) **Numbers of FADs** seeded and monitored: the trend has increased over the past ten years, as shown in fig. 4. While around 2500 FADs were active in 2000-2009, estimates in 2013 were in the order of 10 000 FADs (Maufroy et al 2016), and possibly reaching today numbers 15000 and 20000 FADs, following the recent increase of the number of FAD per vessel[3] and the increase in the number of active purse seiners (more than 20% of increase between 2013 and 2016).

[3] This increase being observed for French, Spanish and Seychelles purse seiners.

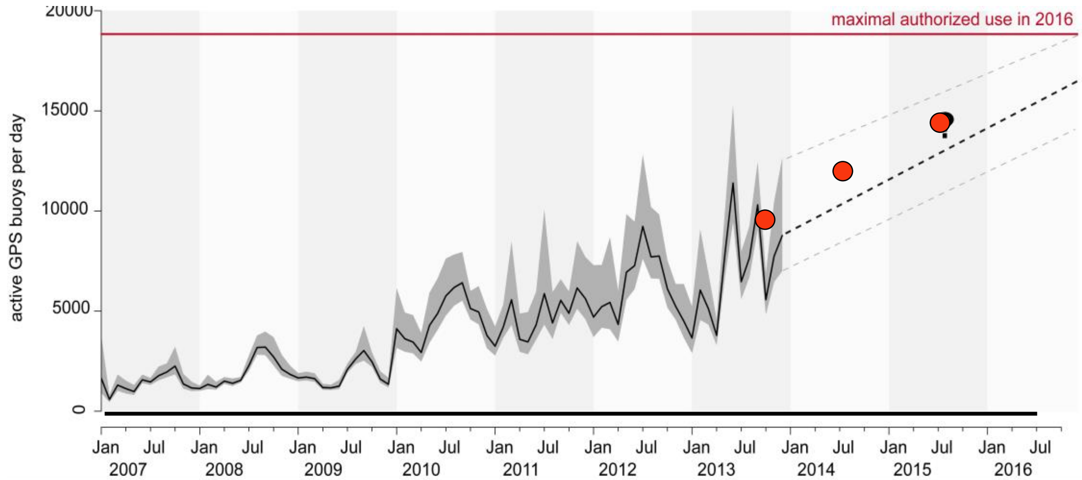


Figure 4: Estimated number of the average yearly number of FADs followed by PS in the Indian oceans 2007-2013 (taken from Maufroy 2016), and estimates of FAD numbers in 2014 & 2015, based on numbers of FADs seeded reported to IOTC (red dots), based on a ratio of 2.1 between the numbers of FADs seeded yearly and FADs followed (a ratio estimated on French PS)

6) **Equipment of FADs**: the FAD electronic technology has improved steadily, from HF radio to GPS buoys and to the latest echo sounder buoys, as evaluated by the EU CECOFAD project and shown in Fig. 3 by Gaertner et al (2016). FADs are then better monitored while drifting, quantity of fish associated to the FAD can be estimated and transmitted in real time to the skipper.

In such a context and if the SKJ stock in the Indian Ocean was still underexploited in recent years, the SKJ CPUEs and SKJ catches should have been permanently increasing during recent years and especially in 2015, a year when the nominal fishing effort of PS reached a peak level. In fact, the reality of the SKJ fisheries was totally different from this expectation. The following section will examine various fishery indicators of the SKJ fisheries.

2- Fishery indicators related to FADs and to SKJ fishing

2-1- Trend in yearly catch

The trend of total catches taken on a given stock can give some indication on the status of that stock (see Grainger and Garcia 1996 and Gaertner and Fonteneau 2001). Basically, catch declines are the consequence of declining effective fishing efforts or management measures that would establish catch limits. However, in some instances, they can also reflect symptoms of stock overfishing. When fishing efforts are in excess of the level producing MSY, there is a logical tendency to observe a decline of the total catches caught on the overfished stock and this decline would depend on the steepness of the stock recruitment relationship. If steepness is high (as often for tuna stocks) decline in total catch is moderate, but it will become more substantial when recruitment levels have been heavily reduced by overfishing of the stock.

The trend of total yearly SKJ catches and of PS catches is shown by Fig. 5a: after reaching a maximum plateau during the 2000-2005 period, both total & PS catches have been showing a marked decline (a 14% decline between our 2 recent periods) that may be indicative of stock overfishing, unless it can be shown that it was the result of a decline in the effective fishing effort targeting SKJ during recent years.

