WHY SO MANY VERY OLD FISHES IN THE SOUTHERN BLUEFIN TUNA CATCHES? PRELIMINARY MODELING OF THE "CRYPTIC"[1] BIOMASS HYPOTHESIS

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ABSTRACT

A recent analysis of southern bluefin tuna otoliths presented by Kalish and Johnston indicates that a high proportion of the large southern bluefin tuna caught during recent years would be very old, between 15 and 30 years. This result is in contradiction with all results presently obtained from the virtual population analysis. The present paper develops a simulation model assuming an underlying population with a fraction of stock which remain partly unavailable to the fisheries. This simple concept and model could easily explain the abundance of very old southern bluefin tuna in the recent catches. This hypothesis of a cryptic biomass may be a realistic one, because of the large area inhabited by the species, because of the present closure of the spawning area to all fisheries and because of the low catch quota which limits the fisheries to operat in the areas of highest tuna densities. This cryptic biomass could introduce significant potential bias in the results obtained from the virtual population analysis, at least for the stocks heavily exploited.

RÉSUMÉ

Des analyses d'otolithes de thon rouge du sud récemment réalisées par Kalish et Johnston indiquent qu'une proportion importante de grands thons rouge du sud capturés durant les années récentes seraient très agés, de 15 à 30 ans. Pour expliquer cette observation qui est en contradiction avec les résultats des analyses de populations virtuelles actuelles, le présent article suggère à partir des résultats d'un modèle de simulation, que l'explication la plus simple serait qu'il existe une fraction de stock de southern bluefin tuna qui demeurerait très peu accessible aux pêcheries actuelles jusqu'à un age avancé. L'existence d'une biomasse cryptique significative semble logique pour une espèce comme le thon rouge du sud, du fait de la très large distribution géographique de cette espèce, de la fermeture de la zone de ponte et des faibles quotas appliqués sur ce stock qui ont pour conséquence que seules certaines concentrations de thons rouge du sud sont actuellement visées par la pêche. L'existence éventuelle de cette biomasse cryptique pourrait introduire des biais importants dans les résultats des analyses de populations virtuelles des stocks fortement exploités.

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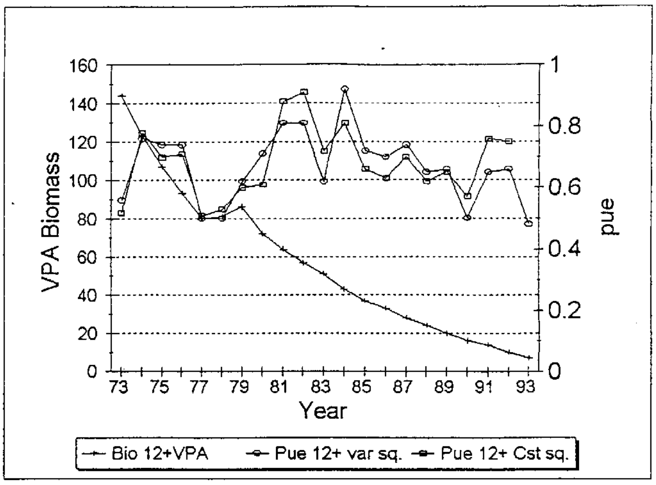
1 "Cryptic" biomass: the cryptic biomass is defined as a fraction of stock which is not available to any fishery (because of the gear used or because of its geographical distribution); this biomass will remain unaivalable (or cryptic) as long at it show no mixing (or very little mixing) with the main stock which is fully available to the fisheries.

Figure 1: Comparison of the southern bluefin longline CPUE age 12+ years and of the estimated number of age 12+ from VPA (provisional data showing the relative trends of those two parameters, not their exact levels).



INTRODUCTION: LOWER M OR LOWER F?

The recent paper by Kalish and Johnson (1995) has shown the existence of a large proportion of very old individuals in the southern bluefin tuna catches taken during recent years:

As quoted from those authors:

"Southern bluefin tuna otoliths for this study were selected at random from large fish sampled by the CSIRO researchers. The sample is not adequate to estimate the range of ages present in the population of southern bluefin tuna, but it does suggest that a large percentage of the fishes greater than 180 cm are at least 20 years of age, and that southern bluefin tuna can live to ages in excess of 25 years".

If the method used and its conclusions are valid, this result may be of major interest for stock assessment and stock management, for southern bluefin and for other heavily-exploited tuna stocks. At this stage, and waiting for a validation of those conclusions, scientists must start thinking about the stock assessment implications of this high proportion of old southern bluefin tuna in recent years.

