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# Electronic Length Frequency Analysis

## A Revised and Expanded User's Guide to ELEFAN 0, 1 and 2

by

THOMAS BREY and DANIEL PAULY

1986

Electronic Length Frequency Analysis (Brey & Pauly)

## E R R A T A

| page | line | read | instead of |
|---|---|---|---|
| 2 | 2 | ESP/ASP $\geq$ 1 | ESP/ASP 3 1 |
| 11 | 20 | $FA_i \geq 1$ | $FA_i$ 3 1 |
| 11 | 21 | $FA_i \leq 1$ | $FA_i$ 1 |
| 23 | 20 | Loo $\geq$ (upper... | Loo 3 (upper... |
| 48 | 26 | Habilitation... | Habitilation... |

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Abstract

This guide presents an updated and extended version of the ELEFAN 0, ELEFAN 1 and ELEFAN 2 programs for Electronic LEngth Frequency ANalysis. These programs can be used to estimate the parameters of a (seasonally oscillating) growth equation, total mortality (Z = P/B ratio) and related parameters, as well as to derive seasonal patterns of recruitment. Input data are length frequency samples collected at regular or irregular intervals, and, optionally, growth informations obtained from tagging-recapture experiments or from ageing studies. The revised programs incorporate modifications suggested by recent simulation studies aimed at identifying sources of the bias in the original ELEFAN procedures. The programs are written in Microsoft Basic and available in a CP/M version (8 bit CPU Zilog Z80), in a MS/DOS version (16 bit CPU Intel 80xx), and in the next future in a CP/M 68K version (16/32 bit CPU Motorola 68000). The listings included here refer to the MS-DOS version of ELEFAN.

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## 1. Introduction

This user's guide to the ELEFAN 0, 1 and 2 programs (henceforthwith called "guide", presents revised and expanded versions of a set of computer-based methods for the estimation of growth, mortality and related parameters in fish population, known as Electronic LEngth Frequency ANalysis (ELEFAN). The methods, initially presented in Pauly and David (1980, 1981) and Pauly (1982) have found wide application throughout the world (see below and References section).

In February 1985, a conference on the "Theory and Application of Length-Based Methods in Stock Assessment" was held in Mazarra del Vallo, Sicily, Italy at which the ELEFAN programs and a number of other, length-based methods were reviewed (Pauly 1985c, Pauly and Morgan 1985). At this conference, simulation studies by Hampton and Majkowski (in press) and Rosenberg and Beddington (in press) were presented, in which the performance of the ELEFAN 1 and 2 programs was assessed, based on simulated length-frequency data sets generated with known values of growth and mortality parameters.

The version of the ELEFAN 1 and 2 programs presented here incorporate the results of these analysis, and thus represent a "second generation" of ELEFAN programs (another second generation version of ELEFAN 0, 1 and 2, for use with Hewlett-Packard computers, is also available, see Saeger and Gayanilo 1985). The new versions presented here include novel approaches for growth parameter estimation also presented at this conference, notably a method, modified from Morgan (in press) for the simultaneous analysis of length-frequency and tagging/recapture and/or length-at-age data, and a method for the direct estimation of $L_{oo}$ and Z/K from length-frequency data (from Wetherall et al., in press).

Important modifications of the ELEFAN 0 program over the original version (David et al. 1982) are:

1) Improved entry and editing routines, and
2) Provision for the entry of probabilities of capture, by length, and correction of a length-frequency data set for selection effects (i.e. creation of a new, corrected data set).

Important modifications of the ELEFAN 1 program over the original version (Pauly et al. 1980) are:

3) Supression of "drifting" as described in Pauly et al. (1980), i.e. of

the output of impossibly low values of K and associated values of ESP/ASP'1 (see Pauly 1985b and section 2.4.).

4) Redefinition of "scores" associated with the largest fish and/or with isolated peaks, such as to counteract (l) the tendency of ELEFAN 1 to overestimate $L_{oo}$, and (b) for single, isolated peaks based on a few animals to strongly affect growth parameter estimation.

5) Output of a table of ESP/ASP values to help assess quality of growth parameter estimates associated with highest ESP/ASP values (as used in very early versions of ELEFAN 1, and in Brouard and Grandperrin 1984).

6) Incorporation of a routine which allows simultaneous analysis of length-frequency data and tagging/recapture and/or length-at-age data, based on an approach from Morgan (in press).

Important modifications of the ELEFAN 2 program are:

7) Addition of new weighting modes for combining a series of length-frequency samples into one single total sample representative of the steady state population.

8) Inclusion of a new method for estimation of $L_{oo}$ and Z/K from length-frequency data and developed, using a rigorous theoretical approach, by Wetherall et al. (in press).

This latter routine, which can be implemented immediately after the ELEFAN 0 program has the advantage that, by providing an estimate of $L_{oo}$, it considerably cuts computation time while providing a well-defined estimate for a parameter which ELEFAN 1 often has problems estimating reliably (Rosenberg and Beddington, in press).

Unfortunately, there will be instances when this routine won't work; in such cases, ELEFAN 1 will have to be used with variable $L_{oo}$ (the user is advised, however, not to let $L_{oo}$ wander to far of the size of the largest fish, as ELEFAN 1, if anything, tends to <u>over</u>estimate $L_{oo}$).

Modification (7) was added to allow use of ELEFAN 2 in temperate areas, where strong seasonal growth oscillations can distort markedly the size-frequency distribution of total samples accumulated over longer periods (T. Brey, pers. obs., H. Salzwedel, pers. comm .).

Modification (6) anticipates a program by G.R. Morgan et al. (in prep.) implemented for use with Apple II microcomputers, and which will be included as ELEFAN 5 in a comprehensive guide to the ELEFAN system (also including ELEFAN 0, 1, 2, 3, 4), to be published soon. Users of this specific routine should credit Morgan (in press, b) for the idea of incorporating ELEFAN 1 with tagging/recapture and/or length-at-age data. Modification (5) provides an output, i.e. a response surface (see Tab.10 for an example) which can be used for a subjective assessment of the reliability of estimates of growth parameters obtained by ELEFAN 1. One aspect of the modifications in (4) are analogous to modification (3) in that the same points (here: negative points associated with large fish) are prevented from being counted over and over again when the ESP value is computed (see section 2.3.). The other aspect of this modification is that isolated peaks, i.e. peaks "surrounded by zero frequencies and which were previously multiplied by a factor whose value descended arithmetically with ascending number of surrounding zero frequencies (i.e. from 1.0 to 0.2, in steps of 0.2, for 0 to 4 zeros) are now multiplied with factors whose value descend geometrically with ascending number of surrounding zeros (see Table 2, section 2.3).

Modification (2), used in the proper fashion, should also contribute to improved growth parameter estimates. What is meant here is that the ELEFAN 1 and 2 programs can be used iteratively as follows:

(i) first estimate $L_{oo}$ using ELEFAN 2B.

(ii) estimate the other growth parameters in a first pass with ELEFAN 1.

(iii) construct a catch curve and associated probabilities of capture for small animals using ELEFAN 2A.

(iv) use the estimated probabilities of capture to correct the original length-frequency data for selection effects (using ELEFAN 0).

(v) reestimate growth parameters (other than $L_{oo}$) in a second pass with ELEFAN 1.

(vi) reestimate catch curve and derived quantities using ELEFAN 2A with the new growth parameters and the original length-frequency data file, etc. (see Fig.1).

Usually, one single iteration will suffice to bring convergence about, i.e. to obtain growth parameters not biased by selection effects (such parameters will usually include higher values of K!).

This iterative procedure will not work, however, only if very low probabilities of capture (say $<$0.01) are used to correct the length-frequency data because very low probabilities would overcompensate for the effects of selection.

Modification (1) is straightforward enough, and comments on it are not really needed. Rather we shall reiterate here the need, when working with the ELEFAN programs, to use length-frequency data as representative as possible of the population sampled, covering a range of length as wide as possible, and biased as little as possible by size-selective sampling gears and uneven distribution of the sampled population. Also, care should be taken to use samples obtained at intervals as regular as possible (this is however not a necessary requirement), and of sizes not varying too widely (see Pauly 1984d for a step-by-step approach to obtain representative length frequency samples from stratified random trawl surveys).

A modification with affects both ELEFAN 1 and 2 is that the growth equation used (see section 2.4.) assumes the parameter D in the generalized von Bertalanffy equation (see Pauly and David 1981 and Pauly 1984c) to be equal to 1 (i.e. the parameter does not occur). This has the important implications that

(i) computation time is reduced for ELEFAN 1, and

(ii) avoids confusing users of the programs with what probably was a superfluous refinement.

We hope that this new version of the ELEFAN 0, 1 and 2 programs will contribute toward the ELEFAN approach fulfilling its promise of simple, cheep and reliable fish stock assessments (Morgan 1983, Mathews, in press), as well as help benthologists and others working on growth and production of invertebrates. Toward this aim, we have added to the reference list - over and beyond the items cited in the text - a number of references presenting applications of the ELEFAN programs to fish and invertebrate stocks throughout the works. Users of this guide are invited to familiarize themselves with these papers, because it is such familiarity which will allow them to make the best of their data and of the programs presented here.

Good luck!

## 2. User's guide, by program

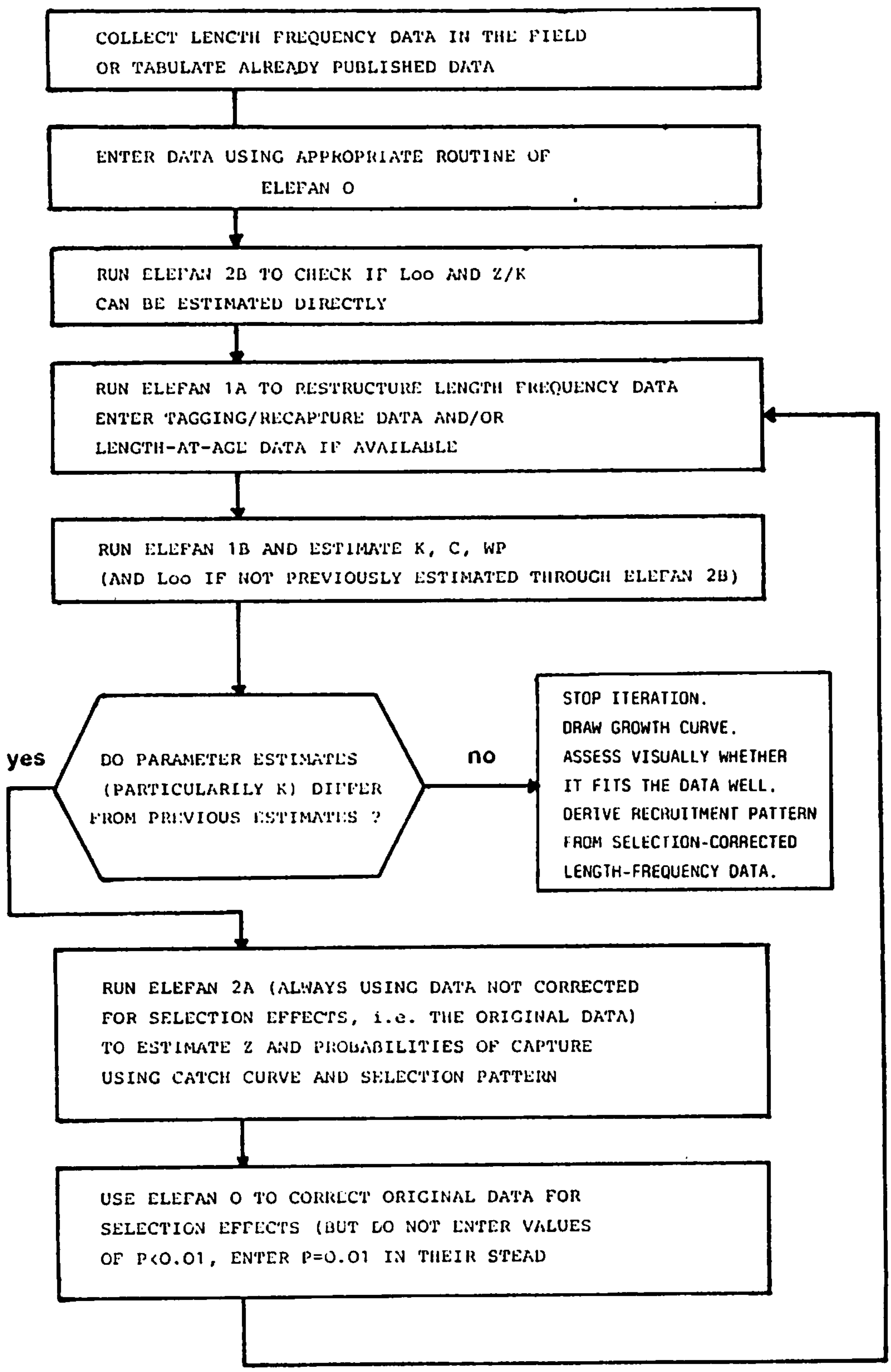
The structure of the ELEFAN program package and the links between the different programs are demonstrated by the flow chart in Fig.1.

The ELEFAN program package consists of the following programs:

START : Main menu program
ELEFAN 0 : Data file managment
including library management subprogram EDITLIB
ELEFAN 1A: Restructuring of length-frequency data
Optional input of tagging data and/or length at-age data
ELEFAN 1B: Identification of the best fitting growth curve
ELEFAN 2B: Estimation of total mortality
Derivation of seasonal patterns of recruitment
ELEFAN 2B: Estimation of Loo and Z/K from mean lengths

- All programs are written in Microsoft Basic (version 5.2). The output procedures are adapted to Epson compatible printers. The program package is availabile on disk in a CP/M version and in a MS-DOS version.
- Each Yes/No decision asked by the program has to be answered by 1 (=Yes) or by 0 (=No).
- Do not use any comma within an "additional information" string.

Fig.1 Flow chart showing the links between the ELEFAN programs.



## 2.1. START: Main menu program

Every ELEFAN program (O, 1A, 1B, 2A, 2B) can be entered directly or by the main menue program START. Finishing the work with any ELEFAN program will leed back automatically to the START program.

## 2.2. ELEFAN O: Data file management

ELEFAN O is the program for the management of length-frequency data and length-frequency data files. The optional procedures are shown in the following menu.

| | |
|---|---|
| CREATE NEW FILE: | <1> |
| SELECT SAMPLES FROM OLD FILE: | <2> |
| EDIT OLD FILE: | <3> |
| EDIT OLD FILE: CORRECTION FOR SELECTION EFFECTS | <4> |
| EDIT OLD FILE: CHANGE LENGTH CLASS SIZE | <5> |
| DATA FILE LIBRARY MANAGMENT | <6> |
| BACK TO ELEFAN MAIN MENU | <7> |

* The maximum size of a data matrix is 24 samples * 30 length classes. *
* Only INTEGER-values can be used as frequency data. If available data are % values only, simply multiply them all by a factor of 100. *
* If ELEFAN O is running for the first time, use option <6> DATA FILE LIBRARY MANAGMENT for the initialization of a first data file library. Maximum number of data files in one file-library: 50 files. *

After any modification of a data file it is reviewd for corrections and can be stored on disk and printed out on a lineprinter. Tab. 1 shows a matrix of 7 length-frequency samples of Syndosmya alba from Kiel Bay as printed with ELEFAN O. These data shall be used throughout this guide (in text, figures and tables) to illustrate the procedures described. Also note that MIDL. stands for "midlength", an abbreviation for the median of a length class.

Tab.1 Syndosmya alba data file

B:SYSF11.DAT

Syndosmya alba / SF 04.1976 - 06.1977 / 1mm classes

| SAMPLE No | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| DAY.MONTH | | 17.04 | 2.07 | 19.09 | 15.12 | 18.02 | 30.04 | 24.06 |
| CLASS | MIDL. | | | | | | | |
| 1 | 1.5 | 0 | 0 | 0 | 2 | 0 | 2 | 0 |
| 2 | 2.5 | 0 | 1 | 9 | 1 | 1 | 1 | 0 |
| 3 | 3.5 | 0 | 1 | 34 | 3 | 0 | 1 | 0 |
| 4 | 4.5 | 1 | 0 | 96 | 3 | 0 | 1 | 0 |
| 5 | 5.5 | 1 | 1 | 68 | 4 | 2 | 1 | 0 |
| 6 | 6.5 | 1 | 0 | 50 | 21 | 4 | 5 | 0 |
| 7 | 7.5 | 3 | 0 | 16 | 33 | 9 | 7 | 1 |
| 8 | 8.5 | 9 | 3 | 2 | 47 | 26 | 12 | 5 |
| 9 | 9.5 | 5 | 3 | 1 | 34 | 30 | 14 | 10 |
| 10 | 10.5 | 0 | 6 | 1 | 16 | 14 | 3 | 3 |
| 11 | 11.5 | 3 | 1 | 0 | 9 | 11 | 0 | 0 |
| 12 | 12.5 | 1 | 0 | 0 | 4 | 4 | 0 | 0 |
| 13 | 13.5 | 1 | 0 | 0 | 3 | 2 | 2 | 0 |
| 14 | 14.5 | 0 | 1 | 0 | 2 | 2 | 1 | 0 |

## Actual run of ELEFAN 0

The user must select a procedure from the menu shown above. A short description of these procedures is given here.

<1> CREATE NEW FILE (Creation of a new data file)

The program asks for:
- DATA FILE NAME
- ADDITIONAL INFORMATIONS
- NUMBER OF SAMPLES
- LOWEST MIDLENGTH [1)]
- HIGHEST MIDLENGTH
- INTERVAL SIZE

The input procedure starts with the first sample, and asks for:
- MONTH (of sampling)

1) Avoid a unit of length which leads to length values > 320 .

- DAY (of sampling)
- LOWEST MIDLENGTH (with F>0 in this sample)
- HIGHEST MIDLENGTH (with F>0 in this sample)

If the sampling date in a given month is unknown, use the 15th; use an "average" sampling date if samples have been pooled within a month.
Then the frequency values of this sample are entered.
After the last sample has been entered, each sample is displayed again in the REVIEW FOR ERRORS procedure. Uncorrect sampling dates or frequency values can be corrected.
When the REVIEW procedure has been completed, the OUTPUT ROUTINE is entered. The data set can be stored on disk (the data file name can be stored in a data file library file) and/or printed out on a lineprinter.

<2> SELECT SAMPLES FROM OLD FILE (forming a new data file)
The program asks for the name of the old data file and loads it. The dates of all samples are displayed. The user must decide wether a sample is to be included in the new file or not. REVIEW and OUTPUT are as described above.

<3> EDIT OLD FILE (Correction of erroneous data)
REVIEW and OUTPUT are as described above. The user must decide wether the corrected file is stored under a new name or under the old name (the latter of which causes the old file to be deleted).

<4> EDIT OLD FILE: CORRECTION FOR SELECTION (probabilities of capture)
Probabilities of capture are estimated by means of a catch curve (i.e. program ELEFAN 2A) or through a gear selection experiment (not discussed here, but see Pope et al. 1975). After loading the data file, the program asks for the probabilities of capture (p), beginning with the lowest length class ( $F_i = F_i/p$). Probabilities of capture < 0.01 should be set equal to 0.01 to prevent inflation of corrected frequencies. REVIEW and OUTPUT are as described above.

<5> EDIT OLD FILE: INCREASE LENGTH CLASS SIZE
A length frequency data file can have its frequencies regrouped into larger classes, e.g. from 1mm length classes to 2mm length classes. The program asks for the number of length classes added up in one new length class. REVIEW and OUTPUT are as described above.

## ⟨6⟩ DATA FILE LIBRARY MANAGEMENT

This subprogram can handle two things:

- Initialization of a new data library file.
- Deletion of data files from a library file and from disk.

## 2.3. ELEFAN 1A: Restructuring of length-frequency data
## Optional input of tagging and/or length-at-age data

ELEFAN 1A provides a linkage between ELEFAN 0 and ELEFAN 1B. The program restructures a data matrix created with ELEFAN 0 and stored on disk. It is used also for the optional addition of tagging data or length-at-age data to the restructured length-frequency data.

### Restructuring of length-frequency data

The aim, in restructuring a set oflength-frequency samples is to arrive at an objective identification (or definition) of the peaks corresponding to "cohorts", independently of the height of the peaks themselves and of any assumed shape for the peaks (i.e. no assumptions are made about the shape of the length-frequency distribution within a single cohort).

The restructuring of length-frequency samples involves the following steps (each step is demonstrated in Tab. 4 with sample No 6 in Tab. 1):

(1) For each length class i (i=1 to n) the moving average $MA_i$ (over 5 length classes) is computed. Zero frequencies are used for the length classes i=0, i=-1, i=n+1, i=n+2.

$$MA_i = \sum_{j=i-2}^{j=i+2} F_j \;/\; 5$$

(2) Each frequency value $F_i$ is divided by its corresponding moving average $MA_i$. The resulting "adjusted" values $FA_i$ identify peaks ($FA_i \geq 1$) and troughs ($FA_i$ 1) of the length-frequency sample when

$$FA_i = F_i / MA_i$$

(3) The average adjusted frequency value FA is computed, which is usually not far from unity. Each $FA_i$ is divided by FA and 1 is subtracted, i.e.

$$F'_i = FA_i / FA - 1$$

At this stage the length-frequency sample consists of peaks ($F'_i > 0$), of points which are neither peaks nor troughs ($F'_i = 0$), of troughs ($-1 =< F'_i < 0$) and of points with $F'_i = -1$, which correspond to the original zero values ($F_i = 0$).

(4) The procedure described in (1)-(3) has the disadvantage that the height of a positive value will be inflated by zero frequencies "surrounding" the length class in question. If a frequency value $F_i$ is surrounded by two zero frequencies on each side, the moving average $MA_i$ will be equal to $F_i/5$ and $FA_i = F_i/(F_i/5) = 5$.

Considering that the "points" of peaks surrounded by nonzero frequencies are generally in the range of 1 or less, all positive values $F'_i$ referring to frequencies surrounded by zero frequencies are multiplied by a factor of $1/(2^{nz})$ for nz surrounding zero frequencies (Tab.2).

Tab.2 Adjustment of peaks $F'_i$ for adjacent zero frequencies (i.e. for frequencies one or two classes to the left or right of a given lengthclass)

| No of zero frequencies included in computation of $MA_i$ | Adjustment of $F'_i$ |
|---|---|
| 1 | $F'_i = 0.5000 * F'_i$ |
| 2 | $F'_i = 0.2500 * F'_i$ |
| 3 | $F'_i = 0.1250 * F'_i$ |
| 4 | $F'_i = 0.0625 * F'_i$ |

An additional, optional procedure to reduce the influence of low frequency values is implemented in the version of ELEFAN described here. All positive restructured values $F'_i$ are divided by a factor depending on $F_i$:

$$F'_i = F'_i \; / \; SQR(1+2/F_i^2)$$

This seems to be useful if length-frequency data including a lot of low values ($F_i < 10$) are examined. The effect of this procedure (not included in previous versions of ELEFAN) is shown in Tab. 3.

Tab.3 Adjustment of peaks for low frequency values

| Frequency value $F_i$ | Adjustment of $F'_i$ |
|---|---|
| 1 | $F'_i = F'_i$ / 1.732 |
| 2 | $F'_i = F'_i$ / 1.225 |
| 3 | $F'_i = F'_i$ / 1.106 |
| 4 | $F'_i = F'_i$ / 1.061 |
| 5 | $F'_i = F'_i$ / 1.039 |
| 10 | $F'_i = F'_i$ / 1.010 |

(5) All values =-1 are set back to zero, the sum of all positive values SUM(+) and the sum of all negative values SUM(-) is calculated and all negative values are multiplied by the ratio SUM(+)/SUM(-). This results in a restructured length-frequency sample with equal sums of positive and negative values.

