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State of major tunas stock in Atlantic East center zone, off Ivory Coast

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Abstract

The technologies used in fisheries became more efficient, just to meet the needs of a galloping population. That significantly affects the sustainable management of living resources, including major tunas (*Thunnus albacares*, *Katsuwonus pelamis*, *Thunnus obesus*). To alert international opinion on the level of exploitation of these fish species, a comparative study was carried out on the quantities of tuna landed by industrial fishery over two decades [(1975-1984) and (2004-2013)]. To achieve this, data 2014 of International Commission for the Conservation of Atlantic Tunas (ICCAT) have been used. As an index of unit of Fishing Effort, we used the number of tides. The Catch Per Unit Effort (CPUE) which provides information on repartition density of species on the fishing area was also used. Schaefer's General Linear Model (GLM), that allows making linear transformations of several dependent variables have been developed to estimate the Maximum Sustainable Yield (MSY). This value (8464 T) provides information on the fishing effort required for sustainable management of the major tuna stock in that area. Size frequencies of those fishes were plotted as histograms by species and year, to learn more about maturity status of captured individuals. Overall, the major tunas are overexploited in that Atlantic East center zone, bordingIvory Coast. But taken individually, *Thunnus albacares* and *Thunnus obesus* are in overexploitation phase, unlike *Katsuwonus pelamis* which is still in full exploitation. Taking efficient protection measures would help to ensure the sustainability of these species, which would be a strong contribution to safeguarding biological diversity.

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Introduction

Material and methods

Material

Technical equipment

Field of study

Fishing area regularly frequented by tuna boats and trawlers operating in an Atlantic East center zone, bording Ivory Coast is illustrated at Figure 1.

Craft and catching gear

Boat gear

The actors, mainly French, Spanish, Chinese and other fishermen community use trawlers and tuna boats as fishing gear. For trawlers (other than Chinese), the 17 recorded in 2010 gradually ceased operations until 2014, when only one remained (PSDEPA, 2014-2020). Conversely, trawlers armed by Chinese have seen a clear increase since 2012. The number of trawlers more than doubled between 2012 and 2014, linked to the increase in the number of Chinese trawlers from 12 in 2012 to 25 in 2014.

Fishing gear

Like fishing gear, the actors mainly French, Spanish, Chinese and other community use trawls rods (TR), reel rods (RR), longlines (LL) and lines (BB). Longline consists of a mainline carrying secondary lines or advance, ended by hooks. The fishing rod is the main tool for fishing. It is composed of a rigid body at the flexible end (bamboo, reed, composite material, etc.), more or less long, on which it is ridded a line, or a reel with a hook, and a bait to catch fishes. Drifting longline gear is widely used throughout the world for large pelagic species capture, particularly tuna. Sliding calipers and scales were used by the investigators on board or at the landing, for respective measurements of sizes and weights of the major tunas encountered in the catches.

Fig. 1. Fishing area in East Atlantic center zone (Ivory Coast).

Biological equipment

The biological material consists of the three main major tunas found in Atlantic East center, near Ivory Coast. They are Albacore (*Thunnus albacares*), Skipjack (*Katsuwonus pelamis*) and Patudo (*Thunnus obesus*). The landed numbers of these different species, their weight catch and the metric parameters have been obtained from 2014 ICCAT database.

Methods

Fishing methods

Fishing technology is the discipline of studying, developing and improving the technics used infish catching. The technics used by these vessels for catching fish include direct means, including fishing gear, fishing vessels and their equipment for navigation, maneuvering and control of the fishing gear. They also use indirect means of capture, in particular the detection of fish (sounders and sonars), the attraction of fish for its capture (light, bait), the knowledge of the behavior of the fish in relation to the gear of fisheries, the location of fishing grounds through the use of environmental data (hydrology, bathymetry). Operations that combine direct and indirect means of capture include fishing methods, tactics and fishing strategy and its vessel exploitation. Longlines allow fishermen to survey rocky areas that are otherwise inaccessible.

The trawl is a pocket-shaped net dragged to the bottom of the water or near the surface by one or two vessels. Industrial fishing, as opposed to small-scale fishing, is practiced by vessels with size and power output much more important. In general, industrial fishing includes all boats propelled by an engine on board. The implementation of Fish Aggragation Devices (FADs) used here by reel pole and line trollers has already led to significant changes in fishing practice. The departure times at sea have been modified, leaving earlier to be on the DCP at sunrise. The use of live bait has become common in fisheries.

Data analysis methods

Fishing effort

The notion of fishing effort has always been very important in fisheries. On the one hand, it is at the base of numerous diagnoses concerning the state of exploited stocks, and on the other hand, the direct or indirect management of the effort is generally considered as a privileged means of regulating the activity of peach. Nominal fishing effort is, according to the work of Laurec and Le Guen, (1981), a management parameter that measures the accumulation of fishing resources used by fishermen to exploit a stock during a unit of time.

This effort was therefore estimated on the basis of the number of tides, or the number of times the vessels went to the fishing area per year (nominal effort). Laurec and Le Guen, (1981) say that, very often a number of vessels, a number of fishing days, or the produce of a number of day's and number of fishing gear are satisfactory units. Fishing effort, basic indicator of fisheries, remain very useful for better understanding many past and present changes in fisheries and tuna stocks (Fonteneau *et al*., 2017).

