

BAY OF BENGAL PROGRAMME

Marine Fishery Resources Management

BOBP/MAG/3

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FISHERY STATISTICS ON THE MICROCOMPUTER

— A BASIC version of Hasselblad's NORMSEP program

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## INTRODUCTION

Like most other biologists, fishery biologists often encounter situations where mixtures of distributions need to be separated into their component distributions.

Such situations arise when, for example, the counts of different-sized ova in a fish gonad have to be separated into batches that will be spawned successively, when length-frequency data have to be separated into age groups or when "pulses" of recruitment are to be quantified (Fig. 1).

There exist a number of graphical and mathematical techniques which can be used for such separation (see Everitt and Hand, 1981, for a review). Most of them assume that the distributions to be separated from the mixture are *normal* distributions (Pearson 1984, Harding 1949, Cassie 1954, Tanaka 1962, Hasselblad 1966, Bhattacharya 1967, Yong and Skillman 1971, MacDonald and Pitcher 1978). Of these, only Bhattacharya's method, as adapted in Pauly and Caddy (1984), and the ENORMSEP program of Yong and Skillman, do not require the external input of the expected number of component distributions in the mixture. The NORMSEP program, of which a BASIC version is presented here, also does require such an input. Thus, although NORMSEP is not the most sophisticated tool available to analyse size-frequency distributions, it is useful in situations where the data to be separated do not greatly overlap, or where previous knowledge exists on the number of probable positions of the means of the component distributions (see Mathew 1974).

The version of NORMSEP presented here is a translation of the FORTRAN IV version of NORMSEP in Abrahamson (1971), written by V Hasselblad and modified by P K Tomlinson.

The following changes were made to the original version :

- (i) A routine was added which automatically computes, using the (guessed) means entered, a very large range of possible values for the standard deviation corresponding to each mean, by using a very small (0.01) and a very large (0.50) coefficient of variation (C.V. = s.d.  $\sqrt{x}$ ) to generate the range. This follows Abrahamson's suggestion that "anyone desiring to maintain the rigour of Hasselblad's original procedure only needs to place extremely wide bounds on the standard deviations".
- (ii) A routine was added which internally computes the number and approximate position of the cut-off points.
- (iii) The input routine has been made completely interactive, with prompts provided by the program, along with routines for checking and correcting the data entered from the keyboard.
- (iv) A routine was added along with prompts, to load length frequency data from a disk into memory, and use them as an input to NORMSEP. Such files must have been created by ELEFAN (see David *et al* 1982). No routine for checking the correctness of file inputs has been included.

The maximum number of iterations, and of component distributions that can be separated, have been set at 125 and 10 respectively; note that the program cannot be used to estimate the parameters (mean, standard deviation) of a single normal distribution. Users should heed Abrahamson's advice, issued in conjunction with the original publication of NORMSEP, that "under any circumstances, Hasselblad (1966) and Cohen (1966) should be reviewed before proceeding."

## AN APPLICATION EXAMPLE

Table 1 : Length-frequency data for testing NORMSEP.

Note number and position of modes (underlined)

Lower class limit	Frequency	Lower class limit	Frequency
0	2	10	5
1	<u>23</u>	11	2
2	<u>22</u>	12	3
3	1	13	6
4	<u>37</u>	14	6
5	<u>28</u>	15	<u>15</u>
6	1	16	6
7	6	17	2
8	<u>17</u>	18	2
9	<u>16</u>	—	—

Table 1 gives a set of frequencies generated (by Everitt and Hand 1981, Table 2.7) from a mixture of components of known characteristics. From the overall appearance of the data, we shall assume that there are four components, with means close to the modes, i.e., 1.5, 4.5, 8.5 and 15.5.

Question : Can our BASIC version of NORMSEP recover the means and standard deviation originally used to generate the data, if these modes are used as initial guesses of the means?