Tab.4 Illustration of restructuring procedure
(Demonstrated with sample No 6 in Tab. 1)

| Midl. | $F_i$ | $MA_i$ | $AF_i$ | $F_i/\overline{AF}$ | Subtract 1 | Adjust for zero frequ | Adjust for $F_i$ | Neutralized |
|---|---|---|---|---|---|---|---|---|
| 1.5 | 2 | 0.8 | 2.500 | 2.187 | + 1.187 | + 0.297 | + 0.242 | + 0.242 |
| 2.5 | 1 | 1.0 | 1.000 | 0.875 | - 0.125 | - 0.125 | - 0.125 | - 0.054 |
| 3.5 | 1 | 1.2 | 0.833 | 0.729 | - 0.271 | - 0.271 | - 0.271 | - 0.117 |
| 4.5 | 1 | 1.8 | 0.556 | 0.486 | - 0.514 | - 0.514 | - 0.514 | - 0.222 |
| 5.5 | 1 | 3.0 | 0.333 | 0.291 | - 0.709 | - 0.709 | - 0.709 | - 0.307 |
| 6.5 | 5 | 5.2 | 0.962 | 0.842 | - 0.158 | - 0.158 | - 0.158 | - 0.069 |
| 7.5 | 7 | 7.8 | 0.897 | 0.785 | - 0.215 | - 0.215 | - 0.215 | - 0.093 |
| 8.5 | 12 | 8.2 | 1.463 | 1.280 | + 0.280 | + 0.280 | + 0.278 | + 0.278 |
| 9.5 | 14 | 7.2 | 1.944 | 1.701 | + 0.701 | + 0.351 | + 0.349 | + 0.349 |
| 10.5 | 3 | 5.8 | 0.517 | 0.452 | - 0.548 | - 0.548 | - 0.548 | - 0.463 |
| 11.5 | 0 | 3.8 | 0 | 0 | - 1 | - 1 | - 1 | 0 |
| 12.5 | 0 | 1.2 | 0 | 0 | - 1 | - 1 | - 1 | 0 |
| 13.5 | 2 | 0.6 | 3.333 | 2.916 | + 1.916 | + 0.240 | + 0.196 | + 0.196 |
| 14.5 | 1 | 0.6 | 1.667 | 1.458 | + 0.458 | + 0.057 | + 0.033 | + 0.033 |

$\overline{AF} = 1.143$

SUM(+) = 1.098
SUM(-) = 2.540
SUM(+)/ SUM(-) = 0.432

(6) The final step is to replace all negative values occuring in the highest lengthclass of a length-frequency data set by zero values and to divide all negative values occuring in the penultimate length class by 2. Simulation studies with the ELEFAN method showed that this contibute to reducing overestimation of $L_{oo}$ (see Introduction).

## Conversion of length-at-age data into growth increment data

Because of the mathematical problems related to the estimation of $t_0$ arising with the inclusion of length-at-age data in the ELEFAN procedure, these data are converted into growth increment data. These growth increment data, having a structure resembling tagging/recapture data are analyzed as if they were, in fact, tagging/recapture data (or tagging data for short). A maximum number of 10 ages can be entered. Because seasonal oscillations in growth are included in the growth model used by ELEFAN, it is important to know the date of sampling of the length-at-age data. Age is entered in form of sampling date and number of years completed until sampling date.[1] For each age, 20 length data can be entered. Thus a maximum number of 200 length-at-age data pairs can be entered.

Sorting the age data in an ascending row ($age_1$, $age_2$,... $age_{10}$), a maximum number of 20 * 20 combinations of growth increments (length at $age_i$ to length at $age_{i+1}$) and a total of 9 * 20 * 20 (=3600) combinations of lengths between adjacent ages exists, representing the growth increment from $age_i$ to $age_{i+1}$.

Using a random procedure, a maximum number of 100 pairs of $age_i$/$length_i$ and $age_{i+1}$/$length_{i+1}$ is selected from all possible combinations.

In order to get a more or less equal distribution of data pairs over the whole length range, this range is divided into 10 intervals of equal size. Each growth increment selected is sorted into these length classes with respect to its mean length $(L_i+L_{i+1})/2$. A maximum number of 10 growth increments/length-interval is possible, which corresponds to the overall maximum number of 100 combinations.

Tab. 5 shows a set of length-at-age data selected from the known growth curve of Syndosmya alba and the length-frequency data in Tab. 1.

Tab.5 Length-at-age data of Syndosmya alba.

| date of sampling | | number of years | length (mm) |
|---|---|---|---|
| day | month | completed | |
| 15 | 12 | 0 | 8.0, 8.5, 8.5, 9.0 |
| 30 | 04 | 0 | 8.5, 9.0, 9.0, 9.5 |
| 02 | 07 | 0 | 9.5, 10.0, 10.5 |
| 30 | 04 | 1 | 13.0, 13.5, 13.5 |
| 30 | 04 | 2 | 14.5, 14.5 |

## Actual run of ELEFAN 1A

The program is entered from the main menu START. It works only with data

1) Years refers to the biological date of birth.

stored on disk (by means of ELEFAN 0).
After loading the data file, the program asks:

```
ADJUSTMENT OF PEAKS: OPTION A <1> OR OPTION B <2> :
```

If 1 is entered, only the adjustment for surrounding zero frequencies is performed, if 2 is entered, the additional adjustment for low frequency value is also performed.
Each sample is restructured and displayed. At the end the Available Sum of Peaks (ASP) is computed and displayed.
Then a short menu is displayed:

```
----- OPTIONAL INPUT MENU -----
INPUT OF TAGGING DATA             <1>
INPUT OF LENGTH-AT-AGE DATA       <2>
GROWTH INCREMENT DATA FROM DISK <3>
NO ADDITIONAL DATA                <4>
                        SELECT NUMBER :
```

<1> INPUT OF TAGGING DATA
Up to 100 sets of tagging/recapture data are allowed. The program asks for the number of data pairs. Data input procedure (Xth data pair):

```
ENTER NUMBER OF DATA PAIRS (<=100):
------------------------------------------

DATA PAIR No X

ENTER TAGGING-   LENGTH, YEAR, MONTH, DAY :
IS THIS CORRECT ? <0> OR <1> :

ENTER RECAPTURE- LENGTH, YEAR, MONTH, DAY :
IS THIS CORRECT ? <0> OR <1> :
```

After all data are entered they are displayed again. The date values have been converted into <u>relative</u> age data (expressed as fraction of year).

<2> INPUT OF LENGTH-AT-AGE DATA
The maximum size of the data matrix is 10 age * 20 lengths at-age.

Age data must be entered in ascending row.

Data input procedure (Xth age, first length):

X th AGE:

ENTER DAY, MONTH OF SAMPLING (ENTER 999, 999 IF READY) :

ENTER NUMBER OF YEARS COMPLETED:

IS THIS CORRECT ? <0> OR <1> :

1 th LENGTH

ENTER LENGTH (ENTER 999 IF READY) :

READY means that all data have been entered. The length data for each age are reviewed before the next age is entered.

The following random procedure for selecting data combinations may require a few minutes of computation. The growth increments selected and their distribution over the available length range are displayed.

<3> GROWTH INCREMENT DATA FROM DISK

If tagging data or length-at-age data have been stored on disk during a previous run of ELEFAN 1A, they can be added to the actual restructured length frequency data using this option.

It is not possible to use this option together with option 1 or option 2 !

ENTER FILENAME :

IS THIS CORRECT ? <0> OR <1>:

If the data file loaded contains no growth increment data the program jumps back to the OPTIONAL INPUT MENU.

Finally, the new data file is named. The very last procedure included in ELEFAN 1A is an OUTPUT-ROUTINE as described above. If the data file is printed out on lineprinter, any growth increment data will optionally be printed. Tab. 6 shows the restructured length-frequency data of Syndosmya alba (Tab. 1) and Tab. 7 shows the randomly selected growth increments depending on the length-at-age data in Tab. 5.

Tab.6 Example output of ELEFAN 1A, length-frequency data

B:SYSF11R.DAT

Syndosmya alba / SF 04.1976 - 06.1977 / 1mm classes / OPTION B

| SAMPLE No | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| DAY.MONTH | | 17.01 | 2.07 | 19.09 | 15.12 | 18.02 | 30.04 | 24.06 |
| CLASS | MIDL. | | | | | | | |
| 1 | 1.5 | 0.000 | 0.000 | 0.000 | 0.161 | 0.000 | 0.242 | 0.000 |
| 2 | 2.5 | 0.000 | 0.067 | -0.515 | -0.275 | 0.130 | -0.054 | 0.000 |
| 3 | 3.5 | 0.000 | 0.041 | -0.023 | 0.216 | 0.000 | -0.117 | 0.000 |
| 4 | 4.5 | 0.077 | 0.000 | 1.210 | -0.338 | 0.000 | -0.222 | 0.000 |
| 5 | 5.5 | -0.165 | 0.067 | 0.542 | -0.452 | -0.161 | -0.306 | 0.000 |
| 6 | 6.5 | -0.490 | 0.000 | 0.275 | 0.044 | -0.229 | -0.069 | 0.000 |
| 7 | 7.5 | -0.194 | 0.000 | -0.258 | 0.274 | -0.173 | -0.093 | -0.373 |
| 8 | 8.5 | 0.642 | -0.032 | -0.694 | 0.617 | 0.440 | 0.278 | 0.016 |
| 9 | 9.5 | 0.072 | -0.096 | -0.588 | 0.313 | 0.533 | 0.349 | 0.528 |
| 10 | 10.5 | 0.000 | 0.378 | 0.069 | -0.149 | -0.101 | -0.237 | -0.171 |
| 11 | 11.5 | 0.172 | -0.528 | 0.000 | -0.182 | -0.071 | 0.000 | 0.000 |
| 12 | 12.5 | -0.057 | 0.000 | 0.000 | -0.251 | -0.184 | 0.000 | 0.000 |
| 13 | 13.5 | -0.028 | 0.000 | 0.000 | -0.036 | -0.107 | 0.196 | 0.000 |
| 14 | 14.5 | 0.000 | 0.103 | 0.000 | 0.039 | 0.031 | 0.033 | 0.000 |

ASP = 5.881

Tab 7. Example output of ELEFAN 1A, growth increment data derived from length-at-age data in Tab. 5.
The random search procedure has selected 40 combinations out of the total of 43 possible combinations.

B:SYSF11R.DAT

Syndosmya alba / SF 04.1976 - 06.1977 / 1mm classes / OPTION B

LENGTH-AT-AGE DATA

| No | L(1) | t(1) | L(2) | t(2) | No | L(1) | t(1) | L(2) | t(2) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 8 | .96 | 8.5 | 1.33 | 21 | 9 | .96 | 9 | 1.33 |
| 2 | 8 | .96 | 9.5 | 1.33 | 22 | 9 | .96 | 8.5 | 1.33 |
| 3 | 8 | .96 | 9 | 1.33 | 23 | 9.5 | 1.5 | 13.5 | 2.33 |
| 4 | 8.5 | .96 | 9 | 1.33 | 24 | 9.5 | 1.33 | 9.5 | 1.5 |
| 5 | 8.5 | .96 | 9 | 1.33 | 25 | 9.5 | 1.33 | 10 | 1.5 |
| 6 | 8.5 | .96 | 9 | 1.33 | 26 | 9.5 | 1.33 | 10.5 | 1.5 |
| 7 | 8.5 | .96 | 9.5 | 1.33 | 27 | 9.5 | 1.5 | 13 | 2.33 |
| 8 | 8.5 | 1.33 | 10.5 | 1.5 | 28 | 9.5 | 1.5 | 13.5 | 2.33 |
| 9 | 8.5 | 1.33 | 9.5 | 1.5 | 29 | 10 | 1.5 | 13.5 | 2.33 |
| 10 | 8.5 | .96 | 8.5 | 1.33 | 30 | 10 | 1.5 | 13 | 2.33 |
| 11 | 8.5 | .96 | 8.5 | 1.33 | 31 | 10 | 1.5 | 13.5 | 2.33 |
| 12 | 8.5 | .96 | 9 | 1.33 | 32 | 10.5 | 1.5 | 13 | 2.33 |
| 13 | 8.5 | 1.33 | 10 | 1.5 | 33 | 10.5 | 1.5 | 13.5 | 2.33 |
| 14 | 8.5 | .96 | 9.5 | 1.33 | 34 | 10.5 | 1.5 | 13.5 | 2.33 |
| 15 | 9 | 1.33 | 10 | 1.5 | 35 | 13 | 2.33 | 14.5 | 3.33 |
| 16 | 9 | 1.33 | 10.5 | 1.5 | 36 | 13 | 2.33 | 14.5 | 3.33 |
| 17 | 9 | 1.33 | 9.5 | 1.5 | 37 | 13.5 | 2.33 | 14.5 | 3.33 |
| 18 | 9 | 1.33 | 10 | 1.5 | 38 | 13.5 | 2.33 | 14.5 | 3.33 |
| 19 | 9 | 1.33 | 9 | 1.5 | 39 | 13.5 | 2.33 | 14.5 | 3.33 |
| 20 | 9 | .96 | 9 | 1.33 | 40 | 13.5 | 2.33 | 14.5 | 3.33 |

## 2.4. ELEFAN 1B: Identification of the best fitting growth curve

This program fits a von Bertalanffy growth curve to a given set of restructured length-frequency samples or to a set of restructured length-frequency samples combined with a set of tagging data and/or length-at-age data (expressed as growth increments, see above).

### Available Sum of Peaks (ASP) and Explained Sum of Peaks (ESP)

Let us assume a set of ns restructured length-frequency samples. Usually we will find a number of np peaks (= runs of positive values) within each of the ns samples. If it is assumed that each peak corresponds to a distinct age class, it follows that any growth curve going through a certain peak will be able to "hit" only one of the length classes constituting this peak. Thus, by definition, the maximum sum of positive point values that can be accumulated by a growth curve fitted to a set of ns samples equals the sum of the highest values of all np peaks in all ns samples. This sum is called Available Sum of Peaks (ASP), and

$$ASP = \sum_{i=1}^{ns} \sum_{j=1}^{np} \text{Highest value of peak}(i,j)$$

i=index of sample, j=index of peak

Any growth curve passing through a restructured length-frequency data matrix will "hit" a number of points (= length L at time t) within this matrix. Adding up the restructured frequency values corresponding to these points, a sum will be obtained which can never exceed the ASP*. A curve which goes through many peaks while avoiding most of the troughs will reach a high sum of points. This curve will interconnect a large number of peaks and is considered here to explain the positions of these peaks as the result of individual growth of the animals investigated. Therefore the sum of values corresponding to the points "hit" by the curve is called Explained Sum of Peaks (ESP).

The ratio ESP/ASP is the index for the goodness of fit of a growth curve. With regard to the definition of ASP and ESP the ESP/ASP-ratio can never exceed 1*, and roughly corresponds to the parameter $r^2$ in correlation analysis.

* Footnote: For this to apply, care must be taken to ensure (as done in this version) that, once a curve has hit any part of a peak, this entire

peak should be "flagged out", i.e. not counted should it be hit again (one year later) by the same curve. This feature, not included in earlier versions of ELEFAN 1 completely supress the possibility of ESP/ASP values >1, prevents "drifting" of K toward impossibly low values (see Pauly et al. 1981) an in fact contributes toward reducing the negative bias associated with many estimates of K (Rosenberg and Beddington, in press, and see also introduction). *

---

## Index of goodness of fit for tagging data and length-at-age data

The calculation of the index of goodness of fit is the same for tagging data and converted length-at-age data (i.e. growth increment data). Therefore references will be made in the following to tagging data only.

A set of tagging data consists of a number nt of data pairs $L_1,t_1$ and $L_2,t_2$ which are one length at time $t_1$ and a second length at time $t_2$.

The change in length per time is given by

$$\Delta L/\Delta t = ( L_2-L_1 ) / ( t_2-t_1 )$$

With any set of growth parameter values K, $L_{oo}$, C, and WP one can also calculate a theoretical length-increment by asking: what length would an animal of length $L_1$ at time $t_1$ have at time $t_2$ if its growth follows exactly the growth equation implied by the current set of growth parameter values?

For each of the nt tagging data pairs the following calculations are performed:

- Calculation of the empirical length increment $\Delta L/\Delta t$
- Calculation of an internal "$t_0$" using the current growth parameter values and $L_1,t_1$
- Calculation of the expected length $L'_2$ at time $t_2$ using the growth parameter values and the "$t_0$".
- Calculation of the theoretical length-increment $\Delta L'/\Delta t$
- Calculation of the difference between empirical and theoretical length-increment $d(incr) = \Delta L/\Delta t - \Delta L'/\Delta t$

Now it is possible to calculate the variance $v_e$ of the empirical length-increment data:

$$v_e = ( \sum(\Delta L/\Delta t)^2 - (\sum \Delta L/\Delta t)^2)/nt)/(nt-1)$$

The variance $v_d$ of the differences d(incr) is calculated in the same way.

The smaller this $v_d$ is, the more of the empirical variance $v_e$ is explained

by the current growth parameter values.
The index

$$GT = ( v_e - v_d ) / v_e$$

is an index for the goodnessof fit (similar to $r^2$) of the growth parameters applied to the tagging data. If the fit is perfect, then all d(incr)=0 and $v_d$=0, which leads to the maximum possible value GT = 1.
For age at length data the calculation routine is exactly the same, but the index for the goodness of fit is called GA.

## Combined goodness of fit indices

In the following definitions are given for the combined indices of goodness of fit for possible combinations of data types considered in this version of ELEFAN 1.

| data type | | | index of goodness of fit |
|---|---|---|---|
| length-frequ. | tagging | length/age | |
| + | - | - | ESP/ASP |
| + | + | - | (ESP/ASP + GT)/2 |
| + | - | + | (ESP/ASP + GA)/2 |
| + | + | + | (ESP/ASP + GT + GA)/3 |

Length-frequency data must be be included in every combination. It will be noted that the combined indices for goodness of fit will never exceed 1 for any combination of data types.

## Optimization of the ESP/ASP-ratio

In the previous sections we explained how, for a given set of growth parameter values, a single value of ESP is obtained and how the ESP/ASP-ratio is calculated.
The main purpose of ELEFAN 1B is to find the optimal ESP/ASP-ratio, i.e. the best fitting growth curve. In the following we will refer only to one growth function, the von Bertalanffy growth function modified for seasonal oscillations in growth (Pauly and Gaschütz 1979):

$$L_t = L_{oo} \cdot (1 - e^{-K \cdot ((t-t_o) + \frac{C}{2\pi} \cdot \sin(2\pi \cdot (t-t_s)))})$$

$L_{oo}$ = asymtotic length

K = growth constant

C = constant expressing the amplitude of growth oscillation

$t_s$ = starting point of oscillation with respect to t=0

$t_0$ = origin of the growth curve

$L_t$ = length at age t

The winterpoint WP used in the ELEFAN programs is defined as the point of slowest growth within the year and is equal to $t_s$+ 0.5.

Obviously this equation reduces to the usual von Beralanffy function when C=0.

The constant $t_0$ cannot be estimated from length-frequency data alone. ELEFAN programs use an internal "$t_0$", whose value depends on the starting point of the growth curve in the length-frequency data matrix. This internal "$t_0$" value does not equal the $t_0$ value of the v.Bertalanffy equation!

It is for the purpose of identifying, from among the millions growth curves that are possible, a single "best fitting" growth that the power of a computer is actually most needed. The reason for this is that there is no continuous function which could be used to express the relationship between a given set of growth parameter values and the ESP/ASP ratio they generate. This implies that any search for an optimum combination of growth parameter values will have to be partly human-aided. In the case of ELEFAN 1B, this human input involves, as suggested by Rosenberg and Beddington (in press):

(i) identification of a (preferably narrow) range of growth parameter values between which the "true" values are expected, and

(ii) examination of the response surface, which should - in the ideal case - have a single clearly identifiable area with high ESP/ASP values (in cases where $L_{oo}$ is the ordinate and K the abcissa, this area should have the shape of a banana, suggestive of similar ESP/ASP for low values of K combined with high values of $L_{oo}$ and vice versa, see Tab. 10).

Actual run of ELEFAN 1B

The following steps are involved in the analysis of a set of length-frequency data by means of ELEFAN 1B:

(1) Load restructured data file

(2) Select search intervals for all growth parameters

GROWTH CONSTANT K:

FIXED K <1> OR VARIABLE K <2> :

VALUE OF K ?

A rather good empirical found first estimation of K is: K = 3/lifespan
If K is to vary, a search interval must be selected by entering a stepsize for K. This interval is K +/- 3*stepsize large.

ENTER STEP SIZE OF K (3 STEPS TO BOTH SIDES) :

(e.g. if K = 1.0 and STEP SIZE = 0.2, the search interval is 1.0 +/- 0.6 and the following seven values of K are used for growth curve calculations: K = 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6)

ASYMPTOTIC LENGTH Loo:

FIXED Loo <1> OR VARIABLE Loo <2> :

VALUE OF Loo ?

If Loo is to vary, the program displays:

LOWER LIMIT OF Loo ' (upper limit of highest length-class)

ENTER STEP SIZE OF Loo (3 STEPS TO BOTH SIDES) :

A first estimation of $L_{oo}$ can be: maximum length in data set divided by 0.95. Another approach to obtain a (first) estimation of $L_{oo}$ is through the ELEFAN 2B program (see introduction).

SEASONAL OSCILLATION IN GROWTH: AMPLITUDE CONSTANT C (O'=C)

SET C=0 IF GROWTH OSCILLATIONS ARE APPARENT

SET C=1 FOR SAMPLES FROM TEMPERATE WATERS

FIXED C <1> OR VARIABLE C <2> :

VALUE OF C ?

If the variable mode is selected:

ENTER STEP SIZE OF C (2 STEPS TO BOTH SIDES) :

If C>0, a value for the winterpoint, i.e. the time of slowest growth within the year, must be selected.

```
     WINTER POINT WP (0<=WP<1)
       FIXED WP <1> OR VARIABLE WP <2> :
       VALUE OF WP ?
```

If the variable mode is selected:

```
       ENTER STEP SIZE OF WP (2 STEPS TO BOTH SIDES) :
```

The last parameter to select is the starting point of the growth curve within the length-frequency data matrix. The starting point is necessary for the calculation of the internal "$t_0$" value.

Three possible options exist:

(i) Fixed starting point.

A given length in a given sample is used as starting point.

(ii) Fixed starting point within an interval of +/- 1/2 length class.

The point selected is the midpoint of an interval +/- 1/2 length class, the latter of which is divided into 10 parts of equal size (= 11 steps).

(iii) Variable starting point.

The highest value of each peak within the restructured length-frequency matrix (midlength and the two points +/- 1/2 lengthclass away) is examined. If the best ESP/ASP-ratio found exceeds 0.6, a search with smaller steps as described above is performed.

Starting point selection procedure:

```
     STARTING POINT VARIABLE                                   <1>
     STARTING POINT FIXED AT LENGTH                            <2>
     STARTING POINT FIXED AT LENGTH +/- 1/2 LENGTH CLASS       <3>
                                        SELECT NUMBER           :
```

Then all parameters entered are displayed, the input procedure repeated if necessary.

** Attention **

Do not allow too many parameters to vary at the same time! Tab. 8 gives an impression of the number of calculations related to different combinations of fixed and variable parameters (with starting point fixed).

Tab. 8 Number of growth curves examined for different growth parameter combinations. fix = fixed, var = variable

| Parameter | No of steps fix | No of steps var | mode | | | | |
|---|---|---|---|---|---|---|---|
| K | 1 | 7 | fix | var | var | var | var |
| Loo | 1 | 7 | fix | fix | var | var | var |
| C | 1 | 5 | fix | fix | fix | var | var |
| WP | 1 | 5 | fix | fix | fix | fix | var |
| | number of runs | | 1 | 7 | 49 | 245 | 1225 |

When working with a microcomputer, a rather economic strategy is to make a first run with all growth parameters fixed and while varying the starting point. In the following runs the growth parameters may be varied while holding the starting point fixed.

