SCRS/1998/074 Col.Vol.Sci.Pap. ICCAT, 49 (2) : 388-399 (1999)

BLUEFIN TUNA STOCK ASSESSMENT IN THE NORTHEAST ATLANTIC: DIFFICULTIES RELATED TO DATA, METHODS AND KNOWLEDGE

Jean-Marc Fromentin[1]

SUMMARY

The robustness of ADAPT concerning the 1996 SCRS bluefin tuna stock assessment for the northeast Atlantic is tested through various sensitivity analyses on the main technical specifications. We also computed simple VPA in order to investigate the reliability of the trends in the recruitment estimates and the stock estimates of ages 2-5 and 8+. It is concluded that: (i) the estimates of the 1996 SCRS working group are very sensitive to the technical specifications on the F-ratios (which determine F for the last group), natural mortality as well as to under-reporting on the catch data; and (ii) the increasing trends of the recruitment and the young ages as well as the strong decline in ages 8+ should be treated with caution.

RÉSUMÉ

La robustesse de l'ADAPT concernant l'évaluation de 1996 du stock de thon rouge nord-atlantique par le SCRS est testée au moyen de diverses analyses de la sensibilité sur les principales spécifications techniques. Une simple VPA est également exécutée pour rechercher le degré de fiabilité de la tendance du recrutement estimé et du stock estimé des âges 2-5 et 8+. Il en est conclu que : i) les estimations du groupe de travail de 1996 du SCRS sont très sensibles aux spécifications techniques des valeurs du F-ratio (qui déterminent la valeur de F pour le dernier groupe), de la mortalité naturelle, ainsi que de la sous-déclaration des donnés de capture ; et ii) il faut traiter avec prudence la tendance croissante du recrutement et des stades juvéniles, ainsi que la forte baisse des âges 8+.

RESUMEN

Este trabajo trata de probar la solidez de ADAPT respecto a la evaluación de stock de atún rojo del Atlántico noroeste en 1996, mediante el sesgo de varios análisis de sensibilidad de los principales parámetros de entrada. También se calculan VPA sencillos con el fin de investigar la fiabilidad de las estimaciones de las tendencias en el reclutamiento y las estimaciones de stock de edades 2-5 y 8+. Se concluye que: (i) las estimaciones del grupo de trabajo del SCRS 1996 son muy sensibles a las especificaciones técnicas de los F-ratios (que determinan la F para el último grupo), la mortalidad natural e información escasa de los datos de captura, y (ii), debería tratarse con cautela la tendencia al aumento del reclutamiento y las edades jóvenes, así como el fuerte declive de las edades 8+.

[1] IFREMER, DRV/RH, Station de Sète, BP 171, 34203 Sète Cedex, France.

1. Introduction

The SCRS Bluefin Tuna (BFT) stock assessment give conclusions on the basis of a process that include several numerical steps (SCRS/96/26). Each of these steps implies one or several models: (i) a growth model to determine length and weight at age (the modelling for BFT being based on the Von Bertallanffy growth model, see Cort 1990), (ii) some models or numerical procedures to calculate the CPUE indices for a given age, (iii) the ADAPT-VPA model to evaluate the fishing mortality and the stock size estimates for the different ages and thus, the spawning stock biomass and the recruitment (see, Geromont and Butterworth 1996, Restrepo 1996, Porch 1997) and (iv) some projection procedures to estimate whether or not the populations can sustain the present fishing pressure (among which the Beverton and Holt stock-recruitment relationships, Beverton and Holt 1957). All these models presuppose some assumptions (e.g. on the distribution of the data, on the stability of some processes through time and space, etc...) as well as technical specifications. The latter are, most of the time, of great importance and are mainly based on knowledge of the fishery and the population, such as information on fishing effort, reproduction, natural mortality and migration. Therefore, one of the core of the stock assessment workgroups is to obtain sufficient quantitative data and basic information to run the models in a reliable way.

The present article aims to review some of the basic assumptions related to the ADAPT-VPA model for the Northeast Atlantic. Because of the under-determination problem (e.g., Gulland 1965), most of the traditional VPA imply: (i) natural mortality (M) for all the ages, (ii) fishing mortality (F) for the last group in all the years and (iii) F for all the groups in the terminal year, to be known. In order to reduce the number of free parameters, ADAPT uses auxiliary data (CPUE indices) to estimate F for all the groups in the terminal year. During the 1996 SCRS stock assessment, F in 1995 (i.e. the terminal year) for the East stock have been estimated for 3 ages of reference (ages 2, 4 and 8) and extended for the other ages through a selectivity at age vector (fixed by the users). F for the last group in all the years was determined through the F_{10+}/F_9 ratio, which can be either fixed by the users (i.e. free parameter) or estimated in a given year and set to be the same for a given period (also fixed by the users). Handling different realistic scenarios, we thus investigated the robustness of ADAPT to these 3 main technical specifications, i.e., (i) M, (ii) the choice of the age of reference in the terminal year and (iii) the F_{10+}/F_9 ratio. We also analysed the consequences of under-reporting and we computed simple VPA in order to investigate the reliability of the trends in the recruitment estimates and the stock estimates of ages 2-5 and 8+.

2. Sensitivity analyses

During the 1996 SCRS Bluefin Tuna stock assessment for the Northeast Atlantic and the Mediterranean Sea (SCRS/96/26, Geromont and Butterworth 1996), it was assumed that:

i. M was constant for all the ages and fixed at 0.14.
ii. F for the all the ages (1 to 10+) in the terminal year (1995) were estimated through 5 CPUE indices directed towards: ages 2, 3, 4+ and 8+ (2 CPUE indices were directed towards age 3, see below). Because CPUE series are not available for all the ages, the ages 2, 4 and 8 were set to be the reference ages for the ages 1 and 3, 5 to 7 and 9 and 10+ respectively. Estimates of F in 1995 for these non-reference ages were made through a selectivity at age vector: $F_{1995,1} = 0.6*F_{1995,2} = 0.6*F_{1995,3}$; $F_{1995,4} = F_{1995,5} = F_{1995,6} = F_{1995,7}$; $F_{1995,8} = F_{1995,9}$.
iii. F for the last age (10+) in all the years (1970-1995) were estimated through the F_{10+}/F_9 ratio. This ratio was fixed at 1 during 1970-1973 years, it was estimated in 1974 and set to be the same for all the 1974-1987 period and it was fixed at 2.02 for 1988-1995.

