

APPLICATION OF "MULTIFAN" TO ESTIMATE THE AGE COMPOSITION  
OF THE NORTH ATLANTIC ALBACORE CATCHES

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SUMMARY

Results on the application of MULTIFAN to estimate the age composition of North Atlantic albacore catches are presented. This method was applied to two different sets of catch-at-length data: 1975-1989 international catches and 1990 Spanish catches. Results demonstrate the utility of the method to estimate catch at age from length data, representing an improvement with regard to the deterministic techniques usually applied to age tuna catches.

RESUMEN

Se presentan los resultados obtenidos con la aplicación de MULTIFAN para descomponer las capturas de atún blanco del Atlántico norte por clases de edad. Este método se aplicó a dos grupos de datos de capturas por talla: capturas internacionales 1975-1989 y capturas españolas de 1990. Los resultados demuestran la utilidad de este método para estimar la composición en edades de las capturas a partir de datos de tallas, representando un avance respecto a las técnicas determinísticas que se han venido utilizando para tal fin.

RESUME

On expose les résultats obtenus par l'application de MULTIPLAN dans le but de décomposer les captures de germon de l'Atlantique nord par groupes d'âge. Cette méthode est appliquée sur deux séries de distribution de fréquence de taille dans les captures: captures internationales 1975-1989 et captures espagnoles de 1990. Les résultats montrent l'utilité de cette méthode dans l'estimation de la composition par âge des captures à partir des distributions de taille. La méthode présente des avantages par rapport aux méthodes déterministes employées jusqu'à présent.

## 1. INTRODUCTION

The age composition of the catches is one of the basic informations needed for the application of the analytical methods for fish stock assessment. For tuna stocks, catch at age tables are usually derived using deterministic "knife-edge" techniques: numbers at length are converted into numbers at age setting different boundaries in the length frequency distributions according to a growth curve equation. The main deficiencies of this technique are that on the one hand it does not take into account the increase of length dispersion with age, and on the other, strong year classes and weak ones are not properly estimated.

The First ICCAT Albacore Workshop (ANON., 1989) discussed about this problem and recommended the investigation of the utility of stochastic methods for estimating the international albacore catch at age data. SANTIAGO (1990) applied one of these methods, the one developed by SCHNUTE & FOURNIER (1980), to albacore size composition of the catches landed by the Basque bait boat fleet, and demonstrated the utility of the stochastic methods, at least for the separation of the younger age groups.

The Second ICCAT Albacore Workshop (ANON., 1990) recommended the use of the stochastic methods to break down the 1975-1989 catch by size tables into age groups, working with the finest strata possible: month/gear for the surface fisheries and quarter for longline.

The 1975-1989 albacore length frequency data have been analyzed using the length frequency analysis package "MULTIFAN"<sup>1</sup>. This method implements the model of SCHNUTE & FOURNIER (1980) to analyze several length frequency data simultaneously. Preliminary results were presented at the Ad-hoc Meeting on Progress in the ICCAT Albacore Research Program (ANON., 1991). During this meeting, the Group continued with the analysis to finally obtain a new 1975-1989 catch at age table.

This paper documents the MULTIFAN analysis carried out with the 1975-1989 albacore length frequency data. It also gives results on the application of this method to the 1990 albacore numbers at length data corresponding to the Spanish troll and bait boat fleets. They show the utility of this approach to estimate the age composition of the catches from length data, specially for youngest ages.

## 2. METHODS AND DATA

### 2.1. The MULTIFAN method

MULTIFAN is a computer package designed by D. Fournier and J. Sibert (Otter Research Ltd.) to analyze length frequency distributions in order to get estimates of growth parameters and age composition. It uses a likelihood-based method that extends the model of

SCHNUTE and FOURNIER (1980) to simultaneously analyze several length frequency data sets, reducing the possibility of ambiguous results. MULTIFAN also introduces a new estimation method that reduces the subjectivity of the analysis. It has been successfully applied to southern bluefin tuna (FOURNIER & SIBERT, 1990).