Capture Per Unit Effort (CPUE)

Tropical fisheries, in particular demersal ones often exploit a large number of species simultaneously, with the result that neither the industrial fishery nor the artisanal fishery, even if well controlled, can provide catch statistics. For this reason, it is not uncommon in tropical fisheries to treat a mixture of different species as if it were a single species (Saville, 1980).

The Capture Per Unit Effort (CPUE) is defined as the yield of the fishing units, that is the ratio of the weight to the effort exerted during a given period.

According to Saville (1980), regardless of the country or the type of fishery, the CPUE by species is the ratio of the obtained weight of this species to the total effort deployed during the time unit considered.

This method, developed for marine species exploited by industrial fishing provided, by the means of balanced production models (Schaeffer models, Fox models, etc.), an excellent stocks estimates (Daget and Iltis, 1965). Nominal fishing effort (F_E) and catch weight (C_W) were recorded annually.

The CPUE has been expressed as the ratio of the weight catch, to the fishing effort deployed annually.

At the end of his thesis works, Laë (1992) has shown that CPUE remains a good indicator of stock abundance for African fisheries. The CPUE by gear type in the Ivorian zone has been calculated. The Kolmogorov-Smirnov comparison test was also used to compare the different values obtained from one decade to the next.

Generalized Linear Model (GLM)

Global production models that are mathematical applications that attempt to best represent the response of marine populations to fishing predation by humans have been used. Global models have been designed to be applied to single-species stocks; however, according to Gulland (1969) and Pope (1979), they can be applied to multispecies stocks. The purpose of fish stock assessment is to describe these processes, and thus the link between input and output data, using tools called models.

In this study, Schaefer's dynamic production model, developed on an Excel sheet following the method of Punt and Polacheck (1996), was therefore used for stock assessment of the main tunas in the Ivorian.

This model makes it possible to estimate Maximum Sustainable Yield (MSY), which corresponds to the highest average catch level that can be taken in the long term from a stock (ICCAT 2006-2009) under the existing environmental conditions and without any significant impact on the stock.

More generally, the generalized model is a tool for analyzing the history of the stock and the study of the coherence of the different time series of abundance and fishing effort.

Size frequencies of fishes

With a caliper, the total length (Lt) of the captured fishes was measured by group of species to the nearest centimeter, by the investigators on board and at the landing stage. Individuals of each species were grouped by size class and represented as a histogram so as to perceive the sizes that predominate in the catches. The Kolmogorov-Smirnov statistic test as also been used to appreciate the significance of difference between the two decades results.

Results and discussion

Comparative production of main tuna between two decades

The total production of the decade 2004-2013 is about one third of that of the previous decade (1975-1984), respectively 37014 t against 122179 t. The Kolmogorov-Smirnov test applied to these two values shows a significant difference ($p < 0.05$). So, fishes quantities landed during the first decade (1975-1984) are therefore very different from those landed during the second one (2004-2013). When applying the same statistical test to the skipjack landed quantities from one decade to the next, no significant difference is obtained.

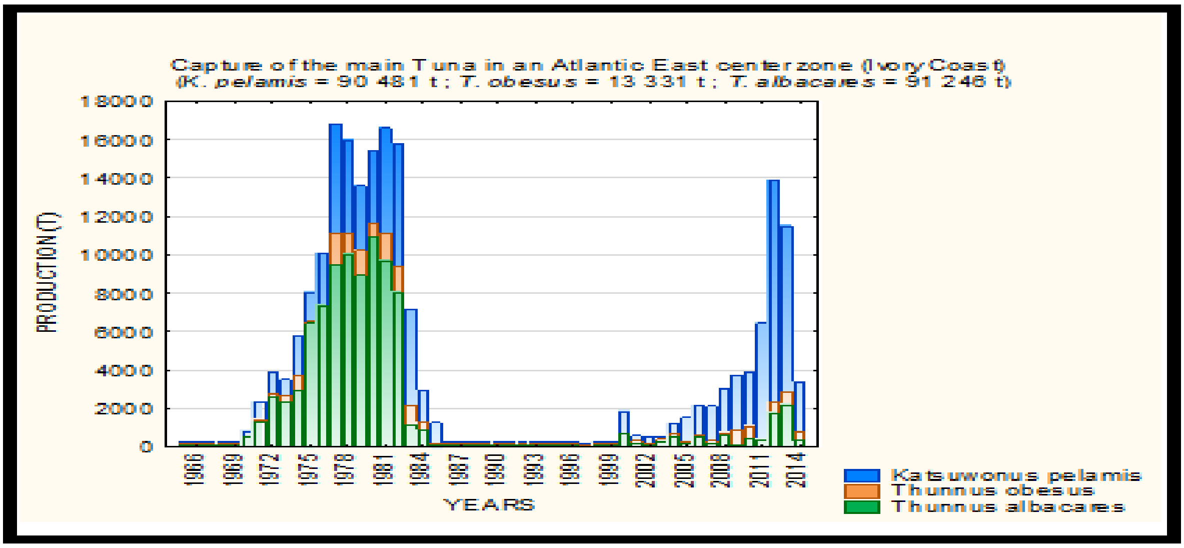

Fig. 2. Capture volume of Albacores, Skipjack and patudos in East center Atlantic zone (Ivory Coast).

