SCRS/2002/133

Col. Vol. Sci. Pap. ICCAT, 55(1): 251-271 (2003)

NORTH ATLANTIC ALBACORE, (*THUNNUS ALALUNGA*) PAST AND PRESENT FISHERIES. DID THE STOCK LOOSE ITS RESILIENCE ?

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SUMMARY

In spite of a long history of exploitation, the magnitude of the North Atlantic albacore resource is still not very well known. In this view, this speculative document intends to stress the uncertainties that might have affected the various analysis of the rate of exploitation in the past, and consequently the possible inconsistencies with the recent assessment of the actual state of exploitation.

RÉSUMÉ

Malgré une longue histoire d'exploitation, la taille de la ressource en thon germon nord Atlantique est encore assez mal appréhendée .Ce document à caractère spéculatif cherche à souligner les incertitudes qui ont pu affecter les analyses de l'état d'exploitation passé du stock et en conséquence les possibles incohérences avec l'estimation de l'état du stock actuellement.

RESUMEN

A pesar de un largo historial de explotación, todavía no se conoce bien el tamaño del recurso de atún blanco del Atlántico norte. En este sentido, este documento de carácter especulativo intenta subrayar las incertidumbres que han podido afectar a los análisis y a la tasa de explotación en el pasado y, por consiguiente, las posibles incoherencias en lo que se refiere a la estimación del actual estado del stock.

KEY WORDS

Thunnus alalunga, *albacore, North Atlantic stock assessment.*

1. INTRODUCTION

In the historical tuna fisheries of Atlantic and Mediterranea, the North Atlantic albacore (NAA) is second to bluefin tuna for the duration of catches statistics available and documentation on fisheries.

The main reason is that NAA have been consistently fished since the end of 19th Century, by a few number of countries in northeast Atlantic. And most of the fish produced were industrially used in canning. Therefore the statistics of landings have been always accurate. But, in spite of this favourable situation, along with a important variations in the effort over the past years that should have produced observable effects, we are still rather uncertain about the magnitude of the stock in the past during the bright years of high production, 1955-1965, then the unfortunate recent years of constantly declining production since 1985 **(Figure 1)**.

A particular conjunction of facts by the end of the decade 80, deficit of researches and emerging competition between traditional and new gears, incited ICCAT to initiate in 1990 a Special Albacore Program (PSG) which completed it work by 1994, (ICCAT, 1996). Unexpectedly, in the same period the production of NAA stock began to decrease continuously. One of the reasons could be the loss of

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rewarding prices, generated by onset of international prices, (Bard and Santiago, 1999); but on an other hand all the analysis, essentially tuned VPA, conducted at this time resulted in estimates of a poor level of recruitment, around 10 million age 1 fish, prevailing since 1980. This low level of recruitment contrasted with the previous estimate of substantially higher recruitment, around 15 million, necessary for accounting the surface catches in the previous decades, plus a minimal escapement of large fish sustaining the longline fisheries, (Bard and Joanny, 1996).

A possible explanation of this puzzling apparent decrease of recruitment level came from two hypotheses of environmental effects on the stock. One analysis by Santiago (1998) favored the direct impact of hydro-climatic changes synthetized by North Atlantic Oscillation (NAO) on the level of recruitment. The other hypothesis relied more on a major change in catchability of young fish due to environmental change on the Eastern Atlantic fishing grounds, teleconnected to the Gulf Stream area in western Atlantic (Ortiz *et al.*, 1998, Bard and Santiago, 1999).

Eventually an ultimate hypothesis, not contradictory with the impact of environmental changes could be that an unnoticed state of overexploitation prevailing in earlier years was strengthened by a new and adverse environmental regime, leading to a loss of resilience of the stock.

It is interesting to recall that in a context of worldwide degradation of fisheries resources, now a subject of intense debates, Pitcher (2000), proposes three *« insidious ratchet like effects that compromise fisheries: (i) harvesting as a selective process and the subsequent difficulty in restoring stocks that are becoming less resilient, (ii) the ecological reference point that are shifting with each generation of scientists as earlier abundance of fish population in regarded as anecdotal, and (iii) economic factors associated with overcapitalisation that generates further investment and an increasing fishing effort »*. The third effect is the less likely in case of albacore for which world prices are poorly attractive, but the two former effects could be relevant in the case of NAA.

Eventually this speculative document intends to stress the uncertainties and inconsistencies that might have affected the various analyses of the rate of exploitation, and reciprocally the estimation of the magnitude of the stock of North Atlantic albacore, in the past and the present.

2. BACKGROUND: BRIEF STORY OF THE FISHERIES AND ASSESSMENTS OF NAA

2.1 The fisheries: from traditional national gears to new international gears

2.1.1 Surface fisheries

Several surface fisheries have exploited the North Atlantic albacore. These fisheries started, peaked and declined rather sequentially, driven by the economical performances **(Table 1, Figure 2)**. By the beginning, national markets were protected but later by the 1980s, the global open market lead to collapse of these specific fisheries. Moreover the generalisation of tropical tuna supply for canning depressed durably the prices. Actually the "white meat" of albacore fetch only slightly better price than meat of commonly canned yellowfin or skipjack, making specific fisheries for albacore hardly profitable.

Trolling is the oldest fishing method and developed rather early in France during the 19th century when the invention of "appertisation" allowed production of canned tuna, highly demanded then. The trolling fleets of France then Spain operated during Summer in the Bay of Biscay, East of longitude 15°W, by short trips of traditional sailing boats, progressively motorized shortly prior to World War II. The range of sizes of the fish captured is stable and the commercial class correspond to clear size classes, which were proved to be year classes 1, 2 and 3 year old **(Figure 3)**. Design of the rigging, poles, design and number of lines, shape and size of hooks, was very traditional and did not change even after World War II. Some innovations, such as slight increase of the size of ships, ice holds, more powerful motorization and radiophony, improved mainly the duration of trips and westward extension of fishing grounds (Bard, 1981). But, due to the loss of a protected market, French trolling declined severely by 1980 and came to an end by the mid-1980s.

In Spain trolling started later than in France, but tradition and codification of fishing methods took place probably as much as in France, although less studied yet. The Spanish trolling fleet is the only trolling fleet remaining active.

The use of pole and line with live bait was introduced in Euzkadi by 1947-48. It was very successful, and extended to Brittany by 1955. The baitboats fleet in France and Spain became the other major contributor to catches of young albacore in northeast Atlantic **(Table 1, Figure 2)**. The size of the fish caught was initially similar to the trolled fish, as the two fleet operated together, but a learning process took place, and by 1958 the catch of large fish around 10 kg, a mixture of ages 3 and 4, became a regular feature of baitboats especially by end of Summer **(Figure 3)**. The French fleet of baitboats declined since 1968, when the major part of the fleet shifted definitely to West African waters, fishing for tropical tuna, and stopped by end of the 1980s.The Spanish baitboat fleet of Euzkadi survived much better, due to a continuous policy of investements, and better marketing condition. Size and technical equipment (sonars) of the baitboats increased particularly during the 1970and 1980s. An extension of fishing grounds in Autumn, off Azores and Southern Spain allowed the onset of a specific pole and line fishery capturing large albacore of pre-adult size (80-110 cm, FL). However this fishery is sensitive to bad weather conditions prevailing in this season.

An ultimate effort of adaptation by French surface fisheries was undertaken in 1986 using gillnet and pair trawl. Sizes of the fish were similar to troll and baitboat with the exception of some larger fish for trawl (Liorzou, 1989). Gillnetting proved economically profitable but socially unacceptable (Antoine, 1995), and came to an end by 2001. Only trawling remains active in France, United Kingdom and Ireland.