(3) Search routine

During the search routine the following informations are displayed:

Actual values of K, Loo, C, WP and the corresonding
BEST ESP/ASP-ratio, SAMPLE No, LENGTH

If the mode "VARIABLE" was selected, each starting point which leads to an ESP/ASP-ratio higher than 0.6 will be rechecked in small steps (of length!)

(4) Further processing

At the end of the search routine the growth parameter combination with the best ESP/ASP-ratio is displayed. The user has to decide:

| | |
|---|---|
| FURTHER SEARCH | <1> |
| RESPONSE SURFACE CALCULATION | <2> |
| GROWTH CURVE CALCULATION | <3> |
| END OF SEARCH | <4> |

Selecting 1 leads back to the growth parameter input procedure.
Selecting 2 leads to the RESPONSE SURFACE CALCULATION and back to this menu.
Selecting 3 leads to the OUTPUT PROCEDURE and back to this menu.

GROWTH CURVE CALCULATION

If tagging data and/or length-at-age data are included, the correlation between ESP/ASP and GT (and/or GA) is computed and displayed.

The best growth parameter values are displayed and the corresponding growth curve is calculated. (Growth curve points refer to the 15th of each month). Output on lineprinter is possible (see Tab.9).

* Important *

It may be impossible to compile ELEFAN 1B using BASCOM in the CP/M-version because the program is too long. In this case the growth curve calculations should be separated from ELEFAN 1B (compiled version).

The following modifications should be done in ELEFAN 1B:

```
line 2040 PRINT "GROWTH CURVE CALCULATION NOT INCLUDED"
line 2050 INPUT "ENTER <RET> TO CONTINUE : ",C1:RETURN
delete lines 2060 - 2500
```

The resulting program (without growth curve calculation) is short enough to be compiled. Use the interpreter-version of ELEFAN 1B for the calculation of the growth curve.

RESPONSE SURFACE CALCULATION

This routine is computing a ESP/ASP-ratio matrix for a fixed startingpoint. Two growth parameters can be held variable. The resulting matrix shows the response of the ESP/ASP-ratio to changes in the growth parameters and gives an impression of the reliability of the "best" growth parameter estimates (as in Brouard and Grandperrin 1984, and see introduction).

Actual running:

```
RESPONSE SURFACE CALCULATION
** 2 GROWTH PARAMETERS (K, Loo, C, WP) VARIABLE **
ENTER GROWTH PARAMETER INTERVALS (LOWER, UPPER LIMITS)
IF FIXED THEN ENTER LOWER LIMIT = UPPER LIMIT
K   : ENTER LOWER, UPPER LIMIT:
Loo : ENTER LOWER, UPPER LIMIT:
C   : ENTER LOWER, UPPER LIMIT:
WP  : ENTER LOWER, UPPER LIMIT:
```

* Important: In the case of the response surface, the lower limit of $L_{oo}$ is allowed to be smaller than the largest size class in the samples, but it

must exceed the length of the starting point. [1]
The response surface is calculated and displayed. Output on linepriner is possible (see Tab. 10).

Tab. 9 Example output of ELEFAN 1B
Growth curve fitted to the restructured data in Table 6.

B:SYSF11R.DAT
Syndosmya alba / SF 04.1976 - 06.1977 / 1mm classes / OPTION B

v.BERTALANFFY GROWTH CURVE FITTED TO THE DATA

GROWTH-PARAMETERs: K = 1.22
Loo= 15.1
C = 1.18
WP = .18

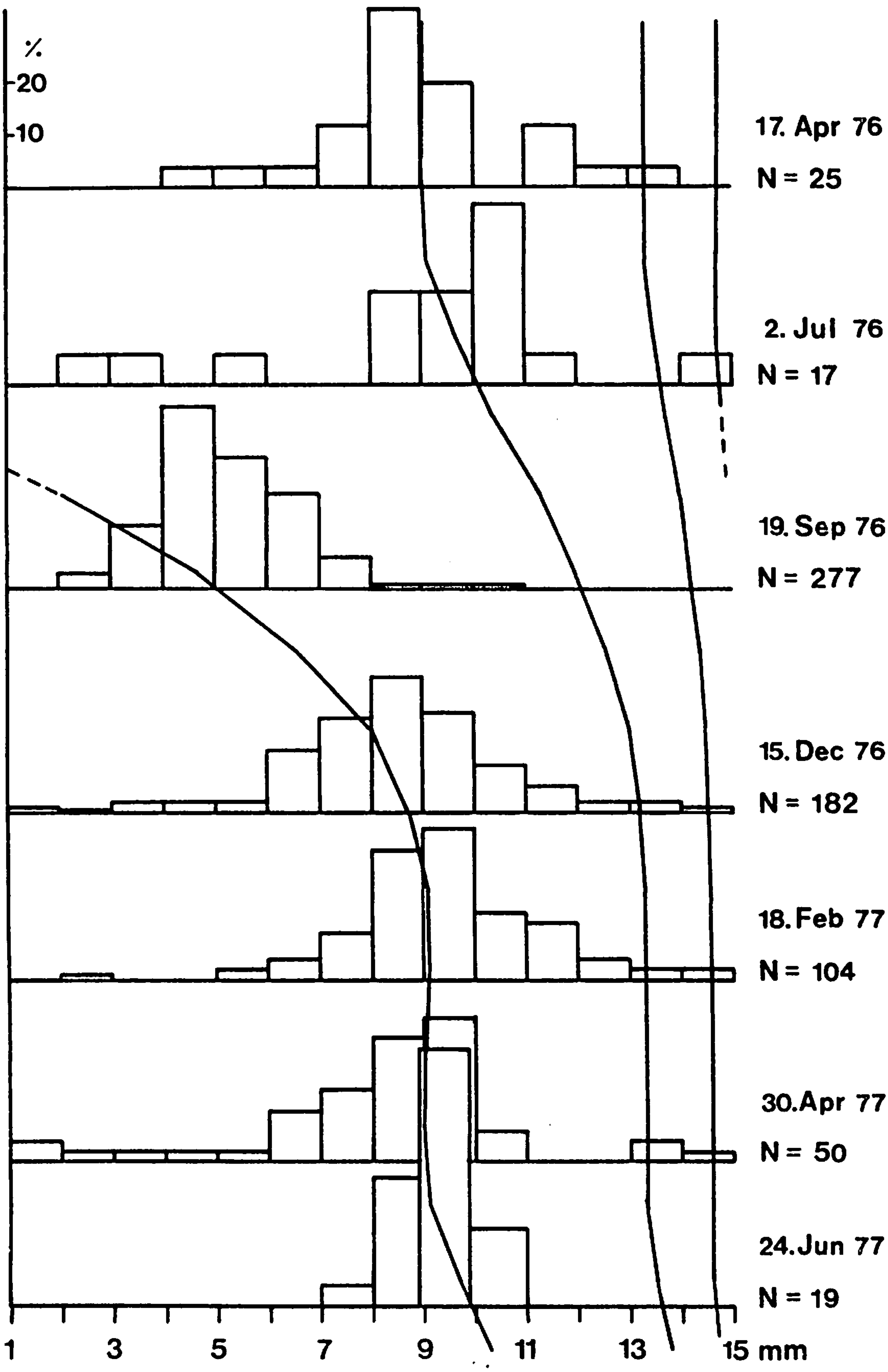
STARTING POINT: SAMPLE 4, CLASS 8, LENGTH 8.74
ESP/ASP = .767

GROWTH CURVE POINTS (LENGTH) FOR THE 15th OF EACH MONTH

| MONTH | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.1 | 4.7 | 6.6 | 8 | 8.7 |
| | 9.1 | 9.1 | 9 | 9 | 9.1 | 9.7 | 10.4 | 11.3 | 12 | 12.6 | 13 | 13.2 |
| | 13.3 | 13.3 | 13.3 | 13.3 | 13.3 | 13.5 | 13.7 | 14 | 14.2 | 14.4 | 14.5 | 14.5 |
| | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.7 | 14.8 | 0 | 0 | 0 | 0 |

1) and the length of each length-increment data pair too, if included.

Fig. 2 Lenght-frequency data of Syndosmya alba with superimposed growth curve fitted by ELEFAN.



Tab. 10 Example of a response surface.
Depending on the Syndosmya alba data (Tab. 6)

B:SYSF11R.DAT

Syndosmya alba / SF 04.1976 - 06.1977 / 1mm classes / OPTION B

RESPONSE SURFACE CALCULATION

K : .62 - 1.70

Loo: 13.1 - 22.1

C : 1.18 - 1.18

WP : .18 - .18

| K | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| .62 | -447 | 133 | 387 | 431 | 454 | 523 | 530 | 616 | 623 | 623 |
| .74 | -212 | 155 | 435 | 459 | 470 | 530 | 641 | 504 | 396 | 396 |
| .86 | -164 | 487 | 445 | 516 | 611 | 641 | 621 | 396 | 187 | 187 |
| .98 | 49 | 369 | 475 | 513 | 744 | 524 | 396 | 187 | 187 | -51 |
| 1.1 | 12 | 445 | 521 | 740 | 541 | 314 | 187 | 103 | -51 | 37 |
| 1.22 | 79 | 445 | 767 | 626 | 314 | 187 | 103 | -51 | 37 | 37 |
| 1.34 | 134 | 474 | 767 | 332 | 314 | 103 | 37 | 37 | 37 | 37 |
| 1.46 | 122 | 683 | 546 | 332 | 103 | 37 | 37 | 37 | 37 | 37 |
| 1.58 | 122 | 701 | 336 | 248 | 191 | 37 | 37 | 37 | 37 | 126 |
| 1.70 | 251 | 409 | 248 | 231 | 37 | 37 | 37 | 37 | 126 | 126 |
| Loo | 13.1 | 14.1 | 15.1 | 16.1 | 17.1 | 18.1 | 19.1 | 20.1 | 21.1 | 22.1 |

## 2.6. ELEFAN 2A: Estimation of total mortality and related parameters

ELEFAN 2A is used for the estimation of (1) the mortality (and related parameters) of the population in question by means of a "length-converted catch curve" and for the calculation of (2) the seasonal recruitment pattern of the population.

### Mortality and the concept of a "length-converted catch curve"

For ecologists, this is the most interesting part of the ELEFAN-programs, because the "length-converted catch curve" is a way to estimate the annual P/B-ratio of the investegated population.
Allen (1971) showed that the total mortality Z of a population is equal to the P/$\bar{B}$-ratio, if mortality can be expressed by a single negative exponential function and if the individual growth can be described by a von Bertalanffy function. ( Valid for steady-state populations only.)
The "length-converted" catch curve is a simple way to estimate the mortality of a population, if the growth parameters are known, and if the assumption of stable age distribution implied in catch curve-based methods is reasonable (see below).

### Theory of catch curves

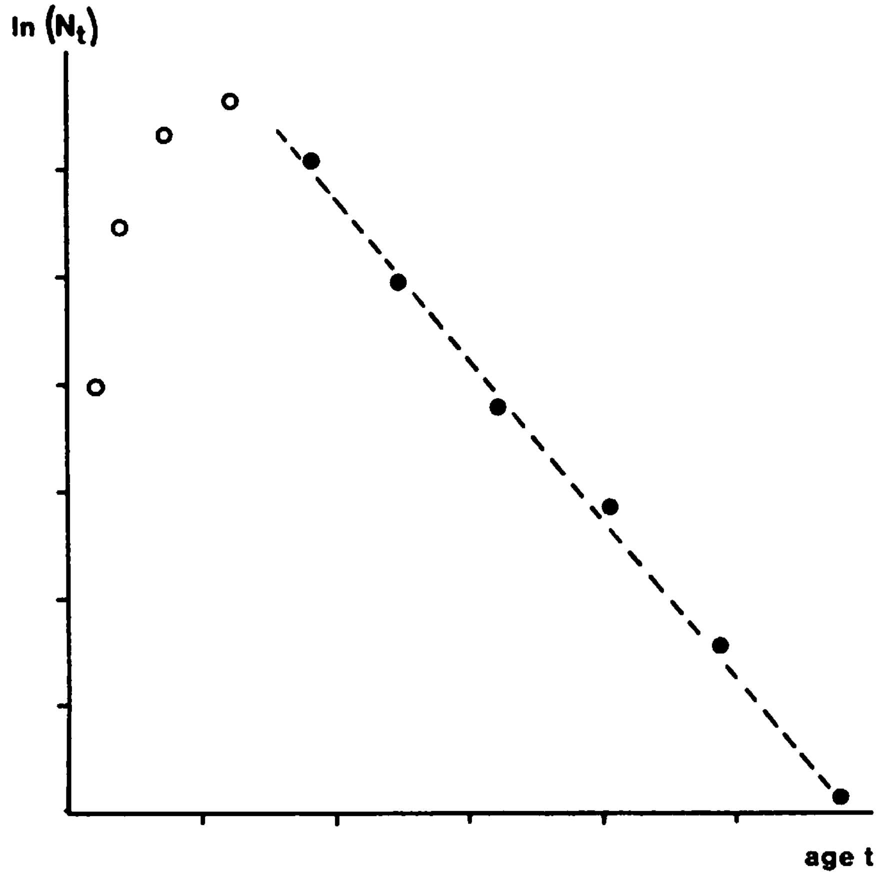
Catch curves are usually constructed for the investigation of the mortality within natural fish populations (see Ricker 1975). Essentially they consist of a plot of the natural logarithm of abundance in various age classes N(t) against their corresponding age t, as shown in Fig.3.
The ascending left part of the plot is due to the decreasing catch efficiency of the gear with decreasing size of fish. The descending right part of the plot can be ascribed to mortality within the population.
If the mortality of the population follows a single negative exponential model

$$N_t = N_0 * e^{-Z*t}$$

then a catch curve will show a rather straight descending right arm, which can be described by a linear equation which is the logarithmic form of the equation above

$$\ln(N_t) = a + b * t$$

Fig. 3 Hypothetical age-structured catch curve




and the total mortality Z is equal to the slope b (with sign changed).

If the individual age of the animals is not known, a "length-converted" catch curve can be used in the same way as described above to determine the total mortality Z (Pauly 1982, 1983a,b, Gulland 1983,p.104-105, Pauly 1984a,b, 1984c, chapter 5).

The "length-converted" catch curve as used in ELEFAN 2A consists of a plot of $\ln(N_i/\Delta t)$ against relative age $t_i$, where $N_i$ is the number of animals in the i-th length class and $\Delta t$ is the time required by an average animal to grow through this length class (all of which can be easily computed if the growth parameter values are known).

The regression function for the estimation of Z is then

$$\ln(N_i/\Delta t) = a + b * t$$

and $Z = - b$

The following assumptions are involved in the estimation of Z from the "length-converted" catch curve:

(i) Z is constant over all age/size classes included in the plot.

(ii) Recruitment fluctuations (with respect to all age classes included) have been small and of random character.

(iii) The gear used has a selection curve such that only the smaller animals are selected against.

(iv) The sample used represents the average population structure over the time considered.

<u>Calculations involved in the estimation of Z</u>

Three major steps are involved in the calculation of the mortality Z:

(1) Pooling of individual length-frequency samples into one large length-frequency sample which is supposed to be representative of the population.

(2) Construction of the catch curve proper, using the large sample and a set of growth parameter values.

(3) Estimation of Z from the descending right arm of the catch curve.

An additional procedure is the

(4) Approximation of the selection curve of the sampling gear and of the mean length at first capture $L_c$ of the sampled animals.

(1) Pooling of individual samples

This is particulary needed in short-lived benthic animals, because their population structure is affected by seasonal recruitment pulses.

To prevent sampling errors from unduly affecting the total sample, several possibilities of weighting the periodic samples prior to pooling in the large sample are given:

- No weighting
- Conversion to % length-frequency
- Weighting by the square-root of sample size
- Conversion to % length-frequ. and then weighting by square-root

The conversion to % length-frequency has the effect of giving the same weight to each sample. In some cases, e.g. if the sampling area is not equal for all samples and sampling is affected by large random deviations it may be appropriate to use an additionally weighting by the square-root of sample size. Use "No weighting" if the data represent a single cohort.

Two other (optional) weighting procedures are included here:

- Weighting with respect to distance in time
  (time elapsed between samples, as suggested by J.L. Munro, pers. comm.)

If the distance in time between the single samples within the year is not

equal, a higher weight can be given to more isolated samples.
For each sample this weight corresponds to the distance dt (as fraction of year) to the nearest sample. Each frequency of the sample is weighted by

$$F_i = F_i * (1 + 2*dt)$$

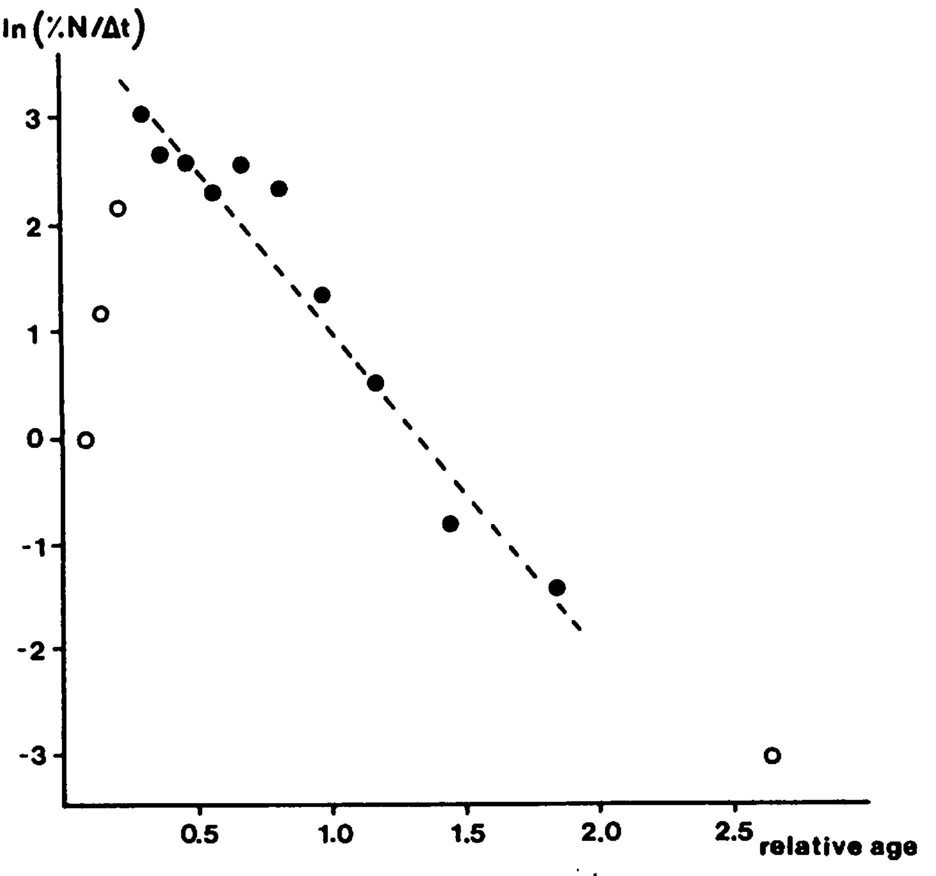
- Weighting with respect to seasonal oscillations in growth (C, WP)

If the growth oscillation constant C of the seasonally oscillationg von Bertalanffy equation exceeds 1, a certain period of stagnation in growth and negative growth occurs around the winterpoint WP. This affects the estimation of Z through the catch curve. If more than one sample is included in the period of stagnation, these samples can be pooled separately into one "winter-sample", which is representative for the period of stagnation in growth.

(2) Construction of the catch curve

All steps included in the computation of the "length-converted" catch curve are demonstrated in Tab. 11 using the pooled samples from Tab. 1.
The relative age at the lower limit, the upper limit and the middle of each

Fig. 4 Example of a length-converted catch cuve
*Syndosmya alba* data from Tab.11



Tab. 11 Construction of a "length-converted" catch curve

Data: <u>Syndosmya alba</u> (from Tab. 1), K = 1.22, Loo = 15.10

* indicates points included in estimation of Z

| class | lower limit | higher limit | mid-length | N | $t_{low}$ | $t_{high}$ | $\Delta t$ | $N/\Delta t$ | $\%(N/\Delta t)$ | $\ln(\% N/\Delta t)$ | $t_{mean}$ years |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 2.0 | 1.5 | 4 | .056 | .116 | .060 | 66.338 | 1.037 | 0.036 | 0.086 |
| 2 | 2.0 | 3.0 | 2.5 | 13 | .116 | .181 | .065 | 199.731 | 3.121 | 1.138 | 0.148 |
| 3 | 3.0 | 4.0 | 3.5 | 39 | .181 | .252 | .071 | 551.586 | 8.619 | 2.154 | 0.216 |
| 4 | 4.0 | 5.0 | 4.5 | 101 | .252 | .330 | .077 | 1305.161 | 20.394 | 3.015 | 0.290* |
| 5 | 5.0 | 6.0 | 5.5 | 77 | .330 | .415 | .085 | 901.008 | 14.079 | 2.645 | 0.371* |
| 6 | 6.0 | 7.0 | 6.5 | 81 | .415 | .510 | .095 | 848.893 | 13.265 | 2.585 | 0.461* |
| 7 | 7.0 | 8.0 | 7.5 | 69 | .510 | .619 | .108 | 638.845 | 9.982 | 2.301 | 0.563* |
| 8 | 8.0 | 9.0 | 8.5 | 104 | .619 | .743 | .124 | 835.803 | 13.060 | 2.570 | 0.678* |
| 9 | 9.0 | 10.0 | 9.5 | 97 | .743 | .890 | .147 | 660.939 | 10.328 | 2.335 | 0.813* |
| 10 | 10.0 | 11.0 | 10.5 | 43 | .890 | 1.069 | .179 | 240.363 | 3.756 | 1.323 | 0.974* |
| 11 | 11.0 | 12.0 | 11.5 | 24 | 1.069 | 1.298 | .229 | 104.727 | 1.636 | 0.493 | 1.175* |
| 12 | 12.0 | 13.0 | 12.5 | 9 | 1.298 | 1.617 | .319 | 28.193 | 0.441 | - 0.820 | 1.442* |
| 13 | 13.0 | 14.0 | 13.5 | 8 | 1.617 | 2.147 | .530 | 15.094 | 0.236 | - 1.445 | 1.840* |
| 14 | 14.0 | 15.0 | 14.5 | 6 | 2.147 | 4.113 | 1.965 | 3.053 | 0.048 | - 3.043 | 2.644 |

length class - $t_{low}$, $t_{high}$ and $t_{mean}$ - are given by

$$t = \ln(1 - (L_t/Loo))/-K$$

The time required to growth through a length class, $\Delta t$ is

$$\Delta t = t_{high} - t_{low}$$

The catch curve is constructed using $\ln(\%N/\Delta t)$ and $t_{mean}$.

(3) Estimation of Z

Using the catch curve plot displayed and the listing of catch curve points (see Tab. 12), it can then be decided wether the single negative exponential mortality model describes adequately the mortality of the population in question. If this appears to be true, the points to be included in the computation of Z are selected. This is the most sensitive part of the whole procedure.

Usually the first point selected (P1 in Fig.3) should be the point immediately to the right of the highest point. In small bivalve molluscs, however, the selection curve of the sieve used is often very steep, so the highest point can often be included.

At the right end of the plot, points should not be included which corresponds to length-values greater than 95% of $L_{oo}$ and/or based on a few ( < 5) animals only.

A first estimate of Z, Z' is calculated by linear regression over the selected points.