A detailed description of the mathematical basis of this method is given in the User's Guide and Reference Manual and in FOURNIER and SIBERT (1990).

The main assumptions of the basic model of MULTIFAN are:

- normality of the distributions of length at age;
- mean lengths at age follow a von Bertalanffy growth model; and
- standard deviations at age are set initially constant.

Additional assumptions may also be included in the model:

- length dependence of standard deviations of length at age,
- size selectivity for the first age class; and
- seasonal component of growth.

The program requires the reorganization of the length distributions according to the time of recruitment; and the introduction of reasonable initial values of von Bertalanffy K and numbers of age classes. An interactive graphics utility is also available to optionally set constraints on mean lengths and proportions at age.

Input values of K and numbers of age classes are needed to create a two dimensional grid search that covers a wide region of the parameter space. Initially, all the parameters included in the model are allowed to vary except von Bertalanffy K, which is set fixed to avoid possible convergences of several fits to the same solution. After this initial search has been completed, a subsequent search is run allowing K to vary.

The introduction of additional hypothesis in the model, such as those mentioned above, is done by creating new systematic searches from the initial or subsequent searches for which K has been held fixed.

A  $\chi^2$  test is used to compare the log-likelihood function values of the different fits, in order to determine objectively the best solution.

### 2.2. The data

Two different sets of data were analyzed:

albacore length distributions of the 1975-1989 international catches (provided by the ICCAT Secretariat). Numbers at length were combined according to the following time and gear strata:

<sup>1</sup> Otter Research LTD, 1988, 1989, 1990

TIME	GEAR
Month	BB, TR, GILL, MWTD <sup>2</sup>
Quarter	BB, TR, GILL, MWTD, LL
Quarter	All combined

- monthly length frequency distributions of the albacore catches landed by the Spanish bait boat and troll fleets during the main fishing season of 1990 (excluding Azores, Canary Islands and the Mediterranean).

### 2.3. Application of MULTIFAN to the albacore data

MULTIFAN was applied to the albacore length frequency data (by time strata and gear), making the following systematic searches:

- Search 0. Initial search.
  - + Bounds on the mean lengths corresponding with well defined modes.
  - + No restriction on the proportions at age.
  - + Initial values of K: 0.1, 0.2, 0.3 and 0.4
  - + Age classes: 3 to 5 for TR (1975-89) and GILL  
8 to 12 for BB (1975-89), MWTD, LL, and all gears combined  
4 to 6 for BB and TR (1990)
- Search 1. Let von Bertalanffy K vary for the initial search.
- Search 2. Add length dependent standard deviation to the initial search.
- Search 3. Let K vary for the systematic search 2.
- Search 4. Add size selectivity for the 1st age class to the initial search.
- Search 5. Let K vary for the systematic search 4.
- Search 6. Add size selectivity for the 1st age class to the search with standard deviation length dependent (search 2).
- Search 7. Let K vary for the systematic search 6.

With the 1975-1989 quarterly length data corresponding to all fleets combined a more subjective approach was also tried, setting several parameters constant: growth parameters of BARD's (1980) equation; number of age groups was set at 10; and, 1.9 was assumed to be the ratio of increase between the standard deviations of the last and first age groups. We

<sup>2</sup> BB=bait boat; TR=troll; GILL=gillnet; MWTD=mid-water-trawl; LL=longline

will refer to this application of MULTIFAN as "subjective approach" to distinguish from the former procedure described above, or "objective approach".

The MULTIFAN version available was the 3.15. This has the capacity to analyze up to 15 samples simultaneously. Because of this limitation, the 1975-89 data by gear and time strata were distributed into different groups. The resulting sets of length distributions were also reorganized according to the month (or quarter) in which the youngest enter the fishery. It was assumed that this occur in the 6th month (2nd quarter).

## 3. THE ANALYSIS

### 3.1. 1975-1989 international length frequency data

#### 3.1.1. Surface fleets by month

For each of the surface gears, numbers at length were organized on a monthly basis. This was the time strata recommended during the Second ICCAT Albacore Workshop to break down the catch at size tables (ANON., 1990).

