Separating mixtures of normal distributions: Basic programs for Bhattacharyya's method and their applications to fish population analysis.
SEPARATING MIXTURES OF NORMAL DISTRIBUTIONS: BASIC PROGRAMS FOR BHATTACHARYA’S METHOD AND THEIR APPLICATIONS TO FISH POPULATION ANALYSIS

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This manual describes computer programs written in Microsoft BASIC (version 2.20B) for use on an Apple IIe micro-computer (with CP/M operating system) and EPSON RX-80 F/T printer.

These programs include a modification of Bhattacharya’s method for identifying and separating normal distributions, in a mixture of distributions in length frequency data, and computation of Chi square statistics for testing goodness of fit, as described by Pauly and Caddy (1985). This package includes a program that plots the frequency distributions for several samples of data. It is useful for estimating growth parameters and calculates the catch at length for each of the mean length groups separated, and gives 95% and 99% confidence limits for each mean.

Growth parameters can also be estimated using length-at-age data by the Ford-Walford Plot and von Bertalanffy Plot programs. In cases where the ages of fish are not known and a series of sizes at relative ages is not available, growth parameters can still be estimated using data on length increase in time (such as also obtained from tagging-recapture data) by the Gulland and Holt Plot program.

This package also includes Sparre’s, Jones’ and Van Zalinge’s method for estimating total mortality coefficients from length frequency data.

A new method for estimating the asymptotic length and mortality coefficient as proposed by J.A. Wetherall is also presented.

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1. INTRODUCTION

Programs for applications of Bhattacharya’s method, Ford-Watford Plot, Gulland and Holt Plot and the Jones and Van Zalinge method were first developed for use with HP-67/97 programmable calculators. (Pauly and Caddy 1985, Pauly 1984); When dealing with large data sets, comprising a large number of samples, methods based on pocket calculators were found to be somewhat tedious.

With advances in technology — programmable calculators are already being replaced by micro computers -the need has arisen for translating some of these programs to micro-computer BASIC.

The user’s instructions in this manual give a step by step instruction format, to enable users with no previous experience with computers or programmable calculators, to operate the programs without any difficulty.

The first two programs presented here, namely —
(a) modification of the Bhattacharya method for separation of normally distributed groups from a mixture of normal distributions, and
(b) computation of Chi square statistics to assess whether the groups identified generate a mixture of normal distributions that fit the original frequencies are discussed by Pauly and Caddy (1985). For the benefit of the users of this program, a brief description of the theory, assumptions and limitations is also presented.

The present program accepts the data for an entire frequency distribution, to identify all the normal distributions which exhibit a regression coefficient ($r$) with value equal to or higher than the critical $r$ value chosen by the user. The program also displays $r$ values for the remaining and unaccounted frequencies, to assist the user in choosing the critical values for a second and third run. The rest of the programs deal with the application of Bhattacharya’s method to fish population analysis.

With these programs, separation of normal distributions, estimation of their mean length values (with 95% and 99% confidence limits) and calculation of catch at each mean length can be executed with length frequency data for 12 months or 4 quarters of a year or even for a number of years. This analysis is expected to provide evidence of seasonal or annual changes in the composition of size groups, modal progressions and parameters for growth and total mortality rate estimation. However, for the latter estimation, the length frequencies should be raised to the total catch of the species before entering the data for the analysis, and any adjustments for gear selectivity should also be incorporated.

The symbols used and derivations of the formulae are not explained in this user manual. For details of all the analyses carried out by the programs, users are requested to refer Pauly (1984), Pauly and Caddy (1985)* and Sparre (1985).

A graphical plot of percentage frequencies for all samples is provided to enhance growth parameter estimation and to identify incorrect assignment of a mode to a component. Note that the graph will be printed only with an EPSON RX-80 F/T printer.

For estimating growth parameters, the program provides the user with three optional methods, namely Ford-Walford Plot, Gulland and Holt Plot, and von Bertalanffy Plot. For theoretical aspects of these methods, users are referred to Pauly (1984) and Sparre (1985).

Three graphical methods are also provided in these programs for estimating total mortality rates.

Detailed program listings (Appendix 1) in Microsoft BASIC language, Chi square and t-distributions and sample printouts are also included for the benefit of the users.

* Errata sheets for these two documents may be obtained by writing to ICLARM, MCC P.O. Box 1501, Manila, Philippines.
2. GETTING STARTED

The program will automatically execute when the Apple IIe is booted (powered on).

(a) Turn on your video display unit.
(b) Insert the program disk into drive A and close the drive door.
(c) Press the power switch of the computer.

Within a few seconds, without the user having to enter any commands, the computer will display the following menu:

**MAIN MENU**

1. FILE MAINTENANCE
2. BHATTACHARYA’S METHOD
3. CHI SQUARE STATISTICS
4. ESTIMATING GROWTH PARAMETERS
5. TOTAL MORTALITY ESTIMATION
6. QUIT TO CP/M

Enter option?

Remember that option “1” has to be selected before option “2”, “3”, item 1 of option “4” or “5”, because the data entered in option “1” will be necessary for the options mentioned.

At the end of a run, remember to enter option 6, to exit from your programs. Then CP/M prompt A > will appear on the screen, indicating that you can remove the disk from the computer and turn the power off from the display unit and the computer.

2.1 Running instructions

Choose option “1” from main menu to display the following screen:

**FILE MAINTENANCE MENU**

1. CREATE A NEW DATA FILE
2. EDIT AN EXISTING DATA FILE
3. LIST/DISPLAY DATA FILE
4. DISPLAY DISK CATALOG
5. DELETE DATA FILES
6. INITIALISE NEW DATA DISK
7. REGROUPING OF LENGTH FREQUENCY DATA
8. RETURN TO MAIN MENU

If “1”, “2”, “3”, “5” or “7” is entered, the prompt “enter file name (maximum 8 characters) ?” appears on the screen.

The file name can be a combination of letters and numbers but should begin with a letter. Do not enter a name with more than eight characters. Remember to enter unique names for all the
data files. File name cannot be blank. Do not use a dot (.) in the file name since CP/M uses a dot to differentiate between different kinds of files.

For creating a new data file (option “1”) several parameters have to be input by the user. With each file, the user can enter any particulars describing the file at this stage. This description of the file will be printed in all the reports under the file name, enabling the user to easily identify the print-outs. This description can be up to 254 characters in length.

Enter the number of samples and number of classes. Then enter the lower and upper limits of the smallest size class for the program to calculate the interval size. Next, the program will display the following prompts for each sample with the sample number appearing on the screen.

Month ?

First midlength of this sample?

Last midlength of this sample?

To enable the user to distinguish between the same months of two different years (in the case of more than 12 samples), the computer will accept any numbers (even >12) for the month and will not perform any month checking here.

Then the frequencies corresponding to the sample can be entered from the first midlength to the last midlength. Note that zero frequencies will not be accepted. If “return” is pressed or zero is entered for frequency, then the computer will display “enter 0.01 for zero frequency.”

Before these frequencies are written on the disk, a chance is given to the user to edit the data for that sample. Enter Y or N for the question “Do you wish to edit data for this sample (Y/N) ?”. If “N” is entered the next sample data can be entered. If “Y” is entered, the computer asks for the number of class to be edited. Enter the number corresponding to the row in which data needs editing. If a number is input which is greater than the total number of length classes in that sample, the computer displays “no such length class” and asks for the number of class to be edited. If the user does not have any other class to edit, then enter zero to quit editing.

The data entering continues until entry of data for all the samples is completed. Then the computer writes these data records in the disk under the file name initially given by the user.

A data file has to be created in this manner before any of the Bhattacharya, Chi square or % frequency plot programs could be run. Once a data file is created, the user can list the contents of this file by using option “3” of the file maintenance menu. Once the name of the data file is entered the computer will prompt “ready the printer and press return to proceed”. When “return” is pressed, the file contents will be displayed on the screen and printed as hard copy.

If any mistakes are found in the data listing or if the user wishes to adjust the previously entered data, option 2 of the file maintenance menu should be used. The description given in the original data file will be displayed on the screen followed by the prompt “O.K. (Y/N) ?”. If “N” is entered, the computer asks for the “new description” to be entered. If Y or return is pressed, the contents of the original file are shown, sample by sample. If month needs to be edited, enter the no. of the new month. Else, press “return”. Editing process is the same as editing data in the “creation of a new data file” stage.

Option “4” can be used to display the disk catalog. File names ending in .BAS and .COM denote program files and system files which need not concern the user. The rest of the files are the data files created by the user.

If at any stage of the operation a “disk full” message appears, the user has to format a new disk for data or delete some of the unnecessary data files from the disk. For deleting purposes, use the option “5” and give the file name to be deleted. Make sure that you want that file erased and enter Y as the answer to the prompt “do you wish to delete this file (Y/N) ?”. If you enter a file name ending with .BAS or .COM the computer will reply “Sorry — program files cannot be erased”.

[3]
Option “6” displays the following message. “If you need to prepare a new blank disk for use as data disks with Bhattacharya’s program, you must initialise the disk first. This process is done at CP/M command level (A>) by typing the command COPY B:/D. Press return, then insert blank disk in drive B and press return again. Make sure that the disk you insert to drive B is blank, otherwise the contents of this disk will be erased. Note down this command and press return to quit to CP/M command level.”

When the user presses “return”, the program will exit to command level, clear the screen and display “A>” on the top of the screen allowing the user to type the COPY command for initializing new disks. If, however, the user wishes not to initialize disks, user can safely turn off the computer at this stage.

Option “7”, in the file maintenance menu, is used for regrouping the length frequency data by widening the interval of the size groups. The original size interval of each group may be doubled, tripled, quadrupled etc. by inserting the corresponding multiplying factor of 2, 3, 4, etc. The program regroups the frequencies accordingly and provides a printout of the regrouped frequency data. It should be noted that only the original length frequencies are saved and stored on the data diskette and not the regrouped data. Therefore, if the regrouped data are to be used in any analysis, they must be re-entered using the printout of the regrouped frequencies with a new file name.

Once file handling is over, use option “8” to enter the main menu to perform analysis.

3. BHATTACHARYA’S METHOD

Bhattacharya’s (1967) method was proposed by its author as a graphical method for the separation of normally distributed groups from a mixture of normal distributions.

When the natural logarithm of ratios of successive frequencies is plotted against the midpoints of the corresponding classes, a straight line with a negative slope will be obtained when a group has been identified.

The straight line is of the form
\[ \ln \left( \frac{f_{i+1}}{f_i} \right) = a + bx \]
where \( b \) denotes a negative slope.

Using the linear regression technique, \( a \) and \( b \) are obtained (for sets of 3 points each) using the following equations:
\[ b = \frac{\sum xy - \sum x \sum y}{\sum x^2 - (\sum x)^2} \]
\[ a = \frac{\sum y}{n} - b \frac{\sum x}{n} \]

When the absolute correlation coefficient calculated according to the equation
\[ r = \frac{\sum xy - \sum x \sum y}{\sqrt{\sum x^2 - (\sum x)^2} (\sum y^2 - (\sum y)^2)} \]

is higher than or equal to the input value of the critical correlation coefficient, the mean \( \mu \), std. deviation \( \sigma \) and number of items in the component distributions \( N \) are calculated using
\[ \mu = (0.5d) \frac{a}{b} \]
\[ \delta = \sqrt{\frac{(l-b)}{(d/12)}} \]
\[ N = \frac{\delta}{d} \exp \left\{ \frac{3}{\delta^2} \right\} \left[ \frac{\sum \ln \left( \frac{f_{i+1}}{f_i} \right)}{3} + \frac{1}{6(\delta^2+(d/12)^2)} \frac{\sum (x_i - \mu)^2}{d^2} + \ln \sqrt{2\pi} \right] \]

where \( d \) is width of the class interval, and \( f_i, x_i \) are the values of the frequencies and mid-points of the three points under consideration respectively.

[4]
Unlike in the HP 67/97 program of Pauly and Caddy (1985) where 3 frequencies at a time are entered, in this program, any number of frequencies for any number of samples can be entered at once.

In view of overlapping distributions, a certain number of items between two adjacent components may be counted into both components resulting in the sum total of the number of items (N) allocated to the identified components being greater than the original number of items input. A correction for this is made by calculating a raising factor, using the ratio of original number of items input to the calculated total number of items in the components and multiplying the calculated number of items in each component, to give the number of items in each component. The size (after correcting) will appear in the percentage frequency plot program. (Example in Appendix 3.)

3.1 Running instructions

Choose option “2” from the main menu to run Bhattacharya’s method. Enter the date. This can be skipped by pressing return but entering the date can be useful, as it will appear on the print-out along with the file name. Next enter the data file name. Return or blank will not be accepted here. If “/” is entered, the main menu will appear.

When the prompt “ready the printer and press return” is displayed, set the printer switch on and press return.

Next, enter a high critical value of correlation coefficient. The program will calculate, display and print the calculated correlation coefficient and the mid-points of each group (consisting of 3 consecutive points) with a negative slope. For cases where calculated correlation coefficient is more than the input value of critical correlation coefficient, the mean, std. deviation and the no. of items in the groups will also be printed.

This calculation and printing will be repeated for all the samples in the data file. Then, the prompt “re-run with different values (Y/N)?” appears on the screen. If “Y” is entered, the user can enter another value for the correlation coefficient and proceed as in the earlier case. If “N” is entered the main menu will appear.

By re-running this program several times with different and lower values of correlation coefficients the user will be able to identify more groups than those identified by higher correlation coefficients.

All these values can then be tested for goodness of fit using the Chi square statistics program.

Note that if the input value of correlation coefficient is too high, genuine distributions might not appear. On the other hand, if it is too low, irrelevant bumps may be misidentified as genuine components.

Using this program, the user may find two or more sets of mean, std. deviation and number of items for the same component because a component distribution which overlaps little with its neighbouring distributions might give rise to more than three points forming a straight line. (Refer to page 2 of Pauly and Caddy (1985).)

When there are several sets of \( \delta, \mu \) and N for mean values which are almost the same or very close to each other, the set of values corresponding to the highest r-value may be chosen, unless the user has reasons for choosing one of the other sets of values.

Zero frequencies will not be accepted by the computer because the logarithm of zero is not defined. Hence, the data will have to be re-grouped with a different interval size so that all the classes will have non-zero data. Alternatively, the user can enter 0.01 as frequency at the data entry stage in the file maintenance routine.
4. CHI SQUARE STATISTICS FOR TESTING RESULTS

For each of the groups identified by Bhattacharya’s method, the Chi square statistics can be calculated to assess whether the groups identified generate a mixture of normal distributions that fits the original frequency data.

The standard measure for goodness of fit, the Chi squared criterion, is defined as

\[ \chi^2 = \sum \left( \hat{f}_i - \frac{N_i}{\Phi} \right)^2 \]

where the predicted frequencies \( \hat{f}_i \) are calculated from the equation

\[ \hat{f}_i = \sum \frac{N_i \cdot d}{\Phi} \cdot \exp \left[ -0.5 \cdot \frac{(x_i - \mu_j)}{\sigma_j} \right] \]

where
- \( d \) = class interval width
- \( x_i \) = mid-point of class corresponding to frequency
- \( \mu_j \) = mean of \( j \)th component identified
- \( \sigma_j \) = std. deviation of \( j \)th component identified
- \( N_j \) = no. of items (size) in \( j \)th component identified

and \( 1 < j < 6 \).

