THE USE OF MULTIFAN TO ESTIMATE GROWTH PARAMETERS OF YELLOWFIN TUNA (*THUNNUS ALBACARES*) IN THE INDIAN OCEAN.

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ABSTRACT.

The MULTIFAN method was applied to purse seine caught yellowfin tuna length frequency data to estimate growth parameters. K and $L\infty$ values obtained were 0.14 y^{-1} and 214.5 cm respectively. In order to assess the adequacy of having applied this method to Indian Ocean yellowfin tuna, several length frequency data sets were simulated, trying to reflect some of the problems encountered in the real data derived from the biology of the species such as continuous recruitment, age selectivity and a random component in the mean lengths at age. MULTIFAN application to simulated data sets showed that this method may give non accurate results in these conditions. In spite of this, the $L\infty$ value obtained by MULTIFAN fit to the real data seem to be more reliable than the higher one (272.7 cm) observed by Stequert et al. (1996), according to the biggest fish ever caught.

INTRODUCTION

Modal progression analysis can be used to compute growth parameters (Sparre et al. 1998). The analysis is much easier if age classes can be followed clearly, which usually happens in young ages where the modes are not so mixed as in older ages. A strong seasonality in the spawning period also helps identify the modes clearly, but this is not often the case for tropical species, in which continuous recruitment may happen.

MULTIFAN (Otter Research Ltd.) was introduced by Fournier et al. (1990). It is a likelihood based method that uses the mixture of distributions approach, with considerations on biological constraints, to simultaneously analyse several length frequency distributions sampled at different times. The growth curve is parameterised as in Schnute and Fournier (1980) and, according to Fournier et al. (1990), the main structural assumptions of the method are: 1) the lengths of the fish in each age class are normally distributed around their mean length, 2) the mean lengths at age lie on (or near) a von Bertalanffy growth curve, and 3) the standard deviations of the actual lengths about the mean length at age are a simple function of the mean length at age.

The method has been probed to be valid for estimating growth parameters and splitting the catch at size into catch at age for different tuna species such as southern bluefin tuna (Fournier et al. 1990), north Atlantic albacore (Santiago and Arrizabalaga 2000), eastern Atlantic bluefin tuna (Rodriguez-Marin et al. 2001) and western Atlantic bluefin tuna (Turner and Terceiro 1994).

It is considered that there is a single stock of yellowfin tuna in the whole Indian Ocean. In the review of Somvanshi (2002) some attempts to estimate growth parameters of this population from length frequency data can be found. Additionally, Stéquert et al. (1996) present a growth study based on otolith reading with reference to works done previously. Regarding yellowfin reproduction, the same author states that the major reproductive period is between November and March, but some of the population spawns from July to September. Another characteristic of yellowfin size frequency data is the absence of intermediate sized fish (10-30 kg) in the catch.

The objective of the present document is to estimate growth parameters from length frequency data using MULTIFAN and to assess the usefulness of this methodology in this particular case, given the characteristics of the biology of the species and the data available.

MATERIALS AND METHODS.

Monthly raw (not substituted) length frequency data for the international (all countries combined) purse seine fleet was used in the present analysis. The period selected for the analysis is from January 1991 to October 1996. Inclusion of data from other fleets such as Iran and Oman was considered but finally they were not included as the quality of the data was unknown.

The months need to be renumbered in MULTIFAN so that "Month 1" is called the month in which the smallest fish enters the fishery. It is considered that in our case this corresponds to April, so all the samples were renumbered according to this.

Only 2 constraints were applied in samples 16 and 28, which appear as an horizontal line in figure 1. The purpose of this was to allow for flexibility in the model fit as the length frequency pattern observed was not very coincident with what would be expected with Stequert's growth model (that is taken as a reference in the present study).

Hypothesis for length dependent standard deviations, selectivity in the first age class (bias parameter = 25.7) and both were tested. Best fit was selected using a likelihood ratio chi-square test (Fournier et al. 1990).

In addition to the MULTIFAN fit to the data, and in order to assess the usefulness of the method in this particular case, several length frequency data sets have been simulated and fitted with MULTIFAN, comparing the growth parameter estimates with the ones used to generate the simulated data. Each simulated data set is composed by 24 length frequency samples, each sample belonging to the length fequency observed in a given month. A steady state length composition is simulated assuming constant recruitment every year (Jones 1987). In this way, the length frequency distribution in a given month is the sum of the normal probability distribution functions (pdf) for each age. The mean of the normal pdf-s is the mean length at age predicted by Stéquert et al. (1996), and the standard deviation used is either 6 or 15 cm. The former simulates a length frequency distribution in which the modes can be followed "clearly", while in the latter case the modes are "unclear". Each pdf is multiplied by a weighting vector (p) that takes into account the selectivity or the presence of each age class in the catch (Hampton and Majkowski 1987).

A total of 12 length frequency data sets were created (table 1). Case 1 is the "ideal" one, with presence of all ages in the catch and in which the modes can be followed "clearly". Case 2 is the same but with higher standard deviation (the "unclear" version of case 1). Cases 3 and 4 are "clear" and "unclear" length distributions when only fish smaller than age 5 is present in the catch. These cases (3 and 4) were selected to test whether the estimation of L∞ depends on the maximum length observed in the catch. Cases 5 and 6 pretend to simulate the selectivity of yellowfin tuna, where usually only 2 or 3 modes appear in the sampled catch, with very few age 0 fish and a lack of intermediate fish. A p vector (0,1,0,1,1,0,0) is applied so that only ages 1, 3 and 4 are present in these distributions. Cases 7 and 8 are somewhat the same, but ages 0, 2 and 5 are allowed to be present in a very small quantity (these would be smoothed versions of cases 5 and 6), that is achieved by applying the p vector (0.1,0.9,0.1,0.8,0.9,0,0). According to Stequert et al. (1996), yellowfin tuna reproduce all along the year, with a maximum activity period from November to March. Case 9 represents the case in which yellowfin tuna recruitment is not discrete in a single month (as supposed up to now), but continuous and lasting 5 months. No simulation of continuous recruitment all along the year was done in this analysis, as such a pattern was not clearly observed in the length frequency data analysed. Case 10 remains with continuous 5 month recruitment period and adds the same selectivity pattern of cases 5 and 6. Case 11 goes back to the case of discrete recruitment but includes an error term in the mean lengths at age predicted by Stequert et al. (1996). This is done by allowing the observed mean length at age be a normally distributed variable with mean the mean length at age predicted by Stequert et al., and standard deviation the 20th fraction of that mean length at age. Finally, case 12 adds "smoothed" age selectivity (as in cases 7 and 8) into case 11.

RESULTS AND DISCUSSION.

