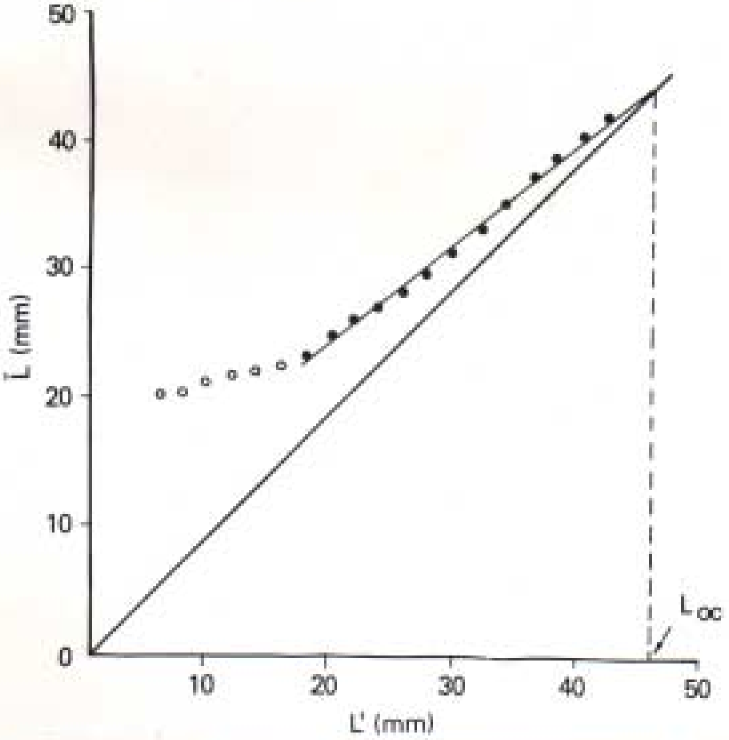
Separating mixtures of normal distributions: Basic programs for Bhattacharya's method and their applications to fish population analysis



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BAY OF BENGAL PROGRAMME

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Marine Fishery Resources Management

BOBP/MAG/4
(RAS/81/051)

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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This document and the programs have not been officially cleared by the governments concerned or by the FAO.

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CONTENTS

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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 Ile 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 "I" 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 eraseci".

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 **initia**lizing 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, quadrapled 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 mid-points 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

$$\ln (f_{i+1}/f_i) = a + bx_i$$

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 :

$$b = \frac{\sum xy - \sum x' \sum y/n}{\sum x^2 - (\sum x)^2/n}$$

$$a = \sum y/n - b \sum x/n$$

When the absolute correlation coefficient calculated according to the equation

$$r = \frac{\sum xy - \sum x' \sum y/n}{\sqrt{\sum x^2 - (\sum x)^2/n) (\sum y^2 - \sum y)^2/n}}$$

is higher than or equal to the input value of the critical correlation coefficient, the mean (μ), std. deviation (σ) and number of items in the component distributions (N) are calculated **using**

$$\mu = (0.5d) - (a/b)$$

$$\delta = \sqrt{(l/-b) - (d2/12)}$$

$$N = \frac{\delta}{d} \exp \left[\frac{\sum_{i=1}^{3} \ln (f_{i+1}/f_i)}{3} + \frac{\sum_{i=1}^{3} (x_i - \mu)^2}{6(\delta^2 + -(\delta^2/12))} + \frac{d^2}{24\delta^2} + \ln \sqrt{2\pi} \right]$$

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.

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

Choosa 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 δ, μ 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

$$\chi^2 = \Sigma \ (f_i - \hat{f}_i)^2 / \hat{f}_i$$

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

$$\hat{f}_i = \sum_{1}^{j} \frac{N_j \ d}{\delta_j \ \sqrt{2\pi}} \cdot \exp \ [-0.5 \ \{ (x_i - \bar{x}_j)/\delta_j \}^2]$$

where d = class interval width
xi = mid-point of class corresponding to frequency
xj = mean of jth component identified
= std, deviation of jth component identified
Nj == no. of items (size) in jth component identified

and i<j<6.

The predicted frequencies deducted from the raw frequencies provide the residual frequencies i.e. $R = f_i - \hat{f}_i$. 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 xi value are added up and the sum obtained is compared with the critical value in the X2 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).

Confidence limits-x $\pm$ t_{n-1}. s/vn.

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_∞ 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_∞ 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

$$L^D_{t+1} = a + b\, L^D_t$$

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

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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_∞ 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,

$$b' = b/r$$

$$a' = y - b'x$$

$$L_\infty[=a'/(1-b')]^{1/D}$$

$$K = -\ln b'/D$$

Fcr 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_∞ 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:

$$\frac{L^D_2 - L^D_1}{t_2 - t_1} = a - K D \left(\frac{L^D_1 + L^D_2}{2} \right)$$

where L1 and L2 are successive lengths corresponding to times t_1 and t_2. This gives:

$$K = -b/D$$

$$L_\infty = (a/KD)^{1/D}$$

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_∞ 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

$$L^D_t = L^D_\infty \left(1 - e^{-KD(t-t_o)} \right)$$

which can be rewritten in the form:

$$-\ln [1 - (L_t/L^D_\infty)] = -KDt_o + KD_t$$

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

$-\ln [1-(L_t/L_\infty)^D]$ as y axis.

If an estimate of L_∞ is available then

$$K = b/D$$

and $t_o = -a/b$

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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_∞ 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_∞ (Note that the method of Wetherall (see below) can be used to obtain estimate of L_∞)

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 petiod 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

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

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 Δt 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

$$Z = -\ln \left[\frac{{}_2N_{t+1} + {}_2N_{t+2} + ..}{{}_1N_{t+1} N_{t+1} + ...} \right]$$

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

$$Z = -\ln \frac{N_{t+1}}{N_t}$$

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 Zaiinge method

The inverse Von Bertalanffy equation

$$t(L) = t_0 - \frac{1}{K} : \quad \ln(1-L/L\infty)$$

and the cumulated catch curve equation lead to the Jones and van Zalinge equation (1981) :

$$\ln(C(L, L,)) = a + \frac{Z}{KD} \quad \ln(L_\infty^D - L^D)$$

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=Z/KD

Thus total mortality rate Z=b.K.D.

in practice, the relationship between In $(L^D_\infty - L^D)$ and in (C $(L, L\infty)$) 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,, 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_{n-2} values.

$$S_b^2 = \frac{1}{n-2} \left[(Sy / Sx)^2 - b^2\right]$$

$$\text{Confidence limit of } Z = \pm Z \quad KD \quad t_{n-2.} \; S_b$$

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.

$$\Delta t = t(L_2) - t(L_1) = \frac{1}{K} \ln \frac{L\infty - L1}{L\infty - L2}$$

The age interval mid-point is given by the equation.

$$t\left[(L_1+L_2) \;/\; 2\right] = t_0 - \frac{1}{K} \ln\left[1 - \frac{L_1+L_2}{2} \;/ L\infty\right.$$

Thus based on the equation

$$\ln\left(\frac{C\,(L_1\,,\,L_2)}{\triangle t}\right) = C - Z\,t_0 - Z\,\frac{1}{K}\,.\,\ln\left[1 - \frac{(L_1+L_2)}{2}\,/L_\infty\right]$$

we obtain

$$\ln\left(\frac{C\,(L_1\,,\,L_2)}{\triangle t}\right) = C - Z\left[\,t\,((L_1 + L_2)\,/\,2)\,\right]$$

which is of the form, y=a+bx with slope b=Z.

The program presents a scatterptot of $t\,((L_1+L_2)\,/\,2)$ *vs.* $\ln\,(C\,(L_1\,,\,L_2)\,/\triangle t)$ 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_∞) 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

$$Z/K = (L_\infty - \bar{L})\,/\,(\bar{L} - L_c)$$

which can be rearranged to

$$\bar{L} = \frac{L_\infty}{1+Z/K} + L_c\,.\,\frac{Z/K}{1+Z/K}$$

to show that the mean length of the selected fish ($\bar{L}$) is a linear function of the selection length (Lc). 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 sampres be raised to the annuaT catch. For a series of arbitrary knife-edge selection lengths (Lc), the corresponding mean lengths (L) of size groups exceeding the selection lengths (Lc) are calculated, ignoring the size groups below the selection length. These when graphically plotted, present a linear relationship according to the above equation with

intercept $a = \dfrac{L_\infty}{1+Z/K}$

slope $b = \dfrac{Z/K}{1+Z/K}$

From these $L_\infty = \dfrac{a}{1-b}$

and $Z/K = \dfrac{b}{1-b}$

and $Z = \left(\dfrac{b}{1-b}\right)K$

(See example 6.4 in Appendix.)

For the knife-edge selection length (Lc) from the length frequency distribujion, 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 $L\infty$ Z/K and also Z if a K value had been entered, initially.

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<<

Appendix 1

DETAILED PROGRAM LISTING

```
10 REM ***** MENU.BAS
20 REM ***** THIS IS A MENU PROGRAM FOR BHATTACHARAYA & CHI SQUARE PROGRAMS,
30 REM ***** DEVELOPED BY HAEZTRA GOONETILLEKE ' BOBP COLOMBO - SRI LANKA,
40 REM ****** LAST UPDATE 25,08,86
50 HOME
60 INVERSE
70 PEINT: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(l5);" 2. BHATACHARAYA'S WBTHOD "
140 PRINT TAB(l5);" 3. CHI SQUARE STATISTICS"
150 PRINT TAB(15);" 4. ESTINATING GROWTH PARAHBTBRS"
160 PRINT TAB(l5) ;" 5, TOTAL MORTALITY BSTIHATION "
170 PRINT TAB(l5);" 6. QUIT TO CP/H "
180 PRINT:HTAE 25:INVERSE:PRINT "enter option?";:NORMAL:H$=INPUT$(1)
190 H=VAL(H$):PRINT H
200 IF H<l OR H>6 THBN 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 "              BSTIHATION OF GROWTH PARAHBTBRS"
270 PRINT "              XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
280 PRINT:PRINT
290PRINTTAB(20);" 1. PLOT OF % FREQUENCIES
300 PRINT TAB(20);" 2. FORD - WALFORD PLOT"
310PRINTTAB(20);" 3. CULLAND & HOLT PLOT"
320 PRINT TAB(20);" 4, VOW BERTALANFFY PLOT"
330 VTAB 15:HTAB 25:INPUT "select option ";HH
340 IF HH<1 OR HH>4 THEN 330 ELSE 350
350 O N HH GOT0 360,370,380,390
360 RUN"GEAPHl.BAS"
370 RUN"FORD.BAS"
380 RUN "HOLT.BAS"
390 RUN "VON.BAS"
400 HONE:PRINT:PRINT:PRINT:PRINT
410 PRINT "                   TOTAL MORTALITY BSTIHATION"
420 PRINT "                  XXXXXXXXXXXXXXXXXXXXXXXXXXXXX"
430 PRINT:PRINT
440PRINTTAB(20);" 1. JONES & VAN ZALINGE HBTHOD"
450 PRINTTAB(20);" 2. SPARRE'S CATCH CURVE BASED HBTHOD"
460 PRINTTAB(20);" 3. WETHERALL ET AL METHOD"
470 PRINTTAB(20);" 4, EXIT TO MAIN MENU"
480 VTAB 15:HTAE 25:INPUT 'enter your choice ";HG
490 IF HC <1 OR HG>4 THEN 480 ELSE 500
500 ON HG GOT0 510,520,530,50
510 RUN"JONES.BAS"
520 RUN"SPARBE.BAS"
530 RUN"WET.BAS"
540 PRINT :PRINT :PRINT"BYE BYE FROM APPLE II e":SYSTEM
550 REM ***********************************************************************************
```


<<

File maintenance rout i no

```
10 REM **** MAIN.BAS
20 REM *** PROGRAMMED BY HARZTRA 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 lie micro computer with Spftcard 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 TAB(15)" ****************************
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 INPUT "ENTER FILE NANE(maximum 8 characters :-
320 IF LEN(F$}=0 THEN 310
330 RETURN
340 REM ***************************************************************************
350 REM ** INPUT & WRITE DATA ROUTINE
360 PRINT:LINE INPUT 'ENTER DESCRIPTION OF THIS FILE
370 PRINT INPUT "NO.OF SAMPLES ",H
380 INPUT 'NUMBER OF CLASSES C
390 DIM X(HJC)F(HJC) C(H),L1(H) ,L2(H),M(H)
400 INPUT 'LOWER LIMIT OF SMALLEST SIZE CLASS ",L1
410 INPUT "UPPER LIMIT OF SMALLEST SIZE CLASS ",L2
420 D=L2-L1
430 IF D< 0 THEN "REENTER" ; GOTO 400
440 FOR K: 1 TO H
450 HOME PRINT TAB(25) ;"DATA ENTRY"
460 PRINT:PRINT TAB(10);"SAMPLE ";K
470 INPUT MONTH", M(K)
480 PRINT
490 INPUT "FIRST MID LENGTH OF THIS SAMPLE
500 INPUT 'LAST MIDLENGTH OF THIS SAMPLE ";L2(K)
510 IF L2(K)<L1(K) THEN PRINT "REENTER ";GOTO 490
520 PRINT
530 INPUT 'ABOVE ENTRIES O.E,(Y/N) ",YYZ$
540 IF YYZ$="Y" THEN 550 ELSE IF YYZ$="N" THEN 4UU ELSE 530
550 PRINT 'NO.";TAB(10);"MID LENGTH' ;TAB(30);"FREQUENCY"
560 C(K)=(L2(K)-L1(K))/D+1:REM NO OF CLASSES IN K th SAMPLE
570 FOR I=1 TO C(K)
```


<<

```
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 (YIN)  ";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) ";0$:IF 0$="N" THEN 980 ELSE DD$:D$:GOTO 990
980 LINE INPUT "NEW DESCRIPTION ?",DD$
990 PRINT "NO.OF SAMPLES : ";H:PRINT "NO.0F CLASSES : ";C:PRINT "SMALLEST SIZE CLASS  :  ;L1;'  - ";L2
1000 PRINT #2,DD$
1010 PRINT #2,H,C,L1,L2
1020 DIM X(H,C},F(H,C}C(H),M(H)
1030 FOR E= I TO H
1040 HOME:PRINT TAB(25);"EDITING PROCESS"
1050 PRINT
1060 INPUT #1,M(K),C(K):PRINT "SAMPLE =";K:PRINT "MONTH =";M(K)
1070 INPUT "NEW MONTH;MM:IF MM:0 THEN 1080 ELSE M(K)=MM
1080 PRINT $2,M(E),C(E}
1090 PRINT "NO,";TAB(10);"MID LENGTH";TAB(30);"FREQUENCY"
1100 FOR J: 1TO C(E):INPUT #1,X(E,J),F(E,J):PRINT;" ";J;TAB(10); X(E,J);TAB(30);F(E,J):NEXT J
1110 GOSUB 180:REM EDIT
1120 FOR J=1 TO C(E):PRINT #2,X(E,J),F(E,J):NEXT J
1130 NEXT E
1140 CLOSE
1150 EILL F$
```