2.2.2 Fishing in the depth by longline

By 1956, the Japenese longliners began to operate in Atlantic ocean, and after some targeting on yellowfin, concentrated on albacore in two distinct fishing grounds, the so-called “spawning grounds” located in the central western tropical Atlantic (roughly the Sargasso Sea) exploited in summer and the “feeding grounds” located more northeastern, exploited in winter, (Koto, 1969; Beardsley, 1969; Shiohama, 1976). From 1960 to 1969, they exploited the large adults (90-120 cm, FL) in the “spawning grounds”, then shifted to “feeding grounds”, targeting the smaller pre-adults (80-100 cm), (Uozumi, 1996). A particular biological feature of the large albacore captured by these fisheries is the desequilibrium of sex ratio towards male fish for biggest sizes **(Figure 4)**.

Later Korean, and more particularly Taiwanese longliners continued this fishery. By 1976, the longlining started to target bigeye tuna of sashimi quality, in the fishing grounds at lower latitude and eastward of the traditional large albacore fishery. Setting of the hooks deepened in the same time and large albacore became a by-catch of sashimi “super freezing” longliners. (Nakano, 1996).

2.2 History of stock assessments

The story of the North Atlantic albacore fisheries demonstrate an heterogeneity the makes the use of their statistics complex for models of population dynamics. Moreover if catches statistics can be considered as accurate, the data necessary for computing effective fishing effort are nil prior to 1967, only valid for French fleet from 1968 to 1971 and complete for all fleets only since 1975. Correct length sampling of fish captured by major fleets and gears has been initiated in France by 1968 in Spain by 1972. Consequently the use of analytical model, based on VPA, relied on limited range of years of exploitation, subsequent to the peak of production of 1964.

Bard and Joanny (1996) reviewed the various trials of classical VPA, from the first (Le Gall and al, 1974), to the last one (Gonzalez Garces *et al.*, (1989) they had in common the basic problem of objective selection of a terminal Fn using the reverse mode. Altogether these trials of VPA resulted in rather high estimates of fishing mortalities, associated to an average recruitments ranging between 10 and 13 million age 1 fish.

Laurec and Bard (1980), proposed a so-called "multi-cohort" method that solves the inherent uncertainty of VPA (n unknown and n-1 equations). This method is based on the stability over years of catchabilities at age 2 and 3 applied to French troll. For the cohorts 1964-1976, using substitution of French surface gears to Spanish ones for years prior to 1972 the method showed that the virtual population of 7 to 10 million fish necessary to sustain large surface fishery was corresponding at a minimum average recruitment about 15 millions recruits age 1. But at least the cohort 1969 must have been as high as 20 million fish.

The application of tuned VPA to N.A.A. was initiated in the 1990s during the ICCAT Special Albacore Program (ICCAT, 1996). The conclusions which did not change much in the recent years, showed a highly exploited stock, with an apparent stable recruitment of about 10 million age 1 fish (ICCAT, 2001), corresponding to a virtual population of 4 to 5 million fish.

On an other hand the heterogeneity of fisheries and the poor estimation of fishing effort affected the few trials of production model. The heterogeneity of fisheries, the clear difference between the sizes captured, young fish by surface fisheries, adults by longlining, makes the computation of a total effective fishing effort dubious.

As an intermediate conclusion, the nature of the N.A.A. fisheries, including two kinds of sequential fisheries with no significant year class exploited simultaneously, and independent evolution of fishing gears, efforts, strategies, make an historical consistent assessment of the exploitation rates complex if not impossible.

3. THE PAST: WHAT COULD HAVE BEEN THE PAST MAGNITUDE OF THE STOCK?

3.1 The absence of assessment during climax years of surface fisheries

Because of the industrial use of albacore in canning, the historical figures of the catches of young fish captured by troll and baitboat and on other hand adults fished by longline are accurate, **(Figure 1, Table 1)**. The stock yielded over 50,000 t/year of albacore steadily during the period 1958-1974 with a peak in 1964. For years 1965-1978, classical or multi-cohort VPA estimated a recruitment level between 13 to 15 million age 1 fish. However as explained before, because of the uncertainties on the data, particularly for length frequencies substituted, and the subjective choice of Fn, these various VPA do not provide fully reliable answers. Moreover, they relate to years slightly after the top production of the stock.

The basic question which remains is: What could have been the real rate of exploitation of such a stock, and consequently the magnitude of a resource apparently able to sustain without damage an exploitation based in major part on the capture of young fish, although leaving escapement to enough adults for sustaining a longline fishery producing 15,000 t/year?

In the definitive absence of sizes composition for surface fisheries during their climax, and uncertainties inherent to VPA, an objective method could be to examine the historical evolution of biological indices, such as mean size (weight of length), versus fisheries development. It happens that such approach is possible for French trollers, during the gradual increase of surface catches and effort since 1922-1958, and onwards. Comparatively, the historical mean lengths of albacore captured by longline are available in the work of Uozumi (1996).

4.2 Development of mean weight of French trollers

The conservatism of fishing gear, commercial categories and catches expressed in number of fish, particularly for trollers from Brittany, enables to constitute of an homogeneous series of average monthly weight relating to a fishing gear which produced from 1922 to 1979 a major part of young albacore caught by the surface fishery **(Table 2, Figure 3)**.

As the outmost part of the catch was used for canning, fish was sold individually after inspection and classification. Consequently in France, and particularly Brittany, the exact number and size categories of the fish were carefully recorded as price was paid accordingly. The commercial classification used (gilled and gutted) was as follows:

"Bonite": less than 3.5 kg
"Demi": between 3.5 kg and 6.5 kg
"Thon": more than 6.5 kg

The price was fixed according to these classes. Bonite were sold separately at lower price, and two demi ("half") counted for the value of one full "thon". These differences were "justified" by the better rate of meat extraction for larger fish during butchering, and the fact that these commercial classes correspond to clear size classes **(Figure 3)**. In several ports of Brittany, the archives of such landings statistics have been recorded. For the period 1924-1931, the main port, by far, was Concarneau and archives of canneries purchasing "vouchers" expressed in number of fish by class have been recorded by Bard (1981).

Since 1932, fish conservation was much improved by use of ice holds, and onset of motorization of the dundee. Consequently quality of fish landed was stabilized and only the total number of demi + thon (bonite sold apart) and corresponding total weight were recorded. These "mercuriales" were published for main Brittanny ports in the commercial monthly review "La Pêche Maritime". The series of this review have been analyzed by Bard for 1934-1969. Since 1970, the mean weight was computed from scientific sampling.

As a global result **Figure 5** displays the history of average weight of Britton trollers, 1922-1969 corresponding to a range of years when production of French troll represented a considerable percentage of surface fisheries catches up to 1978 (**Table 2)**.

The main features of this historical series are:

i) The mean weight was 5.60 kg during the period 1922-1939, years when low effort exerted only by dundees, sailing or with auxiliary engine, producing around 15,000 t/year. It decreased slightly to 5.52 kg during the period 1950-1958 when surface fisheries, mainly troll, increased their production up to 35,000 t/year.

ii) Later, during the years 1959-1968, the surface production increased again with the development of baitboats and production peaked to around 50 000 t/year. A clear decreasing trend of mean weight appears for 1962-1968, down to an average of 4.92 kg for years 1963-1969.

iii) From 1970 to 1975, the surface catch declined and mean weight increased back to about 5.40 kg

iv) From 1976 to 1980, the evolution of catches and mean weight is irregular, and in 1980 the French troll, due to collapse of the prices became negligible and the source of data inaccurate.