These technical assumptions are not always well documented, mainly because of a lack of basic information on the BFT biology and on the fishery. Therefore, it is of interest to test the robustness of the model to these assumptions and if other realistic assumptions lead to significant changes in the estimations of F and N.

2.1. Sensitivity to the natural mortality specification

Many works on fish population indicate that natural mortality is much higher for young ages than older ones (because of higher levels of predation and competition, stronger dependence to food availability etc... see e.g. Wootton 1990). Therefore, we first investigated sensitivity regarding M using, instead of the fixed value of 0.14, the Southern BFT vector of M, for which M=0.49, 0.24, 0.24, 0.24, 0.24, 0.2, 0.175, 0.15, 0.125, 0.1 for the ages 1 to 10+ respectively (a vector determined from extensive tagging experiments). Note the Southern BFT is a close species to the Atlantic BFT, which occupies the same place in the ecosystem. However, we are aware that the Southern BFT vector do not take into account the senescence of the oldest fish. However, this vector remains far more realistic than a constant value of 0.14 for all the ages which has by no means any biological support. Keeping all the other technical specifications similar to the 1996 SCRS stock assessment, the diagnostic shows that the model has accurately converged and that the goodness of fit is about the same than the 1996 SCRS base case 1 (total log-likelihood equal to -21.64 and -20.44, respectively). The results of the analyse show important changes in F and N for the youngest ages: F for age 1 and for ages 2 to 5 are significantly lower (Table 1) and N increase subsequently of about 100% and 40% respectively (Fig. 1). No substantial changes can be detected on F and N for the oldest ages (Table 1, Fig. 1).

Thus, ***taking the M Southern BFT vector instead of a constant M of 0.14, imply to consider higher natural mortality rates for the youngest ages (0.49 and 0.24 against 0.14) and thus lead to lower fishing mortality estimates by ADAPT, so that the stock size estimates for ages 1-5 are much higher.*** In conclusion, the magnitude of the recruitment (i.e. its absolute value) is very much dependent on the assumptions made on M.

2.2. Sensitivity to the ages of reference specification

The 1996 SCRS stock assessment specified age 4 as the age of reference for the ages 4 to 7. However, this group is rather heterogeneous and gathers mature and immature fishes. Furthermore, the catchability of the Spanish traps for age 4 is very low in all the years (< 0.006). Thus, this CPUE index, which is the only one for middle ages, might be better suited for age 6 (for which the catchability of the Spanish traps is higher). Therefore, we made a test of sensitivity by replacing the reference age at 4yr by a reference at 6yr (age 2 remaining the reference age for age 1 and 3 and becoming also the reference to ages 4 and 5). All the other technical specifications remaining the same than for the 1996 SCRS stock assessment, the model ADAPT has accurately converged. However, the goodness of fit is lower than the 1996 SCRS base case 1 (total log-likelihood equal to -32.62 and -20.44, respectively). The results show substantial changes in the estimations of N for ages 1 to 5 in the 5 last years (Fig. 2). For instance, the N of age 1 in 1995 is estimated around 2 millions against 1 million in the 1996 SCRS stock assessment. Although less critical than the technical specifications on M (and on the F-ratios, see below), the choice of the reference age can generate substantial changes in the stock size estimates of the youngest ages in the last years and thus could be of importance for the projection procedures.

2.3. Sensitivity to the F-ratios specification

The third technical specifications tested relates to the F-ratios. The 1996 SCRS stock assessment fixed the F_{10+}/F_9 ratio at 2.02 for 1988-1995, i.e. the fishing mortality was thus set to be twice higher for the age 10+ than age 9 since 1988. Knowledge on the fishery gave poor support to this hypothesis, since it is known that the different fleets directed towards individuals of the spawning stock biomass (i.e., PS, LL and trap) did not target any peculiar age within the adults. Furthermore, the ratio of the catches of the ages 10+ by the age 9 do not indicate any increasing trend, that could justify to set this ratio at 2.02 since 1988 (Fig. 3). Although the total landing display a clear increase during the 1970-1995 period, the ratio C10/C9 remains approximately constant, except in the 70's because of very low catches of individuals of age 9.

Therefore, we made a first sensitivity analysis with only one modification in comparison to the technical specifications of the 1996 SCRS stock assessment: we let the model estimate the F-ratio in 1988 (and set this value to be the same for the period 1988-1995). The model has accurately converged and the goodness of fit is even better than the 1996 SCRS base case 1, (which is not only due to the fact we added one parameter to estimate; total log-likelihood equal to -17.56 and -20.44, respectively). In comparison to the minor change we made, the results are drastically different because of much lower fishing mortality estimates for all the ages (Table 1). Furthermore, if the estimated F-ratios in 1974 in both analyses is similar, the estimated F-ratio in 1988 is about three times lower than the fixed value of 2.02 of the 1996 SCRS base case 1 (Table 1). The stock sizes estimates are subsequently about 20%, 45%, 100% and 180% higher for ages 1, 2-5, 6-7 and 8+ respectively when the F-ratio in 1988 is estimated instead of being fixed at 2.02 (Fig. 4). Note that the differences become stronger as the ages increase, so that ***the technical specifications of the F-ratios appear of primary importance for the oldest ages, and thus for the estimation of the spawning stock biomass.*** Further sensitivity analyses on the F-ratios have been computed. All the results converge to the same conclusion: ***the stock size estimates are highly dependent on the technical specifications made on the last age, i.e. on the F-ratios.***

2.4. Sensitivity to under-reporting

Under-reporting have been increasingly notified for the Northeast Atlantic bluefin fisheries. We thus built a simulated catch-at-age matrix by selecting randomly 50% of the values and adding 25% in each of these selected cases (the 50 % non-selected cases remaining the same as the catch-at-age matrix used in the 1996 SCRS base cases). This level of under-reporting may appear quite high but it is unfortunately not so unrealistic when considering: (i) the number of countries which are known to target BFT but which did not report any or very poor statistics to the SCRS, (ii) the various fisheries with a flag of conveniency, (iii) the sport fishery and (iv) the problem of misreporting within various ICCAT member countries (see e.g. Liorzou and Bigot, SCRS 1998). The simulation was done with the technical specifications of the 1996 SCRS base case 1 and the diagnostic showed that the model has correctly converged (total log-likelihood = -26.05). The F estimates are a bit lower than those estimated by the 1996 SCRS stock assessment (Table 1) but the estimated F-ratio in 1974 is almost the same. However, these small differences in F are sufficient to generate significant changes in N, which are significantly higher of about 30% for ages 1 to 5 and 40% for ages 6 to 10+ (Fig. 5). Thus, ***a under-reporting of 25% in 50% of the catch-at-age data lead to an underestimation of the stock sizes from 30% to 40%*** (the differences in the N estimates being greater than the level of under-reporting).