<<

```
1160 NAME G$ AS F$
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",l,F$
1260 LINE INPUT #1,D$
1270 INPUT #l,H,C,LI,L2
1280 D=L2-Ll
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#l,X(E,J),F(E,J)
1340 NEXT J
1350 NBXT E
1360 CLOSE #1
1370 RETURN
1380 REM ** LIST DATA
1390 GOSUB 1240
1400 HOME :PEINT:LPRINT:LPRINT"                    FILE NAME . ";F$
1410 PRINT D$:LPRINT D$
1420 FOR E=1 TO H
1430 PRINT:LPRINT:LPRINT
1440 PRINT TAB(lO);"SAHPLE ";E
1450 PRINT '          HONTH";H(E)
1460 LPRINT "SAHPLE ";E
1470 LPRINT "HONTH ";H(E):LPRINT
1480 PRINT"HIDLENGTH";TAB(20);"FREQ."
1490 LPEINT"HIDLENGTH";SPC(10)"FREQUENCY"
1500 FOR I= 1 TO C(K)
1510 PRINT X(E,I);TAB(20);P(E,I)
1520 LPEINT USING "###.#           ";X(E,I),:LPRINT USING"#####.##          ";F(E,I)
1530 NEXT I
1540 LPRINT:LPRINT
1550 NEXT E
1560 RETURN
1570 REH************************************************************
1580 REM ** DISPLAY DISK CATALOG
1590 HOME:PRINT:PRINT
1600 INPUT "ENTER DISK DRIVE NUMBER(A/B) ",DD$
1610 ON ERROR GOTO 1650
1620 IF DD$="A" THEN PRINT :PRINT:FILES "A:*3*":GOTO 1670
1630 IF DD$="B" THEN PRINT:PRINT:FILES "B:*.*":GOTO 1670
1640 GOTO 1590
1650 PRINT:PRINT" INSERT DISK IN DRIVE ";DD$;" AND PRESS RETURN TO CONTINUE";:O$=INPUT$(1)
1660 HOME:GOTO 1610
1670 PRINT:PRINT:PRINT:PRINT:INPUT "PRESS RETURN TO EXIT TO NAIN MENU ",OOO$
1880 RBTURN
1890 REM*******************************************
1700 REM * INITIALISE ROUTINE
1710 HOME :VTAB 4:HTAB 10:PRINT "If you need to prepare a new blank disk for use as data disk with BHATTACHARYA
 prograr you aust initialise the disk first."
1720 PRINT:PRINT "This process is done at CP/M connand level (A>) by typing the command"
1730 PRINT ' COPY B:/D"
```


<<

```
1740 PRINT "Press return, then insert blank disk in drive B & press return again."
1750 PrINT:PRINT "Make sure that the disk you insert to drive B is blank ntherwise the contents of this disk
 wi11 be erased,"
1760 PRINT
1770 PRINT "Note down this command & press return to quit to CP/M command level"
1780 INPUT ' ",QQQ$
1790 SYSTEM
1800 REM
1810 REM * DELETE FILES
1820 PRINT "With this process this file will be permanently destroyed"
1830 PRINT
1840 INPUT "do you wish to delete this file (Y/N)";VV$
1850 IF VV$="Y" THEN 1860 ELSE IF VV$="N" THEN 1920 ELSE 1840
1860 IF RIGHT$(F$,4):",BAS" OR RIGHT$(F$,4):".COM" THEN 1870 ELSE 1983
1870 PRINT ' SORRY - PROGRAM FILES CANNOT BE DESTROYED ! ":GOTO 1900
1880 KILL f$
1890 PRINT F$;" is now deleted,"
1900 FOR III = 1 TO 1000:RBM ** DELAY
1910 NEXT III
1920 RETURN
1930 RBM *****************************************************
1940 REM ** REGROUP LENGTH FREQUENCY DATA WITH DIFFERENT CLASS INTERVALS
1950 REM ** AND CREATE A NEW DATA FILE
1960 GOSUB 1240
1970 HOME
1980 INPUT "BNTBR THB MULTIPLICATION FACTOR FOR RECROUPINC YOUR LENGTH FREQUENCIES ",MF
1990 PRINT "EARLIER CLASS INTERVAL = ";D
2000 PRINT "NEW      CLASS INTERVAL = ";MF*D
2010 PRINT :INPUT "O.K.(Y/N) ",QQW$
2020 IF QQW$="Y" THEN 2030 ELSE IF QQW$="N" THEN 1980 ELSE 2010
2030 PRINT :LPRINT "REGROUPED FREQUENCIES OF FILE ";F$
2040ND=MF*D:NL2=Ll+ND:REM NEWCLASSLIHITS
2050 FOR E= 1 TO H
2060 PRINT "SAMPLE ";K
2010 LPRINT "SAMPLE ";E
2080 PRINT "RONTH ' ;M(E]
2090 LPRINT "MONTH ";M(E)
2100PRINT:PRINT"MID PT.";TAB(20);"FREQ"
2110 LPRINT"HIDLENGTH";SPC(10)"FREQUENCY"
2120J=l:CT=0
2130 FOR I =   1 TO C(E)
2140 IF X(E,I)(NL2 +(J-1)*ND THBN 2180 ELSE 2150
2150PRINTNL2+(J-l)*ND-ND/2;TAB(20];CT
2160 LPRINT USING "###.#           ";NL2+(J-l)*ND-ND/2,:LPRINT  USING  "#####.##          T
2170 CT=0:J=J+l:GOTO 2140
2180 CT=CT+F(E,I)
2190 NEXT I
2200 PRINT  NL2+(J-l)*ND-ND/2;TAB[20);C T
2210 LPRINT USING "###,#           ";NL2+(J-l)*ND-ND/2,:LPRINT  USING"#####.##          ";CT
2220 PRINT
2230 NEXT E
2240 RETURN
2250 ************************************************************
```


<<

```
10  REM **** BH3.BAS
20  REM *** PROGRAMMED BY HAEZTRA GOONETILLEKE - BOBP,COLOMBO-SRI LANKA.-JUNE 86
30  REM * A MODIFICATION OF BHATTACHARAYA'S METHOD FOR THE ANALYSIS OF
40  REM * MIXTURES OF NORMAL DISTRIBUTIONS FOR A NUMBER OF SAMPLES
50  REM * LAST UPDATE 04/08/86
60  REM ***********************************************************************
70  REM ** LOG(Fi+1/Fi)=a+bXi
80  REM ** where b={&xy-&x&y/n}/{&x^2-(&x)^2/n}    ** & denotes summation
90  REM ** a=&y/n - b.&x/n
100 REM ** r (abs.corr.coeff.)emp. =Sxy/SQ.RT(SxxSyy)
110 REM ** r={&xy-&x&y/n]/SQ.RT{[&x^2-(&x)^2/n][&y^2-(&y)^2/n]}
120 REM ** MEAN  M=(0.5D)-(a/b) where D=class interval=L2-L1
130 REM ** STD.DEV. S=SQ.RT{(1/-b)-(D^2/12)}
140 REM ** N=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 2.23b - with MBASIC
190 REM ** 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$="Y" THEN 230
260 REM ***********************************************************************
270 REM ** INITIALISATION ROUTINE
280 HOME :VTAB 4:HTAB 15:PRINT " BHATTACHARAYA'S METHOD "
290 PRINT:PRINT TAB(15)" **********************"
300 PRINT:PRINT:INPUT "TODAY'S DATE (dd/mm/yy) ? ",DD$
310 VTAB 16:PRINT"enter / to return to main menu"
320 VTAB 13:INPUT "ENTER FILE NAME(maximum 8 characters ) :- ",F$
330 IF F$="/" THEN GOTO 1010
335 IF LEN(F$)=0 THEN 320
340 VTAB 16:PRINT "                                       "
350 PRINT:PRINT:INPUT "READY THE PRINTER & PRESS RETURN TO PROCEED ",O$
360 RETURN
370 REM ***********************************************************************
380 REM * CALCULATE & PRINT RESULTS
390 HOME:PRINT:PRINT:INPUT "ENTER CRITICAL VALUE OF CORRELATION COEFFICIENT  ",R1
400 LPRINT "BHATTACHARAYA ANALYSIS";SPC(25)DD$
410 LPRINT "**********************"
420 LPRINT
430 LPRINT "FILE NAME :- ";F$:LPRINT
440 LPRINT D$
450 LPRINT :LPRINT "INPUT VALUE OF CRITICAL VALUE OF CORRELATION COEFFICIENT =";R1:LPRINT
460 FOR K=1 TO H
470 HOME :PRINT "SAMPLE ";K:LPRINT "SAMPLE ";K:PRINT
480 PRINT "MONTH ";M(K):LPRINT "MONTH ";M(K):LPRINT:LPRINT
490 J=1:G=1
500 XX=0:YY=0:XY=0:XX2=0:YY2=0
510 IF J+3<=C(K) THEN 530 ELSE 930
520 REM* LINEAR REGRESSION ROUTINE
530 FOR I=J TO J+2
540 XX=XX+X(K,I):YY=YY+LOG(F(K,I+1)/F(K,I)):XY=XY+X(K,I)*(LOG(F(K,I+1)/F(K,I))):XX2=XX2+X(K,I)^2:YY2=
YY2+(LOG(F(K,I+1)/F(K,I)))^2
```

```
550 REM PRINT XX,YY,XY,XX2,YY2
560 NEXT I
570 B1=XY-(XX*YY/3)
580 B2=XX2-((XX^2)/3)
590 B=B1/B2
600 A=YY/3-(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=YY2-((YY^2)/3)
660 B4=(B2*B3)^.5
670 R=B1/B4
680 REM R (calculated) SHD BE HIGHER THAN R critical
690 IF R<0 THEN R=-R
700 PRINT "MID PTS.= ";X(K,J),X(K,J+1),X(K,J+2):PRINT "ABS.CORR.COEFF.=";R
710 LPRINT "MID PTS.= ";X(K,J),X(K,J+1),X(K,J+2)
720 LPRINT "ABS.CORR.COEFF. =";R
730 IF R<=R1 THEN J=J+1:PRINT:LPRINT:GOTO 500
740 REM *ESTIMATE M,S,N
750 M=(.5*D)-(A/B)
755 IF (1/-B)>((D^2)/12) THEN 760 ELSE 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:N2=0
780 FOR I=J TO J+2
790 LF=LF+LOG(F(K,I))
800 N2=N2+((X(K,I)-M)^2)
810 NEXT I
820 LF=LF/3
830 N3=6*(S^2+(D^2/12))
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=G+1: GOTO 500
930 LPRINT "---------------------------------------------------------------------------"
940 LPRINT
950 NEXT K
960 RETURN
970 REM ***********************************************************************
980 REM* TERMINATION
990 HOME:PRINT:INPUT "RERUN WITH DIFFERENT r VALUES (Y/N) ",W$
1000 IF W$="Y" THEN 1020 ELSE IF W$="N" THEN 1010 ELSE 990
1010 CLOSE:RUN"MENU.BAS"
1020 RETURN
1030 REM ***********************************************************************
1040 REM READ DATA FROM DISK
1050 OPEN "I",1,F$
1060 OPTION BASE 1
1070 LINE INPUT #1,D$
1080 INPUT #1,H,C,L1,L2
1090 D=L2-L1
1100 DIM X(H,C),F(H,C),C(H),M(H)
1110 FOR K=1 TO H
```

```
1120 INPUT #1,M(K),C(K)
1130 FOR J=1 TO C(K)
1140 INPUT #1,X(K,J),F(K,J)
1150 NEXT J
1160 NEXT K
1170 CLOSE #1
1180 RETURN
1190 REM ***********************************************************************
```