Under the hypothesis that mean weight of Britton trollers is a valid index of size structure of young fish age 2 and 3, and to less extent age 4, the conclusion is that considerable variation of catches (and effort) of the period 1922-1980 had indeed an effect on the underlying population of young fish.

A simple model of simulation for a single troll fishery, using the ratio of catchabilities coefficients deduced from Laurec's method applied to French troll, shows that the mean weight observed during the historical fishery correspond to a realistic range of exploitation rates of the young albacore **(Figure 6)**. Particularly during the years 1963-1968, when troll and baitboats of Spain and France wrere very active, the fishing mortality seems to have had a sizeable effect on mean weight of the mixture of age2 to 4 captured by troll. However the history of surface fisheries is complex as, shown before. In the future, it would be interesting to conduct more sophisticated simulations for checking the sensibility of mean weight to various scenarios of catch at age for surface fisheries, recruitments levels, versus different hypothesis of effort (baitboat plus troll), to be standardized using the coefficients proposed by Bard, 1981).

Another investigation could be to check if any Spanish archives of troll , are not available for this kind of "data mining" for constituting a comparable series to the French one.

4.3 Historical development of average sizes of longline-caught albacore

The length sampling and logbook coverage of Japenese longliners has been correct since the beginning. Morita (1977) using these statistics associated with seasonal time-area distribution of "spawning grounds" and "feeding grounds", computed a longline catch at age table for large albacore, 1956-1974. His data are displayed in **Figure 7**. A noticeable feature is the very regular decline of large fish aged 8 and plus, balanced by increase of age class 6. But in fact this decrease reflects probably a mixture of the exploitation of accumulated biomass of larger fish; mainly males, in spawning grounds plus the effect of the shift of fishing effort in 1967 towards smaller fish in the feeding grounds. The historical evolution of the mean fork length by ICCAT area, (Uozumi, 1996, his Figure 7), supports this view. The mean size of larger albacore in spawning grounds declined slightly from 1959 to 1971, then stabilized till recent years around 98 cm. Mean size of albacore in the feeding grounds fluctuated from 1971 to 1991 without trend around 88 cm.

4.4 A robust past resource?

This examination of biological indices relating to the past years of considerable production, suggest that the young albacore of North Atlantic has been substantially exploited in the past, particularly during the climax of surface fisheries from 1958 to 1968 but recovered in the decade of the 1970s.

On the other hand for large pre-adults and adults fish, the only biological effect is the depletion of the accumulated biomass of very large male fish in spawning grounds. A similar effect could have happened for very large yellowfin tuna in the Gulf of Guinea when longlining started here, (Fonteneau com. pers).

As an overall conclusion, the North Atlantic albacore stock yielded over 50,000 t/year of albacore for a long period 1958-1974, without signal of over-fishing. This apparent healthy state constrasts with the slump of production in the most recent years.

5. THE PRESENT: WHAT HAPPENED TO THE RESOURCE AND FISHERIES?

5.1 Assessment

By the beginning of the 1980s the yield of the surface fleet decreased notably, mainly due to disappearance of French fleets. But the other fleets did not compensate for this loss of fishing effort, probably because of low profitability. On the other hand, at the same time the longlining shifted to fishing bigeye of sashimi quality. The only vigorous fleets remained the Spanish ones, baitboats, mainly in Euzkadi and troll in Galicia. As a consequence the production level is now at a medium level, with catches being shared between several fisheries, none exceeding 10,000 t/year **(Table 1)**.

At the same time, the various assessments carried out during SCRS sessions concluded to a strong decrease, about 30 %, in the recruitment level of NAA, and correlatively a high level of exploitation. This conclusion on the decrease of recruitment stems from many trials of tuned VPA, mainly driven by several evolutions of indices of abundance and catch at age, which are:

i) The only available index of abundance for age 2 and 3, by far the most numerous catch in number (Santiago, 1999) are those of Spanish trolling. These indices exhibit an inverse evolution since 1980. The index of age 2 is stable, but the index of age 3 decreased, particularly since 1988 (ICCAT 2001, Table 6), resulting in an increasing apparent fishing mortality on age 2 **(Figure 8)**.
ii) The decrease of the catches of age 3 and 4 fish in the baitboats catches (Santiago, 1999)
iii) The continuous decrease of index of abundance of large fish (age 4 to 8+) derived from longline fisheries, Japenese and Taiwanese, suggesting that abundance of adults never recovered since the introduction of longlining, in spite of the decrease of effort exerted on adults **(Figure 9)**.

5.2 Effect of environmental changes

Facing this considerable apparent degradation of the stock, researches focused on biological processes that could explain it. Several authors examined the possibility of the impact of changes in the environmental regime.

An hypothesis proposed by Santiago (1998) is a long-term environmental effect on recruitment. Large environmental oceanographic changes, reflected by the North Atlantic Oceanographic (NAO) index could be at the origin of new conditions prevailing over the fisheries. Particularly the NAO index after a long series of negative index has become generally positive since 1981. Eventually a complementary hypothesis would be that an overexploitation in earlier years of high production, strengthened by a new and adverse environmental regime lead to a loss of resilience of the stock.

Alternatively, a local environmental change affecting the eastern Atlantic fishing grounds, linked to the variations of NAO, teleconnected to Gulf Stream area in the western Atlantic was suggested by Ortiz *et al.* (1998). It could have affected the catchability to Spanish fisheries, baitboats and trollers, actually the major contributors of age 2-4 catches.

6. DISCUSSION

6.1 The impact of environmental change. General, medium or local change?

Santiago (1998) first hypothesis favored a general decrease of recruitment linked to change of regime of NAO. It means a direct effect of hydro-climatic changes on recruitment processes of several spcies of North Atlantic tunas, among them, albacore (Borja and Santiago, 2002). And indeed it is apparent for some past cohorts; The 1969 strong cohort is associated to a negative index of NAO of –5.9, and the very poor 1973 cohort is associated to a positive NAO index of +3.4. An analytical approach of direct effects of hydro-climate on recruitment request a particular study of the processes of recruitment itself (Bakun Triad). Exploring them in the case of North Atlantic albacore, where even the geographic location of larvae remains imprecise, is a difficult task. As a partial conclusion, this hypothesis remains a possibility, but difficult to prove.

Alternatively, as suggested by Bard, (2001), the environmental change, linked to the variations of NAO, shown by Ortiz *et al.* (1998) could have affected the catchability of young albacore to surface fisheries, in two different ways, either a change in the distribution of aggregation of ages 2 and 3, linked to thermic contrasts in northeastern fishing grounds, either an alteration of the migration patterns.

At medium scale, the environmental effects could have been rather a change in the summer migration patterns, as the suitable habitat of young fish during summer extends probably westward of the range of surface fishing gears. This effect could had been ever more pronounced for baitboats which target larger fish, a mixture of age 3 and 4 at proximity of continental slope in the so-called "cantil", where their catch declined dramatically since 1981, (Santiago 1999). Two examples suggest that a key to this hypothesis would be a change in nutrition strategies of young albacore during the summer trophic migration. In the case of North Pacific Bakun (1992) suggested a major decadal change in the pelagic animal populations assemblage what could have modified the North Pacific albacore population. Another example is the alteration of migration patterns of North Pacific bluefin, (*T.thunnus orientalis*) linked to climate induced change in prey abundance (Polovina, 1996).