However, the inspection of the length frequency distributions organized in this way revealed weakness in the data due to different sampling problems. On the one hand, data from some months had been substituted by samples of contiguous strata; on the other hand, the shape of some distributions showed signs of insufficient sampling.

Therefore, it was decided to analyze the 1975-1989 albacore length data corresponding to the different surface gears on a quarterly basis, in order to overcome the inconsistencies found.

#### 3.1.2. Surface fleets by quarter

Results of the analysis of the quarterly length data for the surface fleets were presented in a working document (SANTIAGO, 1991) at the "Ad-hoc Meeting on Progress in the ICCAT Albacore Research Program (PSG)" (ANON., 1991). The main conclusions about this point were:

- Length frequency distributions of several sets did not fit consistently the model, due probably to sampling deficiencies.
- Estimates of mean length at age were in some extent comparable between sets of years and fleets only up to age 4. However, in some cases, the best fits also estimated unrealistic mean lengths at these ages.
- The attainment of more realistic estimates of the parameters and more comparable between sets needed the introduction of additional constraints to the parameters of the model.

### 3.1.3. Longline by quarter

Some trials were made during the 1991 PSG meeting (ANON., 1991) in order to analyze the numbers at length tables corresponding to the longline catches. The different sets of data did not fit the model adequately due to a combination of factors: overlapping of the age component of the mixture, the effect of a differential growth by sex and sampling deficiencies.

### 3.1.4. All fleets combined, by quarter

The analysis of these data was carried out by the PSG group (ANON., 1991) following two different approaches, as described in the methodology. Catch at age tables obtained by this two procedures are in ANON (1991). Figure 1 illustrates in a schematic way the absolute differences between those estimates and the previous catch at age table obtained during the Second ICCAT Albacore Workshop (ANON., 1990), applying a "knife-edge" deterministic method.

- **Objective approach.** Table 1 shows the estimates of the parameters of the models produced by the best fits of the different data sets. There was not a good correspondence between the estimates of the parameters for the different data sets. Only the values of the average standard deviation at age were consistent. Growth parameters estimates were also to some extent comparable except for the 81-83 set, whose values were completely unrealistic.

The results for all the data sets included length dependence of the standard deviation at age; however, in the case of the 87-89 set, the estimate of the ratio of this dependence was close to 1. The 78-80 and 84-86 sets also included the parameter of size selectivity for the first age class in the model of the best fit.

Mean length and standard deviation at age as estimated by MULTIFAN for the five data sets appear in Figure 2. Although the estimated parameters of the von Bertalanffy growth model presented differences between sets, mean length and standard deviation at ages 1 to 4 corresponded well between sets and, in the case of the means, with previous estimates from tagging studies (ANON., 1989) and from hard-parts analysis (BARD, 1980). For older ages, the analysis revealed discrepancies which were probably caused by deficiencies in the length sampling for the period of time considered. Anyway, the results of this approach were considered satisfactory because of their relative consistency, representing an improvement with regard to the deterministic technique used by the Second ICCAT Albacore Workshop (ANON., 1990).

As illustrated in Figure 1a, there were strong differences between the catch at age table obtained by this procedure and the one obtained during the 1990 Albacore Workshop. In general terms, MULTIFAN estimated more 1 and 4 year olds and less individuals for 2 and 3 age groups. For older ages there was not an apparent trend in the deviations. The magnitude of the differences in absolute values, shown in the Figure, was higher for ages 1 to 4. Considering relative terms, the most important

differences were for ages 1, 4 and 5.

- **Subjective approach.** The analysis of the 1975-89 albacore data, setting constant growth parameters, number of age classes and ratio of increase of standard deviations, produced a catch at age table somewhat closer to the estimates of the 1990 Workshop (Figure 1b). This is because MULTIFAN worked like the "knife-edge" method used in ANON (1990), but forcing an increase of the standard deviations of length at age. The strong differences found for ages 1 and 2 were due to the effect of setting the boundaries between the first ages by eye, like the 1990 Workshop made.

A visual inspection of the fits obtained by this "subjective" way demonstrated that length distributions did not fit correctly the model and therefore the results obtained were rejected.