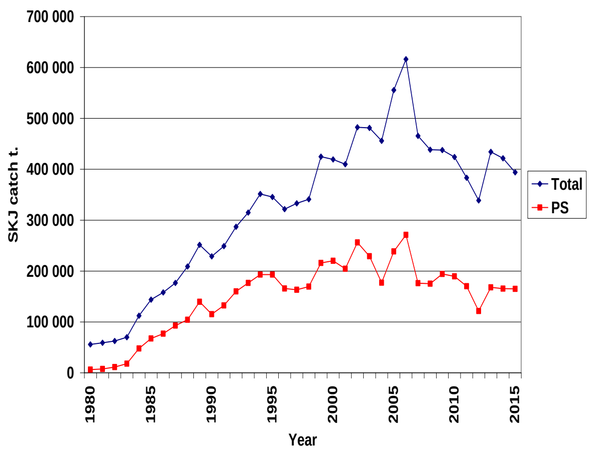


Figure 5a : Yearly catches of SKJ in the Indian Ocean, total and by PS

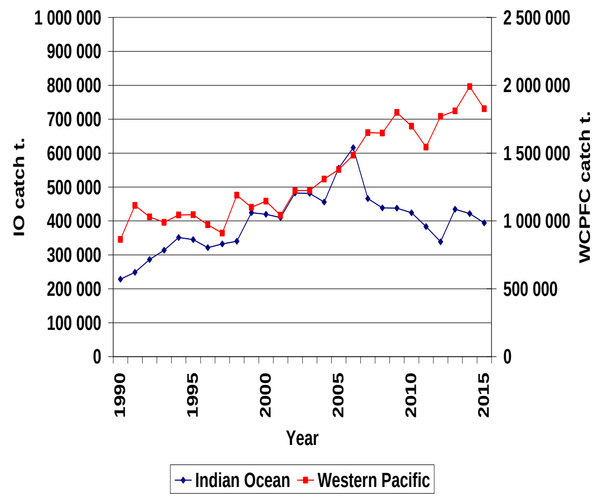


Figure 5b : Yearly catches of SKJ in the Indian Ocean and in the Western Pacific

Yearly SKJ catches in the Indian Ocean can be compared to the yearly SKJ catches in the western Pacific (Fig. 5b), a stock estimated by WCPFC scientists not to be fully exploited (Rice et al 2014). During recent years, its yearly catches have been showing a steadily increasing trend which is typical of a stock exploited at F<FMSY, widely distinct from the trend of SKJ catches observed in the Indian Ocean.

2-2- <u>Trend in nominal CPUEs</u>

Yearly nominal SKJ CPUEs during recent years are shown in Fig. 6. Average nominal CPUEs of SKJ between the 2 periods 2000-2009 and 2010-2015 declined by 6% for France while it increased by only 19% and 10% for Spain and Seychelles respectively.

In recent years, and especially in 2015, none of these fleets have showed the major increase of their CPUEs which might have been expected in line with the increased effort on FADs.