At the local scale, a change in the thermic contrast, could have affected the catchability to Spanish trollers, of age 2 and 3 and consequently the indices of abundance on which the estimation of surface fishing mortalities rely. In the 1970s, Havard Duclos (1973) described a strong association of young albacores during their summer trophic migration, with sea surface temperature (SST) ranging from 16 to 21°C. Sizes groups were separated according to fine patterns of sea surface temperature (SST). Fish, of age 3 are associated to SST of 16-17°C, fish of age 2 are associated to SST of 18-19° C, fish of age 4 are associated with SST of 20-21°C, (along with age 1) A change, in the time-area distribution SST could modify the thermic contrasts in Bay of Biscay that aggregate young fish.

6.2 Does the longline CPUE index the abundance of adults?

Longline CPUE, even corrected as far as possible, could not index properly the abundance of the albacore, and maybe some others tuna .The reason relates to vertical extension of habitat and feeding behavior of large albacore.

It has been shown that vertical extension of habitat of the large albacore is extending to 450 m deep in the central gyres of tropical oceanic basins. Large deep swimming albacore foraging on micronecton follows the diel vertical migration of micronecton and stay in the depth close to the preys, most of the daytime except in very short time at dawn and sunset (Bertrand *et al.*, 2002,a).

This daytime habitat extends deeper that the maximum depth -150 m, of action of conventional longline which was used when albacore was targeted early by Asiatic fleets. The feeding behavior of large deep swimming tuna, could increase this unavaibility to hooks during daytime. From stomaches analysis it seems that only albacore (and other tunas) with low level of stomacal repletion attack the baited hooks (Bard, 2001,b). This low catchability of dead baits is increased by the local distribution of tunas and preys aggregations. Bertrand et al (2002,b), using echo-sounding of large deep swimming tunas and micronecton showed that patchiness of micronecton is directely related to density of tunas. But success of experimental deep longlining sets in the vicinity was lower when density of micronecton was high.

This hypothesis of low catchability of hooked baits of longline could be true for various deep swimming tuna and other fish. For instance, Velasco and Quintans (2000) suggested the same conclusion for swordfish (*X. gladius*) captured off West Africa.

These observations lead to the conclusion that longliners operating in the Atlantic from 1959-1979 with classic longline reaching – 150 m, exploited a marginal habitat of the albacore in the mid Western tropical Atlantic. When they started to use deep longline of various types, they were targeting bigeye, in different fishing grounds, where pre-adults albacore are only a by-catch. Consequently, even corrected as far as possible, the CPUE of longiners do not index correctly the biomass of adult albacore.

An indirect clue is the discrepancy between evolution of longline standardized CPUE (Uozaki, 1999, ICCAT 2001) and the stability of average size of of albacore fished during the period 1970-1991 as shown buy Uozumi (1996). Similarly the average weigth computed for 1975-1997 from data of Santiago (1999) is stable **(Figure 10)**. These fish are clearly a by-catch of bigeye longlining, Another contradiction is the relative stability of index of abundance of large fish captured by Autumn baitboats (Pereira et al., 2000), although the series of data is short.

6.3 A loss of resilience of the stock?

Eventually a last hypothesis is that the stock, previously in a state of under-exploitation, lost its resilience to exploitation, in a context of adverse long term environmental change, (decadal effect). Indeed the young component of the stock seems to have been substantially exploited in the years 1958-1968 as suggested by evolution of mean weight. Moreover, the continuous decrease of the index of abundance derived from longline CPUE suggest a strong decline of the spawning biomass and the drop of level of recruitment in 1981 could lead to a direct spawning recruitment relationship which was investigated by SCRS, (ICCAT, 2001).

But a particular point is that such a drop of recruitment happened without any warning such as irregularity in year class strength, as it happens classically when a fish stock reaches a depletion level such as density dependent mortalities occur. When investigating the effect of NAO on recruitment for the period 1969-1980, Santiago (1998) identified only two apparently irregular cohorts associated with NAO. The 1969 strong cohort is associated to a negative index of NAO of – 5.9, and the very poor 1973 cohort is associated to a positive NAO index of +3.4. And since 1981 the variability of the apparent recruitment computed from tuned VPA is low (ICCAT, 2001).

7. CONCLUSION

The impact of an large environmental changes, reflected by NAO, occurring in the 1980s and 1990s on the availability of young fish to surface fisheries seems probable. But it is hard to conclude between several scenarios of environmental impacts. Change of catchabilities of young fish, change in migrations paths or change in recruitment level ? It is worth to remind that a similar decline of surface fisheries has affected the North Pacific Albacore during the 80’s, Bakun (1992). It seems that these fisheries are actually recovering.

More evidence supports the hypothesis, that the continuous decline of longline CPUE do not reflect the evolution of the spawning biomass. The classical longline used in the historical fisheries seems to have exploited only a marginal habitat of large fish, as well in vertical distribution in Central Northwest Atlantic waters, as in geographical extension of habitat of preadults albacore in winter. The development of new fisheries, albacore, pair trawl in late Summer and baitboat in Autumn suggest that migrations of large albacore, of pre-adults size 80-110 cm, encompass a much larger part of ocean than described before (Koto, 1969; Beardsley, 1969). As an example, the South Pacific albacore stock assessment, using a production model, Skillman (1977) based on longline CPUE concluded to a rather small resource, involving a recruitment between 5 and 10 millions fish age 1. Within the SPAR program, the use of the sophisticated MULTIFAN-CL by Fournier *et al*. (1998), shown a large resource based on an average recruitment of 21 million fish.

As a final conclusion, indeed, the recent SCRS assessments concluding to a severely depleted stock, at the verge of recruitment problems, remain a possibility. However the present document advocate to do not rule out the alternative possibility that North Atlantic albacore resource may have been a rather large stock, substantially exploited in the past time, but now only marginally exploited because of adverse environmental change and few profitability.

New research could help to resolve this uncertainty. It could be new tagging designed according to recommendations of Ortiz and Bertignac (2002). It could be campaign of echo-integration on large deep swimming albacore (and others tuna) using the methods set up by Bertrand *et al.* (2002, b). They estimated tuna density by echo-integration in the central South Pacific around Polynesia during ECOTAP program. In this area, very comparable hydrologically to the central Tropical North Atlantic, they integrated a layer of 0-500 m, and estimated an average density of 1.33 tuna per km², among which, pre-adults albacore are certainly a major component.

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[3]Now *Thunnus orientalis*.

Table 1 : North Atlantic albacore catches (live weight) by gear and contries, Metric tons,1920-2000. Note : Values in italics are estimates.