3. The trends in F and N

The technical specifications mainly influence the absolute values of F and N estimates. However, the trends of F and N are primarily determined by: (i) the catch-at-age matrix and (ii) the terminal F estimated through the CPUE series. Under the technical specifications of the 1996 SCRS base case 1, it can be easily seen that ADAPT did not predict accurately 4 of the 5 CPUE indices (Fig. 6). This might indicate a discrepancy between the catch-at-age matrix and the CPUE indices and/or a discrepancy between the CPUE indices. Indeed, the CPUE indices towards the oldest ages (Japanese-LL and Spanish traps, Fig. 6) and the SCRS stock estimates of age 8+ (Fig. 1) display a clear decline across all the period, whereas the CPUE indices towards the young ages (Spanish-BB and French-PS, Fig. 6) and the SCRS stock estimates for ages 1 to 5 (Fig. 1) show an increase during the same period. If the decline of the ages 8+ and of the spawning stock biomass is real and sufficiently strong, this should generate recruitment-overfishing (e.g. Myers and Barrowman 1996) and thus a subsequent decline of the young ages. Therefore, it might argue that: (1) the decline of ages 8+ is not sufficiently strong to generate recruitment over-fishing or (2) the trends in N of the young ages and/or of the old ages are not real and mainly come from methodological artefacts.

In order to investigate this question, we computed simple VPA (i.e. without tuning) assuming different scenarios on the F for the ages 10+ (i.e., on the trend in the fully-exploited F). First, we postulated that F for the ages 10+ (F10+) did not change through time. We assumed 2 different cases for this scenario: (1) with a rather low exploitation (F10+=0.2 for 1970-1995, c.f. case 1) and (2) with a rather high exploitation (F10+=0.5 for 1970-1995, c.f. case 2). Second, we postulated an increase in F10+, assuming: (1) F10+=0.2 in 1970-79, F10+=0.3 in 1980-89 and F10+=0.4 in 1990-95 (c.f. case 3) and (2) an exponential increase, with F10+=0.175 in 1970 up to F10+=0.760 in 1995. So that the case 1 corresponds to the hypothesis of a constant low exploitation and case 4 to a strong increasing exploitation since 1970 (cases 2 and 3 ranging between these 2 extremes). The results are shown for age 1 (c.f. recruitment), ages 2-5 and ages 8+ and are compared to the stock estimates of the 1996 SCRS assessment (Fig.7).

For ages 1 and 2-5, the results of the simple VPA and of ADAPT converge to the same solution (Fig.7, although values of the 1996 SCRS for ages 2-5 are slightly higher). The stock estimates for the young ages display a clear increase, if we do not take into account the 2 last year for which there is no convergence. For instance, the estimates of ages 2-5 are around 600000 from 1970 to 1975, 900000 in 1976-1983 and 1.5 million from 1984 to 1995. ***Despite different hypotheses on F10+ and different values of F in the terminal year, the catch-at-age matrix lead to estimate an increasing trend in the N for ages 1 to 5.***

In contrast, the results of the simple VPA and of ADAPT for ages 8+ are totally divergent (Fig. 7). None of the simple VPA is able to display a strong decline as the 1996 SCRS assessment. It can be also noted that the absolute values of 1996 SCRS population sizes estimates are dramatically higher than those of the simple VPA (up to 300% in the 70's). These differences in the trend and absolute values actually reflect the temporal pattern of F estimated by ADAPT (and mainly determined by the Japanese-LL CPUE series). In the 1996 SCRS assessment, F were estimated for age 10+ between 0.04 and 0.1 in the 70's and at 0.495 and 0.755 in 1994 and 1995 respectively. So that, F in 1994-1995 are 5 to 18 times higher than in the 70's. As the catches of oldest individuals are important in the 2 last years and much higher than in the 70's, ADAPT logically estimates very high N in the 70's and a strong decline since then. For the simple VPA with a constant F10+, F remain the same during all the period, so that N for ages 8+ only reflect the catches and thus display an increase. For the simple VPA with an increasing F10+, F are 2 and 4.3 times higher in 1995 than in 1970 (for case 3 and 4 respectively). However, the N for ages 8+ display a flat pattern, so that a 2 to 4.3 increase in F do not appear sufficient to generate a decline in N. ***These results indicate that the Japanese-LL CPUE series is of chief importance within the 1996 SCRS assessment because this is this index which mainly determines the strong decline in N for the ages 8+.*** However, the strong decline in ages 8+ estimated by the 1996 SCRS assessment implies that a

5 to 18-fold increase in F since 1970 is realistic. Our knowledge of the fishery can hardly support this hypothesis and the fact that no recruitment-overfishing has been detected tend also to deny such a conjecture. Therefore, ***it cannot be rejected that the strong decline of age 8+ only result from a poor quality of the data*** due, for instance, to misreporting, age slicing problems, etc..., so that the catch-at-age data and/or the CPUE index could be biased (a question that this work does not aim to solve).

4. Stock-recruitment relationships

We also computed stock-recruitment relationships on the estimates obtained by the 1996 SCRS assessment and the 4 above case studies in order to compare the above different scenarios from the stock-recruitment point of view. Because the Beverton and Holt model (1957) could not be applied to the 5 cases, we used the Ricker model (1954). Our aim is to do comparison using the same modelling approach but not to find the 'real' stock-recruitment relationship, which would imply deeper methodological investigations (e.g. to take into account the variability of the recruitment). The 2 cases assuming a constant F10+ showed a linear (case 1) and a convex (case 2) relationship (Fig. 8), so that the observed values are on the left part of the curve. As the trajectories go from the left to the right, the stock recruitment relationships of these two cases would indicate that the East-stock is not fully exploited or recovering from a previous over-exploitation. However, these 2 scenarios were used as school-cases (and for comparison study), but general knowledge on the BFT fisheries clearly indicate that they are highly unlikely. In contrast, the curves are domed in the 3 cases assuming an increase in F10+ (which are more realistic) and the observed values are on the right part of the curve (Fig. 8). The case of the 1996 SCRS assessment shows that the trajectory mainly goes from the right to the left, with the years 1970-75 on the extreme right side of the curve and 1995 is in the middle of the scatter-plot. However, the most recent years do not come back to the origin as in case of over-exploitation. Actually, the stock recruitment relationships do not appear consistent in the 1996 SCRS case. It is indeed difficult to understand why the 70's display the lowest recruitment and the highest SSB levels whereas the fishing effort is known to be much lower in the 70's than in the 80's or the 90's. ***These results might indicate*** (as those of the above analyses) ***that the 1996 SCRS assessment under-estimated the recruitment and/or over-estimated the spawning stock biomass in the 70's.*** Further work would be necessary to solve such a question but it is interesting to note that Fonteneau (1996), on the basis of the work of Farrugio (1981), already suggested that the SCRS might have under-estimated the recruitment during the 70's.