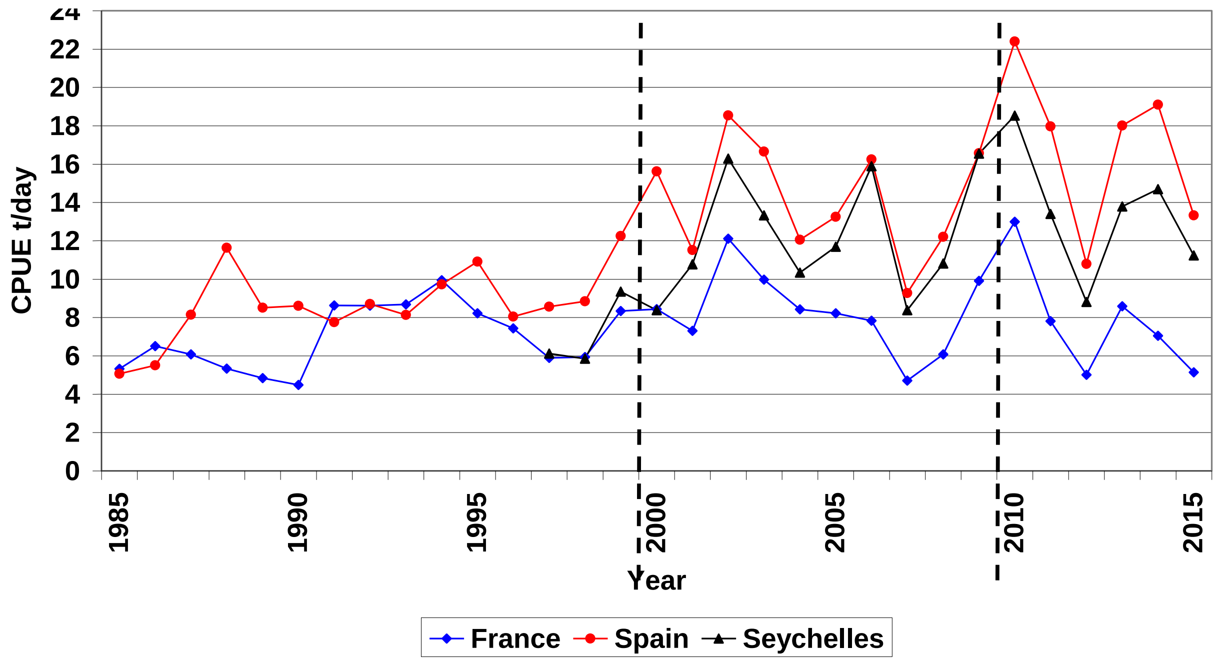


figure 6 : Nominal CPUEs of France, Spanish & Seychelles purse seiners (total yearly SKJ catch in tons / total effort in fishing day)

2-3- <u>Changes in species composition of PS FAD catches</u>

Figure 7 is showing the yearly species composition of the FAD catches by PS in the Western Indian Ocean. Marked changes have been observed over time, especially for SKJ, with opposite patterns between SKJ and YFT: a relatively high percentage (>70%) from 1985-1995, another stable but lower proportion in the range 60-70% over 2000-2009, a sudden decrease for 2010-2013 with a concomitant increase of YFT then a slight increase of SKJ in 2014-2015.

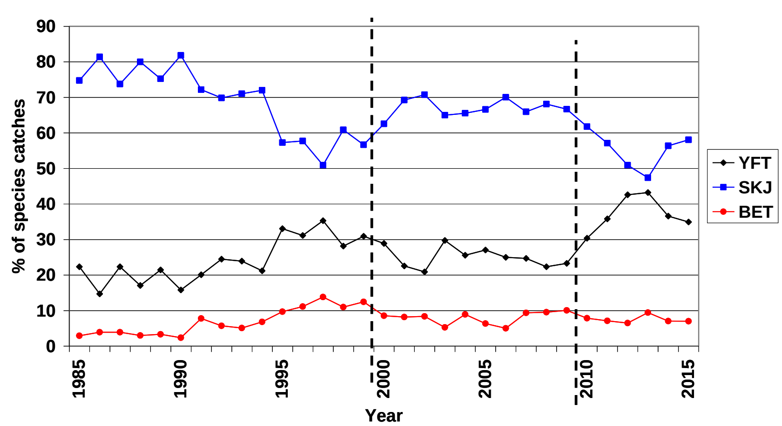


Figure 7 : Average yearly species composition of FAD catches by the EU & Seychelles PS fleet

It should also be noted that such major change in the species composition of FAD catches can be observed over the whole PS fishing zone in the West Indian Ocean (Fig. 8a and 8b).