That's means that the stock of this species is stable for these two decades. In terms of production by species, the first decade shows a predominance of yellowfin tuna (72890 t), followed by skipjack tuna (40367 t) and finally bigeyetuna(8922 t). The second decade shows skipjack as the dominant species in catches, followed by yellowfin tuna and bigeye tuna, with respective values of 31377 t (a decrease of 22.27%), 2846 t (a decrease of 96.10%) and 2790 t (a decrease of 68.73)(Fig. 2).On that figure, from 1986-1999, over a period of fourteen years, no landed catch of these major tunas was declared on behalf of the Ivorian zone to ICCAT.

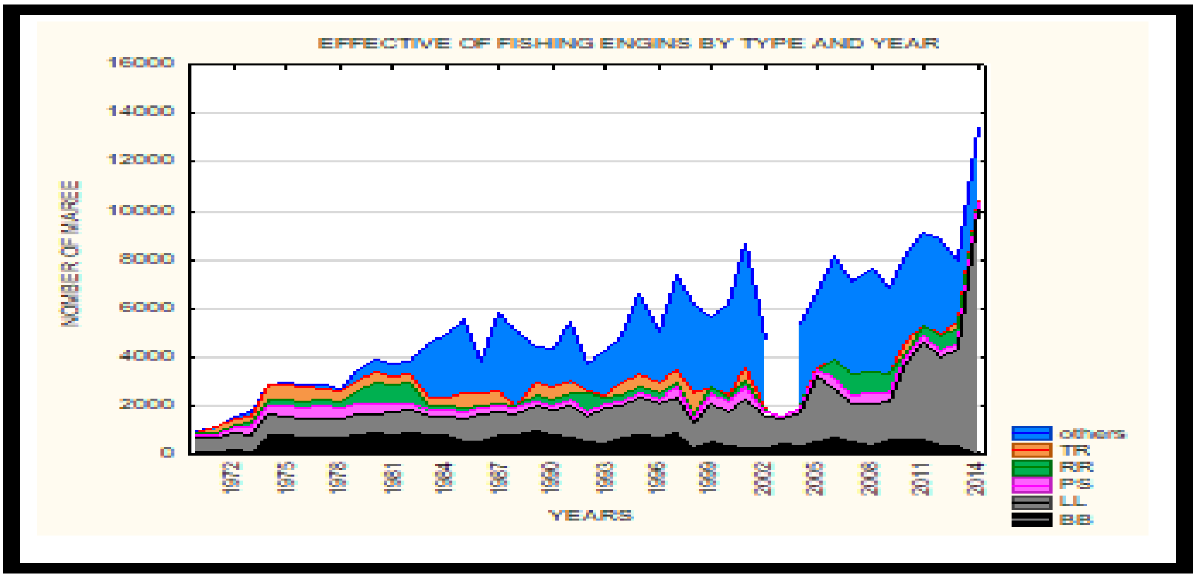

Fig. 3. Number of vessels visited annually at sea by type of fishing gear. LL: longlines, BB: rods, PS: seines, RR: reel rods and TR: lines.

Fishing effort and production

Fishing effort by gear type

In this ocean portion, three types of vessels made the greatest number of tides. It is primarily fishermen using other gear (others: 94627), followed by longliners (LL: 57496) and bait boats (BB: 29550). Gear such as seines (PS), reel rods (RR) and trollers (TR) have been used very little annually in this area. Overall, with the exception of bait boats, which declined slightly since 1999, fishing pressure is maintained throughout the period with variants like others gears and long lines (Fig. 3).

Total fishing effort and production

The figure 4 gives the total number of tides per year for any gear aggregated in Ivory Coast's zone, in relation to tonnages landed by major tuna species (*K. pelamis*, *T. albacares*, *T. obesus*). The total fishing effort, which was 961 tides in 1970, has steadily increased to 4572 tides in 1983. After 1983, there is an ups and downs evolution until 2013 (7965 tides), and this, with a number of tides still beyond 4000, except for the year 1992 (3699 tides). Three essential phases are perceptible at the level of production: the first part from 1970 to 1986, the second from 1986 to 1999, and the last from 2000 to 2013. In the first phase, the tonnages landed are in order of importance:*T. albacares*, *K. pelamis* and *T. obesus*. During this phase, catches of *T. albacares*, which were 523 tons in 1970, evolved to peak in 1980 at 10970 tons. This tonnage, which remains the largest to date, was equivalent to a fishing effort of 3874 tides. Catches declined to 9670 tons in 1981 and 1094 tons in 1985. Skipjack catches, which had a higher value of 289 tons (1970), evolved to 6357 tons (1982), corresponding to 3785 tides as fishing effort. Landed tonnages will fall thereafter, from 6357 tons (1982) to 891 tons (1984). The third species (bigeye tuna) shows the same pace in this first phase, but with tonnages well below the first two. Its largest tonnage was observed in 1977 (1 640 tones) with a fishing effort corresponding to 2881 tides, followed by an irregular decrease until reaching 450 tons in 1984.

The second phase, from 1986 to 1999, does not show any landings of industrial catches of major tunas at the name of East Atlantic center. After this long period, the first catches of these declared species were effective only in 2000.