5. Discussion

The sensitivity analyses have shown that the absolute values of the stock estimates obtained by ADAPT (and thus the projections and the conclusions of the 1996 SCRS assessment) are very sensitive to the various technical specifications, especially those regarding M and the F-ratios. About M, general knowledge on fish biology strongly indicates that a M vector, like the Southern BFT one, is far more realistic than a constant value of 0.14 for all the ages. As the model converged correctly and the goodness of fit is comparable, we recommend it as the prior technical specification of M. The choice of the F-ratios appears the most critical specification: the estimation of the F-ratio in 1988 instead of fixing it at 2.02 lead to dramatically underestimate (up to 180%) the stock sizes. Therefore, this technical specification should be stated with great care (for instance through a detailed study on the potential changes in the dynamics of the various BFT fisheries). Without any further information indicating the presence of a stronger fishing pressure on ages 10+ than on age 9, the setting of all the F-ratios at 1 should be considered as the 'null hypothesis'.

Concerning the stock estimates of the recruitment (age 1) and of the young ages (2-5yr), the converge between the various scenarios of the simple VPA and the SCRS base case indicate that the increasing trends appear mainly due to the structure of the catch-at-age matrix. The terminal F, which are mainly determined the Spanish-BB CPUE series within the 1996 SCRS assessment, only influence the estimates of the 2 last years. Therefore, the reliability of the increasing trend in the recruitment and in the young ages is related to the quality of the catch-at-age matrix, which should be unbiased. However, simulation studies computed during an European workshop in June 1998 (Anonymous 1998a) have pointed out some concerns in the catch-at-age matrix, possibly because of length slicing problems. The reliability of this trend is also related to the spatial consistency of this fishery. This last assumption is however very unlikely. Since 1970, the French and the Italian PS fleets have continuously extended their prospecting within the Mediterranean waters and their spatial patterns changed from year-to-year. If the Spanish bait boat fleet mainly stays in the Bay of Biscay since 1970, there could have been changes in fishing efficiency between 1970 and 1995. Such changes are highly probable during a period of 25 years (Anonymous 1998a) and a recent US report (Anonymous 1998b) showed that an increasing fishing efficiency, that is not taken into account, always lead to over-estimate the recruitment. ***Therefore the increasing trend of the recruitment and the young ages might result from methodological biases, i.e. an under-estimation in the 70's together with an over-estimation in the most recent years.***

The strong decline estimated by the 1996 SCRS assessment for the ages 8+ is related to a 5 to 18-fold increase in F since 1970. This increase, which is very sharp, is actually determined by the absolute value of the F in 1995 for these ages (a value mainly estimated by ADAPT from the Japanese-LL CPUE series). However, this strong decline is not consistent with the increasing trends of the ages 1 to 5 and the various analyses suggest that the 1996 SCRS assessment might have under-estimated the recruitment and/or over-estimated the spawning stock biomass in the 70's. Therefore, ***the strong decline estimated by the 1996 SCRS assessment for the ages 8+ could also result from methodological biases but not from a real decline of these ages.***

The VPA model Xsa (Shepherd 1992) was also applied on the Bluefin Tuna catch-at-age data for the Northeast Atlantic during the above mentioned workshop (Anonymous 1998a). It was concluded that Xsa should not be used on the BFT data in their current form because of (i) poor convergence, (ii) the violation of the separability assumption in the last years and (iii) serious concerns regarding the assumption of constant catchability and the estimates of the fishing mortality derived from the CPUE series (which is also a problem for ADAPT). Although ADAPT is probably the most appropriate VPA model for the BFT data (because of its 'adaptative' framework), its lack of robustness to the various technical specifications as well as the problems related to the trends lead to conclude that the results of the 1996 SCRS Bluefin Tuna Stock Assessment for the Northeast Atlantic must be treated with great caution. The lack of robustness of ADAPT and the problem of the reliability of the trends appear mainly related to the poor underlying data and a serious lack of information on both the fishery and the Bluefin Tuna population in the Northeast Atlantic and the Mediterranean Sea. We would like to stress that the problem of robustness could not be solved, in any way, by a measure of uncertainty of the various estimates, such as the ones given by bootstrapping. Uncertainty and lack of robustness are two different concepts: according to a certain level of variability, the former imply that the parameters estimated by a model are trustworthy, whereas the latter indicates an inability of a model to estimate the parameters. It would be therefore of interest to list all the sources of uncertainty and try to incorporate them into the analyses.

The present work do not conclude that ADAPT or any other VPA models should not be used on BFT data neither there is no problem of overfishing towards the Bluefin Tuna in the Northeast Atlantic and the Mediterranean Sea. The figure 9 clearly shows that there is a tremendous increase of the total landings since 1994. This recent augmentation of the total landings, which mainly results from an increasing efficiency towards the oldest age classes during the 'Balearic campaign', is indeed of great concern. Furthermore, one of the rare optimistic indication, i.e. the increasing trend of the recruitment and of the young ages, do not appear trusty. However, we think that it is hardly difficult, for the moment, to give reliable conclusions through the unique use of ADAPT (or any tuned VPA).