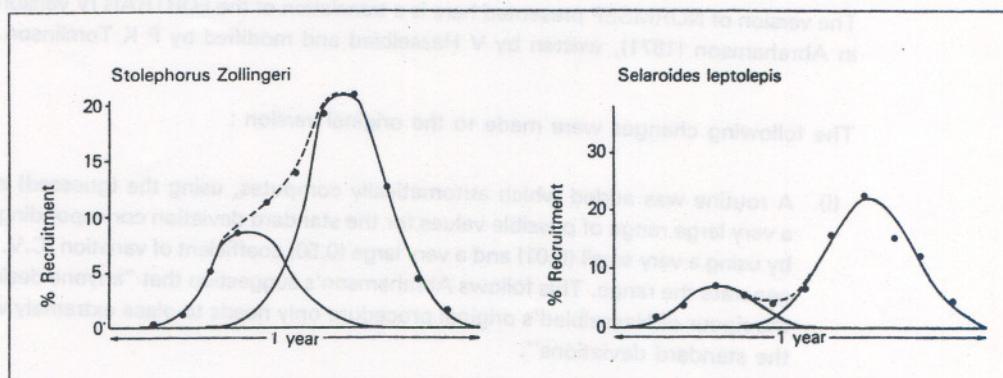


Fig. 1 Recruitment patterns in two stocks of Philippine fishes, derived from length-frequency data projected backwards onto the time axis and used to separate the two pulses of recruitment occurring within a year. The separation of the recruitment patterns into their component distribution was done using NORMSEP; note that the chi-square statistic cannot be used here because recruitment patterns are expressed in % (after Pauly and Navaluna 1984).

The output obtained for a run of our BASIC NORMSEP and the inputs mentioned above are reproduced on page 3. The mean and standard deviations are close to the values used by Everitt and Hand (1981) to generate the data in Table 1.

Component	Mean	Standard deviation
1	2.0	0.5
2	5.0	0.5
3	9.0	1.0
4	15.0	2.0

The only exception is the standard deviation of the 4th component. These results are exactly the same as those obtained by Everitt and Hand (1981). The interpretation of this and other results

obtained by NORMSEP should be undertaken carefully. It is essential, among other things that the user realizes that NORMSEP will always "find" the mean and standard deviation of a distribution if one is assumed to be present, and the preliminary estimate of its mean entered.

### RESULTS FOR FILE : TEST

The NORMSEP output, based on data in Table 1 (see text for interpretation), is given below.

#### Values after 21 iterations

Group	Mean	St dev	Per cent	Size
1	1.94045	.59151	23.7234	47.4468
2	4.92919	.524968	32.9876	65.9751
3	8.96506	.961204	22.6216	45.2432
4	15.0991	1.59989	20.6674	41.3348

Total sample size 200

#### Actual vs. Predicted Frequencies

Actual	Predicted	Actual	Predicted
2	2.6536	16	15.622
23	22.9724	5	5.78087
22	20.091	2	1.61373
1	4.24912	3	2.8621
37	34.0085	6	6.25408
28	28.1286	6	9.4763
1	2.24172	15	9.83824
6	6.21149	6	6.99787
17	16.146	2	3.40968
		2	1.44271

Degrees of Freedom

= 4

Chi Square Value

= 8.18143 Prob = .0851538

Log of likelihood

= 218.802

The "goodness of fit" statistics (the chi-square) may be used to distinguish various alternative interpretations. However, it is essential that this be done after the basic features of the chi-square test have been assimilated (consult a good statistics textbook!).

### RUNNING THE PROGRAM

The corresponding prompts of and input to the program are given below.

Using data from a disk file :

Prompt No.	Prompt	Input
1	ENTER RUN — ID ?	TEST
2	DO YOU WANT TO READ FILE FROM DISK (Y/N). THE ALTERNATIVE IS TO ENTER DATA FROM KEYBOARD ?	Y
3	ENTER FILE NAME ?	B : TEST DATA
4	ENTER NUMBER OF GROUPS YOU WANT TO SPLIT SAMPLE INTO ?	4
5	ENTER ESTIMATE OF MEAN No. 1?	1.5
	ENTER ESTIMATE OF MEAN No. 2?	4.5
	ENTER ESTIMATE OF MEAN No. 3?	8.5
	ENTER ESTIMATE OF MEAN No. 4?	15.5
6	PRINT RESULTS (Y/N) ?	Y
7	PRESS (RETURN)	(RETURN)
8	PRESS (RETURN)	(RETURN)
9	CONTINUE WITH NEXT SAMPLE (Y/N) ?	Y

Using data input from the keyboard :

Prompt No.	Prompt	Input
1	ENTER RUN - ID ?	TEST
2	DO YOU WANT TO READ FILE FROM DISK (Y/N). THE ALTERNATIVE IS TO ENTER DATA FROM KEYBOARD ?	N
3	ENTER NUMBER OF (LENGTH) CLASSES	19
4	ENTER NUMBER OF GROUPS YOU WANT TO SPLIT SAMPLE INTO ?	4
5	ENTER ESTIMATE OF MEAN No. 1? ENTER ESTIMATE OF MEAN No. 2? ENTER ESTIMATE OF MEAN No. 3? ENTER ESTIMATE OF MEAN No. 4?	1.5 4.5 8.5 15.5
6	ENTER LOWER LIMIT OF SMALLEST CLASS ?	0
7	ENTER CLASS WIDTH ?	1
8	ENTER FREQUENCY : 1? ENTER FREQUENCY : 2?	2 23
	... enter frequencies from Table 1 ...	
9	ANY CORRECTIONS (Y/N) ?	N
10	REVIEW FREQUENCIES (Y/N) ?	N
11	PRINT RESULTS (Y/N) ? ... continue as 7 above ...	N

The prompts given by the program are shown above. Error messages for keyboard are not shown. Data files created or extracted by ELEFAN for analysis by NORMSEP must consist of only one sample (i.e., a set of corresponding midlength and frequencies from only one week, month or year etc). For example, a set of monthly samples collected during a year (12 samples) must therefore be subdivided using ELEFAN into 12 sub-files.