After those series of analysis done during the Ad-hoc Meeting on Progress in the ICCAT Albacore Research Program (ANON., 1991), it was decided that the best of the available 1975-1989 catch at age tables was the one obtained by the objective approach of MULTIFAN (Table 4 of the meeting report).

### 3.2. 1990 Spanish data (troll and bait boat)

In 1990 there has been an improvement in the quality of the length composition estimates of the albacore catches due to an increase in the sampling coverage and to the stratification by commercial category. This allowed the application of MULTIFAN to the 1990 Spanish data on a monthly basis, and separate by fleets, in order to check the consistency of the results.

Table 2 presents the estimates of the parameters corresponding to the best fits. In both analysis, with troll and bait boat data, the model included length dependence in the standard deviations and size selectivity for the first age class. There was a consistency in the estimation of the parameters. This is also illustrated in Figure 3 which shows mean length and standard deviation at age obtained for both data sets. Those estimates are similar to the ones obtained for the corresponding ages for the period 1975-1989. There are slight differences partially due to the month of reference considered: the 1990 values refer to the 6th (TR) and 7th (BB) months while the 2nd quarter is the period of reference for the 1975-1989 estimates.

The results of the best fits of the 1990 data are shown in Figures 4 and 5. Histograms represent the length frequency distributions observed, and the continuous line indicates the length frequencies and age compositions predicted by the model.

Catch at age tables for the albacore catches landed by the Spanish troll and bait boat fleet in 1990 (excluding Azores, Canary Islands and Mediterranean) are given in Tables 3 and 4 respectively.

#### 4. CONCLUSIONS

Length frequency analysis methods like MULTIFAN provide reliable information on the age composition of the catches of North Atlantic albacore, specially for youngest ages (up to 4 year olds), representing an improvement with regard to the deterministic "knife-edge" methods applied to age albacore catches. The consistency of the estimates is evident when the model is applied to length distributions derived from adequate samplings, like the 1990 Spanish data.

The analysis of the 1975-1989 international catch at length data revealed sampling deficiencies for that period. It is therefore desirable in the future to analyze with MULTIFAN this complete series in a single set of 60 quarters giving weights to the length distributions proportional to the degree of sampling reliability.

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DATA SET	N	K	$L_{\infty}$	$\lambda_1$	$\lambda_2$	b
75-77	10	0.20	117.9	3.39	1.93	-
78-80	8	0.15	143.5	3.64	1.82	2.6
81-83	9	0.04	300.3	4.10	1.93	-
84-86	10	0.18	133.6	3.84	1.45	3.9
87-89	11	0.12	142.1	3.19	1.00	-

Table 1. Estimates of the MULTIFAN parameters from the best fits to 1975-1989 albacore length data sets analyzed.

N is the number of age classes; K and  $L_{\infty}$  are the von Bertalanffy parameters;  $\lambda_1$  is the average standard deviation of length at age;  $\lambda_2$  defines the trend in the standard deviations; and b determines the amount of size selectivity for the first age-class.

DATA SET	N	K	$L_{\infty}$	$\lambda_1$	$\lambda_2$	b
TR	4	0.28	107.1	3.12	1.94	4.7
BB	4	0.28	111.1	3.64	1.42	5.5