This large number of very old southern bluefin tuna -15 to 25 years old- in the recent catches, if it is real, would be very strange, and in **complete contradiction** with the very high exploitation rates calculated for southern bluefin tuna, at least during the last 20 years. All the present virtual population analyses (VPA) indicate that the very old southern bluefin tuna (for instance age 15+ years) should be presently very rare and could never be found significantly in a small sample of otoliths!!

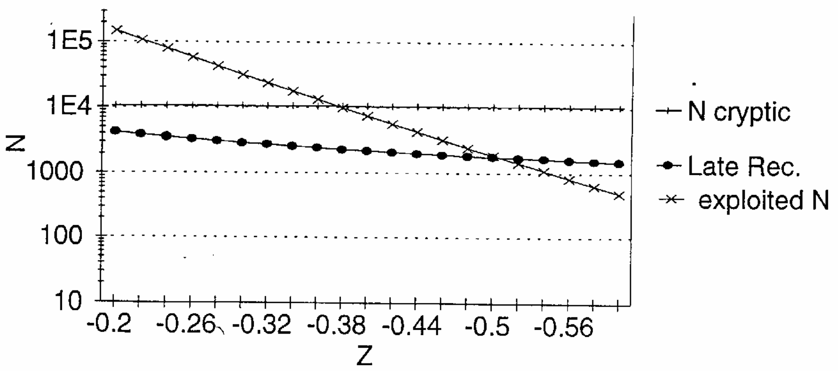
As virtual population analysis is the major tool used by scientists for the management of this stock, this question becomes of major interest!

This surprisingly high number of large southern bluefin tuna presently found in the recent catches could easily be connected to another strange observation, the surprising stability of the longline (LL) CPUE of age 12+ southern bluefin tuna in the fisheries, which was also in complete contradiction with most VPA results (in which the age 12+ biomass show a drastic decrease during recent years). This divergence between the adult LL CPUE and the adult biomass obtained from the VPA is shown by Figure 1 (provisional data, only indicative of the CPUE and N_{12}+ trends).

Both facts -the stability of 12+ years longline CPUEs and the high number of very old survivors- would indicate that there may be a bias in the present virtual population analysis, possibly a very serious one. This potential bias may be serious because the number of survivors left by fisheries is a key component in this type of analysis. This potential bias may have produced serious errors in the estimation of the absolute levels and trends of the spawning stock, a key parameter in the management of the stock.

Two types of virtual population analysis errors could provide part of the explanation: either a Natural mortality (M) lower than presently assumed, or an overestimated exploitation rate.

*Figure 2: Changes in a simulated population of old fishes (N = number of fishes), total number of fishes between ages 12 and 30 years, under a fishing mortality F increasing from zero (z = 0.2, as M = 0.2) to F = 0.4 (and Z = 0.6). (N_1) is the fraction of stock which is never available to any fishery (**N cryptic**, equal to 10% of the initial recruitment); (N_2) is the sub-stock fully available to the fisheries (**Exploited N**), 90% of the recruitment; (N_3) is the **late recruitment** fish, i.e. fish which are transferred from the cryptic biomass to the available one at a yearly rate of 5% of the cryptic biomass, starting at age 10 years.*



The potential for those two types of errors will be reviewed and discussed.

A LOWER M ON ADULT SOUTHERN BLUEFIN TUNA?

Natural mortality was estimated constant at M=0.2. This 'magic number' M could possibly be overestimating the M for adults (the adult M may also be different from the M of younger southern bluefin tuna, for various biological and physiological reasons and because of predators). If the adult M was lower than it is presently assumed, it could explain to some extent our two strange observations. This hypothesis is primarily the one considered realistic by Kalish and Johnston. However, new virtual population analyses need to be done to evaluate the potential consequence of this reduced M in the virtual population analysis results (and the subsequent increase of the older fishes, for instance older than age 12 years).

At this preliminary stage, every simulation indicates the key role played by the high exploitation rate, and not by a low M: a low M for adults allows very few simulated possibilities to run any simulation with a significant number of very old survivors in the population (at least when the entire stock is available to the fishery). Any stock suffering a very high exploitation rate will have very few very old animals surviving. This basic and fundamental rule in all demographic and virtual population analyses is always of major importance! If the southern bluefin tuna stock was really heavily exploited during the last 20 or 30 years, as it is presently estimated with good reasons, very few old (for instance older than 20 years) southern bluefin tuna could survive. The analyses of simulated exploitation indicate that this conclusion, linked to the high exploitation rate, is always valid, quite independently of the natural mortality, M.