#### Acknowledgement

We are most thankful to Mr. H. Larssen, Danish Institute for Fisheries and Marine Research, Denmark for his assistance with testing the program and his suggestions towards improving the routines.

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#### PROGRAM LISTING

The listing given below (pages 6-13) is the version of BASIC suitable for Apple IIe with CP/M operating system, which is a dialect of Microsoft BASIC. It should therefore be easily converted for use of Microcomputers other than Apple IIe using Microsoft BASIC. The BASIC translation guide by Lien (1981) should help in such conversions, should any problem occur.

Our version of NORMSEP does not require that a printer be connected to the computer (although this will be helpful). About 12K of program memory must be available for the program and the data; these memory requirements can be slightly reduced by deleting all REMs. In case a printer is connected, the interface card must be configured for the CP/M system to enable hard copy.

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10 REM =====
20 REM
30 REM
40 REM ***** NORMSEP PROGRAM *****
50 REM
60 REM
70 REM =====
80 REM THIS IS A BASIC LANGUAGE VERSION OF PROGRAM TCPAI
90 REM (FORMALLY NORMSTEP) WHICH IS AVAILABLE IN THE FORTRAN LANGUAGE.
100 REM
110 REM IT WAS TRANSLATED INTO RADIO SHACK'S BASIC II FROM THE ORIGINAL BY
120 REM N. DAVID AND IT'S INPUT ROUTINE MODIFIED AND EXPANDED BY D. PAULY
121 REM (BOTH ICLARM).
130 REM
140 REM THE VERSION FOR APPLE IIe (WITH CP/M-80 OPERATING SYSTEM) WAS PREPARED
150 REM BY J. HERTEL-WULFF, BOBP.
160 REM
170 REM IT USES THE STEEPEST DESCENT METHOD AS NORMAL
180 REM DISTRIBUTION SEPARATOR.
190 REM
200 REM THIS PROGRAM CONSISTS OF A MAIN ROUTINE AND SEVERAL
210 REM SUBROUTINES:
220 REM CHISQ
230 REM NORM
240 REM TRUNC
250 REM GTRUN
260 REM VPLOT
270 REM
280 REM APPLE IIe VERSION, FEB. 1986.
290 REM
300 REM =====
310 CLEAR 200
320 DIM Q(120,10),QQ(120),P(20),MU(20),SG(20),F(120),FS(120),YQ(10)
330 DIM NF(120),NS(20),XT$(8),YT$(50),PP(20),MP(20),SP(20),NX(20),NG(120)
340 DIM BU(20),BL(20),AU(20),AL(20),FX(20),XA$(30),XH$(30)
350 HOME:PRINT TAB(25);"NORMSEP":PRINT
360 C0=.39894228#
370 INPUT"ENTER RUN-ID ";M1$
380 PRINT"DO YOU WANT TO READ FILE FROM DISK (Y/N). THE"
390 INPUT"ALTERNATIVE IS TO ENTER DATA FROM KEYBOARD ";S$
400 IF S$ <> "Y" AND S$ <> "N" THEN GOTO 380
410 IF S$="N" THEN GOTO 430
420 GOSUB 4590:IF S$="Y" THEN GOTO 440
430 INPUT "ENTER NUMBER OF (LENGTH) CLASSES";N
440 INPUT"ENTER NUMBER OF GROUPS YOU WANT TO SPLIT SAMPLE INTO";K
450 LC=1:REM NUMBER OF SETS OF CUT-OFF POINTS SET TO 1 SINCE THE CUT-OFF POINTS
 ARE COMPUTED INTERNALLY...
460 FOR I=1 TO K
470 PRINT"ENTER ESTIMATE OF MEAN NO.";I;:INPUT YQ(I)
480 NEXT I
490 FOR I=1 TO K-1
500 IF YQ(I)>=YQ(I+1) THEN HOME:PRINT "ERROR! ENTER MEAN VALUES FROM LOWEST TO
 HIGHEST":GOTO 460
510 NEXT I:IF S$="Y" THEN GOTO 700
520 IF K>10 THEN K=10:REM MAXIMUM DISTRIBUTIONS IS 10
530 INPUT "ENTER LOWER LIMIT OF SMALLEST CLASS";XI
540 INPUT "ENTER CLASS WIDTH";XL
550 FOR I=1 TO N
560 PRINT"ENTER FREQUENCY";I;:INPUT F(I)
570 NEXT I
580 HOME:PRINT TAB(10);"LOOK FOR ERRORS"
590 FOR I=1 TO N
600 PRINT "FREQUENCY NO.";I;:F(I)
610 IF I=14 THEN INPUT "PRESS <RETURN>";P$
620 NEXT I
630 FOR I=1 TO N
640 INPUT "ANY CORRECTIONS (Y/N)";P$
650 IF P$="N" THEN GOTO 680
660 INPUT"ENTER FREQUENCY NO. TO BE CORRECTED";J:PRINT"FREQ NO. ";J;:INPUT F(J)
670 NEXT I

