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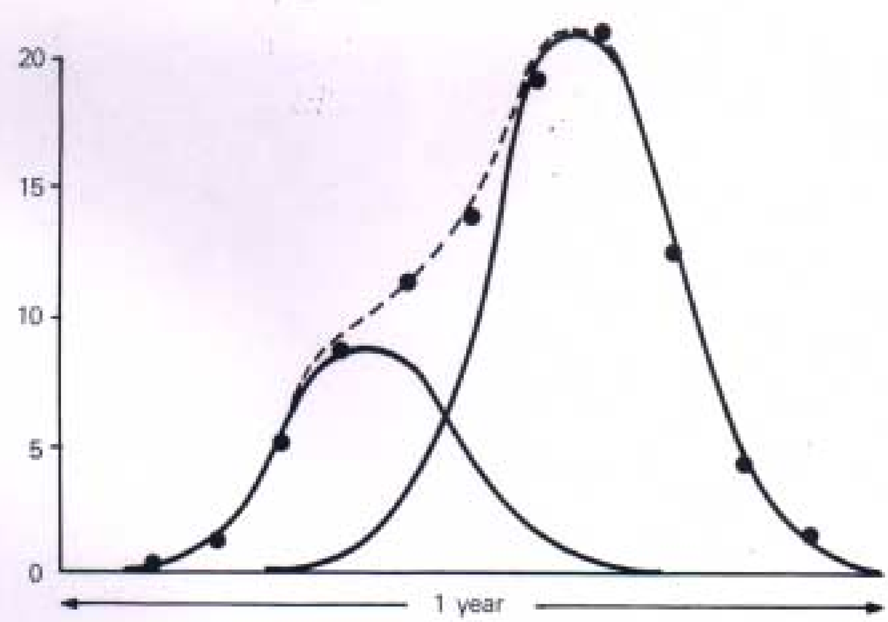
# Fishery statistics on the microcomputer : A BASIC version of Hasselblad's NORMSEP Program




BAY OF BENGAL PROGRAMME

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Marine Fishery Resources Management

BOBP/MAG/3
RAS/81 /051

# FISHERY STATISTICS ON THE MICROCOMPUTER

## – A BASIC version of Hasselblad's NORMSEP program

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This paper provides an outline of a mathematical method to analyse overlapping normal distributions. Separations of mixtures of normal distributions is frequently required in fisheries biological analysis, as in the case of length frequency distribution of fishes. Several methods are available for this. The method presented in this paper was originally developed by V Hasselblad and has been cast in its present form by D Pauly and N David. It was originally published as ICLARM contribution No. 193.

The new version, presented in this paper, is written in Microsoft BASIC and can be implemented on a large variety of microcomputers. The specific version presented here can run without modification on an Apple IIe microcomputer (with CP/M-80 operating system). The Program uses up to 12 K of RAM.

This paper grew out of a training course on the use of computers in fishery resources management. The course was organized by the project "Marine Fishery Resources Management in the Bay of Bengal" in cooperation with member-countries Sri Lanka, Bangladesh, Indonesia, Malaysia, Thailand and Maldives. Dr. Daniel Pauly of ICLARM and Mr J Hertel-Wulff of BOBP worked on the version presented in this paper.

The UNDP-funded project "Marine Fisheries Resources Management in the Bay of Bengal" (RAS/81/051) is a component of the Bay of Bengal Programme (BOBP). It has a duration of four years; it commenced in January 1983. Its immediate objective is to improve the practice of fishery resources assessment among participating countries and to stimulate and assist in joint assessment and management activities between countries sharing fish stocks.

This document is a training manual and has not been officially cleared either by the governments concerned or by the FAO.

## 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 | IO | 5 |
| 1 | 23 | I I | 2 |
| 2 | 22 | I2 | 3 |
| 3 | I | 13 | 6 |
| 4 | 37 | I4 | 6 |
| 5 | 28 | 15 | I5 |
| 6 | 1 | 16 | 6 |
| 7 | 6 | 17 | 2 |
| 8 | I7 | I8 | 2 |
| **9** | 16 | | – |

Table 1 gives a set of frequencies generated (by Everitt and Hand 1981, Table 2.71 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?