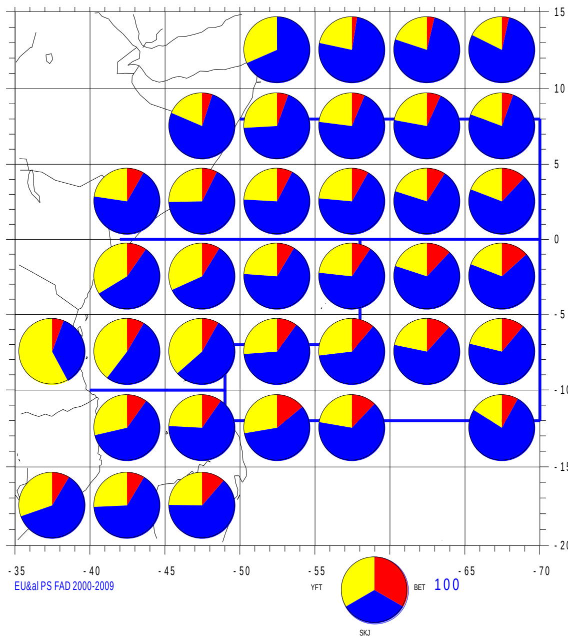


Figure 8a: Average catches by species on FADs by PS during the 2000-2009 period

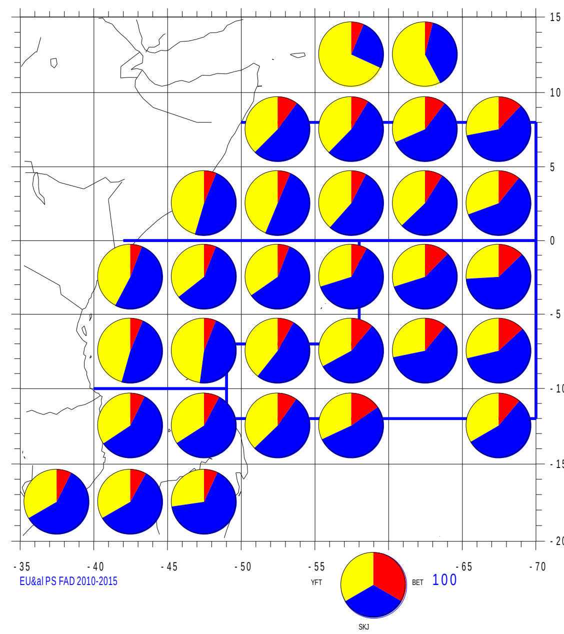


Figure 8b: Average catches by species on FADs by PS during the 2010-2015 period

These changes in the species composition of FAD catches are well captured by the DeFinnetti ternary plots showing the sampled species composition of FAD catches during the 2 periods 2001-2009 and 2010-2015 (based on a large number of 28000 multispecies samples, see fig. 9.

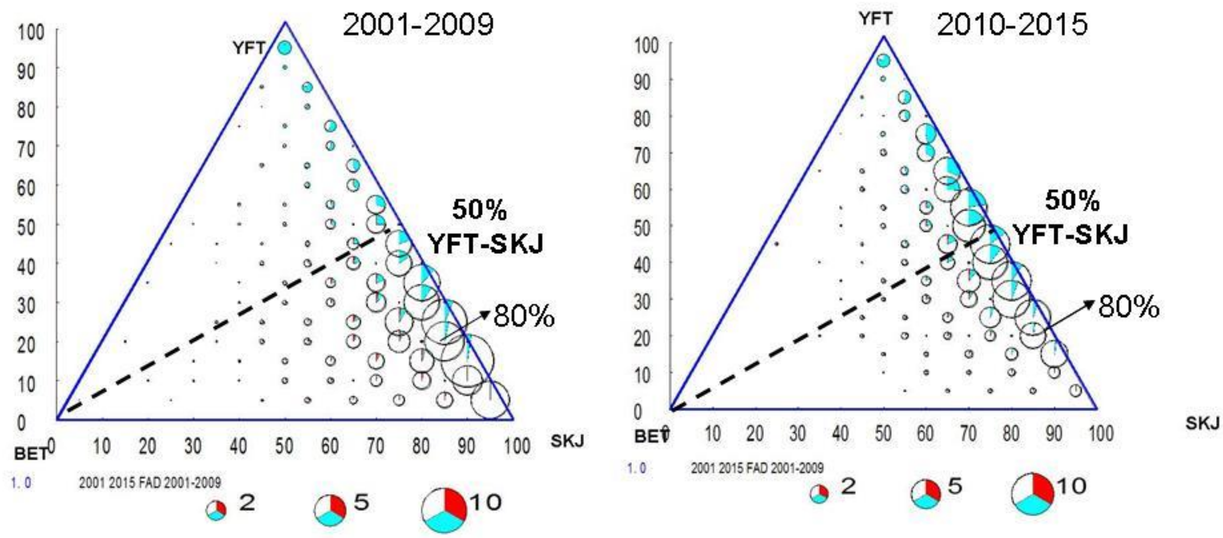


Figure 9: Frequency of the observed species composition of FAD catches during 2 periods, 2001-2009 and 2010-2015 (in blue: large YFT >30kg).

FAD catches always comprises a mixture of the 3 species -YFT, SKJ & BET-, but a distinct species composition appeared in recent years, with balanced proportion between SKJ & YFT catches which was not seen before. Figure 9 also shows the presence of large YFT (in blue) in greater numbers in the recent period.

2-4- SKJ catches on free schools

It has been noticed that levels of SKJ catches on free schools have dramatically decreased since 2007 for all PS fleets (Fig. 10).