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680 INPUT "REVIEW FREQUENCIES (Y/N)";P$           REM PRINT MEAN (X) > X1,X2,...,XN 0001
690 IF P$="Y" THEN GOTO 580                      REM PRINT MEAN (X) > X1,X2,...,XN 0001
700 SF=0                                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
710 FOR I=1 TO N                                 REM PRINT MEAN (X) > X1,X2,...,XN 0001
720 SF=SF+F(I)                                    REM PRINT MEAN (X) > X1,X2,...,XN 0001
730 NF(I)=FIX(F(I)+.5)                          REM PRINT MEAN (X) > X1,X2,...,XN 0001
740 NEXT I                                       REM PRINT MEAN (X) > X1,X2,...,XN 0001
750 REM                                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
760 REM                                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
770 HOME:PRINT TAB(20);"NORMSEP RUNNING. WAIT"   REM PRINT MEAN (X) > X1,X2,...,XN 0001
780 REM ======                                     REM PRINT MEAN (X) > X1,X2,...,XN 0001
790 FOR LY=1 TO LC                               REM PRINT MEAN (X) > X1,X2,...,XN 0001
800 REM ======                                     REM PRINT MEAN (X) > X1,X2,...,XN 0001
810 REM GET CUT-OFF POINTS FX'S                  REM PRINT MEAN (X) > X1,X2,...,XN 0001
820 FOR J=1 TO K-1                             REM PRINT MEAN (X) > X1,X2,...,XN 0001
830   FX(J)=(YQ(J)+YQ(J+1))/2                   REM PRINT MEAN (X) > X1,X2,...,XN 0001
840 NEXT J                                      REM PRINT MEAN (X) > X1,X2,...,XN 0001
850 FX(K)=(N-1)*XL+XI                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
860 REM                                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
870 REM GET LOWER AND UPPER BOUNDS FOR MEANS, BL AND BU'S  REM PRINT MEAN (X) > X1,X2,...,XN 0001
880 BL(1)=YQ(1)-.5*(YQ(2)-YQ(1))               REM PRINT MEAN (X) > X1,X2,...,XN 0001
890 FOR J=1 TO K-1                           REM PRINT MEAN (X) > X1,X2,...,XN 0001
900   BU(J)=YQ(J)+.5*(YQ(J+1)-YQ(J))          REM PRINT MEAN (X) > X1,X2,...,XN 0001
910   BL(J+1)=BU(J)                            REM PRINT MEAN (X) > X1,X2,...,XN 0001
920 NEXT J                                      REM PRINT MEAN (X) > X1,X2,...,XN 0001
930 BU(K)=(N-1)*XL+XI                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
940 REM GET LOWER AND UPPER BOUNDS FOR STANDARD DEVIATION, AL & AU'S  REM PRINT MEAN (X) > X1,X2,...,XN 0001
950 FOR J=1 TO K                                REM PRINT MEAN (X) > X1,X2,...,XN 0001
960   AL(J)=.01*YQ(J)                          REM PRINT MEAN (X) > X1,X2,...,XN 0001
970   AU(J)=.5*YQ(J)                          REM PRINT MEAN (X) > X1,X2,...,XN 0001
980 NEXT J                                      REM PRINT MEAN (X) > X1,X2,...,XN 0001
990 REM                                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
1000 FOR J=1 TO K                               REM PRINT MEAN (X) > X1,X2,...,XN 0001
1010   NX(J)=FIX(((FX(J)-XI)/XL)+.5)            REM PRINT MEAN (X) > X1,X2,...,XN 0001
1020   BL(J)=(BL(J)-XI)/XL                     REM PRINT MEAN (X) > X1,X2,...,XN 0001
1030   BU(J)=(BU(J)-XI)/XL                     REM PRINT MEAN (X) > X1,X2,...,XN 0001
1040   AL(J)=AL(J)/XL                          REM PRINT MEAN (X) > X1,X2,...,XN 0001
1050   AU(J)=AU(J)/XL                          REM PRINT MEAN (X) > X1,X2,...,XN 0001
1060 NEXT J                                      REM PRINT MEAN (X) > X1,X2,...,XN 0001
1070 REM                                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
1080 NX(K)=N                                     REM PRINT MEAN (X) > X1,X2,...,XN 0001
1090 REM                                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
1100 FOR I=1 TO N                               REM PRINT MEAN (X) > X1,X2,...,XN 0001
1110   FS(I)=F(I)                            REM PRINT MEAN (X) > X1,X2,...,XN 0001
1120 NEXT I                                      REM PRINT MEAN (X) > X1,X2,...,XN 0001
1130 NB=1                                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
1140 REM COMPUTE INITIAL ESTIMATES USING HALD'S PROCEDURE  REM PRINT MEAN (X) > X1,X2,...,XN 0001
1150 AS=0                                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
1160 REM                                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
1170 FOR J=1 TO K                               REM PRINT MEAN (X) > X1,X2,...,XN 0001
1180   NE=NX(J)                                REM PRINT MEAN (X) > X1,X2,...,XN 0001
1190   XB=NE                                  REM PRINT MEAN (X) > X1,X2,...,XN 0001
1200   A=0                                     REM PRINT MEAN (X) > X1,X2,...,XN 0001
1210   B=0                                     REM PRINT MEAN (X) > X1,X2,...,XN 0001
1220   C=0                                     REM PRINT MEAN (X) > X1,X2,...,XN 0001
1230 FOR I=NB TO NE                           REM PRINT MEAN (X) > X1,X2,...,XN 0001
1240   CI=XB-I+.5                            REM PRINT MEAN (X) > X1,X2,...,XN 0001
1250   CF=FS(I)                                REM PRINT MEAN (X) > X1,X2,...,XN 0001
1260   A=A+CF                                 REM PRINT MEAN (X) > X1,X2,...,XN 0001
1270   B=B+CF*CI                             REM PRINT MEAN (X) > X1,X2,...,XN 0001
1280   C=C+CF*CI*CI                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
1290 NEXT I                                      REM PRINT MEAN (X) > X1,X2,...,XN 0001
1300 REM                                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
1310 ZZ=A*C/(2*B*B)                          REM PRINT MEAN (X) > X1,X2,...,XN 0001
1320 X=ZZ:GOSUB 4350 :Z=TR: REM CALL TRUNC(ZZ)  REM PRINT MEAN (X) > X1,X2,...,XN 0001
1330 REM                                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
1340 X=Z:GOSUB 3800 :G=GT: REM CALL GTRUN(Z)  REM PRINT MEAN (X) > X1,X2,...,XN 0001
1350 REM                                         REM PRINT MEAN (X) > X1,X2,...,XN 0001
1360 SG(J)=B*G/A                             REM PRINT MEAN (X) > X1,X2,...,XN 0001
1370 IF SG(J) > AU(J) THEN SG(J)=AU(J)        REM PRINT MEAN (X) > X1,X2,...,XN 0001