An iteration procedure (due to Px Sparre, pers. comm) corrects this Z' for the nonlinearity of the growth model and for the fact that some mortality occurs within each length class:

$$\ln(N_i/( 1 - e^{-Z_j * \Delta t_i} )) = a - Z_{j+1} * t_i$$

where i is the lengthclass number, $t_i$ is the relative age at the lower limit of length class i, $Z_j$ and $Z_{j+1}$ are initial and improved estimates of Z, respectively.

Tab. 12 Example output of ELEFAN 2A, catch curve data points *Syndosmya alba* data from Tab.1

B:SYSF11.DAT

Syndosmya alba / SF 04.1976 - 06.1977 / 1mm classes

WEIGHTING MODE No 1

WEIGHTING (TIME): NO

WEIGHTING (C,WP): NO

GROWTH-PARAMETERS: Loo= 15.1, K = 1.22, C = 1.18, WP = .18

| CATCH CURVE POINTS No | LN(%N/delta T) | RELATIVE AGE |
|---|---|---|
| 1 | .0359218 | .085758 |
| 2 | 1.138131 | .148359 |
| 3 | 2.153957 | .216139 |
| 4 | 3.015241 | .2900334 |
| 5 | 2.644673 | .3712555 |
| 6 | 2.585092 | .4614201 |
| 7 | 2.30082 | .5627431 |
| 8 | 2.569552 | .6783812 |
| 9 | 2.33482 | .8130559 |
| 10 | 1.323308 | .9742938 |
| 11 | .4925125 | 1.175214 |
| 12 | -.8197835 | 1.441953 |
| 13 | -1.444563 | 1.83991 |
| 14 | -3.042821 | 2.643868 |

(4) Selection curve and mean length at first capture

If the natural mortality M of the population in question is known, the selection curve of the gear can be inferred from the shape of the ascending left part of the catch curve (see Pauly 1980 for a method to estimate M in fish populations from $L_{oo}$, K and mean enviromental temperature.

The selection curve is computed by setting up a table of probabilities of capture for the length classes not fully selected by the gear.

Tab. 13 shows the table of probabilities of capture computed, based on the results given in Tab. 12.

DELTA T is the difference in time between the two corresponding midlength' $L_i$ and $L_{i+1}$.
MORTALITY 1 is the mortality within a length class. It is calculated by interpolation between M (mortality in the highest lengthclass not caught at all) and Z (i.e the mortality from point P1 on). The step size for the interpolation is estimated from (Z-M)/(n+1) where n is the number of classes for which mortality must be interpolated (here, n = 3).

Tab. 13 Example output of ELEFAN 2A, total mortality, probabilities *Syndosmya alba* data from Tab.1 and Tab.12

B:SYSF11.DAT
Syndosmya alba / SF 04.1976 - 06.1977 / 1mm classes

TABLE OF PROBABILITIES OF CAPTURE
WEIGHTING MODE No 1 POINTS INCLUDED: 4 - 13
WEIGHTING (TIME): NO
WEIGHTING (C,WP): NO
GROWTH-PARAMETERS: Loo= 15.1, K = 1.22, C = 1.18, WP = .18

TOTAL MORTALITY Z = 3.037686
NATURAL MORTALITY M = 3.037686
(LINEAR REGRESSION: Z = 3.056646, CORRELATION COEFF.=-.9711379)

| Midl. | N caught | DELTA T | MORTALITY 1 | MORTALITY 2 | N available | P | P cumulative |
|---|---|---|---|---|---|---|---|
| 1.5 | 4 | | 3.037686 | | 187.8501 | .0213 | .0213 |
| | | .1170586 | | 3.037686 | | | |
| 2.5 | 13 | | 3.037686 | | 155.3193 | .0837 | .105 |
| | | .182249 | | 3.037686 | | | |
| 3.5 | 39 | | 3.037686 | | 126.4173 | .3085 | .4135 |
| | | .2530862 | | 3.037686 | | | |
| 4.5 | 101 | | 3.037686 | | 101 | 1 | 1.4137 |

MEAN LENGTH AT FIRST CAPTURE = 3.5865

MORTALITY 2 is the mortality occuring between adjacent length classes. It is calculated as the mean between MORTALITY 1 of adjacent length classes. The number of animals available in each lengthclass (Nav), is calculated by

$$Nav_i = Nav_{i+1} * e^{MORTALITY\ 2\ *\ DELTA\ T}$$

where $Nav_i$ is the number available in length class i and $Nav_{i+1}$ the number available in the next higher length class. Therefore this calculation has to be started with the length class next to the class with MORTALITY 1 = Z. The probability of capture P for each length class i is calculated by

$$P = Ncaught_i/Nav_i$$

where Ncaught is the number of animals really caught.
The mean length at first capture $L_c$ is the length corresponding to a cumulative probability of capture of 0.5 (=50%).
In marine benthic invertebrates the natural mortality M usually equals the total mortality Z because there is no fisheries impact on the population. Therefore the calculation of MORTALITY 1 AND MORTALITY 2 is superfluous.

Actual run of ELEFAN 2A (Mortality)

After a length-frequency data file is loaded and the growth parameter values are entered, the main menu

```
----- ELEFAN 2A MAIN MENU -----
 RECRUITMENT PATTERN      <1>
 TOTAL MORTALITY          <2>
 RETURN TO START MENU     <3>
           SELECT NUMBER :
```

leads to the mortality routine when <2> is selected.
The first step is the pooling and weighting procedure:

```
----- WEIGHTING/RESTRUCTURING OF SAMPLES -----
 NO WEIGHTING/RESTRUCTURING:                   <1>
 CONVERSION TO % LENGTH-FREQU.:                <2>
 WEIGHTING BY SQUARE ROOT OF SAMPLE SIZE:      <3>
 CONVERSION TO % AND WEIGHTING BY SQUARE ROOT: <4>
                                 SELECT NUMBER :
```

WEIGHTING WITH RESPECT TO DISTANCE IN TIME? <0> OR <1> :

Each sample is displayed. Original and weighted values are presented. The user is allowed to exclude certain samples from further processing. If the amplitude constant C of growth oscillations exceeds 1, weighting with respect to stagnation in growth is possible.

WEIGHTING WITH RESPECT TO C AND WP? <0> OR <1> :

After this procedure the "status" of each sample is displayed.

STATUS OF SAMPLES
0 = EXCLUDED, 1 = INCLUDED, 2 = WEIGHTED WITH RESPECT TO C AND WP
No. STATUS

Then the samples are pooled and the calculations shown in Tab.11 are performed.
If there is a zero frequency value in any length class of the pooled sample, further processing is stopped because of ln(0)=fatal error.

ZERO FREQU. VALUE(S) INCLUDED IN DISTRIBUTION!
FURTHER CALCULATION IMPOSSIBLE!

The pooled sample is displayed. A value of 1 can be inserted in the original length-frequency distribution of one single sample, or the data can be regrouped into larger length classes (both options are performed using ELEFAN 0).
If no zero frequency ocurred, a videoplot of the catch curve is displayed.

VIDEO PLOT: Y-axis: ln(%N/delta t), X-axis: relative age
NOTE POINTS TO BE INCLUDED!

Each point is represented by the number of the corresponding length class.

LISTING OF THE DATA POINTS? <0> OR <1> :

If 1 is entered, the data are listed. Output on lineprinter is possible and should be done (see Tab.12).
Now the points for the estimation of Z are selected.

CONSTRUCTION OF THE CATCH CURVE
ENTER FIRST POINT (No) TO BE INCLUDED :
ENTER LAST POINT (No) TO BE INCLUDED :

Z' and Z are computed. The results are displayed:

TOTAL MORTALITY Z: (value of Z)

Z' and the correlation coefficient r are also displayed.
For the construction of a table of probabilities of capture, a value of the natural mortality M must be entered.* The selection curve is computed and displayed. Output on lineprinter is possible as shown in Tab.13.
Further calculations are optional:

NEW CALCULATION OF Z WITH OTHER POINTS? <0> OR <1>:

NEW CALCULATION WITH DIFFERENT WEIGHTING MODE? <0> OR <1>:

If none of these options is choosen then:

RECRUITMENT PATTERN WITH SAME WEIGHT. MODE? <0> OR <1>:

* Footnote: Pauly (1984a) has shown that the estimates of mean length at first capture $L_c$ obtained through this routine are relatively independent of the value of M entered; thus, entering Z=M will provide reasonable estimates of $L_c$. The curve discussed here is,rigourously speaking, not a "selection", but a "resultant" curve, i.e. the product of a gear selection curve with a recruitment curve (see Gulland 1983 p.127). Therefore, values of Lc estimated by the procedure outlined here will tend to be higher than estimates of Lc obtained from selection experiments. This effect can be counteracted by using here, for the estimation of Lc only those length-frequency samples which include small animals, i.e. samples collected during the recruitment season (Y. Mokhtar, pers. comm.).

## Seasonal recruitment patterns

### Calculation of a recruitment pattern

A recruitment pattern is a graph whose peaks and troughs reflect the seasonality of recruitment to the stock in question. If a set of length-frequency data and a corresponding set of growth parameter values are available, the recruitment pattern can easily be computed by projecting each length-frequency sample backward onto the time axis. In other words, if we calculate the time at which length was zero for each length class of every sample and sum up the abundance of each point of our data matrix (length, sampling time) in the corresponding time interval (here, 12 intervals = 1 year), the result will be a seasonal recruitment pattern.
ELEFAN 2 uses a more complex computation procedure correcting for the fact that growth is not linear.

- Each length class (of each sample) is divided in 10 intervals of equal size.
- The value added to the recruitment pattern memory is $N_i/10$ divided by the time required to grow trough the length interval in question.
- The lowest monthly recruitment value is subtracted from all 12 values resulting in at least one zero value corresponding to the month of lowest recruitment. The resulting distribution is converted into relative frequency.

Because $t_0$ from the v.Bertalanffy function is usually not known (that means the absolute age of the animals in unknown), the exact position of the recruitment pattern within the year is not known also. However, examination of the length-frequency samples should suggest the time of highest recruitment within the year, especially when small sizes are represented in the samples.

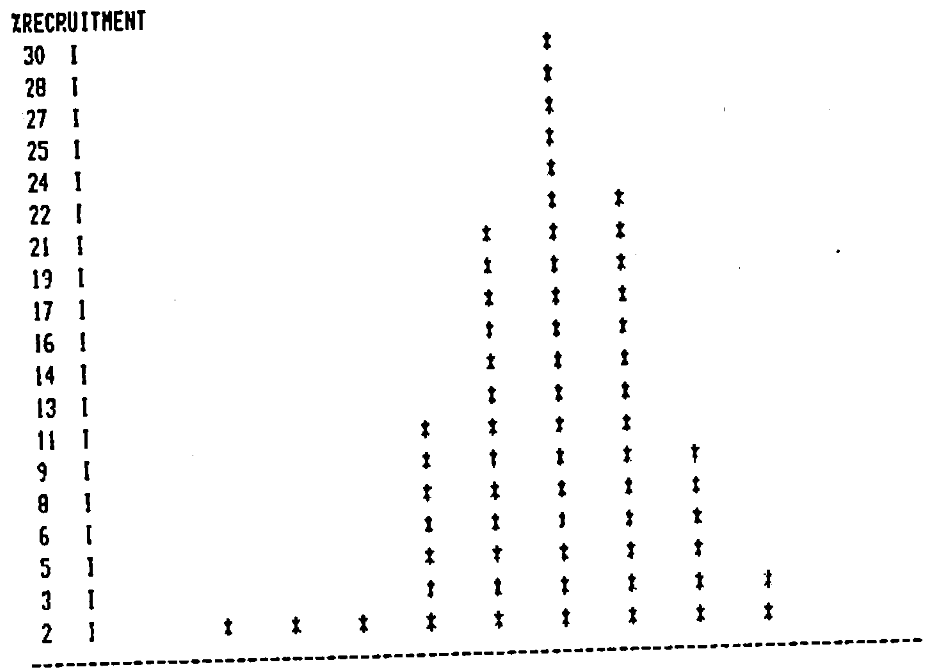
### Actual run of ELEFAN 2A (Recruitment pattern)

This part of the program is entered as described above. The weighting and samples selection procedure are the same as those described above with the exception that optional weighting with respect to growth stagnation (with respect to C and WP) is superfluous.
Computation requires a few minutes on a 8 bit-CPU.

The resulting recruitment pattern is displayed. Output on lineprinter is possible (see Fig.5).

Fig. 5 Example of a recruitment pattern
<u>Syndosmya alba</u> data from Tab. 1, K = 1.22, Loo = 15.1

```
RECRUITMENT PATTERN
WEIGHTING MODE No 1
WEIGHTING (TIME) :NO
GROWTH-PARAMETERS: Loo= 15.1 , K = 1.22 , C= 1.18 , WP = .18
```



## 2.6. ELEFAN 2B

Program ELEFAN 2B is used to obtain a first estimation of $L_{oo}$ and Z/K without any information about growth itself being available.

The method and equations implemented here are due to Wetherall et al. (in press), to whom reference should be made in papers based on this routine (see also Introduction).

The method applies only if the single negative exponential mortality model fits the data, and if a stable age distribution can be assumed.
The program first displays a curve with N(length class) at the Y-axis and length at the X-axis. If this plot shows a smoothy, monotonously descending left arm, the estimation of $L_{oo}$ will be reasonable, otherwise not.
The user then selects one point ($P_1$) of the curve, at the left of which data must be ignored because of selection effects.
Now X/Y data points are calculated, for $i=P_1$ to the last point, where

$X_i$ = lower limit of length $class_i$

$Y_i$ = mean length over all classes above and including i; weighted by cumulative number of individuals up to class i.

$L_{oo}$ and Z/K are estimated from a regression line to the x/y data, where

$Y_i = a + b * X_i$ (regression equation)

$Loo = a / (1-b)$

$Z/K = b / (1-b)$

The actual run is nearly the same like described for ELEFAN 2A

(1) Loading of a length-frequency data file
(2) Selection of samples included in computation
(3) Calculation and presentation of the catch curve
(4) Selection of the lowest lengthclass to be included
(5) Computation of $L_{oo}$ and Z/K, optional output on lineprinter (Tab.14).

Tab. 14 Example output of ELEFAN 2B

B:SYSF11.DAT

*Syndosmya alba* / SF 04.1976 -06.1977 / 1mm classes

ESTIMATION OF INFINITE LENGTH

REGRESSION EQUATION: X = LOWER LIMIT OF SMALLEST LENGTH CLASS
Y = MEAN LENGTH OVER ALL CLASSES
LOWEST CLASS INCLUDED: LENGTHCLASS No 6

Y = 4.563045 + .6815749 * X ; r = .9833799, $r^2$ = .967036
ESTIMATE OF Loo: 14.33004
ESTIMATE OF Z/K: 2.140456

## 3. Acknowledgements

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## 5. Program listings [1)]

```
10 REM START
20 REM MAIN MENU FOR ELEFAN PROGRAMS
30 PRINT CHR$(27) CHR$(91) CHR$(50) CHR$(74)
40 PRINT "***** ATTENTION ****":PRINT
50 PRINT"THIS VERSION OF ELEFAN IS ADAPTED TO EPSON-COMPATIBLE PRINTERS
60 PRINT"CONNECT THE PRINTER NOW !":PRINT
70 INPUT "ENTER <RETURN> TO CONTINUE :" ,C1
80 LPRINT CHR$(27)"!"CHR$(6)CHR$(27)CHR$(81)CHR$(100)
90 PRINT:PRINT:PRINT CHR$(27) CHR$(91) CHR$(50) CHR$(74)
100 PRINT"                          E  L  E  F  A  N
110 PRINT"                 ELECTRONIC LENGTH FREQUENCY ANALYSIS
120 PRINT"                          MS/DOS - VERSION
130 PRINT"              (c) 1985  DANIEL PAULY AND THOMAS BREY
140 PRINT"-------------------------------------------------------------------
150 PRINT"                  MAIN MENU FOR ELEFAN PROGRAMS
160 PRINT"-------------------------------------------------------------------
170 PRINT
180 PRINT "    ELEFAN 0  : FILE MANAGMENT                        <1>
190 PRINT:PRINT "    ELEFAN 1A : DATA RESTRUCTURING"
200 PRINT "                INPUT OF AGE-LENGTH DATA              <2>
210 PRINT:PRINT "    ELEFAN 1B : GROWTH CURVE PARAMETERS               <3>
220 PRINT:PRINT "    ELEFAN 2A : CATCH CURVE + RECRUITMENT PATTERN     <4>
230 PRINT:PRINT "    ELEFAN 2B : ESTIMATION OF Loo AND Z/K             <5>
240 PRINT:PRINT "    END                                               <6>
250 PRINT:INPUT"                                       SELECT NUMBER :",C1
260 IF C1<1 OR C1>6 THEN 170
270 ON C1 GOTO 280,290,300,310,320,330
280 CHAIN "ELEFAN0":GOTO 330
290 CHAIN "ELEFAN1A":GOTO 330
300 CHAIN "ELEFAN1B":GOTO 330
310 CHAIN "ELEFAN2A":GOTO 330
320 CHAIN "ELEFAN2B":GOTO 330
330 END
```

1) We are aware that one cannot hope to catch the last bug in a program, but have made serious efforts to catch the penultimate one. On the other hand, we have not spent as much time as we could have on making the displays look "pretty" and on including all possible error traps. Users interested in distributing to other versions of the ELEFAN programs improved along these lines are invited to contact us.

