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THE NORTH ATLANTIC ALBACORE (*Thunnus alalunga*) ASSESSMENT PROBLEM

F. X. Bard[1] and T. Joanny[1]

ABSTRACT

The aim of this document is to critically review past research on north Atlantic albacore stock assessment, compare it with the current conclusions arrived at in 1993, and to draw conclusions about potential yields of the stock under the hypothesis of an artifact in the decline of recruitment.

RESUME

L'objectif de ce document est d'effectuer un examen en profondeur des recherches réalisées précédemment en ce qui concerne l'évaluation du stock de germon de l'Atlantique Nord, d'établir une comparaison avec les conclusions disponibles jusqu'en 1993 et de tirer des conclusions au sujet des rendements potentiels du stock dans l'hypothèse d'un artefact dans le déclin du recrutement.

RESUMEN

El objetivo de este documento es llevar a cabo un examen crítcio de la investigación realizada en el pasado sobre la evaluación del stock de atún blanco del Atlántico norte, establecer una comparación con las conclusiones disponibles hasta 1993 y sacar conclusiones respecto a los potenciales rendimientos de stock bajo la hipótesis de un efecto en el descenso del reclutamiento.

1. INTRODUCTION

1.1 Production of the north Atlantic albacore stock

The albacore tuna fish (*Thunnus alalunga*), known as "germon" in French and "bonito del norte" in Spanish, has been fished for more than 100 years in the north eastern Atlantic by traditional surface gears, trolling, pole and line, targeting young fish (Bard, 1981). By 1956 Japanese vessels began to fish older fish using longline (Shiohama, 1976) and later other Asiatic countries were involved in longline fishing for Atlantic albacore. During the years 1970 to 1980, research showed that these two categories of fisheries, surface then longline, were exploiting a single stock, namely the north Atlantic stock. This stock is considered to be separate from a south Atlantic stock, the limit being set conventionally at the parallel 5°North. A third stock, the Mediterranean stock, is well separated by the Gibraltar Straits.

The production of the north Atlantic stock increased from about 10-15,000 MT during the years 1920-1940, to a peak of 64,000 MT in 1964. Since then, overall production has been decreasing regularly (ICCAT, 1994). One reason for such a decrease in production was obviously the decline of the French traditional trolling, which began in 1967 and this fishery had nearly disappeared by 1981 for economic reasons (Antoine et Garces, 1983). Another reason was the almost complete cessation of longlining activities after 1987. Longlining targeting albacore was carried out successively by Japanese, then Taiwanese longliners. But these fleets later switched their target to the much more profitable bigeye tuna (*T. obesus*, Figure 1). Albacore caught in the north Atlantic by longlining is now only a by-catch of these "sashimi superfreezers" which use a specific rigging of longline for catching deep-swimming bigeye.

On the other hand, during the past 20 years some improvements have taken place in some ships using surface gears, such as the introduction of sonar in 1975-77 on Spanish baitboats, and the increase in vessel size. In very recent years, France has introduced two new gears, gillnet and midwater trawl (Liorzou 1989). Azorean baitboats began the occasional fishing of large albacore in the Autumn of 1990 and Spanish baitboats resumed their "Autumn fishery" introduced in 1975-1977. They now fish large albacore in Autumn off the Azores, and until early Winter as far as the Canary Islands area.

[1] ORSTOM Scientists, Center for Oceanographic Research (CRO), 15 BP 917 Abidjan, Côte d'Ivoire

The current production of north Atlantic albacore is leveling to about 30,000 MT, which, given the past maximum production attained, could be considered as moderate exploitation. But serious discussion arose when new French gillnetters, targeting young albacore (age 2 and 3) were put into operation, on the grounds that interaction between these new gears and the traditional gears (i.e. baitboats and troll) could have lowered the productivity of the stock.

1.2 Past assessments of the north Atlantic albacore resource

Meanwhile, the ICCAT research activities into north Atlantic albacore stock assessment have been conducted with various levels of intensity. From 1970 to 1982, many studies were carried out, based either on the analytical (structural) model, or the production (global) model.