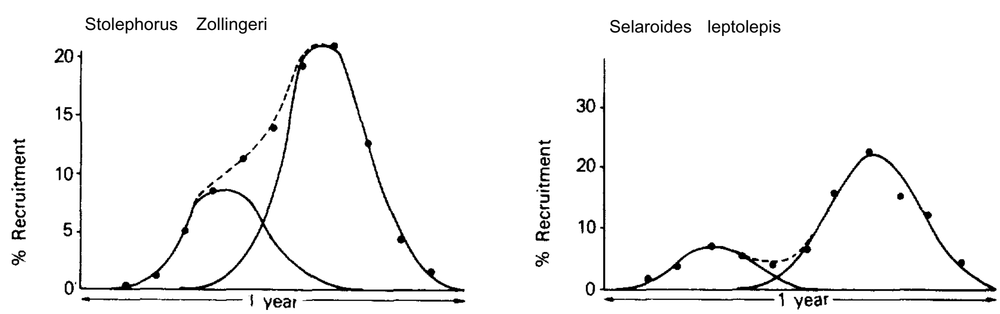


*Fig. 1 Recruitment patterns in two stocks of Philippine fishes, derived from length-frequency data projected backwards onto the time axis and used to separate the two pulses of recruitment occuring within a year. The separation of the recruitment patterns into their component distribution was done using NORMSEP; note that the chi-square statistic cannot be used here because recruitment patterns are expressed in % (after Pauly and Navaluna 19841.*

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 I.

| *Component* | *Mean* | *Standard deviation* |
|---|---|---|
| I | 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 I (see text for interpretation), is given below.

### Values after 21 iterations

| Group | Mean | St dev | Per cent | Size |
|---|---|---|---|---|
| *I* | 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 | I6 | 15.622 |
| 23 | 22.9724 | 5 | 5.78687 |
| 22 | 20.091 | 2 | 1.61373 |
| I | 4.24912 | 3 | 2.8621 |
| 37 | 34.0085 | 6 | 6.25408 |
| 28 | 28.1286 | 6 | 9.4763 |
| I | 2.24172 | I5 | 9.83824 |
| 6 | 6.21149 | 6 | 6.99787 |
| 17 | 16.146 | 2 | 3.46968 |
| | | 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* |
|---|---|---|
| I | 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. I ? | 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 | ENTER LOWER LIMIT OF SMALLEST CLASS? | 0 |
| 7 | ENTER CLASS WIDTH ? | 1 |
| 8 | ENTER FREQUENCY : 1 ? | 2 |
| | ENTER FREQUENCY : 2? | 23 |
| | enter frequencies from Table I | |
| 9 | ANY CORRECTIONS (Y/N) ? | N |
| 10 | REVIEW FREQUENCIES (Y/N) ? | N |
| 11 | PRINT RESULTS (Y/N) ? | N |
| | . continue as 7 above . | |