A LOWER F?

Based on the previous conclusion that a low M can hardly explain the observed apparent abundance of age 12+ fishes, it can probably be assumed that the consequence of an overestimated F would be much more significant than the possible underestimation of M.

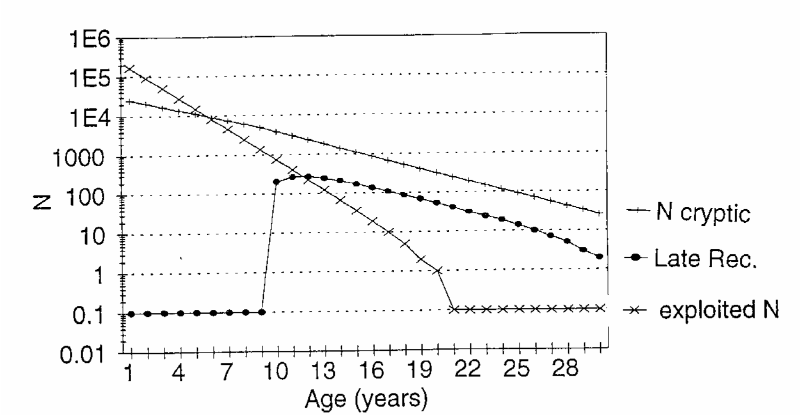
There is no doubt also that the various virtual population analyses presently conducted are giving a reasonably good estimate of the trends of the available stock and the F exerted upon it, at least for younger ages (for instance between recruitment and age 10 to 12 years).

However, the present virtual population analysis was based on the strong hypothesis (possibly false?) that all southern bluefin tuna individuals were available to the fisheries. The alternate hypothesis, that a significant fraction of the southern bluefin tuna biomass remains unavailable to all fisheries (the so called "cryptic biomass") during long periods, may be interesting to consider.

This southern bluefin tuna "cryptic biomass" hypothesis could possibly explain well both:

1. the quite stable trend of longline CPUEs age 12+, and
2. and the new high proportion of very old southern bluefin tuna in the catches.

Figure 3. *Decrease of the population size of the three components of the stock (same as Figure 2), between age 1 and 30 years, under a high constant F = 0.4 (Z = 0.6) exerted on the available fraction of stock.*



The following simulation model was developed to explore the potential dynamics of the population in this "cryptic biomass" hypothesis.

A SIMPLE CRYPTIC BIOMASS MODEL: CRYPTUNA

The model

To help understand the potential mechanism underlying the "cryptic stock biomass" hypothesis and its potential effects on 10+ virtual population analysis biomass, the following very simple simulation model" **CRYPTUNA**" has been developed:

The stock was divided into two fractions:

- **Sub-stock 1** (100-z% of the total recruitment) is fully exploited with a constant age-specific F; this sub-stock will receive yearly x% (yearly) from sub-stock 2, a cryptic component of the population, starting at age NAG. This sub-stock 1 is basically the fraction of stock which can readily be analyzed and followed by the tuned virtual population analysis (following the catches at age from this available cohort, and the abundance indices from the age-specific CPUEs of the fisheries in the fished area).

- **Sub-stock 2** is only a fraction of the total stock (z% of the total recruitment). It remains entirely cryptic (F=0), and entirely unavailable to all fisheries until a given age (NAG); then this cryptic stock loses x% of its biomass yearly, starting at age NAG; and this biomass will enter each year into the exploited stock (fraction 2??), and will then be available to the fisheries. As this sub-stock is never fished, there is no way to take it into account in the virtual population analyses; in all the present virtual population analyses this "cryptic" stock is really a "ghost" stock, which cannot be taken into account in the underlying population obtained from the virtual population analysis.

The goal of this model was to explore the potential effects of the existence of a fraction of southern bluefin tuna stock which could remain cryptic until a given age.