1.2.1 Analytical (structural) model.

The analytical model (suitable for such a long living species) was based on catch at size, and then catch at age tables computed from statistics of longliners and surface gears. Throughout the 70's and early 80's such tables were analyzed by several methods of VPA. These were:

- For Cohorts 1955 to 1973 a traditional VPA was used in the reverse mode, with hypothesis on the F_n used at age 10, computed from annual longline effort multiplied by a catchability coefficient derived from early Japanese studies on Pacific and Indian albacore (Bard, 1981).

- For cohorts 1964 to 1977, in order to solve the inherent uncertainty of classical VPA (*n* unknown and *n*-1 equations), a particular method of virtual population analysis, a multi-cohort analysis (MUCO) was devised by Laurec (1980). It is based on an hypothesis of stability over the years of at least two values of catchability at age, thus providing a way to analyze a sufficient set or equation for the unknowns. In this case this hypothesis of constant was accepted for age 2 and age 3 for French trollers, given the important knowledge gained during studies on this fishery (1965-1979), which demonstrated strong stability in the gear used, vessel size and strategy. Such methods provide an estimate of $F_{3/2}$ fishing mortality for age classes 2 to 3.

- During the years 1980-1990, more VPA applications on this tuna stock were carried out: The updating of MUCO (Antoine and Gonzalez Garces,1982), VPA for cohorts 1959-1972 (Garces and Weber, 1985); and 1978-1984 (Garces *et al.* 1989).

All the assessments using VPA concluded that there was a stock at a high level of exploitation by the 60's and 70's, then a decreasing rate of exploitation between 1973 and 1980. Recruitment appeared stable, averaging around 13-15 million recruits of age 1 fish with rather few exceptional cohorts as low as 4 million or as high as 20 million for the series of years 1965-1977 (Figure 2). For cohorts 1955-1963, recruitment was apparently more steady but it can be linked to the poorer quality of the surface data (see infra). For cohorts 1978-1984, recruitment appeared lower, ranging between 7 and 12 millon fish (but the F_n used was fixed at 0.46 which is high for longline).

In 1991, the standard ICES *Ad-Hoc* method was used but with questionable results. Then since 1992, the ADAPT method was used, tuned by the available indices of abundance by age, which are:

-Indices for ages 1 to 4, computed by GLM by combining data from Spanish troll and baitboat fisheries by 5°x 5°x month for the years 1983-1992 (Mejuto *et al.* 1994).

- Indices for age 5+ computed by GLM from Japanese and Taiwanese longline data. Since 1966 Japanese longliners have been fishing minor quantities of albacore, as have Taiwanese longliners since 1987.

On the basis of all these data, several ADAPT runs were carried out. The best selected solution provides a pattern of recruitment which is shown in Figure 2. The apparent decrease in recruitment since 1981 is obvious, and for the last two cohorts, 90 and 91, it is dramatic. Correlatively, high fishing mortalities for age 2-4 were generated by the model (ICCAT 1994).

1.2.2 Production (global) models

The first use of a production model for the whole stock was made by Garces (1981). He standardized the efforts of surface and longline fisheries using longline *CPUE*. The following studies (Garces and Mejuto, 1984, 1985) used the same method of standardization but using baitboats *CPUE*. Hsu and Liu (1989) used a standardization of longline

CPUE (corrected by GLM). Each time, the model was fitted at equilibrium using PRODFIT. The general conclusion matched the VPA conclusions: The stock was rather highly exploited during the past two decades but without any hint of over-exploitation, particularly with regard to recruitment.

On the other hand, the recent availability of production (global) model "at non equilibrium", allowing the joint use of catch and effort data of several fisheries (ASPIC) seemed to offer a new way of analyzing the state of exploitation of such a complex stock, exploited at various ages by various gears. However, results were very conflicting with those of VPA.