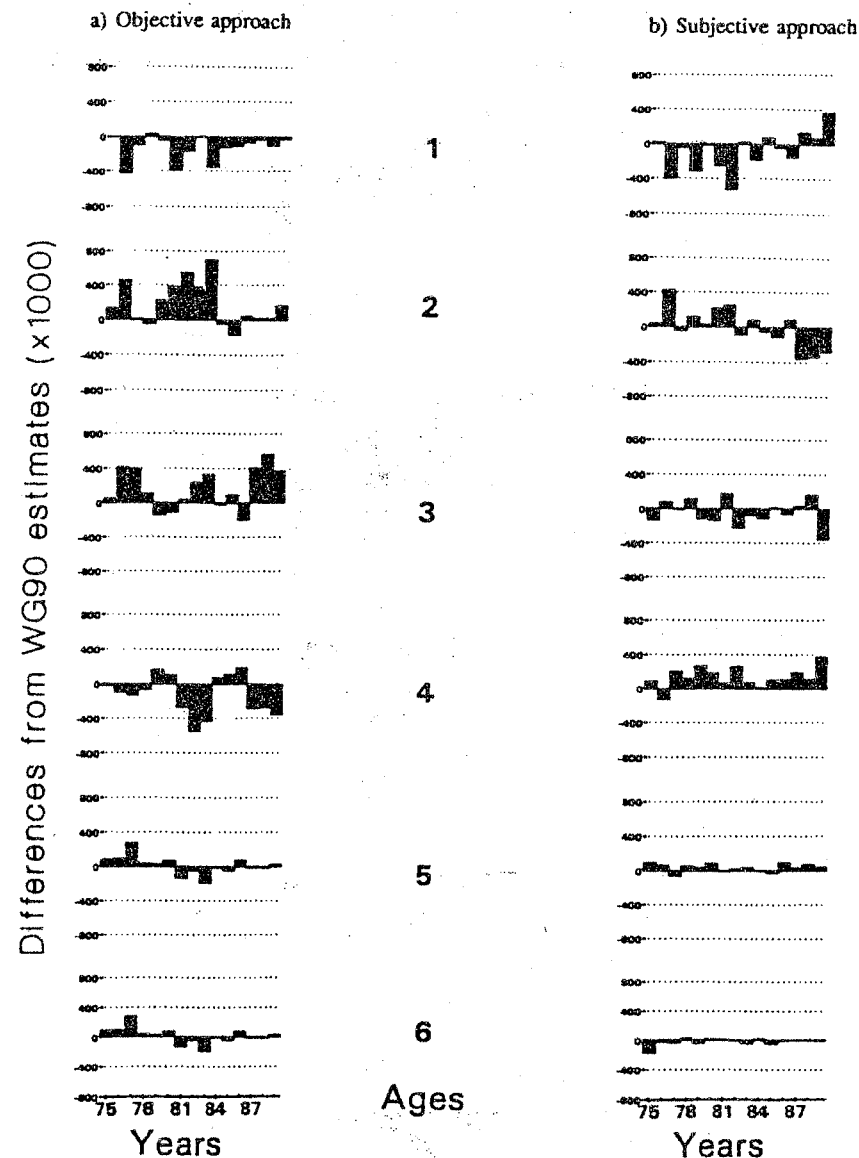
Table 2. Estimates of the MULTIFAN parameters from the best fits to 1990 albacore length data from Spanish troll (TR) and bait boat (BB) fleets.

AGE	MONTHS					TOTAL
	6	7	8	9	10	
1	3958	32523	56030	67796	78027	238334
2	110947	400138	403525	88677	24696	1027963
3	36195	121639	107973	31339	35504	332650
4	526	2925	18317	17591	25341	64700
Σ	151626	557225	585845	205403	163568	1663667

Table 3. Age composition estimates of the monthly catches of albacore made by the Spanish troll fleet in 1990.

AGE	MONTHS					TOTAL
	7	8	9	10	11	
1	15647	60326	299452	324633	4324	704382
2	140775	756597	24867	13295	199	935733
3	145209	206070	67904	31341	434	450958
4	1041	12207	111578	63123	768	188717
Σ	302672	1035199	503801	432393	5725	2279790

Table 4. Age composition estimates of the monthly catches of albacore made by the Spanish bait boat fleet in 1990.



Figures 1a,b. Differences between numbers at age of 1975-1989 international North Atlantic albacore catches as estimated by the 1990 Albacore Workshop (ANON., 1990) and the new age compositions obtained applying MULTIFAN in two different ways (See text for a more complete explanation). Units are in 1000 individuals.