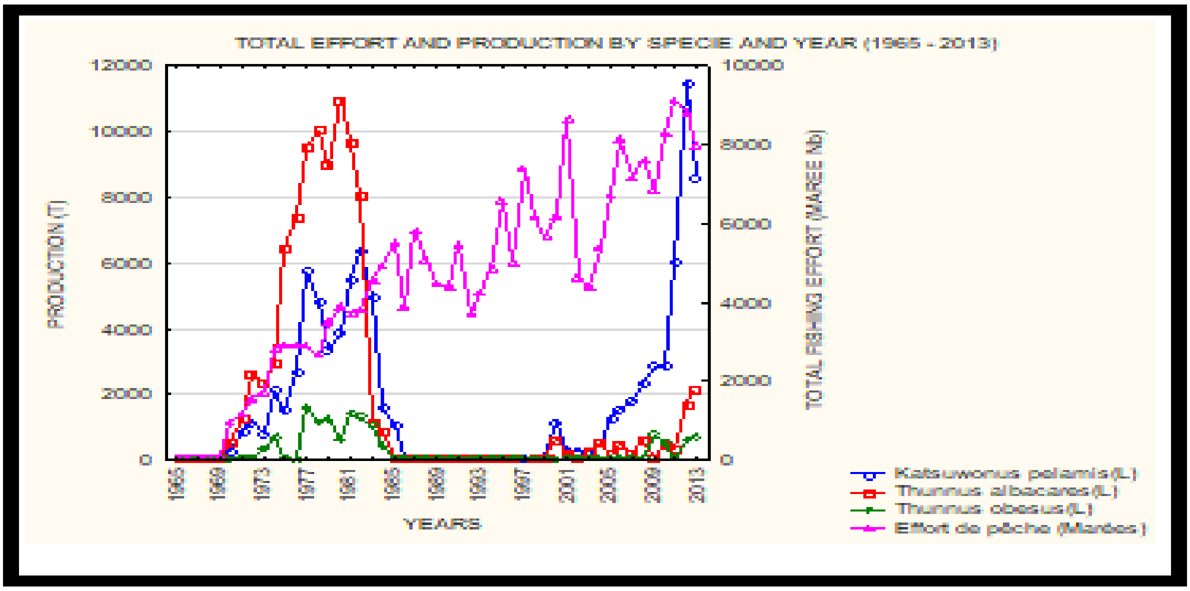

Fig. 4. Evolution of fishing effort and production in the East center Atlantic zone (Ivory Coast).

The third phase (2000-2013) shows a modest recovery in tonnages for these three tunas up to 2003. Since 2004, landings of skipjack tunas have distinguished themselves from other species, progressively increasing from 565 t to 2840 t in 2010. Beyond 2010, we note a strong rise in tonnages of this species to 11485 t in 2012.

That value is the largest annual catch of skipjack over the entire study period. This last phase is marked by a collapse of the stock of yellowfin, and a strong presence of skipjack in the catches of these different gears. Over the whole period from 1965 to 2013, tonnages landed by species are in importance order:*K. pelamis* (25641.78 t), *T. albacares* (2714.30 t) and *T. obesus* (1972,45 t). Comparing the largest peaks of previous annual production with 2014, skipjack rose from 5692 t (1977) to 2568 t (2014); yellowfin tuna, from 10970 t (1980) to 348 t (2014) and bigeye tuna, from 1640 t (1977) to 441 t (2014), which corresponds to a reduction in production of around 81.66 % for all these tunas.

Catch per unit effort (CPUE) by gear

In order to determine the pressure exerted by each gear type on our resources, the CPUE per gear was calculated at the level of the main tunas.

Thus, it can be seen that the use of canes and long lines(Fig. 5 & 6) had little impact on the main tuna stocks in that Atlantic zone; and this, through their low CPUE between 16 and 18 tons / gear / year.

In terms of species, these two gears caught many more yellowfin tuna (YFT) than skipjack tuna (SKJ) between 1970 and 1983. In the last decade, there has been a sharp decline in yellowfin tuna and bigeye tuna CPUE. Total collapse thus, showing skipjack as the most captured species with these two types of gear.

Reel Rods and trollings (Fig. 7 & 8) appear to be the most destructive of tuna resources in the gulf of Guinea through their high CPUE, comparatively to canes and long lines.