Hypotheses

This simple model has been run under the following simplified hypotheses:

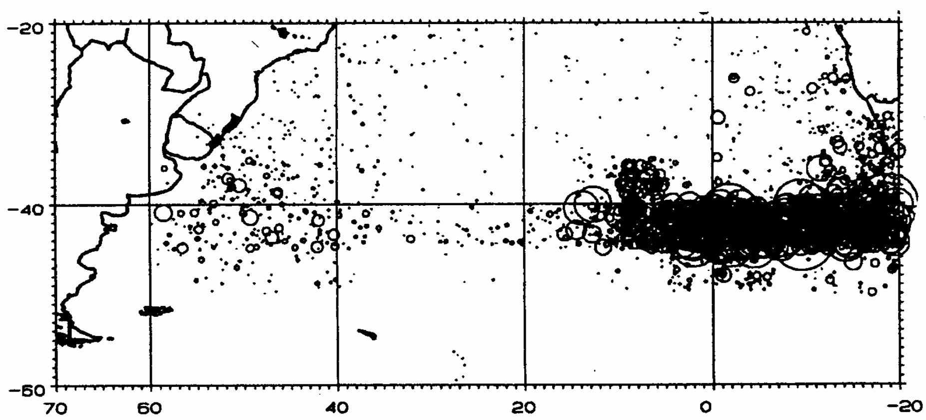
1. That sub-stock 2 has a recruitment equal to 10 % of sub-stock 1.
2. That sub-stock 2 is entirely cryptic until age 10, and then,
3. Loses 5% of its biomass yearly, those fishes being entirely available in the exploited sub-stock 1 and caught by the fisheries with the same F as the exploited stock.
4. The natural mortality was kept constant at a yearly rate of M=0.2; the fishing mortalities on the available sub-stock 1 were fixed at all possible levels in a range between 0 and 0.4 (*i.e.* Z=0.2 to Z=0.6).

Some results:

Figure 2 and 3 summarize the basic conclusions of this type of model:

- Figure 2 shows the various equilibriums underlying populations calculated at increasing levels of F, under those hypothesis, in sub-stocks 1 and 2. The exploited population in the fully-available stock 2 is classified into two groups:
    - group A, the fish recruited, exploited and surviving in sub-stock 1,

Figure 4. Map of the southern bluefin tuna catches by longliners in the Atlantic Ocean, 1956-1993. Shown clearly are various areas where southern bluefin tuna were taken at low densities in the history of the southern bluefin tuna fishery (especially in the western Atlantic). Each circle has an area proportional to the monthly catch during 1956-1993 in the 5° square, and was plotted at a random latitude and longitude within each 5° square. Most of those areas are not presently fished, as the present fisheries are concentrated (seasonally and some years) in the areas of highest southern bluefin tuna densities (in other oceans), primarily because of the low catch quota established for this stock during recent years.



- group B, fish transferred from the cryptic sub-stock 2 ("late recruitment").

- Figure 3 shows the three categories of populations (between recruitment and age 30 years) under the hypothesis of a high constant F of 0.4 (in the order of magnitude of recent southern bluefin tuna fishing mortalities).

The analysis of the results of this simple simulation shows that:

- When F was high, the biomass of the cryptic (and virgin) fraction of the stock may become very quickly dominant compared to the heavily-exploited fraction of the stock (in the simulated example, the cryptic fraction is dominant after only 6 years of exploitation at F = 0.4).
- At an age of 12 years, the exploited fraction of the stock is nearly eliminated, as soon as the exploitation rate is significant; the few fish available in the exploited stock are the "late-recruited fishes" coming from the cryptic fraction of the stock. This cryptic fraction of the stock is working as a **natural refuge of biomass**. This fraction of the stock, previously cryptic but now available and exploited, is always dominant in numbers of fish (even with only a minor fraction (10%) of the recruitment kept unavailable to the fisheries).
- After 25 years of heavy exploitation, a significant number of very old fishes can still be fished, but all from the cryptic fraction of the stock.

WHERE COULD THE CRYPTIC FRACTION OF THE SOUTHERN BLUEFIN TUNA STOCK BE?

The answer to this question should preferably be given by scientists expert in the ecology of southern bluefin tuna. However, results from other tuna species show that this cryptic fraction of stock may be unavailable for various reasons:

- the **type of gear used** and the range of depth exploited by the gear:

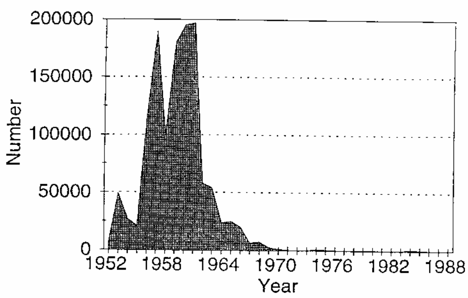
A pole-and-line bait boat is always quite inefficient for catching large yellowfin; longlines have proven to be quite inefficient for fully exploiting the yellowfin stocks. All virtual population analyses done on a yellowfin stock exploited predominantly by longliners always produce a dramatic underestimation of the real recruitment, because they estimate only the population available to the longline, not the real population.

