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TRENDS OF ABUNDANCE INDICES OF ALBACORE TUNA (*Thunnus alalunga*) OBTAINED BY GLM FITTING OF THE FRENCH TROLL AND BAITBOAT CATCH PER UNIT OF EFFORT DATA FOR THE PERIOD 1967 TO 1986.

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ABSTRACT

French troll and baitboat catch data collected in the period 1967 to 1986 were used to obtain abundance indices of Albacore tuna in the north-east Atlantic Ocean. Linear models fitted to the catch per unit of effort data produced indices that increase slightly from 1967 to 1978 and then decrease from 1979 to 1986. The rate of decline in the period 1979 to 1986 is discussed because there are doubts that this decline does not accurately reflect the evolution in actual abundance.

RESUME

Les données de capture des ligneurs et canneurs français collectées pendant la période 1967-86 ont servi à obtenir des indices d'abondance sur le germon dans l'Atlantique Nord-Est. Les modèles linéaires ajustés aux données de capture par unité d'effort ont donné des indices qui croissent légèrement de 1967 à 1978, puis diminuent de 1979 à 1986. Une discussion porte sur le rythme de la baisse pendant la période 1979-86, car des doutes subsistent sur le fait que cette baisse ne refléterait pas de façon précise l'évolution de l'abondance réelle.

RESUMEN

Se utilizaron los datos de captura de curricán y cebo francés recopilados en el período 1967 a 1986 para obtener índices de abundancia de atún blanco en el Océano Atlántico nordeste. Los modelos lineales ajustados a los datos de captura por unidad de esfuerzo produjeron índices que aumentan ligeramente desde 1967 a 1978 y descienden posteriormente desde 1979 a 1986. Se discute la tasa de declive en el período 1979 a 1986 porque existen dudas sobre que este descenso no refleje con precisión la evolución en la abundancia real.

1. INTRODUCTION

Management of the tuna fisheries is one of the fundamental issues of the International Commission for Conservation of the Atlantic Tuna (ICCAT). To achieve this goal, good abundance indices are required in order to correctly tune the models (global or structural). Therefore, the PSG (Programme Special Germon) of the ICCAT rapidly emphasized the need for producing such indices (ICCAT 1993). As a result, IFREMER recovered historical troll and baitboat catch data collected from 1967 to 1986. These data were mainly analyzed by Bard (1981).

2. EVOLUTION OF THE FRENCH ALBACORE TUNA FISHERY

To catch young albacore that migrate through the Bay of Biscay during the summer period, Spanish, French and Portuguese fishermen have developed a surface fishery. They started fishing with sailing trollers in the 19^{th} century (Bard, 1981). The pole and line techniques (used by baitboats) appeared in 1949 (Bard, 1981), and developed with troll so that in 1967 their combined catch reached 48,000 metric tons. However, the French fleet started to decline for economical reasons. The first step was the decrease in the size of the baitboat fleet in the 1960s, as illustrated by Figure 1. In the 1970s, landings stabilized at around 7,500 metric tons a year. However, the trollers began to be phased out in the early 1980's. In the mid 1980's, new surface gear types appeared: the pelagic trawl and the drifting gillnet.

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3. DATA

3.1 Original data

From 1967 to 1986, French historical baitboat and troll catch data have been reported by fishermen in logbooks collected by the CNEXO and since 1974 by IFREMER (when the CNEXO merged with the ISTPM to form the IFREMER). The records contain, among other data, the following information:

- vessel identification
- gear used
- vessel activity (fishing, changing area, facing bad sea conditions)
- position (latitude and longitude in tenth of degree)
- date
- catches in number of albacore (total and for most of the time in traditional commercial size classes)

French Fishermen define three commercial classes that correspond roughly to age 1, age 2 and age 3 (Bard, 1981). Fish weighing more than 10 kg (age 4 or more) were reported separately in the logbooks. Commercial classes will be referred to hereafter as classes 1, 2 and 3, and class 2+3 will be obtained by pooling class 2 and class 3 together.

Fishing effort was derived from vessel activity. Therefore, it was possible to calculate *CPUE* defined as the number of fish caught per fishing day. Data were compiled for mapping representation of effort, catch and *CPUE* data for both gears.

In 1975, there were no more baitboats in the French fleet, and in 1986 due to the drastic reduction of effort of French trollers (Figure 1), data collection stopped. Nevertheless, these data represent a large time series and are certainly useful for estimating trends of albacore abundance in the Bay of Biscay over this period.