	Youngs					Adults			
Year	Troll France	BB France	New gears France+UK+IRI	Troll Spain	BB Spain	BB Spain Autumn	BB Portugal Azores	Asiatic longline	Grand Total
1920	3488			5500					8988
1921	3263			*5000*					8263
1922	4331			*5000*					9331
1923	4106			*5000*					9106
1924	8100			*5000*					13100
1925	6300			*5000*					11300
1926	6525			*5000*					11525
1927	7931			*6000*					13931
1928	10913			*8000*					18913
1929	10575			*8000*					18575
1930	7819			4300					12119
1931	13050			*4000*					17050
1932	10125			3850					13975
1933	8550			3850					12400
1934	13613			6750					20363
1935	13219			9000					22219
1936	11250			6800					18050
1937	10688			4000					14688
1938	11925			4000					15925
1939	13950			4700					18650
1940	5794			6400					12194
1941	6300			7650					13950
1942	6581			10950					17531
1943	1294			15650					16944
1944	0			16950					16950
1945	7950			19600					27550
1946	7100			16150					23250
1947	4900	0		15400					20300
1948	9650	475		14000	0				24125
1949	11650	1377		14800	0				27827
1950	13210	1470		19243	*3000*				36923
1951	12822	1881		15446	*4000*				34149
1952	12640	1700		14177	*4000*				32517
1953	11692	1500		13050	3875				30117
1954	10088	3550		22466	7250				43354
1955	*10600*	*4000*		13700	3125				31425
1956	*11750*	*5000*		18650	5500			0	40900
1957	13105	6959		16923	5000			100	42087
1958	8646	8633		25299	8625		300	900	52403
1959	8224	10697		22572	7250		570	600	49913
1960	10183	9414		22889	8125		600	1300	52511
1961	9165	7927		11742	12593		600	500	42527
1962	12589	7704		18354	13145		620	580	52992
1963	9804	6435		14821	13334		970	14700	60064
1964	12727	6759		15331	13169		500	15900	64386
1965	11365	4183		14179	14846		830	14700	60103
1966	9959	3454		12832	12678		340	7800	47063

1967	11640	3893		19029	13400		740	9600	58302
1968	11030	2209		12963	11269		110	7700	45281
1969	7675	1710		10248	11980		500	14800	46913
1970	4456	1707		11250	12231	250	200	16100	46194
1971	7727	1483		16302	13494	400	300	17900	57606
1972	8683	475		17834	6562	725	300	14600	49179
1973	5785	1074		12927	6394	1778	300	18200	46458
1974	7875	550		13053	11157	3742	1246	14600	52223
1975	4959	707		4515	8547	9032	1033	12600	41393
1976	5685	1115		8200	12346	6341	600	22900	57187
1977	6190	633		10300	9242	5644	100	20900	53009
1978	8437	386		14100	10113	1610	100	14100	48846
1979	7834	220		14200	14974	1604	100	12200	51132
1980	3100	400		9500	15700	0	100	7090	35890
1981	2500	400		8200	12600	0	400	6584	30684
1982	2700	200		10100	15300	0	300	10500	39100
1983	2200	200		10600	19000	0	1800	14254	48054
1984	2800	0		8200	8305	0	775	14923	35003
1985	1800	100		8900	12589	0	657	14899	38945
1986	1100	100	0	9800	15202	0	498	19646	46346
1987	1400	100	300	10000	18756	0	433	6636	37625
1988	400	0	2400	11000	16752	0	184	2117	32853
1989	100	300	3700	10500	15374	0	169	1294	31437
1990	0	0	3340	10350	16871	0	1754	3742	36057
1991	0	0	4160	8959	8274	3031	4	5304	29732
1992	0	0	7375	7348	10828	3229	1248	3103	33131
1993	0	0	8239	6109	12271	4009	821	7659	39108
1994			8423	5959	11039	1813	287	7195	34716
1995			6222	10226	9971	3676	205	4776	35076
1996			5568	6652	9671	596	1634	4620	28741
1997			6531	7870	9424	1277	395	4043	29540
1998			7461	5894	7401	333	91	3874	25054
1999			12047	6845	8521	1206	324	6644	35587
2000			9293	5016	10949	2200	278	6272	34008

Table 2 : Historical evolution of mean weight (Kg, gilled gutted) of albacore, ages 2-4,captured by French Britton trollers , 1922-1980, from various sources, as compared to relative share of French trolling in catches of young fish.

Year	Mean Weight total serie	Sailing Dundees	Dundees auxiliary engine	Brittany motorized troll	Scientific sampling	% French Troll in surface	Total catches Youngs
1922	5,75	5,75				46,4	9331
1923	5,03	5,03				45,1	9106
1924	5,88	5,88				61,8	13100
1925	5,40	5,40				55,8	11300
1926	5,50	5,50				56,6	11525
1927	5,25	5,25				56,9	13931
1928	5,88	5,88				57,7	18913
1929	5,58	5,58				56,9	18575
1930	5,55	5,55				64,5	12119
1931	5,45	5,45				76,5	17050
1932	5,55		5,55			72,5	13975
1933	6,62		6,62			69,0	12400
1934	5,23		5,23			66,9	20363
1935	5,32		5,32			59,5	22219
1936	5,58		5,58			62,3	18050
1937	5,64		5,64			72,8	14688
1938	5,57		5,57			74,9	15925
1939	6,05		6,05			74,8	18650
1940	WWII					47,5	12194
1941	WWII					45,2	13950
1942	WWII					37,5	17531
1943	WWII					7,6	16944
1944	WWII					0,0	16950
1945	WWII					28,9	27550
1946						30,5	23250
1947						24,1	20300
1948	5,50			5,50		40,0	24125
1949	5,70			5,70		41,9	27827
1950	5,52			5,52		35,8	36923
1951	5,55			5,55		37,5	34149
1952	5,48			5,48		38,9	32517
1953	5,07			5,07		38,8	30117
1954	5,50			5,50		23,3	43354
1955	5,62			5,62		33,7	31425
1956	5,83			5,83		28,7	40900
1957	5,31			5,31		31,2	41987
1958	5,64			5,64		16,9	51203
1959	4,94			4,94		16,9	48743
1960	5,70			5,70		20,1	50611
1961	5,38			5,38		22,1	41427
1962	5,27			5,27		24,3	51792
1963	4,90			4,90		22,1	44394
1964	5,02			5,02		26,5	47986
1965	4,66			4,66		25,5	44573
1966	4,97			4,97		25,6	38923
1967	4,76			4,76		24,3	47962
1968	5,20			5,20		29,4	37471

1969	4,96	4,96		24,3	31613
1970	5,37		5,37	15,0	29644
1971	4,76		4,76	19,8	39006
1972	5,41		5,41	25,9	33554
1973	5,40		5,40	22,1	26180
1974	5,33		5,33	24,1	32635
1975	5,90		5,90	26,5	18728
1976	5,03		5,03	20,8	27346
1977	5,12		5,12	23,5	26365
1978	5,18		5,18	25,5	33036
1979	4,88		4,88	21,0	37228
1980	4,90		4,90	10,8	28700
1981	5,45		5,45	10,5	23700

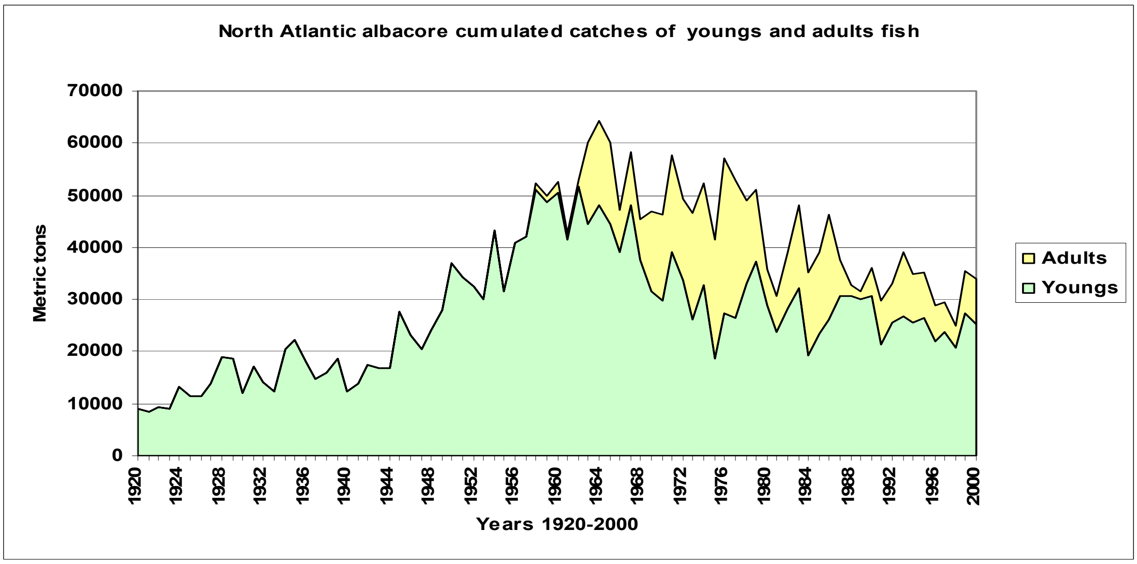


Figure 1: Catches of North Atlantic albacore separated in two components: young and adults fish.(1920-2000)