The predicted frequencies deducted from the raw frequencies provide the residual frequencies i.e. \( R_i = \hat{f}_i - \hat{f}_i \). The results may be used as input data for Bhattacharya’s method, if they suggest that one or more components had been overlooked. For this purpose, when running the Chi square program for the first time, the user can give another file name to be created automatically with the residuals of this analysis. The Chi square values calculated for each \( x_i \) value are added up and the sum obtained is compared with the critical value in the \( \chi^2 \) distribution table (Appendix 3) corresponding to the number of degrees of freedom. Here, the number of degrees of freedom is equal to the number of classes considered minus one, minus twice the number of component distributions used in generating the expected frequency values \( (j) \), or deg. of freedom = \( n - (1 + 2j) \). (Example in Appendix 4.)

When many groups of normal distribution are identified through this method, the degrees of freedom tend towards zero or even a negative value, and the observed Chi square values also tend to be abnormal. In such situations, the user must use her/his judgement to consider which of these groups should be deleted, keeping in mind the relative correlation coefficients obtained and the possible error in sampling.

4.1 Running instructions

Choose option “3” from main menu to obtain the Chi square statistics program. Enter original data file name containing the frequency data. Return or blank will not be accepted for file name. If “/” is entered, the user can exit to main menu.

Next the question “Do you wish to create another file with the residuals of this analysis (Y/N)” appears on the screen. If Y is entered or return is pressed, enter new file name followed by the description of this new file. If N is entered, the program will not create an additional file with the residuals.

Next set the printer on and press return. The user can select sample by sample and run the Chi square test if necessary. If so, enter Y for the question. “Do you wish to select sample by sample for the Chi square test (Y/N) ?”. Then enter the sample number. To quit to main menu, enter zero for sample no. Else, for each sample in the data file, repeat the following procedure.

Enter the number of components to be tested. Note that only up to six sets can be used. Then enter separately the means, standard deviations and sizes of each component. The program will then display and print the values of observed frequencies, predicted frequencies, and
residuals (deviations from prediction). For the Chi square statistics, as a general rule, predicted frequencies less than 5 should be avoided. Therefore, the program will lump classes by adding them with frequencies in contiguous classes to create classes of adequate size and lump the corresponding classes of observed frequencies, then print the set of new residual values along with the Chi square statistics.

Compare this sample \( X^2 \) value with a \( X^2 \) distribution with the appropriate degrees of freedom (given as output by the program). If the sample \( X^2 \) value is greater than the value from the tables (refer to Appendix 2a for \( X^2 \) tables) with the appropriate degrees of freedom the null hypothesis that the sample data are described by the \( y \), \( S \) and \( N \) values entered is therefore rejected (see “Biometry” by Robert R. Sokal and F. James Rohlf, Chapter 16, page 568 and 569 or any other good statistics text). If there are negative residuals, the program will automatically subtract the largest negative residual from all residuals and then save the resultant positive series of numbers as “frequencies” in a new data file.

Using this new data file, the user can rerun Bhattacharya’s method. Note that the number in a component (\( N \)) found this way may not be reliable.

5. SOME APPLICATIONS OF BHATTACHARYA’S METHOD TO FISH POPULATION ANALYSIS

When Bhattacharya’s method for the analysis of length frequencies distributions is applied to separate possible constituent components and to estimate the mean values and their variances, it may serve primarily to identify age groups, the assumption being that modal groups in the length frequency distribution represent year classes or cohorts.

5.1 Identification of age groups

Petersen’s method (1892) for the analysis of length frequency data involves the attribution of assumed ages to the distinct peaks of a single, multi-peaked length frequency sample. There are problems in identifying the real peaks representing age groups, and various authors have suggested methods to separate these peaks on the assumption that they are normally distributed. The Bhattacharya method of separating a mixture of normal distribution is also being increasingly applied, for the same purpose, with the mean length estimated for each modal group and their variances. However, the reliability of results depends very heavily on the unbiased samples of length frequency. In this respect, length frequency samples obtained from catches made by non-selective gears are preferred but if samples are available only from highly size-selective gears, then the data must be adjusted for selectivity before analysis. In many cases, where particular species are caught by more than one type of gear e.g. Indian mackerels caught by purse seines and bottom trawls, the sample must be raised to the catch by each type of gear before adding up their length frequencies. In the case of pelagic species schooling by size, the length frequencies may be different between crafts or vessels operating from the same base and at the same time. In such cases, the length frequency sub-samples from individual boats may have to be raised to their catch before adding them to produce the day’s sample.

Item 1 in option “4” of the programs calculates the confidence limits for the mean values (\( X \)) which may be considered for allocating the size ranges for the age groups (Appendix 4). The results present the percentage frequency distribution of the sample graphically, the mean values and the 95% and 99% confidence limits for these values. The table of values of the “t” statistic used in the program, for 95% and 99% levels, are presented in Appendix 2 (b).

\[
\text{Confidence limits} = x \pm t_{n-1} \frac{s}{\sqrt{n}}.
\]

There will be difficulties in attributing absolute ages to the modal size groups identified by this method. Even if the age (\( t \)) value for the first modal group cannot be determined, the probable age values for the succeeding modal groups can be assigned by using \( t+1 \), \( t+2 \), \( t+3 \) etc. when the intervals between time series data are known to be one month or one year. The growth curve
already determined will help in identifying the modal groups belonging to a cohort, i.e. the same cohort in successive time intervals or even successive cohorts in the same time period.

5.2 Growth parameters

Separation of modal groups in monthly samples of length frequencies for one year series can bring out the monthly modal progression more clearly than the length frequency distributions based on raw data, and growth curves can be constructed with the help of monthly shifts in the mean lengths of the modal groups. Further, by plotting these calculated values of mean length and their variances along with the graphical representation of this frequency distribution, it may be possible to detect modes that may have been incorrectly identified during the separation analysis. A print out of this analysis by the program, for these purposes, is the same as that in 5.1, but will be in series corresponding to the number of months for which the sample data were provided.

5.2.1 Estimating growth parameters

The asymptotic length \( L^\infty \) and growth constant \( K \) will be calculated by three different methods using the length at age data and data on length increase in time. This data for Ford-Walford plot, Gulland and Holt plot and von Bertalanffy plot will not be written on the disk and stored as a data file. As the program uses the generalized VBGF, it is better to enter the appropriate value of surface factor \( D \) if available. Use \( D=1 \) if you want to work with the standard von Bertalanffy equation.

Pauly (1984) should be consulted for details and further reference on the surface factor (D). Also note that the three methods given below for estimating \( L^\infty \) and \( K \) did not include \( D \) in their original form, and that \( D \) effectively disappears from the relevant equations when \( D=1 \).

5.2.2 Running instructions

Enter “4” from the main menu to obtain the following screen:

ESTIMATION OF GROWTH PARAMETERS

1. PLOT OF % FREQUENCIES
2. FORD-WALFORD PLOT
3. GULLAND AND HOLT PLOT
4. VON BERTALANFFY PLOT

5.2.3 Plot of percentage frequencies

Before running this program make sure that Bhattacharya’s analysis has been done because this requires the user to enter the mean values, standard deviations and sizes obtained from that analysis.

Enter the name of the data file. If “/” is entered, the user can exit to main menu. Set the printer on and press return. The program will print the percentage frequency distributions for all the samples in the data file. In the same manner as in the Chi square test program for each sample, choose groups with high “r” values from the results of Bhattacharya’s analysis and enter the number of groups chosen and their means, standard deviations and sizes. Then the program will print the confidence limits for the mean values for each of the samples, and the sizes after applying the correction involving the raising factor as mentioned in Section 3 above. For plotting the length frequency distributions, the percentage frequencies have been rounded to the nearest integer and these values are also printed along with the percentage frequencies.

5.2.4 Ford-Walford plot

This method introduced by Ford, 1933 and Walford, 1946, is based on the equation

\[
L^D_{t+1} = a + b \cdot L^D_t
\]

where \( L^D_t \) and \( L^D_{t+1} \) correspond to lengths separated by a constant time interval.

In the case of a single cohort, when one set of lengths \( (L_t) \) for a series of ages is entered, the computer will automatically create the consecutive length \( (L_{t+1}) \). But for multiple broods, the
user is given the chance to enter both sets of $L_t$ and $L_{t+1}$ values for the different cohorts combined. In this case, however, the $L_\infty$ and $K$ values obtained will represent mean values for the different cohorts.

According to the above equation, both $x$ and $y$ axis are measured with the same error since they are indeed the same data. Hence, a geometric mean (or type II) regression is used to obtain $a'$ and $b'$. If $a$ and $b$ denote the arithmetic mean regression values then,

\[
b' = b/r \\
a' = y - b'x \\
L_\infty = \frac{a'}{1 - (1-b')}^{1/D} \\
K = -\ln \frac{b'}{b'}b
\]

For single broods, enter "S" and press "return". Enter the no. of age classes and the lengths ($L_t$). The computer will automatically generate the table of $L_t$ and $L_{t+1}$ values.

For multiple broods enter M and press return. Enter the no. of pairs of consecutive lengths and the values of $L_t$ and $L_{t+1}$.

Next enter the surface factor ($D$) where $0 < D \leq 1$. In the case of fish capable of reaching large sizes use the appropriate value of $D$ if possible. If the correct value of $D$ is not known enter 1. Set the printer ready and press return. The program will print the table of $L_t$ and $L_{t+1}$ and output values of $a'$, $b'$, $r$, $L_\infty$ and $K$. (Example in Appendix 6.)

52.5 Gulland and Holt plot

This method introduced by Gulland and Holt (1959), is based on the equation:

\[
\frac{L_2 - L_1}{t_2 - t_1} = a - KD \left( \frac{L_1^D + L_2^D}{2} \right)
\]

where $L_1$ and $L_2$ are successive lengths corresponding to times $t_1$ and $t_2$. This gives:

\[
K = -\frac{b}{D} \\
L_\infty = \left(\frac{a}{KD}\right)^{1/D}
\]

Here too data will not be saved on the disk and kept as a data file.

Enter the number of pairs of $L_1, L_2$ and then enter separately $L_1, L_2, t_2-t_1$ values.

Next enter the surface factor ($D$), when $0 < D \leq 1$. Set the printer on and press return. The program will print the table of values of $L_1, L_2, t_2-t_1$ and the coordinates $x$ and $y$. The intercept (a), slope (b), correlation coefficient ($r$), $L_\infty$ and $K$ values will be produced.

The next user can rerun the program with different values of $D$ if necessary. (Example in Appendix 7.)

52.6 Von Bertalanffy plot

The generalized Von Bertalanffy growth formula proposed by Von Bertalanffy (1934) has the form

\[
L_\infty^D = L_\infty - e^{-KD(t-t_0)}
\]

which can be rewritten in the form:

\[-\ln \left[ 1 - \frac{(L_t/L_\infty)^D}{L_\infty} \right] = -KDt + KD_1 \]

This equation defines a linear regression with $t$ as $x$ axis and 

\[-\ln \left[ 1 - \frac{(L_t/L_\infty)^D}{L_\infty} \right] \text{ as } y \text{ axis.} \]

If an estimate of $L_\infty$ is available then

\[
K = \frac{a}{b} \\
t_0 = \frac{a}{b}
\]
Enter the number of pairs of $t$ and $L_t$ values. Zero will not be accepted here. Then enter the values of $t$ and $L_t$. Enter $D$ and $L_\infty$. Set the printer ready and press return. If $D$ is unknown, enter $D=1$.

The table of values of $t$, $L_t$ and the points of the $y$ axis (x axis is $t$) will be output. $a$, $b$, $r$, $t_o$, and $K$ will be calculated and printed. This program can then be rerun with different values of $D$ and $L_\infty$. (Note that the method of Wetherall (see below) can be used to obtain estimate of $L_\infty$)

6. TOTAL MORTALITY ESTIMATION

If the modal groups identified are assumed to represent age groups, then the number of items ($N$) in the modal groups which can be linked through modal shift, over a specified period of time, may be used to estimate the total mortality rates. For such an analysis with this program, each length frequency should be raised to the total catch of that species, going through the raising process mentioned in 5.1. An estimate of total mortality, as explained in Pauly and Caddy (1985) may be obtained through the formula

$$Z = \frac{\ln (N_t - N_{t+\Delta t})}{\Delta t}$$

where $N_t$ is the number of items in a modal group at first instance and $N_{t+\Delta t}$ is the number in corresponding modal group after the time interval $\Delta t$ expressed as a fraction of a year.

A log-linear regression of the numbers in a given component against time provides $Z$ from its slope. $N_t$, $N_{t+1}$, $N_{t+2}$, .... may also be used to calculate the total mortality rates using the formula

$$Z = -\ln \left( \frac{N_{t+1}N_{t+2}...}{N_tN_{t+1}N_{t+2}...} \right)$$

for larger sets of data combined to give a single estimate or

$$Z = -\ln \left( \frac{N_{t+1}}{N_t} \right)$$

for a single group. Alternatively, the data for a long series of years may be analyzed separately for different years and ages to obtain a series of $Z$ values which may exhibit any systematic changes in mortality (Gulland, 1983).

If it is successive cohorts in the same time period, instead of the same cohort in successive time intervals, then it must be assumed that recruitment is not subject to appreciable changes. In this application it is necessary that the numbers refer to fully recruited cohorts.

6.1 Running instructions

When "5" is entered from the main menu, the following screen will be displayed:

TOTAL MORTALITY ESTIMATION

1. JONES & VAN ZALINGE METHOD
2. SPARRE'S CATCH CURVE METHOD
3. WETHERALL ET AL METHOD
4. EXIT TO MAIN MENU
ENTER YOUR CHOICE?

All these three sub-programmes operate on the data file originally created by the file maintenance program. If a data file has not been created already, enter "4", return to main menu and create a data file preferably with total catch figures entered as frequencies. (Example in Appendix 8.)
6.2 Jones and van Zalinge method

The inverse Von Bertalanffy equation
\[ t(L) = t_0 - \frac{1}{K} \ln \left( \frac{1-L}{L_\infty} \right) \]
and the cumulated catch curve equation lead to the Jones and van Zalinge equation (1981):
\[ \ln \left( C(L, L_\infty) \right) = a + \frac{Z}{KD} \ln \left( \frac{L_\infty - L}{L} \right) \]

Here the y axis represents the natural logarithm of the cumulated catch of fish of length L and longer (C). When Z, L_\infty and K are assumed to be constants with age, this equation gives a linear regression with x axis as log (L_\infty-L).

slope b = \frac{Z}{KD}

Thus total mortality rate \( Z = b \cdot K \cdot D \).

In practice, the relationship between \( \ln \left( \frac{L_\infty - L}{L} \right) \) and \( \ln \left( C(L, L_\infty) \right) \) is linear only in the middle part of the plot. This is because the first few length groups which form the ascending part of the curve consist of fish not yet fully recruited to the fishery. Also the last few age groups, which are close to \( L_\infty \), give rise to an uncertain relationship between age (t_L) and length (L). Hence, the regression analysis should be limited to the central, straight portion of the curve.