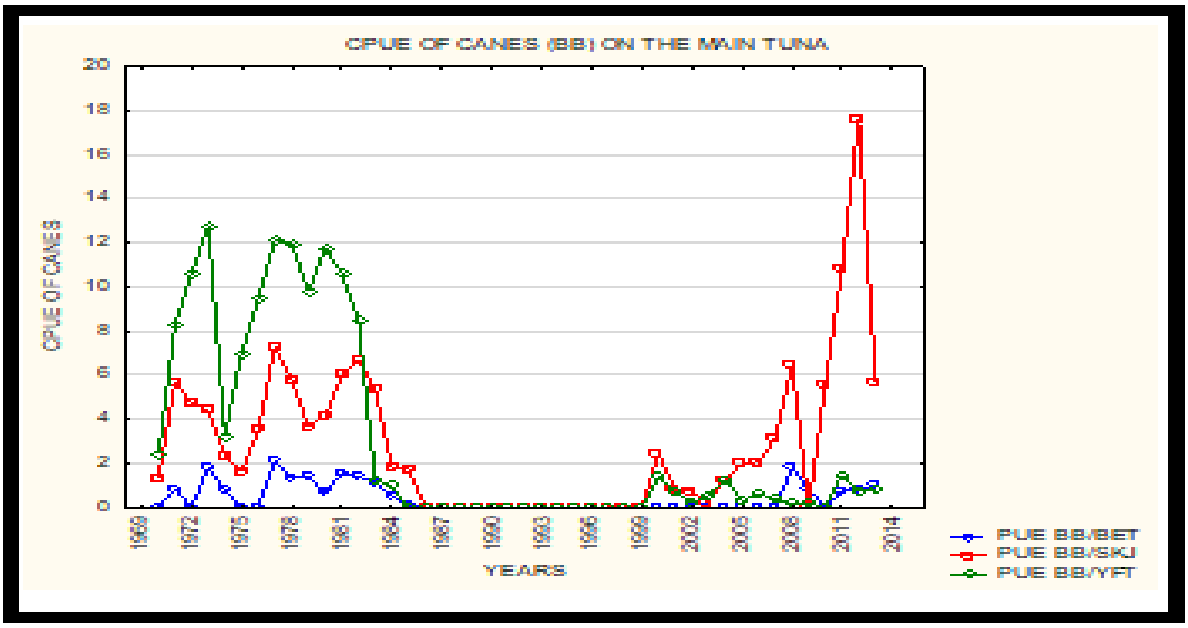

Fig. 5. CPUE of canes (BB) on the main tunas of East center Atlantic zone (Ivory Coast).

In 2003, the values of this index reached 302 tones / gear / year in yellowfin (reel rods) and in 2011, 772 tones / gear / year in skipjack (trolling).

Maximum sustainable yield (MSY)

The resulting curve shows the maximum sustainable yield (MSY) of 8464 tones with an optimal effort level of 4200 tides (Fig. 9).Through this graph, an MSY value of 8 464 tones is recorded, which corresponds to a fishing effort (F_{MSY}) of 4200 tides. The catch and fishing effort in 2013 is 11481 tones for 7965 tides. These 2013 situations show that catches are up 35.64% and the fishing effort is 89.64% higher than the optimal situation (MSY). No proportionality therefore appears between the fishing effort and the production of major tunas in 2013, since the exponential increase in fishing effort no longer leads to an increase in the same threshold of the overall weight production of these species.

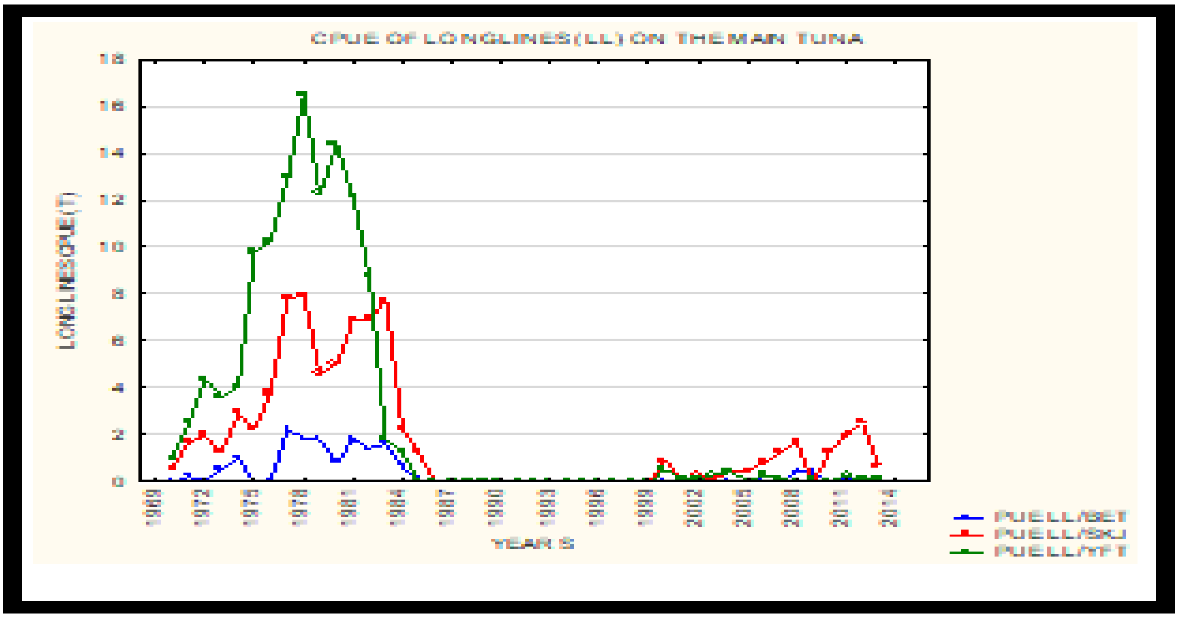

Fig. 6. Longline CPUE (LL) on main tunas of East center Atlantic zone (Ivory Coast).

Size frequencies of the main tunas

Bigeye tuna (Thunnus obesus)

Throughout 2012, 2786 fish of this species were measured in the Ivorian zone. No individual was more than 40 cm long.

In addition, fry of 10 to 15 cm appeared in catches. The bigeye tuna larger than 50 cm disappeared in the captures, in favor of smaller individuals (10 to 15 cm) (Fig. 10).

Albacore (Thunnus albacares)

During 2012, 3320 Albacore catched in the Ivorian EEZ showed a single peak between 40 and 60 cm (Fig. 11). We noted the disappearance of mature individuals of this species in Ivorian catches.