1.3 The present dilemma

At the beginning of the 90's, ICCAT stressed the need to carry out some more research, and this need was highlighted by the rising conflict between French (new gears) and Spanish (traditional gears). In 1989, a working group reviewed statistics and the basics of biology and ecology. Various working groups during 1990-1993 worked essentially on VPA for cohorts born 1975 and onwards.

Recent ICCAT working groups (PSG meeting in 1992 and SCRS 1993) have consequently been unable to decide between two hypothesis:

- The stock is at a high level of exploitation, in spite of its low production (30,000 MT), mainly because of a consistent decrease in the level of recruitment since 1981 cohort, (as suggested by the application of the ADAPT method) jointly with an exploitation pattern centered on young fish, and a sharp decline of the exploitation of large fish.
- If the recent recruitment decline is an artifact of the VPA analyze, the exploitation rate is moderate for young fish and very low for large fish.

The aim of this document is to critically review past research on north Atlantic albacore stock assessment, compare it with the current conclusions arrived at in 1993, and to draw conclusions about potential yields of the stock under the hypothesis of an artifact in the decline of recruitment.

2. DISCUSSION

2.1 Fisheries statistics quality

The nominal catches of all albacore fishing fleets (Task I) has been registered correctly over the past 50 years as albacore is easy to distinguish from others tunas, and moreover the specific quality of flesh (white meat) called for specific prices. The quality of Task II varied considerably with fleets and gears over the past years.

2.1.1 Surface fisheries

For the years 1955-1964, the catch at size data for surface gears from France (trollers and baitboats) were reconstituted from landing forms using commercial categories (very clear for ages 1, 2, 3 sold at different prices). They were extrapolated, gear by gear to the Spanish trollers and baitboats.

For the years 1965-1971, the catch at size of French surface gears were computed from commercial categories reported in log-books, cross-checked by length frequency sampling of fish landings. Extrapolation to Spanish catches was made by gear. Since 1972, length sampling of trollers and baitboat of France and Spain was conducted regularly, providing correct catch at size data. Since 1986, however, the almost complete disappearance of the French fleet left only catch at size data available from the Spanish fleet (troll and baitboats).

It is noteworthy that during the 80's, the rate of recovery of log-books from the surface fleet fell dramatically, and therefore Task II became imprecise for all surface gears (use of only the two large geographical areas: ICCAT Alb-1 and Alb-2). The new French gears have never provided, up to now, Task II data suitable for computing indices of abundance.

2.1.2 Longline fisheries

The Task II data were always provided regularly by scientists in charge in Japan and Taiwan, when the quantities of albacore caught were considerable. Since 1987 however, as catches of albacore in the north Atlantic became negligible, the logbook quality of reporting and length sampling has become questionable.

2.2 Biological parameters

The growth curve is that of Bard (1974) which was still considered valid (ICCAT, 1990). However, until recently, for separating the 1 cm size frequencies into 10 year classes, it was the "chopper" method which was used. Until now the length-weight relationship used was that stemming from the work of Beardsley (1969). Recently a study by Santiago (1993), using samples from surface fisheries proposed a more comprehensive relationship. But in fact, it only differs from that of Beardsley for large fish over 100 cm, that is fish caught by longline.

Major progress has been made by the considerable improvement in transforming the catch at size tables in biologically likely catch at age, achieved by the use of MULTIFAN (Santiago, 1993a). The resulting catch at age (ICCAT 1994), shows a rather constant catch of fish aged 1 to 3, a decrease of catch of age 4 for 1990-1992, and a marked decrease in the number of fish aged 5, 6 and 7+, coinciding with the decline of longline fisheries.

For previous analyses, the natural mortality *M* vector was the one proposed by Suda (i.e. growing *M* with age) according to the scheme:

$M = 0.2$ for ages 1-4,
$M = 0.4$ for ages 5-6,
$M = 0.6$ for age 7-8,
$M = 0.8$ for age 9 and over.