This program utilizes the data created and saved as a data file under file maintenance routine. Enter the name of the data file. In this case the frequencies should have been raised to the total catch. If “/” is entered, the main menu can be obtained. Enter an estimated value of L_\infty, D (or set D = 1) and K. Set the printer on and press “return”. The table of values of length intervals, catch frequencies, cumulated catch figures, and x and y coordinates will be printed. The screen will also display the scatter diagram for the points to help the user in choosing the points for the regression analysis. However, users are strongly urged to plot the points on graph paper for choosing the points, as the screen display will tend to be distorted. For this reason, the following message appears on the screen. “If you wish to display the above scattergram on the screen again, enter Y or else press return”. If return is pressed, the prompt appears: “Please draw a scattergram with the printed values, then select points belonging to the straight segment of the plot. Enter the starting and ending numbers of the points selected for regression”. When the user enters the starting number and the ending number of the straight portion of the graph, the program will execute the regression analysis to produce a series of \( Z/KD \) values, initially with the first three selected points and then repeating the analysis after including each of the successive points selected. Then the Z values are calculated using the K and D values input and then printed. Their 95% confidence limits are also automatically calculated and printed, using the variances (S_b^2) and the corresponding t_2 values.

\[
S_b^2 = \frac{1}{n-2} \left[ \left( \frac{S_y}{S_x} \right)^2 - b^2 \right]
\]

Confidence limit of \( Z = \pm Z \cdot KD \cdot t_{n-2, S_b} \)

This procedure will be repeated for all samples in the data file. (Example in Appendix 9.)

6.3 Sparre’s (1985) catch curve method based on length composition data

The method of Sparre (1985) is a variant of the method of Jones and van Zalinge (1981) which also starts with the inverse von Bertalanffy equation, which is used to estimate the time taken.

The time taken for an average fish to grow from length \( L_1 \) to length \( L_2 \) i.e.
\[ \Delta t = t(L_2) - t(L_1) = \frac{1}{K} \ln \left( \frac{L_\infty - L_1}{L_\infty - L_2} \right) \]

The age interval mid-point is given by the equation.
\[ t \left[ \frac{(L_1 + L_2)}{2} \right]_{t=0} - \frac{1}{K} \ln \left[ \frac{1}{L_1 + L_2} \right]_{L_\infty} \]

[1]
Thus based on the equation
\[
\ln \left( \frac{C (L_1, L_2)}{\Delta t} \right) = C - Z \frac{L_1}{K} - Z \frac{1}{K} \ln \left[ 1 - \frac{(L_1 + L_2)}{2} \right]
\]
we obtain
\[
\ln \left( \frac{C (L_1, L_2)}{\Delta t} \right) = C - Z \left( \frac{L_1 + L_2}{2} \right)
\]
which is of the form, \( y = a + bx \) with slope \( b = Z \).

The program presents a scatterplot of \( t \left( \frac{(L_1 + L_2)}{2} \right) \) vs \( \ln \left( \frac{C (L_1, L_2)}{\Delta t} \right) \) which is used to identify the straight portion of the catch curve. The calculations and the regression for the selected points are as in the previous method but in this case, the slope \( b = Z \). As in the previous case (6.1) some points are excluded from the regression analysis, for the same reasons. The calculation of a series of \( Z \) values and their confidence limits and printing of the results, follow the same procedure as in 6.1. (Example in Appendix 10.)

6.4 Wetherall method for estimating growth and mortality parameters from length frequency data

This simple method estimates asymptotic length \( (L_\infty) \) and the ratio of the coefficients of mortality and growth \( (Z/K) \), using only the length frequency data (Wetherall 1986).

The principle is based on Beverton and Holt's formula
\[
Z/K = \frac{(L_\infty - \bar{L})}{(\bar{L} - L_c)}
\]
which can be rearranged to
\[
\bar{L} = \frac{L_\infty}{1 + \frac{Z}{K}} + L_c \cdot \frac{Z/K}{1 + \frac{Z}{K}}
\]
to show that the mean length of the selected fish \( \bar{L} \) is a linear function of the selection length \( (L_c) \). However application of this method assumes the sampled fish population to have

(a) constant annual recruitment
(b) von Bertalanffy growth
(c) continuous mortality occurring at a uniform rate, which are rarely fully satisfied in practice.

For better results it is expected that the length frequency samples be raised to the annual catch. For a series of arbitrary knife-edge selection lengths \( (L_c) \), the corresponding mean lengths \( (L) \) of size groups exceeding the selection lengths \( (L_c) \) are calculated, ignoring the size groups below the selection length. These when graphically plotted, present a linear relationship according to the above equation with

\[
\text{intercept } a = \frac{L_\infty}{1 + \frac{Z}{K}}
\]
\[
\text{slope } b = \frac{Z/K}{1 + \frac{Z}{K}}
\]

From these \( L_\infty = \frac{a}{1-b} \)
and \( Z/K = \frac{b}{1-b} \)
and \( Z = \left( \frac{b}{1-b} \right) K \)
(See example 6.4 in Appendix.)

For the knife-edge selection length \( (L_c) \) from the length frequency distribution, the lower limits of the size groups have been chosen.

This program utilizes the data created and saved as a data file under file maintenance routine. Enter the name of the data file. If “/” is entered main menu can be obtained. Enter estimated value of \( K \), if available. The program estimates the mean lengths for the series of corresponding arbitrary selection length values identified by the user. Next the values are printed and a scatterplot
appears on the screen, to help the user to identify the lowest value of the selection length, to be used in the linear regression analysis. When the points for the regression analysis are entered, the program will print out estimates of $L^\infty \frac{Z}{K}$ and also $Z$ if a $K$ value had been entered, initially.

7. REFERENCES CITED

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DETAILED PROGRAM LISTING

Appendix 1

10 REM ***** MENU.BAS
20 REM ***** THIS IS A MENU PROGRAM FOR BHATTACHARYA & CHI SQUARE PROGRAMS,
30 REM ***** DEVELOPED BY HAZTRA GUNATILLEKE BOBP COLOMBO - SRI LANKA,
40 REM ***** LAST UPDATE 25,08,86
50 HOME
60 INVERSE
70 PRINT:PRINT:PRINT:PRINT:PRINT
80 HTAB 20
90 PRINT ' NORMAL DISTRIBUTION SEPARATION MENU
100 NORMAL
110 PRINT:PRINT
120 PRINT TAB(15);" 1.  FILE MAINTENANCE"
130 PRINT TAB(15);" 2. BHATACHARYA'S WBTOD "
140 PRINT TAB(15);" 3. CHI SQUARE STATISTICS"
150 PRINT TAB(15);" 4. ESTIMATING GROWTH PARABERTBRS"
160 PRINT TAB(15);" 5. TOTAL MORTALITY  ESTIMATION "
170 PRINTTAB(15);" 6. QUIT TO CP/H'
180 PRINT:H=INV:PRINT 'enter option?';:NORMAL:$/INPUT$(1)
190 H=VAL(H$):PRINT  H
200 IF H<1 OR H<6 THEN 50
210 ON H GOTO 220,230,240,250,400,540
220 RUN "MAIN.BAS"
230 RUN "BH3.BAS"
240 RUN "CHI.BAS"
250 HOME:PRINT:PRINT:PRINT:PRINT
260 PRINT ' ESTIMATION OF GROWTH PARABERTBRS'
270 PRINT ' xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
280 PRINT:PRINT
290 PRINTTAB(20);" 1 PLOT OF % FREQUENCIES
300 PRINT TAB(20);" 2. FORD - WALFORD PLOT"
310 PRINTTAB(20);" 3. CULLAND & HOLT PLOT"
320 PRINT TAB(20);" 4. VON BERTALANFFY PLOT"
330 VTAB 15:HTAB 25:INPUT *select option*;HH
340 IF HH<1 OR HH>4 THEN 330 ELSE 350
350 ON HH GOTO 360,370,380,390
360 RUN "GRAPH1.BAS"
370 RUN "FORD.BAS"
380 RUN "HOLT.BAS"
390 RUN "VON.BAS"
400 HOME:PRINT:PRINT:PRINT:PRINT
410 PRINT ' TOTAL MORTALITY  ESTIMATION'
420 PRINT ' xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
430 PRINT:PRINT
440 PRINTTAB(20);" 1. JONES & VAN ZALINGE METHOD"
450 PRINTTAB(20);" 1. SPARRE'S CATCH CURVE BASED METHOD"
460 PRINTTAB(20);" 3. WETHERALL'S AL METHOD"
470 PRINTTAB(20);" 4. EXIT TO MAIN MENU"
480 VTAB 15:HTAB 25:INPUT 'enter your choice*;HG
490 IF HG<1 OR HG>4 THEN 480 ELSE 500
500 ON HG GOTO 510,520,530,50
510 RUN "JONES.BAS"
520 RUN "SPARRE.BAS"
530 RUN "WET.BAS"
540 PRINT :PRINT:PRINT:BYE BYE FROM APPLE II e*:SYSTEM
550 */
FILE MAINTENANCE ROUTINE

10 REM **** MAIN.BAS
20 REM *** PROGRAMMED BY HARIZTRA GOONETILLEKE - BOBP, COLOMBO-SRI LANKA - JUNE 86
30 REM ** FILE MAINTENANCE ROUTINE
40 REM LAST UPDATE 04/08/86
50 REM
60 REM ** This program is written using Microsoft version 2.23b with MBASIC
70 REM ** for APPLE IIe micro computer with Softcard CP/M
80 REM
90 GOSUB 130: REM INITIALISATION
100 ON B GOSUB 350, 880, 1380, 1570, 1800, 1700, 1940: REM CREATE, EDIT, LIST, CATALOG, DELETE, INIT, REGROUP
110 GOSUB 1180: REM TERMINATION
120 REM
130 REM ** INITIALISATION ROUTINE
140 OPTION BASE 1
150 HOME: VTAB 4: HTAE 15: PRINT FILE MAINTENANCE MENU"
160 PRINT: PRINT "***************************"
170 PRINT: PRINT: PRINT
180 PRINT I CREATE A NEW DATA FILE
190 PRINT 2 EDIT AN EXISTING DATA FILE
200 PRINT 3 LIST/DISPLAY DATA FILE
210 PRINT 4 DISPLAY DISK CATALOG
220 PRINT 5 DELETE DATA FILES
230 PRINT 6 INITIALISE NEW DATA DISK
240 PRINT 7 REGROUPING OF LENGTH FRE, DATA"
250 PRINT 8 RETURN TO MAIN MENU
260 PRINT: PRINT: PRINT
270 INPUT select option E
280 IF B<1 OR B>8 THEN 150
290 ON B GOTO 300, 300, 300, 330, 300, 1700, 300, 1180
300 PRINT: PRINT: PRINT
310
320 INPUT "ENTER FILE NAME(maximum 8 characters":-
330 IF LEN(F$)=0 THEN 310
340 RETURN
350 REM
360 PRINT: LINE INPUT "ENTER DESCRIPTION OF THIS FILE"
370 PRINT INPUT "NO.OF SAMPLES " , H
380 PRINT "NUMBER OF CLASSES C"
390 DIM X(H) F(H), C(H), L1(H), L2(H), M(H)
400 INPUT "LOWER LIMIT OF SMALLEST SIZE CLASS ", L1
410 INPUT "UPPER LIMIT OF SMALLEST SIZE CLASS ", L2
420 D=L2-L1
430 IF D<1 THEN "REENTER" ; GOTO 400
440 FOR K=1 TO H
450 HOME: PRINT TAB(25); "DATA ENTRY"
460 PRINT: PRINT TAB(10); "SAMPLE "; K
470 INPUT "MONTH", M(K)
480 PRINT
490 INPUT "ABOVE ENTRIES O.E, (Y/N)", YYZ$ 
500 IF YYZ$="Y" THEN 550 ELSE IF YYZ$="N" THEN 4UU ELSE 530
510 IF L2(K)<L1(K) THEN PRINT "REENTER "; GOTO 400
520 PRINT
530 INPUT "FIRST MID LENGTH OF THIS SAMPLE"
540 INPUT "LAST MIDLENGTH OF THIS SAMPLE "; L2(K)
550 IF L2(K)<L1(K) THEN PRINT "REENTER "; GOTO 400
560 PRINT
570 FOR I=1 TO C(K)
580 PRINT
580 X(E,I)=L1(E)+(I-1)*D
590 PRINT ;"I;TAB(10);I(E,I);TAB(30);
600 INPUT F(E,I)
610 IF F(E,I)=0 THEN PRINT "enter 0.01 for zero frequency :GOTO 590
620 NEXT I
630 GOSUB 780:REH EDIT IF NECESSARY
640 NEXT E
650 OPEN "0",1,F$
660 PRINT #,D$
610 PRINT #1,H,C,L1,L2:REM SAMPLES,CLASSES,LIMITS
680 FOR E=1 TO H
690 C(E)=(L2(E)—L1(E)) /(D+1
700 PRINT #1,M(K),C(K):REM MTH,NO.OF CASES IN Kth SAMPLE
710 FOR I=1 TO C(K)
120 PRINT #1,X(E,I),F(E,I):REM WRITE RECORDS
730 NEXT I
740 NEXT E
750 CLOSE #1
760 RETURN
770 REM
780 REM * EDIT DATA DURING CREATE FILE STAGE
790 PRINT:INPUT"DO YOU WISH TO EDIT DATA FOR THIS SAMPLE (YN) ",Y$
800 IF Y$="Y" THEN 810 ELSE IF Y$="N" THEN 810 ELSE 790
810 INPUT "NO.OF CLASS TO EDIT ",E
820 IF E>C(E) THEN PRINT "no such length class:"GOTO 810
830 IF E=0 THEN 870
840 PRINT ;"E;TAB(10);X(E,E);TAB(30);
850 INPUT F(K,E)
860 GOTO 790
870 RETURN
880 REM
890 REM * EDIT EXISTING DATA FILE
900 OPEN "I",1,F$
910 G$:="CCCCCCC"
920 MID$(G$,1,2)=MID$(F$,1,2)
930 OPEN "0",2,G$
940 LINE INPUT #1,D$
950 INPUT #1,H,C,L1,L2
960 HOME :PRINT "DESCRIPTION ";D$
970 INPUT "O.E.(Y/N) ",O$:IF O$="N" THEN 980 ELSE DD$:D$:GOTO 990
980 LINE INPUT "NEW DESCRIPTION ",DD$
990 PRINT "NO.OF SAMPLES ";H:PRINT "NO.OF CLASSES ";C:PRINT "SMALLEST SIZE CLASS ";L1;-'";L2
1000 PRINT #2,D$
1010 PRINT #2,H,C,L1,L2
1020 DIM X(H,C),F(H,C),C(H),M(H)
1030 FOR E=1 TO H
1040 HOME:PRINT TAB(25):"EDITING PROCESS"
1050 PRINT
1060 INPUT #1,M(K),C(K):PRINT "SAMPLE =";X;PRINT "MONTH =";M(K)
1070 INPUT "NEW MONTH;MM:IF MM:<0 THEN 1080 ELSE M(K)=MM
1080 PRINT #2,M(K),C(K)
1090 PRINT "NO.",TAB(10);"MID LENGTH";TAB(30);"FREQUENCY"
1100 FOR J=1 TO C(E):INPUT #1,X(E,J),F(E,J):PRINT ;";J;TAB(10); X(E,J);TAB(30);F(E,J):NEXT J
1110 GOSUB 180:REM EDIT
1120 FOR J=1 TO C(E):PRINT #2,X(E,J),F(E,J):NEXT J
1130 NEXT E
1140 CLOSE
1150 EILL F$
1160 NAME GS AS FS
1170 RETURN
1180 REM ****************************************************
1190 REM ' TBRHINATION
1200 HOME
1210 CLOSE:RUN"MENU.BAS"
1220 RETURN
1230 REM *****************************************************
1240 REM LOAD DATA FROM FILE
1250 OPEN "I",1,FS
1260 LINE INPUT #1,D$
1270 INPUT #1,H,C,L1,L2
1280 D=L2-L1
1290 DIM X(H,C),F(H,C),C(H),M(H)
1300 FOR E=1 TO H
1310 INPUT #1,M(E),C(K)
1320 FOR J=1 TO C(K)
1330 INPUT #1,X(E,J),F(E,J)
1340 NEXT J
1350 NEXT E
1360 CLOSE #1
1370 RETURN
1380 REM ** LIST DATA
1390 GOSUB 1240
1400 HOME :PEANT:LPRINT:LPRINT"         FILE NAME .  ";FS
1410 PRINT D$:LPRINT D$
1420 FOR E=1 TO H
1430 PRINT
1440 NEXT E
1450 RETURN
1460 REM ****************************************************
1470 REM ** DISPLAY DISK CATALOG
1480 HOME:PRINT:LPRINT
1490 INPUT "ENTER DISK DRIVE NUMBER(A/B)  ",DD$
1500 IF DD$="A" THEN PRINT :FILES  "A:*.*":GOTO 1570
1510 IF DD$="B" THEN PRINT :PRINT:FILES  "B:*.*":GOTO 1570
1520 FOR I=1 TO C(K)
1530 LPRINT USING "###.# ";X(E,I),F(E,I)
1540 NEXT E
1550 RETURN
1560 REM *******************************************************
1570 REM ** INITIALISE ROUTINE
1580 REM **********************************************************
PRINT "Press return, then insert blank disk in drive B & press return again."
PRINT "Make sure that the disk you insert to drive B is blank otherwise the contents of this disk will be erased."
PRINT "Note down this command & press return to quit to CP/M command level"
INPUT " ",QQQ$
SYSTEM
REM
REM * DELETE FILES
PRINT "With this process this file will be permanently destroyed"
INPUT "do you wish to delete this file (Y/N)";VV$
IF VV$="Y" THEN 1860 ELSE IF VV$="N" THEN 1920 ELSE 1840
IF RIGHT$(F$,4):",BAS" OR RIGHT$(F$,4):",COM" THEN 1870 ELSE 1983
PRINT "SORRY - PROGRAM FILES CANNOT BE DESTROYED ! ":GOTO 1900
KILL F$
PRINT F$;" is now deleted,"
FOR III = 1 TO 1000:REM " DELAY
NEXT III
RETURN
REM *************************************************************
REM ** REGROUP LENGTH FREQUENCY DATA WITH DIFFERENT CLASS INTERVALS
REM ** AND CREATE A NEW DATA FILE
GOSUB 1240
HOME
INPUT "BNTBR THB MULTIPLICATION FACTOR FOR REGROUPINC YOUR LENGTH FREQUENCIES ",MF
PRINT "EARLIER CLASS INTERVAL = ";D
PRINT "NEW CLASS INTERVAL = ";MF*D
INPUT "O.K.(Y/N) ",QQW$
IF QQW$="Y" THEN 2030 ELSE IF QQW$="N" THEN 1980 ELSE 2010
PRINT "REGROUPED FREQUENCIES OF FILE ";F$
ND=MF*D:NL2=L1+ND:REM NEW CLASS LIMITS
FOR E=1 TO H
PRINT "SAMPLE ";E
LPRINT "MONTH ";M(E)
PRINT:PRINT "MID  PT.");CT:PRINT "#FREQ"
LPRINT "LENGTH ";SPC(10)"FREQUENCY"
J=1:CT=0
FOR I=1 TO C(E)
IF X(E,I)(NL2+(J-1)*ND THBN 2180 ELSE 2150
CT=CT+F(E,I)
NEXT I
PRINT NL2+(J-1)*ND-ND/2;TAB(20);CT
LPRINT USING "#####.## ";CT
NEXT E
Modification of Bhattacharya's method