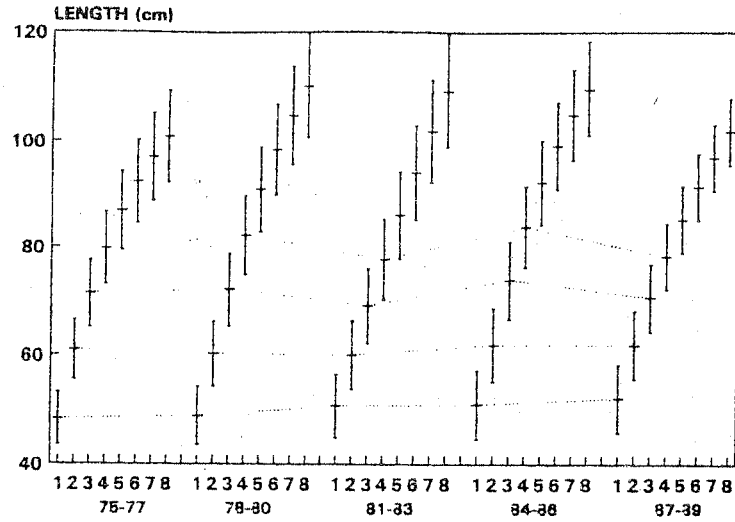


Figure 2. Mean length and standard deviation of length at age estimated by MULTIFAN for several sets of albacore length distributions (1975-1989). Redrawn from ANON (1991).

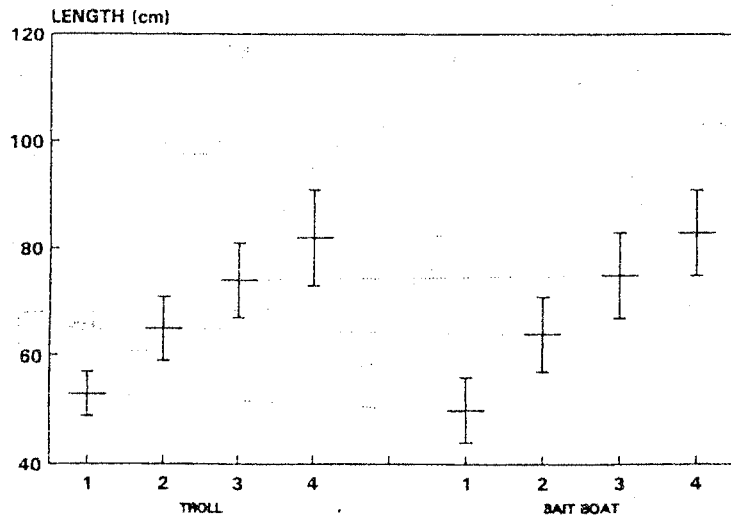


Figure 3. Mean length and standard deviation of length at age estimated by MULTIFAN from the 1990 albacore length distributions corresponding to Spanish troll and bait boat.

