# Age and Growth Estimation for the White Shrimp, *Penaeus setiferus*, from the Offshore Fishery of the Northwestern Gulf of Mexico

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ABSTRACT

Age and growth of the white shrimp, *Penaeus setiferus*, from the Northwestern Gulf of Mexico was estimated through the application of the ELEFAN program developed as part of the LFDA software. Data consisted of monthly series of catch per unit of effort (CPUE)-at-length composition for 1975. It was assumed growth follows the von Bertalanffy curve, and a nonparametric estimate of standard deviation for the growth rate (K) and the asymptotic length (L ) was also obtained following the Jackknife technique and analyzed by using the phi-prime index of growth performance. Results indicate a mean value for $K = 1.1156$ year$^{-1}$ and its standard deviation, $sd_k = 0.0497$; and $L = 191.35$ mm (total length) and its standard deviation, $sd_L = 4.34$. The range of variation of the ESP/ASP ratio was 0.55 to 0.66. The phi-prime index gives a mean value of $\phi' = 4.61$, and its standard deviation was, $sd_\phi = 0.011$. *P. setiferus* is a relatively slow growing shrimp compared with other species in the Gulf of Mexico, with a well defined growth pattern.

## INTRODUCTION

The shrimp fishery is the most important fishing activity in the Gulf of Mexico because of the economical and social impacts. There are several penaeid species distributed in three main regions along the coast of Mexico (Figure 1): the Northwestern coast, where the brown (*Penaeus aztecus*) and white (*P. setiferus*) shrimps are the most important species (Arreguín-Sánchez and Chavez, 1985; Castro, 1987; Castro and Arreguín-Sánchez, 1991); the Campeche Bank, with three species, the pink shrimp (*P. duorarum*), and the white and brown shrimps (Schultz-Ruíz y Chávez, 1976; Arreguín-Sánchez and Chavez, 1985; Gracia, 1991); and Contoy, where the pink-spotted shrimp (*P. brasiliensis*) and the rock shrimp (*Sicyonia brevirostris*) are the two exploited species (Arreguín-Sánchez, 1981a, b; Arreguín-Sánchez and Chavez, 1985). Among these, *P. setiferus* have been poorly studied from the population dynamics point of view, and this contribution aims to analyze some aspects of the age and growth estimates as well as its variability.