3.2 Subset of data used for the study

The corrected original data set contained 71,543 observations. Each observation corresponds to the parameters and catch (in number of fish by class) of a fishing day and a boat. However, vessels could have different activities: fishing all day long, fishing while changing area or fishing in a rough sea with the vessel facing the waves. For these last two activities, data were considered to be without precise effort (data). The data set could be described as shown in Table 1.

Since fishing effort could not be precisely estimated when a vessel was searching for fish or facing a rough sea, observations of these activities were not used in the final runs. Nevertheless, runs including these data with an estimated effort showed similar trends of abundance.

Extrapolation of non-distributed catch was carried out but the results from the linear model fit were very similar in trend. There was no data available concerning the vessel characteristics, thus it was not possible to ascertain the class of vessels except for gear types. Standardized *CPUE*s by vessel were calculated by means of a GLM on the corrected original data set and showed that most of the 494 vessels were very similar in terms of mean *CPUE*.

It was decided that vessels that did not produce a minimum of 20 annual observations during at least 3 years would be omitted from the analyses. In fact these data are less useful to describe trends in abundance, since they can not be compared over years. Therefore, 22,617 catch observations of 127 vessels (5 baitboats and 122 trollers with similar mean *CPUE*) remained for the main analyses. This subset of data was called the selected dataset. Nevertheless, runs were made to check that no information was lost when using this dataset.

4. METHODS

4.1 Abundance indices estimates

The trends in albacore abundance are estimated by looking at the catch per unit of effort (*CPUE*) data with a multivariate linear model. The following general model was applied to each commercial class c (2, 3 and 2+3):

$$\ln(CPUE_{c,v,d}) = \mu + E_y + E_g + E_p + E_a + E_{c'\neq c} + I_{c'\neq c,y,g,p,a} + \varepsilon_{c'\neq c,v,d} \qquad (1)$$

where	$CPUE_{c,v,d}$	are the *CPUE* of commercial class *c* for the vessel *v* during the day *d* (of year *y*, at period *p* in area a);
	μ	is a constant;
	E_y	is the year effect that measures the variability between years and can be interpreted as an estimator of the index of abundance for year *y*;
	E_g	is the vessel category (gear, for instance) effect which is assumed constant over time for a given vessel category;
	E_p	is the period effect;
	E_a	is the area effect;
	$E_{c'\neq c}$	is the effect of the other commercial classes *CPUE*s;
	$I_{c'\neq c,y,g,p,a}$	is the sum of the interactions between effects; and
	$\varepsilon_{c'\neq c,v,d}$	is a residual term.

In the case of this study, monthly 5°×5° areas strata (*s*) were used rather than the daily positions of the catch data.

4.2 Choice of models

A general model was used to select the predominant effects. The criteria for selection was based on the F value. In a first step, vessels were aggregated by gear category since SAS was not able to handle the many empty matrix cells when using a vessel effect.

Table 2 shows the sum of squares (SSQ) of the major terms of the general model. The P-levels for all the terms listed in the table were less than 0.0001. Other terms had an F value of less than 4, and increasing P-levels. From this table, it appears that the year effect is significant. Also the area-time (or strata) effect month × area (E_s) is significant and can be interpreted as the catchability of fish in the spatio-temporal strata.

Because models with no crossed effects showed that the vessel effect had a larger SSQ than the year effect but with a lower *F* value and 126 degrees of freedom, vessel effect was kept for the other models. Moreover, final analyses were conducted only with troll catch data because baitboat catch data did not extend over the whole period and because they represented only 1.67 % of the usable subset of catch data. This resulted in the month × vessel effect becoming insignificant. The trends for the beginning of the studied period were not modified.

Finally, *CPUE* data of the first class (age 1) were not used in this study because these fish were not targeted and were even avoided. Also, previous analyses and comments made at the ICCAT Albacore Workshop in June 1994, suggested fitting models for class 2+3 *CPUE*. A model was fitted with a year × vessel effect instead of a spatio-temporal effect to look at the last year's indices since we suspected some change in the vessel efficiency as the fleet decreases.

Therefore, the models described in Table 3, among others, were fitted using the GLM procedure of the software SAS on a Unix workstation.

4.3 Abundance indices calculation

The residuals of the effects E_y generated by the GLM for year *y* are assumed to have a Normal distribution with mean μ_y and standard deviation σ_y. Hence, the standardized *CPUE* (and in a similar way, the confidence intervals) were then estimated using the following transformation (Patterson, 1966):

$$IA_y = \exp(\mu_y + \sigma_y^2/2) \quad (2)$$

These terms were divided by their mean over all the period in order to obtain abundance indices.