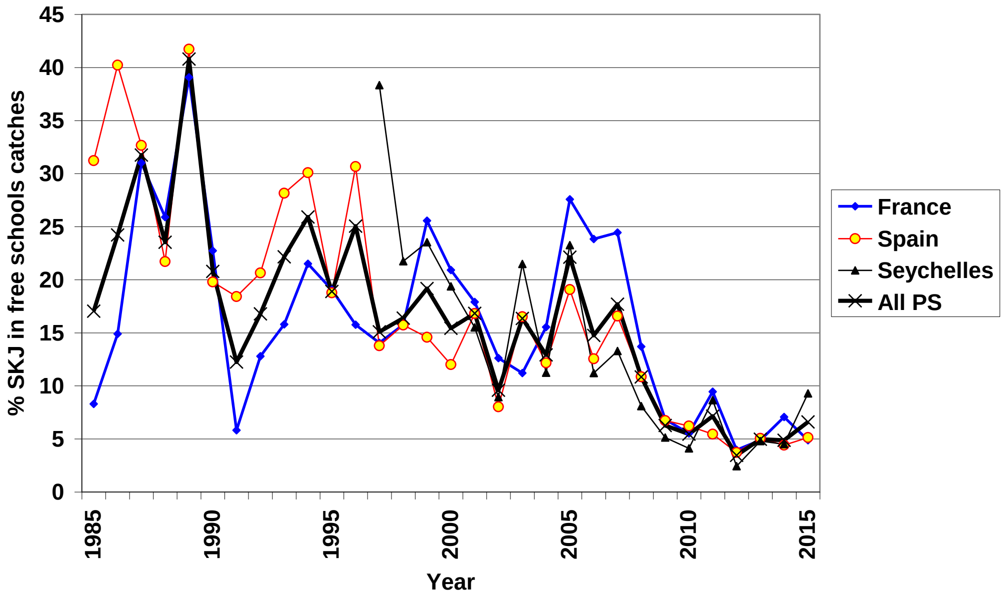


Figure 10: Yearly percentage of SKJ in the free schools catches landed by purse seiners, by flag.

2-5- <u>Size of FAD sets</u>

The average yearly SKJ catch per positive set on FAD set has shown a marked decline in recent years.. The decline is 33% between the 2 recent periods 2000-2009 and 2010-2014 (figure 11)

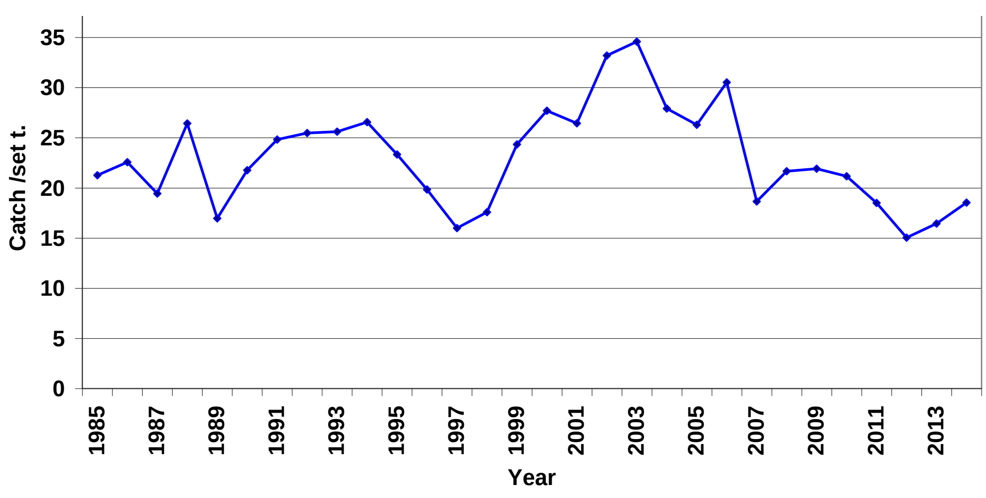


Figure 11: Average yearly catch of SKJ per positive set on FAD, all flags combined (based on Table 10, Chassot et al 2015).

2-7- Average weight of SKJ caught by PS

The yearly average weight of SKJ landed by PS in the Indian Ocean used to be quite high since the beginning of the fishery, reaching an average weight of **2.9** kg during the 1985-2006 period, while it has shifted to a slightly lower level (2.4 kg) after 2007, although a moderate increase has been recorded since 2011 (Fig. 12). The same figure also shows a similar decline of the SKJ average weight in the Maldivian baitboat fishery