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 etch. 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.

```
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 SHACICS 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 3. HERTEL—WULFF, BOBP.
160 REM
110 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        STRUN
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 CO=.39894228#
370 INPUT"ENTER RUN—ID ";M1$
380 PRINI"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 1=1 TO K
470 PRINT"ENTER ESTIMATE OF MEAN NO.";I;:INPUT YQ(I)
480 NEXT I
490 FOR 1=1 TO K—1
500 IF YQ(I)>YQ(I+1) THEN HOME:PRINT "ERRORS ENTER MEAN VALUES FROM LOWEST TO
 HIGHEST": GOTO 460
510 NEXT I:IF S$="Y" THEN GOTO 700
520 IF K>10 THEN K=10:REM MAXIMUM DISTRIBUTIONS IS 10
530 INPUT "ENTER LOWER LIMIT OF SMALLEST CLASS";XI
540 INPUT "ENTER CLASS WIDTH";XL
550 FOR 1=1 TO N
560 PRINT"ENTER FREQUENCY:"; I;: INPUT F(I)
570 NEXT I
580 HOME:PRINT TAB(10);"LOOK FOR ERRORS"
590 FOR I=1 TO N
600 PRINR "FREQUENCY NO.";l;F(I)
610 IF 1—14 THEN INPUT "PRESS <RETURN>":P$
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
```

```
680   INPUT "REVIEW FREQUENCIES (Y/N) ";P$
690   IF P$="Y" THEN GOT0 580
700   SF=0
710   FOR I=1 TO N
720   SF=SF+F(I)
7.30  NF(I)=FIX(F(I)+.5)
740   NEXT I
750   REM
760   REM
770 HOME:FRINT TAB (20) ; "NORMSEF RUNNING. WAIT"
780 REM  =================
790   FOR LY=1 TO LC
800 REM  =================
810 REM GET CUT-OFF POINTS FX'S
820   FOR J=l TO K-l
830       FX(J)=(YQ(J)+YQ(J+l) )/2
840   NEXT J
850  FX (K)=(N-l)*XL+XI
860   REM
870   REM GET LOWER AND UPPER BOUNDS FOR MEANS, BL AND BU'S
880   BL(l)=YQ(l)-.5+(YQ(2)-YQ(l))
890   FOR J=l TO K-1
900       BU(J)=YQ(J)+ .5*(YQ(J+l)-YQ(J))
910       BL(J+l)=BU(J)
920   NEXT J
930   BU(K)=(N-l)*XL+XI
940   REM GET LOWER AND UPPER BOUNDS FOR STANDARD DEVIATION, AL & AU 'S
950   FOR J=1 TO K
960       AL(J)=. 0l*YQ(J)
970       AU(J)=.5+YQ(J)
980   NEXT J
990   REM
1000   FOR J=l TO K
1010       NX(J)=FIX(((FX(J)-XI)/XL)+.5)
1020       BL(J)=(BL(J)-XI)/XL
1030       BU(J)=(BU(J)-XI)/XL
1040       AL(J)=AL(J)/XL
1050       AU(J)=AU(J)/XL
1060   NEXT J
1070   REM
1080   NX (K) =N
1090   REM
1100   FOR I=l TO N
1110       FS(I)=F(I)
1120   NEXT I
1130  NB=l
1140  REM COMPUTE INITIAL ESTIMATES USING HALD'S PROCEDURE
1150  AS=0
1160  REM
1170  FOR J=l TO K
1180      NE=NX (J)
1190      XB=NE
1200       A=0
1210       B=0
1'220      C=0
1230  FOR I=NB 'TO NE
1240      CI=XB-I+. 5
1250      CF=F'S(I)
1260       A=A+CF
12 7 0     B=B+CF'+C I
1280       C=C+CF+CI+CI
1290  NEXT I
1300  REM
1310  ZZ=A*C/ (2*B*B)
1320   X=ZZ: GOSUB 4350 : Z=TR: REM CALL TRUNC(ZZ)
1330  REM
1340  X=Z:GOSUB 3800 :G=GT: REM CALL GTRUN(Z)
1350  REM
1360  SG (J) =B*G/A
1370  IF SG(J) > AU(J) THEN SG(J)=AU(J)
```

```
1380 IF SG(J) < AL(J) THEN SG(J)=AL(J)
1390 AU=-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 F(J)=A/PK
1530 AS=AS+P(J)
1540 FOR KK=l TO N
1550      I I=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 :KF=NR:REM CALL NORM (ULIM)
1600        X=BM: GOSUB 4080 : KP=KP-NR: REM CALL NORM (BM)
1610      KP=A*KP/PK
1626      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 GOT0 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-l TO K
1740   P(J)=P(J)/AS
1756 NEXT J
1760 L1=0
1770 REM COMPUTE LIKELIHOOD FUNCTION Ll
1780 FOR I=1 TO N
1790     QQ(I)=0
1800     FOR J=l TO K
1810          G(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(l0)
1850 NEXT I
1866 REM START OF METHOD OF STEEPEST DESCENT
1870 FOR IT=1 TO 125
1880      L3=IT
1890      PS=0
1900      FOR J=l 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) 3 BU(J) THEN MP(J)=BU(J)
2050 SF(J)=SQR(S3/XD)
2060 IF SP(J) > AU(J) THEN SP'(J)=AU(J)
2070 IF SP(J) < AL(J) THEN
```

```