10 REM **H3.BAS
20 REM PROGRAMMED BY HAEZTRA GOONETILLEKE - BOHF, COLOMBO - SRI LANKA - JUNE 86
30 REM A MODIFICATION OF BHATTACHARYA'S METHOD FOR THE ANALYSIS OF
40 REM MIXTURES OF NORMAL DISTRIBUTIONS FOR A NUMBER OF SAMPLES
50 REM LAST UPDATE 04/30/86
60 REM
70 REM:***********************************************************************
80 REM: LOG(Fi+1/Fi)=a+bXi
90 REM
100 REM: \[ \log(a+bXi) = \log(Fi+1/Fi) \]
110 REM: \[ \therefore a = \log(Fi+1/Fi) \]
120 REM: \[ \therefore b = \frac{\log(Fi+1/Fi) - \log(Fi)}{X_i} \]
130 REM: \[ \log(Fi+1/Fi) = \frac{X_i}{\log(Fi+1/Fi)} \]
140 REM: \[ N = \text{NO. OF ITEMS IN THE COMPONENT DISTRIBUTIONS} \]
150 REM: This programme will estimate mean M, std. dev. S, and N values for each
160 REM: triplet of Fi and xi pairs when the abs. corr. coeff. (calculated)
170 REM: is higher than the r critical (input)
180 REM: This program is written using Microsoft version 2.33b - with MEASIC
190 REM: H for APPLE IIe micro computer with Softcard CP/M
200 REM: **********
210 GOSUB 270: REM INITIALISATION
220 GOSUB 1040: REM READ DATA FILE
230 GOSUB 380: REM CALCULATE & PRINT RESULTS
240 GOSUB 980: REM TERMINATION
250 IF W$"Y" THEN 230
260 REM:***********************************************************************
270 REM: INITIALISATION ROUTINE
280 HOME: VTAB 4: PRINT "BHATTACHARYA'S METHOD"
290 PRINT: PRINT: PRINT "ENTER CRITICAL VALUE OF CORRELATION COEFFICIENT " , R1
300 PRINT: PRINT: PRINT "FILE NAME:" ; F$;
310 IF F$="" THEN GOTO 1010
320 IF LEN(F$)=0 THEN 320
330 PRINT "READY THE PRINTER & PRESS RET";
340 RETURN
350 REM:***********************************************************************
360 REM: INITIALISATION ROUTINE
370 REM:***********************************************************************
380 REM: CALCULATE & PRINT RESULTS
390 HOME: PRINT: PRINT: PRINT: PRINT "ENTER CRITICAL VALUE OF CORRELATION COEFFICIENT " , R1
400 LPRINT "BHATTACHARYA ANALYSIS";
410 LPRINT "FILE":F$;
420 LPRINT "FILE NAME:" ; F$;
430 IF F$="" THEN GOTO 380
440 LPRINT "INPUT VALUE OF CRITICAL VALUE OF CORRELATION COEFFICIENT = " , R1
450 FOR I=1 TO H
460 IF J>3 THEN 530
470 IF J=1 THEN GOTO 530
480 PRINT "MONTH " ; M(I); LPRINT "MONTH " ; M(I); LPRINT "LPRINT "LPRINT
490 J=J+1
500 IF J>3 THEN GOTO 530
510 IF J>3 THEN GOTO 530
520 REM: LINEAR REGRESSION ROUTINE
530 FOR J TO J+2
540 IF J=1 THEN GOTO 530
550 IF J=1 THEN GOTO 530
560 IF J=1 THEN GOTO 530
570 IF J=1 THEN GOTO 530
550 REM PRINT XX,YY,XY,XX2JYY2
560 NEXT I
570 B1=XY-(3*YY/3)
580 B2=XX-((XX/2)/3)
590 B=B1/B2
600 A=YY/(B*XX/3)
610 REM PRINT "INTERCEPT a =";A
620 REM PRINT "SLOPE b =";B
630 IF B>0 THEN J=J+1:GOTO 500:REM SLOPE SHD BE NEGATIVE
640 REM * CORRELATION ROUTINE
650 B3=YY^2-((YY/2)/3)
660 B4=(B3+B3)^2/5
670 R=B1/B4
680 REM R (calculated) SHD BE HIGHER THAN R critical
690 IF R<0 THEN R=-R
700 PRINT "KID PTS.: "X(K,J),X(K+1),X(K+2):PRINT "ABSCORR,COEFF.:';R
710 LPRINT "MID PTS.: "X(K,J),X(K+1),Y(K+2)
720 LPRINT "ABS.CORR.COEFF. '";R
730 IF R<R1 THEN J=J+1:PRINT:LPRINT:GOTO 510
740 REM SESTIMATE M,S,N
750 M=(.5*D)-(A/B)
760 IF (1/-B)^((D/2)/12) THEN PRINT "STD.DEV. CANNOT BE CALCULATED SINCE SQUARE ROOT OF NEGATIVE NUMBERS CANNOT BE FOUND":S=0:GOTO 770
760 S=((1-B)-((D/2)/12))^.5
770 LF=0:M2=0
780 FOR I=1 TO J+2
790 LF=LF+LOG(F(K,I))
800 M2=M2+((X(K,I)-M)^2)
810 NEXT I
820 LF=LF/3
830 N3=S^2+(D/12)
840 N4=D^2/(24*S^2)+LOG((2*22/7)^.5)
850 N5=EXP(LF+(N2/N3)+N4)
860 N=(S*N5)/D
870 REM * PRINT VALUES
880 PRINT "GROUP ";G;TAB(15);"MEAN=";M;TAB(30);"STD.DEV.=";S;TAB(55);"NO.OF ITEMS=";N
890 LPRINT "GROUP ";G;" MEAN = ";M
900 LPRINT "STD.DEV. = ";S;" NO.OF ITEMS =";N
910 PRINT :LPRINT
920 J=J+1:G=1:GOTO 500
930 LPRINT "--------------------------------------------------------"  
940 LPRINT
950 NEXT K
960 RETURN
970 REM " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " 

20
Chi square calculations

10 REM *************************************************
20 REM *** CHI.BAS
30 REM *** PROGRAMMED BY N. A. A. H. GEETTILKERR - R.G.P., COLOMBO - SRI LANKA, JUNE 86
40 REM *** ANALYSIS OF FREQUENCIES FROM A MIXTURE OF NORMAL DISTRIBUTION
50 REM *** PROGRAM TO CALCULATE THE CHI SQUARE STATISTIC TO ASSESS WHETHER
60 REM *** THE GROUPS IDENTIFIED GENERATE A MIXTURE OF NORMAL DISTRIBUTIONS
70 REM *** THAT FITS THE ORIGINAL FREQUENCY DATA.
80 REM *** LAST UPDATE 04/08/86
90 REM *************************************************

100 REM # This programme will use the mean M, std.dev.S, and size N of a number
110 REM # of Normal Distributions (i=j) to estimate combined frequencies f
120 REM # f = exp{-0.5((x-M)/S)^2}/(2pi)^0.5
130 REM # The residuals (f-f) and values for the computation of the
140 REM # CHI SQUARE STATISTIC (f-f^2/f) will be calculated
150 REM # Note that classes with f<5 should be pooled to prevent inflating
160 REM # the test statistic.
170 REM # This program is written using Microsoft version 2.23 B with MBASIC
180 REM # for APPLE II micro computer with Softcard CP/M
190 REM *************************************************

200 GOSUB 270:REM INITIALISATION ROUTINE
210 GOSUB 1310:REM READ DATA FROM ORIGIORAL FILE
220 GOSUB 520:REM INPUT,CALCULATE & PRINT RESULTS
230 IF FY$="Y" THEN 230 ELSE 250
240 IF CS$="Y" THEN 250
250 GOSUB 1460:REM CREATE NEW DATA FILE FOR +VE RESIDUALS
260 GOSUB 1260:REM TERMINATION ROUTINE
270 REM *************************************************
280 OPTION BASE 1
290 DIM P(6),S(6),N(6)
300 HOME :VTA 4:VTAB 17:PRINT "CHI SQUARE STATISTICS"
310 PRINT TAB(16):"\n320 PRINT:PRINT
330 PRINT "This program will produce expected size frequencies and residuals"
340 PRINT "For the original frequencies entered in Brattacharya Analysis."
350 PRINT "This before running this program you should run the Brattacharya"
360 PRINT "Analysis Program and obtain the values of mean, standard deviation"
370 PRINT "And no. of items as input to this program."
380 VTAB 18:PRINT "enter / to return to main menu"
390 VTAB 15:INPUT "Enter original data file name : ",FS$:
400 IF FS$="Y" THEN GOTO 1290
410 IF LEN(FS$)=0 THEN 350
420 INPUT "Do you wish to create another file with the residuals of this analysis? \nY/N: ",YY$:
430 IF YY$="Y" THEN 450
440 IF YY$="N" THEN 490
450 INPUT "Enter new file name : ",CS$:
460 IF CS$="/" THEN GOTO 1280
470 VTAB 18:PRINT " 
480 PRINT:LINE INPUT "description of this file?";ND$
490 INPUT "READY THE PRINTER & PRESS RETURN TO PROCEED";O$
500 RETURN
510 REM*************************************************************************
520 REM ** INPUT ROUTINE
530 IF H=1 THEN INPUT "DO YOU WISH TO SELECT SAMPLE BY SAMPLE FOR THE CHI SQUARE TEST (Y/N)";CS$ ELSE GOTO 550
540 IF CS$="N" THEN 550
550 INPUT "sample",K:IF K=0 THEN 1240
560 IF K>H THEN PRINT "no such sample";GOTO 560
570 GOTO 6130
580 GOTO 600
590 FOR K=1 TO H
600 INPUT ROUTINE
610 PRINT:PRINT TAB(25);"CHI SQUARE STATISTICS"
620 PRINT "MONTH ";M(K)
630 PRINT INPUT "NO. OF GROUPS (6) OF MEAN,STD.DEV.&SIZE ";Z
640 IF Z=0 THEN 1230 
650 IF Z>6 THEN 600
660 IF INT(Z)=Z THEN 670 ELSE GOTO 630
670 FOR B=1 TO Z
680 PRINT "GROUP ";B
690 PRINT "MEAN ";U(B):PRINT "STD.DEV. ";S(B):PRINT "SIZE ";N(B)
700 PRINT "entries O.K. (Y/N) ");OK$
710 IF OK$="Y" THEN 740
720 IF OK$="N" THEN 690
730 PRINT:NEXT B
740 PRINT
750 PRINT :PRINT:NEXT B
760 REM ** CALCULATE & PRINT RESULTS
770 LPRTINT "CHI SQUARE STATISTICS"
780 LPRTINT "**************************"
790 LPRTINT :LPRTINT
800 LPRTINT "FILE NAME ";F$
810 LPRTINT D$
820 LPRTINT 
830 LPRTINT "SAMPLE ";K
840 LPRTINT "MONTH ";M(K):LPRTINT:LPRTINT
850 LPRTINT "MEAN = ";:FOR B=1 TO Z:LPRTINT USING "####.##### ";U(B):NEXT B:LPRTINT
860 LPRTINT "STD.DEV. = ";:FOR B=1 TO Z:LPRTINT USING "####.##### ";S(B):NEXT B:LPRTINT
870 LPRTINT "SIZE = ";:FOR B=1 TO Z:LPRTINT USING "####.##### ";N(B):NEXT B:LPRTINT
880 LPRTINT :LPRTINT:LPRTINT
890 LPRTINT "MID LENGTH ";TAB(15);"FREQ. ";TAB(27);"PREDICTED F ";TAB(42);"FREQ.- EXP.FREQ. ";
900 LPRTINT "MID LENGTH ";SPC(5)"FREQUENCY";SPC(6)"PREDICTED F ";SPC(10)"RESIDUALS"
910 FOR I=1 TO C(K)
920 FF=0
930 FOR B=1 TO Z
940 FF=FF+(S(B)*N(B)*SQR(2*L+7))/(S(B)*N(B)*5)
950 NEXT B
960 PRINT I(K,I);TAB(15);F(K,I);TAB(27);FF;TAB(45);F(K,I)-FF
970 LPRTINT USING "####.##### ";F(K,I);LPRTINT USING "####.##### ";F(K,I)
980 LPRTINT USING "####.##### ";F(K,I)-FF
990 LPRTINT D$
1000 NEXT I
1010 LPRTINT 
1020 REM ** LUMP CLASSES WITH FF<5 TO CALCULATE CHI SQ. STAT.
1030 PRINT: PRINT: PRINT: PRINT  " FREQUENCIES GROUPED INTO CLASSES WITH PRED. FREQ. > 5 " : PRINT
1040 LPRINT: LPRINT " FREQUENCIES GROUPED INTO CLASSES WITH PREDICTED FREQUENCIES > 5 "
1050 LPRINT " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " 23
Graph plot