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1380 IF SG(J) < AL(J) THEN SG(J)=AL(J)
1390 AV=-Z*SG(J)
1400 IF AV > BU(J) THEN AV=BU(J)
1410 IF AV < BL(J) THEN AV=BL(J)
1420 IF ZZ >=.55 THEN GOTO 1490
1430 AV=B/A
1440 IF AV > BU(J) THEN AV=BU(J)
1450 IF AV < BL(J) THEN AV=BL(J)
1460 SG(J)=SQR ((C-B*B/A)/A)
1470 IF SG(J) > AU(J) THEN SG(J) = AU(J)
1480 IF SG(J) < AL(J) THEN SG(J) = AL(J)
1490 REM
1500 X=AV/SG(J):GOSUB 4080 :PK=NR:REM CALL NORM (AV/SG(J))
1510 REM
1520 P(J)=A/PK
1530 AS=AS+P(J)
1540 FOR KK=1 TO N
1550   II=KK+NE
1560   IF II>N THEN GOTO 1670
1570   UM=(AV+KK)/SG(J)
1580   BM=(AV+KK-1)/SG(J)
1590   X=UM:GOSUB 4080 :KP=NR:REM CALL NORM (ULIM)
1600   X=BM:GOSUB 4080 :KP=KP-NR:REM CALL NORM (BM)
1610   KP=A*KP/PK
1620   REM SUBTRACT ESTIMATED JTH SAMPLE FROM REMAINING ONES
1630   FS(II)=FS(II)-KP
1640   IF FS(II) < 0 THEN FS(II)=0
1650   IF KP < .05 THEN GOTO 1670
1660 NEXT KK
1670 REM CONTINUE
1680 NB=NE+1
1690 MU(J)=NX(J)-AV
1700 IF MU(J) > BU(J) THEN MU(J)=BU(J)
1710 IF MU(J) < BL(J) THEN MU(J)=BL(J)
1720 NEXT J
1730 FOR J=1 TO K
1740   P(J)=P(J)/AS
1750 NEXT J
1760 L1=0
1770 REM COMPUTE LIKELIHOOD FUNCTION L1
1780 FOR I=1 TO N
1790   QQ(I)=0
1800   FOR J=1 TO K
1810     Q(I,J)=CO*EXP(-(I-MU(J)-.5)^2/(2!*SG(J)*SG(J)))/SG(J)
1820   QQ(I)=QQ(I)+Q(I,J)*P(J)
1830 NEXT J
1840 L1=L1+F(I)*LOG(QQ(I))/LOG(10)
1850 NEXT I
1860 REM START OF METHOD OF STEEPEST DESCENT
1870 FOR IT=1 TO 125
1880   L3=IT
1890   PS=0
1900   FOR J=1 TO K
1910     XD=0
1920     SX=0
1930     S3=0
1940     FOR I=1 TO N
1950       TE=F(I)*Q(I,J)/QQ(I)
1960       XD=XD+TE,
1970       CI=I-.5
1980       CF=CI-MU(J)
1990       SX=SX+TE*CI
2000       S3=S3+TE*CF*CF
2010 NEXT I
2020 MP(J)=SX/XD
2030 IF MP(J) < BL(J) THEN MP(J)=BL(J)
2040 IF MP(J) > BU(J) THEN MP(J)=BU(J)
2050 SP(J)=SQR(S3/XD)
2060 IF SP(J) > AU(J) THEN SP(J)=AU(J)
2070 IF SP(J) < AL(J) THEN SP(J)=AL(J)

```