Chi square calculations

```
10  REM **** CHI.BAS
20  REM *** PROGRAMMED BY HAEZTRA GOONETILLEKE - BOBP,COLOMBO-SRI LANKA.-JUNE 86
30  REM * ANALYSIS OF FREQUENCIES FROM A MIXTURE OF NORMAL DISTRIBUTION
40  REM * PROGRAM TO CALCULATE THE CHI SQUARE STATISTIC TO ASSESS WHETHER
50  REM * THE GROUPS IDENTIFIED GENERATE A MIXTURE OF NORMAL DISTRIBUTIONS
60  REM * THAT 'FITS' THE ORIGINAL FREQUENCY DATA.
70  REM * LAST UPDATE 04/08/86
80  REM ***********************************************************************
90  REM * This programme will use the mean M, std.dev.S,and size N of a number
100  REM * of Normal Distributions (1<j<6) to estimate combined frequencies ff
110  REM ** ff=&(N*D*exp[-0.5*((x-M)/S)^2]/(S*sq.rt(2pi)))
120 REM ** THE RESIDUALS (F-FF) AND VALUES FOR THE COMPUTATION OF THE
130 REM ** CHI SQUARE STATISTIC (F-FF)^2/FF WILL BE CALCULATED
140 REM ** NOTE THAT CLASSES WITH FF<5 SHOULD BE POOLED TO PREVENT INFLATING
150 REM ** THE TEST STATISTIC.
160 REM ** This program is written using Microsoft version 2.23 B with MBASIC
170 REM ** for APPLE IIe micro computer with Softcard CP/M
180 REM ***********************************************************************
190 GOSUB  270:REM INITIALISATION
200 GOSUB 1310:REM READ  DATA FROM ORIGINAL FILE
210 GOSUB 520:REM INPUT,CALCULATE & PRINT RESULTS
220 IF YY$="Y" THEN 230 ELSE 250
230 IF CS$="Y" THEN 250
240 GOSUB 1460:REM CREATE NEW DATA FILE FOR +VE RESIDUALS
250 GOSUB 1260:REM TERMINATION
260 REM ***********************************************************************
270 REM ** INITIALISATION ROUTINE
280 OPTION BASE 1
290 DIM U(6),S(6),N(6)
300 HOME :VTAB 4:HTAB 17:PRINT " CHI SQUARE STATISTICS  "
310 PRINT TAB(16);"_________________________"
320 PRINT:PRINT
330 PRINT "THIS PROGRAM WILL PRODUCE EXPECTED SIZE FREQUENCIES AND RESIDUALS "
340 PRINT "FOR THE ORIGINAL FREQUENCIES ENTERED IN BHATTACHARAYA ANALYSIS."
350 PRINT "THUS BEFORE RUNNING THIS PROGRAMME YOU SHOULD RUN THE BHATTACHARAYA"
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 :-  ",F$
400 IF F$="/" THEN GOTO 1280
410 IF LEN(F$)=0 THEN 390
420 INPUT "Do you wish to create another file with the residuals of this analysis(Y/N) :- ",YY$
430 IF YY$="Y" THEN 450
440 IF YY$="N" THEN 490
450 INPUT "ENTER NEW FILE NAME :- ",G$
```

```
460 IF G$="/"THEN GOTO 1280
470 VTAB 18:PRINT "                                        "
480 PRINT:LINE INPUT "description of this file ?";ND$
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 590
540 IF CS$="N" THEN 590
550 IF CS$="Y" THEN 560 ELSE 590
560 INPUT "sample",K:IF K=0 THEN 1240
570 IF K>H THEN PRINT "no such sample":GOTO 560
580 GOTO 600
590 FOR K= 1 TO H
600 HOME :PRINT TAB(25);" CHI SQUARE STATISTICS"
610 PRINT:PRINT  TAB(10);"SAMPLE ";K
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 PRINT
680 FOR B=1 TO Z
690 PRINT "GROUP  ";B
700 INPUT "MEAN      ";U(B):INPUT "STD.DEV.  ";S(B):INPUT "SIZE      ";N(B)
710 INPUT "entries O.K.(Y/N) ? ",OK$
720 IF OK$="Y" THEN 740
730 IF OK$="N" THEN 690
740 PRINT:NEXT B
750 PRINT
760 REM * CALCULATE & PRINT RESULTS
770 LPRINT "CHI SQUARE STATISTICS"
780 LPRINT "*********************"
790 LPRINT :LPRINT
800 LPRINT "FILE NAME ;";F$
810 LPRINT D$
820 LPRINT
830 LPRINT "SAMPLE ";K
840 LPRINT "MONTH ";M(K):LPRINT:LPRINT
850 LPRINT "MEAN    = ";:FOR B=1 TO Z:LPRINT USING "    ####.###      ";U(B),:NEXT B:LPRINT
860 LPRINT "STD.DEV.= ";:FOR B=1 TO Z:LPRINT USING "       #.###      ";S(B),:NEXT B:LPRINT
870 LPRINT "SIZE    = ";:FOR B=1 TO Z:LPRINT USING "########.##       ";N(B),:NEXT B:LPRINT
880 LPRINT:LPRINT:LPRINT
890 PRINT "MID LEN.";TAB(15);"FREQ.";TAB(27);"PREDICTED F";TAB(42);"FREQ.- EXP.FREQ."
900 LPRINT "MIDLENGTH";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+(EXP(-.5*(((X(K,I)-U(B))/S(B))^2)))*(N(B)*D/(S(B)*SQR(2*22/7)))
950 NEXT B
960 PRINT X(K,I);TAB(15);F(K,I);TAB(27);FF;TAB(45); F(K,I)-FF
970 LPRINT USING "###.#          ";X(K,I),:LPRINT USING "#####.##       ";F(K,I),
 :LPRINT USING "########.###          ";FF,
980 LPRINT USING "########.###              ";F(K,I)-FF
990 FF(K,I)=FF
1000 NEXT I
1010 LPRINT
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 "    ****************************************************************"
1060 PRINT "  FREQ.              PRE.FREQ.          RESIDUALS       CHI SQ.STAT."
1070 LPRINT:LPRINT " FREQUENCY       PRE.FREQ.           RESIDUALS             CHI SQUARE STAT."
1080 PF=0:TF=0:CST=0:CL=0
1090 FOR I=1 TO C(K)
1100 PF=PF+FF(K,I):TF=TF+F(K,I)
1110 IF PF <5 THEN 1160
1120 PRINT TAB(5);TF;TAB(20);PF;TAB(40);TF-PF;TAB(55);((TF-PF)^2)/PF
1130 LPRINT USING "#####.#            ";TF,:LPRINT USING "########.###          ";PF,
1140 LPRINT USING "########.###                 ";TF-PF,:LPRINT USING "#######.###";((TF-PF)^2)/PF
1150 CST=CST+((TF-PF)^2)/PF:TF=0:PF=0:CL=CL+1
1160 NEXT I
1170 LPRINT:LPRINT
1180 LPRINT USING "&";"                               CHI -SQUARE STATISTIC = ";:LPRINT USING "#######.###";CST
1190 PRINT:PRINT "CHI SQUARE STATISTIC = ";CST:PRINT "FOR ";CL;" CLASSES & ";CL-(1+2*Z);" D.F."
1200 LPRINT USING "&";"                               FOR ";:LPRINT USING "##";CL;:LPRINT USING "&";" CLASSES AND ";
 :LPRINT USING "##";CL-(1+2*Z);:LPRINT USING "&";" D.F."
1210 LPRINT"------------------------------------------------------------------------":LPRINT:LPRINT:LPRINT:LPRINT
1220 IF CS$="Y" THEN HOME:GOTO 560
1230 NEXT K
1240 RETURN
1250 REM ***********************************************************************
1260 REM* TERMINATION
1270  HOME:PRINT:PRINT
1280 CLOSE :RUN "MENU.BAS"
1290 RETURN
1300 REM ***********************************************************************
1310 REM READ DATA FROM DISK
1320 OPEN "I",1,F$
1330 LINE INPUT#1,D$
1340 INPUT #1,H,C,L1,L2
1350 D=L2-L1
1360 DIM X(H,C),F(H,C),C(H),M(H),FF(H,C)
1370 FOR K=1 TO H
1380 INPUT #1,M(K),C(K)
1390 FOR J=1 TO C(K)
1400 INPUT #1,X(K,J),F(K,J)
1410 NEXT J
1420 NEXT K
1430 CLOSE #1
1440 RETURN
1450 REM ***********************************************************************
1460 REM CREATE NEW DATA FILE FOR RESIDUALS
1470 OPEN "O",2,G$
1480 PRINT #2,ND$
1490 PRINT #2,H,C,L1,L2
1500 FOR K=1 TO H
1510 PRINT #2,M(K),C(K)
1520 HOME
1530 PRINT "SAMPLE ";K
1540 PRINT "MONTH  ";M(K)
1550 INPUT "ENTER THE +ve VALUE OF LOWEST NEGATIVE RESIDUAL OR ZERO ? ",LRL
1560 IF LRL <0 THEN 1550
1570 FOR I=1 TO C(K)
1580 VTAB 22:PRINT "WRITING RECORD ON DISK "; I
1590 FRES =F(K,I)-FF(K,I)+LRL
```

<<

```
1600 IF FRES <= 0 THEN FRES=.01
1610 PRINT #2,X(K,I),FRES
1620 NEXT I
1630 NEXT K
1640 RETURN
1650 REM ************************************************************************
```

Graph plot

```
10  REM **** GRAPH1
20  REM *** PROGRAMMED BY HAEZTRA GOONETILLEKE - BOBP,COLOMBO-SRI 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 ************************************************************************
80  REM * This programme will calculate raising factor = total frequency/sum N
90  REM ** This program is written using Microsoft version 2.23 B with MBASIC
100 REM ** for APPLE IIe micro computer with Softcard CP/M
110 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 ** INITIALISATION ROUTINE
190 OPTION BASE 1
200 DIM U(6),S(6),N(6),CL1(2,6),CL2(2,6)
210 HOME :VTAB 4:HTAB 17:PRINT " % FREQUENCY PLOT  "
220 PRINT TAB(18);"_________________"
230 PRINT:PRINT
240 PRINT"THIS PROGRAM WILL PLOT  THE % LENGTH FREQUENCY DATA "
250 PRINT "FOR ALL THE SAMPLES.THIS GIVES YOU THE CONFIDENCE LIMITS"
260 PRINT "FOR THE MEANS OBTAINED IN THE BHATTACHARAYA PROGRAM."
270 VTAB 18:PRINT "enter / to return to main menu"
280 VTAB 15:INPUT "ENTER ORIGINAL DATA FILE NAME :-  ",F$
290 IF F$="/" THEN GOTO 880
300 VTAB 18:PRINT "                                        "
310 INPUT"READY THE PRINTER & PRESS RETURN TO PROCEED",O$
320 RETURN
330 REM ***********************************************************************
340 REM ** PRINT  ROUTINE
350 LPRINT:LPRINT:LPRINT
360 LPRINT "FILE NAME :-";F$
370 LPRINT D$
380 FOR K= 1 TO H
390 HOME :PRINT
400 PRINT:PRINT  TAB(10);"SAMPLE ";K
410 PRINT "         MONTH ";M(K)
420 LPRINT
430 LPRINT "SAMPLE ";K
440 LPRINT "MONTH ";M(K):LPRINT
450 PRINT "MID LEN.";TAB(15);"FREQ.";TAB(27);"% FREQ.."
460 LPRINT "MIDLENGTH";SPC(5)"FREQUENCY";SPC(6)"% FREQUENCY";SPC(6)"%FREQ.(ROUNDED)"
470 FOR I=1 TO C(K)
```

```
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),
:LPRINT USING "#####.###            ";F(K,I)*100/T(K),
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 BHATTACHARAYA ANALYSIS"
530 INPUT "NO.OF GROUPS FOR THIS SAMPLE ",Z
540 IF Z>6 THEN 530
550 TN=0
560 FOR B=1 TO Z:PRINT "GROUP  ";B
570 INPUT "MEAN   ";U(B):INPUT "STD.DEV.   ";S(B):INPUT "SIZE    ";N(B):PRINT
580 TN=TN+N(B)
590 IF N(B)-1 <= 30 THEN 620 ELSE IF N(B)-1 <40 THEN 660 ELSE IF N(B)-1 <60 THEN 670
600 IF N(B)-1 <80 THEN 680 ELSE IF N(B)-1 <100 THEN 690
610 IF N(B)-1 <120 THEN 700 ELSE IF N(B)-1 =120 THEN 710 ELSE 720
620 RESTORE
630 FOR CC=1 TO 30:READ CONF,CONF1,CONF2
640 IF CONF=N(B)-1 THEN CC=30
650 NEXT CC:GOTO 740
660 RESTORE 1750:GOTO 730
670 RESTORE 1760:GOTO  730
680 RESTORE 1770:GOTO 730
690 RESTORE 1780:GOTO 730
700 RESTORE 1790 :GOTO 730
710 RESTORE 1800:GOTO 730
720 RESTORE 1810
730 READ CONF,CONF1,CONF2
740 NEXT B
750 FOR B=1 TO Z:CL1(1,B)=U(B)-CONF1*S(B)/SQR(N(B)):CL2(1,B)=U(B)+CONF1*S(B)/SQR(N(B)):CL1(2,B)=
U(B)-CONF2*S(B)/SQR(N(B)):CL2(2,B)=U(B)+CONF2*S(B)/SQR(N(B))
760 NEXT B
770 PRINT:PRINT "   RAISING FACTOR = ";T(K)/TN
780 FOR B=1 TO Z:PRINT "MEAN= ";U(B);"      SIZE = ";N(B)*T(K)/TN
790 LPRINT USING "&";"   MEAN = ";:LPRINT USING "###.#";U(B),:LPRINT USING "&";"      SIZE = ";:LPRINT USING "#####"
;N(B)*T(K)/TN
800 LPRINT USING "&";"   95% CONF.LIMITS = ";:LPRINT USING "###.####";CL1(1,B);:LPRINT USING "   ###.####";CL2(1,B)
:LPRINT USING "&";"   99% CONF.LIMITS = ";:LPRINT USING "###.####";CL1(2,B);:LPRINT USING "   ###.####";CL2(2,B)
810 LPRINT
820 NEXT B
830 NEXT K
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,F$
930 LINE INPUT#1,D$
940 INPUT #1,H,C,L1,L2
950 D=L2-L1
960 DIM X(H,C),F(H,C),C(H),M(H),T(H),G(H,C),A(H),X2(H,C)
970 FOR K=1 TO H
980 INPUT #1,M(K),C(K)
990 T(K)=0
1000 FOR J=1 TO C(K)
1010 INPUT #1,X(K,J),F(K,J)
```


<<

```
1015 X2(K,J)=X(K,J)
1020 T(K)=T(K)+F(K,J)
1030 NEXT J
1040 NEXT K
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 K=1 TO H
1130  FOR I=1 TO C(K)
1140 VTAB 22:PRINT "CALCULATIONS IN PROGRESSS -- PLEASE WAIT ** "
1150 G(K,I)=F(K,I)*100/T(K)+.5
1160  REM LPRINT X(K,I),G(K,I)
1170 NEXT I
1180 REM **** SORT % FREQ. IN DESCENDING ORDER
1190 FLIP=1
1200 WHILE FLIP
1210 FLIP=0
1220 FOR I=1 TO C(K)-1
1230 IF G(K,I)<G(K,I+1) THEN SWAP G(K,I),G(K,I+1):SWAP X(K,I),X(K,I+1):FLIP=1
1240 NEXT I
1250 WEND
1260 NEXT K
1270 REM **** GET HIGHEST VALUE OF ALL
1280 FOR K= 1 TO H:A(K)=G(K,1):NEXT K
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
1362 CHANGE=0
1363 FOR K=1 TO H:IF X2(K,C(K))-U>35 THEN CHANGE=1:NEXT K
1365 IF CHANGE=0 THEN 1370 ELSE 1367
1367 LPRINT "             X axis - MID PTS. (from ";U;")     SCALE 1:1":GOTO 1380
1370 LPRINT "             X axis - MID PTS. (from ";U;")     SCALE 1:2"
1380 LPRINT "             Y axis - % FREQ.  (from 0 to ";INT(A(1));" ) SCALE 1:1"
1390 LPRINT
1400 REM **** PLOT THE GRAPH
1410 FOR K= 1 TO H
1420 M=INT(G(K,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$(5);"+":NEXT J
1490 FOR I= 1 TO C(K)
1500 IF I=1 THEN 1520
1510 IF M-INT(G(K,I))-LP-1 <>-1 THEN LPRINT :REM FORCE A CR/LF
1520 IF M-INT(G(K,I))-LP-1=0 THEN 1620
1530 IF M-INT(G(K,I))-LP-1=-1 THEN 1540 ELSE GOTO 1590
1540 LPRINT CHR$(27);"3";CHR$(20);
1550 IF LX+1 >7  THEN GOTO 1560 ELSE 1580
```

```
1560 FOR QQ=1 TO 7  :LPRINT CHR$(8);:NEXT QQ:BX=LX-6
1570 FOR QQ =1 TO BX:LPRINT CHR$(127);CHR$(8);:NEXT QQ:GOTO 1650
1580 FOR QQ=1 TO LX+1 :LPRINT CHR$(8);:NEXT QQ:GOTO 1650
1590 FOR Q=1 TO M-INT(G(K,I))-LP-1
1600 LPRINT CHR$(27);"f";CHR$(0);CHR$(5);"+"
1610 NEXT Q
1620 REM
1630 LPRINT CHR$(27);"f";CHR$(0);CHR$(5);"+";
1640 IF CHANGE=1 THEN 1645 ELSE IF (X(K,I)-U)*2 =9 THEN LPRINT CHR$(27);"f";CHR$(0);CHR$(10);CHR$(8);"*";:GOTO 1660
1645 IF X(K,I)-U =9 THEN LPRINT CHR$(27);"f";CHR$(0);CHR$(10);CHR$(8);"*";:GOTO 1660
1650 IF CHANGE=1 THEN 1655 ELSE LPRINT CHR$(27);"f";CHR$(0);CHR$((X(K,I)-U)*2);"*";:GOTO 1660
1655 LPRINT CHR$(27);"f";CHR$(0);CHR$((X(K,I)-U));"*";
1660 LP=M-INT(G(K,I)) .
1670 IF CHANGE=1 THEN 1675 ELSE LX=(X(K,I)-U)*2:GOTO 1680
1675 LX=X(K,I)-U
1680 NEXT I
1690 LPRINT:LPRINT "     ------------------------------------------------------------------------->"
1700 LPRINT CHR$(27);"2";
1705 LPRINT "                              SAMPLE ";K ;"   MONTH ";M(K)
1710 NEXT K:RETURN
1720 DATA 1,12.706,63.657,2,4.303,9.925,3,3.182,5.841,4,2.776,4.604,5,2.571,4.032,6,2.447,3.707,7,2.365,3.499,8,
2.306,3.355,9,2.262, 3.250,10,2.228,3.169
1730 DATA 11,2.201,3.106,12,2.179,3.055,13,2.160,3.012,14,2.145,2.977,15,2.131,2.947,16,2.120,2.921,17,2.110,2.898,
18,2.101,2.878,19,2.093,2.861,20,2.086,2.845
1740 DATA 21,2.080,2.831,22,2.074,2.819,23,2.069,2.807,24,2.064,2.797,25,2.060,2.787,26,2.056,2.779,27,2.052,2.771,
28,2.048,2.763,29 ,2.045,2.756
1750 DATA 30,2.042,2.750
1760 DATA 40,2.021,2,704
1770 DATA 60,2.000,2.660
1780 DATA 80,1.99,2.64
1790 DATA 100,1.98,2.63
1800 DATA 120,1.980,2.617
1810 DATA 9999,1.960,2.576
```