Special attention should be thus firstly given to improve the database and our knowledge. For instance, trends in fishing effort should be intensively studied (which is not an easy task since fishing effort of the BFT fisheries is very difficult to quantify) and the F-ratios should be objectively quantified. Various biological and ecological information regarding natural mortality, spatial and temporal variability of growth, reproduction and mortality rates as well as the number of spawning areas, the locations of the feeding grounds should be also investigated. In addition, the serious lack of data on migration rates across the Atlantic should be also resolved (SCRS/96/26). Although it sounds reasonable to take into account for migration in the BFT stock assessment (see e.g. Fonteneau 1997), the high sensitivity of ADAPT to the various technical specifications regarding M and F make, for the moment, nonsensical the use of migration functions as soon as data on migration rates would not be drastically improved (see Porch 1994, Turner and Powers 1994,) and the ecology of the populations better known. Otherwise, we would add an additional source of instability and the model would converge to highly different solutions with slight changes on the migration parameters (see Porch et al. 1994). Note also that all the ICCAT historical catch data (1950 to 1995) should be taken into account for the assessment and not only the catch data since 1970 as for the 1996 SCRS assessment. The figure 9 shows that the interpretation of the trend on the total catch is totally different if we consider the period 1950-1995 or only the period 1970-1995. The total landings in 1994-95 are indeed comparable to those in the 50's which are characterised by an important Nordic fishery (which collapsed in the 60's).

In the meantime, the management of the East-Atlantic and Mediterranean BFT population should use all sources of quantitative and qualitative information, such as the results from various modelling (simple and tuning VPA, global models, yield per recruit, stock-recruitment models); the comparison of the trends in: F, N, CPUE indices, average weights, growth rates, f of the various fleets (and of their spatial pattern), etc... All these sources of information should be listed, studied and compared, so that the conclusions of the SCRS working group would result from the most probable point of convergence obtained from the different approaches. It should be added that the study of the historical time series of the Western Mediterranean traps could allow an estimation of the catches sustained by the Mediterranean fishery since the beginning of the 17th century (Fig. 10, see also Farrugio 1981, Addis et al. 1996). Fonteneau (1996) indicate that, all together, the Mediterranean traps could have caught yearly 15 000 to 20 000 tonnes during centuries. This source information could be gathered and studied rather quickly and could be of great help for the management of the Bluefin Tuna in the Northeast Atlantic and the Mediterranean Sea.

Acknowledgements

I would like to thank V. Restrepo for providing the code of FADAPT 3.0 and for his help and useful comments as well as C. Porch who provided the code of VPA-2BOX and its manual.

Thanks are also due to H. Farrugio, A. Fonteneau, F. Gauthiez and B. Liorzou for their helpful comments on the analyses and the manuscript.

References

Addis P.A., Cau A., Davini M.A., Secci E. and Scibaldi G. (1996). Collection of Tuna data catches by trap-nets in Sardinia: historical (1825-1980) and recent catches (1992-1995). SCRS/96/133.

Anonymous (1998a). Contract Report from the Workshop of Technical Experts on Bluefin Tuna. CEFAS Lowestoft Laboratory, U.K., 29th June-3rd July 1998.

Anonymous (1998b). Improving stock asssessment. National Research Council, National Academy Press, 177p.

National Academy press, 177p.Beverton R.J.H. and Holt S.J. (1957). On the dynamics of exploited fish populations. Fishery Investigation, London, 19, 533pp.

Cort J.L. (1990). Age and growth of the Bluefin Tuna, *Thunnus thynnus* (L.) of the Northeast Atlantic. SCRS/90/66.

Farrugio H. (1981). Exploitation et dynamique des populations de thon rouge, *Thunnus thynnus* (Linné, 1758), Atlanto-Méditerranéennes. Thèse de Doctorat d'Etat, Université des Sciences et Techniques du Languedoc, Montpellier, 226 pp.

Fonteneau (1996). Rapport Réunion ICCAT 1996. Symposium ICCAT 1996. Beckett ed. (in press).

Fonteneau (1997). Le thon rouge de l'Atlantique: un futur menacé? Conférence Journée Thon Rouge M'Dicq, 14 Juillet 1997. 11 pp.

Geromont H.F. and Butterworth D.S. (1996). Specifications for the ADAPT VPA code, September 1996, SCRS/96/127.

Gulland J.A. (1965). Estimation of mortality rates. Annex to Arctic Fisheries Working Group Report ICES C.M. Doc. No.3. (mimeo).

Liorzou B., Bigot J.L. (1998). La dégradation des données recueillies sur le thon rouge exploitée au large des côtes francaises de Méditerranée. SCRS/98/xx.

Myers R.A., Barrowman N.J. (1996). Is fish recruitment related to spawner abundance? Fish Bull 94: 707-724

Porch C. E. (1994). A two-are VPA with discrete mixing: can we discriminate between mixing rates given by the present condition of the data? SCRS/94/75.

Porch C. E. (1997). A user's manual for VPA-2BOX Version 2.0. National Marine Fisheries Service, Miami. USA.

Porch C.E., Restrepo V, Turner S.C. and Scott G.P. (1994). Virtual population analysis of Atlantic bluefin tuna incorporating movement and tagging data. SCRS/94/73.

Restrepo V. C. (1996). FADAPT Version 3.0, a guide. University of Miami. USA.

Ricker W.E. (1954). Stock and recruitment. J. Fish. Res. Bd Can. 11: 559-623.

SCRS/96/26. Report of the 1996 SCRS Bluefin Tuna stock Assessment Session, Genoa, September 12-20, 1996.

Shepherd J.G. (1992). Extended survivors analysis: an improved method for the analysis of the catch-at-age data and catch-per-unit-effort data. Working paper No. 11 ICES Multi-species Assessment Working Group, June 1992, Copenhagen, Denmark. 22pp. (mimeo).

Turner S.C. and Powers J.E. (1994). Review of information related to Atlantic bluefin tuna east-west movement. SCRS/94/74.

Wootton R.J. (1990). Ecology of Teleost Fishes. Chapman & Hall, London, 404pp.