The vector of variable *M* was proposed by Suda for accounting for the low proportion of old fish encountered by longliners when beginning to fish virgin stocks such as those of the south Atlantic and south Pacific. However, when using a constant coefficient of natural mortality of $M = 0.3$ over the age range, as used by the First Albacore Meeting in 1989 (ICCAT, 1990) some consequences arose: The theoretical biomass unharvested curves are different (Figure 3) and, moreover, the fishing mortalities coefficient generated by past VPA differ and need to be recomputed for comparing estimated past and present state of the stock.

2.3 Discussion of VPA

VPA on historical cohorts 1955-1963 were conducted on cohorts of age 10 class by classical VPA used in inverse mode, selecting F_n according to the mean catchability coefficient for large fish caught by longline. The large number of fish caught (virtual populations ranging between 7 and 11 million fish; Bard 1992), distributed over 10 classes, guaranteed a convergence of earlier years and resulted in a steady recruitment level of about 13 million fish. But the catch at age used was plagued by poor data for surface length frequencies. It was therefore judged unnecessary to recompute these VPA.

For cohorts 1964-1977, the MUCO method used, with correct catch at age table, at least for age 1-4, is still valid. Consequently, recruitment was recomputed with MUCO using the value $M = 0.3$ (instead of $M = 0.2$). The recruitment generated is slightly higher than the previous computations. The level of recruitment of cohorts 1974-77 match the estimates of ADAPT 93 (Figure 2); the level of cohorts 1978-80 is still in the range of previous recruitment.

But from 1981 to 1989, if the estimates of ADAPT are correct, there has indeed been a drop in the recruitment level. The apparent change in the level of recruitment and correlatively the increase in fishing mortality by surface gears since 1981 raises several questions:

(i) The reality of decrease in recruitment:

It was hypothesized at the time of the SCRS meeting in 1993 that the decline in recruitment for recent cohorts could be an artifact of ADAPT tuned VPA. Up to now, no ecological or biological reason can explain it. It has been suggested that such a decline could be part of a natural cycle, as has been suspected for north Pacific albacore. But it has to be remembered that the Pacific and Atlantic Oceans differ fundamentally in oceanographic variability (Bakun, 1994). The Pacific Ocean presents important inter-annual variability (such as El-Niño), while the Atlantic, with a high seasonal intra-annual variability, is much more stable at the inter-annual level. The north Pacific albacore spawning and nursery grounds can be affected by El-Niño or other annual events, and it is hypothesized by Bakun that the low level of north Pacific albacore recruitment could follow a cycle of about ten years, (contrary to the phases of Japanese sardine recruitment). In the Atlantic, because of its inherent regularity, such a cycle, although not ruled out, is more doubtful.

(ii) The increase of the fishing mortalities for ages 2-4.

Figure 14 of the 1993 SCRS Report (ICCAT 1994), shows the 1983-1992 evolution of indices of age 1 to 4. The most interesting point is the difference in trends between the age 2 and age 3 indices. Age 2 is increasing, age 3 is decreasing. This divergence is fundamental. As the catches in number of these two groups are the most important of the total catches in number (around 40-50 %) this apparent high mortality with high impact on a large number of fish "drives" the VPA to a low recruitment. On the other hand, these indices of abundance (corrected by GLM for two different gears) are the only ones available for these crucial age groups. It is worth noting that this divergence is obvious since 1990. Several possible explanations are:

- It could be hypothesized that catchability of age class 3 has changed since 1990, maybe because of the interaction of traditional (Spanish) and new (French) gears. A basic condition for any VPA is that catchabilities for a given age and gear do not change over the years analyzed. If true, such a change in catchability would affect ADAPT.

- An invert co-variance between the *CPUE* of age 2 and 3. It is indeed well known that schools of young albacore (age 1-3) are separated by size (and therefore age) and that their thermal *preferentum* is particularly different by the first half of the summer fishing season when the schools move northward (Havard-Duclos, 1973; Liorzou *et al.*, 1987).