Ford-Walford plot

```
10  REM **** FORD.BAS
20  REM *** PROGRAMMED BY HAEZTRA GOONETILLEKE - BOBP,COLOMBO-SRI LANKA.-AUG-86
30  REM * FORD WALFORD PLOT
40  REM * LAST UPDATE 25/08/86
50  REM ************************************************************************
60  REM ** (L(t+dt))^D=a+b (Lt)^D
70  REM ** where b=[&xy-&x&y/n]/[&x^2-(&x)^2/n]   ** & denotes summation
80  REM ** a=&y/n - b.&x/n
90 REM ** r (abs.corr.coeff.)emp. =Sxy/SQ.RT(SxxSyy)
100 REM ** r=[&xy-&x&y/n]/SQ.RT{[&x^2-(&x)^2/n][&y^2-(&y)^2/n]}
110 REM ** Loo=(a/(1-b))^(1/D) & K=-(lnb)/D
120 REM ** Since both Lt & Lt+dt are measured with the same error,Geometric mean
130 REM ** or type II regression is used here.
140 REM ** b'=b/r & a'=&y/n -b'&x/n
150 REM ** This program is written using Microsoft version 2.23b - with MBASIC
160 REM ** for APPLE IIe micro computer with Softcard CP/M
170 REM ***********************************************************************
180 GOSUB  240:REM INITIALISATION
190 GOSUB 900:REM INPUT DATA
200 GOSUB 380:REM CALCULATE & PRINT RESULTS
```


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```
210 GOSUB 840:REM TERMINATION
220 IF W$="Y" THEN 200
230 REM ************************************************************************
240 REM ** INITIALISATION ROUTINE
250 HOME :HTAB 25:PRINT " FORD - WALFORD PLOT "
260 PRINT:PRINT TAB(25)" *******************"
270 PRINT:PRINT:PRINT "IN THE CASE OF A SINGLE BROOD  USER HAS ONLY TO ENTER THE VALUES OF LENGTHS FOR A SERIES OF
 AGES. THE COMPUTER WILL AUTOMATICALLY CREATE A TABLE WITH PAIRS OF  CONSECUTIVE LENGTHS."
280 PRINT:PRINT "BUT FOR MULTIPLE BROODS USER MUST ENTER BOTH Lt & Lt+1 FIGURES. THE K,Loo VALUES CALCULATED WILL
 BE THE MEAN FIGURES FOR THE DIFFERENT BROODS COMBINED."
290 PRINT:PRINT "Remember that in both cases the time difference between consecutive lengths must remain constant
 - either 1 year or 1 month."
300 PRINT :PRINT :PRINT " enter  S for SINGLE BROODS" "
310 PRINT "        M for MULTIPLE BROODS"
320 VTAB 19:INPUT"        / to  return to main menu  ",F$
330 IF F$="/" THEN GOTO 870
340 IF LEN(F$)=0 THEN 320
350 IF F$="S" THEN 360 ELSE IF F$="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<0 THEN 390  ELSE 410
410 PRINT:LINE INPUT "ENTER DESCRIPTION (species,source etc.)? ",DES$
420 PRINT:INPUT "READY THE PRINTER & PRESS RETURN ",R1
430 LPRINT "            FORD - WALFORD PLOT"
440 LPRINT "          ***********************"
450 LPRINT
460 LPRINT DES$:LPRINT
470 LPRINT "SURFACE FACTOR D= ";D:LPRINT
480 LPRINT " (L";CHR$(27);"S";CHR$(1);"t";CHR$(27);"T";")";
490 LPRINT CHR$(27);"S";CHR$(0);"D";CHR$(27);"T";
500 LPRINT TAB(38);"(L";CHR$(27);"S";CHR$(1);"t+1";CHR$(27);"T";")";
510 LPRINT CHR$(27);"S";CHR$(0);"D";CHR$(27);"T"
520 LPRINT "-----";TAB(30);"------"
530 FOR K=1 TO I
540 LPRINT X(K)^D;TAB(30);Y(K)^D
550 NEXT K
560 XX=0:YY=0:XY=0:XX2=0:YY2=0
570 REM* LINEAR REGRESSION ROUTINE
580 FOR K=1 TO I
590 XX=XX+X(K)^D:YY=YY+Y(K)^D:XY=XY+(X(K)^D)*(Y(K)^D):XX2=XX2+(X(K)^D)^2:YY2=YY2+(Y(K)^D)^2
600 NEXT K
610 B1=XY-(XX*YY/I)
620 B2=XX2-((XX^2)/I)
630 B3=YY2-((YY^2)/I)
640 B4=(B2*B3)^.5
650 R=B1/B4
660 B=B1/B2
670 BB=B/R:REM *** GEOMETRIC MEAN OR TYPE II REGRESSION
680 AA=YY/I-(BB*XX/I)
690 LPRINT
700 LPRINT "INTERCEPT a =";AA
710 LPRINT "SLOPE     b =";BB
720 LPRINT "CORRELATION COEFFICIENT r =";R
730 LL=(AA/(1-BB))^(1/D)
740 KK=-(LOG(BB))/D
750 LPRINT:LPRINT
760 LPRINT "L";CHR$(27);"S";CHR$(1);"00";CHR$(27);"T";" = ";LL
```

```
770 LPRINT "K   = ";KK
780 PRINT "Loo =";LL
790 PRINT "K   =";KK
800 LPRINT "------------------------------------------------------------------------"
810 LPRINT
820 RETURN
830 REM ************************************************************************
840 REM* TERMINATION
850 HOME:PRINT:INPUT "RERUN WITH DIFFERENT D VALUES (Y/N) ",W$
860 IF W$="Y" THEN 880 ELSE IF W$="N" THEN 870 ELSE 850
870 CLOSE:RUN"MENU.BAS"
880 RETURN
890 REM ************************************************************************
900 REM INPUT DATA ROUTINE
910 IF F$="S" THEN  920 ELSE 950
920 VTAB 1:INPUT "NO. OF AGE CLASSES ? ",J
930 IF J=1 OR J=0 THEN 920
940 I=J-1:GOTO 970
950 VTAB 1:INPUT "NO. OF PAIRS OF CONSECUTIVE LENGTHS ? ",I
960 IF I=0 THEN 950
970 OPTION BASE 1
980 DIM X(I+1),Y(I)
990 VTAB 3:PRINT " t";TAB(10);"L(t)";TAB(30);"L(t+1)"
1000 FOR K=1 TO I
1010 VTAB 4+K:PRINT K;TAB(10);
1020 INPUT X(K)
1030 IF F$="M" THEN 1040 ELSE 1050
1040 VTAB 4+K:HTAB 30:INPUT Y(K)
1050 NEXT K
1060 IF F$="S" THEN 1070 ELSE 1110
1070 HTAB 10:INPUT X(I+1)
1080 FOR K=1 TO I
1090 VTAB 4+K:HTAB 30:Y(K)=X(K+1):PRINT Y(K)
1100 NEXT K
1110 RETURN
1120 REM ************************************************************************
```

Gulland & Holt plot

```
10  REM **** HOLT.BAS
20  REM *** PROGRAMMED BY HAEZTRA GOONETILLEKE - BOBP,COLOMBO-SRI LANKA.-AUG-86
30  REM * GULLAND & HOLT PLOT
40  REM * LAST UPDATE 25/08/86
50  REM ************************************************************************
60  REM ** (L2^D-L1^D)/(t2-t1)=a+b(L1^D+L2^D)/2
70  REM ** where b=[&xy-&x&y/n]/[&x^2-(&x)^2/n]    ** & denotes summation
80  REM ** a=&y/n - b.&x/n
90 REM ** r (abs.corr.coeff.)emp. =Sxy/SQ.RT(SxxSyy)
100 REM ** r=[&xy-&x&y/n]/SQ.RT{[&x^2-(&x)^2/n][&y^2-(&y)^2/n]}
110 REM ** Loo=(a/KD)^(1/D) & K=-b/D
120 REM ** This program is written using Microsoft version 2.23b - with MBASIC
130 REM ** for APPLE IIe micro computer with Softcard CP/M
140 REM ************************************************************************
150 GOSUB 700:REM INITIALISATION & INPUT DATA
160 GOSUB 200:REM CALCULATE & PRINT RESULTS
170 GOSUB 640:REM TERMINATION
```


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```
180 IF W$="Y" THEN 160
190 REM ************************************************************************
200 REM * CALCULATE & PRINT RESULTS
210 PRINT :INPUT "enter surface factor D (0-1) ";D
220 IF D>1 THEN 210  ELSE IF D<0 THEN 210  ELSE 230
230 PRINT :LINE INPUT "ENTER DESCRIPTION (source,species etc.) ?";DES$
240 PRINT:INPUT "READY THE PRINTER & PRESS RETURN ",R1
250 LPRINT "            GULLAND & HOLT PLOT "
260 LPRINT "           ***********************"
270 LPRINT
280 LPRINT DES$:LPRINT
290 LPRINT "SURFACE FACTOR D= ";D:LPRINT
300 LPRINT " L";CHR$(27);"S":CHR$(1);"1";CHR$(27);"T";TAB(24);"L";CHR$(27);"S";CHR$(1);"2";CHR$(27);"T";TAB(38);
"t";CHR$(27);"S";CHR$(1);"2";CHR$(27);"T";"-t";CHR$(27);"S";CHR$(1);"1";CHR$(27);"T";"       X";"         Y"
310 LPRINT " --";TAB(20);"--";TAB(30);"-----";TAB(42);"-";TAB(52);"-"
320 FOR K=1 TO I
330 X(K)=(L1(K)^D+L2(K)^D)/2
340 Y(K)=(L2(K)^D-L1(K)^D)/T(K)
350 LPRINT L1(K);TAB(20);L2(K);TAB(30);T(K);TAB(40);X(K);TAB(50);Y(K)
360 NEXT K
370 XX=0:YY=0:XY=0:XX2=0:YY2=0
380 REM* LINEAR REGRESSION ROUTINE
390 FOR K=1 TO I
400 XX=XX+X(K):YY=YY+Y(K):XY=XY+X(K)*Y(K):XX2=XX2+X(K)^2:YY2=YY2+Y(K)^2
410 NEXT K
420 B1=XY-(XX*YY/I)
430 B2=XX2-((XX^2)/I)
440 B3=YY2-((YY^2)/I)
450 B4=(B2*B3)^.5
460 R=B1/B4
470 B=B1/B2
480 A=YY/I-(B*XX/I)
490 LPRINT
500 LPRINT "INTERCEPT a =";A
510 LPRINT "SLOPE     b =";B
520 LPRINT "CORRELATION COEFFICIENT r =";R
530 KK=-B/D
540 LL=(A/(KK*D))^(1/D)
550 LPRINT:LPRINT
560 LPRINT "L";CHR$(27);"S";CHR$(1);"00";CHR$(27);"T";" = ";LL
570 LPRINT "K   = ";KK
580 PRINT "Loo =";LL
590 PRINT "K   =";KK
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 730
```


<<

```
750 OPTION BASE 1
760 DIM X(I),Y(I),L1(I),L2(I),T(I)
770 VTAB 7:PRINT "No.";TAB(12);"L1";TAB(22);"L2";TAB(32);"t2-t1"
780 FOR K=1 TO I
790 VTAB 7+K:PRINT K;TAB(10);
800 INPUT L1(K)
810 VTAB 7+K:HTAB 20:INPUT L2(K)
820 VTAB 7+K:HTAB 30:INPUT T(K)
830 NEXT K
840 RETURN
850 REM ************************************************************************
```

Von Bertalanffy plot

```
10  REM **** VON.BAS
20  REM *** PROGRAMMED BY HAEZTRA GOONETILLEKE - BOBP,COLOMBO-SRI LANKA.-AUG-86
30  REM * VON BERTALANFFY PLOT
40  REM * LAST UPDATE 26/08/86
50  REM ************************************************************************
60  REM ** LOG (1-(Lt/Loo)^D)=KDto-KDt
70  REM ** where b=[&xy-&x&y/n]/[&x^2-(&x)^2/n]   ** & denotes summation
80  REM ** a=&y/n - b.&x/n
90  REM ** r (abs.corr.coeff.)emp. =Sxy/SQ.RT(SxxSyy)
100 REM ** r=[&xy-&x&y/n]/SQ.RT{[&x^2-(&x)^2/n][&y^2-(&y)^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 IIe micro computer with Softcard CP/M
140 REM ************************************************************************
150 GOSUB 700:REM INITIALISATION & INPUT DATA
160 GOSUB 200:REM CALCULATE & PRINT RESULTS
170 GOSUB 640:REM TERMINATION
180 IF W$="Y" THEN 160
190 REM ************************************************************************
200 REM * CALCULATE & PRINT RESULTS
210 PRINT :INPUT "enter surface factor D (0-1) ";D
220 IF D>1 THEN 210  ELSE IF D<0 THEN 210  ELSE 230
230 PRINT:INPUT "ENTER Loo ";LL
240 PRINT :LINE INPUT "ENTER DESCRIPTION (including species,source etc.)?";DES$
250 PRINT:INPUT "READY THE PRINTER & PRESS RETURN ",R1
260 LPRINT "             VON BERTALANFFY PLOT "
270 LPRINT "           ***********************"
280 LPRINT
290 LPRINT DES$:LPRINT
300 LPRINT "SURFACE FACTOR D = ";D:LPRINT:LPRINT "L";CHR$(27);"S";CHR$(1);"00";CHR$(27);"T";" = ";LL:LPRINT
310 LPRINT "  t";TAB(15);"L";CHR$(27);"S";CHR$(1);"t";CHR$(27);"T";TAB(38);"Y"
320 LPRINT "  -";TAB(15);"--";TAB(34);"-"
330 FOR K=1 TO I
340 Y(K)=-LOG(1-(L(K)/LL)^D)
350 LPRINT X(K);TAB(13);L(K);TAB(30);Y(K)
360 NEXT K
370 XX=0:YY=0:XY=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=XX2-((XX^2)/I)
```

```
440 B3=YY2-((YY^2)/I)
450 B4=(B2*B3)^.5
460 R=B1/B4
470 B=B1/B2
480 A=YY/I-(B*XX/I)
490 LPRINT
500 LPRINT "INTERCEPT a =";A
510 LPRINT "SLOPE     b =";B
520 LPRINT "CORRELATION COEFFICIENT r =";R
530 KK=B/D
540 T0=-A/B
550 LPRINT:LPRINT
560 LPRINT "t";CHR$(27);"S";CHR$(1);"0";CHR$(27);"T";"  = ";T0
570 LPRINT "K   = ";KK
580 PRINT "to  =";T0
590 PRINT "K   =";KK
600 LPRINT "--------------------------------------------------------------------------"
610 LPRINT
620 RETURN
630 REM ********************************************************************
640 REM* TERMINATION
650 HOME:PRINT:INPUT "RERUN WITH DIFFERENT D VALUES (Y/N) ",W$
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 " VON BERTALANFFY PLOT "
720 PRINT :PRINT TAB(25);"*********************"
730 VTAB 5:INPUT "NO. OF PAIRS OF t,Lt  ? ",I
740 IF I=0 THEN 730
750 OPTION BASE 1
760 DIM X(I),Y(I),L(I)
770 VTAB 7:PRINT "No.";TAB(12);"t";TAB(22);"Lt"
780 FOR K=1 TO I
790 VTAB 7+K:PRINT K;TAB(10);
800 INPUT X(K)
810 VTAB 7+K:HTAB 20:INPUT L(K)
820 NEXT K
830 RETURN
840 REM ********************************************************************
```