2) The ESC-sequence chr$(27) chr$(91) chr$(50) chr$(74) should make "clear screen". Substitute it by the adequate command of your system.

```
10 REM ELEFAN 0
20 DEFINT A,C,I,N:WIDTH LPRINT 250
30 DIM A(24,30):DIM A1(24):DIM AM(24):DIM AD(24):DIM E1$(50):DIM E2$(50)
40 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74)
50 PRINT"----------------------------------------------------------------------
60 PRINT"                              PROGRAM ELEFAN 0
70 PRINT"                    DATA INPUT AND FILE MANAGMENT PROGRAM
80 PRINT"----------------------------------------------------------------------
90 PRINT
100 PRINT"THIS PROGRAM CAN HANDLE UP TO 24 SAMPLES AND 30 MIDLENGTH (=CLASSES)
110 PRINT:PRINT"IMPORTANT!"
120 PRINT"LENGTH-FREQU. DATA: INPUT INTEGER VALUES ONLY
130 FOR I1=1 TO 24:FOR I2=1 TO 30:A(I1,I2)=0:NEXT:NEXT
140 REM READ LIBRARY
150 PRINT:PRINT:INPUT "READ A DATA FILE LIBRARY? <0> OR <1>: ",C1
160 IF C1=0 THEN GOTO 210 ELSE GOSUB 1990
170 PRINT:PRINT"  * DATA FILE LIBRARY "LIB$" *":PRINT
180 FOR IL=1 TO NF:PRINT E1$(IL) TAB(17) E2$(IL)
190 IF IL/10=INT(IL/10) THEN INPUT "PRESS <RET> TO CONTINUE: ",C1
200 NEXT IL
210 PRINT"---------------------------------------------------------------------
220 REM *** ELEFAN 0  MAIN MENU ***
230 PRINT:PRINT"----- SELECT FROM THE FOLLOWING -----
240 REM A=FREQU.-VALUE, A1=+/- COUNTER, AM=MONTH, AD=DAY
250 PRINT" CREATE NEW FILE:                                     <1>
260 PRINT" SELECT SAMPLES FROM OLD FILE:                        <2>
270 PRINT" EDIT OLD FILE:                                       <3>
280 PRINT" EDIT OLD FILE: CORRECTION FOR SELECTION EFFECTS:     <4>
290 PRINT" EDIT OLD FILE: CHANGE LENGTH CLASS SIZE:             <5>
300 PRINT" DATA FILE LIBRARY MANAGMENT:                         <6>
310 PRINT" BACK TO ELEFAN MAIN MENU:                            <7>
320 INPUT "                                    SELECT NUMBER :",C1
330 IF C1=7 THEN 2570
340 ON C1 GOSUB 370,700,1020,1230,1460,2560
350 GOTO 130
360 REM ====================================================
370 REM ***** CREATE NEW FILE *****
380 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74)
390 PRINT"---------------------------------------------------------------------
400 PRINT"                            CREATE NEW FILE
410 PRINT"                           DATA INPUT ROUTINE
420 PRINT"---------------------------------------------------------------------
430 PRINT"DATA FILE NAME = DRIVE(A or B):NAME(<=8 CHARACTERS).DAT
440 INPUT D1$
450 PRINT"INFORMATIONS ABOUT THE DATA FILE (SPECIES / AREA / PERIOD)
460 INPUT D2$
470 PRINT:INPUT "NUMBER OF SAMPLES: ",N1:IF N1>24 THEN 470
480 INPUT "LOWEST MIDLENGTH : ",M1
490 INPUT "HIGHEST MIDLENGTH: ",M2
500 INPUT "INTERVAL SIZE    : ",SI
```

```
510 REM N2=NUMBER OF MIDLENGTHS (CLASSES)
520 N2=(M2-M1)/SI+1:IF N2>30 THEN PRINT:PRINT"MORE THEN 30 CLASSES!":GOTO 480
530 REM INPUT ROUTINE: I1 TO N1 SAMPLES, I2 TO N2 MIDLENGTH
540 FOR I1=1 TO N1
550 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"SAMPLE"I1
560 INPUT "MONTH";AM(I1):INPUT "DAY";AD(I1)
570 INPUT "LOWEST MIDLENGTH IN THIS SAMPLE:";ML
580 IF ML<M1 THEN PRINT"** ERROR ** "ML"<"M1:GOTO 570
590 INPUT "HIGHEST MIDLENGTH IN THIS SAMPLE:";MH
600 IF MH>M2 THEN PRINT"** ERROR ** "MH">"M2:GOTO 590
610 NL=(ML-M1)/SI+1:NH=N2-(M2-MH)/SI
620 REM NL=LOWEST MIDL., NH=HIGHEST MIDL. WITH FREQU.>0
630 FOR I2=NL TO NH
640 PRINT"MIDLENGTH"ML+(I2-NL)*SI", FREQUENCY:":INPUT A(I1,I2)
650 NEXT:NEXT
660 GOSUB 1660:REM TO REVIEW
670 GOSUB 2090:REM TO OUTPUT
680 RETURN
690 REM ==========================================================
700 REM ***** SELECT SAMPLES FROM OLD FILE *****
710 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74)
720 PRINT"----------------------------------------------------------------------
730 PRINT"                   ROUTINE TO EXTRACT A SUBSET DATA FILE
740 PRINT"----------------------------------------------------------------------
750 REM INPUT OLD DATA FILE
760 PRINT:INPUT "ENTER OLD FILE NAME: ",D1$
770 GOSUB 1880:REM TO READ
780 PRINT:PRINT D1$:PRINT D2$:PRINT
790 INPUT "IS THIS CORRECT ? <0> OR <1>:",C1:IF C1<>1 THEN 760
800 PRINT"NUMBER OF SAMPLES  "N1
810 PRINT"NUMBER OF MIDLENGTHS"N2
820 PRINT"INTERVAL SIZE       "SI:PRINT:FOR I1=1 TO 500:NEXT
830 PRINT:PRINT"SAMPLE No" TAB(15) "DAY" TAB(20) "MONTH"
840 FOR I1=1 TO N1:PRINT TAB(4) I1 TAB(15) AD(I1) TAB(20) AM(I1):NEXT
850 PRINT:PRINT"SELECT SAMPLES INCLUDED IN THE NEW SAMPLE":PRINT:N3=0
860 PRINT"SAMPLE No" TAB(15)"DAY" TAB(20) "MONTH" TAB(40) "NEW SUBSAMPLE"
870 FOR I1=1 TO N1:PRINT TAB(4) I1 TAB(15) AD(I1) TAB(20) AM(I1)
880 INPUT"                                 INCLUDED? <0> OR <1> : ",A1(I1):N3=N3
+A1(I1):NEXT
890 REM CREATION OF THE SUBSAMPLE
900 I1=0
910 FOR I3=1 TO N3
920 I1=I1+1:IF A1(I1)=0 THEN 920
930 FOR I2=1 TO N2:A(I3,I2)=A(I1,I2):NEXT
940 AM(I3)=AM(I1):AD(I3)=AD(I1):NEXT I3
950 N1=N3
960 INPUT "NEW DATA FILE NAME: ",D1$
970 PRINT"INFORMATIONS THE NEW DATA FILE (SPECIES / AREA / PERIOD)":INPUT D2$
980 GOSUB 1660:REM TO REVIEW
990 GOSUB 2090:REM TO OUTPUT
1000 RETURN
```

```
1010 REM ====================================================
1020 REM ***** FILE EDITING *****
1030 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74)
1040 PRINT"----------------------------------------------------------------------
1050 PRINT"                                EDIT OLD FILE
1060 PRINT"----------------------------------------------------------------------
1070 PRINT:INPUT "ENTER FILE NAME: ",D1$
1080 GOSUB 1880:REM TO READ
1090 PRINT:PRINT D1$:PRINT D2$:PRINT
1100 INPUT "IS THIS THE CORRECT FILE? <0> OR <1>:",C1
1110 IF C1<>1 THEN 1070
1120 INPUT "IS THIS THE RIGHT NAME/INFORMATION? <0> OR <1>:",C1
1130 IF C1=1 THEN 1150
1140 INPUT "ENTER NEW NAME: ",D1$:INPUT "ENTER NEW INFORMATION: ",D2$
1150 GOSUB 1660: REM TO REVIEW
1160 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"DELETE OLD FILE AND OLD NAME F
OR NEW FILE:  <1>
1170 PRINT"SAVE OLD FILE AND NEW NAME FOR EDITED FILE: <2>
1180 INPUT C1:IF C1=1 THEN KILL D1$:GOTO 1200
1190 INPUT "ENTER NEW FILE NAME: ",D1$
1200 GOSUB 2090:REM TO OUTPUT
1210 RETURN
1220 REM ====================================================
1230 REM ***** EDIT OLD FILE: CORRECTION FOR SELECTION EFFECTS *****
1240 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"CORRECTION OF DATA USING PROBA
BILITIES OF CAPTURE"
1250 PRINT:INPUT "ENTER OLD FILE NAME: ",D1$
1260 GOSUB 1880:REM TO READ
1270 PRINT:PRINT D1$:PRINT D2$:PRINT
1280 INPUT "IS THIS CORRECT ? <0> OR <1>:",C1
1290 IF C1=0 THEN 1250
1300 PRINT:PRINT"LOWEST MIDLENGTH:"M1
1310 PRINT"HIGHEST MIDLENGTH:"M2
1320 PRINT"INTERVALL:          "SI:PRINT
1330 FOR I2=1 TO N2
1340 PRINT:PRINT"SIZE CLASS"I2", MIDLENGTH"M1+(I2-1)*SI
1350 INPUT "PROBABILITY? (IF THIS AND THE FOLLOWING VALUES =1 THEN ENTER 99):",F
V
1360 IF FV>=99 THEN 1400
1370 FOR I1=1 TO N1
1380 A(I1,I2)=INT(A(I1,I2)/FV+.5):NEXT
1390 NEXT I2
1400 GOSUB 1660:REM TO REVIEW
1410 PRINT:INPUT "ENTER NEW FILE NAME: ",D1$
1420 INPUT "INFORMATION ABOUT THE DATA FILE: ",D2$
1430 GOSUB 2090:REM TO OUTPUT
1440 RETURN
1450 REM ====================================================
1460 REM ***** EDIT OLD FILE: CHANGE LENGTH CLASS SIZE *****
1470 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"CHANGE LENGTH CLASS SIZE":PRIN
T
1480 INPUT "ENTER OLD FILE NAME: ",D1$
1490 GOSUB 1880:REM TO READ
1500 PRINT:PRINT D1$:PRINT D2$:PRINT
```

```
1510 INPUT "IS THIS CORRECT ? <0> OR <1>:",C1
1520 IF C1=0 THEN 1480
1530 PRINT:INPUT "NUMBER OF OLD INTERVALS INCLUDED IN 1 NEW INTERVAL: ";ST
1540 N3=INT(N2/ST):IF N3<N2/ST THEN N3=N3+1
1550 FOR I1=1 TO N1:I3=1-ST
1560 FOR I2=1 TO N3:I3=I3+ST:SU=0
1570 FOR I4=I3 TO I3+ST-1:SU=SU+A(I1,I4):NEXT
1580 A(I1,I2)=SU:NEXT I2
1590 NEXT I1:N2=N3:M1=M1+(ST-1)*SI/2:SI=ST*SI:M2=M1+(N3-1)*SI
1600 N2=N3:GOSUB 1660:REM TO REVIEW
1610 PRINT:INPUT "NEW FILE NAME: ",D1$
1620 INPUT "INFORMATION ABOUT THE DATA: ",D2$
1630 GOSUB 2090:REM TO OUTPUT
1640 RETURN
1650 REM =========================================================
1660 REM ***** subroutine REVIEW *****
1670 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74)
1680 PRINT"-----------------------------------------------------------------------
1690 PRINT"                              REVIEW FOR ERRORS
1700 PRINT"-----------------------------------------------------------------------
1710 FOR I1=1 TO N1
1720 PRINT:PRINT"SAMPLE"I1:PRINT"DAY"AD(I1)"  MONTH"AM(I1)
1730 INPUT "IS THIS CORRECT? <0> OR <1>:",C1
1740 IF C1<>1 THEN INPUT "NEW DATE: DAY,MONTH ",AD(I1),AM(I1)
1750 PRINT:PRINT"DATA IN SAMPLE"I1
1760 PRINT"CLASS" TAB(10) "MIDL." TAB(20) "FREQUENCY"
1770 FOR I2=1 TO N2:PRINT TAB(2) I2 TAB(10) M1+(I2-1)*SI TAB(23) A(I1,I2)
1780 IF I2/21=INT(I2/21) THEN INPUT "PRESS <RET> TO CONTINUE",C1
1790 NEXT I2
1800 PRINT:INPUT "IS THIS CORRECT? <0> OR <1>:",C1
1810 IF C1=1 THEN 1850
1820 INPUT "CLASS WITH ERRONEOUS FREQUENCY:";C2
1830 PRINT"CLASS"C2", MIDL."M1+(C2-1)*SI", FREQU."A(I1,C2)
1840 INPUT "RIGHT FREQUENCY: ",A(I1,C2):GOTO 1800
1850 NEXT I1
1860 RETURN
1870 REM ==========================================================
1880 REM *****  subroutine READ FROM DISKETTE *****
1890 ON ERROR GOTO 1910
1900 OPEN "I",#1,D1$:GOTO 1920
1910 PRINT"** ERROR ** NONEXISTING FILE **":CLOSE#1:RESUME 1980
1920 INPUT#1,D2$
1930 INPUT#1,N1,N2,M1,M2,SI
1940 FOR I1=1 TO N1:INPUT#1,AM(I1),AD(I1)
1950 FOR I2=1 TO N2:IF EOF(1) THEN 1970 ELSE INPUT#1,A(I1,I2)
1960 NEXT:NEXT
1970 CLOSE#1
1980 RETURN
1990 REM ***** subroutine READ LIBRARY *****
2000 ON ERROR GOTO 2030
```

```
2010 INPUT "ENTER THE NAME OF THE DATA FILE LIBRARY: ",LIB$
2020 GOTO 2040
2030 CLOSE#1:RESUME 2010
2040 OPEN "I",#1,LIB$
2050 INPUT#1,NF
2060 FOR IL=1 TO NF:INPUT#1,E1$(IL),E2$(IL):NEXT
2070 CLOSE#1:RETURN
2080 REM =====================================================
2090 REM ***** subroutine OUTPUT  (LINEPRINTER, DISKETTE) *****
2100 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74)
2110 PRINT"--------------------------------------------------------------------------
2120 PRINT"                            OUTPUT ROUTINE
2130 PRINT"--------------------------------------------------------------------------
2140 PRINT"----- OUTPUT MENU -----
2150 PRINT" OUTPUT ON LINEPRINTER  <1>
2160 PRINT" STORAGE ON DISKETTE    <2>
2170 PRINT" END OF PROGRAM         <3>
2180 INPUT "                SELECT NUMBER :",C1
2190 IF C1=3 THEN PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):RETURN
2200 ON C1 GOSUB 2210,2400:PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):GOTO 2140
2210 REM ***** OUTPUT ON LINEPRINTER
2220 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"OUTPUT ON LINEPRINTER, FORMAT:
 X-AXIS = SAMPLES, Y-AXIS = MIDLENGTH
2230 NP=INT(N1/12+11/12)
2240 IS=1:IP=12:IF N1<12 THEN IP=N1:NP=1
2260 PRINT NP"SHEETS OF PAPER REQUIRED":PRINT
2270 FOR I3=1 TO NP:PRINT I3". SHEET OF PAPER"
2280 INPUT "LINEPRINTER READY? <RET>:",C1
2290 LPRINT D1$:LPRINT D2$:LPRINT:LPRINT"SAMPLE No";
2300 FOR I1=IS TO IP:LPRINT TAB(17+(I1-IS)*7) I1;:NEXT:LPRINT" "
2310 LPRINT"DAY.MONTH";
2320 FOR I1=IS TO IP:LPRINT TAB(17+(I1-IS)*7) USING "##.##"; (AD(I1)*100+AM(I1))
/100;:NEXT:LPRINT
2330 LPRINT:LPRINT"CLASS  MIDL."
2340 FOR I2=1 TO N2:LPRINT TAB(2) I2 TAB(8) M1+(I2-1)*SI;
2350 FOR I1=IS TO IP:LPRINT TAB(17+(I1-IS)*7) A(I1,I2);:NEXT:LPRINT
2360 NEXT I2
2370 IS=IP+1:IP=IP+12:IF IP>N1 THEN IP=N1
2380 NEXT I3
2390 RETURN
2400 REM ***** STORAGE ON DISKETTE
2410 OPEN "O",#1,D1$
2420 PRINT#1,D2$
2430 PRINT#1,N1;N2;M1;M2;SI;
2440 FOR I1=1 TO N1:PRINT#1,AM(I1);AD(I1);",";
2450 FOR I2=1 TO N2:PRINT#1,A(I1,I2);:NEXT:NEXT
2460 CLOSE#1
2470 REM WRITE LIBRARY
2480 PRINT:INPUT"STORAGE OF FILE-NAME IN A DATA FILE LIBRARY? <0> OR <1> :",C1
2490 IF C1=1 THEN GOSUB 2000 ELSE 2550
2500 IF NF<50 THEN NF=NF+1:E1$(NF)=D1$:E2$(NF)=D2$ ELSE PRINT" MAXIMUM NUMBER OF
 NAMES ALREADY STORED!:goto 2480
2510 OPEN "O",#1,LIB$
2520 PRINT#1,NF
2530 FOR IL=1 TO NF:PRINT#1,E1$(IL);",";E2$(IL);",";:NEXT
2540 CLOSE#1
2550 RETURN
2560 CHAIN "EDITLIB"
2570 CHAIN "START"
```

```
10 REM EDITLIB
20 DEFINT C,I
30 DIM E1$(50):DIM E2$(50)
40 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"MANAGMENT OF DATA FILE LIBRARYS"
:PRINT
50 PRINT"  INITIALIZATION OF A NEW LIBRARY     <1>
60 PRINT"  EXCLUSION OF FILES                  <2>
70 PRINT"  BACK TO ELEFAN 0                    <3>
80 INPUT"                         SELECT NUMBER:",C1
90 IF C1<1 OR C1>3 THEN 40
100 IF C1=3 THEN 490
110 ON C1 GOSUB 130,200:GOTO 40
120 REM ==============================================
130 REM ***** INITIALIZATION OF A LIBRARY *****
140 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"INITIALIZATION OF A LIBRARY FIL
E":PRINT
150 INPUT" ENTER THE NAME OF THE NEW LIBRARY FILE :",LIB$
160 OPEN "O",#1,LIB$
170 PRINT#1,0
180 CLOSE#1:RETURN
190 REM ==============================================
200 REM ***** DATA FILE EXCLUSION *****
210 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"EXCLUSION OF DATA FILES":PRINT
220 ON ERROR GOTO 250
230 INPUT "ENTER DATA FILE LIBRARY NAME :",LIB$
240 GOTO 260
250 CLOSE#1:RESUME 230
260 OPEN "I",#1,LIB$
270 INPUT#1,NF
280 FOR IL=1 TO NF:INPUT#1,E1$(IL),E2$(IL):NEXT
290 CLOSE#1
300 PRINT:PRINT"ELEFAN DATA FILE LIBRARY "LIB$:PRINT
310 FOR IL=1 TO NF:PRINT IL TAB(5) E1$(IL) TAB(22) E2$(IL)
320 IF IL/15=INT(IL/15) THEN INPUT "PRESS <RET> TO CONTINUE: ",C1
330 NEXT
340 PRINT"-------------------------------------------------------------
350 INPUT "EXCLUSION OF A FILE FROM LIBRARY? <0> OR <1> :",C1
360 IF C1=0 THEN 450
370 INPUT "ENTER NUMBER OF DATA FILE: ",CF
380 INPUT "DELETE FILE FROM DISK ALSO? <0> OR <1> :",CL
390 ON ERROR GOTO 410
400 GOTO 420
410 CLOSE #1:RESUME 430
420 IF CL=1 THEN KILL E1$(CF)
430 FOR IL=CF TO NF-1:E1$(IL)=E1$(IL+1):E2$(IL)=E2$(IL+1):NEXT
440 NF=NF-1:GOTO 300
450 OPEN "O",#1,LIB$
460 PRINT#1,NF
470 FOR IL=1 TO NF:PRINT#1,E1$(IL);",";E2$(IL);",";:NEXT
480 CLOSE#1:RETURN
490 CHAIN "ELEFANO"
```

```
10 REM ELEFAN 1A
20 DEFINT A,C,I,N:WIDTH LPRINT 250
30 DIM A1(24,30):DIM AM(24):DIM AD(24):REM A1=DATA, AM=MONTH, AD=DAY
40 DIM FO(30):DIM A2(150):REM FO CALCULATION VARIABLE, A2=POSITION OF PEAKS
50 DIM AT(12):FO(0)=-1
60 DIM AA(200):DIM AB(200):DIM DA(200):DIM DB(200):REM TAGGING DATA
70 DIM AG(10):DIM AV(10):DIM AL(10,20):DIM AF(8,20,20)
80 REM N1=N OF SAMPLES; N2=N OF MIDLENGTHS; M1, M2=MIN, MAX MIDL.; SI=INTERVAL
90 REM N3=N OF FREQU.>0 IN ONE SAMPLE, NL, NH= LOWEST, HIGHEST POSITION
100 AT(1)=0:AT(2)=31:AT(3)=59:AT(4)=90:AT(5)=120:AT(6)=151:AT(7)=181:AT(8)=212:A
T(9)=243:AT(10)=273:AT(11)=304:AT(12)=334
110 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74)
120 PRINT"----------------------------------------------------------------------------
130 PRINT"                                   ELEFAN 1A
140 PRINT"                  PROGRAM FOR RESTRUCTURING OF LENGTH-FREQUENCY DATA
150 PRINT"              AND ADDITIONAL INPUT OF TAGGING DATA AND AGE-LENGTH DATA
160 PRINT"----------------------------------------------------------------------------
170 PRINT" ":PRINT"DATA INPUT FROM DISK ONLY (DATA ENTRY TROUGH ELEFANO)
180 REM ***** INPUT DATA FILE
190 ON ERROR GOTO 220
200 PRINT:INPUT "ENTER FILE NAME : ",D1$
210 GOTO 230
220 CLOSE #1:RESUME 200
230 OPEN "I",#1,D1$:GOTO 240
240 INPUT#1,D2$
250 INPUT#1,N1,N2,M1,M2,SI
260 FOR I1=1 TO N1:INPUT#1,AM(I1),AD(I1)
270 FOR I2=1 TO N2:IF EOF(1) THEN 290 ELSE INPUT#1,A1(I1,I2)
280 NEXT:NEXT
290 CLOSE#1
300 PRINT" ":PRINT D1$:PRINT D2$:PRINT" "
310 INPUT "IS THIS CORRECT ? <0> OR <1>:",C1
320 IF C1=0 THEN 200
330 PRINT" ":INPUT "ADJUSTMENT OF PEAKS: OPTION A <1> OR OPTION B <2>:",CD
340 REM =========================================================================
350 REM ***** RESTRUCTURING ROUTINE *****
360 FOR I1=1 TO N1
370 FOR I2=1 TO N2:FO(I2)=0:NEXT
380 REM SEARCH LOWEST, HIGHEST MIDLENGTH WITH VALUE>0
390 FOR I2=1 TO N2:IF A1(I1,I2)=0 THEN NEXT ELSE NL=I2
400 FOR I2=N2 TO NL STEP -1:IF A1(I1,I2)=0 THEN NEXT ELSE NH=I2
410 N3=NH+1-NL
420 REM ***** CALCULATE ACTUAL FREQU./RUNNING AVERAGE
430 SF=0
440 FOR I2=NL TO NH
450 C1=I2-2:C2=I2-1:C3=I2+1:C4=I2+2
460 IF C1<NL THEN C1=0
470 IF C3>NH THEN C3=0
480 IF C4>NH THEN C4=0
490 FS=(A1(I1,C1)+A1(I1,C2)+A1(I1,I2)+A1(I1,C3)+A1(I1,C4))/5
500 IF FS<>0 THEN FO(I2)=A1(I1,I2)/FS:SF=SF+FO(I2)
510 NEXT
```

```
520 REM ***** DIVIDE VALUE BY AVERAGE IN SAMPLE AND SUBTRACT 1
530 IF SF=0 THEN 560 ELSE IF N3>1 THEN SF=SF/N3 ELSE SF=1
540 FOR I2=NL TO NH:FO(I2)=FO(I2)/SF-1:NEXT
550 REM ***** DEEMPHASIZE PEAKS
560 FOR I2=NL TO NH
570 IF FO(I2)<=0 THEN 690
580 C1=I2-2:C2=I2-1:C3=I2+1:C4=I2+2:C5=0
590 IF C4>NH THEN C4=0
600 IF C3>NH THEN C3=0
610 IF C1<NL THEN C1=0
620 IF C2<NL THEN C2=0
630 IF FO(C1)<=-1 THEN C5=C5+1
640 IF FO(C2)<=-1 THEN C5=C5+1
650 IF FO(C3)<=-1 THEN C5=C5+1
660 IF FO(C4)<=-1 THEN C5=C5+1
670 FO(I2)=FO(I2)*(1/2^C5)
680 IF CD=2 THEN FO(I2)=FO(I2)/SQR(1+2/A1(I1,I2)^2)
690 NEXT
700 REM ***** SET ZERO FREQU. = 0
710 FOR I2=NL TO NH:IF FO(I2)=-1 THEN FO(I2)=0
720 NEXT
730 REM ***** RAISE NEGATIVE VALUES BY RATIO
740 S1=0:S2=0
750 FOR I2=NL TO NH:IF FO(I2)>0 THEN S1=S1+FO(I2) ELSE S2=S2+FO(I2)
760 NEXT
770 SZ=1:IF S2<>0 THEN SZ=ABS(S1/S2)
780 FOR I2=NL TO NH:IF FO(I2)<0 THEN FO(I2)=FO(I2)*SZ
790 NEXT
800 REM ------------------------------------------------------
810 REM RESTRUCTURED DATA  A1(I1,x)=1000*FO(x)
820 FOR I2=NL TO NH:A1(I1,I2)=INT(1000*FO(I2)+.5):NEXT
830 PRINT"SAMPLE"I1
840 FOR I2=1 TO N2:PRINT USING "##.###"; A1(I1,I2)/1000:NEXT:PRINT
850 NEXT I1
860 REM ======================================================
870 REM ***** DEEMPHASIZE NEGATIVE VALUES IN CLASS N2, N2-1 *****
880 FOR I1=1 TO N1:IF A1(I1,N2)<0 THEN A1(I1,N2)=0
890 IF A1(I1,N2-1)<0 THEN A1(I1,N2-1)=INT(.5*A1(I1,N2-1)+.5)
900 NEXT
910 REM ------------------------------------------------------------
920 REM ***** COMPUTE AVAILABLE SUM OF PEAKS ASP *****
930 SA=0:IM=1
940 FOR I1=1 TO N1:N3=1
950 FOR I2=N3 TO N2
960 IF A1(I1,I2)>0 THEN NB=I2:GOTO 980
970 NEXT I2:GOTO 1060
980 FOR I3=NB TO N2
990 IF A1(I1,I3)>0 THEN NEXT I3 ELSE NE=I3-1:GOTO 1010
1000 NE=N2
1010 FM=A1(I1,NB):FI=NB
1020 FOR I4=NB+1 TO NE:IF A1(I1,I4)>FM THEN FM=A1(I1,I4):FI=I4
1030 NEXT I4
1040 SA=SA+FM/1000:IF FM>100 THEN A2(IM)=I1*100+FI:IM=IM+1
1050 IF NE+1<=N2 THEN N3=NE+1:GOTO 950
1060 NEXT I1
1070 NA=IM-1: PRINT"ASP ="SA:NB=0:NC=0
```

```
1080 REM ================================================
1090 REM ***** OPTIONAL INPUT *****-
1100 PRINT:PRINT"      ----- OPTIONAL INPUT MENU -----
1110 PRINT"      TAGGING DATA                      <1>
1120 PRINT"      AGE AT LENGTH DATA                <2>
1130 PRINT"      GROWTH INCREMENT DATA FROM DISK <3>
1140 PRINT"      NO ADDITIONAL DATA                <4>
1150 INPUT "                          SELECT NUMBER   :",C1
1160 IF C1<1 OR C1>4 THEN 1100
1170 IF C1=4 THEN 2230
1180 ON C1 GOSUB 1210,1400,2000:PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):GOTO 1100
1190 REM -----------------------------------------------------
1200 REM ***** INPUT OF TAGGING DATA *****
1210 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"INPUT OF TAGGING DATA":PRINT
1220 INPUT" ENTER NUMBER OF DATA PAIRS (<=100) :",NB:PRINT
1230 IF NB>100 THEN 1220
1240 FOR IB=1 TO NB:PRINT"DATA PAIR No"IB
1250 INPUT "ENTER TAGGING-     LENGTH, DAY, MONTH, YEAR :",L,DD,DM,Y1
1260 INPUT "IS THIS CORRECT ? <0> OR <1> :",C1:IF C1<>1 THEN 1250
1270 AA(IB)=INT(100*L+.5):DA(IB)=INT(1000*((AT(DM)+DD)/365))/1000
1280 INPUT "ENTER RECAPTURE-   LENGTH, DAY, MONTH, YEAR :",L,DD,DM,Y2
1290 INPUT "IS THIS CORRECT ? <0> OR <1> :",C1:IF C1<>1 THEN 1280
1300 AB(IB)=INT(100*L+.5):DB(IB)=INT(1000*((AT(DM)+DD)/365+(Y2-Y1)))/1000
1310 PRINT:NEXT
1320 PRINT:PRINT"REVIEW OF TAGGING DATA":PRINT
1330 PRINT"No" TAB(10) "L(1)" TAB(20) "t(1)" TAB(30) "L(2)" TAB(40) "t(2)"
1340 FOR IB=1 TO NB
1350 PRINT IB TAB(10)AA(IB)/100 TAB(20)DA(IB) TAB(30)AB(IB)/100 TAB(40)DB(IB)
1360 NEXT
1370 INPUT "PRESS <RET> TO CONTINUE :",C1:PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74)
:RETURN
1380 REM -------------------------------------------------------
1390 REM ***** INPUT OF LENGTH AT AGE DATA *****
1400 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"INPUT OF LENGTH AT AGE DATA":P
RINT
1410 PRINT"MAXIMUM SIZE OF DATA MATRIX: 10 AGES * 20 LENGTHS-AT-AGE"
1420 PRINT"IF POSSIBLE, ENTER SIMILAR NUMBERS OF LENGTHS FOR EACH AGE":PRINT
1430 FOR I1=1 TO 10:PRINT:PRINT I1"th AGE
1440 INPUT "ENTER    DAY, MONTH OF SAMPLING (ENTER 999,999 IF READY) : ",CD,CM
1450 IF CD>=999 THEN 1600
1460 INPUT "ENTER    NUMBER OF YEARS COMPLETED UNTIL SAMPLING : ",CY
1470 INPUT "IS THIS CORRECT ? <0> OR <1> : ",C1:IF C1<>1 THEN 1440
1480 AG(I1)=INT(100*(CY+(AT(CM)+CD)/365)+.5):IF AG(I1)<=AG(I1-1) THEN AG(I1)=AG(
I1)+100
1490 FOR I2=1 TO 20:PRINT I2"th LENGTH"
1500 INPUT "ENTER    LENGTH (ENTER 999 IF READY) : ",L
1510 IF L<999 THEN AL(I1,I2)=INT(100*L+.5):NEXT I2 ELSE 1520
1520 PRINT:PRINT"REVIEW OF LENGTH DATA, AGE"AG(I1)/100:PRINT
1530 PRINT"No" TAB(15) "LENGTH"
1540 FOR I3=1 TO I2-1:PRINT I3 TAB(15) AL(I1,I3)/100:NEXT
1550 INPUT "IS THIS CORRECT? <0> OR <1> :",C1
1560 IF C1=1 THEN 1590
1570 INPUT"ERRONEOUS DATA: ENTER No, CORRECT VALUE : ",C1,L
1580 AL(I1,C1)=INT(100*L+.5):GOTO 1550
1590 NEXT I1
```

```
1600 NP=I1-1:PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"- WAIT -     RANDOM SEL
ECTION"
1610 FOR I2=20 TO 1 STEP -1
1620 FOR I1=1 TO NP:IF AL(I1,I2)=0 THEN NEXT ELSE 1640
1630 NEXT
1640 NZ=I2:L1=10000:L2=10000:L3=0:L4=0
1650 FOR I2=1 TO NZ
1660 IF AL(1,I2)<L1 AND AL(1,I2)>0 THEN L1=AL(1,I2)
1670 IF AL(2,I2)<L2 AND AL(2,I2)>0 THEN L2=AL(2,I2)
1680 IF AL(NP-1,I2)>L3 THEN L3=AL(NP-1,I2)
1690 IF AL(NP,I2)>L4 THEN L4=AL(NP,I2)
1700 NEXT
1710 L1=(L1+L2)/200:L3=(L3+L4)/200:SL=(L3-L1)/10:IC=100:RANDOMIZE(1)
1720 NR=NZ*NZ*(NP+1)+50:IF NR>1000 THEN NR=1000
1730 FOR I1=1 TO NR
1740 C1=INT((NP-1)*RND)
1750 C2=INT(NZ*RND+1):IF AL(C1+1,C2)=0 THEN 1750
1760 C3=INT(NZ*RND+1):IF AL(C1+2,C3)=0 THEN 1760
1770 IF AF(C1,C2,C3)>0 THEN 1810
1780 AF(C1,C2,C3)=1:L=(AL(C1+1,C2)+AL(C1+2,C3))/200
1790 FOR IL=1 TO 10:IF L>L1+IL*SL THEN NEXT
1800 IF AV(IL)<10 THEN IC=IC+1:AA(IC)=AL(C1+1,C2):AB(IC)=AL(C1+2,C3):DA(IC)=AG(C
1+1)/100:DB(IC)=AG(C1+2)/100:AV(IL)=AV(IL)+1
1810 NEXT I1
1820 NC=IC
1830 REM ** SORTING **
1840 FOR I5=101 TO NC-1:I6=I5:K1=AA(I6):K2=DA(I6):K3=AB(I6):K4=DB(I6)
1850 FOR I7=I5+1 TO NC:IF AA(I7)>K1 THEN 1870
1860 I6=I7:K1=AA(I6):K2=DA(I6):K3=AB(I6):K4=DB(I6)
1870 NEXT I7
1880 AA(I6)=AA(I5):DA(I6)=DA(I5):AB(I6)=AB(I5):DB(I6)=DB(I5)
1890 AA(I5)=K1:DA(I5)=K2:AB(I5)=K3:DB(I5)=K4:NEXT
1900 PRINT:PRINT"REVIEW OF RANDOMLY SELECTED AGE-LENGTH DATA PAIRS":PRINT
1910 PRINT"No" TAB(10) "L(1)" TAB(20) "t(1)" TAB(30) "L(2)" TAB(40) "t(2)"
1920 FOR IC=101 TO NC
1930 PRINT IC-100 TAB(10)AA(IC)/100 TAB(20)DA(IC) TAB(30)AB(IC)/100 TAB(40)DB(IC
)
1940 NEXT
1950 PRINT:PRINT"DISTRIBUTION OF DATA":PRINT
1960 PRINT"MEAN LENGTH" TAB(20) "FREQUENCY"
1970 FOR I1=1 TO 10:PRINT TAB(5) ">"L1+(I1-1)*SL TAB(20) AV(I1):NEXT:PRINT
1980 INPUT "ENTER <RET> TO CONTINUE :",C1:PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74)
:RETURN
1990 REM ================================================
2000 REM ***** GROWTH INCREMENT DATA FROM DISK *****
2010 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"GROWTH INCREMENT DATA FROM DIS
K":PRINT
2020 ON ERROR GOTO 2050
2030 INPUT "ENTER FILENAME: ",D1$
2040 GOTO 2060
2050 CLOSE#1:RESUME 2030
2060 OPEN "I",#1,D1$
2070 INPUT#1,D2$:INPUT#1,C1,C2,C3,C4,C5,C6,NB,NC
2080 IF NB+NC=0 THEN CLOSE#1:PRINT"NO GROWTH INCREMENT DATA AVAILABLE":INPUT "EN
TER <RET> TO CONTINUE : ",C1:GOTO 2200
```

```
2090 FOR I1=1 TO C1:INPUT#1,C3,C4
2100 FOR I2=1 TO C2:INPUT#1,C3:NEXT:NEXT
2110 FOR I1=1 TO C6:INPUT#1,C3:NEXT
2120 IF NB=0 THEN 2140
2130 FOR IB=1 TO NB:INPUT#1,AA(IB),DA(IB),AB(IB),DB(IB):NEXT
2140 IF NC=0 THEN 2160
2150 FOR IC=101 TO NC:INPUT#1,AA(IC),DA(IC),AB(IC),DB(IC):NEXT
2160 INPUT#1,C3:CLOSE#1
2170 PRINT:PRINT D1$:PRINT D2$:PRINT
2180 INPUT "IS THIS CORRECT ? <0> OR <1>: ",C1:IF C1=1 THEN 2200
2190 FOR IB=1 TO 200:AA(IB)=0:DA(IB)=0:AB(IB)=0:DB(IB)=0:NEXT:NB=0:NC=0
2200 RETURN
2210 REM ============================================================
2220 REM ***** OUTPUT ROUTINE (LINEPRINTER, DISKETTE) *****
2230 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74)
2240 PRINT"----------------------------------------------------------------------
2250 PRINT"                              OUTPUT ROUTINE
2260 PRINT"----------------------------------------------------------------------
2270 PRINT:INPUT "NEW FILE NAME:",D1$
2280 INPUT "INFORMATIONS ABOUT NEW FILE:",D2$
2290 PRINT" ":PRINT" "
2300 PRINT"----- OUTPUT MENU -----
2310 PRINT" OUTPUT ON LINEPRINTER  <1>
2320 PRINT" STORAGE ON DISKETTE    <2>
2330 PRINT" NO OUTPUT AND END      <3>
2340 INPUT"           SELECT NUMBER :",C1
2350 IF C1=3 THEN 2870
2360 ON C1 GOSUB 2370,2720:PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):GOTO 2300
2370 REM ***** OUTPUT ON LINEPRINTER
2380 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"OUTPUT ON LINEPRINTER, FORMAT:
 X-AXIS=SAMPLES, Y-AXIS=MIDLENGTH
2390 NP=INT(N1/12+11/12)
2400 IS=1:IP=12:IF N1<12 THEN IP=N1:NP=1
2410 PRINT NP"SHEETS OF PAPER REQUIRED":PRINT" "
2420 FOR I3=1 TO NP:PRINT I3". SHEET OF PAPER"
2430 INPUT "LINEPRINTER READY? <RET>:";C1
2440 LPRINT D1$:LPRINT D2$:LPRINT" ":LPRINT"SAMPLE No";
2450 FOR I1=IS TO IP:LPRINT TAB(19+(I1-IS)*7) I1;:NEXT:LPRINT" "
2460 LPRINT"DAY.MONTH";
2470 FOR I1=IS TO IP:LPRINT TAB(18+(I1-IS)*7) USING "##.##"; (AD(I1)*100+AM(I1))
/100;:NEXT:LPRINT
2480 LPRINT" ":LPRINT"CLASS  MIDL."
2490 FOR I2=1 TO N2:LPRINT TAB(2) I2 TAB(8) M1+(I2-1)*SI;
2500 FOR I1=IS TO IP:LPRINT TAB(17+(I1-IS)*7) USING "##.###"; A1(I1,I2)/1000;:NE
XT:LPRINT
2510 NEXT I2
2520 IS=IP+1:IP=IP+12:IF IP>N1 THEN IP=N1
2530 NEXT I3
2540 LPRINT" ":LPRINT"ASP="SA
2550 IF NB<1 THEN 2630
```

```
2560 PRINT:INPUT "READY FOR TAGGING DATA? <RET> :",C1
2570 CB=INT(NB/2+.5):LPRINT D1$:LPRINT"TAGGING DATA"
2580 LPRINT "No" TAB(10) "L(1)" TAB(20) "t(1)" TAB(30) "L(2)" TAB(40) "t(2)" TAB
(50) "No" TAB(60) "L(1)" TAB(70) "t(1)" TAB(80) "L(2
)" TAB(90) "t(2)"
2590 FOR IB=1 TO CB
2600 LPRINT IB TAB(10)AA(IB)/100 TAB(20)DA(IB) TAB(30)AB(IB)/100 TAB(40)DB(IB);
2610 LPRINT TAB(50)IB+CB TAB(60)AA(IB+CB)/100 TAB(70)DA(IB+CB) TAB(80)AB(IB+CB)/
100 TAB(90)DB(IB+CB)
2620 NEXT
2630 IF NC<101 THEN 2710
2640 PRINT:INPUT "READY FOR AGE - LENGTH DATA? <RET> :",C1
2650 CB=INT((NC-100)/2+.5):LPRINT D1$:LPRINT"LENGTH-AT-AGE DATA"
2660 LPRINT "No" TAB(10) "L(1)" TAB(20) "t(1)" TAB(30) "L(2)" TAB(40) "t(2)" TAB
(50) "No" TAB(60) "L(1)" TAB(70) "t(1)" TAB(80) "L(2
)" TAB(90) "t(2)"
2670 FOR IC=101 TO CB+100
2680 LPRINT IC-100 TAB(10)AA(IC)/100 TAB(20)DA(IC) TAB(30)AB(IC)/100 TAB(40)DB(I
C);
2690 LPRINT TAB(50) IC-100+CB TAB(60)AA(IC+CB)/100 TAB(70)DA(IC+CB) TAB(80)AB(IC
+CB)/100 TAB(90)DB(IC+CB)
2700 NEXT
2710 RETURN
2720 REM ***** STORAGE ON DISKETTE
2730 OPEN "O",#1,D1$
2740 PRINT#1,D2$
2750 PRINT#1,N1;N2;M1;M2;SI;NA;NB;NC;
2760 FOR I1=1 TO N1:PRINT#1,AM(I1);AD(I1);",";
2770 FOR I2=1 TO N2:PRINT#1,A1(I1,I2);:NEXT:NEXT
2780 FOR I1=1 TO NA:PRINT#1,A2(I1);:NEXT
2790 IF NB<1 THEN 2810
2800 FOR IB=1 TO NB:PRINT#1,AA(IB);DA(IB);AB(IB);DB(IB);:NEXT
2810 IF NC<101 THEN 2830
2820 FOR IC=101 TO NC:PRINT#1,AA(IC);DA(IC);AB(IC);DB(IC);:NEXT
2830 PRINT#1,SA
2840 CLOSE#1
2850 RETURN
2860 REM ---------------------------------------------
2870 CHAIN "START"
2880 END
```

```
10 REM ELEFAN 1B
20 DEF FNF1(X1,X2,X4,X5,X6,X7)=X1*(1-EXP(-X2*((X7-X5)+X4*SIN((X7-X6)*6.28319)/6.
28319)))
30 DEF FNF2(X1,X2,X5,X7)=X1*(1-EXP(-X2*(X7-X5)))
40 DEFINT A,C,I,N:WIDTH LPRINT 250
50 DIM A0(24,30):DIM A1(24,30):DIM D1(24):DIM AT(12):DIM DY(12)
60 DIM A2(100):DIM CE(6,6,4,4):DIM CS(6,6,4,4):DIM CP(6,6,4,4):DIM ST$(2)
70 DIM AA(200):DIM DA(200):DIM AB(200):DIM DB(200):DIM AE(100):DIM AP(100)
80 AT(1)=0:AT(2)=31:AT(3)=59:AT(4)=90:AT(5)=120:AT(6)=151:AT(7)=181:AT(8)=212:AT
(9)=243:AT(10)=273:AT(11)=304:AT(12)=334
90 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"-----------------------------------
--------------------------------------
100 PRINT"                                        ELEFAN 1B
110 PRINT"     PROGRAM FOR FITTING A GROWTH CURVE TO LENGTH-FREQUENCY DATA
120 PRINT"                     (AND OPTIONAL GROWTH INCREMENT DATA)
130 PRINT"---------------------------------------------------------------------------
140 PRINT:PRINT"DATA INPUT FROM DISK ONLY
150 PRINT"INPUT DATA: RESTRUCTURED DATA ONLY! (PROGRAM ELEFAN 1A)
160 REM ***** DATA INPUT *****
170 ON ERROR GOTO 200
180 PRINT:INPUT "ENTER FILENAME: ",D1$
190 GOTO 210
200 CLOSE #1:RESUME 180
210 OPEN "I",#1,D1$
220 INPUT#1,D2$
230 INPUT#1,N1,N2,M1,M2,SI,NA,NB,NC
240 FOR I1=1 TO N1:INPUT#1,AM,AD:D1(I1)=(AT(AM)+AD)/365
250 FOR I2=1 TO N2:INPUT#1,A0(I1,I2):NEXT:NEXT
260 FOR I1=1 TO NA:INPUT#1,A2(I1):NEXT
270 IF NB=0 THEN 290
280 FOR IB=1 TO NB:INPUT#1,AA(IB),DA(IB),AB(IB),DB(IB):NEXT
290 IF NC=0 THEN 310
300 FOR IC=101 TO NC:INPUT#1,AA(IC),DA(IC),AB(IC),DB(IC):NEXT
310 INPUT#1,SA:CLOSE#1
320 PRINT:PRINT D1$:PRINT D2$:PRINT
330 INPUT "IS THIS CORRECT ? <0> OR <1>: ",C1:IF C1<>1 THEN 180
340 FOR I1=1 TO N1:FOR I2=1 TO N2:A1(I1,I2)=A0(I1,I2):NEXT:NEXT
350 SA=SA*1000:M0=M1-SI/2:M3=M2+SI/2:ST$(1)="FIXED":ST$(2)="VARIABLE"
360 IF NB+NC=0 THEN EA$="ESP/ASP =":CF=1000:GOTO 400
370 IF NB=0 THEN EA$="(ESP/ASP + GA)/2 =":CF=2000:GOTO 400
380 IF NC=0 THEN EA$="(ESP/ASP + GT)/2 =":CF=2000:GOTO 400
390 EA$="(ESP/ASP + GT + GA)/3 =":CF=3000
400 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"--------------------------------
---------------
410 PRINT"IDENTIFICATION OF THE BEST FITTING GROWTH CURVE"
420 PRINT"-----------------------------------------------":PRINT
430 PRINT"VARIABLES ARE: K, Loo, C, WP, STARTING POINT":PRINT
440 PRINT"GROWTH CONSTANT K"
450 INPUT "FIXED K <0> OR VARIABLE K <1>: ";K:IF K<>0 AND K<>1 THEN 450 ELSE CK=
K
460 INPUT "VALUE OF K ? ",K:IF CK=0 THEN DK=0:KL=K:GOTO 490
470 INPUT "ENTER STEP SIZE OF K (3 STEPS TO BOTH SIDES) : ",DK
480 KL=K-3*DK:IF KL<=0 THEN 470
490 PRINT:PRINT"ASYMPTOTIC LENGTH Loo"
500 INPUT"FIXED Loo <0> OR VARIABLE Loo <1>: ";LI:IF LI<>0 AND LI<>1 THEN 500 EL
SE CL=LI
```

```
510 INPUT "VALUE OF Loo ? ",LI:IF LI<=M2+SI/2 THEN 510
520 IF CL=0 THEN DL=0:LL=LI:GOTO 560
530 PRINT"LOWER LIMIT OF Loo >"M3
540 INPUT "ENTER STEP SIZE OF Loo (3 STEPS TO BOTH SIDES) : ",DL
550 LL=LI-3*DL:IF LL<=M3 THEN 540
560 PRINT:PRINT"SEASONAL OSCILLATION IN GROWTH: AMPLITUDE CONSTANT C (0<=C)"
570 PRINT"SET C=0 IF GROWTH OSCILLATIONS ARE APPARENT
580 PRINT"SET C=1 FOR SAMPLES FROM TEMPERATE WATERS"
590 INPUT "FIXED C <0> OR VARIABLE C <1>: ";OC:IF OC<>0 AND OC<>1 THEN 590 ELSE
CC=OC
600 INPUT "VALUE OF C ? ",OC
610 IF CC=0 THEN OL=OC:DC=0:GOTO 640
620 INPUT "ENTER STEP SIZE (2 STEPS TO BOTH SIDES): ",DC
630 OL=OC-DC*2:IF OL<0 THEN OL=0
640 IF OC=0 AND CC=0 THEN CT=0:C3=2:GOTO 710 ELSE C3=1
650 PRINT:PRINT"WINTER POINT WP (0<=WP<1):"
660 INPUT "FIXED WP <0> OR VARIABLE WP <1>: ";TS:IF TS<>0 AND TS<>1 THEN 660 ELS
E CT=TS
670 INPUT "VALUE OF WP ? ", TS:TS=TS-.5
680 IF CT=0 THEN TL=TS:DT=0:GOTO 710
690 INPUT "ENTER STEP SIZE (2 STEPS TO BOTH SIDES): ",DT
700 TL=TS-2*DT:IF TL<0 THEN TL=1+TL
710 PRINT:PRINT"STARTING POINT VARIABLE                                    <1>
720 PRINT"STARTING POINT FIXED AT LENGTH                             <2>
730 PRINT"STARTING POINT FIXED AT LENGTH +/- 1/2 LENGTH CLASS        <3>
740 INPUT"                                   SELECT NUMBER        : ",CM
750 IF CM=1 THEN 770 ELSE INPUT "SAMPLE No, LENGTH: ",P1,PL:PC=PL
760 IF PL<0 OR PL>M2+SI/2 THEN PRINT"LENGTH OUT OF RANGE":GOTO 750
770 NO=4*CC:NT=4*CT:NL=6*CL:NK=6*CK:PRINT
780 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"PARAMETERS ENTERED:"
790 PRINT"K   ="K TAB(15) ST$(CK+1):PRINT"Loo ="LI TAB(15) ST$(CL+1)
800 PRINT"C   ="OC TAB(15) ST$(CC+1):PRINT"WP  ="TS+.5 TAB(15) ST$(CT+1)
810 IF CM=1 THEN PRINT"STARTING POINT VARIABLE":GOTO 830
820 PRINT"STARTING POINT: SAMPLE"P1", LENGTH"PL
830 INPUT "IS THIS CORRECT? <0> OR <1> : ",C1
840 IF C1=0 THEN 420 ELSE PRINT:PRINT"- SEARCH ROUTINE _":PRINT
850 REM ===================================================
860 REM ***** SEARCH FOR BEST FITTING GROWTH CURVE *****
870 FOR IK=0 TO NK:K=KL+IK*DK
880 FOR IL=0 TO NL:LI=LL+IL*DL
890 FOR IO=0 TO NO:OC=OL+IO*DC
900 FOR IT=0 TO NT:TS=TL+IT*DT
910 IF NB>0 THEN NS=1:NE=NB:PM=PL:GOSUB 1760:PL=PM
920 IF NC>0 THEN NS=101:NE=NC:PM=PL:GOSUB 1760:PL=PM
930 ON CM GOSUB 1210,1340,1370:SM=INT(1000*(SM+GT+GA)+.5)
940 CE(IK,IL,IO,IT)=SM:CS(IK,IL,IO,IT)=P1:CP(IK,IL,IO,IT)=PL*100
950 PRINT:PRINT"K ="K TAB(15) "Loo="LI TAB(30) "C ="OC TAB(45) "WP ="TS+.5
960 PRINT"BEST "EA$;SM/CF,"SAMPLE"P1", LENGTH"PL
970 NEXT IT
980 NEXT IO
990 NEXT IL
1000 NEXT IK
```

```
1010 IF CK+CL+CC+CT>0 THEN SM=-1000
1020 FOR IK=0 TO NK:FOR IL=0 TO NL:FOR IO=0 TO NO:FOR IT=0 TO NT
1030 IF CE(IK,IL,IO,IT)<=SM THEN 1050
1040 SM=CE(IK,IL,IO,IT):P1=CS(IK,IL,IO,IT):PL=CP(IK,IL,IO,IT)/100:CK=IK:CL=IL:CC
=IO:CT=IT
1050 NEXT:NEXT:NEXT:NEXT
1060 K=KL+CK*DK:LI=LL+CL*DL:OC=OL+CC*DC:TS=TL+CT*DT
1070 P2=INT((PL-M1)/SI+.5)+1:IF OC=0 THEN WP=0 ELSE WP=TS+.5:IF WP>=1 THEN WP=WP
-1
1080 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT EA$;SM/CF
1090 PRINT "K  ="K TAB(15) "Loo="LI TAB(30) "C  ="OC TAB(45) "WP ="WP
1100 PRINT"STARTING POINT: SAMPLE"P1", CLASS"P2", LENGTH"PL:PRINT
1110 PRINT"FURTHER SEARCH                              <1>
1120 PRINT"RESPONSE SURFACE CALCULATION                <2>
1130 PRINT"GROWTH CURVE CALCULATION                    <3>
1140 PRINT"END OF SEARCH                               <4>
1150 INPUT"                    SELECT NUMBER           :",C1:PRINT
1160 T2=D1(P1):ON C1 GOTO 420,1170,1180,3010
1170 GOSUB 2540:PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):GOTO 1110
1180 GOSUB 1930:PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):GOTO 1110
1190 REM ==============================================
1200 REM ***** STARTING POINT VARIABLE *****
1210 FOR IP=1 TO NA:P1=INT(A2(IP)/100):P2=A2(IP)-P1*100:P3=M1+(P2-1.5)*SI
1220 T2=D1(P1):PM=0:SP=-1000
1230 FOR IO=0 TO 2:PL=P3+IO*SI/2:GOSUB 1450:GOSUB 1500
1240 IF SE>.6 THEN GOSUB 1380:SE=SM
1250 IF SE>SP THEN SP=SE:PM=PL
1260 NEXT
1270 AE(IP)=1000*SP:AP(IP)=100*PM:NEXT
1280 SM=-1000:IM=0
1290 FOR IP=1 TO NA:IF AE(IP)>SM THEN SM=AE(IP):IM=IP
1300 NEXT
1310 SM=SM/1000:P1=INT(A2(IM)/100):PL=AP(IM)/100:RETURN
1320 REM ----------------------------------------------
1330 REM ***** STARTING POINT FIXED AT LENGTH *****
1340 T2=D1(P1):GOSUB 1450:GOSUB 1500:SM=SE:RETURN
1350 REM ----------------------------------------------
1360 REM ***** STARTING POINT FIXED AT LENGTH +/- 1/2 CLASS *****
1370 IF CM=3 THEN PL=PC
1380 SM=-1000:T2=D1(P1):P4=PL-.5*SI:DP=SI/10
1390 FOR I1=0 TO 10:PL=P4+I1*DP:GOSUB 1450:GOSUB 1500
1400 IF SE>SM THEN SM=SE:PM=PL
1410 NEXT
1420 PL=PM:RETURN
1430 REM ==============================================
1440 REM ***** SUBROUTINE TO *****
1450 TO=LOG(1-PL/LI)/K+T2
1460 IF OC=0 THEN 1480
1470 TO=TO+SIN((T2-TS)*6.28319)*OC/6.28319
1480 RETURN
```

```
1490 REM ***** SUBROUTINE GROWTH FUNCTION *****
1500 SE=0:I5=0
1510 FOR IS=1 TO N1:T1=D1(IS)+I5
1520 ON C3 GOSUB 1890,1900
1530 IF L1<=M0 THEN 1560
1540 IF L1>=M3 THEN 1580
1550 I4=INT((L1-M1)/SI+.5)+1:SE=SE+A1(IS,I4):IF A1(IS,I4)>0 THEN GOSUB 1690
1560 NEXT IS
1570 IF I5<12 THEN I5=I5+1:GOTO 1510
1580 I5=1
1590 FOR IS=N1 TO 1 STEP -1:T1=D1(IS)-I5
1600 ON C3 GOSUB 1890,1900
1610 IF L1<=M0 THEN 1650
1620 I4=INT((L1-M1)/SI+.5)+1:SE=SE+A1(IS,I4):IF A1(IS,I4)>0 THEN GOSUB 1690
1630 NEXT IS
1640 IF I5<12 THEN I5=I5+1:GOTO 1590
1650 FOR I3=1 TO N1:FOR I4=1 TO N2:A1(I3,I4)=A0(I3,I4):NEXT:NEXT
1660 SE=INT(1000*SE/SA+.5)/1000:RETURN
1670 REM ----------------------------------------
1680 REM SET POSITIVE RUN = 0
1690 A1(IS,I4)=0:IZ=I4+1
1700 IF A1(IS,IZ)>0 THEN A1(IS,IZ)=0:IZ=IZ+1:GOTO 1700
1710 IZ=I4-1
1720 IF A1(IS,IZ)>0 THEN A1(IS,IZ)=0:IZ=IZ-1:GOTO 1720
1730 RETURN
1740 REM -----------------------------------------------------
1750 REM ***** SUBROUTINE TAGGING/ AGE-LENGTH DATA *****
1760 SV=0:SW=0:SX=0:SY=0
1770 FOR IS=NS TO NE:T3=DB(IS)-DA(IS):WE=(AB(IS)-AA(IS))/(100*T3)
1780 SV=SV+WE:SW=SW+WE*WE
1790 PL=AA(IS)/100:T2=DA(IS):GOSUB 1450:T1=DB(IS):ON C3 GOSUB 1890,1900
1800 WT=(L1-PL)/T3:WT=WE-WT:SX=SX+WT:SY=SY+WT*WT:NEXT
1810 NE=NE-NS+1:WE=(SW-SV*SV/NE)/(NE-1):WT=(SY-SX*SX/NE)/(NE-1)
1820 WE=(WE-WT)/WE:SZ=SZ+1:IF WE<0 THEN WE=0
1830 IF NS>100 THEN 1850
1840 S1=S1+SE:S2=S2+WE:S3=S3+SE*SE:S4=S4+WE*WE:S5=S5+SE*WE:GT=WE:GOTO 1860
1850 S6=S6+SE:S7=S7+WE:S8=S8+SE*SE:S9=S9+WE*WE:S0=S0+SE*WE:GA=WE
1860 RETURN
1870 REM -----------------------------------------------------
1880 REM FUNCTION CALL
1890 L1=FNF1(LI,K,DC,TO,TS,T1):RETURN
1900 L1=FNF2(LI,K,TO,T1):RETURN
1910 REM =====================================================
1920 REM ***** OUTPUT ROUTINE *****
1930 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):IF NB=0 OR SZ<3 THEN 1980
1940 XQ=S1/SZ:YQ=S2/SZ:FW=S5-S1*S2/SZ:FX=S3-S1*S1/SZ:FY=S4-S2*S2/SZ
1950 MF=FW/FX:TF=YQ-MF*XQ:IF FX*FY>=0 THEN RT=FW/SQR(FX*FY) ELSE RT=0
1960 PRINT"CORRELATION BETWEEN ESP/ASP AND GT:"
1970 PRINT"GT = "TF" + "MF" * ESP/ASP  ; r ="RT"; N ="SZ
1980 IF NC=0 OR SZ<3 THEN 2040
1990 XQ=S6/SZ:YQ=S7/SZ:FW=S0-S6*S7/SZ:FX=S8-S6*S6/SZ:FY=S9-S7*S7/SZ
2000 MF=FW/FX:TF=YQ-MF*XQ:IF FX*FY>=0 THEN RA=FW/SQR(FX*FY) ELSE RA=0
```

```
2010 PRINT:PRINT"CORRELATION BETWEEN ESP/ASP AND GA:"
2020 PRINT"GA = "TF" + "MF" * ESP/ASP  ; r ="RA"; N ="SZ
2030 PRINT:INPUT "ENTER <RET> TO CONTINUE : ",C1
2040 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"GROWTH CURVE CALCULATION":PRIN
T
2050 PRINT "K  ="K TAB(15) "Loo="LI TAB(30) "C  ="OC TAB(45) "WP ="WP
2060 PRINT:PRINT"STARTING POINT: SAMPLE"P1", CLASS"P2", LENGTH"PL:PRINT
2070 PRINT EA$;SM/CF
2080 REM CALCULATION OF THE GROWTH CURVE POINTS FOR THE 15th OF EACH MONTH
2090 TS=WP-.5:IF TS<0 THEN TS=1+TS
2100 FOR I1=1 TO 12:DY(I1)=(AT(I1)+15)/365:NEXT
2110 GOSUB 1450:NO=INT(TO)-2
2120 FOR I2=1 TO 20
2130 FOR I1=1 TO 12:A1(I1,I2+1)=0:T1=DY(I1)+I2+NO:ON C3 GOSUB 1890,1900
2140 IF L1<0 THEN A1(I1,I2)=0:GOTO 2170
2150 IF L1>=LI*.9799999 THEN 2190
2160 A1(I1,I2)=INT(10*L1+.5)
2170 NEXT I1
2180 NEXT I2
2190 NH=I2:NL=1
2200 FOR I2=1 TO NH:SN=0
2210 FOR I1=1 TO 12:SN=SN+A1(I1,I2):NEXT
2220 IF SN=0 THEN NL=NL+1:NEXT I2
2230 REM *** OUTPUT OF GROWTH CURVE POINTS
2240 PRINT:PRINT"GROWTH CURVE POINTS (LENGTH) FOR THE 15th OF EACH MONTH"
2250 PRINT"MONTH";
2260 FOR I1=1 TO 12:PRINT TAB(8+(I1-1)*6) I1;:NEXT
2270 PRINT"-----------------------------------------------------------------------
---------
2280 FOR I2=NL TO NH
2290 FOR I1=1 TO 12:PRINT TAB(8+(I1-1)*6) A1(I1,I2)/10;:NEXT
2300 NEXT I2
2310 REM OUTPUT ON LINEPRINTER
2320 PRINT:INPUT "OUTPUT ON LINEPRINTER? <0> OR <1>: ",C1:IF C1<>1 THEN 2490
2330 INPUT "LINEPRINTER READY? <RET>: ",C1
2340 LPRINT D1$:LPRINT D2$:LPRINT
2350 LPRINT"v.BERTALANFFY GROWTH CURVE FITTED TO THE DATA":LPRINT
2360 LPRINT"GROWTH-PARAMETERs: K  ="K
2370 LPRINT"                   Loo="LI
2380 LPRINT"                   C  ="OC
2390 LPRINT"                   WP ="WP
2400 LPRINT"STARTING POINT: SAMPLE"P1", CLASS"P2", LENGTH"PL
2410 LPRINT EA$;SM/CF:LPRINT
2420 LPRINT:LPRINT"GROWTH CURVE POINTS (LENGTH) FOR THE 15th OF EACH MONTH"
2430 LPRINT:LPRINT"MONTH";
2440 FOR I1=1 TO 12:LPRINT TAB(8+(I1-1)*7) I1;:NEXT:LPRINT
2450 LPRINT"-----------------------------------------------------------------------
-----------------------"
2460 FOR I2=NL TO NH
2470 FOR I1=1 TO 12:LPRINT TAB(8+(I1-1)*7) A1(I1,I2)/10;:NEXT:LPRINT" "
2480 NEXT I2
2490 FOR I1=1 TO N1:FOR I2=1 TO N2:A1(I1,I2)=A0(I1,I2):NEXT:NEXT
2500 RETURN
```

```
2510 REM =========================================================
2520 REM ***** RESPONSE SURFACE *****
2530 REM §§§§§ PRINT"NOT INCLUDED!":RETURN
2540 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"RESPONSE SURFACE CALCULATION":
PRINT
2550 KM=K:LM=LI:OM=OC:WM=WP:MS=SM
2560 PRINT" **  2 GROWTH PARAMETERS (K, Loo, C, WP) VARIABLE **
2570 PRINT"ENTER GROWTH PARAMETER INTERVALS (LOWER, UPPER LIMIT)
2580 PRINT"IF FIXED THEN ENTER LOWER LIMIT = UPPER LIMIT":PRINT
2590 PRINT"LOWER LIMIT OF Loo MUST BE > "PL
2600 INPUT " K    : ENTER LOWER, UPPER LIMIT :",KL,KU:DK=(KU-KL)/9
2610 INPUT " Loo : ENTER LOWER, UPPER LIMIT :",LL,LU:DL=(LU-LL)/9
2620 INPUT " C    : ENTER LOWER, UPPER LIMIT :",OL,OU:DC=(OU-OL)/9
2630 INPUT " WP  : ENTER LOWER, UPPER LIMIT :",TL,TU:DT=(TU-TL)/9
2640 IF OL+DC=0 THEN C3=2 ELSE C3=1
2650 PRINT:PRINT"- Please wait, I'll be back in a few minutes -"
2660 IF SGN(DK)+SGN(DL)+SGN(DC)+SGN(DT)<>2 THEN PRINT"MORE THAN 2 PARAMETERS VAR
IABLE!":GOTO 2570
2670 IF DK>0 THEN Y$="K":YL=KL:DY=DK ELSE IF DL>0 THEN Y$="Loo":YL=LL:DY=DL ELSE
 Y$="C":YL=OL:DY=DC:X$="WP":XL=TL:DX=DT:GOTO 2710
2680 IF LL <= PL THEN PRINT"LOWER LIMIT OF Loo MUST BE > "PL:GOTO 2560
2690 IF Y$="K" THEN IF DL>0 THEN X$="Loo":XL=LL:DX=DL ELSE IF DC>0 THEN X$="C":X
L=OL:DX=DC ELSE X$="WP":XL=TL:DX=DT
2700 IF Y$="Loo" THEN IF DC>0 THEN X$="C":XL=OL:DX=DC ELSE X$="WP":XL=TL:DX=DT
2710 IE=1:NK=9*SGN(DK):NL=9*SGN(DL):NO=9*SGN(DC):NT=9*SGN(DT)
2720 IF OL=0 AND DC=0 THEN C3=2 ELSE C3=1
2730 TL=TL-.5:IF TL<0 THEN TL=1+TL
2740 FOR IK=0 TO NK:K=KL+IK*DK
2750 FOR IL=0 TO NL:LI=LL+IL*DL
2760 FOR IO=0 TO NO:OC=OL+IO*DC
2770 FOR IT=0 TO NT:TS=TL+IT*DT
2780 IF NB>0 THEN NS=1:NE=NB:PM=PL:GOSUB 1760:PL=PM
2790 IF NC>0 THEN NS=101:NE=NC:PM=PL:GOSUB 1760:PL=PM
2800 T2=D1(P1):GOSUB 1450:GOSUB 1500:SM=SE:AE(IE)=INT(1000000!*(SM+GT+GA)/CF+.5)
:IE=IE+1
2810 NEXT IT:NEXT IO:NEXT IL:NEXT IK
2820 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"RESPONSE SURFACE":PRINT Y$
2830 FOR I1=0 TO 90 STEP 10:PRINT INT(1000*(YL+I1/10*DY)+.5)/1000;
2840 FOR I2=1 TO 10:IE=I1+I2:PRINT TAB(8+I2*6) AE(IE);:NEXT:PRINT
2850 NEXT
2860 PRINT:PRINT X$;
2870 FOR I2=1 TO 10:PRINT TAB(8+I2*6) INT(100*(XL+(I2-1)*DX)+.5)/100;:NEXT
2880 PRINT:INPUT "OUTPUT ON LINEPRINTER? <0> OR <1> : ",C1:IF C1<>1 THEN 2990
2890 INPUT "PRESS <RET> TO CONTINUE :",C1:IF DT>0 THEN TL=TU-.5 ELSE TL=TU
2900 LPRINT D1$:LPRINT D2$:LPRINT:LPRINT"RESPONSE SURFACE CALCULATION"
2910 LPRINT"STARTINGPOINT: SAMPLE"P1", LENGTH"PL
2920 LPRINT" K   :"KL" - "KU:LPRINT" Loo:"LL" - "LU
2930 LPRINT" C   :"OL" - "OU:LPRINT" WP :"TL" - "TU
2940 LPRINT:LPRINT Y$
2950 FOR I1=0 TO 90 STEP 10:LPRINT INT(1000*(YL+I1/10*DY)+.5)/1000;
2960 FOR I2=1 TO 10:IE=I1+I2:LPRINT TAB(8+I2*6) AE(IE);:NEXT:LPRINT
2970 NEXT:LPRINT:LPRINT X$;
2980 FOR I2=1 TO 10:LPRINT TAB(8+I2*6) INT(100*(XL+(I2-1)*DX)+.5)/100;:NEXT:LPRI
NT
2990 FOR I1=1 TO 100:AE(I1)=0:NEXT:K=KM:LI=LM:OC=OM:WP=WM:SM=MS:RETURN
3000 REM =========================================================
3010 CHAIN "START"
3020 END
```

```
10 REM ELEFAN 2A
20 DEFINT A,C,I,N
30 DIM AO(24,30):DIM AD(24):DIM AM(24):DIM CM(24):DIM AT(12):DIM D1(24)
40 DIM BO(24,30):DIM B1(30):DIM B2(30):DIM TL(31):DIM TM(30):DIM TH(30)
50 DIM MW(30):DIM MB(30):DIM B3(30):DIM PC(30)
60 DIM RP(12):DIM AP(12):DIM RW$(1):RW$(0)="NO":RW$(1)="YES"
70 AT(1)=0:AT(2)=31:AT(3)=59:AT(4)=90:AT(5)=120:AT(6)=151:AT(7)=181:AT(8)=212:AT
(9)=243:AT(10)=273:AT(11)=304:AT(12)=334
80 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74)
90 PRINT"-------------------------------------------------------------------------
100 PRINT"                              ELEFAN 2A
110 PRINT"    PROGRAM FOR ESTIMATING RECRUITMENT PATTERNS AND MORTALITY
120 PRINT"         FROM LENGTH-FREQUENCY DATA AND GROWTH PARAMETERS"
130 PRINT"-------------------------------------------------------------------------
140 REM ***** DATA INPUT *****
150 PRINT:PRINT"INPUT OF LENGTH-FREQUENCY DATA FROM DISK ONLY":PRINT
160 ON ERROR GOTO 180:INPUT "ENTER DATA FILE NAME : ",D1$
170 GOTO 190
180 CLOSE #1:RESUME 160
190 OPEN "I",#1,D1$:GOTO 200
200 INPUT#1,D2$
210 INPUT#1,N1,N2,M1,M2,SI
220 FOR I1=1 TO N1:INPUT#1,AM(I1),AD(I1)
230 FOR I2=1 TO N2:IF EOF(1) THEN 250 ELSE INPUT#1,AO(I1,I2)
240 NEXT:NEXT
250 CLOSE#1:NM=N2:MO=M1
260 PRINT:PRINT D1$:PRINT D2$:PRINT" "
270 INPUT "IS THIS CORRECT ? <0> OR <1>:",C1:IF C1<>1 THEN 160
280 FOR I1=1 TO N1:D1(I1)=(AT(AM(I1))+AD(I1))/365:NEXT
290 PRINT:PRINT"ENTER GROWTH PARAMETERS":PRINT
300 INPUT "VALUE OF TO AVAILABLE? <0> OR <1>: ";CT
310 IF CT=0 THEN TO=0 ELSE INPUT "VALUE OF TO: ",TO
320 PRINT:INPUT "GROWTH CONSTANT K: ",K
330 INPUT "INFINITE LENGTH Loo: ",LI
340 INPUT "SEASONAL GROWTH OSCILLATIONS: AMPLITUDE CONSTANT C: ",OC
350 IF OC>0 THEN INPUT "WINTER POINT WP: ",WP
360 TS=WP-.5:IF TS<0 THEN TS=1+TS
370 INPUT "IS THIS CORRECT ? <0> OR <1> :",C1: IF C1<>1 THEN 290
380 REM ==================================================
390 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"----- ELEFAN 2A MAIN MENU -----
400 PRINT"        RECRUITMENT PATTERN     <1>"
410 PRINT"        TOTAL MORTALITY         <2>"
420 PRINT"        RETURN TO START MENU    <3>"
430 INPUT "                SELECT NUMBER:   ",CC:IF CC<1 OR CC>3 THEN 390
440 IF CC=3 THEN 2930
450 REM ***** RESTRUCTURING OF SAMPLES *****
460 FOR I2=1 TO N2:B1(I2)=0:B2(I2)=0:NEXT
470 PRINT:PRINT"----- WEIGHTING/RESTRUCTURING OF SAMPLES -----
480 PRINT"        NO WEIGHTING/RESTRUCTURING:              <1>"
490 PRINT"        CONVERSION TO % LENGTH-FREQU.:           <2>"
500 PRINT"        WEIGHTING BY SQUARE ROOT OF SAMPLE SIZE: <3>
510 PRINT"        CONV. TO % AND WEIGHTING BY SQUARE ROOT: <4>"
520 INPUT "                           SELECT NUMBER: ",CR
```

```
530 IF CR<1 OR CR>4 THEN 470
540 FOR I1=1 TO N1:S1=0:SQ=1
550 FOR I2=1 TO N2:S1=S1+A0(I1,I2):NEXT
560 IF CR>2 THEN SQ=SQR(S1)
570 IF CR=1 OR CR=3 THEN S1=1
580 FOR I2=1 TO N2:B0(I1,I2)=A0(I1,I2)*SQ/S1:NEXT
590 NEXT I1
600 IF N1<3 THEN 720
610 PRINT:INPUT "WEIGHTING WITH RESPECT TO DISTANCE IN TIME? <0> OR <1> :",CQ
620 IF CQ<>1 THEN 720
630 FOR I1=1 TO N1:DM=D1(I1):DH=.5
640 FOR I3=1 TO N1: IF I3=I1 THEN 670
650 DT=ABS(D1(I3)-DM):IF DT>.5 THEN DT=1-DT
660 IF DT<DH THEN DH=DT
670 NEXT
680 TH(I1)=INT(1000*(1+DH*2)+.5)/1000:NEXT
690 FOR I1=1 TO N1:FOR I2=1 TO N2:B0(I1,I2)=B0(I1,I2)*TH(I1):NEXT:NEXT
700 FOR I1=1 TO N1:TH(I1)=0:NEXT
710 REM ***** SELECTION OF SAMPLES *****
720 IF N1=1 THEN CM(1)=1:CS=1:GOTO 850
730 FOR I1=1 TO N1:CM(I1)=0:NEXT
740 CS=0:PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"SELECTION OF SAMPLES"
750 FOR I1=1 TO N1:PRINT:PRINT"SAMPLE"I1:PRINT
760 PRINT "CLASS" TAB(20) "FREQU" TAB(30) "WEIGHTED FREQUENCY"
770 FOR I2=1 TO N2:PRINT TAB(2) I2 TAB(20) A0(I1,I2) TAB(34) B0(I1,I2):NEXT
780 PRINT:INPUT "INCLUDED? <0> OR <1>: ",C1
790 IF C1>0 THEN CM(I1)=1:CS=CS+CM(I1)
800 NEXT I1
810 IF CS>1 THEN 850
820 FOR I1=1 TO N1:IF CM(I1)=0 THEN NEXT ELSE CI=I1
830 CM(1)=1:N1=1
840 FOR I2=1 TO N2:A0(1,I2)=A0(CI,I2):NEXT
850 IF CC=1 THEN PRINT:PRINT"- WAIT -":GOTO 2210
860 REM ======================================================
870 REM ***** TOTAL MORTALITY *****
880 PRINT:PRINT"ESTIMATION OF TOTAL MORTALITY
890 IF N1<3 OR OC<=1 THEN 1040
900 INPUT "WEIGHTING OF SAMPLES WITH RESPECT TO C AND WP? <0> OR <1> : ",CW
910 IF CW=0 THEN 1040 ELSE CS=0:DC=INT(1000*SQR(OC-1)/3+.5)/1000
920 FOR I1=1 TO N1:IF CM(I1)=0 THEN 950
930 DT=ABS(WP-D1(I1)):IF DT>.5 THEN DT=1-DT
940 IF DT<=DC THEN CM(I1)=2:CS=CS+1
950 NEXT
960 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT "STATUS OF SAMPLES"
970 PRINT"  0 = EXCLUDED, 1 = INCLUDED, 2 = WEIGHTED WITH RESPECT TO C AND WP"
980 PRINT"No","STATUS"
990 FOR I1=1 TO N1:PRINT I1,CM(I1):NEXT:INPUT "ENTER <RET> :",C1
1000 FOR I1=1 TO N1:IF CM(I1)<2 THEN 1020
1010 FOR I2=1 TO N2:B1(I2)=B1(I2)+B0(I1,I2):NEXT
1020 NEXT:IF CS=0 THEN 1060
1030 FOR I2=1 TO N2:B1(I2)=B1(I2)/CS:NEXT
1040 PRINT"- WAIT -"
```

```
1050 REM *** ADDING UP SAMPLES
1060 FOR I1=1 TO N1:IF CM(I1)<>1 THEN 1080
1070 FOR I2=1 TO N2:B1(I2)=B1(I2)+B0(I1,I2):NEXT
1080 NEXT I1
1090 FOR I2=1 TO N2:B2(I2)=B1(I2):NEXT
1100 REM CHECK FOR ZERO VALUES
1110 FOR I2=1 TO N2:IF B1(I2)=0 THEN NEXT ELSE NL=I2
1120 IF NL=1 THEN 1160
1130 ND=NL-1
1140 FOR I2=1 TO N2-ND:B1(I2)=B1(I2+ND):B2(I2)=B2(I2+ND):NEXT
1150 N2=N2-ND:M1=M1+ND*SI
1160 FOR I2=N2 TO 1 STEP -1:IF B1(I2)=0 THEN NEXT ELSE NH=I2
1170 M2=M2-(N2-NH)*SI:N2=NH
1180 FOR I2=1 TO N2:IF B1(I2)><0 THEN NEXT ELSE GOTO 2070
1190 REM *** COMPUTING N/delta T
1200 SA=0:LT=M1-SI/2
1210 GOSUB 2690:TL(1)=TF
1220 FOR I2=1 TO N2:LT=LT+SI:GOSUB 2690:TH(I2)=TF
1230 DT=TH(I2)-TL(I2):B1(I2)=B1(I2)/DT:SA=SA+B1(I2)
1240 TL(I2+1)=TH(I2):NEXT I2
1250 FOR I2=1 TO N2:B1(I2)=B1(I2)*100/SA:NEXT
1260 FOR I2=1 TO N2:IF B1(I2)>0 THEN B1(I2)=LOG(B1(I2)) ELSE B1(I2)=-99
1270 NEXT
1280 FOR I2=1 TO N2:LT=M1+(I2-1)*SI:GOSUB 2690:TM(I2)=TF:NEXT
1290 REM *** COMPUTATION OF Z
1300 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"VIDEO PLOT: LOG(%N/deltaT) ON
RELATIVE AGE"
1310 GOSUB 2760
1320 INPUT "LISTING OF THE (x,y) DATA? <0> OR <1>: ",C1:IF C1=0 THEN 1440
1330 PRINT:PRINT" No" TAB(10) "LN(%N/delta T)" TAB(30) "RELATIVE AGE"
1340 FOR I2=1 TO N2:PRINT TAB(1) I2 TAB(13) B1(I2) TAB(33) TM(I2):NEXT
1350 PRINT:PRINT"NOTE POINTS (No) TO BE INCLUDED IN CATCH CURVE"
1360 PRINT:INPUT "OUTPUT ON LINEPRINTER? <0> OR <1>: ",C1:IF C1=0 THEN 1430
1370 INPUT "LINEPRINTER READY? PRESS <RET> :",C1
1380 LPRINT D1$:LPRINT D2$:LPRINT:LPRINT"WEIGHTING MODE No"CR
1390 LPRINT"WEIGHTING (TIME): ";RW$(CQ):LPRINT"WEIGHTING (C,WP): ";RW$(CW)
1400 LPRINT"GROWTH-PARAMETERS: Loo="LI", K ="K", C ="OC", WP ="WP:LPRINT
1410 LPRINT"CATCH CURVE POINTS" TAB(20) "No" TAB(30) "LN(%N/Delta T)" TAB(50) "R
ELATIVE AGE"
1420 FOR I2=1 TO N2:LPRINT TAB(21) I2 TAB(33) B1(I2) TAB(53) TM(I2):NEXT
1430 INPUT "DISPLAY VIDEO PLOT AGAIN? <0> OR <1>: ",C1:IF C1=1 THEN 1300
1440 REM *** SELECTION OF POINTS
1450 PRINT:PRINT"CONSTRUCTION OF THE CATCH CURVE":PRINT
1460 INPUT "ENTER FIRST POINT (No) TO BE INCLUDED: ",P1
1470 INPUT "ENTER LAST  POINT (No) TO BE INCLUDED: ",P2
1480 IF P2<=P1 OR P2>N2 THEN PRINT"* NONSENSE!! ENTER AGAIN!":GOTO 1460
1490 S1=0:S2=0:S3=0:S4=0:S5=0:NP=P2-P1+1
1500 FOR IC=P1 TO P2:X=TM(IC):Y=B1(IC):S1=S1+X:S2=S2+Y:S3=S3+X*X:S4=S4+Y*Y:S5=S5
+X*Y:NEXT
1510 GOSUB 2170
1520 VZ=-MC:ZM=VZ:KM=KC
1530 REM *** ITERATION OF Z
1540 S1=0:S2=0:S3=0:S4=0:S5=0
1550 FOR IC=P1 TO P2:X=TL(IC):Y=LOG(B2(IC)/(1-EXP(MC*(TH(IC)-TL(IC)))))
1560 S1=S1+X:S2=S2+Y:S3=S3+X*X:S4=S4+Y*Y:S5=S5+X*Y:NEXT
1570 GOSUB 2170
```

```
1580 IF ABS(VZ+MC)>.001 THEN VZ=-MC:GOTO 1540
1590 VZ=-MC
1600 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"ESTIMATED TOTAL MORTALITY Z ="
VZ
1610 PRINT"(LINEAR REGRESSION: Z ="ZM", CORRELATION COEFF.="KM")":PRINT
1620 REM *** SELECTION CURVE
1630 PRINT:PRINT"COMPUTATION OF PROBABILITIES OF CAPTURE":PRINT
1640 PRINT "ENTER NATURAL MORTALITY COEFFICIENT M"
1650 INPUT "IN UNEXPLOITED STOCKS M = Z :",MM
1660 IF VZ=MM THEN FOR I2=0 TO P1:MW(I2)=MM:NEXT:GOTO 1690
1670 FOR I2=0 TO P1:MW(I2)=MM+I2*(VZ-MM)/P1:NEXT
1680 FOR I2=1 TO P1-1:MB(I2)=(MW(I2)+MW(I2+1))/2:NEXT
1690 B3(P1)=B2(P1)
1700 FOR I2=P1-1 TO 1 STEP -1:B3(I2)=B3(I2+1)*EXP(MB(I2)*(TM(I2+1)-TM(I2))):NEXT
1710 PT=0
1720 FOR I2=1 TO P1:PC(I2)=INT(10000*B2(I2)/B3(I2)+.5)/10000:PT=PT+PC(I2):NEXT
1730 DI=(P1+.5)-PT:PL=INT(DI):LL=M1+(PL-1)*SI:LC=LL+(DI-PL)*SI:PT=0
1740 PRINT:PRINT"PROBABILITIES OF CAPTURE, BY LENGTH"
1750 PRINT"-----------------------------------------------------------------------
----------
1760 PRINT"Z ="VZ", M ="MM:PRINT
1770 PRINT"Midl." TAB(8) "N" TAB(15) "Delta T" TAB(25) "Mortality" TAB(35) "Mort
ality" TAB(49) "N" TAB(59) "P" TAB(69) "P"
1780 PRINT TAB(6) "caught" TAB(29) "1" TAB(39) "2" TAB(45) "available" TAB(65) "
cumulative"
1790 FOR I2=1 TO P1:PT=PT+PC(I2):PRINT M1+(I2-1)*SI TAB(6) B2(I2) TAB(26) MW(I2)
 TAB(46) B3(I2) TAB(56) PC(I2) TAB(66) PT
1800 IF I2=P1 THEN 1820
1810 PRINT TAB(15) (TM(I2)+TM(I2+1))/2 TAB(36) MB(I2):NEXT
1820 PRINT:PRINT"MEAN LENGTH AT FIRST CAPTURE ="LC:PRINT
1830 PRINT:INPUT"OUTPUT ON LINEPRINTER? <0> OR <1>: ",C1
1840 IF C1=0 THEN 1990
1850 PT=0:INPUT "LINEPRINTER READY? PRESS <RET>: ",C1
1860 LPRINT D1$:LPRINT D2$:LPRINT
1870 LPRINT"PROBABILITIES OF CAPTURE, BY LENGTH"
1880 LPRINT"WEIGHTING MODE No"CR",      POINTS INCLUDED:"P1"-"P2
1890 LPRINT"WEIGHTING (TIME): ";RW$(CQ):LPRINT"WEIGHTING (C,WP): ";RW$(CW)
1900 LPRINT"GROWTH-PARAMETERS: Loo="LI", K ="K", C ="OC", WP ="WP
1910 LPRINT:LPRINT"TOTAL MORTALITY Z  ="VZ:LPRINT"NATURAL MORTALITY M ="MM
1920 LPRINT"(LINEAR REGRESSION: Z ="ZM", CORRELATION COEFF.="KM")":LPRINT
1930 LPRINT"Midl." TAB(8) "N" TAB(15) "DELTA T" TAB(25) "MORTALITY" TAB(35) "MOR
TALITY" TAB(49) "N" TAB(59) "P" TAB(69) "P"
1940 LPRINT TAB(6) "caught" TAB(29) "1" TAB(39) "2" TAB(45) "available" TAB(65)
"cumulative"
1950 FOR I2=1 TO P1:PT=PT+PC(I2):LPRINT M1+(I2-1)*SI TAB(6) B2(I2) TAB(26) MW(I2
) TAB(46) B3(I2) TAB(56) PC(I2) TAB(66) PT
1960 IF I2=P1 THEN 1980
1970 LPRINT TAB(15) (TM(I2)+TM(I2+1))/2 TAB(36) MB(I2):NEXT
1980 LPRINT:LPRINT"MEAN LENGTH AT FIRST CAPTURE ="LC:PRINT CHR$(27)CHR$(91)CHR$(
50)CHR$(74)
1990 PRINT:INPUT"NEW CALCULATION OF Z WITH OTHER POINTS? <0> OR <1>: ";C1
2000 IF C1=1 THEN 1430 ELSE N2=NM:M1=MO
2010 PRINT:INPUT"NEW CALCULATION WITH DIFFERENT WEIGHTING MODE? <0> OR <1>: ",C1
2020 IF C1=0 THEN 2030 ELSE 460
2030 PRINT:INPUT "RECRUITMENT PATTERN WITH SAME WEIGHT. MODE? <0> OR <1>: ",C1
2040 IF C1=0 THEN 390 ELSE PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"- WAIT -
":GOTO 2210
2050 REM -------------------------------------------------------------
```