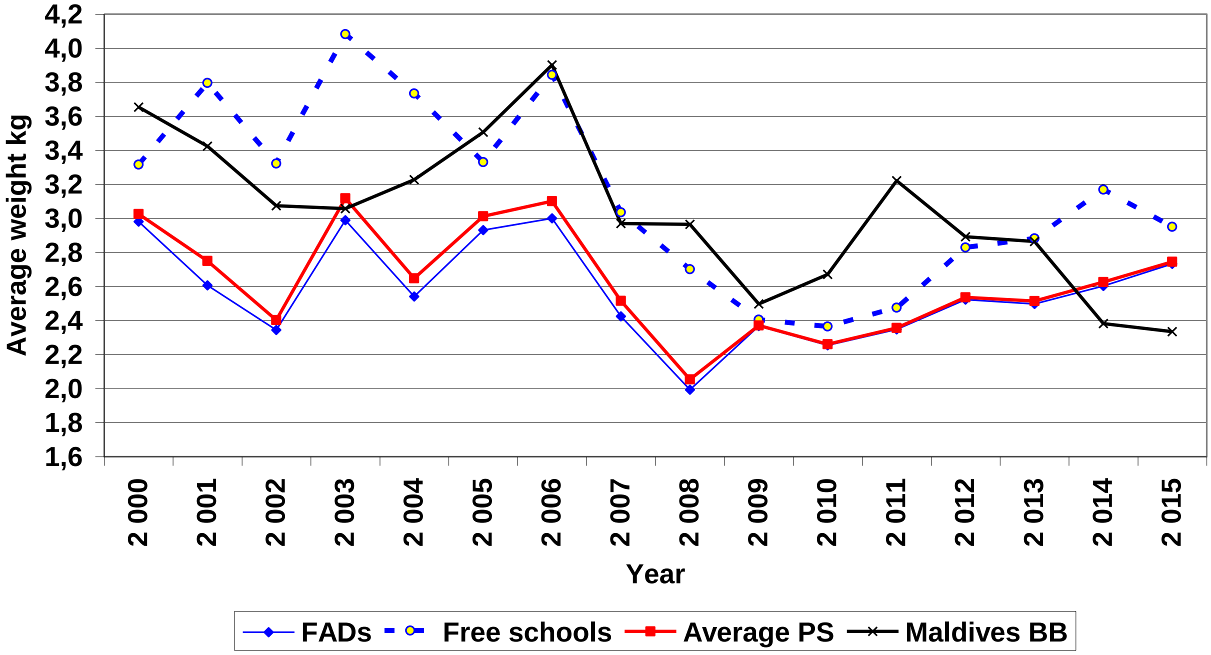


Figure 12: Average weight of SKJ caught by PS in the Indian Ocean, on FADs and on free schools, and average weight of SKJ caught by Maldivian baitboats.

The comparison of catch at size for two distinct periods (1990-2006 and 2007-2015) can indicate why the average weight has been declining (Fig. 13):

- SKJ above 47 cm FL were less represented in the FAD catch in the second period, but this change would induce a minor decline in the average weight ;
- During the second period, the significant drop of SKJ catches on free schools (which are composed of large size SKJ) is considered as the major cause of the declining average weight for SKJ

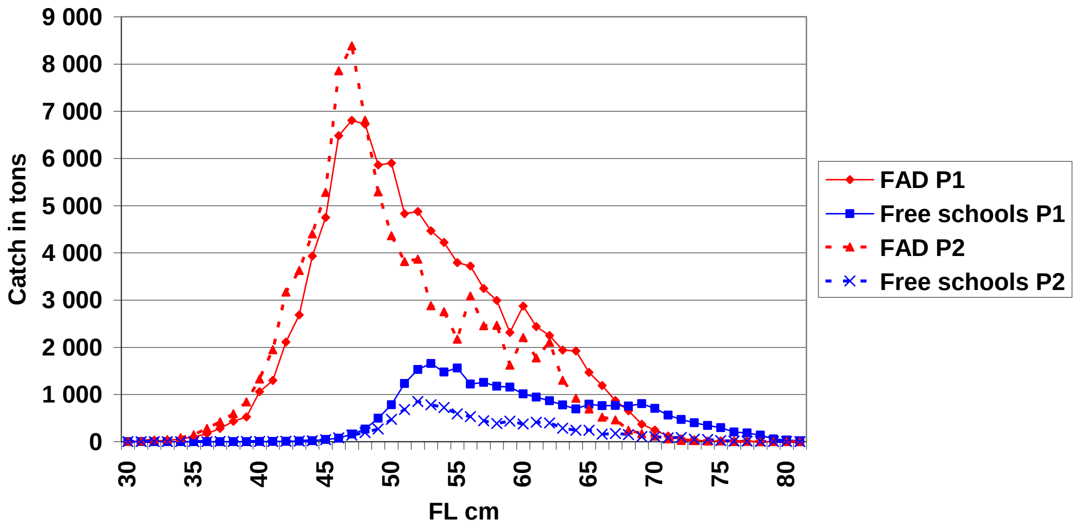


Figure 13: Average catch at size of SKJ by PS of FADs & free schools catches, during two periods: 1990-2006 (P1) and 2007-2015 (P2).

2-8- Yearly numbers of sets on FAD and on free schools

These numbers are important to analyse and they are showing a rather strange paradox, as the major increase in the number of FADs during the last 10 years (Figure 4) did not produced significant increases in the total number of FAD sets during the period (fig. 14). On the opposite a marked decline of the number of free schools sets was observed since 2008 (probably in relation with the increase in FAD fishing). It should also be noted that during the same period, the average total number of sets per fishing day of the PS fleet was quite stable since 1991 (fig. 15) and at an average level lower than 1 set per day.

