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Computer Programs for Fish Stock Assessment
2nd edition

prepared by
Resource Assessment Division
Analytical Programs Working Group

edited by
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APPROVED FOR DISTRIBUTION

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INTRODUCTION

The following manual is an updated edition of the Computer Programs for Fish Stock Assessment manual prepared by the Resource Assessment Division ADP Needs Committee in January 1976. The programs in this manual have been written by Northeast Fisheries Center (NEFC) personnel utilizing FORTRAN77 to run on the NEFC/WHOI VAX 11/785 computer, or by programmers in other institutions and converted, as necessary, to run on the VAX system. Each of the programs has been tested and is assumed to be error free, however, any problems encountered while using the programs should be reported to the Analytical Programs Working Group. No responsibility can be accepted for problems or consequences resulting from the use of these programs. The Manual is not intended to represent a completed software library; suggestions for additional analytical programs are welcome.

The programs in this library are arranged into six sections based upon the type of analysis performed. Documentation includes a description, instructions for running, any specific restrictions, references, and an example run of each program. Any program may be run interactively, although runs utilizing the larger programs should be submitted to run in batch mode. Recommended methods for running are discussed in each program's documentation.

All of the programs reside in a master subdirectory of Account 712. Subdirectories containing sample data files and command files (where applicable) are also available. The directory arrangement is as follows:

Executable files	FSHA:[712.MASTER.XEQ]
Source code listings	FSHA:[712.MASTER.SOURCE]
Sample data files	FSHA:[712.MASTER.DATA]
Command files	FSHA:[712.MASTER.COM]

The following persons, listed alphabetically, wrote, converted and/or documented the programs in this manual: Frank Almeida, Stephen Clark, Michael Fogarty, Karen Foster, Wendy Gabriel, Anne Lange, Ralph Mayo, Steven Murawski, Gordon Waring, NEFC, Resource Assessment Division; Jeremy Collie, WHOI; and Brian O'Gorman, Massachusetts Division of Marine Fisheries.

Accessing the NEFC/WHOI VAX 11/785 Computer

To access the VAX computer system, the following instructions must be used.

MODEM communication

1) Dial the telephone number for the system:

Baud Rate	NEFC Data phone
300 (AJ & TI only) or 1200	540-6000

2) When the high-pitched tone is heard, either place the handset in the acoustic coupler (AJ or TI terminals) or flip the CONNECT switch on the high speed modems, and press the RETURN key twice on the terminal keyboard.

3) After the computer responds with:

enter class

type GRAY and you will then be prompted for your Username and Password.

4) Once you have gained access to the system, follow the INSTRUCTIONS FOR RUNNING section in the program you intend to run.

COAXIAL CABLE communication

If the terminal you are using communicates with the VAX via the coaxial cable network, to access the system simply turn the terminal on and press the RETURN key twice on the keyboard and proceed from step 4 above.

CONTENTS

I. POPULATION ANALYSES

FMBVPA....allows estimation of initial population size in weight and number, and instantaneous fishing mortality (F) for a given cohort in any year given catch-at-age data, values for instantaneous natural mortality and an initial estimate of F for the oldest age in which the cohort was fished. . . . . I. 1

SVPA.....determines values of fishing mortality from a catch-at-age matrix based on the assumption that age-specific patterns of exploitation are constant over time. I.14

POPE.....is an extension of Pope's multispecies cohort analysis which incorporates species interactions through predation into species, year and age specific calculations of stock size, fishing mortality and total natural mortality. I.25

DELPOP....estimates catchability coefficients and population size in numbers using smoothed relative abundance indices. I.35

CATCURV...analyzes a vector of catch at age data and provides estimates of the survival rate (S), the instantaneous total mortality rate (Z), and associated statistical measures (variances, standard errors and confidence limits). I.47

LESLIE....simulates the growth of the female portion of a population utilizing the Leslie matrix model. Each individual female is assumed to have age specific fecundity and rates of survival, which remain constant over time. I.55