For the MULTIFAN analysis to the real data, a fit in which age dependent standard deviation and selectivity in the first age class were allowed was selected as best fit. Table 1 shows the parameter estimates for this fit. Estimated values of K and L∞ were 0.14 y^{-1} and 214.5 cm respectively, with really small standard deviations. The total penalty value is the contribution of all the penalty functions to the objective function, which is quite high in this case. Table 2 shows de correlation matrix of the estimated parameters, showing very high negative correlation between K and L∞.

Figure 1 shows the observed and predicted length frequency distributions. Vertical lines indicate mean length predicted by the model for each age class. Taking into account the large number of samples considered, the model predicts quite well the observed data, but there are some samples (such as nº23, 24, 46, 67, 68, 69, …) in which the observed and predicted modes do not coincide.

Regarding the analysis for the 12 simulated data sets, table 3 gives a summary of the results obtained. Additionally, and to have a visual idea of the shape of the length distributions and the corresponding fits, blobs plots and an observed-predicted length frequency sample are showed for cases 1, 9 and 12 in figures 2, 3 and 4 respectively. The fit in the case 1 is perfect (figure 2) and the expected values of L∞ and K are very accurate. The higher value of s.d. (15 cm) considered in case 2 does have an effect in the loglikelihood value (which is much lower), and the average s.d. obtained (10.59) presents some deviance with respect to the one used to generate the simulated data. In spite of this, the values of K and L∞ remain really accurate. The accuracy in the estimated values of K and L∞ is constant for cases 1 to 8. An interesting observation is that although fits 3-6 have a total penalty value higher than 10, the values of L∞ and K are really accurate. It seems that for all cases in which there is a non smoothed selectivity for certain ages (cases 3, 4, 5, 6, 10) the total penalty value is high.

Case 9 (continuous recruitment) presents a slight departure from Stequert's original values of K and L∞ (0.18 y^{-1} and 278.9 cm respectively) used to simulate the length distribution data sets. Nevertheless, the highest departures from these values are present in cases 10 (continuous recruitment together with age selectivity), 11 (error in observed mean length at age) and 12 (same as case 11 with smoothed selectivity).

Figure 5 shows the comparison of the growth curves obtained by Stequert et al. (1996), Kaymaram (1990) (obtained applying ELEFAN to the Oman Sea length frequency data) and the curves obtained in the present analysis with real and simulated data (cases 9 to 12). Taking into account that simulated data is based on the growth equation of Stequert et al., it is observed that no significant departures in the mean length at age are observed with data simulated under constant recruitment during 5 months (case 9). Significant departures from expected mean length at age for fish older than 5 years can be obtained under constant recruitment with age selectivity (case 10) and when there is an error term in the observed mean lengths at age (both with and without selectivity, cases 11 and 12).

The growth curves obtained with real data predicts much lower mean lengths at age than Stequert's curve, and somewhat similar values to the ones predicted by Kaymaram (1990) in the Oman Sea. In relation to this, it is noted that according to the IOTC length frequency database, the biggest fish ever observed is a yellowfin tuna with 200 cm, caught by a Taiwanese longliner in 1986. Moreover, the world game fishing record is a 173 kg yellowfin tuna (IGFA 1996), that corresponds to a length of 205 cm, according to the length weight relationship described in Somvanshi (2002) (a=0.00001585; b=3.0449). The L∞ value obtained with MULTIFAN (214.5 cm) seem to be more in accordance with maximum lengths ever observed than the higher L∞ value predicted by Stequert (1996) (272.7 cm) based mainly in otolith reading of fish in size range of 28-140 cm.

CONCLUSSION.

The results obtained from applying MULTIFAN to real data give values of K (0.14 y^{-1}) and L∞ (214.5 cm) parameters that may be reliable. In spite of this, simulation results suggest that MULTIFAN results may not be accurate if constant recruitment and age selectivity are present, or if the observed mean lengths present a stochastic component. According to current knowledge, yellowfin tuna meets all three conditions, so application of MULTIFAN to these data may not be giving accurate results. In spite of this, L∞ value obtained by MULTIFAN seem to be more reliable than the one obtained by Stequert, according to the biggest fish ever caught.

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Table 1. Parameter estimates for best fit of MULTIFAN applied to real yellowfin tuna length frequency data. Numbers in brackets in K and L¥ are the standard deviations of the estimates. Sd1/sd2 is the ratio between the first and the last standard deviation.

Nº age classess	K	Linf	Avge sd	sd1/sd2	LL	nº parameters	Total penalty
7	0,14 (0,0017)	214,5 (1,5412)	5,81	1,72	42363	426	38,27

Table 2. Correlation matrix of the estimated parameters in the best MULTIFAN fit to real data.

	K	Linf	Avge sd	sd1/sd2
K	1			
Linf	-0,99	1		
Avge sd	0,37	-0,44	1	
sd1/sd2	0,77	-0,74	0,29	1

Table 3. Summary results for the MULTIFAN analysis on the 12 simulated data sets.

	Simulated data				**Results**						
Case	p*	sd	Contin. Recr.**	Error in mla***	K	Linf	Avge sd	nº parameters	nº ages	Total Penalty	LL
1	(1,1,1,1,1,1,1)	6			0,176	274,1	4,261	148	7	0,15	30046
2	(1,1,1,1,1,1,1)	15			0,173	278,4	10,59	148	7	0,15	24705
3	(1,1,1,1,1,0,0)	6			0,176	274,6	4,25	124	6	177,89	22825
4	(1,1,1,1,1,0,0)	15			0,176	274,6	10,586	124	6	239,67	25144
5	(0,1,0,1,1,0,0)	6			0,176	274,7	4,258	124	6	485,12	22291
6	(0,1,0,1,1,0,0)	15			0,177	273,7	10,575	124	6	265,34	23405
7	(0.1,0.9,0.1,0.8,0.9,0,0)	6			0,176	274,7	4,257	124	6	0,16	23001
8	(0.1,0.9,0.1,0.8,0.9,0,0)	15			0,175	276,1	10,59	124	6	0,16	25039
9	(0.5,1,1,1,1,1,1)	6	yes		0,18	278,9	6,1	124	6	0,12	14587
10	(0.5,1,0,1,1,0,0)	6	yes		0,143	324,3	7,26	124	6	15,617	15177
11	(1,1,1,1,1,1,1)	6		yes	0,226	231,1	5,1	172	8	1,89	14646
12	(0.1,0.9,0.1,0.8,0.9,0,0)	6		yes	0,251	212,6	5,01	148	7	3,89	14590

*Weighting factor for ages 0,1,2,3,4,5,6, and 7 respectively.