10 REM **** GRAPH
20 REM *** PROGRAMMED BY HARETEA GOONSTILLEKE - BOBP, COLOMBO-SEI LANKA. - JUNE 86
30 REM + ANALYSIS OF FREQUENCIES FROM A MIXTURE OF NORMAL DISTRIBUTION
40 REM + PROGRAM TO CALCULATE & PRINT VALUES FOR GRAPHS OF % FREQUENCIES vs.
50 REM + LENGTH CLASSES WITH SIZE COMPONENTS & CONFIDENCE LIMITS.
60 REM + LAST UPDATE 04/08/86
70 REM +
120 GOSUB 180: REM INITIALISATION
130 GOSUB 910: REM READ DATA FROM ORIGINAL FILE
140 GOSUB 1080: REM DRAW THE GRAPH ROUTINE
150 GOSUB 340: REM PRINT VALUES
160 GOSUB 860: REM TERMINATION
170 REM +
180 REM +
190 OPTION BASE 1
200 DIM U(6), S(6), M(6), C1(2, 6), C2(2, 6)
210 HOME: VTAB 4: HTAB 17: PRINT ' FREQUENCY PLOT '
220 PRINT ' THIS PROGRAM WILL PLOT THE % LENGTH FREQUENCY DATA '
230 PRINT ' FOR ALL THE SAMPLES. THIS GIVES YOU THE CONFIDENCE LIMITS '
240 PRINT ' FOR THE MEANS OBTAINED IN THE BHATTACHARYA PROGRAM. '
250 VTAB 18: PRINT ' enter / to return to main menu'
260 VTAB 18: INPUT ' ENTER ORIGINAL DATA FILE NAME :- ', F$
270 IF F$: "J" THEN 0010 880
280 INPUT ' READY THE PRINTER & PRESS RETURN TO PROCEED ', O$
290 RETURN
300 REM +
310 REM +
320 REM +
330 REM +
340 REM + PRINT ROUTINE
350 LPRINT: LPRINT: LPRINT
360 LPRINT ' FILE NAME :- ', F$
370 LPRINT D$
380 FOR I = 1 TO H
390 HOME: LPRINT
400 PRINT ' PRINT TAB(10):"SAMPLE ";H
410 PRINT " MONTH "; M(I)
420 LPRINT
430 LPRINT "SAMPLE "; E
440 LPRINT " MONTH "; M(I): LPRINT
450 PRINT " MID LEN. "; TAB(15): " FREQ. "; TAB(27): " % FREQ. ";
460 LPRINT " MID LENGTH "; SPC(5): " FREQ. "; SPC(6): " % FREQ. "; SPC(6): " FREQ. "; ROUNDED)"
470 FOR I=I TO C(E)
480 PRINT X2(K,I);TAB(15);F(K,I);TAB(27);F(K,I)*100/T(K)
490 LPRINT USING "###.###";X2(K,I);LPRINT USING "###.###";F(K,I).
500 LPRINT USING "###.###";INT(F(K,I)*100/T(K))+.5)
510 NEXT I
520 PRINT:PRINT"CHOOSE GROUPS WITH HIGHEST R VALUES FROM THE PRINTED RESULTS OF BHATTACHARYA ANALYSIS"
530 IF Z>6 THEN 530
540 TN=0
550 FOR B=1 TO 2:PRINT "GROUP ";B
560 INPUT "MEAN ";U(B):INPUT "STD.DEV. ";S(B):INPUT "SIZE ";N(B):PRINT
570 TN=TN+N(B)
580 IF N(B)< 30 THEN 620 ELSE IF N(B)<40 THEN 660 ELSE IF N(B)<60 THEN 610
590 IF N(B)<120 THEN 700 ELSE IF N(B)<120 THEN 710 ELSE 720
600 RESTORE
610 FOR CC=1 TO 30:READ CONF,CONF1,CONF2
620 IF CONF>N(B) THEN CC=30
630 NEXT CC:GOTO 740
640 RESTORE 7150:GOTO 730
650 RESTORE 1820:GOTO 730
660 RESTORE 1830:GOTO 730
670 RESTORE 1840:GOTO 730
680 RESTORE 1850:GOTO 730
690 RESTORE 1860:GOTO 730
700 RESTORE 1870:GOTO 730
710 RESTORE 1880:GOTO 730
720 RESTORE 1890:GOTO 730
730 READ CONF,CONF1,CONF2
740 NEXT B
750 FOR B=1 TO Z:CLI(1,B)=U(B)-CONF1*S(B)/SQR(N(B));CL2(1,B)=U(B)+CONF1*S(B)/SQR(N(B));
760 NEXT B
770 PRINT:PRINT"RAISING FACTOR = ";T(K)/TN
780 FOR B=1 TO 2:PRINT "MEAN ";U(B);" SIZE ";N(B)*T(K)/TN
790 LPRINT USING "###.###";U(B);LPRINT USING "###.###";S(B);LPRINT USING "###.###";CONF1*S(B)/SQR(N(B));
800 LPRINT USING "###.###";CONF2*S(B)/SQR(N(B));LPRINT USING "###.###";CONF1*S(B)/SQR(N(B));
810 PRINT
820 NEXT B
830 NEXT B
840 RETURN
850 REM *************************************************************
860 REM TERMINATION
870 HOME
880 CLOSE :RUN "MENU.BAS"
890 RETURN
900 REM *************************************************************
910 REM READ DATA FROM DISK
920 OPEN "I",1,$
930 LINE INPUT$1,D$
940 INPUT H,C,L1,L2
950 D=L2-1
960 DIM X(H,C),F(H,C),M(H,C),T(H,C),A(H),X2(H,C)
970 FOR E=1 TO H
980 INPUT #1,H,E+1)
990 T(E)=0
1000 FOR J=1 TO C(E)
1010 INPUT #1,H,E, J,F(E,J)
1020 X2(H,E,J)=F(E,J)
1015 Z2(K,J)=X(K,J)
1020 T(E)=T(E)+P(E,J)
1030 NEXT J
1040 NEXT E
1050 CLOSE #1
1060 RETURN
1070 REM #####################################################################
1080 REM GRAPH ROUTINE
1090 LPRINT "FILE NAME :-",F$
1100 LPRINT D$
1110 REM **** CALCULATE % FREQUENCIES & ROUND TO NEAREST INTEGER
1120 FOR E=1 TO H
1130 FOR I=1 TO C(E)
1140 VTAB 22;PRINT "CALCULATIONS IN PROGRESS -- PLEASE WAIT ** "
1150 G(E,I)=P(E,I)/100*T(E)+.5
1160 REM LPRINT X(K,I),G(E,I)
1170 NEXT I
1180 REM SORT % FREQ. IN DESCENDING ORDER
1190 FLIP:0
1200 WHILE FLIP
1210 FLIP:0
1220 FOR I=1 TO C(E)-1
1230 IF G(E,I)<G(E,I+1) THEN SWAP G(E,I),G(E,I+1);SWAP X(K,I),X(K,Is1);FLIP:1
1240 NEXT I
1250 WEND
1260 NEXT E
1270 REM **** GET HIGHEST VALUE OF ALL
1280 FOR E=1 TO H:A(E)=G(E,1):NEXT E
1290 FLIP=1
1300 WHILE FLIP
1310 FLIP=0
1320 FOR J=1 TO H-1
1330 IF A(J) < A(J+1) THEN SWAP A(J),A(J+1);FLIP=1
1340 NEXT J
1350 WEND
1360 U=L1+(L2-L1)/2
1370 CHANGE=0
1380 FOR E=1 TO H:IF Z2(E,C(E))-U>35 THEN CHANGE=1:NEXT E
1385 IF CHANGE=0 THEN 1370 ELSE 1367
1367 LPRINT "X axis - MID PTS. (from ";U;") SCALE 1:1":GOTO 1380
1370 LPRINT "Y axis - MID PTS. (from ";U;") SCALE 1:2"
1380 LPRINT "Y axis - % FREQ. (from 0 to ";INT(A(1));" ) SCALE 1:"
1390 LPRINT
1400 REM **** PLOT THE GRAPH
1410 FOR E=1 TO H
1420 M=INT(G(E,1))+1
1430 LPRINT CHR$(27);"3";CHR$(20);
1450 LP=0
1460 IF INT(A(1))+1=M THEN 1490 ELSE 1470
1470 FOR J=1 TO INT(A(1))+1-M
1480 LPRINT CHR$(27);"f";CHR$(0);CHR$(5);"+":NEXT J
1490 FOR I=1 TO C(E)
1500 IF I=1 THEN 1520
1510 IF M-INT(G(E,I))-LP-1 <0 THEN LPRINT :REM FORCE A CR/LF
1520 IF M-INT(G(E,I))-LP-1 =0 THEN 1520
1530 IF M-INT(G(E,I))-LP-1 =-1 THEN 1540 ELSE GOTO 1590
1540 LPRINT CHR$(27);"3";CHR$(20);
1550 IF LX+1 >7 THEN GOTO 1560 ELSE 1580
1580 LPRINT
Ford-Walshford plot

10 REM **** FORD.BAS
20 REM **** PROGRAMMED BY RABTEA GODDTOLLBAR - BOP, COLOMBO-SRI LANKA - AUG-85
30 REM # WOLFWALD PLOT
40 REM # LAST UPDATE 25/08/86
50 REM
60 REM ************************************************************
70 REM 
80 REM ** (Lt+dt)"D=a+b (Lt)"D
90 REM ** where b=(x*y-x^2/n)/(x^2-(x)^2/n) ** a denotes summation
100 REM ** a=x*y/n - b=x/n
110 REM ** r = corrr.eff (emp. =Sxy/SQ.RT(SxSxSy))
120 REM ** r = (x*y-x^2/n)/SQ.RT((x^2-(x)^2/n) (y^2-(y)^2/n))
130 REM ** L(x/a-(1-b))^1/D & L=[(1-b)/D]
140 REM ** Since both L & L+dt are measured with the same error, geometric mean
150 REM ** or type II regression is used here.
160 REM ** b=a+b/a a=a/n - b=a/n
170 REM ** This program is written using Microsoft version 2.23b - with MBASIC
180 REM ** for APPLE Ile micro computer with Softcard CP/M
190 REM ************************************************************
200 OSUB 400:REM INITIALISATION
210 OSUB 900:REM INPUT DATA
220 OSUB 380:REM CALCULATE & PRINT RESULTS
210 GOSUB 840: REM TERMINATION
220 IF W$ = "Y" THEN 200
230 REM *************************************************************
240 REM ** INITIALIZATION ROUTINE **
250 HOME : TAB 25 : PRINT " FORD - WALFORD PLOT "
260 PRINT : PRINT TAB (25) " ******************
270 PRINT : PRINT : PRINT : PRINT : PRINT " IN THE CASE OF A SINGLE BROOD USER HAS ONLY TO ENTER THE VALUES OF LENGTHS FOR A SERIES OF AGES. THE COMPUTER WILL AUTOMATICALLY CREATE A TABLE WITH PAIRS OF CONSECUTIVE LENGTHS."
280 PRINT : PRINT " BUT FOR MULTIPLE BROODS USER MUST ENTER BOTH LT & LT+1 FIGURES. THE M Loo VALUES CALCULATED WILL BE THE MEAN FIGURES FOR THE DIFFERENT BROODS COMBINED."
290 PRINT : PRINT " Remember that in both cases the time difference between consecutive lengths must remain constant - either 1 year or 1 month."
300 PRINT : PRINT : PRINT " enter S for SINGLE BROODS" 
310 PRINT " M for MULTIPLE BROODS"
320 VTAB 19 : INPUT " M to return to main menu ", FS
330 IF FS = "M" THEN GOTO 870
340 IF LEN (FS) = 0 THEN 320
350 IF FS = "S" THEN 360 ELSE IF FS = "M" THEN 360 ELSE GOTO 320
360 HOME : RETURN
370 REM *************************************************************
380 REM ** CALCULATE & PRINT RESULTS **
390 PRINT : INPUT " enter surface factor D (0-1) ", D
400 IF D > 1 THEN 390 ELSE IF D < 1 THEN 390 ELSE 410
410 PRINT : PRINT : PRINT " READY THE PRINTER & PRESS RETURN ", R
420 PRINT : INPUT : PRINT " PRINTER & PRESS RETURN ", R
430 LPRINT FORD - WALFORD PLOT"
440 LPRINT " "
450 LPRINT " "
460 LPRINT DBS$ : LPRINT
470 LPRINT "SURFACE FACTOR D : ": D : LPRINT
480 LPRINT " (L" ; CHR$(27) ; "S" ; CHR$(1) ; "; " ; CHR$(27) ; "; " ; " ) ; "
490 LPRINT CHR$(27) ; "S" ; CHR$(27) ; "; D" ; CHR$(27) ; "; T" ; 
500 LPRINT TAB (38) ; " (L" ; CHR$(27) ; "; S" ; CHR$(1) ; "; T+1" ; CHR$(27) ; "; T" ; " ) ; 
510 LPRINT CHR$(27) ; "S" ; CHR$(27) ; "D" ; CHR$(27) ; "T" 
520 LPRINT " ----" ; TAB (30) ; "------- 
530 FOR K = 1 TO I
540 LPRINT X ( K ) ; "D" ; TAB (30) ; Y ( K ) ; 
550 NEXT K
560 LX = 0 : YT = 0 : XX = 0 : YY = 0 : XT = 0 : YT = 0
570 REM ** LINEAR REGRESSION ROUTINE **
580 FOR K = 1 TO I
590 XX = XX + X ( K ) ; YT = YT + Y ( K ) ; D = D + 1 ; XX2 = XX2 + (X ( K ) ; D) ; YY2 = YY2 + (Y ( K ) ; D) ; 2 ; YY = YY + (Y ( K ) ; D) ; 2
600 NEXT K
610 B1 = YT / (XX * YY / D)
620 B2 = XX - (XX * XX) / D
630 B3 = YY - (YY * YY) / D
640 B4 = (B2 * B3) / 5
650 B = B1 / B4
660 B = B1 / B2
670 BB = B / E : REM *** GEOMETRIC MEAN OR TYPE II REGRESSION
680 AA = YY / (1 - BB * XX)
690 LPRINT
700 LPRINT "INTERCEPT a = " ; AA
710 LPRINT "SLOPE b = " ; BB
720 LPRINT "CORRELATION COEFFICIENT r = " ; R
730 LL = (AA / (1 - BB)) ^ (1 / D)
740 EE = (LOG (BB)) / D
750 LPRINT : LPRINT
760 LPRINT "L" ; CHR$(27) ; "S" ; CHR$(1) ; "00" ; CHR$(27) ; "T" ; "; ": ; LL
770 LPRINT "K = ";K
780 PRINT "Loo = ";L
790 PRINT "X = ";X
800 LPRINT
810 LPRINT
820 RETURN
830 REM #####################################################################
840 REM TERMINATION
850 HOME:PRINT:INPUT "RESUM WITH DIFFERENT D VALUES (Y/N) ",W$;
860 IF W$="Y" THEN 880 ELSE IF W$="N" THEN 870 ELSE 850
870 CLOSE:BUN"MNU.BAS"
880 RETURN
890 REM #####################################################################
900 REM INPUT DATA ROUTINE
910 IF P$="S" THEN 920 ELSE 950
920 VTAB 1:INPUT "NO. OF AGE CLASSES? ",J
930 IF J=1 OR J=0 THEN 920
940 I=J+1:GOTO 970
950 VTAB 1:INPUT "NO. OF PAIRS OF CONSECUTIVE LENGTHS? ",I
960 IF I=0 THEN 950
970 OPTION BASE 1
980 DIM X(I+1),Y(I)
990 VTAB 3:PRINT "L";TAB(10);"L(L)";TAB(30);"L(L+1)"
1000 FOR K=1 TO I
1010 VTAB 4:PRINT K;TAB(10);
1020 INPUT X(K)
1030 IF P$="M" THEN 1040 ELSE 1050
1040 VTAB 4:HTAB 30:INPUT Y(K)
1050 NEXT K
1060 IF P$="S" THEN 1070 ELSE 1110
1070 HTAB 10:INPUT X(I+1)
1080 FOR K=1 TO I
1090 VTAB 4:HTAB 30:Y(K)=X(K+1):PRINT Y(K)
1100 NEXT K
1110 RETURN
1120 REM #####################################################################