```

2080  PP(J)=XD*P(J)
2090  PS=PS+PP(J)
2100  NEXT J
2110  FOR J=1 TO K
2120    PP(J)=PP(J)/PS
2130  NEXT J
2140  LL=0
2150  FOR I=1 TO N
2160    QQ(I)=0
2170    FOR J=1 TO K
2180      Q(I,J)=CO*EXP(-(I-MP(J)-.5)^2/(2!*SP(J)*SP(J)))/SP(J)
2190      QQ(I)=QQ(I)+Q(I,J)*PP(J)
2200  NEXT J
2210  LL=LL+F(I)*LOG(QQ(I))/LOG(10)
2220  NEXT I
2230  REM TEST FOR IMPROVED LIKELIHOOD FUNCTION LL
2240  IF LL<=L1 THEN GOTO 2320
2250  FOR J=1 TO K
2260    P(J)=PP(J)
2270    MU(J)=MP(J)
2280    SG(J)=SP(J)
2290  NEXT J
2300  L1=LL
2310  NEXT IT
2320  REM
2330  L3=L3-1
2340  FOR I=1 TO N
2350    QQ(I)=0
2360    FOR J=1 TO K
2370      X=(I-MU(J))/SG(J):GOSUB 4080 :Q(I,J)=NR
2380      X=(I-MU(J)-1!)/SG(J):GOSUB 4080 :Q(I,J)=Q(I,J)-NR
2390      QQ(I)=QQ(I)+Q(I,J)*P(J)
2400  NEXT J
2410  FS(I)=QQ(I)*SF
2420  NEXT I
2430  X=-MU(1)/SG(1):GOSUB 4080 :QQ(1)=QQ(1)+NR*P(1)
2440  X=(MU(K)-N)/SG(K):GOSUB 4080 :QQ(N)=QQ(N)+NR*P(K)
2450  FS(1)=QQ(1)*SF
2460  FS(N)=QQ(N)*SF
2470  NN=MU(1)+1!
2480  PR=0
2490  REM COLLAPSE CHI-SQUARE TABLE
2500  FOR I=1 TO NN
2510    II=I
2520    PR=PR+FS(I)
2530  IF PR-5! < 0 THEN GOTO 2540 ELSE GOTO 2550
2540  NEXT I
2550  NL=II
2560  NN=N-MU(K)+1
2570  PS=0
2580  FOR I=1 TO NN
2590    NC=N-I+1
2600    PS=PS+FS(NC)
2610  IF PS-5! < 0 THEN GOTO 2620 ELSE GOTO 2630
2620  NEXT I
2630  NT=NC
2640  AF=0
2650  FOR I=1 TO NL
2660  AF=AF+F(I)
2670  NEXT I
2680  CH=(AF-PR)^2/PR
2690  NH=NT-1
2700  L2=NL+1
2710  FOR I=L2 TO NH
2720    CH=CH+(F(I)-FS(I))^2/FS(I)
2730  NEXT I
2740  AF = 0
2750  FOR I=NT TO N
2760    AF=AF+F(I)
2770  NEXT I

```