**Recruitment of age 0 fish lasts 5 months

***Errors in mean lengths at age (mla) predicted by Stequert (1996) distributed normally around mla with standard deviation equal to mla/20

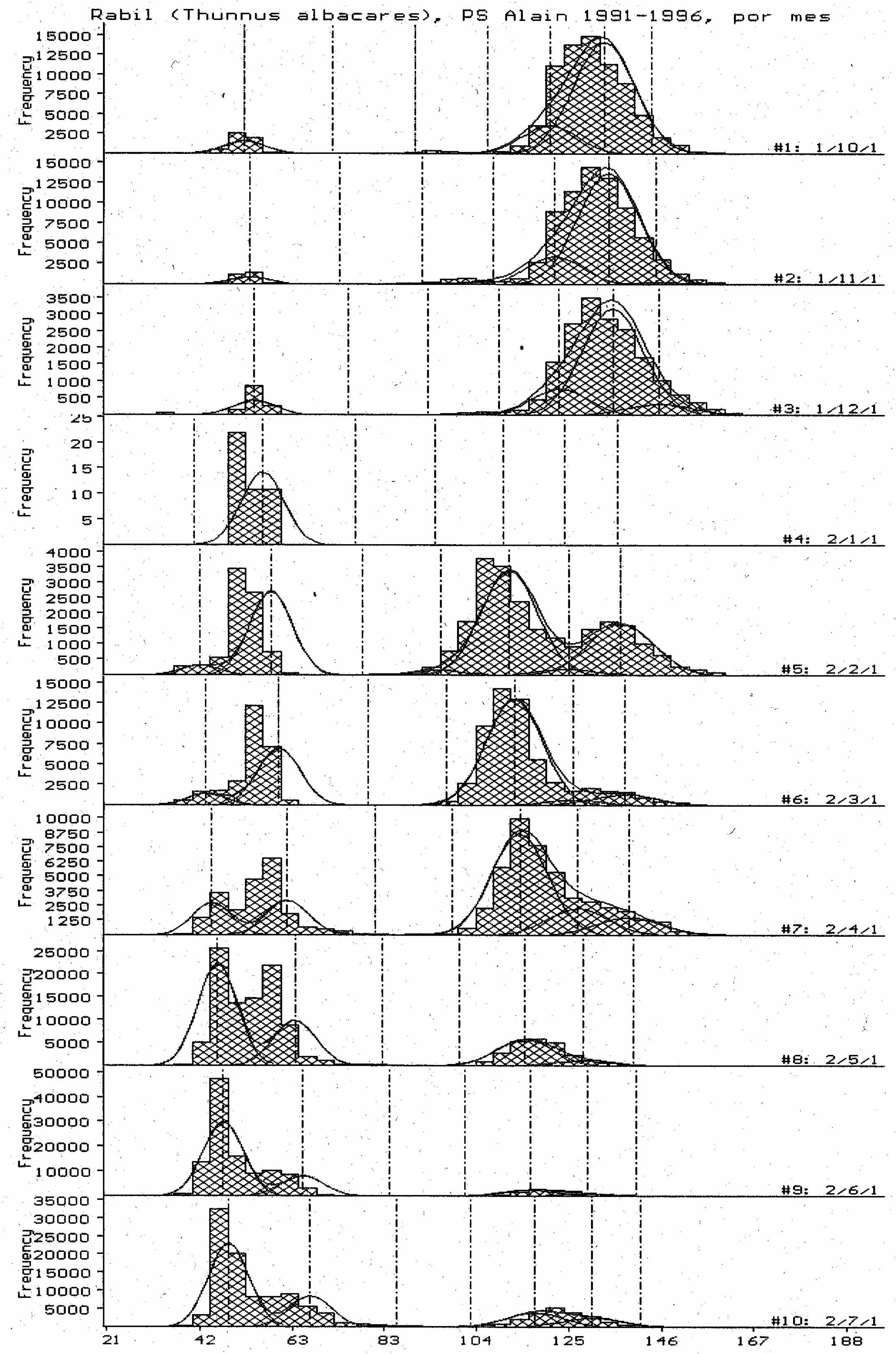
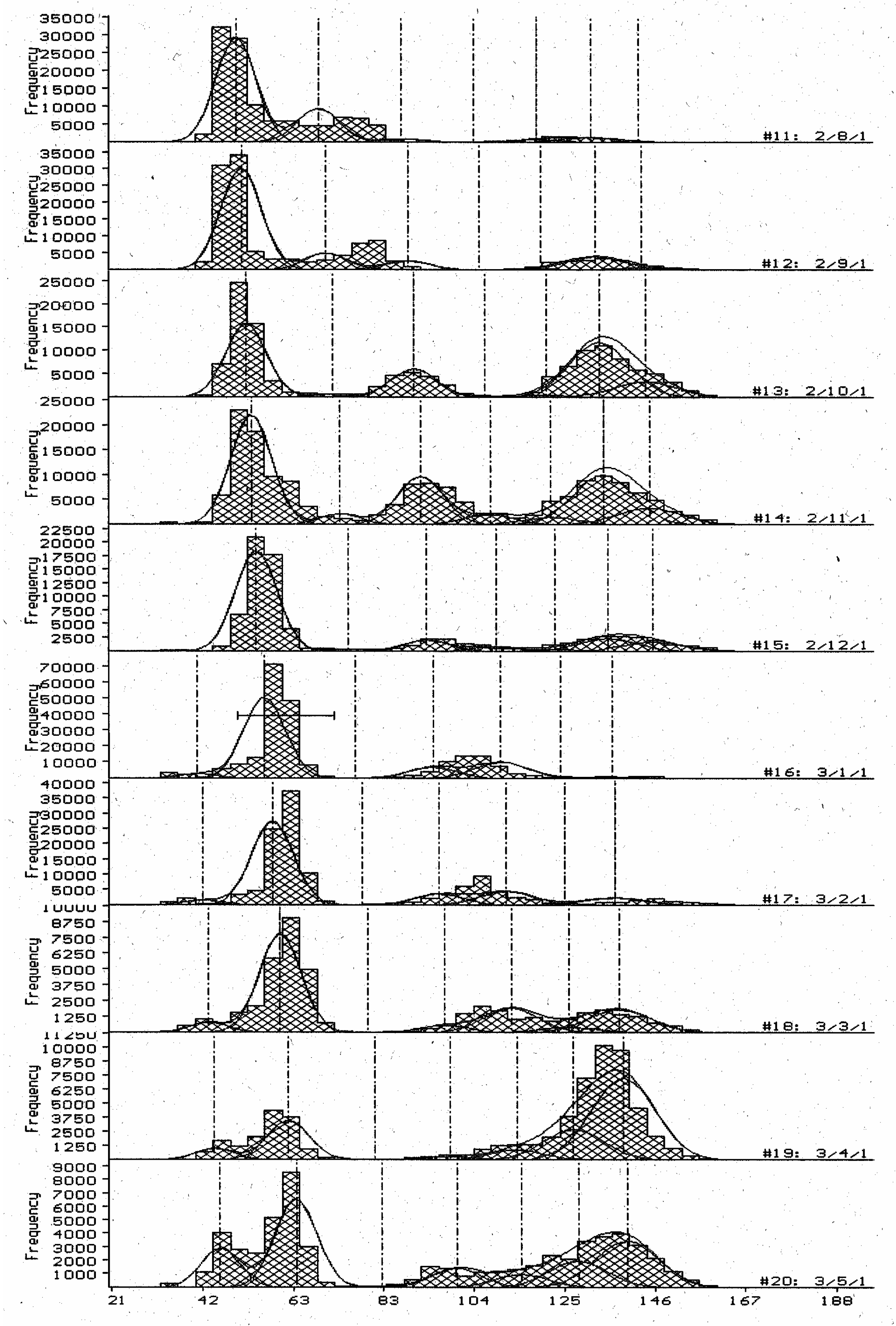


Figure 1. Observed (bars) and predicted (lines) monthly length frequency distributions for purse seine caught yellowfin tuna from January 1991 to October 1996. Vertical lines indicate mean length predicted by the model for each age class.