Jones & Von Zalinge method

```
10  REM **** JONES.BAS
20  REM *** PROGRAMMED BY HAEZTRA GOONETILLEKE - BOBP,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 ** LOG(C(L,Loo))=a+(Z/KD)*LOG(Loo^D-L^D)
80  REM ** where b=[&xy-&x&y/n]/[&x^2-(&x)^2/n]    ** & denotes summation
90  REM ** a=&y/n - b.&x/n
100 REM ** r (abs.corr.coeff.)emp. =Sxy/SQ.RT(SxxSyy)
110 REM ** r=[&xy-&x&y/n]/SQ.RT{[&x^2-(&x)^2/n][&y^2-(&y)^2/n]}
120 REM ** Z=b*K*D
130 REM ** This programme will estimate total mortality rate Z.
```

```
140 REM ** This program is written using Microsoft version 2.23b - with MBASIC
150 REM ** for APPLE IIe micro computer with Softcard CP/M
160 REM **********************************************************************
170 GOSUB  260:REM INITIALISATION
180 GOSUB 1340:REM READ DATA FILE
190 FOR K=1 TO H
200 GOSUB 430:REM CALCULATE & PRINT RESULTS
210 NEXT K
220 GOSUB 1270:REM TERMINATION
230 IF W$="Y" THEN GOSUB 920:REM REGRESSION CALCULATION ROUTINE
240 GOTO 220
250 REM **********************************************************************
260 REM ** INITIALISATION ROUTINE
270 HOME :HTAB 15:PRINT " JONES & VAN ZALINGE METHOD"
280 PRINT:PRINT TAB(15)" **************************"
290 VTAB 10:PRINT"enter / to return to main menu"
300 VTAB  7:INPUT "ENTER FILE NAME(maximum 8 characters ) :- ",F$
310 IF F$="/" THEN GOTO 1310
320 IF LEN(F$)=0 THEN 300
330 VTAB 10:PRINT "                              "
340 VTAB 12:INPUT "ENTER Loo ";LL
350 IF LL=0 THEN 340
360 VTAB 13:INPUT "ENTER K   ";KK
370 IF KK=0 THEN 360
380 VTAB 14:INPUT "ENTER D   ";DD
390 IF DD<0 OR DD>1 THEN 380
400 PRINT:PRINT:INPUT "READY THE PRINTER & PRESS RETURN TO PROCEED ",O$
410 RETURN
420 REM *******************************************************************
430 REM * CALCULATE & PRINT RESULTS
440 LPRINT "                 JONES & VAN ZALINGE METHOD"
450 LPRINT "                 **************************"
460 LPRINT
470 LPRINT "FILE NAME :- ";F$:LPRINT
480 LPRINT D$
490 LPRINT:LPRINT "L";CHR$(27);"S";CHR$(1);"00";CHR$(27);"T";" = ";LL:LPRINT "K   = ";KK
500 LPRINT "D   = ";DD
510 LPRINT
520 HOME :PRINT "SAMPLE ";K:LPRINT "SAMPLE ";K:PRINT
530 PRINT: LPRINT
540 XX=0:YY=0:XY=0:XX2=0:YY2=0:TT=0:TN=0
550 FOR I=1 TO C(K)
560 L1(K,I)=X(K,I)-D/2
570 Z(K,I)=LOG(LL^DD-L1(K,I)^DD)
580 REM * X AXIS = LOG OF (Loo-L1)
590 NEXT I
600 FOR I= C(K) TO 1 STEP -1
610 TT=TT+F(K,I)
620 Y(K,I)=LOG(TT)
630 REM * Y AXIS = LOG OF CUMULATED CATCH C(L1,Loo)
640 NEXT I
650 LPRINT "   L";CHR$(27);"S";CHR$(1);"1";CHR$(27);"T";"-L";CHR$(27);"S";CHR$(1);"2";CHR$(27);"T";
660 LPRINT TAB(24);"C(L";CHR$(27);"S";CHR$(1);"1";CHR$(27);"T";",L";CHR$(27);"S";CHR$(1);"2";CHR$(27);"T";")";
670 LPRINT TAB(43);"C(L";CHR$(27);"S";CHR$(1);"1";CHR$(27);"T";",L";CHR$(27);"S";CHR$(1);"00";CHR$(27);"T";")";
680 LPRINT "    ln(C(L";CHR$(27);"S";CHR$(1);"1";CHR$(27);"T";",L";CHR$(27);"S";CHR$(1);"00";CHR$(27);"T";"))";
690 LPRINT "    ln(L";CHR$(27);"S";CHR$(1);"00";CHR$(27);"T";"-L";CHR$(27);"S";CHR$(1);"1";CHR$(27);"T";")"
700 LPRINT "   -----";TAB(16);"--------";TAB(27);"---------";TAB(40);"------------";TAB(57);"----------"
710 FOR I= 1 TO C(K)
720 LPRINT L1(K,I);TAB(7);"-";L1(K,I)+D;TAB(16);F(K,I);TAB(28);INT(EXP(Y(K,I)));TAB(40);Y(K,I);TAB(57);Z(K,I)
```


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```
730 NEXT I
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 I=1 TO C(K)
810 IF CINT(Y(K,I)*2)<0  OR CINT(Y(K,1)*2)+1-CINT(Y(K,I)*2)>24 OR  CINT(Z(K,I)*SS)<=0 OR CINT(Z(K,I)*SS)>80
 THEN 830 ELSE GOTO 820
820 VTAB CINT(Y(K,1)*2)+1-CINT(Y(K,I)*2):PRINT TAB(CINT(Z(K,I)*SS)) "*";I
830 NEXT I
840 FOR TTT = 1 TO 5000
850 REM DELAY FOR VIEWING GRAPH
860 NEXT TTT
870 INPUT "IF YOU WISH TO DISPLAY THE ABOVE SCATTERGRAM ON THE SCREEN AGAIN ENTER Y        ELSE PRESS RETURN ";AA$
880 IF AA$="Y" THEN 750 ELSE 890
890 PRINT:PRINT "PLEASE DRAW A SCATTERGRAM WITH THE PRINTED VALUES"
900 PRINT "THEN SELECT POINTS BELONGING TO THE STRAIGHT SEGMENT OF THE PLOT"
910 PRINT:PRINT:PRINT
920 REM ***** REGRESSION CALCULATION ROUTINE
930 PRINT "ENTER THE STARTING & ENDING NUMBER OF THE POINTS SELECTED FOR REGRESSION"
940 PRINT:INPUT "STARTING NO.";S1
950 IF S1=0 OR S1>C(K) THEN 940
960 PRINT :INPUT "ENDING NO.";S2
970 IF S2=0 OR S2>C(K) THEN 960
980 IF S1>=S2 THEN PRINT "ERROR -ENTER AGAIN ":GOTO 940
990 IF S2-S1<2 THEN PRINT "ERROR -ENTER AGAIN ":GOTO 940
1000 LPRINT "SAMPLE ";K
1010 LPRINT "   L";CHR$(27);"S";CHR$(1);"1";CHR$(27);"T";"-L";CHR$(27);"S";CHR$(1);"2";CHR$(27);"T";
"       slope      Z         N Sb";CHR$(27);"S";CHR$(0);"2";CHR$(27);"T";TAB(64);"CONFIDENCE LIMITS OF Z"
1020 LPRINT "   -----";TAB(16);"-----";TAB(25);" -";TAB(34);" -";TAB(40);" ---";TAB(52);"----------------------
1030 FOR I=S1 TO S1+1
1040 XX=XX+Z(K,I):YY=YY+Y(K,I):XY=XY+Z(K,I)*Y(K,I):XX2=XX2+Z(K,I)^2:YY2=YY2+Y(K,I)^2:TN=TN+1
1050 LPRINT L1(K,I);TAB(7);"-";L1(K,I)+D;TAB(16);" -";TAB(25);" -";TAB(34);TN;TAB(41);" -";TAB(64);" -"
1060 NEXT I
1070 FOR I= S1+2 TO S2
1080 XX=XX+Z(K,I):YY=YY+Y(K,I):XY=XY+Z(K,I)*Y(K,I):XX2=XX2+Z(K,I)^2:YY2=YY2+Y(K,I)^2:TN=TN+1
1090 B1=XY-(XX*YY/TN)
1100 B2=XX2-((XX^2)/TN)
1110 B=B1/B2
1120 A=YY/TN-(B*XX/TN)
1130  B3=YY2-((YY^2)/TN)
1140 B4=(B2*B3)^.5
1150 R=B1/B4
1160 SB2=(B3/B2-B^2)/(TN-2)
1170 IF SB2<0 THEN SB2=0:REM AVOID NEGATIVE VALUES BEFORE FINDING ROOT
1180 SB=SQR(SB2)
1190 GOSUB 1500
1200 LPRINT L1(K,I);TAB(7);"-";L1(K,I)+D;TAB(14);B;TAB(24);KK*B*DD;TAB(34);TN;TAB(38);SB2;TAB(48);KK*B*DD;"-";
CONF1*SB*KK*DD;TAB(68);"=";KK*B*DD-CONF1*SB*KK*DD
1210 LPRINT TAB(48);KK*B*DD;"+";CONF1*SB*KK*DD;TAB(68);"=";KK*B*DD+CONF1*SB*KK*DD
1220 NEXT I
1230 LPRINT "--------------------------------------------------------------------------------"
1240 LPRINT
1250 RETURN
1260 REM ************************************************************************
1270 REM* TERMINATION
```

```
1280 HOME:PRINT:INPUT "RERUN WITH DIFFERENT STARTING & ENDING POINTS(Y/N)", W$
1290 IF W$="Y" THEN 1300 ELSE IF W$="N" THEN 1310 ELSE 1280
1300 INPUT "SAMPLE NO.";K:IF K=0 OR K>H THEN 1300 ELSE 1320
1310 CLOSE:RUN"MENU.BAS"
1320 RETURN
1330 REM ************************************************************************
1340 REM READ DATA FROM DISK
1350 OPEN "I",1,F$
1360 OPTION BASE 1
1370 LINE INPUT #1,D$
1380 INPUT #1,H,C,L1,L2
1390 D=L2-L1
1400 DIM X(H,C),F(H,C),C(H),M(H),L1(H,C),Y(H,C),Z(H,C)
1410 FOR K=1 TO H
1420 INPUT #1,M(K),C(K)
1430 FOR J=1 TO C(K)
1440 INPUT #1,X(K,J),F(K,J)
1450 NEXT J
1460 NEXT K
1470 CLOSE #1
1480 RETURN
1490 REM ************************************************************************
1500 REM *** CONFIDENCE LIMITS ROUTINE
1510 IF TN-2 <= 30 THEN 1540 ELSE IF TN-2 <40 THEN 1580 ELSE IF TN-2 <60 THEN 1590
1520 IF TN-2 <80 THEN 1600 ELSE IF TN-2 <100 THEN 1610
1530 IF TN-2 <120 THEN 1620 ELSE IF TN-2 =120 THEN 1630 ELSE 1640
1540 RESTORE
1550 FOR CC=1 TO 30:READ CONF,CONF1
1560 IF CONF=TN-2 THEN CC=30
1570 NEXT CC:GOTO 1660
1580 RESTORE 1700:GOTO 1650
1590 RESTORE 1710:GOTO  1650
1600 RESTORE 1720:GOTO 1650
1610 RESTORE 1730:GOTO 1650
1620 RESTORE 1740 :GOTO 1650
1630 RESTORE 1750:GOTO 1650
1640 RESTORE 1760
1650 READ CONF,CONF1
1660 RETURN
1670 DATA 1,12.706,2,4.303,3,3.182,4,2.776,5,2.571,6,2.447,7,2.365,8,2.306,9,2.262,10,2.228
1680 DATA 11,2.201,12,2.179,13,2.160,14,2.145,15,2.131,16,2.120,17,2.110,18,2.101,19,2.093,20,2.086
1690 DATA 21,2.080,22,2.074,23,2.069,24,2.064,25,2.060,26,2.056,27,2.052,28,2.048,29,2.045
1700 DATA 30,2.042
1710 DATA 40,2.021
1720 DATA 60,2.000
1730 DATA 80,1.99
1740 DATA 100,1.98
1750 DATA 120,1.980
1760 DATA 9999,1.960
```

Sparre's method

```
10  REM **** SPARRE.BAS
20  REM *** PROGRAMMED BY HAEZTRA GOONETILLEKE - BOBP,COLOMBO-SRI LANKA.-SEP. 86
30  REM * THE CATCH CURVE BASED ON LENGTH COMPOSITION DATA.
40  REM * SPARRE'S METHOD FOR CALCULATING TOTAL MORTALITY
50  REM * LAST UPDATE 05/09/86
```

```
60  REM ***********************************************************************
70  REM ** LOG(C(L1,L2)/dT)=c -Z t((L1+L2)/2)
80  REM ** where b=[&xy-&x&y/n]/[&x^2-(&x)^2/n]   ** & denotes summation
90  REM ** a=&y/n - b.&x/n
100 REM ** r (abs.corr.coeff.)emp. =Sxy/SQ.RT(SxxSyy)
110 REM ** r=[&xy-&x&y/n]/SQ.RT([&x^2-(&x)^2/n][&y^2-(&y)^2/n])
120 REM ** Z=b
130 REM ** This programme will estimate total mortality rate Z.
140 REM ** This program is written using Microsoft version 2.23b - with MBASIC
150 REM ** for APPLE IIe micro computer with Softcard CP/M
160 REM ***********************************************************************
170 GOSUB  260: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 1260:REM TERMINATION
230 IF W$="Y" THEN GOSUB 910
240 GOTO 220
250 REM ***********************************************************************
260 REM ** INITIALISATION ROUTINE
270 HOME :HTAB 15:PRINT " SPARRE'S CATCH CURVE METHOD"
280 PRINT:PRINT TAB(15)" ***************************"
290 VTAB 10:PRINT"enter / to return to main menu"
300 VTAB  7:INPUT "ENTER FILE NAME(maximum 8 characters ) :- ",F$
310 IF F$="/" THEN GOTO 1300
320 IF LEN(F$)=0 THEN 300
330 VTAB 10:PRINT "                                     "
340 VTAB 12:INPUT "ENTER Loo ";LL
350 IF LL=0 THEN 340
360 VTAB 13:INPUT "ENTER K   ";KK
370 IF KK=0 THEN 360
380 PRINT:PRINT:INPUT "READY THE PRINTER & PRESS RETURN TO PROCEED ",O$
390 RETURN
400 REM ***********************************************************************
410 REM * CALCULATE & PRINT RESULTS
420 LPRINT "                SPARRE'S CATCH CURVE METHOD"
430 LPRINT "                ***************************"
440 LPRINT
450 LPRINT "FILE NAME :- ";F$:LPRINT
460 LPRINT D$
470 LPRINT:LPRINT "L";CHR$(27);"S";CHR$(1);"00";CHR$(27);"T";" = ";LL:LPRINT "K   = ";KK
480 LPRINT:LPRINT
490 HOME :PRINT "SAMPLE ";K:LPRINT "SAMPLE ";K:PRINT
500 PRINT: LPRINT: LPRINT
510 XX=0:YY=0:XY=0:XX2=0:YY2=0:TT=0:TN=0
520 FOR I=1 TO C(K)
530 L1(K,I)=X(K,I)-D/2
540 IF LL<L1(K,I) OR LL<L1(K,I)+D THEN Y(K,I)=0:GOTO 570
550 Y(K,I)=(1/KK)*(LOG((LL-L1(K,I))/(LL-L1(K,I)-D)))
560 REM * DELTA T
570 IF X(K,I)/LL >1 THEN Z(K,I)=0:GOTO 590
580 Z(K,I)=-(1/KK)*(LOG(1-X(K,I)/LL)):REM * X AXIS
590 NEXT I
600 LPRINT "   L";CHR$(27);"S";CHR$(1);"1";CHR$(27);"T";"-L";CHR$(27);"S";CHR$(1);"2";CHR$(27);"T";
610 LPRINT "       C(L";CHR$(27);"S";CHR$(1);"1";CHR$(27);"T";
620 LPRINT ",L";CHR$(27);"S";CHR$(1);"2";CHR$(27);"T";
630 LPRINT ")     D";CHR$(27);"S";CHR$(1);"t";CHR$(27);"T";
```


<<