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2060 REM *** CHECK FOR INTERVENNING ZERO VALUE(S)
2070 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"ZERO FREQU. VALUE(S) INCLUDED
IN DISTRIBUTION!"
2080 PRINT"FURTHER CALCULATION IMPOSSIBLE!"
2090 PRINT "CLASS" TAB(20) "FREQU"
2100 IF CS=1 THEN 2130
2110 FOR I2=1 TO N2:PRINT TAB(2) I2 TAB(20) B2(I2):FOR I3=1 TO 1000:NEXT:NEXT
2120 GOTO 2140
2130 FOR I2=1 TO N2:PRINT TAB(2) I2 TAB(20) B0(1,I2):FOR I3=1 TO 1000:NEXT:NEXT
2140 PRINT:PRINT"ELIMINATE ZERO FREQU. USING PROGRAM ELEFAN 0"
2150 INPUT "PRESS <RET> FOR START MENUE :",C1:GOTO 2930
2160 REM *** SUBROUTINE LINEAR REGRESSION
2170 XQ=S1/NP:YQ=S2/NP:FW=S5-S1*S2/NP:FX=S3-S1*S1/NP:FY=S4-S2*S2/NP
2180 MC=FW/FX:TC=YQ-MC*XQ:KC=FW/SQR(FX*FY):RETURN
2190 REM ==========================================================
2200 REM **** RECRUITMENT PATTERN ****
2210 FOR I2=1 TO N2:L1=M1+(I2-1)*SI-SI/2
2220 FOR I1=1 TO N1:IF CM(I1)+B0(I1,I2)=0 THEN 2320
2230 B3=B0(I1,I2)/10:T1=D1(I1):LT=L1:GOSUB 2700:TL=TF-TO
2240 FOR I3=1 TO 10
2250 LT=LT+SI/10:GOSUB 2700:TH=TF-TO:DT=ABS(TH-TL)
2260 LT=LT-SI/20:GOSUB 2700:TB=TF-TO
2270 LT=LT+SI/20:TL=TH:TB=(TB-INT(TB))*365
2280 FOR I4=1 TO 12:IF TB>AT(I4) THEN NEXT
2290 TB=I4-1
2300 RP(TB)=RP(TB)+B3/DT
2310 NEXT I3
2320 NEXT I1
2330 NEXT I2
2340 RM=RP(1):IP=0
2350 FOR I1=2 TO 12:IF RP(I1)<RM THEN RM=RP(I1):IP=I1
2360 NEXT:RS=0
2370 FOR I1=1 TO 12:RP(I1)=RP(I1)-RM:RS=RS+RP(I1):NEXT
2380 FOR I1=1 TO 12:RP(I1)=INT(RP(I1)*100/RS+.5):NEXT:RS=0
2390 FOR I1=1 TO 12:IF RP(I1)>RS THEN RS=RP(I1)
2400 NEXT:RS=(INT(RS/10+.5))*10:YF=19/RS
2410 FOR I1=1 TO 12:AP(I1)=INT(RP(I1)*YF+.5):NEXT
2420 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"RECRUITMENT PATTERN - VIDEO PL
OT"
2430 PRINT"% RECRUITMENT"
2440 FOR I2=19 TO 1 STEP -1:PRINT INT(I2/YF+.5) TAB(6) "I";
2450 FOR I1=IP TO 12:IF AP(I1)>=I2 THEN PRINT TAB(6+(I1+1-IP)*6) "*";
2460 NEXT
2470 FOR I1=1 TO IP-1:IF AP(I1)>=I2 THEN PRINT TAB(6+(I1+13-IP)*6) "*";
2480 NEXT
2490 PRINT:NEXT I2
2500 PRINT"--------------------------------------------------------------------------------
---------"
```