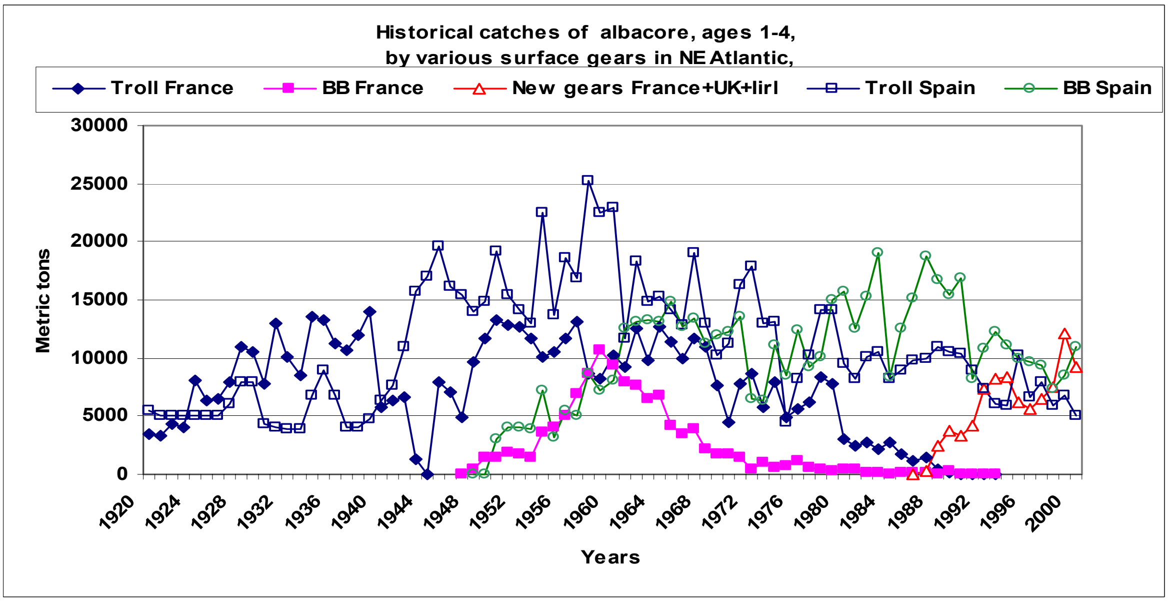


Figure 2 : History of young albacore age 1-4, catches by gear and major contries, 1920-2000

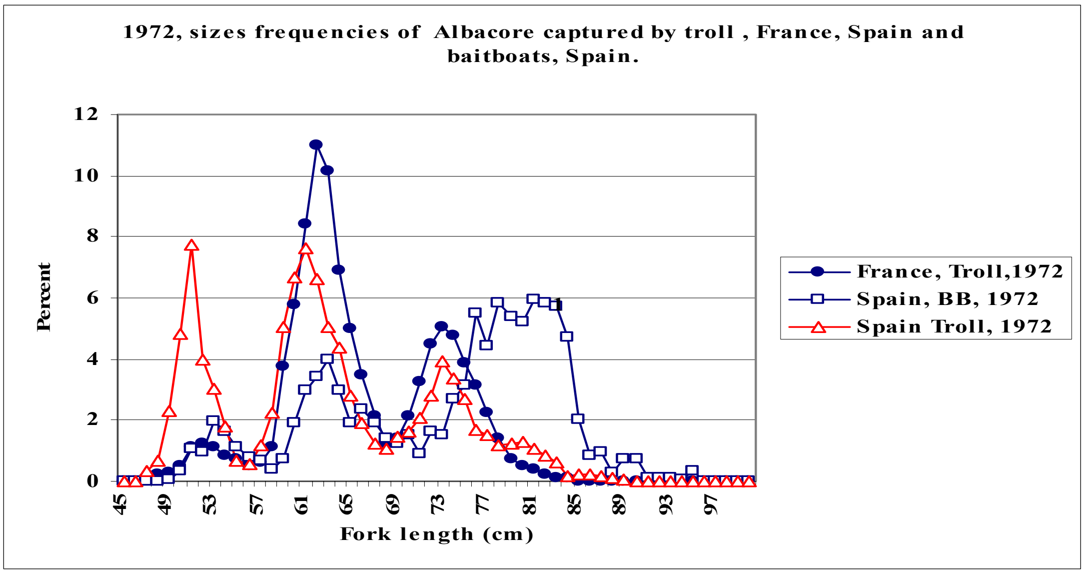


Figure 3 : Typical sizes frequencies (Fork length) of albacore captured by France and Spanish troll , and Spanish baitboats, 1972. The size classes are identified as age classes 1 to 4.