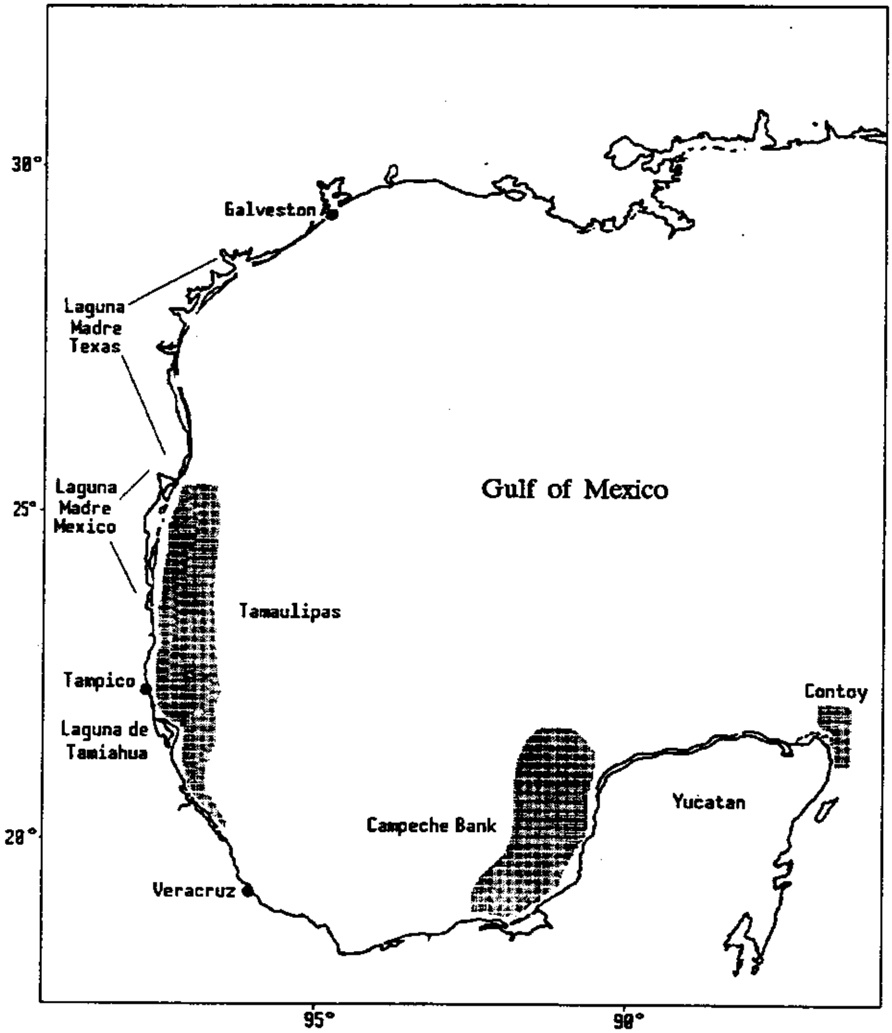


**Figure 1.** Main fishing grounds of the offshore shrimp fishery along the Mexican coast of the Gulf of Mexico. The white shrimp, *Penaeus setiferus,* studied is fished in the Tamaulipas region.

The key point of the age and growth studies is associated with the use of this information to assess the availability of biomass per unit of time (usually years for complete reproductive periods), and how its variability could affect the stock assessment and fishing strategies.

## METHODS

### Source of Data

Because the brown and pink shrimps are the most important species, information about population dynamics of *P. setiferus* is scarce. Data from commercial classification (tail-counts) from 1975 were used to obtain length-frequency distributions. The average weight of each commercial category was converted to the respective length, and a length-frequency distribution was obtained with unequally sized length classes, where the area under the curve corresponds to the total catch (in numbers). Then, partial integration was used to obtain the number of shrimps for equally sized length intervals.

Because of the seasonal behavior of the population and fishing effort dynamics, the catch per unit of fishing effort (CPUE) was used as the best index of population abundance. Then monthly series of CPUE-at-length composition were available as length distributions to estimate age and growth.

### Growth Estimation

The ELEFAN I method of the LFDA software (Holden and Bravington, 1991) was applied to estimate the parameters of the von Bertalanffy growth equation (VBGE), which assumes white shrimp grows according this model,

$$L_t = L \quad \{1 - \exp^{-K(t - t_0)}\} \qquad (1)$$

where

$L_t$ = length at age t

L = maximum asymptotic length

K = growth curvature parameter

$t_0$ = computed age at length zero

The ELEFAN I program identify peaks and troughs in the length frequency distributions and fits the growth curve which follows a maximum number of peaks (Pauly *et al.*, 1984; Pauly, 1987). An index of goodness of fit is estimated as the ESP/ASP ratio, where ESP stands for the "Explained Sum of Peaks" and ASP for "Available Sum of Peaks". The best combination of K and L is that corresponding to the maximum Score of the ESP/ASP ratio.

**Standard deviation estimates for K and L**

Once the parameters of the VBGE were obtained, a nonparametric estimate of the standard deviation for K and L following the Jackknife technique (Efron, 1982) were computed ($\sigma_{Jack}$) as follows:

$$\sigma_{Jack}\,(K,L\ ) = \{(n-1)/n \bullet \sum_{i=1}^{n} (\ \overline{x}_{(i)} - \ \overline{x}_{(\bullet)})^2\}^{1/2} \qquad (2)$$

where
n = represents the number of samples
x = estimates of K and L obtained when ELEFAN I was running take-off one sample each time.
i, j = indexes of samples

$$\overline{x}_{(i)} = (1/n\text{-}1) \sum_{j\ i}^{n} x_j$$

$$\overline{x}_{(\bullet)} = (1/n) \sum_{i=1}^{n} x_{(i)}$$

As a criterion to compare different VBGE estimates, the standard growth index $\phi'$ (Pauly and Munro, 1984) was employed as a measure of the overall growth performance (Sparre *et al.*, 1989). This index is defined as

$$\phi' = 2\log_{10}(L\ ) + \text{Log}_{10}(K) \qquad (3)$$

This criterion was chosen because it provides an index of growth performance which must remains reasonably constant despite the variation of K and L due to the specific information contained within each sample.