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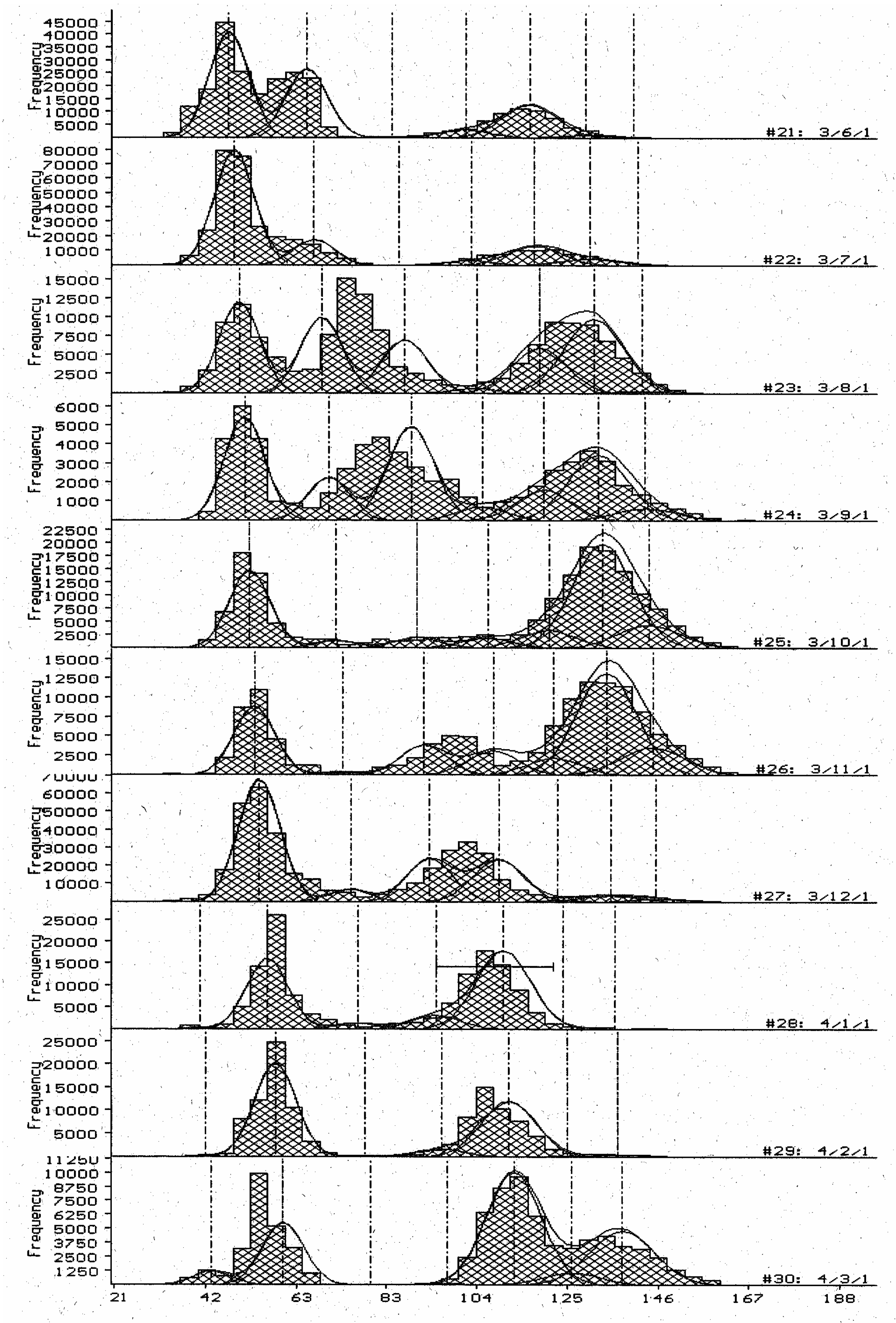

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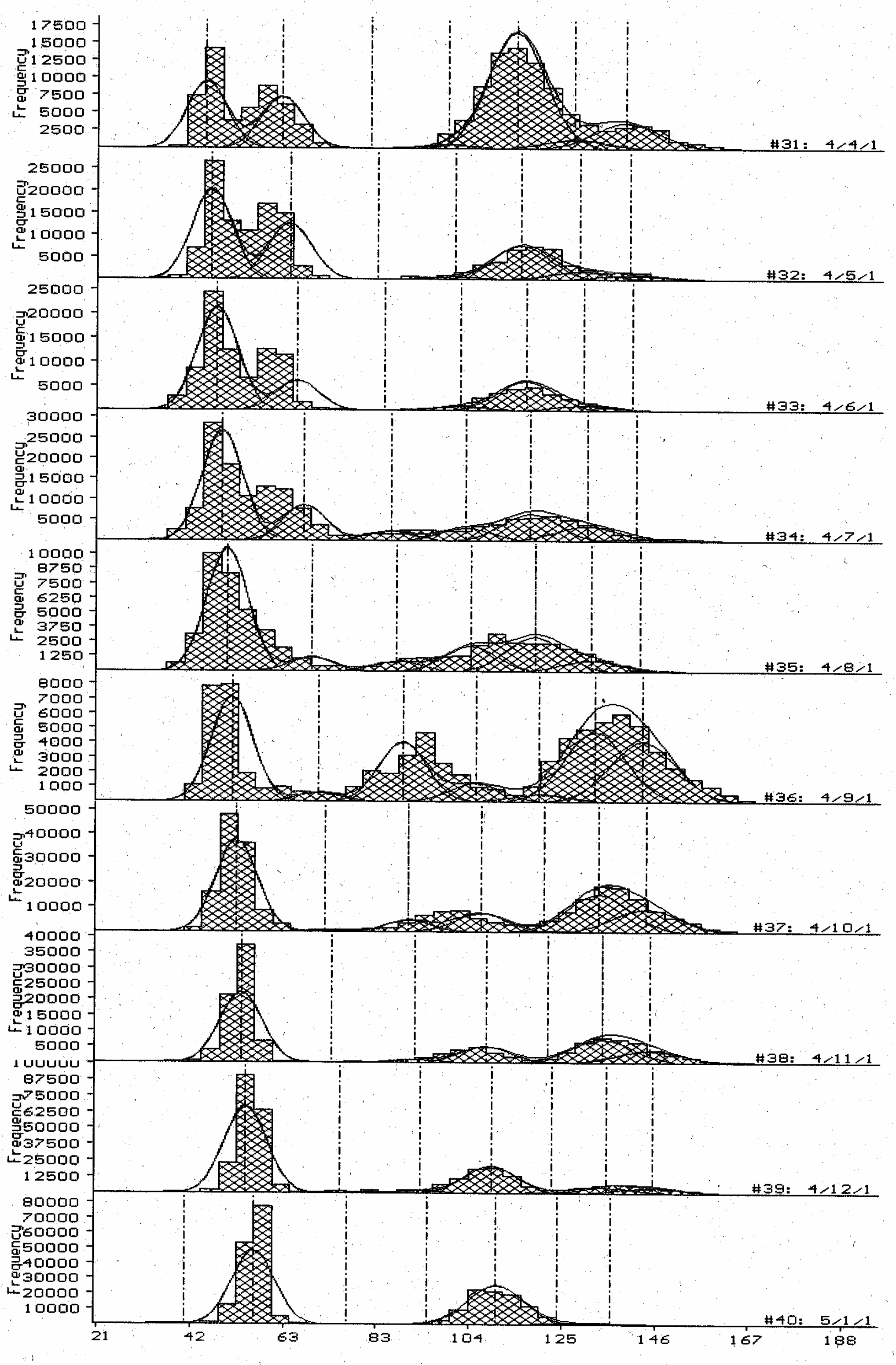