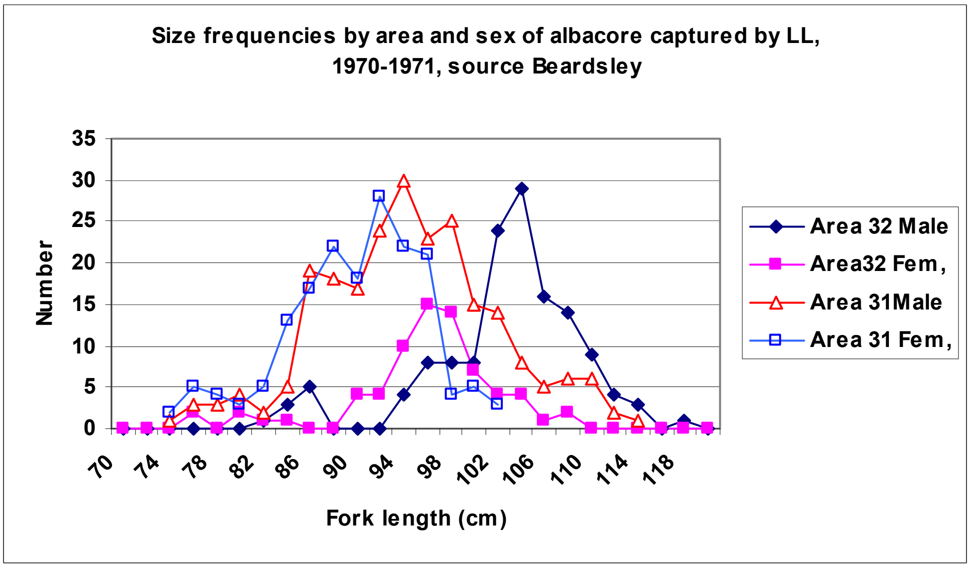
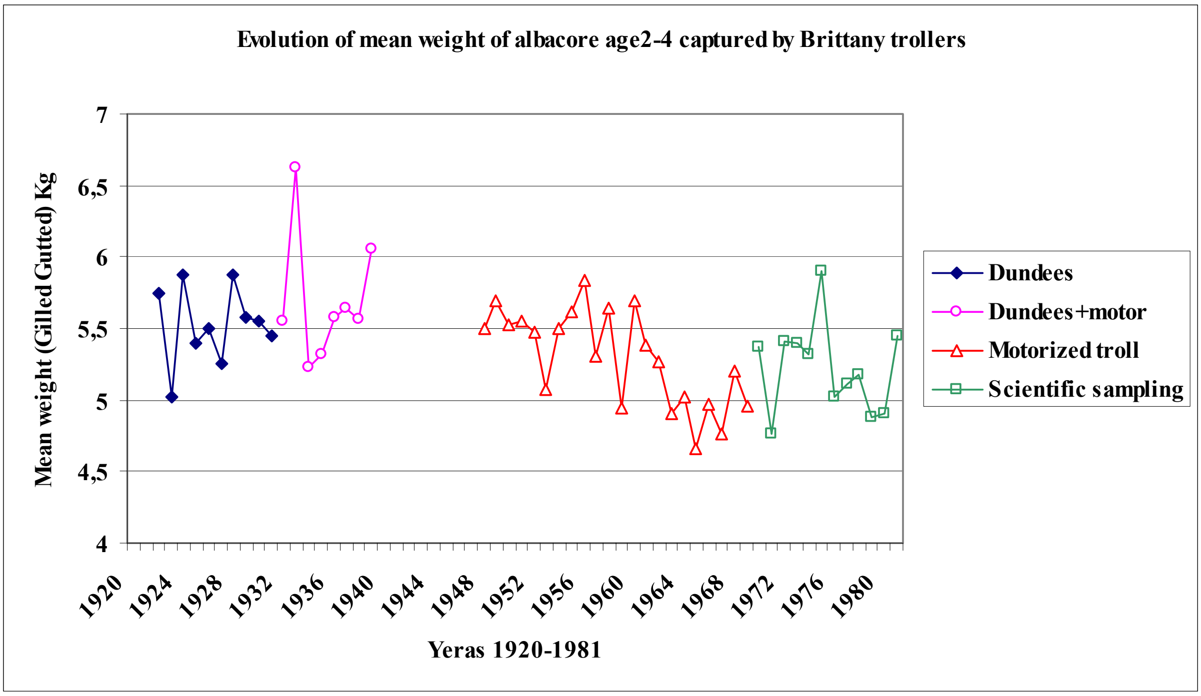


Figure 4 : Size frequencies(Fork length) by sex of albacore captured by longline, for two areas. Area ICCAT 31 is encompasses winter « feeding » ground, area ICCAT 32 encompasses summer « spawning grounds. Source Beardsley.



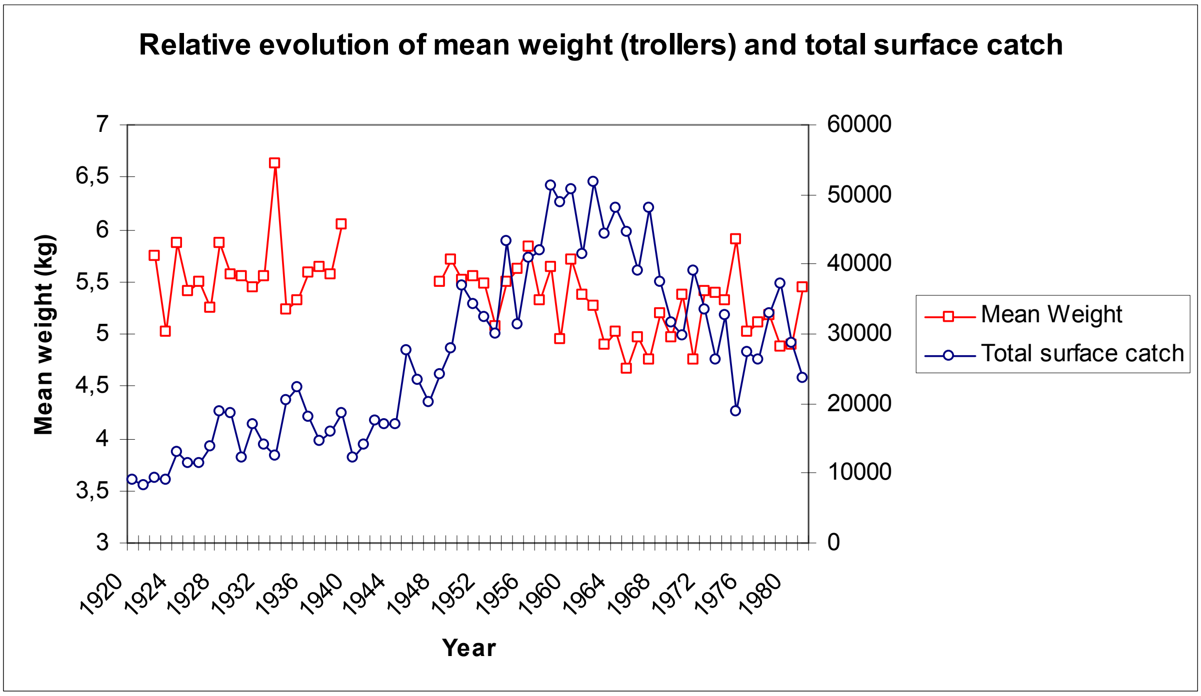


Figure 5 : Historical evolution of mean weight (gilled gutted) of albacore, ages 2-4,captured by French Britton trollers , 1922-1980, ; top : data with indication of sources, down : compared overall evolution compared of mean weight and total surface catches (Mt).

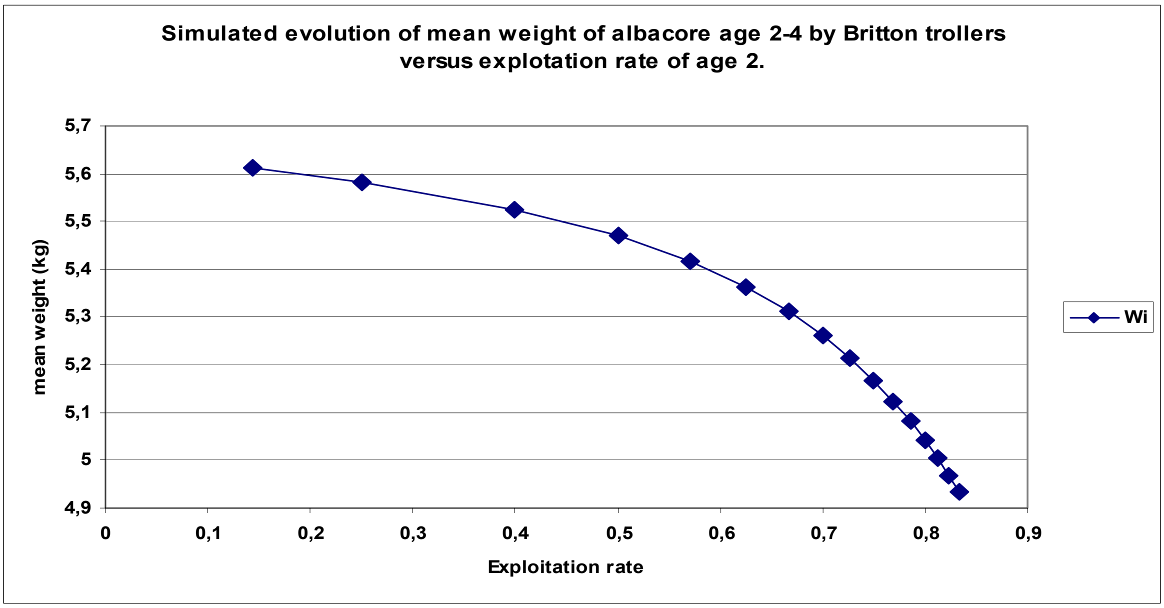


Figure 6 : Theorical change of mean weight for age 2-4 with troll catchabilities, versus exploitation rate for age 2, (F/Z). Parameters used are : Relative catchabilities coefficient for age 2 to 4 computed from Laurec's method applied to French troll by Bard,1981 are: age 2 : **30**, age 3 : **17**, age 4 : **4**. Growth curve of Bard, 1981, L/W of Santiago, natural mortality M : 0.3. Caches computed by Baranov equation.applied on a yearly basis.