```
2510 INPUT "OUTPUT ON LINEPRINTER? <0> OR <1>: ",C1
2520 IF C1=0 THEN 390
2530 INPUT "LINEPRINTER READY? PRESS <RET>: ",C1
2540 LPRINT D1$:LPRINT D2$:LPRINT
2550 LPRINT"RECRUITMENT PATTERN":LPRINT"WEIGHTING MODE No"CR
2560 LPRINT"WEIGHTING (TIME) :";RW$(CQ)
2570 LPRINT"GROWTH-PARAMETERS: Loo="LI", K ="K", C="OC", WP ="WP:LPRINT
2580 LPRINT"%RECRUITMENT"
2590 FOR I2=19 TO 1 STEP -1:LPRINT INT(I2/YF+.5) TAB(6) "I";
2600 FOR I1=IP TO 12:IF AP(I1)>=I2 THEN LPRINT TAB(6+(I1+1-IP)*6) "*";
2610 NEXT
2620 FOR I1=1 TO IP-1:IF AP(I1)>=I2 THEN LPRINT TAB(6+(I1+13-IP)*6) "*";
2630 NEXT
2640 LPRINT:NEXT I2
2650 LPRINT"------------------------------------------------------------------------
------------"
2660 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):FOR I1=1 TO 12:RP(I1)=0:NEXT:GOTO 39
0
2670 REM ==================================================
2680 REM *** SUBROUTINE T (AGE)
2690 TF=LOG(1-LT/LI)/(-K)+T0:RETURN
2700 TF=T1+LOG(1-LT/LI)/K
2710 IF OC=0 THEN 2730
2720 TF=TF+OC*SIN(6.28319*(T1-TS))/6.28319
2730 RETURN
2740 REM --------------------------------------------------
2750 REM *** SUBROUTINE VIDEO PLOT
2760 I3=0:L9=95*LI/100
2770 FOR I2=N2 TO 1 STEP -1:IF M1+(I2-1)*SI+SI/2>=L9 THEN I3=I3+1
2780 NEXT
2790 NH=N2-I3:YL=0
2800 FOR I2=1 TO NH:IF B1(I2)<YL AND B1(I2)>-99 THEN YL=B1(I2)
2810 NEXT
2820 YH=0
2830 FOR I2=1 TO NH:IF B1(I2)>YH THEN YH=B1(I2)
2840 NEXT
2850 YD=YH-YL+.01:YF=YD/25:XF=75/(TM(NH)-TM(1))
2860 PRINT"NOTE POINTS TO BE INCLUDED
2870 FOR I1=0 TO 24:YA=YH-I1*YF:YB=YA-YF
2880 FOR I2=1 TO NH:IF YA>=B1(I2) AND B1(I2)>YB THEN PRINT TAB(1+INT((TM(I2)-TM(
1))*XF+.5)) I2;
2890 NEXT I2:PRINT:FOR I3=1 TO 1000:NEXT:NEXT I1
2900 PRINT"------------------------------------------------------------------------
-----------"
2910 RETURN
2920 REM ================================================
2930 CHAIN "START"
2940 END
```