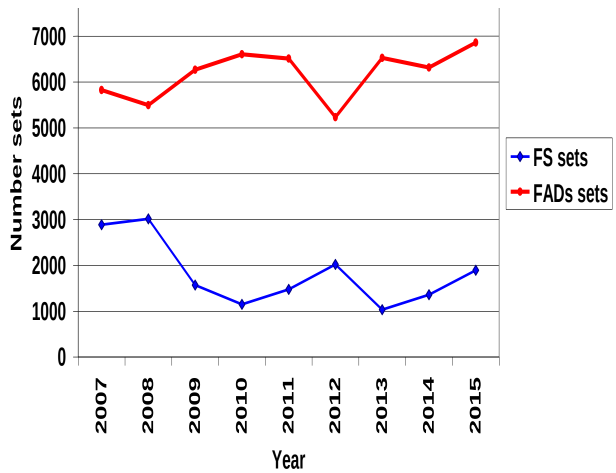


Figure 14: Yearly numbers of sets on FADs and on free school.

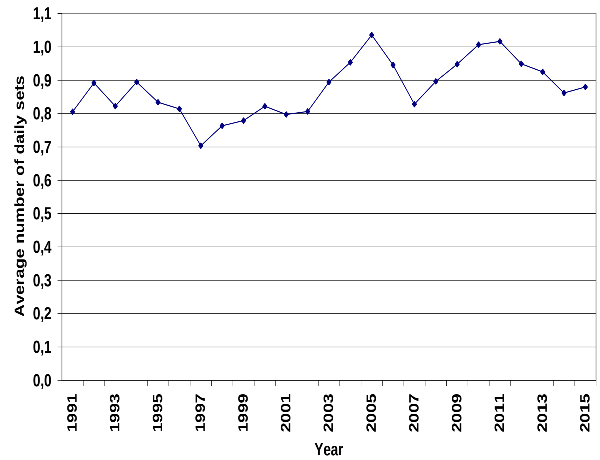
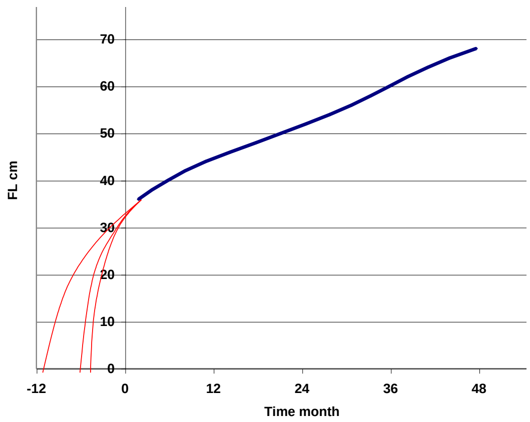


Figure 15: Average yearly numbers of set per fishing day of the PS fishery (ratio of yearly number of fishing days and of number of sets)

Based on these information, it should be concluded that the massive increase in the number of FADs in recent years (fig. 4) did not produced an increase in the number of daily sets, while this increase would have been feasible, as purse seiners can easily set several times per day when they are exploiting strata of high abundance. This lack of increase in daily sets might be explained by average biomass of SKJ at FADs declining below the threshold level where it is worth for purse seiners to make a set.

3- Discussion & conclusion: SKJ stock status based on these fishery indicators

Most or all the fishery indicators examined in this work are symptomatic and typical of stock overfishing situations. It should be kept in mind that the symptoms of overfishing, e.g. declining catches at excessive fishing mortality, are rapidly visible for a SKJ stock, simply because of the biology of the species: a short life and few age classes exploited (Fig. 16 and 17), high natural mortality and high productivity of the stock.



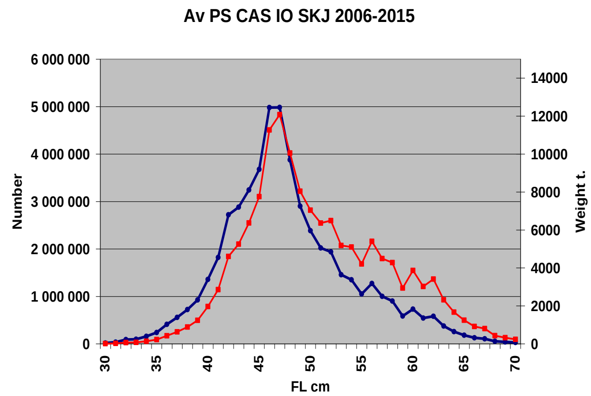


Figure 16: Estimated growth of SKJ during its period of exploitation by PS (based on recovery data)

Figure 17: Average catch at size of SKJ by PS during the period 2006-2015, in number & in weight.