RESULTS AND DISCUSSION

The CPUE-at-length composition data were obtained and the ELEFAN I program from the LFDA software executed. The surface of response to select the best estimates of the VBGE parameters found multiple peaks (Figure 2) as follows:

**First Peak:**

K= 1.1193 year$^{-1}$, L = 192 mm, $t_0$ = -0.3 years, Score = 0.59615

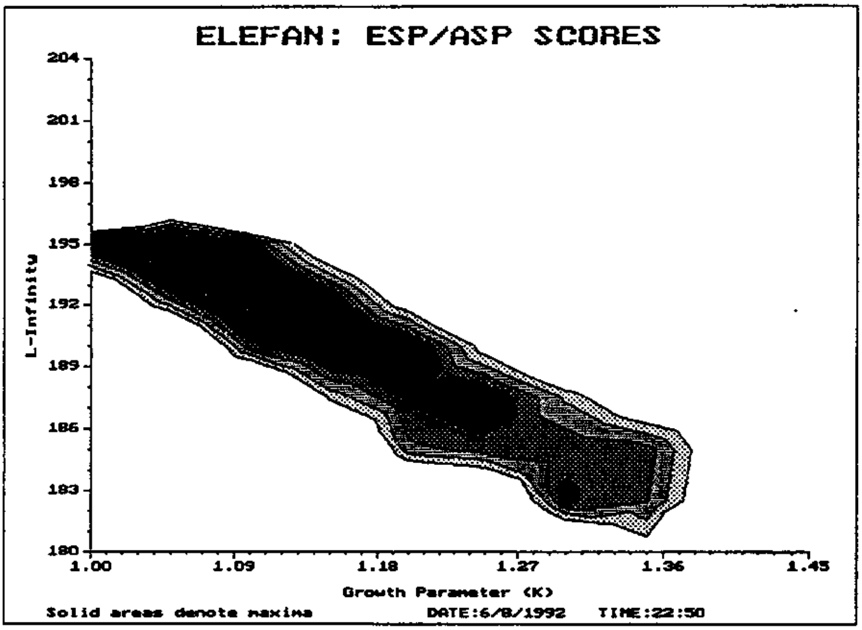


**Figure 2.** Contour plot of the surface of response from the ELEFAN I method to select best estimates of K and L . Solid areas denote maximum Score. Note the presence of two maxima (for explanation see text).

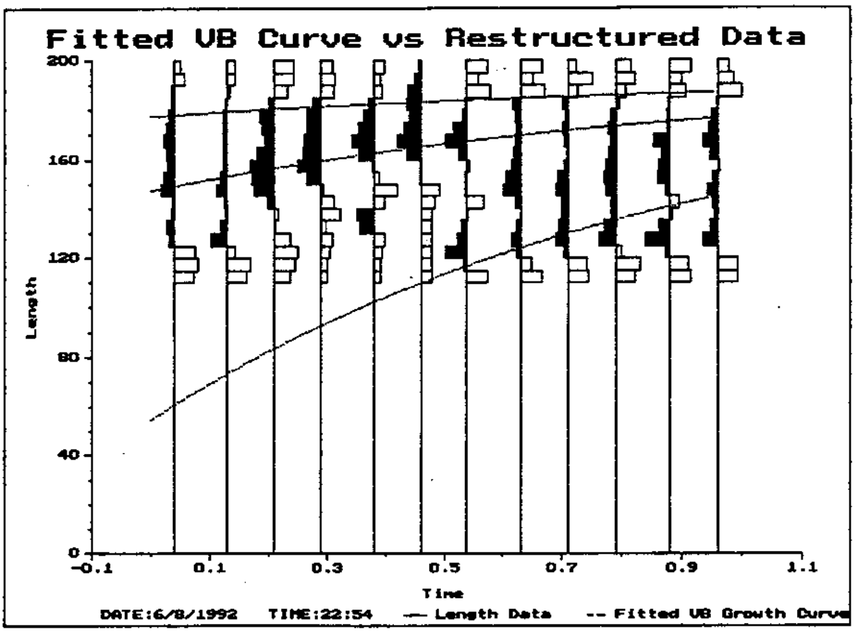


**Figure 3.** Fitted von Bertalanffy growth curve to restructured data from the ELEFAN I method. Solid areas correspond to expected age groups.

**Second Peak:**

K= 1.2658 year$^{-1}$, L = 187 mm, $t_0$ = -0.24 years, Score = 0.59062

For these combinations of K and L , the $\phi'$ values were 4.615, and 4.646, respectively. Although the difference between the Scores (= ESP/ASP ratios) is not significant, the values of the first peak were selected, and the growth curve fitted (Figure 3).

In order to estimate the standard deviation of the VBGE parameters using the Jackknife technique ($\sigma_{Jack}${K, L }), the ELEFAN I was executed by removing one CPUE-at-lenght sample each time. Results are shown in Table 1.