- A change in the fishing strategy of the Spanish fleet, driven by the interaction with the French fleet could have resulted in a change of catchabilities since the year 1990. Unfortunately, the low level of detailed logbook returns from any surface gears (French or Spanish) in recent years has not enabled these two hypothesis to be examined in detail up to now.

- Discarding of fish fatally injured by gillnets. If real, it would have the effect of an increased fishing mortality without yielding catch. (A kind of intermediate mortality between *F* and *M*). But the hypothesis of huge discard rates has never been proved.

(iii) Albacore as longline by-catch

Longliners are now fishing for tuna of quality suitable for shashimi. In tropical waters, where bigeye and albacore co-exist, price is now a strong incentive to fish for bigeye. Consequently area and seasons of high abundance of large albacore may be avoided. This strategy has two consequences:

(i) The indices of abundance for large albacore, even standardized by GLM, from by-catches could be misleading. A comparison of the maps of early longline grounds for albacore (Shiohama, 1976) and recent longline areas for bigeye clearly show that the two large oceanic basins with deep thermocline where large albacore in spawning season were initially fished are definitely different from present bigeye fishing grounds (which are generally east of these areas). It has been even suggested that super-freezer longliners practice "upgrading" by occasionally rejecting by-catches of albacore.

(ii) There has been no significant number of large albacore caught for age classes 5 and over since 1987. (ICCAT, 1994). It is interesting to note that the apparent drop in recruitment, reflecting a lower virtual population, begins at cohort 1981, arriving at age 5 in 1986.

These two effects could also have affected the results of ADAPT.

2.4 Discussion of Production model

Production models at equilibrium (generally using PRODFIT) used have always been based on a standardization of *CPUE* of a specific gear (either troll, baitboat, or longline). But from the theoretical standpoint such methods are contradictory with the fact that the fisheries by different gear are sequential, and this is particularly true for surface versus longline fisheries. Consequently it is still impossible to compute a synthetic index accounting for the whole biomass, necessary for any production model. This conclusion is also true for the use of non-equilibrium models such as ASPIC, where several sets of catch and effort data are in fact averaged (as far as the authors understood!) by the method itself. A solution could come from age-structured production models which have not often been applied to these types of tuna fisheries.

3. CONCLUSION

The systematic decrease in recruitment since 1981 is still not firmly established, and the current lack of directed intensive fishery on large albacore from which meaningful indices of abundance could be drawn precludes simple conclusions on that matter. Maybe the development of the Autumn baitboat fishery could provide data in the future. If not, analysis of the state of the stock could become similar to of skipjack in the eastern Atlantic. Skipjack is fished for three years, then large fish emigrate to the central Atlantic where they are no longer fished: Cohort analysis of skipjack proved inconclusive (ICCAT, 1986).

4.1 What is high exploitation, from the Yield per Recruit point of view?

A question raised during discussions at the SCRS about the real state of the north Atlantic albacore stock was: If, as suggested by the nominal catch and effort figures, the exploitation rate of small fish decreased, and if recruitment is constant, what is happening to the yield per recruit and why are the catch rates not increasing? What is a high state of exploitation if you are not fishing large fish? In fact the answer lies in the fact that the surface and longline fisheries are sequential.

To evaluate how the yield per recruit of the stock, past or recent, behaves under hypotheses of constant or non-constant recruitment, fishing mortality resulting from VPA was used. The historical fishing mortalities at age were recomputed for the years 1965-1978 by a direct VPA, knowing the initial recruitment from MUCO. No problem of "blewing off " occurred when using the Suda vector of natural mortalities (Bard 1981). But when recomputing the fishing mortality coefficients using constant $M=0.3$ some problems of "blewing off "appeared. One explanation could be mis-ageing of large fish by the "chopper" method, but could also be due to the inadequacy of $M=0.3$ for old fish, as supposed by Suda. Fishing mortalities for each set of computation are displayed in Tables 1 and 2.