```
640 LPRINT "         t{(L";CHR$(27);"S";CHR$(1);"1";CHR$(27);"T";"+L";CHR$(27);"S";CHR$(1);"2";CHR$(27);"T";
"}/2}   ln(C(L";CHR$(27);"S";CHR$(1);"1";CHR$(27);"T";
650 LPRINT ",L";CHR$(27);"S";CHR$(1);"2";CHR$(27);"T";")/D";CHR$(27);"S";CHR$(1);"t";CHR$(27);"T";")"
660 LPRINT "   -----";TAB(16);"---------";TAB(29);"--";TAB(39);"------------";TAB(54);"---------------"
670 FOR I= 1 TO C(K)
680 IF LL<L1(K,I) OR LL<L1(K,I)+D OR X(K,I)/LL >1 THEN 690 ELSE 700
690 LPRINT L1(K,I);TAB(7);"-";L1(K,I)+D;TAB(16);F(K,I);TAB(28);" -";TAB(42);" -";TAB(56);" -":GOTO 720
700 LPRINT L1(K,I);TAB(7);"-";L1(K,I)+D;TAB(16);F(K,I);TAB(26);Y(K,I);TAB(40);Z(K,I);TAB(54);LOG(F(K,I)/Y(K,I))
710 Y(K,I)=LOG(F(K,I)/Y(K,I)):REM * Y AXIS
720 NEXT I
730 REM *** PLOT GRAPH ON SCREEN
740 HOME
750 IF CINT(Z(K,1)*20)>80 THEN 760 ELSE 770
760 SS=10:GOTO 780:REM X AXIS SAME SCALE
770 SS=20:REM X AXIS.SCALE *2
780 FOR I=1 TO C(K)
790 IF CINT(Y(K,I)*2)<0  OR CINT(Y(K,I)*2)>24 OR  CINT(Z(K,I)*SS)<=0 OR CINT(Z(K,I)*SS)>80 THEN 810 ELSE GOTO 800
800 VTAB 24-CINT(Y(K,I)*2):PRINT TAB(CINT(Z(K,I)*SS)) "*";I
810 NEXT I
820 LPRINT
830 FOR TTT = 1 TO 5000
840 REM DELAY FOR VIEWING GRAPH
850 NEXT TTT
860 INPUT "IF YOU WISH TO DISPLAY THE ABOVE SCATTERGRAM ON THE SCREEN AGAIN ENTER Y        ELSE PRESS RETURN ";AA$
870 IF AA$="Y" THEN 730 ELSE 880
880 PRINT:PRINT "PLEASE DRAW A SCATTERGRAM WITH THE PRINTED VALUES"
890 PRINT "THEN SELECT POINTS BELONGING TO THE STRAIGHT SEGMENT OF THE PLOT"
900 PRINT:PRINT:PRINT
910 REM **** REGRESSION CALCULATION ROUTINE
920 PRINT "ENTER THE STARTING & ENDING NUMBER OF THE POINTS SELECTED FOR REGRESSION"
930 PRINT:INPUT "STARTING NO.";S1
940 IF S1=0 OR S1>C(K) THEN 930
950 PRINT :INPUT "ENDING NO.";S2
960 IF S2=0 OR S2>C(K) THEN 950
970 IF S1>=S2 THEN PRINT "ERROR -ENTER AGAIN ":GOTO 930
980 IF S2-S1<2 THEN PRINT "ERROR -ENTER AGAIN ":GOTO 930
990 LPRINT "SAMPLE ",K
1000 LPRINT "   L";CHR$(27);"S";CHR$(1);"1";CHR$(27);"T";"-L";CHR$(27);"S";CHR$(1);"2";CHR$(27);"T";
"           Z              N  Sb";CHR$(27);"S";CHR$(0);"2";CHR$(27);"T";"        CONFIDENCE LIMITS OF Z"
1010 LPRINT "   -----";TAB(20);" -";TAB(34);" -";TAB(40);" ---";TAB(52);"----------------------"
1020 FOR I=S1 TO S1+1
1030 XX=XX+Z(K,I):YY=YY+Y(K,I):XY=XY+Z(K,I)*Y(K,I):XX2=XX2+Z(K,I)^2:YY2=YY2+Y(K,I)^2:TN=TN+1
1040 LPRINT L1(K,I);TAB(7);"-";L1(K,I)+D;TAB(20);" -";TAB(34);TN;TAB(41);" -";TAB(64);" -"
1050 NEXT I
1060 FOR I= S1+2 TO S2
1070 XX=XX+Z(K,I):YY=YY+Y(K,I):XY=XY+Z(K,I)*Y(K,I):XX2=XX2+Z(K,I)^2:YY2=YY2+Y(K,I)^2:TN=TN+1
1080 B1=XY-(XX*YY/TN)
1090 B2=XX2-((XX^2)/TN)
1100 B=B1/B2:B=-B
1110 A=YY/TN-(B*XX/TN)
1120  B3=YY2-((YY^2)/TN)
1130 B4=(B2*B3)^.5
1140 R=B1/B4
1150 SB2=(B3/B2-B^2)/(TN-2)
1160 IF SB2<0 THEN SB2=0:REM AVOID NEGATIVE VALUES BEFORE FINDING THE ROOT
1170 SB=SQR(SB2)
1180 GOSUB 1490
1190 LPRINT L1(K,I);TAB(7);"-";L1(K,I)+D;TAB(20);B;TAB(34);TN;TAB(38);SB2;TAB(48);B;"-";CONF1*SB;TAB(68);"=";B-CONF1*SB
```


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```
1200 LPRINT TAB(48);B;"+";CONF1*SB;TAB(68);"=";B+CONF1*SB
1210 NEXT I
1220 LPRINT "-----------------------------------------------------------------------------"
1230 LPRINT
1240 RETURN
1250 REM ************************************************************************
1260 REM* TERMINATION
1270 HOME:PRINT:INPUT "RERUN 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,",K:IF K=0 OR K>H THEN 1290 ELSE 1310
1300 CLOSE:RUN"MENU.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),M(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-2 <= 30 THEN 1530 ELSE IF TN-2 <40 THEN 1570 ELSE IF TN-2 <60 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,CONF1
1550 IF CONF=TN-2 THEN CC=30
1560 NEXT CC:GOTO 1650
1570 RESTORE 1690: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 1,12.706,2,4.303,3,3.182,4,2.776,5,2.571,6,2.447,7,2.365,8,2.306,9,2.262,10,2.228
1670 DATA 11,2.201,12,2.179,13,2.160,14,2.145,15,2.131,16,2.120,17,2.110,18,2.101,19,2.093,20,2.086
1680 DATA 21,2.080,22,2.074,23,2.069,24,2.064,25,2.060,26,2.056,27,2.052,28,2.048,29,2.045
1690 DATA 30,2.042
1700 DATA 40,2.021
1710 DATA 60,2.000
1720 DATA 80,1.99
1730 DATA 100,1.98
1740 DATA 120,1.980
1750 DATA 9999,1.960
```


<<

Wetheral et al. method

```
10  REM **** WET.BAS
20  REM *** PROGRAMMED BY HAEZTRA GOONETILLEKE - BOBP,COLOMBO-SRI LANKA.-SEP. 86
30  REM * WETHERAL ET AL METHOD FOR ESTIMATING Loo & Z/K
40  REM * LAST UPDATE 16/09/86
50  REM ***************************************************************************
60  REM ** Y=Loo/(1+Z/K) + X*(Z/K)/(1+Z/K)
70  REM ** y=a+xb
80  REM ** where b=[&xy-&x&y/n]/[&x^2-(&x)^2/n]    ** & denotes summation
90  REM ** a=&y/n - b.&x/n
100 REM ** r (abs.corr.coeff.)emp. =Sxy/SQ.RT(SxxSyy)
110 REM ** r=[&xy-&x&y/n]/SQ.RT([&x^2-(&x)^2/n][&y^2-(&y)^2/n])
120 REM ** Y AXIS = MEAN LENGTH
130 REM ** X AXIS =LOWER LIMIT OR CUT -OFF PTS.
140 REM ** Z/K=b/(1-b) and Loo=a/(1-b)
150 REM ** This programme will estimate total mortality rate Z and Loo.
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 GOSUB  280:REM INITIALISATION
200 GOSUB 1240:REM READ DATA FILE
210 FOR K= 1 TO H
220 GOSUB 410:REM CALCULATE & PRINT RESULTS
230 NEXT K
240 GOSUB 1170:REM TERMINATION
250 IF W$="Y" THEN GOSUB 820:REM REGRESSION CALCULATION ROUTINE
260 GOTO 240
270 REM **************************************************************************
280 REM ** INITIALISATION ROUTINE
290 HOME :HTAB 15:PRINT " WETHERALL et al METHOD"
300 PRINT:PRINT TAB(15)" *********************"
310 VTAB 10:PRINT"enter / to return to main menu"
320 VTAB  7:INPUT "ENTER FILE NAME(maximum 8 characters ) :- ",F$
330 IF F$="/" THEN GOTO 1210
340 IF LEN(F$)=0 THEN 320
350 VTAB 10:PRINT "
360 VTAB 11:PRINT "IF K IS NOT KNOWN PRESS RETURN"
370 VTAB 13:INPUT "ENTER K   ";KK
380 PRINT:PRINT:INPUT "READY THE PRINTER & PRESS RETURN TO PROCEED ",O$
390 RETURN
400 REM ************************************************************************
410 REM * CALCULATE & PRINT RESULTS
420 LPRINT "               WETHERALL ";CHR$(27);"4";"ET AL";CHR$(27);"5";" METHOD"
430 LPRINT "               **********************"
440 LPRINT
450 LPRINT "FILE NAME :- ";F$:LPRINT
460 LPRINT D$
470 IF KK=0 THEN 480 ELSE LPRINT:LPRINT  "K   = ";KK
480 LPRINT
490 HOME :PRINT "SAMPLE ";K:LPRINT "SAMPLE ";K:PRINT
500 PRINT: LPRINT
510 XX=0:YY=0:XY=0:XX2=0:YY2=0:TT=0:TN=0
520 FOR J=1 TO C(K)
530 T=0:Y=0
540 FOR I=J TO C(K)
550 Y=Y+X(K,I)*F(K,I)
560 T=T+F(K,I)
570 NEXT I
```

```
580 Y(K,J)=Y/T
590 REM * Y AXIS = MEAN LENGTH
600 NEXT J
610 LPRINT "   SELECTION LENGTH (X) ";TAB(30);"MEAN LENGTH (Y)"
620 LPRINT "   -------------------- ";TAB(30);"---------------"
630 FOR I= 1 TO C(K)
640 Z(K,I)=X(K,I)-D/2
650 LPRINT "         ";Z(K,I);TAB(32);Y(K,I)
660 NEXT I
670 LPRINT:LPRINT
680 REM *** PLOT GRAPH ON SCREEN
690 HOME
700 FOR I=1 TO C(K)
705 IF 24-CINT(Y(K,I))+CINT(Y(K,1))=0 THEN 715 ELSE 709
709 IF 24-CINT(Y(K,I))+CINT(Y(K,1))<0 THEN 720
710 VTAB 24-CINT(Y(K,I))+CINT(Y(K,1))
715 PRINT TAB(CINT(Z(K,I))) "*";I
720 NEXT I
730 LPRINT
740 FOR TTT = 1 TO 5000
750 REM DELAY FOR VIEWING GRAPH
760 NEXT TTT
770 INPUT "IF YOU WISH TO DISPLAY THE ABOVE SCATTERGRAM ON THE SCREEN AGAIN ENTER Y       ELSE PRESS RETURN ";AA$
780 IF AA$="Y" THEN 680 ELSE 790
790 PRINT:PRINT "PLEASE DRAW A SCATTERGRAM WITH THE PRINTED VALUES"
800 PRINT "THEN SELECT POINTS BELONGING TO THE STRAIGHT SEGMENT OF THE PLOT"
810 PRINT:PRINT:PRINT
820 REM ***** REGRESSION CALCULATION ROUTINE
830 PRINT "ENTER THE STARTING & ENDING NUMBER OF THE POINTS SELECTED FOR REGRESSION"
840 PRINT:INPUT "STARTING NO.";S1
850 IF S1=0 OR S1>C(K) THEN 840
860 PRINT :INPUT "ENDING NO.";S2
870 IF S2=0 OR S2>C(K) THEN 860
880 IF S1>=S2 THEN PRINT "ERROR -ENTER AGAIN ":GOTO 840
890 IF S2-S1<2 THEN PRINT "ERROR -ENTER AGAIN ":GOTO 840
900 LPRINT "SAMPLE ";K
910 LPRINT "POINTS TAKEN FOR REGRESSION = ";S1;" TO ";S2
920 LPRINT
925 XX=0:YY=0:XY=0:XX2=0:YY2=0:TN=0
930 FOR I=S1 TO S2
940 XX=XX+Z(K,I):YY=YY+Y(K,I):XY=XY+Z(K,I)*Y(K,I):XX2=XX2+Z(K,I)^2:YY2=YY2+Y(K,I)^2:TN=TN+1
950 NEXT I
960 B1=XY-(XX*YY/TN)
970 B2=XX2-((XX^2)/TN)
980 B=B1/B2
990 A=YY/TN-(B*XX/TN)
1000  B3=YY2-((YY^2)/TN)
1010 B4=(B2*B3)^.5
1020 R=B1/B4
1030 LL=A/(1-B)
1040 IF KK=0 THEN ZZ=B/(1-B):GOTO 1060
1050 Z=KK*B/(1-B)
1060 LPRINT "correlation coefficient = ";R
1070 LPRINT "slope                  b = ";B
1080 LPRINT "intercept              a = ";A
1090 LPRINT
1100 LPRINT "ASYMPTOTIC LENGTH    L";CHR$(27);"S";CHR$(1);"00";CHR$(27);"T";"= ";LL
1110 IF KK=0 THEN LPRINT "                    Z/K=";ZZ:GOTO 1130
```

```
1120 LPRINT "MORTALITY COEFFICIENT Z = ";Z
1130 LPRINT "------------------------------------------------------------------------------"
1140 LPRINT
1150 RETURN
1160 REM ************************************************************************
1170 REM* TERMINATION
1180 HOME:PRINT:INPUT "RERUN WITH DIFFERENT STARTING & ENDING POINTS(Y/N)", W$
1190 IF W$="Y" THEN 1200 ELSE IF W$="N" THEN 1210 ELSE 1180
1200 INPUT "SAMPLE NO.";K:IF K=0 OR  K>H THEN 1200 ELSE 1220
1210 CLOSE:RUN"MENU.BAS"
1220 RETURN
1230 REM ************************************************************************
1240 REM READ DATA FROM DISK
1250 OPEN "I",1,F$
1260 OPTION BASE 1
1270 LINE INPUT #1,D$
1280 INPUT #1,H,C,L1,L2
1290 D=L2-L1
1300 DIM X(H,C),F(H,C),C(H),M(H),L1(H,C),Y(H,C),Z(H,C)
1310 FOR K=1 TO H
1320 INPUT #1,M(K),C(K)
1330 FOR J=1 TO C(K)
1340 INPUT #1,X(K,J),F(K,J)
1350 NEXT J
1360 NEXT K
1370 CLOSE #1
1380 RETURN
1390 REM *************************************************************************
1400 REM *** CONFIDENCE LIMITS ROUTINE
1410 IF TN-2 <= 30 THEN 1440 ELSE IF TN-2 <40 THEN 1480 ELSE IF TN-2 <60 THEN 1490
1420 IF TN-2 <80 THEN 1500 ELSE IF TN-2 <100 THEN 1510
1430 IF TN-2 <120 THEN 1520 ELSE IF TN-2 =120 THEN 1530 ELSE 1540
1440 RESTORE
1450 FOR CC=1 TO 30:READ CONF,CONF1
1460 IF CONF=TN-2 THEN CC=30
1470 NEXT CC:GOTO 1560
1480 RESTORE 1600:GOTO 1550
1490 RESTORE 1610:GOTO  1550
1500 RESTORE 1620:GOTO 1550
1510 RESTORE 1630:GOTO 1550
1520 RESTORE 1640 :GOTO 1550
1530 RESTORE 1650:GOTO 1550
1540 RESTORE 1660
1550 READ CONF,CONF1
1560 RETURN
1570 DATA 1,12.706,2,4.303,3,3.182,4,2.776,5,2.571,6,2.447,7,2.365,8,2.306,9,2.262,10,2.228
1580 DATA 11,2.201,12,2.179,13,2.160,14,2.145,15,2.131,16,2.120,17,2.110,18,2.101,19,2.093,20,2.086
1590 DATA 21,2.080,22,2.074,23,2.069,24,2.064,25,2.060,26,2.056,27,2.052,28,2.048,29,2.045
1600 DATA 30,2.042
1610 DATA 40,2.021
1620 DATA 60,2.000
1630 DATA 80,1.99
1640 DATA 100,1.98
1650 DATA 120,1.980
1660 DATA 9999,1.960
```