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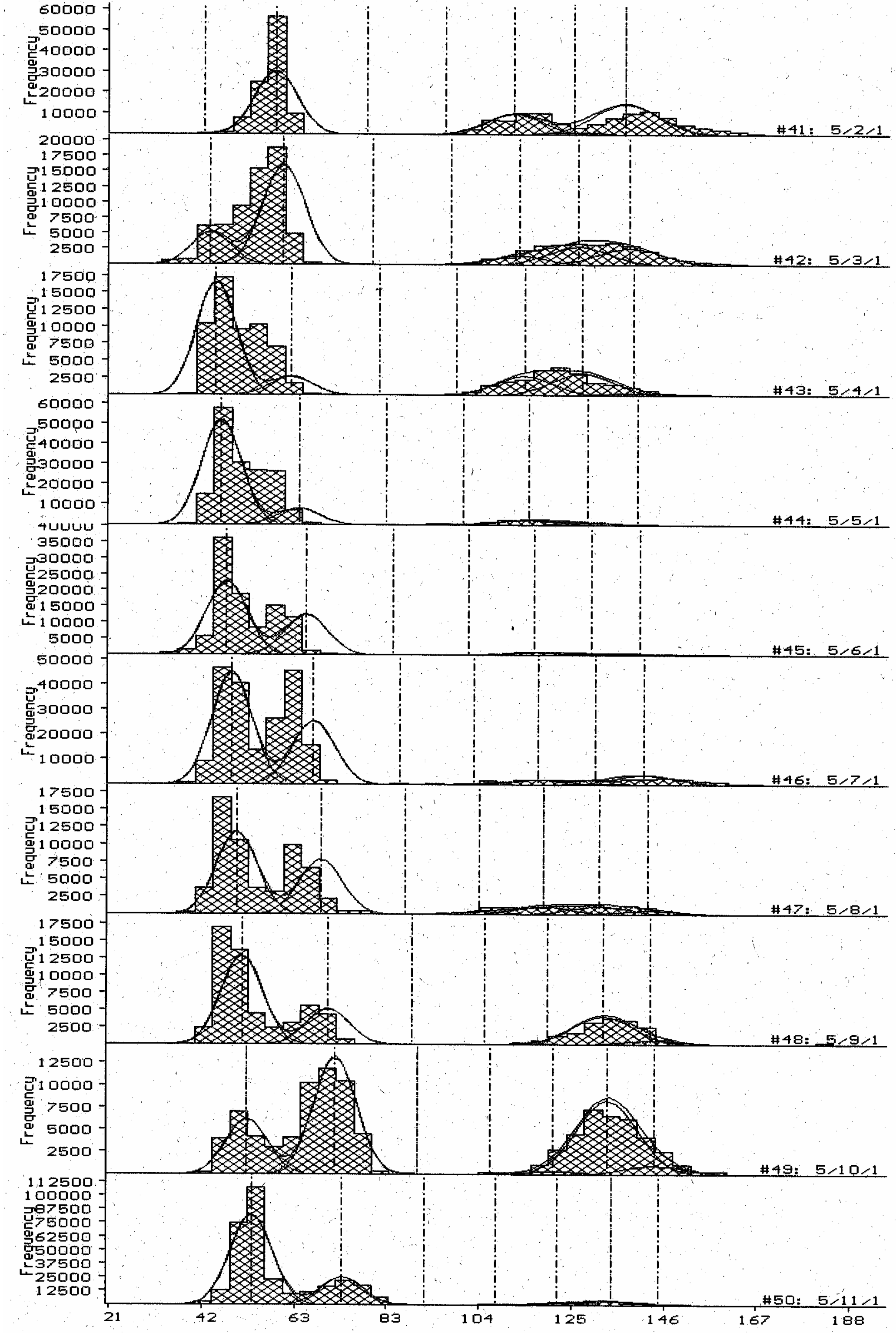