5. RESULTS

Table 3 gives the results of the fitting procedure of the different models where *CV* and *DF* are the coefficient of variation and the degrees of freedom of the models. All models had P-level less than 0.0001.

5.1 Abundance indices of class 2 and class 3

For class 2, abundance indices are slowly increasing from 1967 to 1979 (Figure 2), with two periods of low standardized *CPUE*: 1970 and 1975 corresponding to two well known low recruitments of fish born in 1968 and 1973

(Bard, 1981). After 1979, class 2 abundance indices clearly decrease by a factor of 10. Class 3 abundances also increase at the beginning of the period, but start to decrease as early as 1976 and seem to stabilize at about 40% of the average over the period 1967 to 1986. This difference in trends is reflected by a change in the catch structure: from 1967 to 1975, class 3 represents more than 20% of the total catch of the trollers whereas after 1976, it represents only half this amount. Catch data of tuna weighing more than 10 kg (class 4 or more) show two peaks, one in 1970 and the second (higher) in 1976.

Due to the predominance of class 2 albacore (65 to 75 % of the total catch), trends of class 2+3 reflect those of class 2, with a slow increase in abundance until 1979, followed by a sharp decrease (Figure 3).

The first period is punctuated by two low values in 1970 and 1975. These two events follow the years 1968 and 1973 that were already known for their low recruitment (Bard, 1981).

The model without spatio-temporal effect, as proposed by Laurec (1977), but taking into account a crossed effect year × vessel shows that the decrease in abundance starts two years later. The fluctuation of these indices are more important than for the M3 indices due to the fact that less vessels were used to fit the *CPUE*s.

6. DISCUSSION

Several observations lead us to prefer indices from model M4 for the period 1979 to 1986:

- By looking at the mapping of the repartition of the effort, one can see that the fishermen reduced first their fishing area in 1980 and 1981. The logbooks also show that they did not fish anymore during October after 1979. Afterwards, it appears clearly from the dataset used for the analysis that the numbers of vessels and of fishing days are decreasing to zero. This depletion of the trolling activity after 1979 can be seen in Figure 1.

- If one looks at the crossed effects vessel × year in model M4, all the least square means tend to decrease after 1981, reflecting the fact that the vessel efficiency has decreased with time. In fact, the explanation of this may come from the fact that in this fishery, the communication between vessels increases their ability to find the schools rapidly, so the less vessel there are, the less efficient they might be. This suggests that the apparent decreasing in the abundance indices might be explained by a diminution in efficiency of the vessels (the year effect does not only correspond to abundance variations). Since all vessels show a decrease in efficiency, the year effects of model M4 are still biased.

- Nevertheless, the trends of M4 correspond roughly with those observed for the indices obtained with the Spanish troll catch data (Mejuto and García, 1996). However, fluctuations of our indices are bigger. This is probably due to the fact that the number of the vessels used for the fit is low and thus the estimates have a higher variance.

On the other hand, it is possible that the vessels' efficiency has increased over time for the period 1967 to 1979 due to the enhancement of the fishing techniques and of the communication between vessels. The abundance indices for the period 1967 to 1977 would then be relatively stable. That is in concordance with Bard (1981) who refers to an almost constant recruitment for albacore acknowledged by the scientific community. In any case, class 2+3 abundance indices obtained in this analysis range roughly from a factor of .4 to 1.6 over the period 1967 to 1986.

Therefore, we suggest the use of the abundance indices given by M3 to 1979 and then those given by M4 or obtained from Spanish troll *CPUE* data for this period. It would be even better to fit a GLM on Spanish and French catch data pooled together.

7. CONCLUSION

Indices given in Table 4 were selected from this analysis for the purpose of VPA tuning. Until 1981, they show a slight increase in abundance preceding a period of decline due, in unknown proportions, to a decrease in albacore abundance and a decrease in vessel efficiency.

8. ACKNOWLEDGEMENT

We express our gratitude to F. X. Bard and P. Neal who contribute to this paper with their respective knowledge of the French albacore surface fishery and English.

Table 1. **Composition of catch data in number of observations by day and boat.**

Gear	Troll	Baitboat	Both
Catch data usable in the analysis	32,045	545	32,590
Catch data without precise effort	16,912	602	17,514
Catch data not distributed by class	23,677	1,511	25,188
Total	69,236	2,307	71,543

Table 2. **Sum of squares (SSQ) of the major terms of the general model. The P-levels for all the terms listed in the table were less than 0.0001. Other ter** and increasing P-levels.