A graph of $Log_{10}$ (L ) versus growth rate (K) was plotted (Figure 4) and a group of points appears to be well defined, except for those when samples of June and August were removed (points 6 and 8). This suggests that other estimations describe a well defined growth pattern. ELEFAN I was applied again with the grouped samples and a second set of estimates of the VBGE parameters obtained. As in the case with all samples, multiple peaks were found (Figure 5) with the following values:

**First Peak:**

K = 1.2849 year$^{-1}$, L = 178 mm, $t_0$ = -0.37 years, Score = 0.61806

**Second Peak:**

K = 1.3338 year$^{-1}$, L = 188 mm, $t_0$ = -0.12 years, Score = 0.61773

where the $\phi'$ values were 4.60971 and 4.6734, respectively.

Despite these results a new graph was plotted using the $\phi'$ values as dependent variable and the removed sample as the independent (Figure 6). The tendency of $\phi'$ values is more or less constant, except for August (sample 8). This means that, except for running without sample 8, all others describe a similar growth pattern for the white shrimp.

With these results two estimations were obtained for $\bar{x}_{(\cdot)}$ as the average estimates of the VBGE, and their standard deviation $\sigma_{Jack}$ {K,L } by using the complete set of values, and without the August sample. Values computed are given in Table 1, and the resulting growth curve fitted versus data to observe the goodness of fit (Figure 7).

For the present analysis, the estimations of the VBGE parameters without the August sample were selected because they suggest a well defined growth performance pattern along the year. However, interpretation of information contained in August is not so clear. Initially it is assumed that there is not a sampling design problem because all the information comes from the commercial tail-counts. The problem arises in regard to information that is not

**Table 1.** Parameters of the Von Bertalanffy growth equation estimated during the Jackknife test.

| Month Removed | K | L | $t_0$ | Score | Log L | $\phi'$ |
|---|---|---|---|---|---|---|
| | *Penaus setiferus* | | | Tamaulipas, 1975 | | |
| 1 | 1.1199 | 191.95 | -0.30 | 0.56530 | 2.2832 | 4.6156 |
| 2 | 1.1427 | 191.11 | -0.29 | 0.60965 | 2.2813 | 4.6205 |
| 3 | 1.1195 | 191.96 | -0.30 | 0.55969 | 2.2832 | 4.6154 |
| 4 | 1.1199 | 191.95 | -0.30 | 0.56669 | 2.2832 | 4.6156 |
| 5 | 1.0469 | 192.40 | -0.35 | 0.61879 | 2.2842 | 4.5883 |
| 6 | 1.2285 | 178.48 | -0.39 | 0.61140 | 2.2516 | 4.5926 |
| 7 | 1.0771 | 195.57 | -0.27 | 0.61919 | 2.2913 | 4.6149 |
| 8 | 1.3612 | 187.32 | -0.11 | 0.63512 | 2.2726 | 4.6791 |
| 9 | 1.1427 | 191.11 | -0.29 | 0.57042 | 2.2813 | 4.6205 |
| 10 | 1.0876 | 193.94 | -0.31 | 0.60381 | 2.2877 | 4.6118 |
| 11 | 1.1427 | 191.11 | -0.29 | 0.65824 | 2.2813 | 4.6205 |
| 12 | 1.0439 | 195.22 | -0.33 | 0.60803 | 2.2905 | 4.5997 |
| avg(12) | 1.1361 | 191.01 | -0.294 | 0.60219 | | 4.6162 |
| std(12) | 0.0829 | 4.30 | 0.064 | 0.02945 | | 0.0217 |
| avg(s/8) | 1.1156 | 191.35 | -0.311 | 0.5992 | | 4.6105 |
| std(s/8) | 0.0497 | 4.34 | 0.032 | 0.0290 | | 0.0110 |

included in the analysis when a given sample is not considered. It is clear that information contained in August is very important for the growth patterns estimated by ELEFAN I because it is included within all the others, and obviously the key point is: What is occurring in August that affects growth tendencies? Unfortunately there is no previous information on population dynamics. Figure 7, however, suggests that during August new recruits (120 to 140 mm) are massively incorporated, while in July, most shrimp are longer (up to 160 mm). If this is correct, Defeo *et al.* (1992) have proposed that this suggests that recruitment time and its magnitude could be an important population process influencing the performance of the ELEFAN I and probably other length-based methods to estimate age and growth.