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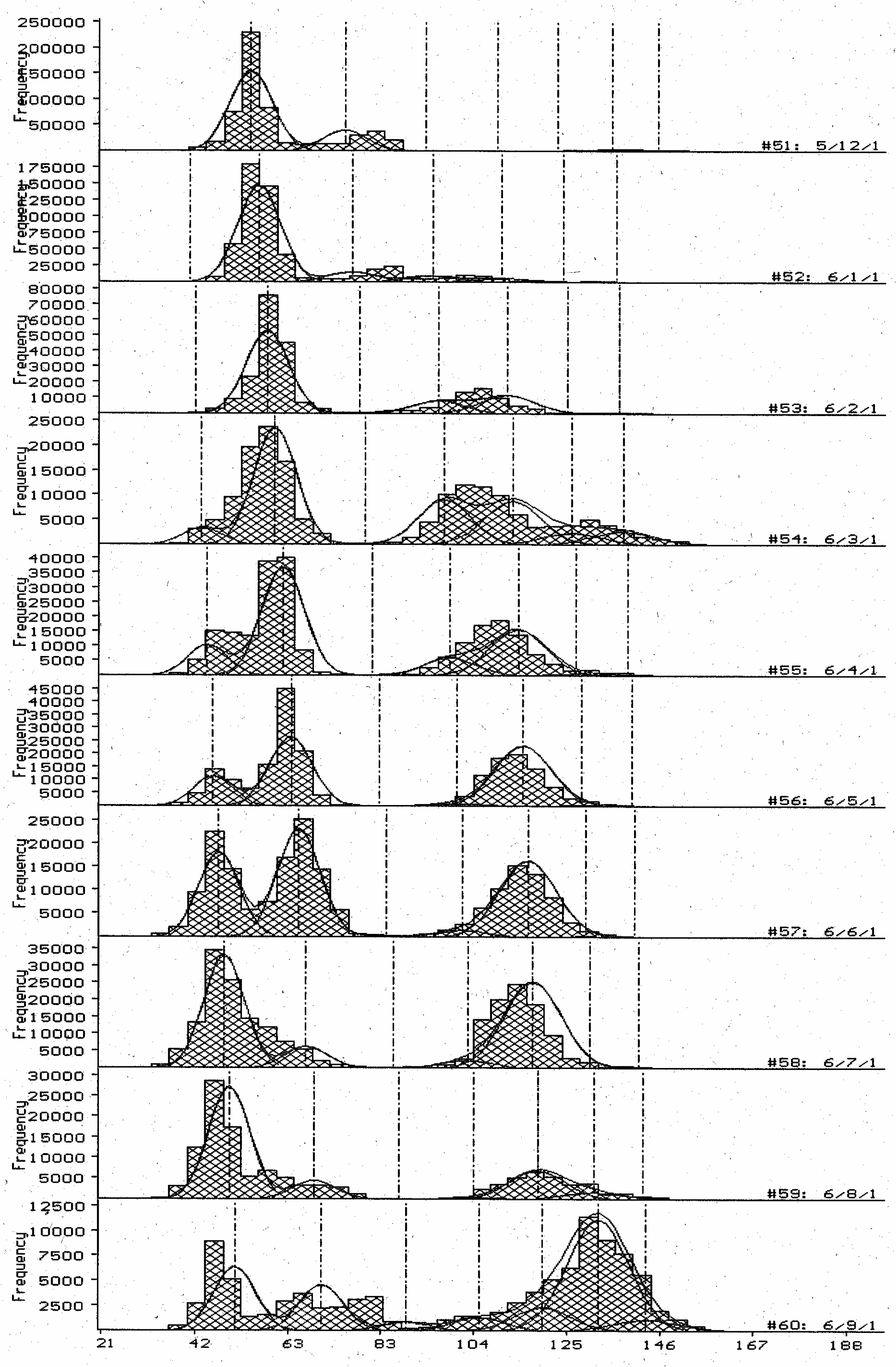

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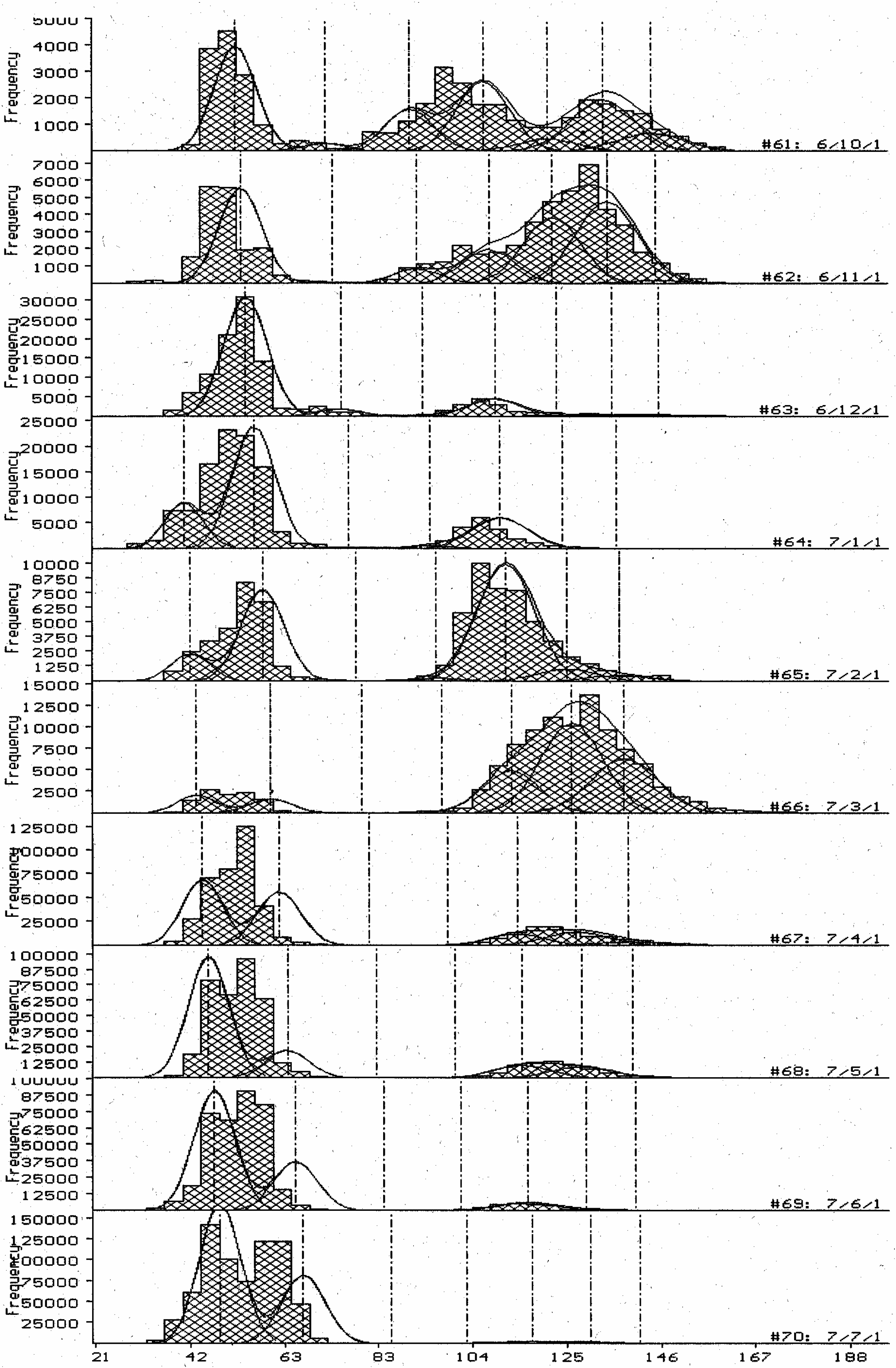