Term	Degree of freedom	SSQ	F value
Year	19	242	10.6
Month area	23	229	8.3
Year month	74	693	7.8
Month gear	4	36	7.4
Year area	123	1,078	7.3
Year area month	136	1,090	6.7
Total model	442	14,287	26.9
Error	22,174	26,600	-

Table 3. Summary of the GLM fits over the period 1967 to 1986, except for M4 fitted over 1978 to 1986.

Run n°	Class targeted	Model $\ln(CPUE_{c,y,v,s}) = \mu + \ldots + e_{c' \neq c,y,v,s}$	R^2	CV	DF	F value
M1	2	$E_y + E_v + E_s + E_1 + E_3$	0.28	36.8	195	44.5
M2	3	$E_y + E_v + E_s + E_1 + E_2$	0.29	98.2	195	47.9
M3	2+3	$E_y + E_v + E_s + E_1$	0.24	29.7	189	36.6
M4	2+3	$E_y + E_{y,v} + E_1$	0.19	30.8	126	10.74

Table 4. Abundance indices used for VPA tuning, north Atlantic albacore.

Model (Class) year	M1 (2)	M2 (3)	M3 (2+3)	M4 (2+3)
67	0.68	1.01	0.69	
68	0.85	1.99	1.11	
69	1.02	0.85	1.12	
70	0.43	1.34	0.63	
71	1.31	0.62	1.25	
72	1.25	1.56	1.33	
73	0.99	1.75	1.31	
74	0.78	1.66	1.36	
75	0.42	2.48	0.95	
76	1.15	1.22	1.23	
77	1.66	0.68	1.46	
78	1.56	0.89	1.27	1.04
79	1.96	0.71	1.46	1.46
80	1.65	0.36	1.13	1.57
81	1.25	0.50	0.99	1.55
82	0.55	0.61	0.60	0.86
83	0.70	0.26	0.47	0.47
84	0.91	0.46	0.71	1.70
85	0.66	0.47	0.67	0.37
86	0.22	0.58	0.24	0.62

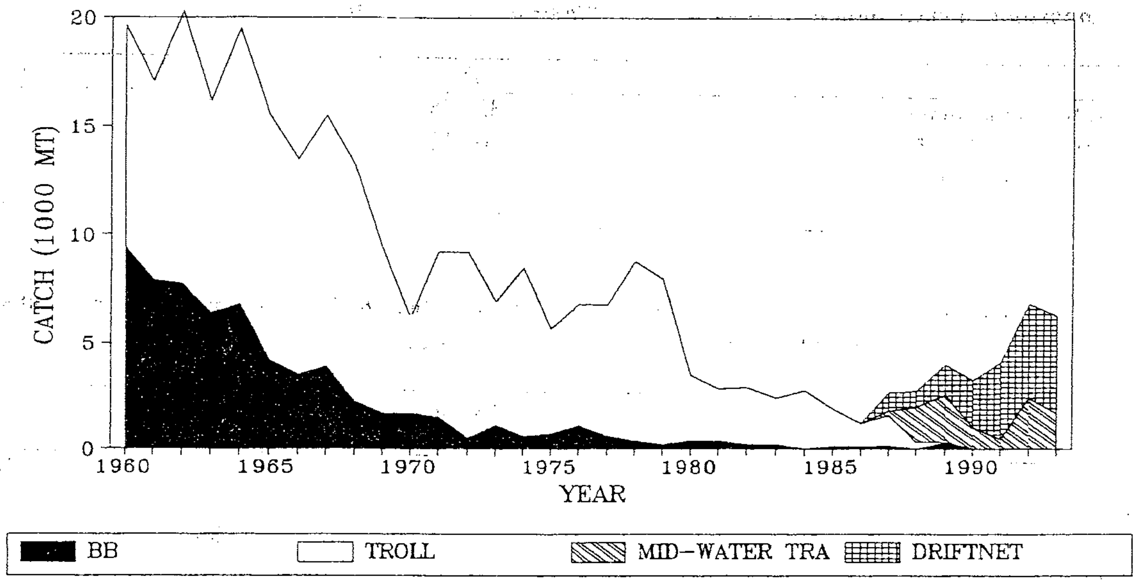

Fig. 1.Evolution of the landings of the French albacore tuna fishery since 1960.