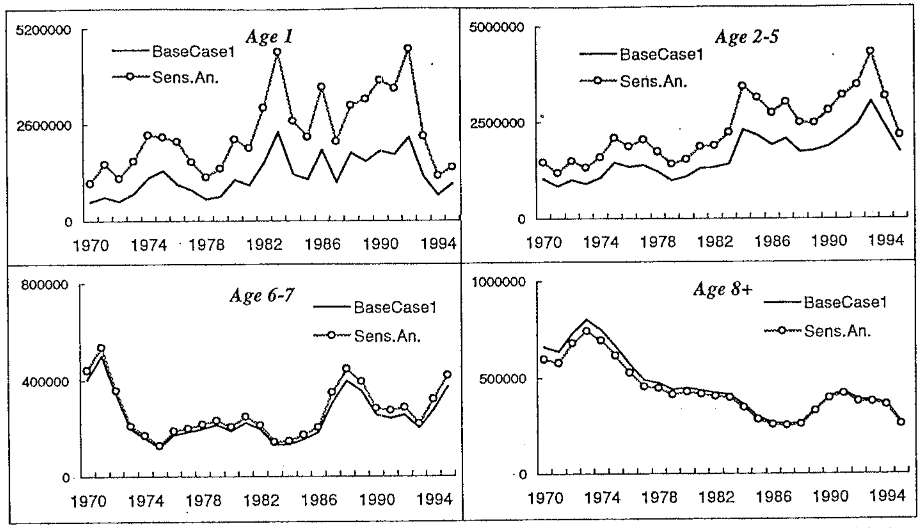

Figure 1. Comparison of the stock sizes estimates (N) for the Bluefin Tuna East stock between (1) the base Case 1 of the 1996 SCRS assessment and (2) the sensitivity analysis (Sens.An.) on the natural mortality (M). The constant M of 0.14 have been replaced by the Southern BFT vector (see text), but all the other specifications remained the same. According to the VPA-2BOX specifications (Porch, 1997), N are summarised into 4 groups: ages 1, 2-5, 6-7 and 8+. The total log-likelihood function is about –20.44 and –21.64 for the base case 1 and the sensitivity analysis, respectively.

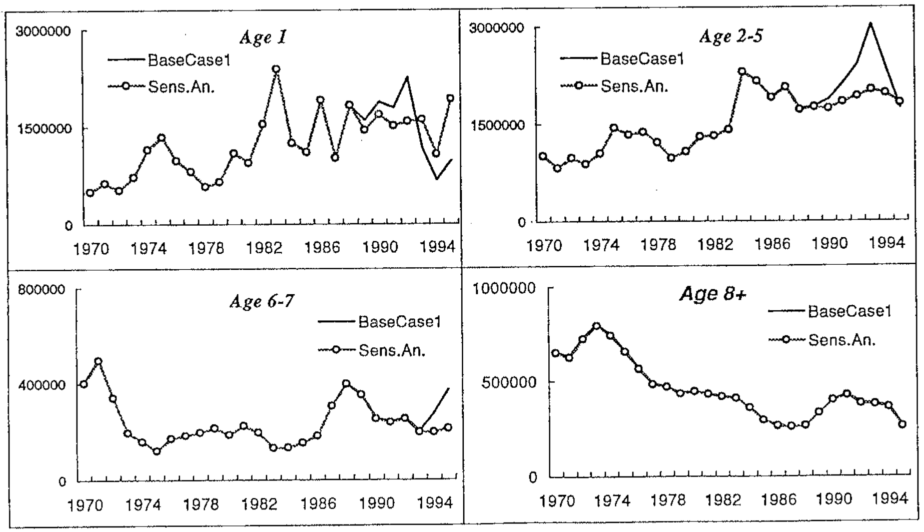

Figure 2. Comparison of N between (1) the base case 1 and (2) the sensitivity analysis on the reference age (the reference age 4 being replaced by age 6; all the other specifications remained the same). The total log-likelihood is about –32.62 and –21.64 for the base case 1 and the sensitivity analysis, respectively.

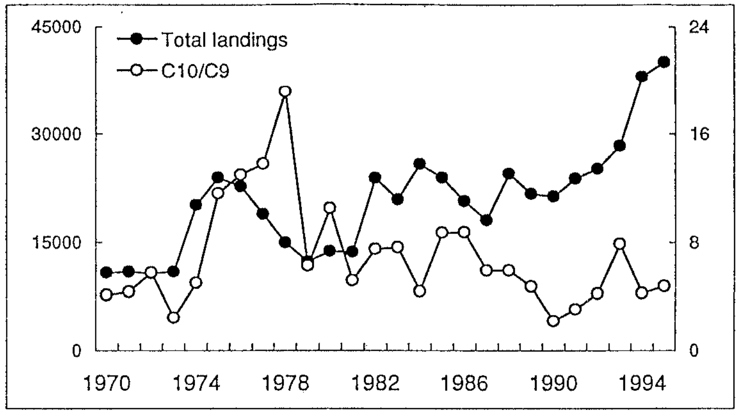

Figure 3. Total landings and ratio of the total catches of age 10+ by those of age 9 for the East BFT stock from 1970 to 1995

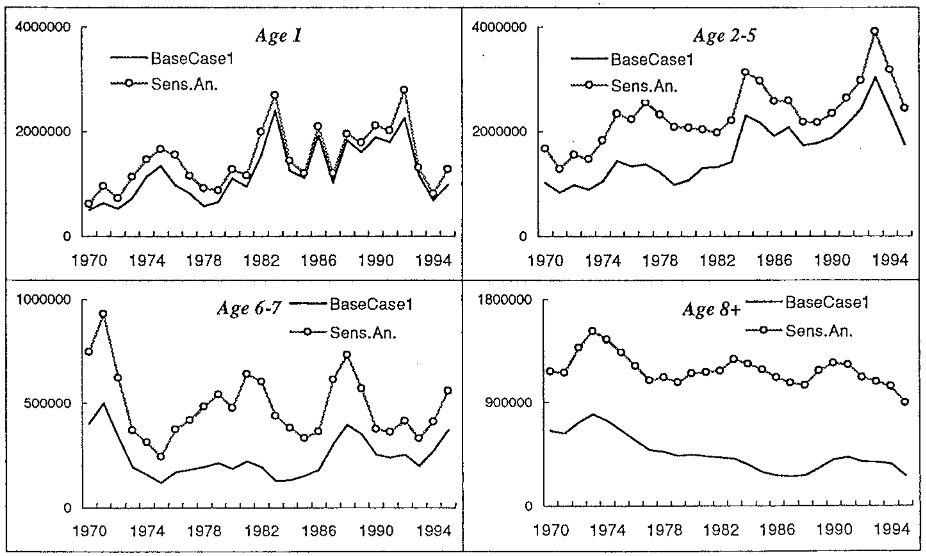

Figure 4. Comparison of N between (1) the base Case 1 and (2) the sensitivity analysis on the F-ratio (the F-ratio in 1988 have been estimated and set to be the same for the period 1988-1995 instead of being fixed at 2.02). All the other specifications remained the same. The total log-likelihood is about –17.56 and –21.64 for the 1996 SCRS base case 1 and the sensitivity analysis, respectively