```
10 REM ELEFAN 2B
20 DEFINT A,C,I,N
30 DIM AO(24,50):DIM AD(24):DIM AM(24):DIM CM(24):DIM AT(12):DIM D1(24)
40 DIM B1(50):DIM B2(50):DIM TL(50):DIM TM(50):DIM TH(50)
50 AT(1)=0:AT(2)=31:AT(3)=59:AT(4)=90:AT(5)=120:AT(6)=151:AT(7)=181:AT(8)=212:AT
(9)=243:AT(10)=273:AT(11)=304:AT(12)=334
60 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74)
70 PRINT"------------------------------------------------------------------------------
80 PRINT"                                   ELEFAN 2B
90 PRINT"                PROGRAM FOR ESTIMATION OF Loo AND Z/K FROM
100 PRINT"                        FROM LENGTH-FREQUENCY DATA
110 PRINT"------------------------------------------------------------------------------
120 REM ***** DATA INPUT *****
130 PRINT:PRINT"INPUT OF LENGTH-FREQUENCY DATA FROM DISK ONLY":PRINT
140 ON ERROR GOTO 170
150 INPUT "ENTER DATAFILE NAME :",D1$
160 GOTO 180
170 CLOSE#1:RESUME 150
180 OPEN "I",#1,D1$
190 INPUT#1,D2$
200 INPUT#1,N1,N2,M1,M2,SI
210 FOR I1=1 TO N1:INPUT#1,AM(I1),AD(I1)
220 FOR I2=1 TO N2:IF EOF(1) THEN 240 ELSE INPUT#1,AO(I1,I2)
230 NEXT:NEXT
240 CLOSE#1
250 PRINT:PRINT D1$:PRINT D2$:PRINT" "
260 INPUT "IS THIS CORRECT ? <0> OR <1>:",C1
270 IF C1=0 THEN 150
280 REM ==================================================
290 REM ***** SELECTION OF SAMPLES *****
300 IF N1=1 THEN CM(1)=1:CS=1:GOTO 430
310 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"SELECTION OF SAMPLES"
320 FOR I1=1 TO N1:PRINT:PRINT"SAMPLE"I1:PRINT
330 PRINT "CLASS" TAB(20) "FREQU."
340 FOR I2=1 TO N2:PRINT TAB(2) I2 TAB(20) AO(I1,I2):NEXT
350 PRINT:INPUT "INCLUDED? <0> OR <1>: ",C1
360 IF C1>0 THEN CM(I1)=1:CS=CS+CM(I1)
370 NEXT I1
380 IF CS>1 THEN 430
390 FOR I1=1 TO N1:IF CM(I1)=0 THEN NEXT ELSE CI=I1
400 CM(1)=1:N1=1
410 FOR I2=1 TO N2:AO(1,I2)=AO(CI,I2):NEXT
420 REM *** ADDING UP SAMPLES
430 FOR I1=1 TO N1:IF CM(I1)=0 THEN 450
440 FOR I2=1 TO N2:B1(I2)=B1(I2)+AO(I1,I2):NEXT
450 NEXT I1
460 NO=0
470 FOR I2=N2 TO 1 STEP -1:IF B1(I2)=0 THEN NO=NO+1 ELSE 490
480 NEXT
490 N2=N2-NO
500 FOR I2=1 TO N2:B2(I2)=B1(I2):NEXT
510 REM ==============================================
```

```
520 REM ***** ESTIMATION OF Loo *****
530 FOR I2=1 TO N2:TM(I2)=(I2-1)*SI+M1-SI/2:TL(I2)=0:NEXT
540 PRINT CHR$(27)CHR$(91)CHR$(50)CHR$(74):PRINT"VIDEO PLOT: X = LENGTH, Y = N(L
ENGTH)
550 GOSUB 870: REM * TO VIDEOPLOT
560 INPUT "LOWEST CLASS (No) TO BE INCLUDED ? :",P1
570 B2(N2)=B1(N2):NP=B2(N2)
580 FOR I2=N2-1 TO P1 STEP -1:B2(I2)=B2(I2+1)+B1(I2):NP=NP+B2(I2):NEXT
590 FOR I2=P1 TO N2
600 FOR I3=I2 TO N2:TL(I2)=TL(I2)+B1(I3)*(M1+(I3-1)*SI):NEXT
610 TL(I2)=TL(I2)/B2(I2):NEXT I2
620 S1=0:S2=0:S3=0:S4=0:S5=0
630 FOR I2=P1 TO N2
640 S1=S1+TM(I2)*B2(I2):S3=S3+TM(I2)*TM(I2)*B2(I2)
650 S2=S2+TL(I2)*B2(I2):S4=S4+TL(I2)*TL(I2)*B2(I2)
660 S5=S5+TM(I2)*TL(I2)*B2(I2):NEXT
670 GOSUB 1020: REM * TO LINREG
680 PRINT:PRINT"REGRESSION EQUATION: MEAN LENGTH PLOTTED ON LOWER CLASS LIMIT"
690 PRINT"WEIGHTED BY CUMULATIVE N":PRINT
700 PRINT" Y = "TC" + "MC" * X  ,  r ="KC", r^2 ="KC*KC
710 PRINT"ESTIMATION OF ASYMPTOTIC LENGTH: Loo ="TC/(1-MC)
720 PRINT"ESTIMATION OF Z/K:               : Z/K ="MC/(1-MC)
730 PRINT:INPUT "OUTPUT ON LINEPRINTER? <0> OR <1> :",C1
740 IF C1<>1 THEN 830 ELSE INPUT "LINEPRINTER READY? <RET> :",C1
750 LPRINT D1$:LPRINT
760 LPRINT"ESTIMATION OF INFINITE LENGTH":LPRINT
770 LPRINT"REGRESSION EQUATION: X = LOWER LIMIT OF SMALLEST LENGTH CLASS
780 LPRINT"                     Y = MEAN LENGTH OVER ALL CLASSES
790 LPRINT"                     LOWEST CLASS INCLUDED: LENGTH CLASS No"P1
800 LPRINT" Y = "TC" + "MC" * X  ; r ="KC", r^2 ="KC*KC
810 LPRINT"ESTIMATE OF Loo: "TC/(1-MC)
820 LPRINT"ESTIMATE OF Z/K: "MC/(1-MC)
830 PRINT:INPUT "NEW CALCULATION WITH OTHER POINTS? <0> OR <1> :",C1
840 IF C1=0 THEN 1060 ELSE 530
850 REM ================================================
860 REM *** SUBROUTINE VIDEO PLOT
870 YL=0
880 FOR I2=1 TO N2:IF B1(I2)<YL AND B1(I2)>-99 THEN YL=B1(I2)
890 NEXT
900 YH=0
910 FOR I2=1 TO N2:IF B1(I2)>YH THEN YH=B1(I2)
920 NEXT
930 YD=YH-YL+.01:YF=YD/25:XF=75/(TM(N2)-TM(1))
940 PRINT"NOTE POINTS TO BE INCLUDED
950 FOR I1=0 TO 24:YA=YH-I1*YF:YB=YA-YF
960 FOR I2=1 TO N2:IF YA>=B1(I2) AND B1(I2)>YB THEN PRINT TAB(1+INT((TM(I2)-TM(1
))*XF+.5)) I2;
970 NEXT I2:PRINT:FOR I3=1 TO 1500:NEXT:NEXT I1
980 PRINT"-----------------------------------------------------------------------
---------"
990 RETURN
1000 REM ------------------------------------------------
1010 REM *** SUBROUTINE LINREG
1020 XQ=S1/NP:YQ=S2/NP:FW=S5-S1*S2/NP:FX=S3-S1*S1/NP:FY=S4-S2*S2/NP
1030 MC=FW/FX:TC=YQ-MC*XQ:KC=FW/SQR(FX*FY):RETURN
1040 RETURN
1050 REM ================================================
1060 CHAIN "START"
1070 END
```

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