II. STOCK SIZE AND CATCH PREDICTONS

FMBPRED...computes catch and remaining stock size, given various levels of instantaneous fishing (F) and natural (M) mortality,

initial stock size, and recruitment, according to the Murphy catch equation. II.1

III. YIELD PER RECRUIT ANALYSES

YR.....computes equilibrium yield and spawning stock biomass per recruit (in numbers and weight), and values of F(0.1) and F(max). The algorithm of Thompson and Bell (1934) is used to sum yields from the various age groups. The last age can be specified as a plus-group. III.1

FMBYPCTC..provides equilibrium yield values for a given recruitment according to Beverton and Holt's formula. The model assumes constant fishing mortality over the fishable life span with 'knife-edge' selection and a value of 3.0 for b in the length-weight equation. III.16

FMBRIKR...computes an approximate yield isopleth for a given number of recruits to a fishery when both growth and natural mortality are estimated empirically. The calculations are carried out using a modified form of Ricker's method for estimating equilibrium yield. III.22

YPIB.....uses the incomplete Beta function in the Beverton-Holt yield equation to produce an array of coordinates for plotting yield isopleths. III.29

YPER.....uses a modification of the Beverton-Holt yield equation to produce relative yield per recruit isopleths for different E (F/F+M) and C (lc/l(infinity)) values as a function of M and K. III.41

MGEAR.....computes estimates of yield per recruit and several related parameters for fisheries that are exploited by several gears which may have differing vectors of age specific fishing mortality. The Ricker (1958) yield equation is used for computations. III.52

IV. CATCH EFFORT ANALYSES

PCNT.....computes the percentage composition of a single species in the total commercial landings of a series of fishing trips on a trip by trip landed weight basis. Summary data are displayed arrayed in 5-percent intervals by month. IV.1

FPOW.....estimates relative fishing power and relative population density utilizing analysis of variance. IV.6

ESP3.....provides an estimation procedure for determining relative fishing power coefficients using a two-way classification model with no interaction. Fishing effort is adjusted to an arbitrarily selected standard (e.g. gear-tonnage class combination). IV.15

V. SURPLUS PRODUCTION MODELS

GENPROD...fits the generalized stock production model to catch and effort data and estimates equilibrium yield as a function of effort V.1

PRODFIT...fits the generalized stock production model to fishery catch and effort data by least squares using an equilibrium approximation approach. V.11

VI. GROWTH ANALYSES

BGCII.....fits the von Bertalanffy growth curve by least squares with weights proportional to sample size at each age group. A constant time interval between ages is required, but the number of lengths in the age groups may be unequal VI.1

BGCIII....fits the von Bertalanffy growth in length curve to unequally spaced age groups with unequal sample sizes for separate ages. VI.5

BGCIV.....fits the von Bertalanffy growth in length equation when lengths of an

individual fish at points in time are known, but the absolute age of the fish may not. It lends itself well to fitting the equation to mark and recapture data VI.10

NORMSEP...separates length frequency sampling distributions into component normal distributions. It is used to estimate relative abundance of age groups in length samples when age data are not available.. . . . . VI.15

PROGRAM NAME: Virtual Population Analysis

PROGRAM TYPE: Main

DATE CREATED: unknown

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]FMBVPA.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]FMBVPA.EXE

AUTHOR: M. Parrack

DOCUMENTED BY: F.P. Almeida

REVISIONS (Date/Reviser - Description)

Sept 1979 /M. Thompson -
Modified to allow for input of catch-at-age and mean weight-at-age matrices and automatic calculation of weighted mean F.
Jan 1982 /F.P. Almeida -
Revised to increase number of age classes and to conform with VAX 11/780 compatible FORTRAN77.
Nov 1984 /O.L. Jackson -
Revised to include plus-group calculations, allow for input of maturity ogive multipliers, and calculate stock size projections for the year following the last year in the analysis.