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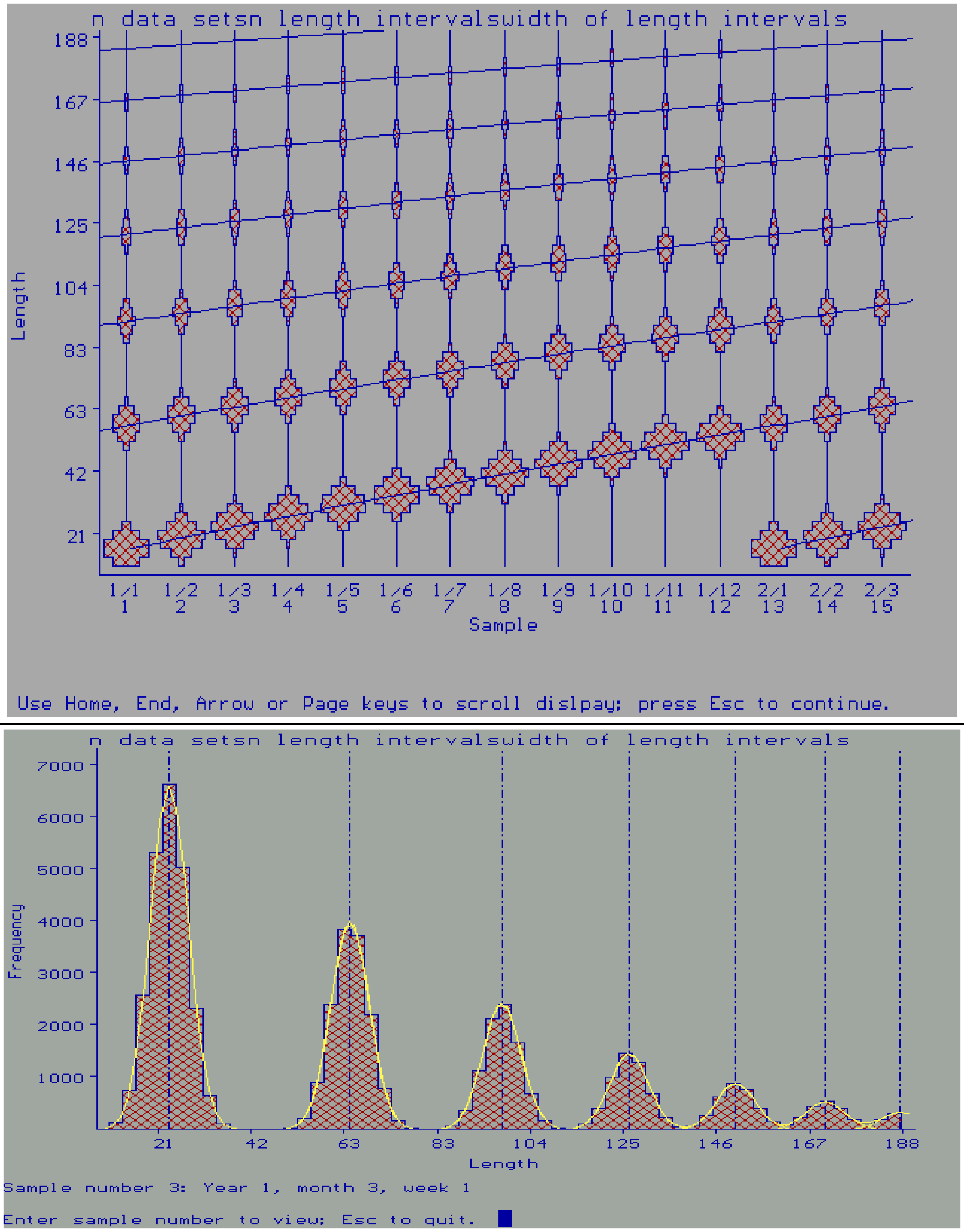

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Figure 2: Blobs plot (upper panel) and observed-predicted length frequencies (lower panel) for "ideal" Case 1.