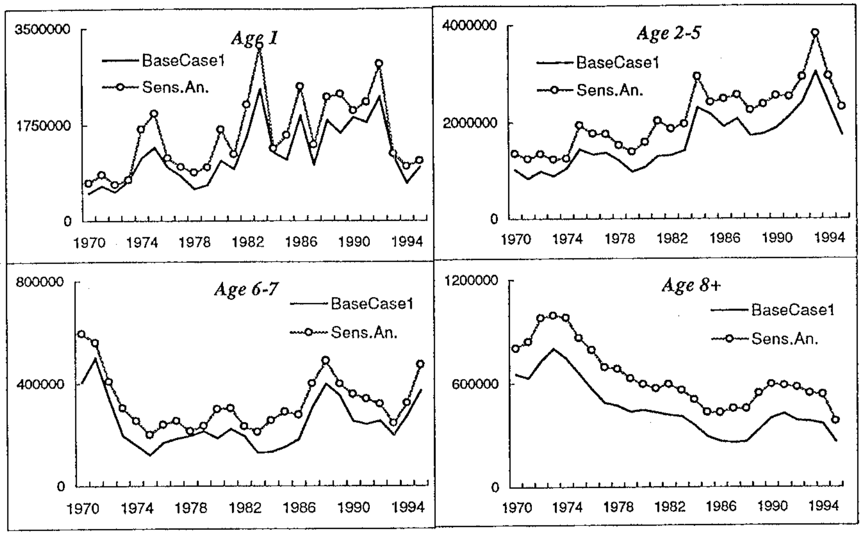

Figure 5. Comparison of N between (1) the base Case 1 and (2) the sensitivity analysis on misreporting (a simulated catch at age matrix was built by selecting at random 50% of the values of the original matrix to which was added 25%). All the other specifications remained the same. The total log-likelihood is about –26.05 and –21.64 for the base case 1 and the sensitivity analysis, respectively

Fs in 1995	ICCAT Base-case 1	M vector Sect. 2.1	Ref. ages Sect. 2.2	F-ratios Sect. 2.3	Misreporting Sect. 2.4
Age 1	0.534	0.398	0.237	0.381	0.463
Age 2	0.889	0.664	0.394	0.635	0.771
Age 3	0.889	0.664	0.394	0.635	0.771
Age 4	0.125	0.114	0.394	0.081	0.096
Age 5	0.125	0.114	0.394	0.081	0.096
Age 6	0.125	0.114	0.231	0.081	0.096
Age 7	0.125	0.114	0.231	0.081	0.096
Age 8	0.374	0.392	0.385	0.171	0.366
Age 9	0.374	0.392	0.385	0.171	0.366
Age 10+	0.755	0.792	0.777	0.133	0.739
Fs age 10+					
1970-1973	1	1 fixed	1 fixed	1 fixed	1 fixed
1974-1987	1.489 est.	1.469 est.	1.513 est.	1.445 est.	1.465 est.
1988-1995	2.02 fixed	2.02 fixed	2.02 fixed	0.775 est.	2.02 fixed

Table 1. Estimates of Fs in 1995 for all the ages and values of the F-ratios across 1970-1995 for the 1996 SCRS base case 1 and for the different sensitivity analyses

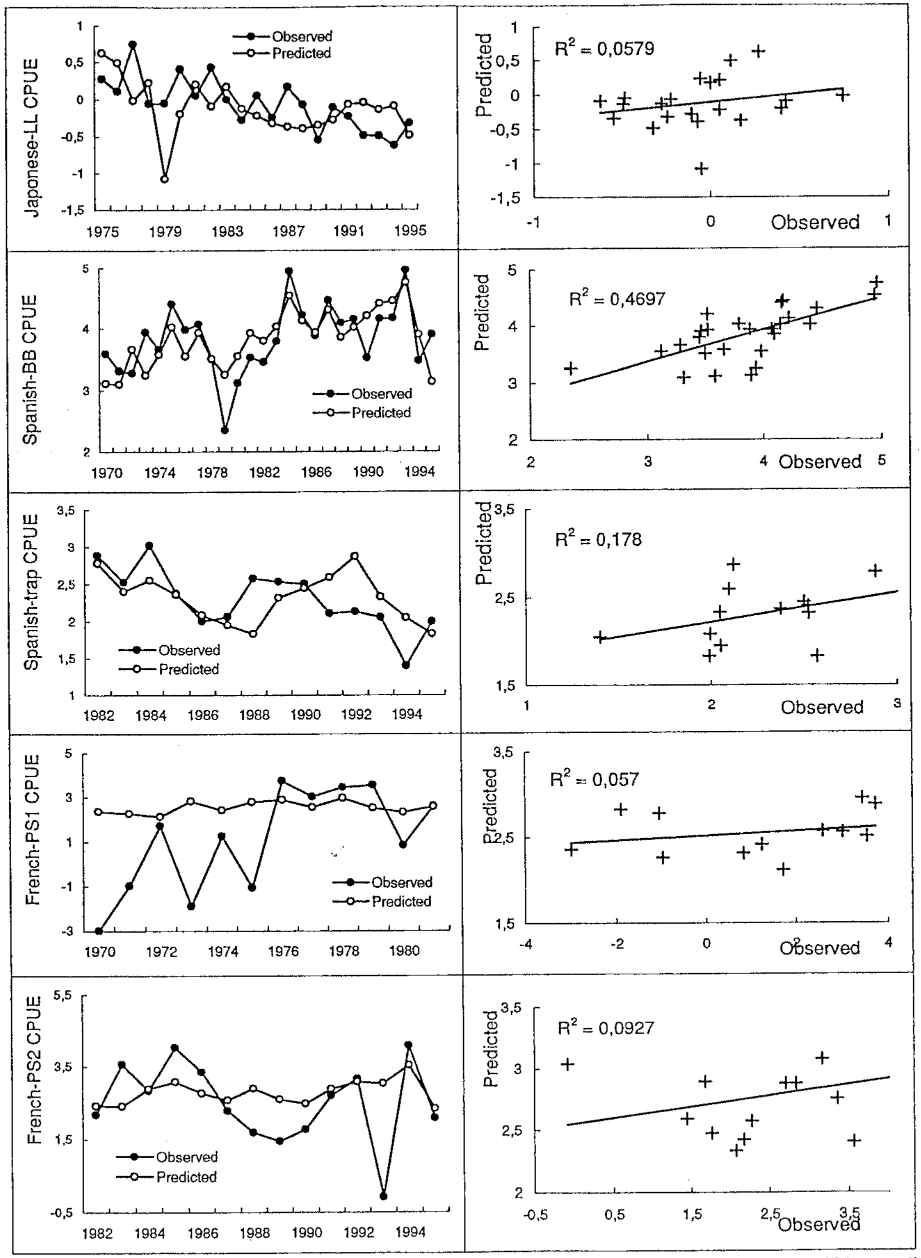

Figure 6. Left panels: Plots of the 5 CPUE indices used for the estimations of the East stock (Observed). The predictions of these indices by ADAPTare superimposed. Right panels: Scatter-plots between observed and predicted CPUE indices, together with the linear regression and the determination coefficient