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

The program allows estimation of initial population size in weight and number, and instantaneous fishing mortality (F) for a given cohort in any year given catch-at-age data, values for instantaneous natural mortality (M) and an initial estimate of F for the oldest true age in which the cohort was fished. It also provides estimates of projected stock sizes in the last year + 1 given estimates of recruitment in the final years.

DESCRIPTION:

The program performs an analysis on matrices of catch-at-age data. Output consists of age specific fishing mortality, stock size in numbers, stock biomass and catch in matrix form with data organized by calendar year.

The equation:

$$C_i = N_i \frac{F_i}{F_i+M} (1-e^{-(F_i+M)})$$

where:

C_i = catch of a cohort at age i (in numbers),
N_i = cohort size at the beginning of year i,
F_i = instantaneous fishing mortality rate of a cohort at age i,
M = instantaneous natural mortality rate,

is used to solve for N_i which is then substituted for N_{i+1} in the equation:

$$\frac{N_{i+1}}{C_i} = \frac{(F_i+M)e^{-(F_i+M)}}{F_i(1-e^{-(F_i+M)})}$$

which is solved iteratively for F_i. Mean weighted F values for fully recruited ages in a given calendar year are calculated as follows:

$$F_i = \frac{\sum_{j=r_i}^{r_{\lambda-1}} F_j N_j}{\sum_{j=r_i}^{r_{\lambda-1}} N_j}$$

where:

F_j = fishing mortality levels for each age,
N_j = stock size (in numbers) for each age,
r_j = age at 100% recruitment,
r_λ = last age for which catch-at-age data is available.

The estimation of annual plus-group stock sizes is accomplished utilizing the following equation:

$$N = C \frac{(F+M)}{F} \frac{1}{1-e^{-(F+M)}}$$

and will allow for three options of terminal F:

1) fully recruited weighted mean F values,
2) F calculated for the oldest true age, or
3) a user supplied array of F values.

For a more complete description of the algorithms used in virtual population analysis see Gulland (1965), Pope (1972) and Anderson (1978).

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

Input Description:

Data file assignments must be performed before the program is executed. Input will be preceeded by specific questions which may be answered interactively or by placing the responses, in proper sequence, in an input data file. Any array or file must be input beginning with the youngest age and/or earliest calendar year. Some flexibility exists for reentering incorrectly input values, but in most cases a mistake will lead to an abort call or incorrect calculations.

Input consists of files of catch-at-age in matrix form and mean weight-at-age data in matrix or array form (see example). The program automatically calculates weighted mean fishing mortalities (STARTING F's), stock size in numbers and stock biomass estimates. The catch-at-age data file can contain a maximum of 45 calendar years (rows) and 35 age groups (columns). The left columns are reserved for calendar year beginning with the earliest year. It can be either 4 digits (19__) or the last two digits of the calendar year. If there is no data available for an age group within a year class, 0.0 should be entered (Note: If your catch-at-age data matrix contains holes i.e. no catch for a particular age in one year and then some catch for the next age in the following year, the program will issue a warning and then abort.)

In order to calculate stock biomass estimates, the user has the option of inputting a data file containing age specific mean weights. The file must contain a weight-at-age value for each stock size value the user intends to sum. In place of the data file, the summations can be performed using an array of mean weights-at-age. These values will be applied to all calendar years.

The program also calculates stock sizes in the year following the final year of available catch-at-age data. This projection is performed utilizing the standard catch equation. However, to calculate stock sizes in the final years of the analysis, recruitment estimates will be necessary. The user will be prompted to input values for those years requiring recruitment estimates.

Estimates of total stock size (ie. all ages included in the analysis) in weight and numbers are automatically produced by the program. If the user has an adequate maturity ogive to calculate spawning stock size, an array of percent mature-at-age multipliers may be input. If a maturity ogive is not available, the user may simply sum stock sizes beginning at any ages desired.

To calculate the weighted mean fishing mortality for a calendar year, the age at 100% recruitment must be identified.

An array of ages, separated by commas and beginning with the earliest calendar year must be entered. The number of values input must equal the number of rows in the catch matrix, i.e. one for each calendar year.