For recent years, 1975-1992, F_s were computed using either an hypothetical constant recruitment level of 15,000 fish (average from MUCO,computed with $M=0.3$) and *Fs* are in Table 3, or selected from ADAPT 93 selected solution. Yield per Recruit was computed using the Ricker yield model. The historic Y/R was computed by averaging *F* for years of reference 1972-76, when both surface and longline gears were fishing a high level of albacore and had stabilized. For the recent period, the years selected are 1990-92, for reflecting the most recent state of the stock.

Figure 3 compares various curves of Y/R.

The general conclusion is that if, under the current fishing pattern for 1990-1992, the resource can be said to be highly exploited, and even fully exploited, it is in fact stupidly exploited (from a yield per recruit point of view!). The reason is simple: large fish are escaping. The current Y/R value ranges between 2 and 4 kg/R as compared with 4.5-6 for the years 1973-1976, and certainly some wiser fishing pattern could reach values close to 7 kg/R.

All these comments have been made to recall the history of the research into this resource. In order to help discussion at the *Programme Special Germon* final meeting, to achieve a rational conclusion regarding the current status of this resource and its potential use.

Table 1. Estimates of fishing mortalities at age, Fi, for years 1965-1978 computed through MUCO method with Suda natural mortality (Bard 1981)

Year	F age 1	F age 2	F age 3	F age 4	F age 5	F age 6	F age 7	F age 8	F age 9
1965	0.23								
1966	0.05	0.65							
1967	0.14	0.77	0.61						
1968	0.09	0.86	0.44	0.10					
1969	0.08	0.62	0.41	0.11	0.06	0.16			
1970	0.15	0.51	0.46	0.10	0.19	0.17	0.08		
1971	0.08	0.59	0.47	0.15	0.24	0.17	0.09	0.10	
1972	0.07	0.31	0.25	0.11	0.08	0.17	0.32	0.12	0.12
1973	0.02	0.37	0.33	0.11	0.17	0.19	0.28	0.48	0.35
1974	0.03	0.25	0.36	0.09	0.10	0.22	0.83	0.58	0.67
1975	0.04	0.28	0.19	0.20	0.12	0.26	0.17	0.55	0.25
1976	0.05	0.28	0.35	0.60	0.33				
1977	0.04	0.22	0.47	0.18					
1978	0.05	0.36	0.25						
F^{mean} 72-76	0.042	0.298	0.296	0.258	0.208	0.202	0.338	0.366	0.375

Table 2. Estimates of fishing mortalities at age, Fi computed for years 1965-1978 on the basis of F_2 and F_3 computed by MUCO method, and adjusted for constant M=0.3.

Year	F age 1	F age 2	F age 3	F age 4	F age 5	F age 6	F age7-10
1966	0.05						
1967	0.14	0.84					
1968	0.09	0.83	0.64				
1969	0.07	0.59	0.56	0.19			
1970	0.15	0.70	0.36	0.26	0.40		
1971	0.04	0.63	0.66	0.27	0.46	0.39	
1972	0.07	0.37	0.37	0.39	0.13	0.41	0.20
1973	0.02	0.29	0.40	0.29	1.55	0.29	*
1974	0.03	0.25	0.33	0.23	0.22	*	0.37
1975	0.04	0.32	0.28	0.15	0.15	0.41	*
1976	0.05	0.36	0.60	0.23	0.43	0.39	0.15
1977	0.04	0.43	0.54	0.15	0.43		
1978	0.14	0.36	0.28	0.50	0.84		
F^{mean} 72-76	0.042	0.318	0.396	0.284	0.496	0.30	0.24

Table 3. Estimates of fishing mortalities F computed by VPA in direct mode (Program GERREC) for years under the hypothesis of a constant recruitment at a level of 15 million fish at age 1. Note that for cohort born in 1977, the minimum recruitment possible is 20 million. M is set as constant at 0.3.