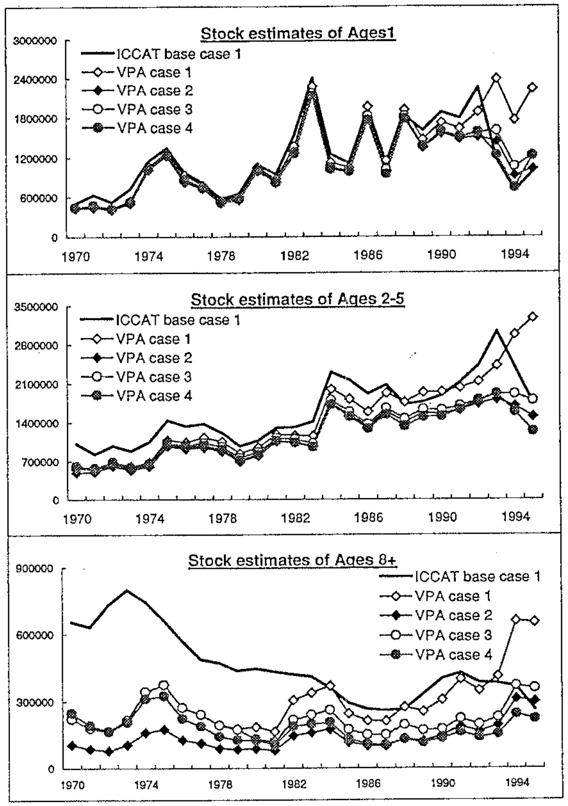

Figure 7. Comparison of the stock estimates of age 1, ages 2-5 and ages 8+ between (1) the ICCAT base case 1 and results from simple VPA assuming: (i) a constant exploitation pattern with rather low F (Case 1, F=0.2), (ii) a constant exploitation pattern with a rather high F (Case 2, F=0.5), (iii) an increasing exploitation pattern with a moderate increase (Case 3) and (iv) a strong exponential increase (Case 4)

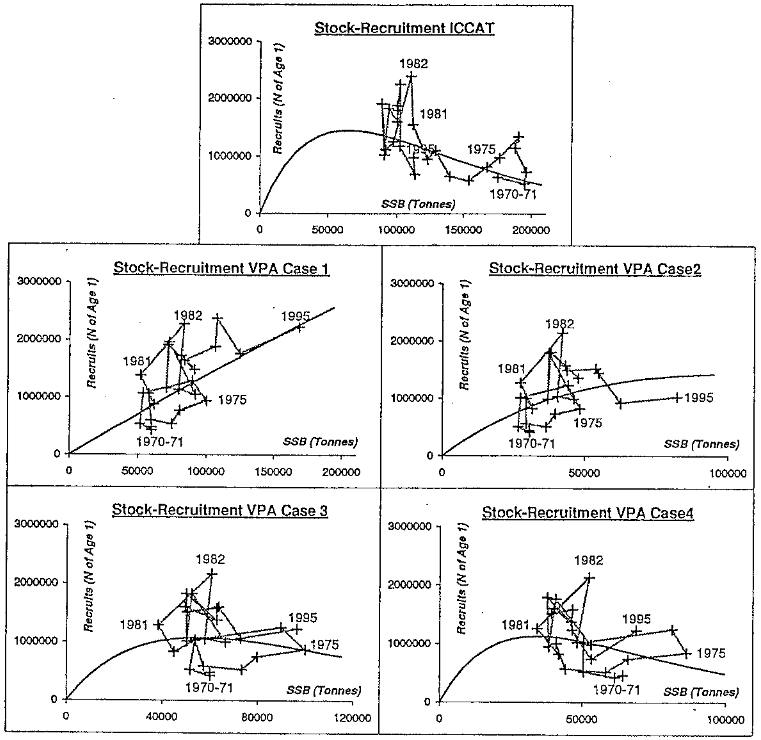

Figure 8. Comparison of the Ricker stock-recrutment relationships between the ICCAT base case 1 (top panel) and simple VPA assuming: (1) a constant exploitation pattern (left panels) with rather low F (Case 1, F=0.2) and rather high F (Case 2, F=0.5) and (2) an increasing exploitation pattern (right panels) with a moderate increase (Case 3) and a strong exponential increase (Case 4).

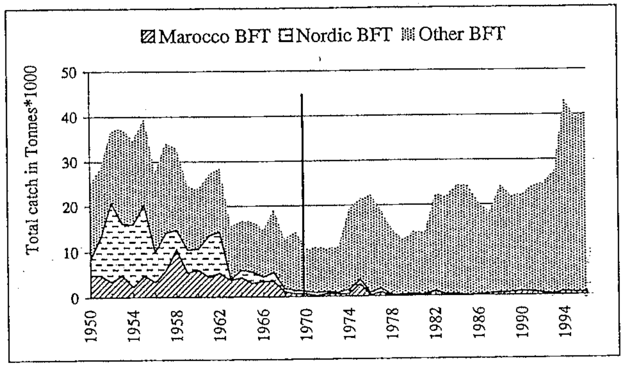

Figure 9. Total catch of the Northeast-Atlantic Bluefin Tuna from 1950 to 1996 (ICCAT)

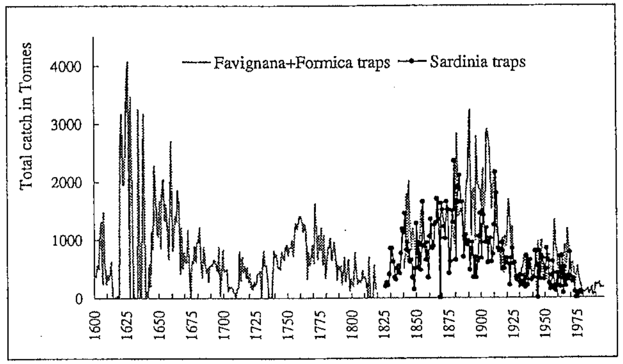

Figure 10. Yearly catches of 2 Italians traps since 1600 and of the Sardinia traps since 1826 (see Addis et al. 1996)