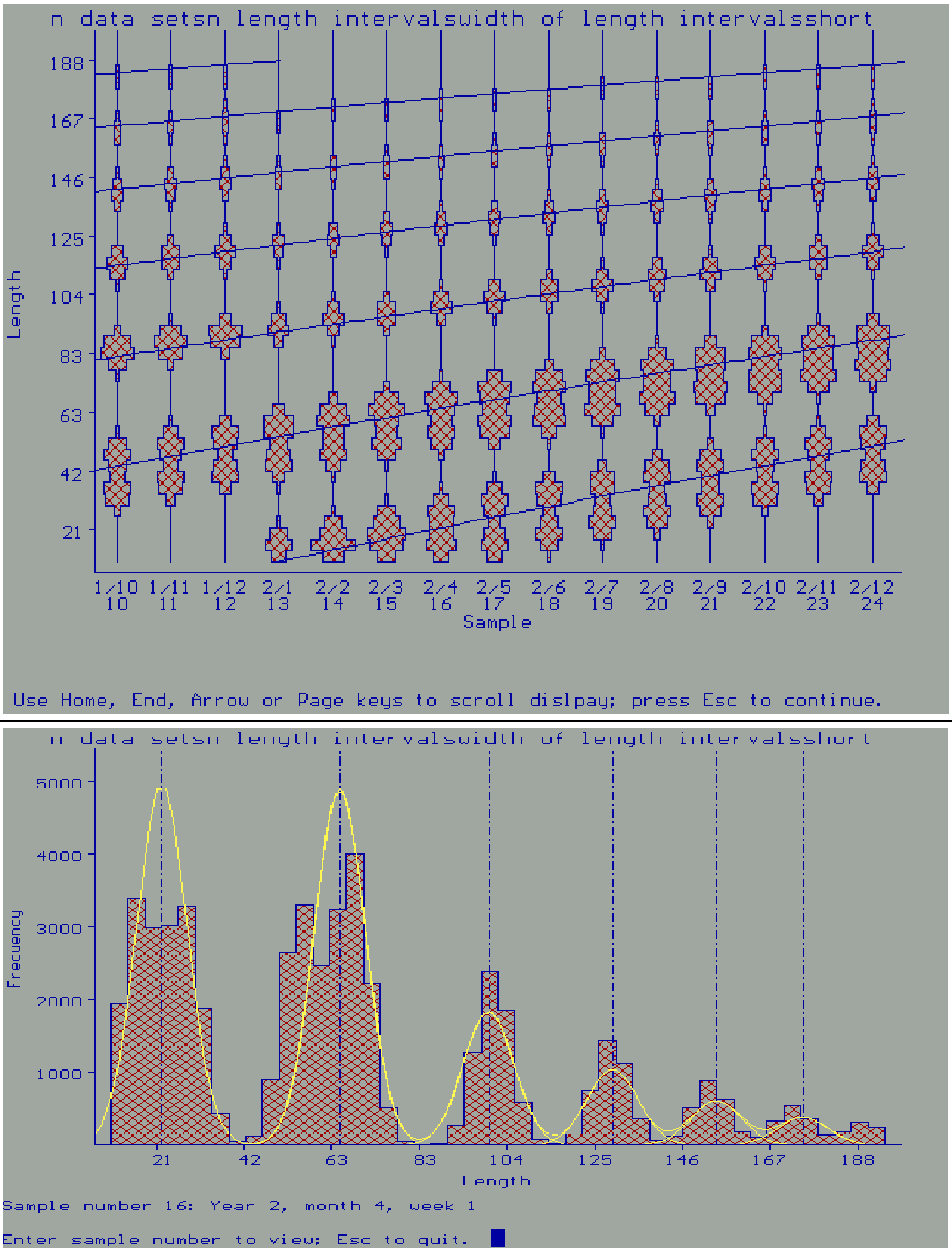

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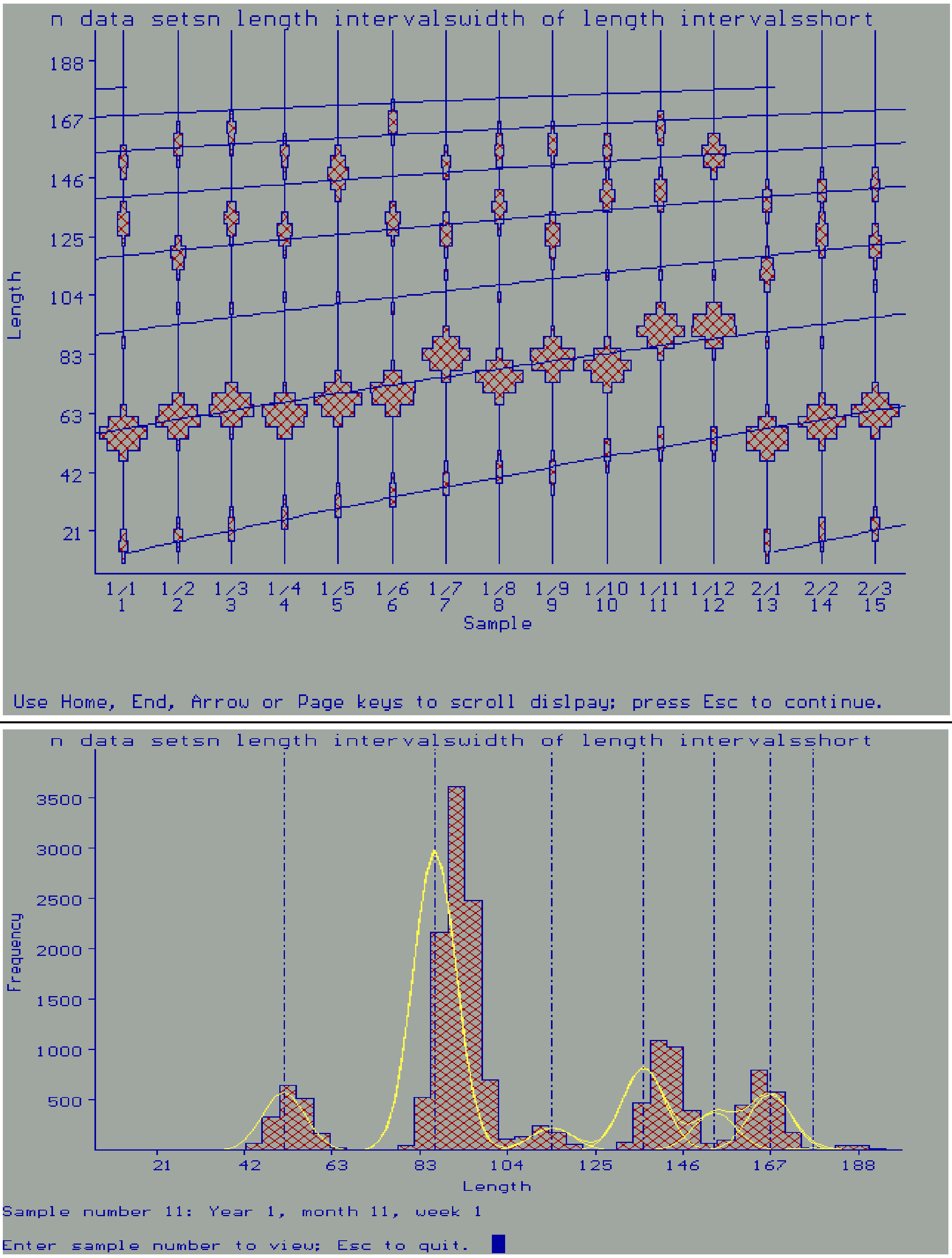
Figure 3: Blobs plot (upper panel) and observed-predicted length frequencies (lower panel) for Case 9 reflecting continuous recruitment during 5 months.



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Sample number 11: Year 1, month 11, week 1

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Figure 4: Blobs plot (upper panel) and observed-predicted length frequencies (lower panel) for Case 12 reflecting error in observed mean lengths at age with respect to the ones predicted by Stequert et al. (1996) and age selectivity (see table 3 for details)

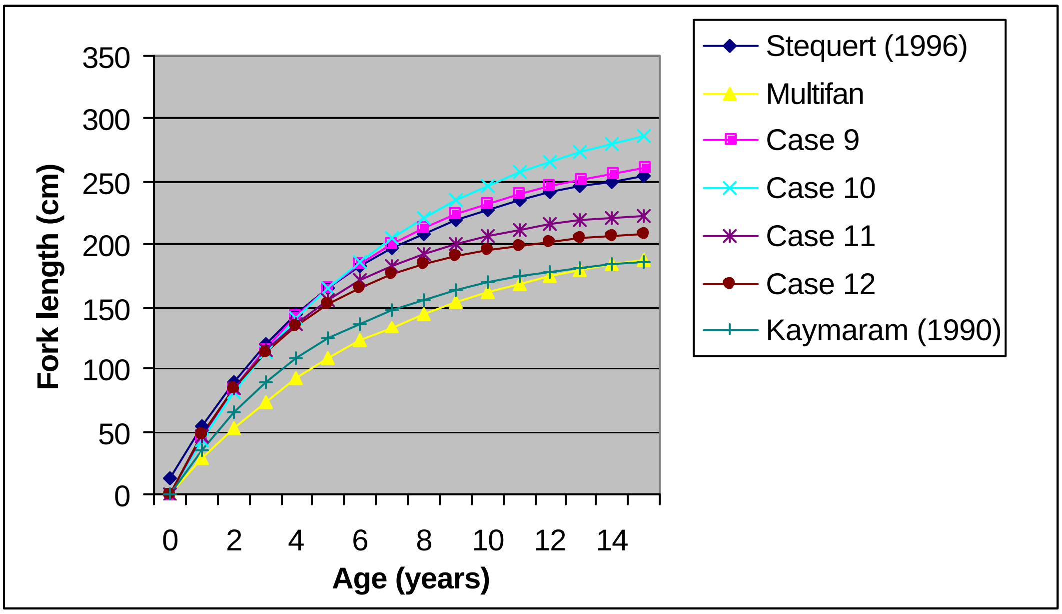

Figure 5. Comparison of growth curves obtained with MULTIFAN applied to real and simulated data (cases 9 to 12) and the ones from Stequert et al. (1996) and Kaymaram et al. (2000).