Year	F age 1	F age 2	F age 3	F age 4	F age 5	F age 6	F age 7-10
1975	0.019						
1976	0.057	0.268					
1977	0.024	0.283	0.241				
1978		0.331	0.162	0.497			
1979	0.050		0.345	0.298	0.065		
1980	0.134	0.132		0.288	0.122	0.064	
1981	0.074	0.149	0.215		0.102	0.067	0.108
1982	0.006	0.153	0.351	0.283		0.081	0.157
1983	0.064	0.110	0.281	0.459	0.194		0.266
1984	0.026	0.143	0.109	0.214	0.107	0.130	
1985	0.081	0.111	0.171	0.136	0.077	0.194	0.263
1986	0.051	0.017	0.141	0.318	0.083	0.219	0.828
1987	0.018	0.206	0.327	0.167	0.038	0.024	0.085
1988	0.133	0.228	0.185	0.253	0.223	0.045	0.017
1989	0.075	0.197	0.237	0.270	0.019	0.022	0.297
1990	0.085	0.276	0.214	0.135	0.056	0.041	0.080
1991	0.084	0.277	0.114	0.100	0.014	0.029	0.043
1992	0.097	0.203	0.169	0.151	0.033	0.016	0.061
Mean F 90-91	0.088	0.252	0.165	0.129	0.034	0.027	0.061

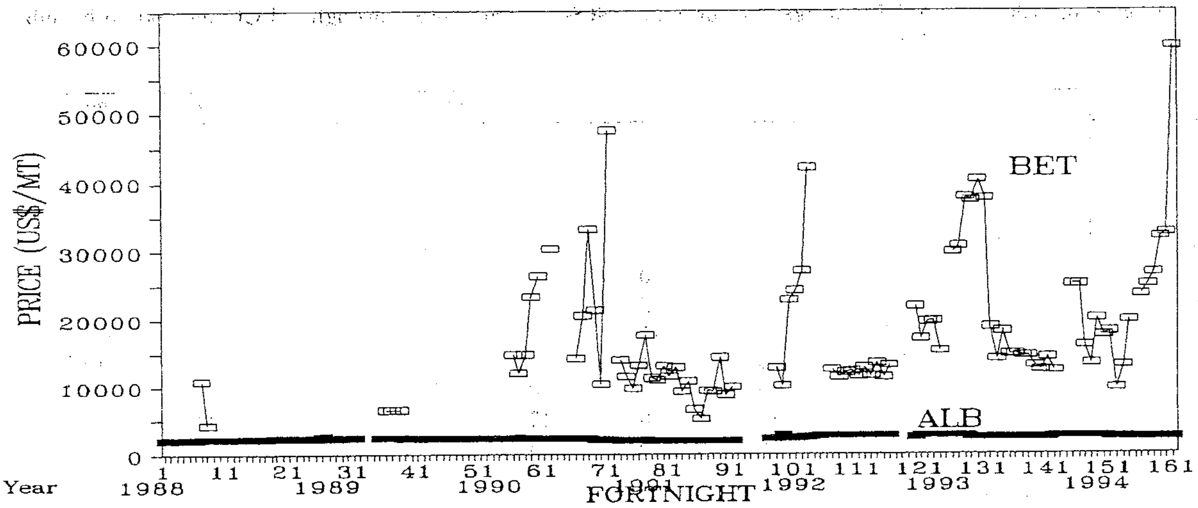

Fig. 1. Compared international prices of frozen tunas caught by longliners, 1988-1994. Albacore price is in Samoa (converted from short tons to metric tons) and bigeye price is that for Tokyo Central market (computed as a geometric mean). Source: INFOPECHE, Abidjan.