Appendix 2a

PERCENTAGE POINTS OF THE χ^2 DISTRIBUTION

For $v>30$ take $\chi^2_v(\alpha)=v\left[1-\frac{2}{9v}+u_\alpha\sqrt{\frac{2}{9v}}\right]^3$ where u_α is such that $\Pr(U>u_\alpha)=\alpha$, and $U \sim N(0, 1)$.

v \ a	0.250	0.100	0.050	0.025	0.010	0.005	0.001
1	1.32330	2.70554	3.84146	5.02389	6.63490	7.87944	10.828
2	2.77259	4.60517	5.99146	7.37776	9.21034	10.5966	13.816
3	4.10834	6.25139	7.81473	9.34840	11.3449	12.8382	16.266
4	5.38527	7.77944	9.48773	11.1433	13.2767	14.8603	18.467
5	6.62568	9.23636	11.0705	Ii.8325	15.0863	16.7496	20.515
6	7.84080	10.6446	12.5916	14.4494	16.8119	18.5476	22.458
7	9.03715	12.0170	14.0671	16.0128	18.4753	20.2777	24.322
8	10.2189	13.3616	15.5073	17.5345	20.0902	21.9550	26.125
9	11.3888	14.6837	16.9190	19.0228	21.6660	23.5894	27.877
10	12.5489	15.9872	18.3070	20.4832	23.2093	25.1882	29.588
11	13.7007	17.2750	19.6751	21.9200	24.7250	26.7568	31.264
12	14.8454	18.5493	21.0261	23.3367	26.2170	28.2995	32.909
13	15.9839	19.8119	22.3620	24.7356	27.6882	29.8195	34.528
14	17.1169	21.0641	23.6848	26.1189	29.1412	31.3194	36.123
15	18.2451	22.3071	24.9958	27.4884	30.5779	32.8013	37.697
16	19.3689	23.5418	26.2962	28.8454	31.9999	34.2672	39.252
17	20.4887	24.7690	27.5871	30.1910	33.4087	35.7185	40.790
18	21.6049	25.9894	28.8693	31.5264	34.8053	37.1565	42.312
19	22.7178	27.2036	30.1435	32.8523	36.1909	38.5823	43.820
20	23.8277	28.4120	31.4104	34.1696	37.5662	39.9968	45.31 5
21	24.9348	29.6151	32.6706	35.4789	38.9322	41.4011	46.797
22	26.0393	30.8133	33.9244	36.7807	40.2894	42.7957	48.268
23	27.1413	32.0069	35.1725	38.0756	41.6384-	44.1813	49.728
24	28.2412	33.1962	36.4150	39.3641	42.9798	45.5585	51.179
25	29.3389	34.3816	37.6525	40.6465	44.3141	46.9279	52.618
26	30.4346	35.5632	38.8851	41.9232	45.6417	48.2899	54.052
27	31.5284	36.7412	40.1133	43.1945	46.9629	49.6449	55.476
28	32.6205	37.9159	41.3371	44.4608	48.2782	50.9934	56.892
29	33.7109	39.0875	42.5570	45.7223	49.5879	52.3356	58.301
30	34.7997	40.2560	43.7730	46.9792	50.8922	53.6720	59.703
40	45.6160	51.8051	55.7585	59.3417	63.6907	66.7660	73.402
50	56.3336	63.1671	67.5048	71.4202	76.1539	79.4900	86.661
60	66.9815	74.3970	79.0819	83.2977	88.3794	91.9517	99.607
70	77.5767	85.5270	90.5312	95.0232	100.425	104.215	112.317
80	88.1303	96.5782	101.879	106.629	112.329	116.321	124.839
90	98.4699	107.565	113.145	118.136	124.116	128.299	137.208
100	109.141	118.498	124.342	129.561	135.807	140.169	149.449

<<

Appendix 2b

PERCENTAGE POINTS OF THE t DISTRIBUTION

conf. lim. f	95% t(f)	99% t(f)
1	12.706	63.657
2	4.303	9.925
3	3.182	5.841
4	2.776	4.604
5	2.571	4.032
6	2.447	3.707
7	2.365	3.499
8	2.306	3.355
9	2.262	3.250
10	2.228	3.169
11	2.201	3.106
12	2.179	3.055
13	2.160	3.012
14	2.145	2.977
15	2.131	2.947
16	2.120	2.921
17	2.110	2.898
18	2.101	2.878
19	2.093	2.861
20	2.086	2.845
21	2.080	2.831
22	2.074	2.819
23	2.069	2.807
24	2.064	2.797
25	2.060	2.787
26	2.056	2.779
27	2.052	2.771
28	2.048	2.763
29	2.045	2.756
30	2.042	2.750
40	2.021	2.704
60	2.000	2.660
80	1.99	2.64
100	1.98	2.63
120	1.980	2.617
∞	1.960	2.576

Appendix 3

BHATTACHARYA ANALYSIS

Test Data

SAMPLE 1, MONTH 1

Mid-Length	Frequency
0.5	2.00
1.5	23.00
2.5	22.00
3.5	1.00
4.5	37.00
5.5	28.00
6.5	1 .00
7.5	6.00
8.5	17.00
9.5	16.00
10.5	5.00
11.5	2.00
12.5	3.00
13.5	6.00
14.5	6.00
15.5	15.00
16.5	6.00
17.5	2.00
18.5	2.00

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. =.997593
Group 2 Mean =5
Std. Dev. =.452461 No. of Items=69.0703

Mid Pts.6.5 7.5 8.5
Abs. Corr. Coeff. = .994056

Mid Pts=7.5 8.5 9.5
Abs. Corr. Coeff.= 1
Group 3 Mean =8.94487
Std. Dev. =.907667 No. of Items=45.3859

<<

Mid Pts. 8.5 9.5 10.5
Abs. Corr. Coeff. .739446

Mid Pts. 11.5 12.5 13.5
Abs. Corr. Coeff. .5821

Mid Pts. 13.5 14.5 15.5
Abs. Corr. Coeff. .500008

Mid Pts. 14.5 15.5 16.5
Abs. Corr. Coeff. .904039

File Name : Pauly
Test Data from Pauly & Caddy (1985) — Page 4
Input value of critical value of correlation coefficient .904

SAMPLE 1

MONTH 1

Mid Pts. .5 1.5 2.5
Abs. Corr. Coeff. .998299
Group 1 Mean 1.91649
Std. Dev. .52736 No. of Items 49.296

Mid Pts. 3.5 4.5 5.5
Abs. Corr. Coeff. .997593
Group 2 Mean 5
Std. Dev. .452461 No. of Items 69.0703

Mid Pts. 6.5 7.5 8.5
Abs. Corr. Coeff. .994056
Group 3 Mean 8.99782
Std Dev. .998164 No. of Items 46.9219

Mid Pts. 7.5 8.5 9.5
Abs. Corr. Coeff. 1
Group 4 Mean 8.94487
Std. Dev. .907667 No. of Items 45.3859

Mid Pts. 8.5 9.5 10.5
Abs. Corr. Coeff. .739446

Mid Pts. 11.5 12.5 13.5
Abs. Corr. Coeff. .582177

Mid Pts. 13.5 14.5 15.5
Abs. Corr. Coeff. .500008

Mid Pts. 14.5 15.5 16.5
Abs. Corr. Coeff. .904039
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

Mean	1.920	5.000	8.940	15.640
Std. Dev.	0.527	0.452	0.908	0.954
Size	49.30	69.10	45.40	28.80

Mid-length	Frequency	Predicted F	Residuals
0.5	2.00	0.989	1.011
1.5	23.00	27.160	-4.160
2.5	22.00	20.363	1.637
3.5	1.00	0.664	0.336
4.5	37.00	33.071	3.929
5.5	28.00	33.086	-5.086
6.5	1.00	0.787	0.213
7.5	6.00	5.671	0.329
8.5	17.00	17.734	-0.734
9.5	16.00	16.489	-0.489
10.5	5.00	4.559	0.441
11.5	2.00	0.376	1.624
12.5	3.00	0.063	2.937
13.5	6.00	0.973	5.027
14.5	6.00	5.896	0.104
15.5	15.00	11.912	3.088
16.5	6.00	8.021	-2.021
17.5	2.00	1.800	0.200
18.5	2.00	0.135	1.865

FREQUENCIES GROUPED INTO CLASSES WITH PREDICTED FREQUENCIES >5

Frequency	Pre. Freq.	Residuals	Chi Square Stat.
25.0	28.150	-3.150	0.352
22.0	20.363	1.637	0.132
38.0	33.736	4.264	0.539
28.0	33.086	-5.086	0.782
7.0	6.458	0.542	0.046
17.0	17.734	-0.734	0.030
16.0	16.489	-0.489	0.015
16.0	5.970	10.030	16.852
6.0	5.896	0.104	0.002
15.0	11.912	3.088	0.800
6.0	8.021	-2.021	0.509

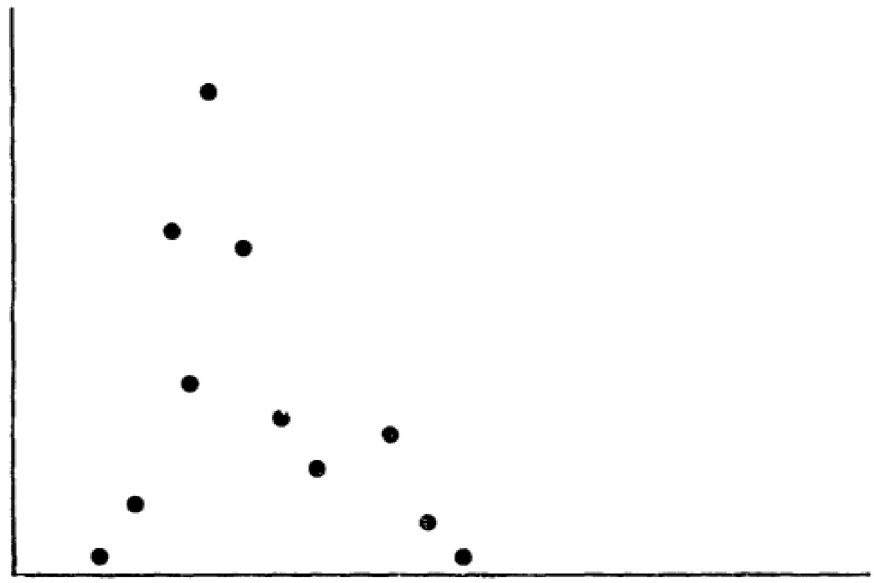
Chi Square Statistic=20.059

For 11 Classes and 2 D.F.