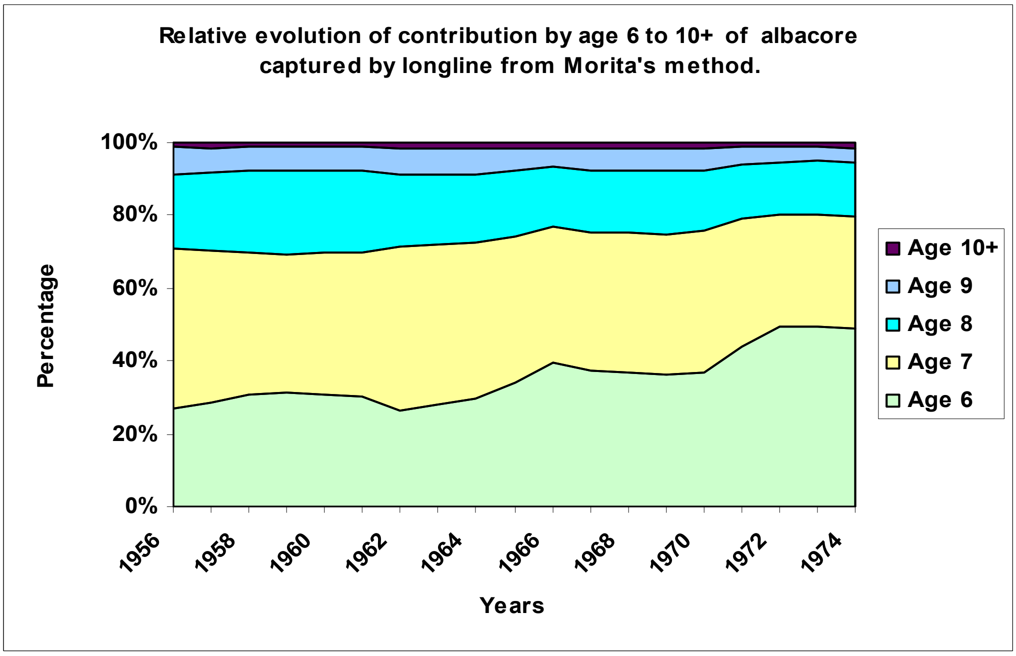


Figure 7 : Evolution of contribution of age classes 6 to 10+ computed by Morita (1977) in longliners albacore catches, 1956-1974.

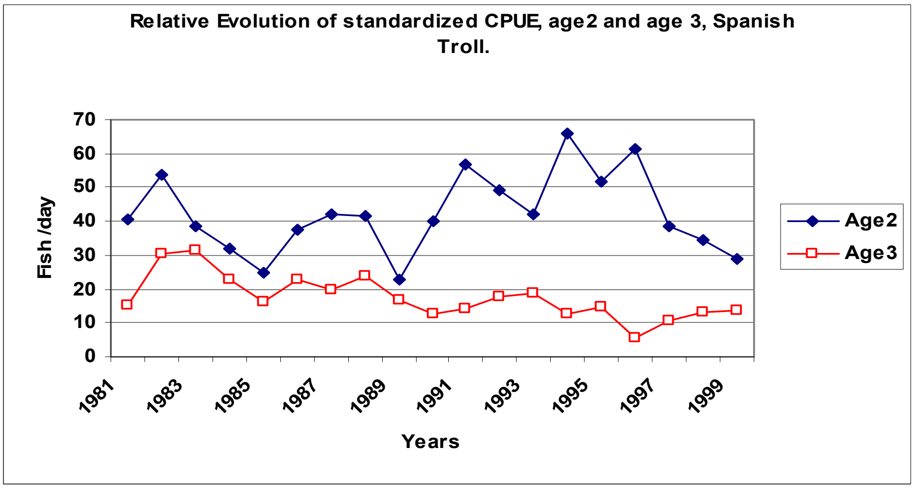


Figure 8 : Relative evolution of age 2 and age 3 indices of abundance, Spanish troll , 191-1999, source Report SCRS 2000.

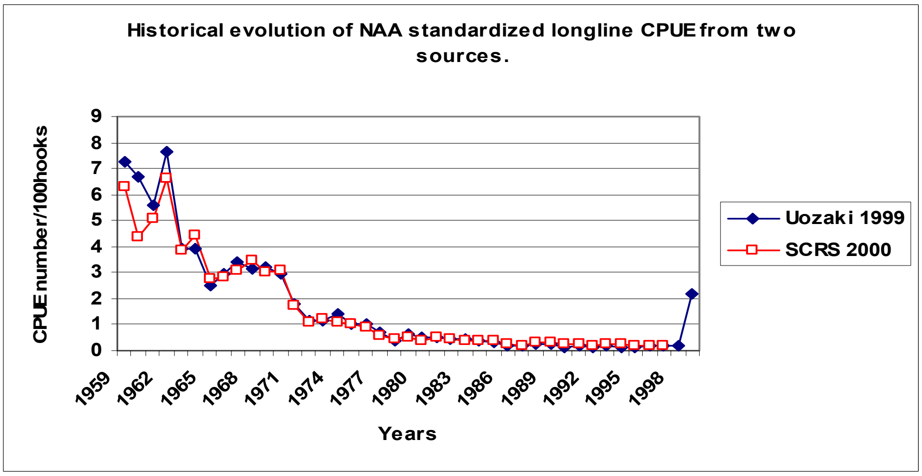


Figure 9 : Evolution of standardized longline CPUE for large albacore, for Japanese longliners from two sources , Uozaki (1999) and SCRS2000.

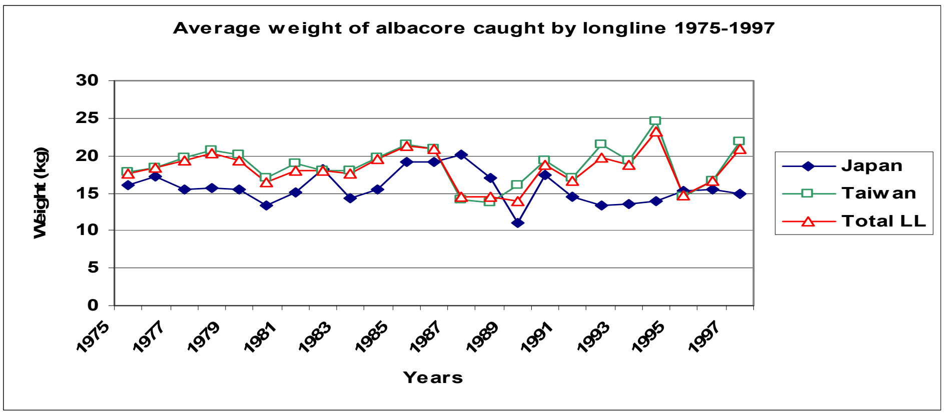


Figure 10 : Evolution of mean weight of albacore captured by longline computed from Santiago (1999) catch at age table.