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!*SG(J)*SG(J)))/SG(J)
2190          QQ(I)=00(1>+Q(I,J)*PP(3)
2200  NEXT J
2210  LL=LL+F(I>*LOG(00(I)))/LOG(10)
2220  NEXT I
2230  REM TEST FOR IMPROVED LIKELIHOOD FUNCTION LL
2240  IF LL<=L1 THEN GOTO 2320
2250  FOR 3=1 TO K
2260      P(J)=PP(3)
2270      MU(J)=MP(J)
2280      SG(J)=SP(J)
2290  NEXT J
2:300 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
239CY         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 1=1 TO NN
2510      II=I
2520      PR=PR+FS(I>
2530 IF PR—5!   0 THEN GOTO 2540 ELSE 6010 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!<0THEN 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
2Th0  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:BEEP 15,1O:  FOR J=1 TO 200:NEXT 3
2860   NEXT I
2870  REM
2880  REM ==========================================================
2890 HOME:  INPUT"PRINT RESULTS (Y/N)";P$
2900  PRINT 'RESULTS FOR RUN:";M1$
2910  IF P$="Y" THEN LPRINT" ":LPRINT"RESULTS FOR RUN: ";Ml$:LPRINT"------
-----"
2920 PRINT'VALUES AFTER"; L3;" ITERATIONS"
2930  IF P$="Y"  THEN LPRINTVALUES AFTER";L3;   ITERATIONS'
2940  PRINT"GROUP        MEAN       ST DEV      PERCENT      SIZE"
2950  IF P$="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  PRINTACTUAL 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*1O 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  PR IN T" DEGREES OF FREEDOM=";  · ND
.3250  IF P$="Y" THEN LPRINT - ':LPRINT"DEGREES OF FREEDOM="  ;ND
3260  X1=CH:N1=ND:GOSUB 3390 :S=CH*
3270  PRINT"CHI SQUARE VALUE  ";CH;"  PROS.   ;S
3280  IF P$="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*
```

```
3470 REM
3480 SU=0
3490 IF X 1>0 AND N 1 >0 THEN GOTO 3520
3500 CH#= 1 !
3510 RETURN
3520 REM
3530 IF FIX(N1/2)*2 <>NI THEN GOTO 3650
3540 IF N1 <= 2 THEN GOTW 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 (-X I/2 !)*(1!+SU)
3630 REM
3640 RETURN
3650 REM
3660 TE#=I!/X1
3670 REM
3680 REM
3690 FOR IO=1 TO FIX ( (N1-1)/2)
3700 CI#=2!+IO-I!
3710 TE#=TE#*X1/CI
3720 SU=SU+TE#
3730 NEXT IO
3740 XS=SQR (X 1)
3750 X=XS: GOSUB 4080 : CH#=2 ! -2 ! *NR+XS*EXP (-X 1/2 ! ) *. 797885*SU: REM" CA
S)
3760 RETURN
3770 REM
3780 REM         END OF ROUTINE CHISQ
3790 REM
3800 REM ====================
3810 REM ROUTINE GTRUN (X)
3820 REM
38.30 REM G(X) - HALD - MAX-LIKE EST. - ANNALS MATH STAT.
3840 REM          VOL 2 4 , P.557
3850 REM
3860 REM       INPUT . . . . .    X
3870 REM       OUTPUT . . . .     GT
3880 REM
3890 SP#=1.12837917*
3900 P# = .32759 1
3910 A1#= .225836846000000 1#
3920 A2#=-. 252128668#
3930 A3#=1.25969513#
3940 A4#=- 1.28782245#
3950 A5#=. 940646070000000 1#
3960 52#=.7071067810000001#
3970 REM
3980 XN#=I!/(1!+P#*ABS(X+S2#))
3990 PH#=SP#*EXP(-X*X/2!)
4000 PS#=1 ! -XN#*(A1#+XN#*(A2#+XN#*(A3#+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. - HHSTINGS, P. 169
4120 REM
4130 REM      INPUT . . . . .   X
4140 REM      OUTPUT . . . .   NR
4150 REM
```

```
4160  SP#=1.12837917#
4170  P# =. 327591
4180  Al#= .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#=l!- 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  AO#=34.758 138#
4420  Al#=-69.1654
4430  A2#=38.338991#
4440  A3#=-5.38194
4450  B1#=5.019750360000001#
4460  82#=-7.0780578#
4470  B3#=1.6336409#
4480  REM
4490 Z#=SQR(-2!*LOG(X-.5))
4500  TR=(((A3#+Z#+A2#)+Z#+Al#)*Z#+A0#)/(((B3#*Z#+B2#)*Z#+Bl#)*Z#+l!)
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 #l
4710 RETURN
```

## *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 audiences.

*Miscellaneous Papers* (BOBP/MIS/ ) concern work not originated by BOBP staff or consultants - but which is relevant to the Programme's objectives

*Information 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.

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