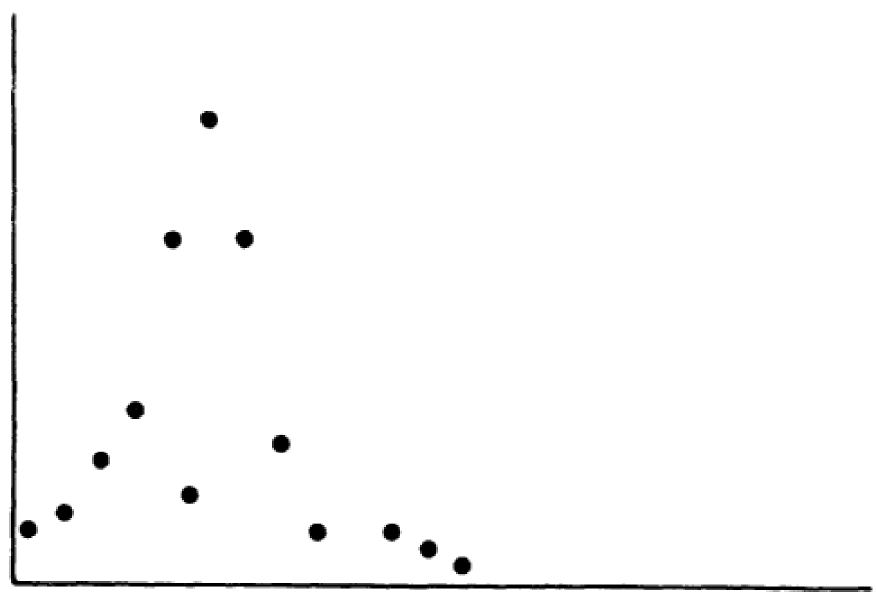
<<

Appendix 5 PLOT OF PERCENTAGE FREQUENCIES

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



Sample 1 Month 1



Sample 2 Month 2

<<

File Name : Sardinella

Test Data from Sanders (1984) — Page 155

SAMPLE 1, MONTH 1

Mid-length	Frequency	% Frequency	% Freq. (rounded)
12.5	145.1	0.425	0
13.5	1052.2	3.085	3
14.5	6331 .1	18.564	19
15.5	9269.9	27.181	27
16.5	6149.7	18.032	18
17.5	2594.1	7.606	8
18.5	1777.8	5.213	5
19.5	3483.0	10.213	10
20.5	2557.8	7.500	7
21.5	689.3	2.021	2
22.5	54.4	0.160	0

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

Mid-length	Frequency	% Frequency	% Freq. (rounded)
10.5	1168.1	1.637	2
11.5	1800.1	2.522	3
12.5	4500.2	6.305	6
13.5	6204.5	8.693	9
14.5	13692.0	19.184	19
15.5	18364.5	25.731	26
16.5	13213.2	18.513	19
17.5	5323.6	7.459	7
18.5	1780.9	2.495	2
19.5	2853.3	3.998	4
20.5	1780.9	2.495	2
21.5	612.8	0.859	1
22.5	76.6	0.107	0

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

Appendix 6

FORD - WALFORD PLOT

EXAMPLE FOR 5.2.4

D. Pauly — Page 31 — Table 4.4 (1984)

Surface Factor D=1

$(L_t)^D$	(L_{t+1})
35	**55**
55	75
75	90
90	105
105	115

Intercept a =26.0522

Slope b =.860387

Correlation Coefficient r =.998122

L_∞ 186.602

K 1 50374

Ford - Walford Plot

Hilsa Data — BOBP (1987), Page 74

Surface Factor D=1

$(L_t)^D$	$(L_{t+1})^D$
22.1	40.7
40.7	49.9
36.8	47.2

Intercept a=29.9267

Slope b=.482129

Correlation Coefficient r =.996006

L_∞ =57.7878

K = .729544

Appendix 7

GULLAND & WOLT PLOT

EXAMPLE FOR 5.2.5

Sparre — Page 78 (1985)

Surface Factor D=1

L_1	L_2	t_2-t_1	X	Y
25.7	36	1	30.85	10.3
36	42.9	1	39.45	6.9
42.9	47.5	1	45.2	4.6
47.5	50.7	1	49.1	3.19999
50.7	52.8	1	51.75	2.1
50.7	52.8	1	51.75	2.1

Intercept a =22.3632

Slope b =-.391623

Correlation Coefficient r = - .9999 13

L_∞ = 57.104

k = .391623

Appendix 8

VON BERTALANFFY PLOT

EXAMPLE FOR 5.2.6

Sparre — Page 82 (1985)

Surface Factor D = 1

L_∞- 5 0

t	Lt	Y
.64	17.3	.424648
1 .16	27.9	.816445
1.65	35.3	1.22418
2.1	40.2	1.62964
2.64	43.2	1.9951
3.21	45.5	2.40795

Intercept a = -.0658255

Slope b= .78008

Correlation Coefficient r =.999126

t_0 = .084383

K = .78008

Appendix 9

JONES & VAN ZALINGE METHOD

EXAMPLE FOR 6.2

File Name: Test data

Sparre-Page193 (1985)

L_∞ =23.1

K = .59

D =l

SAMPLE 1

L_1-L_2	$C(L_1-L_2)$	$C(L_1, L_\infty)$	ln $(C(L_1, L_\infty))$	ln $(L_\infty-L1)$
6- 7	3	3816	8.24696	2.83908
7- 8	143	3813	8.24617	2.77882
8- 9	271	3670	8.20795	2.7147
9-l 0	318	3399	8.13124	2.64618
10-11	416	3081	8.03301	2.57261
11-12	488	2665	7.88796	2.49321
12-13	614	2177	7.68571	2.40695
13-14	613	1563	7.35437	2.31254
14-15	493	950	6.85647	2.20827
15-16	278	457	6.12471	2.09186
16-17	93	179	5.18744	1.9601
17-18	73	86	4.45446	1.80829
18-19	7	13	2.56572	1.62924
19-20	2	6	1.79342	1.41099
20-21	2	4	1.38879	1.1314
21-22	.0l	2	.698135	.741938
22-23	1	2	.693147	.0953104
23-24	1	1	0	-2.30258

L_1-L_2	Slope	Z	N	S2b	Confidence Limits of Z
13-14	-	-	1	-	-
14-15	-	-	2	-	-
15-16	5.58638	3.29597	3	.1 86893	3.29597-3.24084=.0551233 3.29597+3.24084=6.53681
16-17	6.18883	3.65141	4	.131784	3.65141 -.921628 = 2.72978 3.65141+.921628=4.57304
17-18	5.94177	3.50565	5	.0540237	3.50565- .43636 =3.06929 3.50565+.43636 -3.942
18-19	6.82803	4.02854	6	.207118	4.02854-.745385 =3.28315 4.02854+.745385 =4.77392
19-20	6.50108	3.83564	7	.1 0968	3.83564-.502364=3.33328 3.83564+.502364=4.338

Appendix 10

SPARRE'S CATCH CURVE METHOD

EXAMPLE FOR 63

File Name: Testdata

Sparre – Page 193 (1985)

L_∞ =23.1

K =.59

SAMPLE 1

L_1–L_2	$C(L_1, L_2)$	D_t	$t((L_1+L_2)/2)$	$\ln(C(L_1, L_2)/D_t)$
6— 7	3	.102134	.560051	3.38008
7— 8	143	.108686	.665359	7.18214
8— 9	271	.116135	.777646	7.75512
9—10	318	.124682	.897903	7.84404
10—11	416	.134588	1.02735	8.03623
11—12	488	.146204	1.1675	8.11307
12—13	614	.160016	1.3203	8.25248
13—14	613	.176713	1.48825	8.15159
14—15	493	.197306	1.6747	7.82351
15—16	278	.223338	1.88421	7.12669
16—17	93	.257298	2.12333	5.89012
17—18	73	.303472	2.40181	5.48293
18—19	7	.369921	2.73521	2.94038
19—20	2	.473873	3.15068	1.43996
20—21	2	.66011	3.70224	1.1085
21—22	.01	1.09598	4.52513	—4.69682
22—23	1	4.06422	6.18756	—1 .40222
23—24	1	–		–

L_1—L_2	Z	N	S_b^2	Confidence Limits of *Z*
13—14	–	1	–	–
14—15	–	2	–	–
15—16	2.60359	3	.202594	2.60359—5.71903=—3.11544
				2.60359 + 5.71 903 = 8.32262
16—17	3.58035	4	.291922	3.58035—2.3249 = 1.25544
				3.58035 ±2.3249 = 5.90525
17—18	3.19128	5	.121946	3.19128—1.11118= 2.0801
				3.19128+1.11118= 4.30246
18—19	4.03499	6	.20921	4.03499—1.26973= 2.76526
				4.03499+1.26973= 5.30472
19—20	4.19501	7	.09086	4.19501 —.774976 = 3.42003
				4.19501 +.774976= 4.96999

<<

Appendix 11

WETHERALL ET AL METHOD

TEST DATA

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

File Name: Plota

Test Data from Ng Fong Oon (1986) — Page 13

<<

SAMPLE 1

Selection Length (X)	Mean Length (Y)
6	19.9792
8	20.1404
10	21 .1 634
12	22.2958
14	22.8394
16	23.2828
18	24.2372
20	25.4752
22	26.626
24	27.7005
26	28.9473
28	30.3709
30	32.1374
32	33.9756
34	36.2036
36	38.414
38	39.8379
40	41.4985
42	43

Sample 1

Points taken for regression 7 to 19

Correlation coefficient -=.994904

Slope b=.812634

Intercept a =8.57666

Asymptotic Length **L_∞ =45.775**

Z/K -4.33716

<<

Publications of the Bay of Bengal Programme (BOBP)

The BOBP brings out six types of publications.

Reports (BOBP/REP/. . . .) describe and analyze completed activities such as seminars, annual meetings of BOBP's Advisory Committee, and projects in member-countries for which BOBP inputs have ended.

Working Papers (BOBP/WP/. . .) are progress reports that discuss the findings of ongoing BOBP work.

Manuals *and Guides* (BOBP/MAG/. . .) are instructional documents for specific audieuces.

Miscellaneous *Papers* (BOBP/MIS/. . .) concern work not originated by BOBP — but which is relevant to the Programme's objectives.

lnformation *Documents* (BOBP/INF. . .) are bibliographies and descriptive documents on the fisheries of member-countries in the region.

Newsletters (*Bay* of Bengal News), issued quarterly, contain illustrated articles and features in non-technical style on BOBP work and related subjects.

A list of publications follows.

Reports (BOBP/REP/.)

1. Report of the First Meeting of the Advisory Committee. Colombo, Sri Lanka, 28-29 October 1976. (Published as Appendix 1 of IOFC/DEV/78/44.1, FAO, Rome, 1978)
2. Report of the Second Meeting of the Advisory Committee. Madras, India, 29-30 June 1977. (Published as Appendix 2 of IOFC/DEV/78/44.1, FAO, Rome, 1978)
3. Report of the Third Meeting of the Advisory Committee. Chittagong, Bangladesh. 1--10 November 1978 Colombo, Sri Lanka, 1978.
   (Reissued Madras, India, September 1980)
4. Role of Women in Small-Scale Fisheries of the Bay of Bengal. Madras, India, October 1980.
5. Report of the Workshop on Social Feasibility in Small-Scale Fisheries Development. hladras, India, 3-8 September 1979. Madras, India, April 1980.
6. Report of the Workshop on Extension Service Requirements in Small-Scale Fisheries. Colombo, Sri Lanka, 8-12 October 1979. Madras, India, June 1980.
7. Report of the Fourth Meeting of the Advisory Committee. Phuket, Thailand, 27-30 November 1979. Madras, India, February 1980.
8. Pre-Feasibility Study of a Floating Fish Receiving and Distribution Unit for Dubla Char, Bangladesh. G. Eddie, M. T. Nathan. Madras, India, April 1980.
9. Report of the Training Course for Fish Marketing Personnel of Tamil Nadu. Madras, India, 3-14 December 1979. Madras, India, September 1980.

10.1 Report of the Consultation on Stock Assessment for Small-Scale Fisheries in the Bay of Bengal. Chittagong, Bangladesh, 16-21 June 1980. Volume 1: Proceedings. Madras, India, September 1980.

10.2 Report of the Consultation on Stock Assessment for Small-Scale Fisheries in the Bay of Bengal. Chittagong, Bangladesh, 16-2 1 June 1980. Volume 2: Papers. Madras, India, October 1980.

11. Report of the Fifth Meeting of the Advisory Committee. Penang, Malaysia, 4-7 November 1980. Madras, India, January 1981.
12. Report of the Training Course for Fish Marketing Personnel of Andhra Pradesh. Hyderabad, India, 1 l-26 November 1980. Madras, India, September 1981.
13. Report of the Sixth Meeting of the Advisory Committee. Colombo, Sri Lanka, l-5 December 1981. Madras, India, February 1982.
14. Report of the First Phase of the "Aquaculture Demonstration for Small-Scale Fisheries Development Project" in Phang Nga Province, Thailand. Madras, India, March 1982.
15. Report of the Consultation-cum-Workshop on Development of Activities for Improvement of Coastal Fishing Families. Dacca, Bangladesh, October 27-November 6, 1981. Madras, India, May 1982.
16. Report of the Seventh Meeting of the Advisory Committee. New Delhi, India, January 17-21, 1983. Madras, India, March 1983.
17. Report of Investigations to Improve the Kattumaram of India's East Coast. Madras, India, July 1984.

13. Motorization of Country Craft, Bangladesh. Madras, India, July 1984.

19. Report of the Eighth Meeting of the Advisory Committee. Dhaka, Bangladesh, January 16-19, 1984. Madras, India, May 1984.

20. Coastal Aquaculture Project for Shrimp and Finfish in Ban Merbok, Kedah, Malaysia. Madras, India, December 1984.

21. Income-Earning Activities for Women from Fishing Communities in Sri Lanka. E. Drewes. Madras, India, September 1985.

22. Report of the Ninth Meeting of the Advisory Committee. Bangkok, Thailand, February 25-26, 1985. Madras, India, May 1985.

23. Summary Report of BOBP Fishing Trials and Demersal Resources Studies in Sri Lanka. Madras, India, March 1986.

24. Fisherwomen's Activities in Bangladesh: A Participatory Approach to Development. P. Natpracha. Madras, India, May 1986.

25. Attempts to Stimulate Development Activities in Fishing Communities of Adirampattinam, India. P. Natpracha, V.L.C. Pietersz. Madras, India, May 1986.

26. Report of the Tenth Meeting of the Advisory Committee. Male, Maldives. 17-18 February 1986. Madras, India, April 1986.

27. Activating Fisherwomen for Development through Trained Link Workers in Tamil Nadu, India. E. Drewes. Madras, India, May 1986.

28. Small-Scale Aquaculture Development Project in South Thailand: Results and Impact. E. Drewes. Madras, India, May 1986.

29. Towards Shared Learning: An Approach to Non-formal Adult Education for Marine Fisherfolk of Tamil Nadu, India. L. S. Saraswathi and P. Natpracha. Madras, India, July 1986.

30. Summary Report of Fishing Trials with Large-Mesh Driftnets in Bangladesh. Madras, India, May 1986.

31. In-Service Training Programme for Marine Fisheries Extension Officers of Orissa, India. U. Tietze. Madras, India, August 1986.

32. Bank Credit for Artisanal Marine Fisherfolk of Orissa, India. U. Tietze. Madras, India, May 1987.

34. The Coastal Set Bagnet Fishery of Bangladesh-Fishing Trials and Investigations. S.E. Akerman. Madras, India, November 1986.

35. Brackishwater Shrimp Culture Demonstration in Bangladesh. M. Karim. Madras, India, January 1987.

36. Hilsa Investigations in Bangladesh. Colombo, Sri Lanka, June 1987.

37. High-opening Bottom Trawling in Tamil Nadu, Gujarat and Orissa, India: A Summary of Effort and Impact. Madras, India, February 1987.

38. Report of the Eleventh Meeting of the Advisory Committee. Bangkok, Thailand, March 26-29, 1987. Madras, India, June 1987.

Working Papers (BOBP/ WP/ . . .)

1. Investment Reduction and Increase in Service Life of Kattumaram Logs. R. Balan. Madras, India, February 1980.
2. Inventory of Kattumarams and their Fishing Gear in Andhra Pradesh and Tamil Nadu. T. R. Menon. Madras, India, October 1980.
3. Improvement of Large-Mesh Driftnets for Small-Scale Fisheries in Sri Lanka. G. Pajot. Madras, India, June 1980.
4. Inboard Motorisation of Small G.R.P. Boats in Sri Lanka. Madras, India, September 1980.
5. Improvement of Large-Mesh Driftnets for Small-Scale Fisheries in Bangladesh. G. Pajot. Madras, India, September 1980.
6. Fishing Trials with Bottom-Set Longlines in Sri Lanka. G. Pajot, K. T. Weerasooriya. Madras, India, September 1980.
7. Technical Trials of Beachcraft Prototypes in India. 0. Gulbrandsen, G. P. Gowing, R. Ravikumar. Madras, India, October 1980.
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