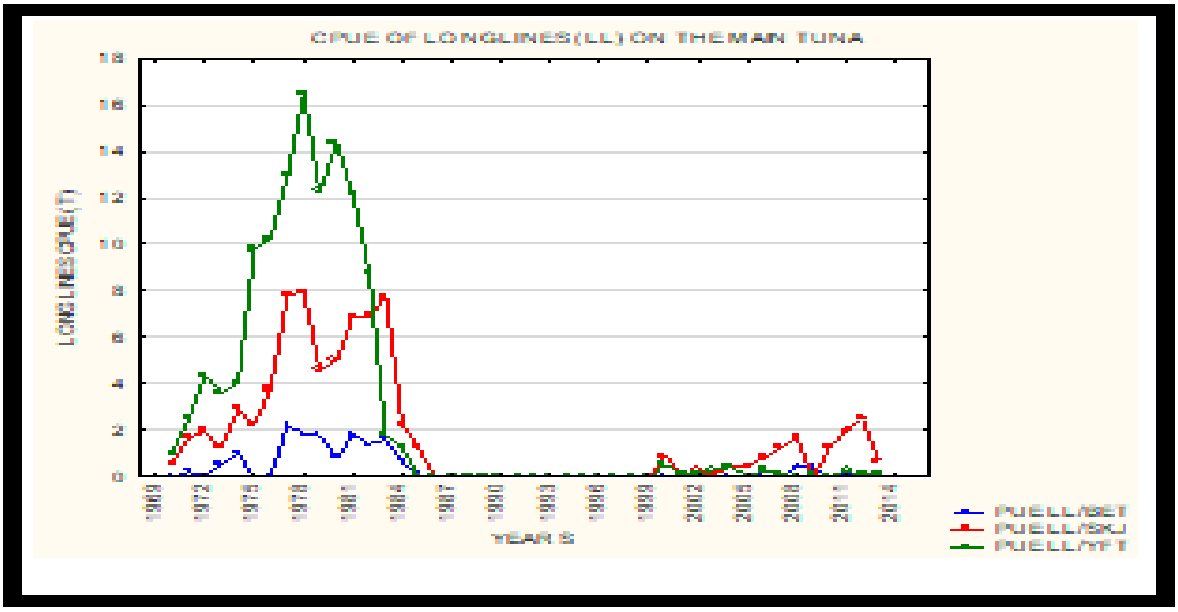

Fig. 7. CPUE of the reel rods (RR) on the main tunas of East center Atlantic zone (Ivory Coast).

Skipjack (katsuwonus pelamis)

In 2012, all Skipjack catches in the Ivorian EEZ (11460 fishes) are confined between 35 and 65 cm, the largest peak of which is observed at 50 cm (Fig. 12).

Discussion

Fishing effort and production

Ship activity, up from 2012 to 2014, as a result of the redeployment of some vessels from the Indian Ocean to the Atlantic Ocean, did not substantially increase the rate of production. Explanatory factors for this state of affairs could be the deterioration of environmental conditions, the weakness of upwelling in recent years due to climate change or the depletion of the stock of major tunas.

It should be noted that the motive power has a significant impact on the efficiency of the fishing gear. Thus, from 2012 to 2014, the increase in the number of Chinese trawlers, from one to two, did not maintain the peak of overexploitation, since the motive power of these machines was reduced by half (440 hp to 240 hp). The high rate of decline in yellowfin tuna production suggests a possible depletion of the stock of this species, if the fishing pressure is thus kept increasing. Bigeye already in small quantities in this area has also experienced a drastic decline, reflecting a case of overexploitation (FAO, 2016).The only one specie that produces a rate of production proportional to the fishing effort is skipjack, and this, until the end of 2012.The lag in production, as a result of the comparison of the main tuna catches between the two decades (1975-1984 and 2005-2014), indicates that, in total, the tuna fishery in Ivory Coast's zone today represents a tiny fraction of catches of the past.