Culland & Holt plot

10 REM ### HOLT.BAS
20 REM ### PROGRAMMED BY HAZTRA GOONATTERA - 80BP,COLOMBO-SRI LANKA.-AUG-86
30 REM # GULLAND & HOLT PLOT
40 REM # LAST UPDATE 25/08/86
50 REM #####################################################################
60 REM # (L2-D-L1)/[(L2-L1)-a+b(L1*D+L2*D)/2]
70 REM # where b=(axy-axy/n)/[(ax)2-(ax)2/n]  ii & denotes summation
80 REM # a-axy/n - b.ax/n
90 REM # r (abs.corrCoeff).emp. =Sxy/SQ.ET(SxxSyy)
100 REM # r=[axy-axy/n]/SQU.ET[(ax)2-(ax)2/n][(axy)2-(axy)2/n]
110 REM # Loc=(a/bD)"(1/D) & k=-b/D
120 REM # This program is written using Microsoft version 2.23b - with MBASIC
130 REM # for APPLE Ile micro computer with Softcard CP/M
140 REM #####################################################################
150 GOSUB 700:REM INITIALISE & INPUT DATA
160 GOSUB 200:REM CALCULATE & PRINT RESULTS
170 GOSUB 640:REM TERMINATION
180 IF W$='Y' THEN 160
190 REM
200 REM* CALCULATE & PRINT RESULTS
210 PRINT:INPUT "enter surface factor D (0-1) ";D
220 IF D<0 THEN 210 ELSE IF D>1 THEN 210 ELSE 230
230 PRINT:INPUT "READY THE PRINTER & PRESS RETURN ";E1
240 LPRINT "GULLAND & HOLT PLOT"
250 LPRINT "" **--------------------------**
260 LPRINT **--------------------------**
270 LPRINT **--------------------------**
280 LPRINT DES$:LPRINT
290 LPRINT "SURFACE FACTOR D: ";D:LPRINT
300 LPRINT "L:CHR$(27);"$";CHR$(11);"$";CHR$(27);"T";TAB(24);"L":CHR$(27);"S":CHR$(41);"2":CHR$(27);"T";TAB(38);"L":CHR$(27);"S":CHR$(41);"2":CHR$(27);"T";TAB(27);"S":CHR$(11);"T";CHR$(27);"T";CHR$(27);"T";CHR$(27);"T";CHR$(27);"T";CHR$(27);"T";CHR$(27);"T";CHR$(27);"T"
310 LPRINT "---";TAB(20);"---";TAB(30);"-----";TAB(42);"-";TAB(52);"---"
320 FOR K=1 TO I
330 X(K)=L1(K)'D+L1(K)'D)/I
340 Y(K)=L2(K)'D-L1(K)'D)/I
350 LPRINT L1(K);TAB(20);L2(K);TAB(30);T(K);TAB(40);E(K);TAB(50);Y(K)
360 NEXT K
370 XX=0:YY=0:XX2=0:YY2=0
380 REM* LINEAR REGRESSION ROUTINE
390 FOR K=1 TO I
400 XX=XX+X(K):YY=YY+Y(K):XY=XY+X(K)*Y(K):XX2=XX2+X(K)'2:YY2=YY2+Y(K)'2
410 NEXT K
420 B1=XY-((XX*YY)/I)
430 B2=XX-((XX'2)/I)
440 B3=YY-((YY'2)/I)
450 B4=(B2*B3)'5
460 B=B1/B4
470 B=B1/B2
480 A=YY/I-[(B*XY)/I]
490 LPRINT
500 LPRINT "INTERCEPT a =";A
510 LPRINT "SLOPE b =";B
520 LPRINT "CORRELATION COEFFICIENT r =";R
530 R=E-D/B
540 LL=[A/[(E+D)]'1/2
550 LPRINT:LPRINT
560 LPRINT "L:CHR$(27);"$";CHR$(41);"00";CHR$(27);"T";" = ";LL
570 LPRINT "E = ";E
580 PRINT "Loo = ";LL
590 PRINT "K = ";K
600 LPRINT "" **------------------------------------------**
610 LPRINT
620 RETURN
630 REM**---------------------------------------------------------------------**
640 REM* TERMINATION
650 HOME:PRINT:INPUT "RERUN WITH DIFFERENT D VALUES (Y/N) ";W$
660 IF W$='Y' THEN 680 ELSE IF W$='N' THEN 670 ELSE 650
670 CLOSE:RUN "MENU.BAS"
680 RETURN
690 REM**---------------------------------------------------------------------**
700 REM* INITIALISATION & INPUT DATA ROUTINE
710 HOME:HTAB 25:PRINT " GULLAND & HOLT PLOT"
720 PRINT:PRINT TAB(25);"-------------------------
730 VTAB 4:INPUT "NO. OF PAIRS OF L1,L2 ? ";I
740 IF I=0 THEN 720

30
Von Bertalanffy plot

10 REM **** VON.BAS
20 REM *** PROGRAMMED BY HARBTRA GOOMETILLERA - GOSBP, COLOMBO-SRI LANKA - AUG-86
30 REM + VON BERTALANFFY PLOT
40 REM + LAST UPDATE 26/08/86
50 REM ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
60 REM ++ LOG (1-(LTL/Lo)"D):EDto-KDt
70 REM ++ where b:[alx-axay/n]/[ax'2-(alx)'2/n] | & denotes summation
80 REM ++ a=ay/n - b.ax/n
90 REM ++ r (abs.corr.coeff.)=Sxy/SQ.RT(SxxSyy)
100 REM ++ r =([alx-axay/n]/SQ.RT([ax'2-(alx)'2/n][ay'2-(alx)'2/n])
110 REM ++ K=b/D & to=-a/b
120 REM ++ This program is written using Microsoft version 2.23b - with MBASIC
130 REM ++ for APPLE lile micro computer with Softcard CP/M
140 REM ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
150 GOSUB 7150:REM INITIALISATION & INPUT DATA
160 GOSUB 200:REM CALCULATE & PRINT RESULTS
170 GOSUB 640:REM TERMINATION
180 IF $="Y" THEN 160
190 REM ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
200 REM + CALCULATE & PRINT RESULTS
210 PRINT "enter surface factor D (0-l( ;D"
220 IF D>1 THEN 210 ELSE IF D<0 THEN 210 ELSE 230
230 PRINT:INPUT "ENTER Loo ";LL
240 PRINT LINE INPUT "ENTER DESCRIPTION (including species,source etc.):";DES$
250 PRINT:INPUT "READY THE PRINTER & PRESS RETURN ";RI
260 LPRINT
270 LPRINT
280 LPRINT
290 LPRINT DES$:LPRINT
300 LPRINT "SURFACE FACTOR D = ";D:LPRINT:LPRI
310 LPRINT "CHS#(27);"S":CHS#(1);"D0":CHS#(27);"T":=":LL:LPRINT
320 LPRINT "T":TAB(15);"L":CHS#(27);"S":CHS#(1);"L":CHS#(27);"T":TAB(38);"Y"
330 LPRINT "":"-":TAB(15);"-":TAB(34);"-"
340 FOR K=1 TO [340 Y(K)=LOG(1-(L(K)/LL))
350 LPRINT X(K);TAB(13);L(K);TAB(30);Y(K)
360 NEXT K
370 XX=0:YY=0:XX2=0:YY2=0
380 REM + LINEAR REGRESSION ROUTINE
390 FOR K=1 TO [400 XX=XX+X(K):YY=YY+Y(K):XX2=XX2+X(K)^2:YY2=YY2+Y(K)^2
410 NEXT K
420 B1=XY-(XX*YY/1)
430 B2=XX2-((XX^2)/11)
Jones & Von Zalinge method

10 REM **** JONES, BAS
20 REM *** PROGRAMMED BY HASITHA GOONSTILLERE - BOSP, COLOMBO-SRI LANKA - AUG. 86
30 REM ** THE CUMULATED CATCH CURVE BASED ON LENGTH COMPOSITION DATA.
40 REM ** JONES & VAN ZALINGE METHOD FOR CALCULATING TOTAL MORTALITY
50 REM ** LAST UPDATE 05/09/86
60 REM ##########################################################################
70 REM LOGC(L,Loo) = a + (Z*OD) + LOG(Loo) - L/D
80 REM \[ where b = \sqrt{\frac{\sum(xy-\bar{x}\bar{y})}{n}} \] \[ \bar{x} \text{ and } \bar{y} \text{ denote summation} \]
90 REM \[ a = \bar{y}/n - b \bar{x}/n \]
100 REM \[ r = \frac{\text{abs.corr.coeff.}}{\text{emp.}} = \frac{\sum Sx \sqrt{Sx} \sqrt{Sy}}{\sum Sx \sqrt{Sx} \sqrt{Sy}} \]
110 REM \[ r^2 = \frac{\sum (xy-\bar{x}\bar{y})^2/n}{\sum (\bar{x} - (\bar{x})^2/n)} \]
120 REM \[ z = b \cdot r \]
130 REM ** This programme will estimate total mortality rate Z.
This program is written using Microsoft version 2.23b - with MBASIC

For APPLE IIe micro computer with Softcard CP/M

This program is written using Microsoft version 2.23b - with HEASIC

for APPLE II micro computer with Softcard CP/M

This program is written using Microsoft version 2.23b - with CP/M

This program is written using Microsoft version 2.23b - with CP/M

This program is written using Microsoft version 2.23b - with CP/M

This program is written using Microsoft version 2.23b - with CP/M
730 NEXT 1
740 LPRINT: LPRINT: LPRINT
750 REM #### PLOT GRAPH ON SCREEN
760 HOME
770 IF CINT(Z(K,1)*20~80) THEN 780 ELSE 790
780 SS:10:GOTO 800:REM X AXIS SAME SCALE
790 SS:20:REM X AXIS SCALE *2
800 FOR 1=1 TO C(K)
810 IF CINT(Y(K,1)*2)<0 OR CINT(Y(K,1)*2)+1-CINT(Y(K,1)*2)>24 OR CINT(Z(K,1)*SS)<0 OR CINT(Z(K,1)*SS)>80
820 THEN 830 ELSE GOTO 820
830 XX=XX+Z(K,1):YY=YY+Y(K,1):XY=XY+Z(K,1)*Y(K,1):XX2=XX2+Z(K,1)*2:YY2=YY2+Y(K,1)*2
840 FOR I=1 TO 5000
850 REM DELAY FOR VIEWING GRAPH
860 NEXT I
870 INPUT 'IF YOU WISH TO DISPLAY THE ABOVE SCATTERGRAM ON THE SCREEN AGAIN ENTER Y ELSE PRESS RETURN ";AA$'
880 IF AA$="Y" THEN 750 ELSE 890
890 PRINT: PRINT 'PLEASE DRAW A SCATTERGRAM WITH THE PRINTED VALUES'
900 PRINT "THEN SELECT POINTS BELONGING TO THE STRAIGHT SEGMENT OF THE PLOT"
910 PRINT: PRINT: PRINT
920 REM ~25*5 REGRESSION CALCULATION ROUTINE
930 PRINT "ENTER THE STARTING & ENDING NUMBER OF THE POINTS SELECTED FOR REGRESSION"
940 PRINT: INPUT "STARTING NO.";S1
950 IF S1<0 OR S1>C(K) THEN 940
960 PRINT: INPUT "ENDING NO.";S2
970 IF S2<0 OR S2>C(K) THEN 960
980 IF S2-S1 THEN PRINT "ERROR - ENTER AGAIN ":GOTO 940
990 IF S2-S1 THEN PRINT "ERROR - ENTER AGAIN ":GOTO 940
1000 LPRINT "SAMPLE ",K
1010 LPRINT " L",CHR$(27);"S",CHR$(1);"T",CHR$(27);"T","",CHR$(27);"T","",CHR$(27);"T","",CHR$(27);"T","",CHR$(27);"T","slope Z"
1020 LPRINT " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " 

PROGRAMMED BY HAEZTRA GOINETILLEKE - BOBP, COLOMBO - SRI LANKA - SEP. 86

THE CATCH CURVE BASED ON LENGTH COMPOSITION DATA.
SPARRE'S METHOD FOR CALCULATING TOTAL MORTALITY
LAST UPDATE 05/09/86
REM 60 SPARRE'S CATCH CURVE METHOD