```

2780 CH=CH+ (AF-PS)^2/PS
2790 ND=NT-NL-3*K+1
2800 REM =====
2810 REM
2820 REM           ***** ALARM *****
2830 REM
2840 FOR I=1 TO 5
2850 BEEP 15,10:BEEP 15,10:FOR J=1 TO 200:NEXT J
2860 NEXT I
2870 REM
2880 REM =====
2890 HOME: INPUT"PRINT RESULTS (Y/N) ";P$
2900 PRINT "RESULTS FOR RUN: ";M1$
2910 IF P$="Y" THEN LPRINT"RESULTS FOR RUN: ";M1$:LPRINT"-----
-----"
2920 PRINT"VALUES AFTER";L3;" ITERATIONS":
2930 IF P$="Y" THEN LPRINT"VALUES AFTER";L3;" ITERATIONS"
2940 PRINT"GROUP      MEAN      ST DEV      PERCENT      SIZE"
2950 IF P$="Y" THEN LPRINT"GROUP      MEAN      ST DEV      PERCENT      SIZE"
2960 FOR J=1 TO K
2970   SO=SG(J)*XL
2980   XV=MU(J)*XL+XI
2990   PZ=P(J)*SF
3000   PS=P(J)*100!
3010   PRINT J;TAB(11);XV;TAB(21);SO;TAB(32);PS;TAB(44);PZ
3020   IF P$="Y" THEN LPRINT J;TAB(11);XV;TAB(21);SO;TAB(32);PS;TAB(44);PZ
3030   NEXT J
3040   NS%=FIX(SF+.5)
3050   PRINT"TOTAL SAMPLE SIZE";NS%
3060   IF P$="Y" THEN LPRINT" ";LPRINT "TOTAL SAMPLE SIZE";NS%
3070   INPUT"PRESS <RETURN>";S$
3080   PRINT"ACTUAL VS. PREDICTED FREQUENCIES"
3090   IF P$="Y" THEN LPRINT" ";LPRINT"ACTUAL VS. PREDICTED FREQUENCIES"
3100   PRINT"ACTUAL";TAB(12);"PREDICTED"
3110   IF P$="Y" THEN LPRINT"ACTUAL";TAB(12);"PREDICTED"
3120   NZ%=(N-1)/10+1
3130   FOR I=1 TO NZ%
3140     Q1%=I*10 -9
3150     Q2%=N
3160     IF Q2% > I*10 THEN Q2%=I*10
3170     FOR J=Q1% TO Q2%
3180       PRINT F(J);TAB(12);FS(J)
3190       IF P$="Y" THEN LPRINT F(J);TAB(12);FS(J)
3200   NEXT J
3210   REM
3220   NEXT I
3230   INPUT"PRESS <RETURN>";S$
3240   PRINT"DEGREES OF FREEDOM =":ND
3250   IF P$="Y" THEN LPRINT" ";LPRINT"DEGREES OF FREEDOM =";ND
3260   X1=CH:N1=ND:gosub 3390 :S=CH#
3270   PRINT"CHI SQUARE VALUE =";CH;" PROB. =";S
3280   IF P$="Y" THEN LPRINT"CHI SQUARE VALUE =";CH;" PROB. =";S
3290   PRINT"LOG OF LIKELIHOOD =";L1
3300   IF P$="Y" THEN LPRINT"LOG OF LIKELIHOOD =";L1
3310   REM=====
3320   NEXT LY
3330   REM=====
3340   INPUT"CONTINUE WITH NEXT SAMPLE (Y/N) ";S$
3350   IF S$="Y" THEN GOTO 310
3360   RUN "ELEFANO.BAS"
3370   REM
3380   REM .....
3390   REM =====
3400   REM ROUTINE CHISQ(X,N)
3410   REM
3420   REM EXACT FORMULA - SHARE DISTRIBUTION NO.528
3430   REM
3440   REM INPUTS ..... X1
3450   REM ..... N1
3460   REM OUTPUT ..... CH#