The opposite is observed for bigeye tuna, which are caught efficiently only by longliners. For that same fishery of bigeye exploited by longliners, the gear is more efficient when deep longlines are used; the recruitments estimated by virtual population analysis usually increase when the longline fishery is increasing its use of deep longlines.

The **area exploited is smaller than the area of distribution,** with little mixing occurring between the fishes in the exploited and the unexploited zones:

This case was observed for various tuna fisheries world-wide. Two good examples of this problem were in the eastern Atlantic and eastern Pacific yellowfin fisheries, where the estimated recruitment and estimated MSY have

Figure 5. Numbers of southern bluefin tuna taken by the historical longline fishery in the southern bluefin tuna spawning area south of Java (10° to 20°S, 100° to 130° E).



been increasing in proportion to the exploited areas (Laloe, 1989; Die *et al.,* 1990).

It may be difficult to know where the cryptic biomass of southern bluefin tuna could be: vertical distribution deeper than the fishing area of the present gear? in unexploited areas? others? However, various good possible explanations could be explored:

(1) Habitat larger than the fishing zones:

It is quite clear that the potential circumpolar habitat of the southern bluefin tuna is very large, whereas only the areas of highest densities, most of them areas of feeding concentrations, are exploited. A comparison of the fishing maps during the early period of the fishery, and the fishery during recent years, shows that there are presently various areas where southern bluefin tuna could potentially still be present, such as the western Atlantic (Figure 4) and possibly the central Pacific, but not exploited by the fisheries (southern bluefin tuna being at too low densities and/or in very remote areas). If the mixing rate between those fishes and the southern bluefin tuna in the exploited areas was very low, those areas could well be refuges for a fraction of the southern bluefin tuna stock. As a very small fraction of cryptic biomass may easily explain the recent large abundance of very old fishes, the potential presence of southern bluefin tuna in those areas should be explored by scientific longline cruises; and tagging of those fishes could usefully be conducted to test the hypothesis that those fishes show little mixing with the exploited stock.

(2) No catches in the spawning strata:

For a species like southern bluefin tuna, which show a homing behavior and a seasonal spawning in a given stratum (South of Java), it could be assumed that most of the spawners are available to the fisheries in this stratum. However, when there is no more fishing activity in this area (as shown in Figure 5) for conservation or economic reasons, the availability of the spawners may be much lower, depending of their **migration routes** (within or outside exploited zones) and **behavior** (schooling or not, feeding or not) towards and from the spawning strata. Following this principle, it is quite clear that the closure since the mid-1960s of fishing activities in the southern bluefin tuna spawning stratum () has potentially reduced the availability of various segments of the southern bluefin tuna stock (those components being potentially cryptic now).

CONCLUSION: SOUTHERN BLUEFIN TUNA AND OTHER TUNA SPECIES?

The potential existence of a **fraction of the southern bluefin tuna stock which remains unavailable to the fisheries during extended periods** is probably a major problem in most tuna stock assessments of various species.

The worse case is probably when the tuned virtual population analyses are applied to a heavily exploited stock with a small but significant cryptic fraction of stock. In this case, the virtual population analysis based only on the abundance trends of the fraction of stock which remains available to the fisheries, will always **overestimate the real exploitation rate** of the real total stock (especially when the stock is heavily exploited). This analysis will also of course have as a subsequent bias an overdramatization of the adult stock size decrease, and an underestimation (potentially very large?) of the absolute number of spawners (a key result for management).

Now a key question would be to know if this cryptic biomass could be a real biological component for southern bluefin tuna and other tuna stocks, or if it is an incorrect concept. Scientific longline cruises conducted in both the spawning areas and in unexploited areas where the habitat is suitable for southern bluefin tuna (for instance, in the strata where southern bluefin tuna was caught historically) would probably be the only method for solving those uncertainties. Tagging of those fishes, in both the spawning and unfished areas of the southern bluefin tuna habitat, should be conducted to measure the mixing of those fishes with the exploited stock.

This comparison of the relative proportion of very old fishes in the catches by the fisheries and in the stock assessment models could also be of major interest for various tuna stocks, such as the Atlantic bluefin, yellowfin, and bigeye tunas and swordfish. All research aiming to measure the real age of the large individuals caught should then be recommended for those species and stocks which are heavily exploited. It should be also of major interest to develop the use of simple simulation models such as the CRYPTUNA model, in order to evaluate the potential effect on the stock assessment by VPA of a variable fraction of biomass which remains unavailable to the fisheries.

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