50 REM
60 REM ** LOG(C(L1,L2)/dT) = -2(L1+L2)/2
70 REM ** where b:=(y-x^2y/n)/(kx^2-(kx)^2/n)  ## a denotes summation
80 REM ** a=(y/n - b.kx/n)
90 REM ** b=(abs.corr.coeff).emp. =Sxy/SQRT(SxxSyy)
100 REM ** r:=(y-x^2y/n)/SQUARERT((kx^2-(kx)^2/n))
110 REM ** for APPLE IIe micro computer with Softcard CP/M
120 REM
130 REM * This programme will estimate total mortality rate Z.
140 REM * This program is written using Microsoft version 2.23b - with M chaotic
150 REM * for APPLE IIe micro computer with Softcard CP/M
160 REM
170 GOSUB 250:REM INITIALISATION
180 GOSUB 1330:REM READ DATA FILE
190 FOR K=1 TO H
200 GOSUB 410:REM CALCULATE & PRINT RESULTS
210 NEXT K
220 GOSUB 1250:REM TERMINATION
230 IF $="Y" THEN GOSUB 910
240 GOTO 220
250 REM
260 REM ** initialise ROUTINE
270 HOME :HTAB 15:PRINT "SPARRE'S CATCH CURVE METHOD"
280 PRINT:PRINT TAB(15)"*" **********
290 VTAB 10:PRINT "Enter / to return to main menu"
300 VTAB 7:INPUT "ENTER FILE NAME(maximum 8 characters ) : ",FS$;
310 IF FS$=""/" THEN GOTO 1300
320 IF LEN(F$):0 THEN 300
330 VTAB 10:PRINT "*
340 VTAB 12:INPUT "ENTER LL ";LL
350 IF LL:0 THEN 340
360 VTAB 13:INPUT "ENTER K ";KK
370 IF KK:0 THEN 360
380 PRINT:PRINT "READY THE PRINTER & PRESS RETURN TO PROCEED ",0$;
390 RETURN
400 REM
410 REM * calculate & print results
420 LPRINT "SPARRE'S CATCH CURVE METHOD"
430 LPRINT "*" **********
440 LPRINT
450 LPRINT "FILE NAME :- ",FS$;LPRINT
460 LPRINT $;
470 LPRINT "L";CHR$(27);"S";CHR$(1);"00";CHR$(27);"T";"=";"LL;LPRINT "K = ";KK
480 LPRINT: LPRINT
490 HOME :PRINT "SAMPLE ";X;LPRINT "SAMPLE ";X;PRINT
500 PRINT: LPRINT: LPRINT
510 XX=0;YY=0;XXZ=0;YYZ=0;TT=0;TN=0
520 FOR I=1 TO C(X)
530 K(K,1)=X(K, 1)-D/2
540 IF LL<X(K,1) OR LL<X(K,1)+D THEN Y(K,1)=0:GOTO 570
550 Y(K,1)=(1/KK)*LOG(LL-L1(K,1))/((LL-L1(K,1)-D))/
560 REM * DELTA T
570 IF X(K,1)/LL >1 THEN Z(K,1)=0:GOTO 590
580 Z(K,1)=-(1/KK)*LOG((X(K,1)/LL)/(X(K,1)-D))
590 REM * DELTA T
600 IF X(K,1)/LL >1 THEN Z(K,1)=0:GOTO 590
610 PRINT "L";CHR$(27);"S";CHR$(1);"T";CHR$(27);"T";CHR$(27);"T";CHR$(27);"T";
620 LPRINT "C";CHR$(27);"S";CHR$(1);"T";CHR$(27);"T";
630 LPRINT "D";CHR$(27);"S";CHR$(1);"T";CHR$(27);"T";
640 LPRINT "L(L";CHR$(27);"S";CHR$(1);"I";CHR$(27);"T";"4L";CHR$(27);"S";CHR$(1);"L";CHR$(27);"T";
"1/21) :L=CHR$(27);"S";CHR$(1);"I";CHR$(27);"T";
650 LPRINT "L(L";CHR$(27);"S";CHR$(1);"I";CHR$(27);"T";"4L";CHR$(27);"S";CHR$(1);"L";CHR$(27);"T";
660 LPRINT "-----";TAB(16);"-----";TAB(29);"-----";TAB(39);"-----";TAB(54);"-----"
670 FOR I=1 TO C(K)
680 IF LL<LI(K,I) OR LL<LI(K,I)+D OR X(K,I)/LL >1 THEN 690 ELSE 700
690 LPRINT L(K,I);TAB(7);"-";LI(K,I)+D;TAB(16);F(K,I);TAB(28);"-";TAB(42);"-";TAB(56);"-";GOTO 720
700 LPRINT L(K,I);TAB(7);"-";LI(K,I)+D;TAB(16);F(K,I);TAB(28);Y(K,I);TAB(42);Z(K,I);TAB(54);LOG(F(K,I)/Y(K,I))
710 Y(K,I)=LOG(F(K,I)/Y(K,I));REM * Y AXIS
720 NEXT I
730 REM *** PLOT GRAPH ON SCREEN
740 HOME
750 IF CINT(Z(K,I)*2O)>80 THEN 760 ELSE 770
760 SS:10:GOTO 780:REM X AXIS SAME SCALE
770 SS:20:REM X AXIS SCALE *2
780 FOR I=1 TO C(K)
790 IF CINT(Y(K,I)*2)<0 OR CINT(Y(K,I)*2)>24 OR CINT(Z(K,I)*SS)<0 OR CINT(Z(K,I)*SS)>80 THEN 810 ELSE 820
800 V TAB 24-CINT(Y(K,I)*2);PRINT TAB(CINT(Z(K,I)*SS)) '*';I
810 NEXT I
820 LPRINT
830 FOR TTI = 1 TO 5000
840 REM DELAY FOR VIEWING GRAPH
850 NEXT TTI
860 INPUT "IF YOU WISH TO DISPLAY THE ABOVE SCATTERGRAM ON THE SCREEN AGAIN ENTER Y ELSE PRESS RETURN ";AA$
870 IF AA$="Y" THEN 730 ELSE 880
880 PRINT:PRINT "PLEASE DRAW A SCATTERGRAM WITH THE PRINTED VALUES"
890 PRINT "THEN SELECT POINTS BELONGING TO THE STRAIGHT SEGMENT OF THE PLOT"
900 PRINT:PRINT
910 REM **** REGRESSION CALCULATION ROUTINE
920 PRINT "ENTER THE STARTING & ENDING NUMBER OF THE POINTS SELECTED FOR REGRESSION"
930 PRINT:INPUT "STARTING NO.";S1
940 IF S1=0 OR S1>C(K) THEN 930
950 PRINT:INPUT "ENDING NO.";S2
960 IF S2=0 OR S2>C(K) THEN 950
970 IF S1=S2 THEN PRINT "ERROR -ENTER AGAIN ";GOTO 930
980 IF S2-S1<2 THEN PRINT "ERROR -ENTER AGAIN ";GOTO 930
990 LPRINT "SAMPLE ",K
1000 LPRINT "L";CHR$(27);"S";CHR$(1);"I";CHR$(27);"T";"L";CHR$(27);"S";CHR$(1);"Z";CHR$(27);"T";
"-" 0 N Sb";CHR$(27);"S";CHR$(0);"Z";CHR$(27);"T";"CONFIDENCE LIMITS OF R"
1010 LPRINT "-----";TAB(20);"-----";TAB(34);"-----";TAB(40);"-----";TAB(52);"-----"
1020 FOR I=S1 TO S1+1
1040 LPRINT L(K,I);TAB(7);"-";LI(K,I)+D;TAB(20);"-";TAB(34);TN;TAB(41);"-";TAB(64);"-";
1050 NEXT I
1060 FOR I=S1+2 TO S2
1080 B1:Y(-XX*YY/TN)
1090 B2:XX2-((XX*2)/TN)
1100 B=BB/B2-B
1110 N=Y/7N-(B**X/TN)
1120 B3=Y2-((Y**2)/7N)
1130 B4=(B2+B3)^2.5
1140 R=BI/B4
1150 SB2=(SB2*B2-2)/7N
1160 IF SB2=0 THEN REM AVOID NEGATIVE VALUES BEFORE FINDING THE ROOT
1170 SB2=SQR(SB2)
1180 GOSUS 1490
1190 LPRINT L(K,I);TAB(7);"-";LI(K,I)+D;TAB(20);B;TAB(34);TN;TAB(38);SB2;TAB(48);B;"-";CONFG;SB;TAB(68);"-";B-CONFG;SB
1200 UPRINT TAB(48);"+";CONF;"+";TAB(68);"+";CONF;"+"
1210 NEXT I
1220 UPRINT
1230 LPRINT
1240 RETURN
1250 REM ###################################################################
1260 REM TERMINATION
1270 GOTO:PRINT:INPUT "REBURN WITH DIFFERENT STARTING & ENDING POINTS(Y/N) ",W$ 
1280 IF W$="Y" THEN 1290 ELSE IF W$="N" THEN 1300 ELSE 1270
1290 INPUT "SAMPLE NO.",X:IF X=0 OR X=1 THEN 1290 ELSE 1310
1300 CLOSE:RUN"MRU.BAS"
1310 RETURN
1320 REM ###################################################################
1330 REM READ DATA FROM DISK
1340 OPEN "I",1,F$
1350 OPTION BASE 1
1360 LINE INPUT #1,D$
1370 INPUT #1,H,C,L1,L2
1380 D=L2-L1
1390 DIM X(H,C),F(H,C),C(H),W(H),L1(H,C),Y(H,C),Z(H,C)
1400 FOR K=1 TO H
1410 INPUT #1,M(K),C(K)
1420 FOR J=1 TO C(K)
1430 INPUT #1,X(K,J),F(K,J)
1440 NEXT J
1450 NEXT K
1460 CLOSE #1
1470 RETURN
1480 REM ###################################################################
1490 REM CONFIDENCE LIMITS ROUTINE
1500 IF TN-Z 1): 30 THEN 1530 ELSE IF TN-2 (40 THEN 1570 ELSE IF TN-2 i0 THEN 1580
1510 IF TN-2 (80 THEN 1590 ELSE IF TN=2 (100 THEN 1600
1520 IF TN=2 (120 THEN 1610 ELSE IF TN=2:120 THEN 1620 ELSE 1630
1530 RESTORE
1540 FOR CC=1 TO 30:READ CONF,00NF1
1550 IF CONF=TN-2 THEN CC=30
1560 NEXT CC:GOTO 1650
1570 RESTORE 1650:GOTO 1640
1580 RESTORE 1700:GOTO 1640
1590 RESTORE 1710:GOTO 1640
1600 RESTORE 1720:GOTO 1640
1610 RESTORE 1730 :GOTO 1640
1620 RESTORE 1740:GOTO 1640
1630 RESTORE 1750
1640 READ CONF,CONF1
1650 RETURN
1660 DATA 1,1.206,2,1.903,3,1.003,4,1.182,5,1.776,6,2.571,7,2.447,8,2.355,9,2.262,10,2.224
1670 DATA 11,2.201,12,2.179,13,2.160,14,2.145,15,2.131,16,2.126,17,2.110,18,2.101,19,2.093,20,2.086
1680 DATA 21,2.081,22,2.074,23,2.069,24,2.064,25,2.060,26,2.056,27,2.052,28,2.048,29,2.045
1690 DATA 30,2.042
1700 DATA 40,2.021
1710 DATA 50,2.000
1720 DATA 60,1.99
1730 DATA 70,1.98
1740 DATA 90,1.98
1750 DATA 9999,1.060
1760 DATA 100,1.069
1770 DATA 120,1.080
Wetheral et al. method

10 REM **** WET.BAS
20 REM *** PROGRAMMED BY HAZZREA GOONETHILLEKERE - BGFPE, COLOMBO-SRI LANKA - SLP - 86
30 REM * WETHERAL ET AL METHOD FOR ESTIMATING \( l_0 \) & \( Z/K \)
40 REM * LAST UPDATE 16/03/86
50 REM******************************************************************************
60 REM \( Y = l_0 \left[ (l + Z/K) + Z(2/Z) / (l + Z/K) \right] \)
70 REM \( y = a + xb \)
80 REM where \( b = \frac{\sum (x_i - \overline{x})(y_i - \overline{y})}{\sum (x_i - \overline{x})^2} \)
90 REM \( a = \overline{y} - b \overline{x} \)
100 REM \( r = \frac{s_{xy}}{s_x s_y} \)
110 REM \( s_{xy} = \sqrt{\sum (x_i - \overline{x})^2 \sum (y_i - \overline{y})^2} \)
120 REM \( y \) AXIS = MEAN LENGTH
130 REM \( x \) AXIS = LOWER LIMIT OR CUT-OFF PTS.
140 REM \( Z/K = \frac{b}{l - b} \) and \( l_0 = \frac{a}{l - b} \)
150 REM This programme will estimate total mortality rate \( Z \) and \( l_0 \).
160 REM This program is written using Microsoft version 2.23b - with MBASIC
170 REM for APPLE IIe micro computer with Softcard CP/M
180 REM******************************************************************************
190 280:REM INITIALISATION
200 1240:REM READ DATA FILE
210 FOR \( K = 1 \) TO \( H \)
220 410:REM CALCULATE & PRINT RESULTS
230 NEXT \( K \)
240 1170:REM TERMINATION
250 IF \( W\$ = "Y" \) THEN 820:REM REGRESSION CALCULATION ROUTINE
260 240 GOTO 40
270 REM******************************************************************************
280 240 REM ** INITIALISATION ROUTINE
290 230 HOME :HTAB 15:PRINT "WETHERAL et al METHOD"
300 PRINT:PRINT TAB(15)***
310 190:REM INITIALISATION ROUTINE
320 200:REM READ DATA FILE
330 FOR \( X = 1 \) TO \( N \)
340 210 FOR \( K = 1 \) TO \( C(K) \)
350 \( Y = Y + X(K) \)
360 \( T = T + F(K) \)
370 NEXT \( I \)
380 END

39
REM = I V AXIS : MEAN LENGTH
81 = (1) / 76
82 = (1) / 25
90 A:YY:IN-1B=XX/N
101 = 03:71:2 - (0Y"2) / TN)
1011 = (B2*b3) .5
1720 R:E1/B4
[1]30
1868
1070 IF KE=0 THEN LPRINT "ERROR - ENTER AGAIN " : GOTO 1060
1080 Z=KE*B/(1-B)
1090 LPRINT "correlation coefficient = " : R
1080 LPRINT "slope = " : E
1080 LPRINT "intercept = " : A
1080 LPRINT
1100 LPRINT "ASYMPTOTIC LENGTH L" :CHR$(27);"S";CHR$(1);"<">";CHR$(27);"T";"=" ; "LL
1110 IF KE=0 THEN LPRINT "Z/E=" ; Z:GOTO 1100
REM READ DATA FROM DISK
OPEN 'I',I,F$
OPTION BASE I
LINE INPUT #1,D8
INPUT t1,HC,L1,L2
DATA 30,2.042
DATA 40,2.021
DATA 60,2.000
DATA 80,1.99
DATA 100,1.98
DATA 120,1.980
DATA 9999,1.960
LPRINT 'MORTALITY COEFFICIENT 7. :
LPRINT
RETURN
REM TERMINATION
HOME:PRINT:INPUT "RE-BRUN WITH DIFFERENT STARTING & ENDING POINTS [Y/N]", W$
IF W$='Y' THEN 1200 ELSE IF W$='N' THEN 1210 ELSE 1180
INPUT "SAMPLE NO.";K:IF K=0 OR K>1 THEN 1200 ELSE 1220
 RETURN
REM READ DATA FROM DISK
OPEN "I",I,F$
OPTION BASE 1
LINE INPUT #1,0$
INPUT #1,H,C,L1,L2
D=L2-L1
DIM X(H,C),F(H,C),C(H),M(H),L1(H,C),L2(H,C),Z(H,C)
FOR K=1 TO H
INPUT ~I,M(K),C(K)
FOR J=1 TO C(K)
INPUT #1,X(K,J),F(K,J)
NEXT 3
NEXT K
CLOSE #1
RETURN
REM CONFIDENCE LIMITS ROUTINE
IF TN-2 THEN 1440 ELSE IF TN-4 THEN 1480 ELSE IF TN-6 THEN 1490
IF TN-8 THEN 1500 ELSE IF TN-10 THEN 1510
IF TN-12 THEN 1520 ELSE IF TN-12 THEN 1530 ELSE 1540
RESTORE
FOR CC=1 TO 30:READ CONF,00NFI
NEXT CC:GOTO 1560
RESTORE 1600:GOTO 1560
RESTORE 1610:GOTO 1560
RESTORE 1620:GOTO 1560
RESTORE 1630:GOTO 1560
RESTORE 1640:GOTO 1560
RESTORE 1650:GOTO 1560
RESTORE 1660
READ CONFI,CONF1
DATA 1,12.706,2,4.303,3,3.182,4,2.776,5,2.571,6,2.365,7,2.160,8,1.945,9,1.732,10,1.521,11,1.318,12,1.117,13,0.918,14,0.729,15,0.542,16,0.363,17,0.194,18,0.124,19,0.064,20,0.014,21,0.003,22,0.001,23,0.000,24,0.000,25,0.000,26,0.000,27,0.000,28,0.000,29,0.000,30,0.000
RETRUN
Appendix 2a

PERCENTAGE POINTS OF THE $\chi^2$ DISTRIBUTION

For $v > 30$ take $\chi^2(v) = v \left[ 1 - \frac{2}{v} + u_\alpha \sqrt{\frac{2}{v}} \right]$, where $u_\alpha$ is such that $Pr(U > u_\alpha) = \alpha$, and $U \sim \mathcal{N}(0, 1)$.