## CONCLUSIONS

The growth estimates for the white shrimp *P. setiferus* suggest a relatively slow growing peneid shrimp, compared with other penaeids from the Gulf of Mexico. The mean values for the parameters of the VBGE were: K = 1.1156 $year^{-1}$ and L = 191.35 mm (total length). The Jackknife standard deviation for these parameters were computed using as criterion the tendency of the index of

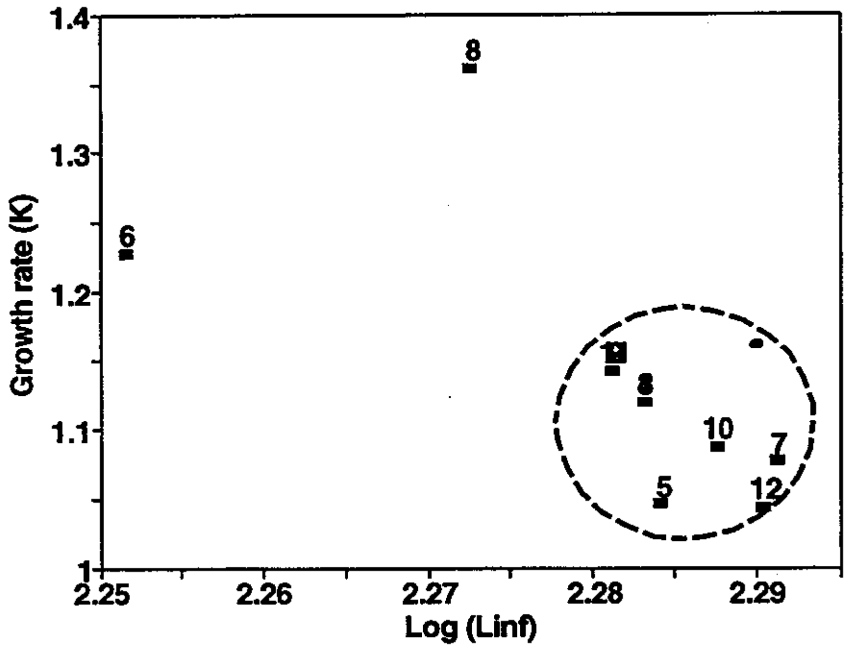


**Figure 4.** Growth rate (K) versus $Log_{10}$ (L ) plot for the Jackknife estimates of K and L when each monthly sample was removed. Data within the dashed circle denote a similar growth parameters. Numbers correspond to months. January (1) to December (12).

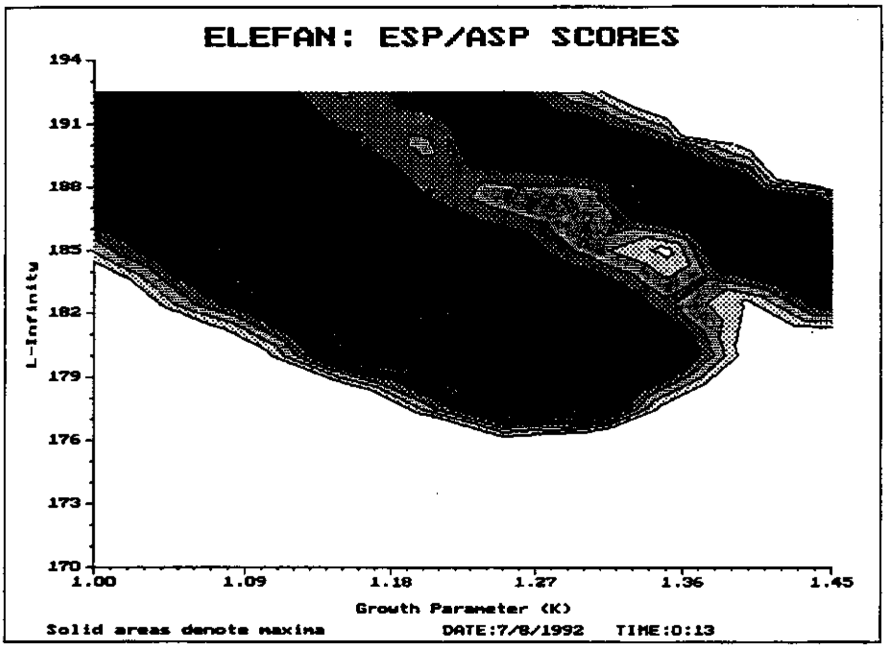


**Figure 5.** Contour plot of the surface of response from the ELEFAN I method to select best estimates of K and L as resulted from the Jackknife test. Solid areas denote maximum Score. Note the presence of multiple maxima (for explanation see text).