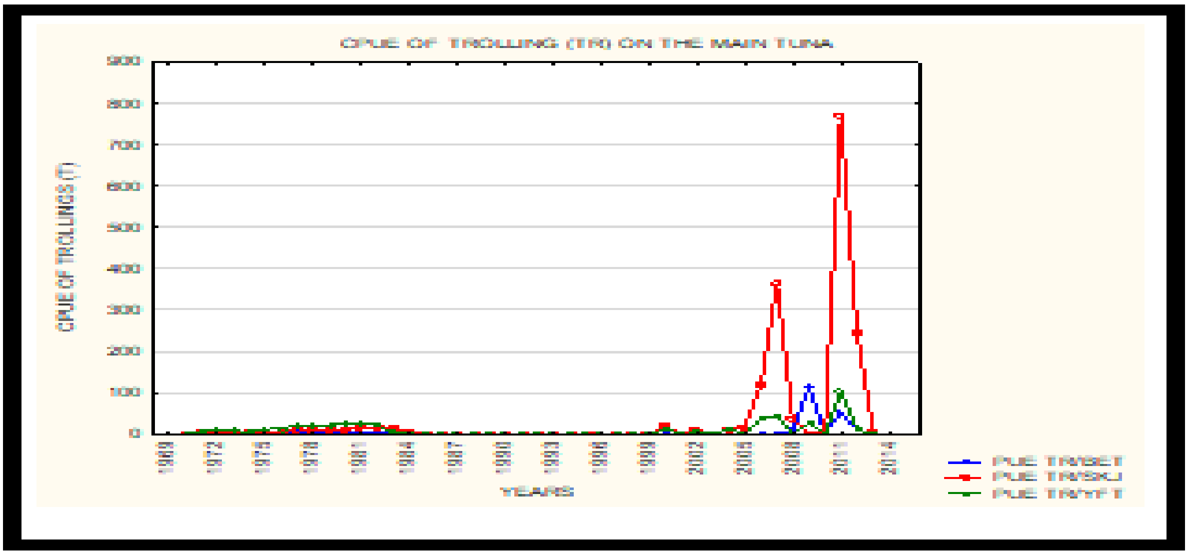

Fig. 8. CPUE of trolling (TR) on the main tunas of East center Atlantic zone (Ivory Coast).

Gear types and nuisance on major tunas via CPUE

Fishing reel Rods and trollings that are used in rocky areas zones manage to make big catches.

This would suggest residual stocks in these limited access areas to other gear. Overall, the marked decrease in CPUE over the past five years reflects a decline in the distribution density of these species in the surveyed area. In the 2010-2020 decade when the status of the tuna stock will remains a global concern, there is a need to reduce the use of a number of gears including rods and trolling which are elsewhere uses in Fish Agragating Devices (FADs).

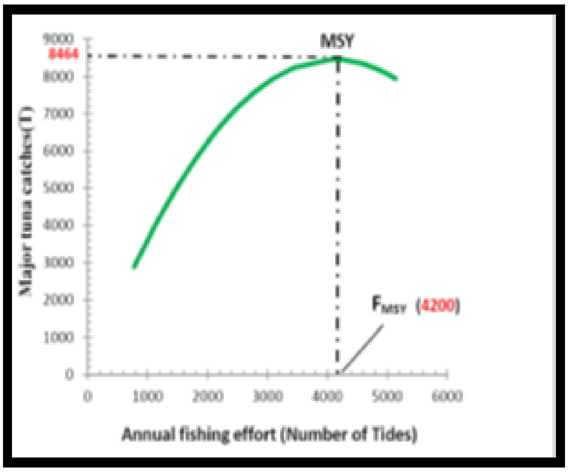

Fig. 9. Dynamic model of production of major tunas of East center Atlantic zone (Ivory Coast).

On the basis of fishing techniques, trawling is one of the causes of benthic habitat destruction, thus reducing the survival rate of the sedentary species that depend on it. Also, the fishing pressure that is now well above that expected to provide Maximum sustainable yield (MSY) should be revised downward in the profitability of the activity, and also to protect the resource.

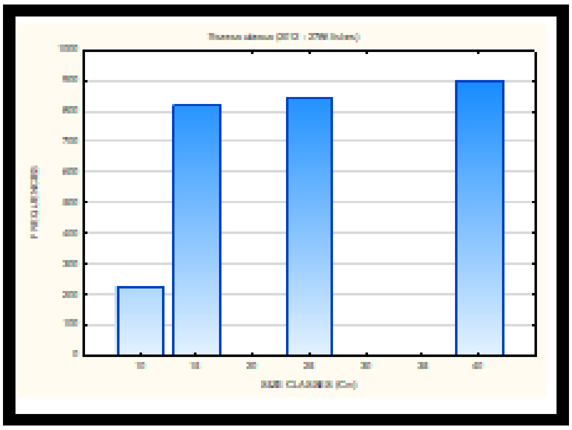

Fig. 10. Size frequencies histogram of bigeye tuna in 2012 captured in East center Atlantic zone (Ivory Coast).

Exploitation status of major tunas

The total absence of landed catches of major tunas in the name of Côte d'Ivoire between 1986 and 1999 is explained by the fact that tuna fishing in this area has been plagued by difficulties following bankruptcy of national armaments (COFREPECHE *et al.*, 2012).

From 2000 to 2011, the fishing pressure reached values well above the fishing effort corresponding to the maximum sustainable yield (MSY), and the volume of production, below the maximum of biologic production.

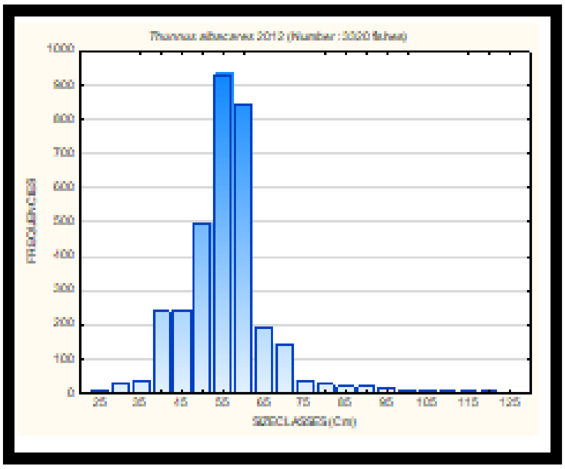

Fig. 11. Size frequencies histogram of Albacore in 2012 captured in East center Atlantic zone (Ivory Coast).