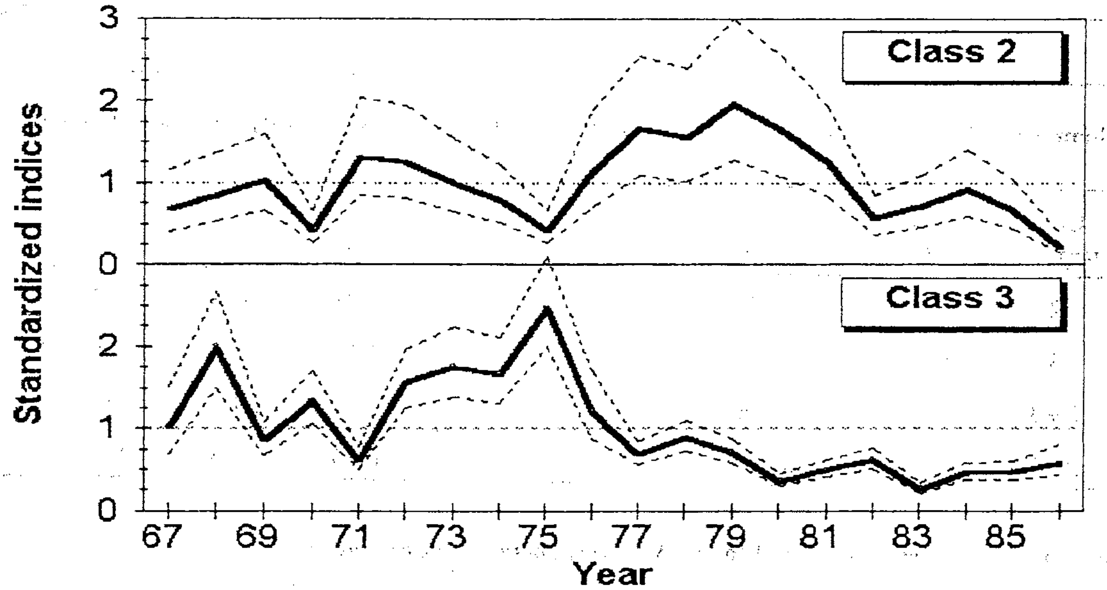

Fig. 2.Evolution of albacore abundance indices for classes 2 and 3.

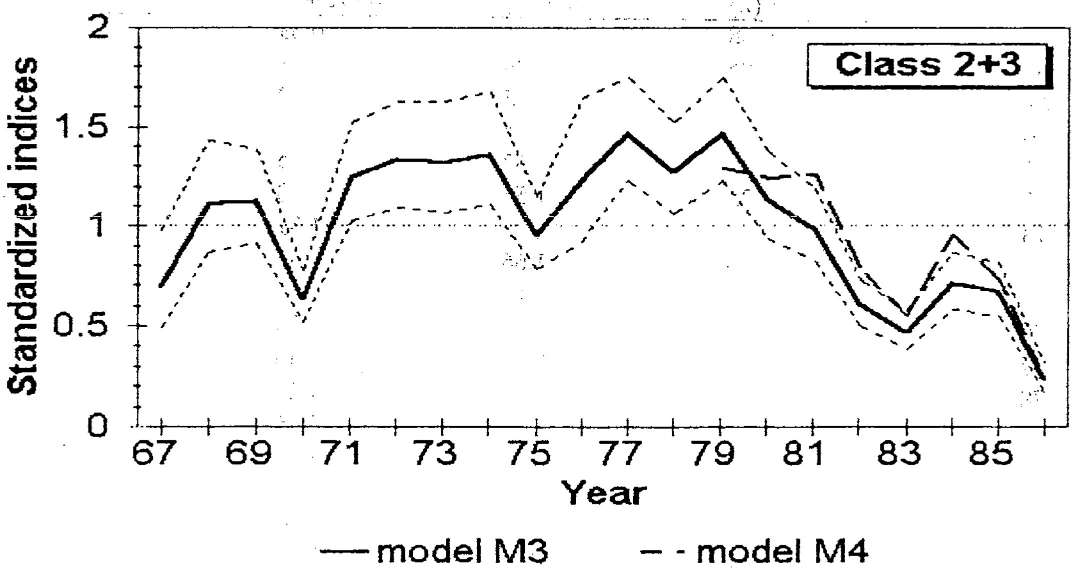

Fig. 3. Evolution of albcore abundance indices for class 2+3.