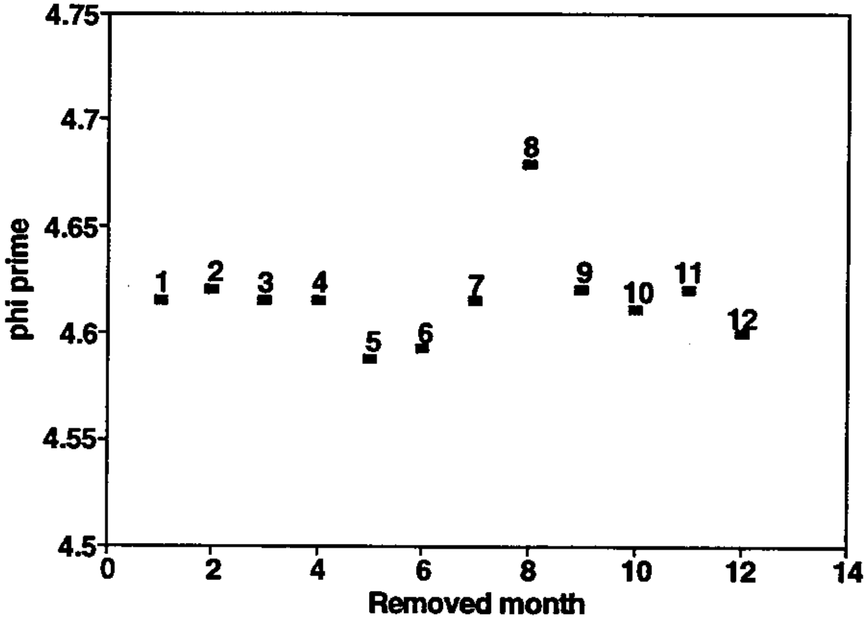


**Figure 6.** ' versus removed month plot from the Jackknife test showing the tendency of the growth performance index. Excepting for August (point 8), others points suggest a relatively constant growth pattern (for discussion see text).

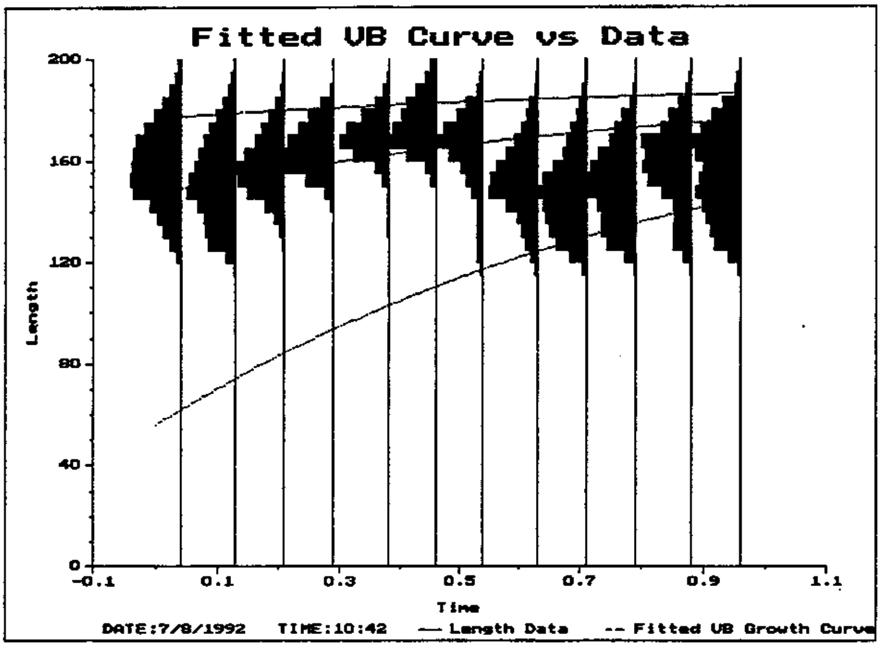


Figure 7. Fitted von Bertalanffy growth curve to length composition data from the ELEFAN I method.

growth performance $\phi'$, and results obtained were as follows: $\sigma_{Jack}$ (K) = 0.0497, and $\sigma_{Jack}$ (L ) = 4.34. It was observed that samples containing recruitment time information (and probably its magnitude) have a strong influence on the growth patterns estimates.

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