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```

3470 REM
3480 SU=0
3490 IF X1>0 AND N1>0 THEN GOTO 3520
3500 CH#=1!
3510 RETURN
3520 REM
3530 IF FIX(N1/2)*2 <> N1 THEN GOTO 3650
3540 IF N1 <= 2 THEN GOTO 3620
3550 REM
3560 TE#=1
3570 FOR IO=1 TO FIX(N1/2-1)
3580   CI#=2*IO
3590   TE#=TE##*X1/CI#
3600   SU=SU+TE#
3610 NEXT IO
3620 CH#=EXP(-X1/2!)*(1!+SU)
3630 REM
3640 RETURN
3650 REM
3660 TE#=1!/X1
3670 REM
3680 REM
3690 FOR IO=1 TO FIX((N1-1)/2)
3700   CI#=2!*IO-1!
3710   TE#=TE##*X1/CI
3720   SU=SU+TE#
3730 NEXT IO
3740 XS=SQR(X1)
3750 X=XS:GOSUB 4080 :CH#=2!-2!*NR+XS*EXP(-X1/2!)*.797885*SU: REM" CALL NORM (X
S)
3760 RETURN
3770 REM
3780 REM      END OF ROUTINE CHISQ
3790 REM
3800 REM =====
3810 REM ROUTINE GTRUN (X)
3820 REM
3830 REM G(X) - HALD - MAX-LIKE EST. - ANNALS MATH STAT.
3840 REM          VOL 24, P.557
3850 REM
3860 REM      INPUT ..... X
3870 REM      OUTPUT .... GT
3880 REM
3890 SP#=1.12837917#
3900 P# = .327591
3910 A1#=.2258368460000001#
3920 A2#=-.252128668#
3930 A3#=1.25969513#
3940 A4#=-1.28782245#
3950 A5#.9406460700000001#
3960 S2#.7071067810000001#
3970 REM
3980 XN#=1!/(1!+P##*ABS(X*S2#))
3990 PH#=SP##*EXP(-X*X/2!)
4000 PS#=1!-XN##*(A1#+XN##*(A2#+XN##*(A3#+XN##*(A4#+XN##*A5#))))*PH#
4010 TE#=.5*PS#
4020 IF X>0 THEN TE#=-TE#
4030 GT=1!/(PH#/(2.82842712##*(TE#+.5))-X)
4040 RETURN
4050 REM
4060 REM END OF ROUTINE GTRUN
4070 REM
4080 REM =====
4090 REM ROUTINE NORM(X)
4100 REM
4110 REM APPROX. FOR DIG. COMP. - HASTINGS, P. 169
4120 REM
4130 REM      INPUT ..... X
4140 REM      OUTPUT .... NR
4150 REM

```

```

4160 SP#=1.12837917#
4170 P#=.327591
4180 A1#.2258368460000001#
4190 A2#=-.252128668#
4200 A3#=1.25969513#
4210 A4#=-1.28782245#
4220 A5#.9406460700000001#
4230 S2#=.7071067810000001#
4240 XN#=1!/ (1!+P#*ABS(X*S2#))
4250 PH#=SP#*EXP(-X*X/2!)
4260 PS#=1!-XN##(A1#+XN##(A2#+XN##(A3#+XN##(A4#+XN##A5#))))*PH#
4270 TE#=.5*PS#
4280 IF X < 0 THEN TE#=-TE#
4290 NR = .5+TE#
4300 REM
4310 RETURN
4320 REM
4330 REM      END OF ROUTINE NORM
4340 REM
4350 REM =====
4360 REM      ROUTINE TRUNC
4370 REM
4380 REM      INPUT ..... X
4390 REM      OUTPUT ..... TR
4400 REM
4410 A0#=34.758138#
4420 A1#=-69.1654
4430 A2#=38.338991#
4440 A3#=-5.38194
4450 B1#=5.019750360000001#
4460 B2#=-7.0780578#
4470 B3#=1.6336409#
4480 REM
4490 Z#=SQR(-2!*LOG(X-.5))
4500 TR=(((A3#*Z#+A2#)*Z#+A1#)*Z#+A0#)/(((B3#*Z#+B2#)*Z#+B1#)*Z#+1!)
4510 REM
4520 RETURN
4530 REM
4540 REM
4550 REM      END OF ROUTINE TRUNC
4560 REM
4570 REM
4580 REM =====
4590 REM
4600 REM      ***** READ DATA FROM FILE *****
4610 REM
4620 REM =====
4630 LINE INPUT"ENTER FILENAME? ";FT$
4640 OPEN "I",1,FT$
4650 REM READING CATCH AT LENGTH DATA FROM DISK
4660 INPUT#1,N1,N,XL,XI,XH
4670 FOR I=1 TO N
4680 INPUT#1,SN,L,F(I),M,D
4690 NEXT I
4700 IF S1>9999 THEN CLOSE #1
4710 RETURN

```