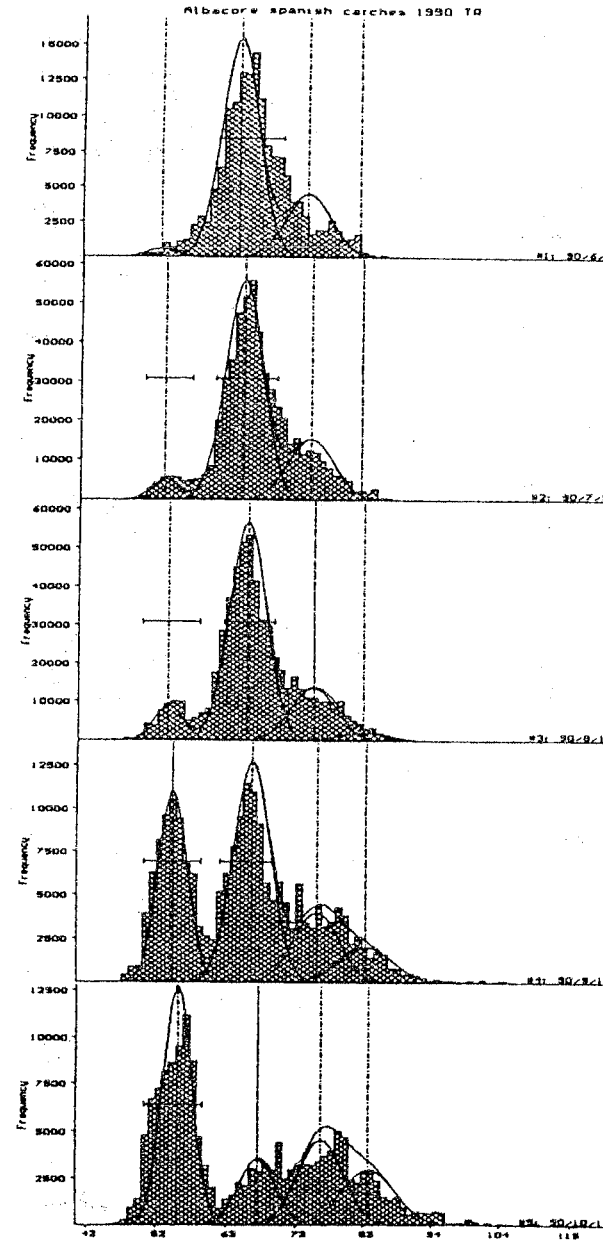


Figure 4. Monthly length frequency distributions of albacore catches landed by the Spanish troll fleet in 1990 and results of the best fit to the MULTIFAN model. Horizontal bars indicate the constraints imposed to mean lengths at age.

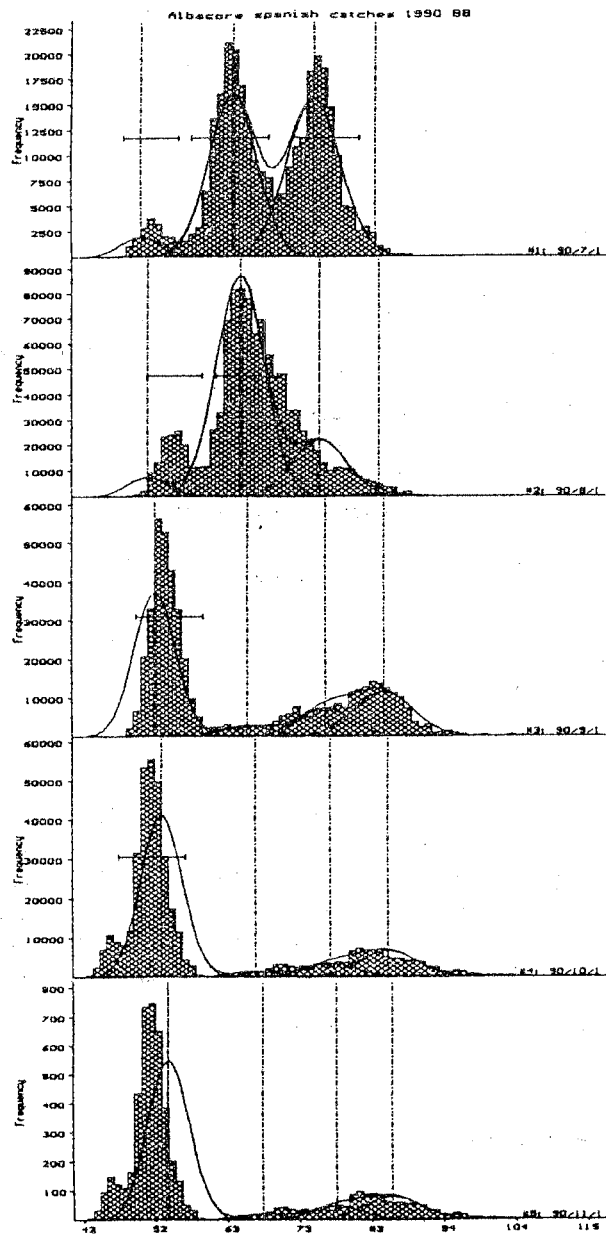


Figure 5. Monthly length frequency distributions of albacore catches landed by the Spanish bait boat fleet in 1990 and results of the best fit to the MULTIFAN model. Horizontal bars indicate the constraints imposed to mean lengths at age.