These findings confirm a case of biological overexploitation. Indeed, overexploitation of a species is characterized by symptoms such as the decline in tonnages fished and the decrease in catch size, despite the rise in fishing effort. In this specific case, the increase in fishing effort no longer corresponds to a weight increase in catches of yellowfin tuna and bigeye tuna, but on the contrary, a decline in them. Given to the size of the bigeye tuna in catches, the smallest sizes appeared in the catches of IRD Thonier Observatory (2010) over four decades are greater than 22 cm. Across the Atlantic, Collette and Nauen (1983) obtained 180 cm as the common size in the catches. Throughout 2013, catches of this species in Atlantic East center do not exceed 40 cm. In addition, fry of 10 to 15 cm appeared in catches, well below the size of sexual maturity which is about 100-110 cm (IRD Thonier Observatory, 2010).

There is a disappearance of bigeye tuna of 50 cm. Given the tonnages and sizes landed, we can conclude that, this species is in full biological overexploitation. Relatively to the yellowfin tuna, the common sizes are between 35 and 180 cm, fork length (Fonteneau and Marcille,1988).In 2010, the [14]have noted two intervals of catch peaks in the Atlantic, one between 40 and 60 cm, and the second between 120 and 140 cm over four decades (1980, 1990, 2000 and 2010).

Throughout 2013, catches of Albacore in this sector have a single peak between 40 and 60 cm. We note the disappearance of mature individuals, namely those of the second peak observed beyond 120cm by IRD Thonier Observatory (2010) over the 40years period. The drop in landed tonnages of this species, followed by a sharp reduction in catch sizes, also symbolizes a biological overexploitation of yellowfin tuna. So, Skipjack is the only one species of major tunas with tonnages that evolve in phase with the fishing effort. In the Atlantic, exploited sizes ranging from 35 to 75 cm and acquired sexual maturity around 40 cm, make it possible to affirm that most of the catches only concern individuals who have reproduced at least once. In 2010, the IRD Thonier Observatory (2010)obtained a catch peak between 40 and 55 cm over the four decades (1980, 1990, 2000 and 2010).

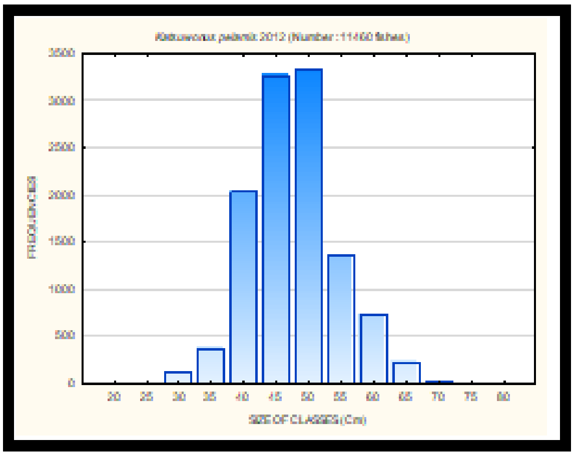

Fig. 12. Size frequencies histogram of Skipjack in 2012 captured in East center Atlantic zone (Ivory Coast).

The confinement of catches between 35 and 65 cm and the observation of the most important capture peak at 50 cm, allow us to affirm that the structuration of the skipjack size in this zone has the same characteristics as that obtained by the IRD Thonier Observatory (2010). Given the evolution of tonnages and sizes in catches, skipjack remains the only major tuna species still fully exploited in the Atlantic East center. These results are contrary to those obtained by Amon Kothias and Xavier (1993).During their studies, these authors had obtained only the yellowfin tuna, as the only species momentarily overexploited among the major tunas of the Ivorian zone.

In terms of landed quantities and size frequencies, we can conclude that bigeye tuna and yellowfin tuna are in a state of overexploitation, since catches are predominantly made up of small individuals (immature), who have not yet made any spawning. The mature individuals of bigeye tuna and yellowfin tuna are disappearing as a result of intensive non-selective fisheries. Skipjack tuna with predominantly mature catches that have reproduced at least once are still in full exploitation. Today, this dominant species in the catches represents more than 2/3 of the catches landed in Ivory Coast. Size frequencies have been used to evaluate the state of tuna stock, because it is said to be a key parameter for efficient decision-making in fisheries management and assessment (Enin, 1994). Different variations in distributions over time and space can help to understand population dynamics. Also, they allow the identification of problems such as growth deficits, low recruitment or excessive annual mortalities (Boussou, 2013). These results are in line with the conclusions drawn from the Catch Per Unit Effort (CPUE).

Conclusion

The average fishing effort (7598 tides)in 2013 is significantly higher than that required to provide maximum sustainable yield (MSY) (4200 tides). In addition, the quantities landed continue to decline, and there is fry predominance (immature) in the catches (10 to 15cm). Adult sizes of bigeye tuna and yellowfin tend to disappear. In terms of quality and quantities landed, including size frequencies, we can conclude that bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) are over-exploited in the Eastern central of Atlantic Ocean. Skipjack tuna (*Katsuwonus pelamis*) is the only one species of major tunas that has predominantly mature catches which have reproduced at least once. This species is still in full exploitation phase. In addition to overfishing, they are Illegal, Unregulated and Unreported (IUU) fishing activities in that East center Atlantic zone (Ivory Coast). If conditions for responsible fishing are not strictly observed, bigeye tuna and yellowfin tuna could disappear from this area, followed by a strong appearance of immature skipjack, and a reduction of mature individuals of this species in catches during the coming decades, sign of specific extinction.

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