As a consequence, when a SKJ stock is overfished, the decline of its total yearly catches does occur very quickly, which is not the case for BET, YFT, ALB or BFT overfished stocks, where catches well over the MSY can be sustained during several years when fishing mortalities are increasing over F_{MSY}. This basic rule in the SKJ overfishing is easily demonstrated by simulations and MSE analysis.

The basis of this diagnosis if that the recent increase in the fishing targeting FADs and indirectly SKJ should have produced, as in the Western Pacific, a steady increase of SKJ catches and of SKJ CPUEs. However, this is not the situation reflected by the indicators presented in this paper.

Based on this analysis, our conclusion are then widely distinct and more pessimistic than the results of the last SKJ stock assessment by the IOTC in 2014 and its final diagnosis that: "*All the runs carried out in 2014 indicate the stock is above a biomass level that would produce MSY in the long term (i.e. SB2013/SBMSY > 1) and in all runs that the current proxy for fishing mortality is below the MSY-based reference level (i.e. Ccurrent/CMSY < 1)*". However, it should also be recognized that many stock assessment analysis have been facing major difficulties to estimate the real status of SKJ stocks because of multiple additive factors such as; (a) major statistical deficiencies for many fleets, (b) major changes in PS fishing power, (c) lack of realistic SKJ CPUE index, (d) effects of FADs on SKJ stock and fisheries, (e) insufficient tagging & recovery data). Our view is that results of the 2014 stock assessment should be considered as being widely uncertain and possibly wrong, as it was noted in the 2014 SC report: " *There remains considerable uncertainty in the assessment, and the range of runs analysed illustrate a range of stock status to be between 0.73–4.31 of SB2013/SBMSY based on all runs examined*"

Furthermore, it is striking to note that most of the SKJ indicators that are for us a source of worry (for instance decreasing catch per FAD set, major increases in the efficiency & numbers of FADs, major changes in the species composition of FAD catches, vanishing biomass of free schools SKJ, etc..) have never been incorporated in any SKJ assessment model.

To summarize, the negative trends that have been observed in most of the SKJ indicators during the last 6 years, and especially in 2015, a year when the fishing efforts of PS were at its maximal level and probably maximal efficiency, might reflect some degree of stock overfishing. Several causes can be examined:

1) **Growth overfishing** (Cushing 1977)**:** a quite stable recruitment, but an excessive fishing mortality producing a decline of the yield per recruit: in this hypothesis, in a context of high steepness typical of SKJ stocks, the moderate decline of the SKJ catches (total & by PS) would simply be the consequence of a decline in yield per recruit, a situation typical of growth overfishing.

2) **Recruitment overfishing**: It should also be hypothesised, based on the fishery data that SKJ recruitment has been heavily declining during recent years. Such phenomenon has very seldom been observed for SKJ stocks. This decline could for instance be linked to the excessive number of FADs presently active in the eastern Indian Ocean. It could be hypothesized that these FADs could have a negative impact on SKJ spawning, reducing the spawning potential of the SKJ biomass trapped under FADs, based on the results of Grande et al 2016 showing that SKJ spawning is related with the short term feeding activity. As SKJ under FADs may tend to feed less that free schools SKJ and if most adult SKJ are associated to FADs today (as suggested by the fact that SKJ caught in free schools have been vanishing during recent years), then the real fecundity of the SKJ stock could have been reduced.

3) **Declining catchability** of the SKJ stock to PS: this hypothesis could for instance be envisaged in relation to the increasing numbers of FADs seeded in recent years. To illustrate this, considering a SKJ biomass of 500 000 t in the area and 5000 FADs drifting, the average biomass of SKJ per FAD would be equal to 100 t, under the assumption that all SKJ individuals would be associated to FADs. However, this biomass per FAD would decrease to only 25 t. if 20 000 FADs were drifting in the area. In this hypothesis of « School fragmentation by FADs » the SKJ stock would not be overfished, but its catchability would have been reduced for PS by an excessive number of FADs.

Our conclusion is that most or all indicators of the Indian Ocean PS SKJ fisheries are strongly indicative that the SKJ stock may have undergone an excessive fishing pressure during the recent years, and possibly experiencing in the Western Indian Ocean fishing mortalities well above the F_{MSY} level targeted by the IOTC. Our recommendation is that the indicators presented in this paper should be considered as a potential source of worry and that in-depth analysis of the stock status should urgently be conducted on this valuable resource. Extensive use of operating models, such as the MSE model proposed by Bentley and Adam 2015 should also be developed based on updated data and methods, as most stock assessment models have been facing serious difficulties to consistently evaluate the status of SKJ stocks, and as this MSE approach is potentially more realistic to understand the real dynamics of the SKJ stocks and fisheries.

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