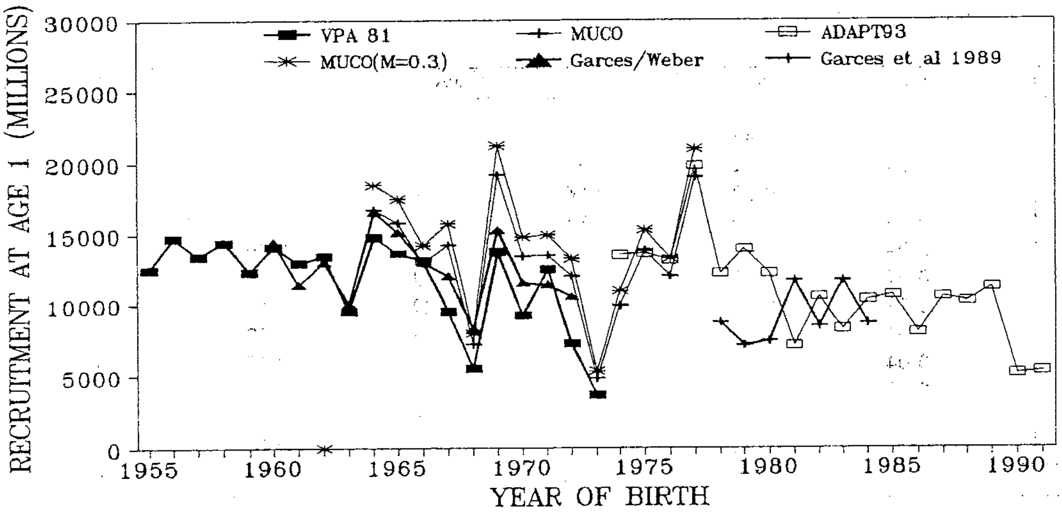

Fig. 2. Estimates of recruitment at age 1 for north Atlantic albacore stock, 1955-1984, according to several methods of VPA historically used (see text). Years indicated are the birth years. Values for recruitment of 1964-1977 cohorts issued from MUCO computation, were estimated either with M=0.2 or adjusted for M=0.3.

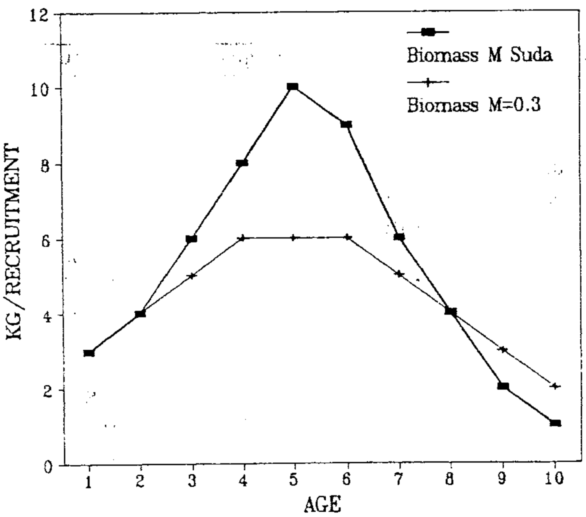

Fig. 3. Non harvested biomass at age, under the two hypothesis of natural mortalities.

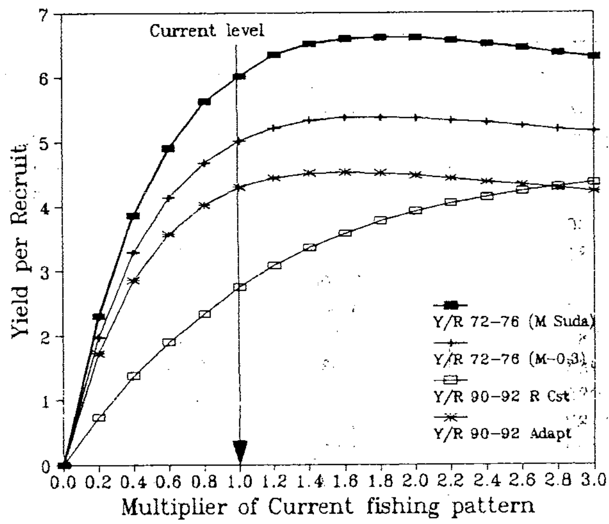

Fig. 4. Compared Y/R as function of multiplier of current Fs pattern, at various periods in the exploitation of the north Atlantic albacore stock.