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### PERCENTAGE POINTS OF THE t DISTRIBUTION

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Appendix 3

BHATTACHARYA ANALYSIS

Test Data

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File Name: Pauly

Test Data from Pauly & Caddy (1985) — Page 4

Input value of critical value of correlation coefficient == .997

SAMPLE 1

MONTH 1

Mid Pts. = 0.5 1.5 2.5
Abs. Corr. Coeff. = 0.998299
Group 1 Mean = 1.91649
Std. Dev. = 0.52736 No. of Items = 49.296

Mid Pts. = 3.5 4.5 5.5
Abs. Corr. Coeff. = 0.997593
Group 2 Mean = 5
Std. Dev. = 0.452461 No. of Items = 69.0703

Mid Pts. = 6.5 7.5 8.5
Abs. Corr. Coeff. = 0.994056

Mid Pts. = 7.5 8.5 9.5
Abs. Corr. Coeff. = 1
Group 3 Mean = 8.94487
Std. Dev. = 0.907667 No. of Items = 45.3859
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File Name: Pauly
Test Data from Pauly & Caddy (1985) — Page 4
Input value of critical value of correlation coefficient .904

SAMPLE 1

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Group 1 Mean 1.91649
Std. Dev. .52736 No. of Items 49.296
Group 2 Mean 5
Std. Dev. .452461 No. of Items 69.0703
Group 3 Mean 8.99782
Std. Dev. .998164 No. of Items 46.9219
Group 4 Mean 8.94487
Std. Dev. .907667 No. of Items 45.3859
Group 5 Mean 15.6365
Std. Dev. .95354 No. of Items 28.7834
## Appendix 4

### CHI SQUARE STATISTICS

File Name: Pauly

Test Data from Pauly & Caddy (1985) — Page 4

**SAMPLE 1**

**MONTH 1**

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### FREQUENCIES GROUPED INTO CLASSES WITH PREDICTED FREQUENCIES >5

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Chi Square Statistic=20.059

For 11 Classes and 2 D.F.
NAME: SARDINELLA
Data from Sanders (1984) - Page 155
X axis — MID PTS. (from 10.5) Scale 1: 2
V axis — % FREQ. (from 0 to 27) Scale 1: 1
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Mean: -15.5  Size: 25555
95% Conf. Limits: 15.5150  15.5410
99% Conf. Limits: 15.5110  15.5450

Mean: 19.7  Size: 8549
95% Conf. Limits: 19.6995  19.7385
99% Conf. Limits: 19.6934  19.7446
**SAMPLE 2, MONTH 2**

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Mean 15.3  Size 63780

95% Conf. Limits 15.2874  15.3086

99% Conf. Limits 15.2841  15.3119

Mean 19.5  Size 7590

95% Conf. Limits 19.4949  19.5431

99% Conf. Limits 19.4873  19.5507

[49]
Appendix 6

FORD – WALFORD PLOT

EXAMPLE FOR 5.2.4


Surface Factor D=1

\[
\begin{align*}
(L_t)^D & \quad (L_{t+1})^D \\
35 & \quad 55 \\
55 & \quad 75 \\
75 & \quad 90 \\
90 & \quad 105 \\
105 & \quad 115
\end{align*}
\]

Intercept \( a = 26.0522 \)

Slope \( b = 0.860387 \)

Correlation Coefficient \( r = 0.998122 \)

\( L_\infty = 186.602 \)

\( K = 0.150374 \)

Ford – Walford Plot

Hilsa Data – BOBP (1987), Page 74

Surface Factor D=1

\[
\begin{align*}
(L_t)^D & \quad (L_{t+1})^D \\
22.1 & \quad 40.7 \\
40.7 & \quad 49.9 \\
36.8 & \quad 47.2
\end{align*}
\]

Intercept \( a = 29.9267 \)

Slope \( b = 0.482129 \)

Correlation Coefficient \( r = 0.996006 \)

\( L_\infty = 57.7878 \)

\( K = 0.729544 \)
Appendix 7
GULLAND & WOLT PLOT
EXAMPLE FOR 5.2.5
Sparre — Page 78 (1985)
Surface Factor D = 1

<table>
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<th>Y</th>
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Intercept a = 22.3632
Slope b = -0.391623
Correlation Coefficient r = -0.999913
Lₘ = 57.104
k = 0.391623

Appendix 8
VON BERTALANFFY PLOT
EXAMPLE FOR 5.2.6
Sparre — Page 82 (1985)
Surface Factor D = 1
Lₘ = 50

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Intercept a = -0.0658255
Slope b = 0.78008
Correlation Coefficient r = 0.999126
t₀ = 0.084383
K = 0.78008

7 - A

[51]
Appendix 9

JONES & VAN ZALINGE METHOD

EXAMPLE FOR 6.2

File Name: Test data

Sparre-Page193 (1985)

$L_{\infty} = 23.1$

$K = 0.59$

$D = 1$

SAMPLE 1

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<th>$\ln (C(L_1, L_{\infty}))$</th>
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<td>7</td>
<td>0.0968</td>
</tr>
</tbody>
</table>

[52]
### Appendix 10

**SPARRE'S CATCH CURVE METHOD**

**EXAMPLE FOR 63**

File Name: Testdata

*Sparre* – Page 193 (1985)

$L_{\infty} = 23.1$

$K = .59$

**SAMPLE 1**

<table>
<thead>
<tr>
<th>$L_1$—$L_2$</th>
<th>$C(L_1, L_2)$</th>
<th>$D_t$</th>
<th>$t((L_1 + L_2)/2)$</th>
<th>$\ln(C(L_1, L_2)/D_t)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>6— 7</td>
<td>3</td>
<td>.102134</td>
<td>.560051</td>
<td>3.38008</td>
</tr>
<tr>
<td>7— 8</td>
<td>143</td>
<td>.108686</td>
<td>.665359</td>
<td>7.18214</td>
</tr>
<tr>
<td>8— 9</td>
<td>271</td>
<td>.116135</td>
<td>.777646</td>
<td>7.75512</td>
</tr>
<tr>
<td>9—10</td>
<td>318</td>
<td>.124682</td>
<td>.897903</td>
<td>7.84404</td>
</tr>
<tr>
<td>10—11</td>
<td>416</td>
<td>.134588</td>
<td>1.02735</td>
<td>8.03623</td>
</tr>
<tr>
<td>11—12</td>
<td>488</td>
<td>.146204</td>
<td>1.1675</td>
<td>8.11307</td>
</tr>
<tr>
<td>12—13</td>
<td>614</td>
<td>.160016</td>
<td>1.3203</td>
<td>8.25248</td>
</tr>
<tr>
<td>13—14</td>
<td>613</td>
<td>.176713</td>
<td>1.48825</td>
<td>8.15159</td>
</tr>
<tr>
<td>14—15</td>
<td>493</td>
<td>.197306</td>
<td>1.6747</td>
<td>7.82351</td>
</tr>
<tr>
<td>15—16</td>
<td>278</td>
<td>.223338</td>
<td>1.88421</td>
<td>7.12669</td>
</tr>
<tr>
<td>16—17</td>
<td>93</td>
<td>.257298</td>
<td>2.12333</td>
<td>5.89012</td>
</tr>
<tr>
<td>17—18</td>
<td>73</td>
<td>.303472</td>
<td>2.40181</td>
<td>5.48293</td>
</tr>
<tr>
<td>18—19</td>
<td>7</td>
<td>.369921</td>
<td>2.73521</td>
<td>2.94038</td>
</tr>
<tr>
<td>19—20</td>
<td>2</td>
<td>.473873</td>
<td>3.15068</td>
<td>1.43996</td>
</tr>
<tr>
<td>20—21</td>
<td>2</td>
<td>.66011</td>
<td>3.70224</td>
<td>1.1085</td>
</tr>
<tr>
<td>21—22</td>
<td>.01</td>
<td>1.09598</td>
<td>4.52513</td>
<td>-4.69682</td>
</tr>
<tr>
<td>22—23</td>
<td>1</td>
<td>4.06422</td>
<td>6.18756</td>
<td>-1.40222</td>
</tr>
<tr>
<td>23—24</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$L_1$—$L_2$</th>
<th>$Z$</th>
<th>$N$</th>
<th>$S_b^2$</th>
<th>Confidence Limits of $Z$</th>
</tr>
</thead>
<tbody>
<tr>
<td>13—14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14—15</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15—16</td>
<td>2.60359</td>
<td>3</td>
<td>.202594</td>
<td>2.60359−5.71903=−3.11544</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16—17</td>
<td>3.58035</td>
<td>4</td>
<td>.291922</td>
<td>3.58035−2.3249 = 1.25544</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17—18</td>
<td>3.19128</td>
<td>5</td>
<td>.121946</td>
<td>3.19128−1.11118 = 2.0801</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18—19</td>
<td>4.03499</td>
<td>6</td>
<td>.20921</td>
<td>4.03499−1.26973 = 2.76526</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19—20</td>
<td>4.19501</td>
<td>7</td>
<td>.09086</td>
<td>4.19501−7.74976 = 3.42003</td>
</tr>
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</table>

8 [53]
### Appendix 11

**WETHERALL ET AL METHOD**

**TEST DATA**

<table>
<thead>
<tr>
<th>Mid-Length</th>
<th>Frequency</th>
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</thead>
<tbody>
<tr>
<td>7.0</td>
<td>11.00</td>
</tr>
<tr>
<td>9.0</td>
<td>74.50</td>
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<td>11.0</td>
<td>81.33</td>
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<tr>
<td>13.0</td>
<td>40.33</td>
</tr>
<tr>
<td>15.0</td>
<td>36.92</td>
</tr>
<tr>
<td>17.0</td>
<td>86.08</td>
</tr>
<tr>
<td>19.0</td>
<td>108.33</td>
</tr>
<tr>
<td>21.0</td>
<td>93.75</td>
</tr>
<tr>
<td>23.0</td>
<td>83.33</td>
</tr>
<tr>
<td>25.0</td>
<td>88.83</td>
</tr>
<tr>
<td>27.0</td>
<td>81.25</td>
</tr>
<tr>
<td>29.0</td>
<td>62.58</td>
</tr>
<tr>
<td>31.0</td>
<td>30.00</td>
</tr>
<tr>
<td>33.0</td>
<td>12.91</td>
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<tr>
<td>35.0</td>
<td>3.66</td>
</tr>
<tr>
<td>37.0</td>
<td>1.00</td>
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<td>39.0</td>
<td>0.66</td>
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<tr>
<td>41.0</td>
<td>0.25</td>
</tr>
<tr>
<td>43.0</td>
<td>0.08</td>
</tr>
</tbody>
</table>

*File Name: Plota*

Test Data from Ng Fong Oon (1986) — Page 13
<table>
<thead>
<tr>
<th>Selection Length (X)</th>
<th>Mean Length (Y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>19.9792</td>
</tr>
<tr>
<td>8</td>
<td>20.1404</td>
</tr>
<tr>
<td>10</td>
<td>21.1634</td>
</tr>
<tr>
<td>12</td>
<td>22.2958</td>
</tr>
<tr>
<td>14</td>
<td>22.8394</td>
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<td>16</td>
<td>23.2828</td>
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<tr>
<td>18</td>
<td>24.2372</td>
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<td>20</td>
<td>25.4752</td>
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<tr>
<td>22</td>
<td>26.626</td>
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<td>24</td>
<td>27.7005</td>
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<tr>
<td>26</td>
<td>28.9473</td>
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<td>28</td>
<td>30.3709</td>
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<td>30</td>
<td>32.1374</td>
</tr>
<tr>
<td>32</td>
<td>33.9756</td>
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<td>34</td>
<td>36.2036</td>
</tr>
<tr>
<td>36</td>
<td>38.414</td>
</tr>
<tr>
<td>38</td>
<td>39.8379</td>
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<tr>
<td>40</td>
<td>41.4985</td>
</tr>
<tr>
<td>42</td>
<td>43</td>
</tr>
</tbody>
</table>

Sample 1

Points taken for regression 7 to 19
Correlation coefficient = .994904
Slope \( b = .812634 \)
Intercept \( a = 8.57666 \)
Asymptotic Length \( L_\infty = 45.775 \)
\[ Z/K = -4.33716 \]
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Working Papers (BOBP/ WP . . .)
49. Pen Culture of Shrimp by Fisherfolk: The BOBP Experience in Killai, Tamil Nadu, India.

   Madras, India, November 1986.


52. Experimental Culture of Seaweeds (Grallaria Sp.) in Penang, Malaysia.
   (Based on a report by Max welD Doty and Jack Fisher.) Madras, India, August 1987.


   Madras, India, January 1987.

55. Fishing Trials with Benchlanding Craft at Uppada, Andhra Pradesh, India. L. Nybørg.
   Madras, India, June 1987.

56. Identifying Extension Activities for Fisherwomen in Visakhapatnam District, Andhra Pradesh, India.

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4. Separating Mixtures of Normal Distributions: Basic Programs for Bhattacharya’s Method and Their
   Applications to Fish Population Analysis. H. Goonetilleke, K. Sivasubramaniam.
   Madras, India, November 1987.

   Madras, India, September 1987.

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2. Consultation on Social Feasibility of Coastal Aquaculture.


   Madras, India, November 1986.

Information Documents (BOBP/INF/...)

1. Women and Rural Development in the Bay of Bengal Region: Information Sources.
   Madras, India, February 1982.


9. Food and Nutrition Status of Small-Scale Fisherfolk in India’s East Coast States:

Newsletters (Bay of Bengal News) :


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