Data input consists of the following steps:

> The user will be asked whether or not data will be entered interactively or whether the answers to the following questions will be provided via a parameter file.

> Enter a title line (60 character maximum).

> Enter the first, then last calendar years (rows) associated with the catch-at-age matrix (four digits (maximum = 45).

> The user will be asked whether or not age specific biomass estimates are required. Answer YES or NO.

> The user will be asked whether or not calculated stock size weights for each calendar year should be adjusted by the observed to calculated weight ratios. If YES, the number of ratios entered must equal the number of calendar years in the catch-at-age matrix.

> Enter the youngest, then oldest true ages in the data set, i.e. those ages for which adequate ageing data is available (maximum = 35).

> The user will be asked whether or not a plus group is present in addition to the true ages entered above. If YES, options for providing fishing mortality values to the plus group are displayed. The options include 1)The weighted mean F for fully recruited ages, 2) the F value calculated for the oldest true age, or 3) a user supplied F. If the ´user supplied´ option is chosen, F values for each calendar year must be input.

> Enter the format used in reading the catch-at-age data file e.g. (I2,T9,F7.1) or (I4,10F6.1). The format must read data from all ages, including the plus group if present.

> Enter the first, then last cohorts (calendar years) for which processing is required.

> The user will be asked whether natural mortality (M) will be constant or age specific. In the latter case, an array of values must be entered.

> The number of STARTING F´s in the last calendar year (i.e. the number of fully recruited cohorts) must be entered followed by the array of STARTING F´s for those cohorts.

> The program will determine how many user input recruitment estimates are required and will ask for their input.

> Total stock is automatically produced by the program. The user will be asked whether spawning stock sizes should be calculated. If YES, then an array of percent mature-at-age multipliers will be requested.

> The user will be asked whether or not any summations

in addition to total stock are desired. If YES, the program will ask how many summations are requested and then the ages at which to start the summations. The maturity ogive, if supplied for spawning stock calculaitons will not be applied to the additional summations.

> The user will be asked if a matrix of mean weights-at-age will be utilized. Answer YES or NO. If YES, enter the format to be used in reading the data file. This format should also read data for the plus group if present. If NO, enter an array of values, one for each age, including the plus group.

> Enter an array of ages of full recruitment. The number of values input must equal the number of rows in the catch matrix.

Output Description:

The analysis provides matrices of age specific fishing mortality, stock size, stock biomass, and catch values together with summed stock numbers and biomass estimates (adjusted or unadjusted) by calendar year. Weighted mean F values for fully recruited ages in each calendar year are also output. The four matrices can either be output at the terminal or assigned to a designated file on unit FOR030.

Input File Description:

Catch-at-age File (assigned to FOR010): This file is organized with the calendar year in the leftmost column. The uppermost year is the earliest. In each row are the catch-at-age values for that calendar year. The format is determined by the user, 35 catch values per calendar year is the maximum. The format must be constant for all rows, a maximum of 45 rows is allowed. The calendar year will be identified as an integer, while the catch values are reals.

Mean Weight-at-age File (assigned to FOR020): This file is organized similar to the catch-at-age file. Its format is also determined by the user. See other specifications above.

Control Parameter File (assigned to FOR050): Answers to the questions may optionally be placed in sequential order in this file. This file is free-formatted, i.e. separate multiple responses in each record by a comma or space.

Output File Description:

Primary Output Tables (assigned to FOR030): This file will contain the four basic output matrices generated by the analysis. File size will vary depending on the number of years involved in

the analysis. The output format is fixed and provides tables with calendar years as columns and ages in rows (see example).

Control Command Setup:

To run the program the following commands must be used:

```
$ASSIGN [directory]catchfile.DAT   FOR010
$ASSIGN [directory]weightfile.DAT  FOR020
$ASSIGN [directory]outputfile.DAT  FOR030
$ASSIGN SYS$COMMAND                FOR005
        and optionally
$ASSIGN [directory]controlfile.DAT FOR050
$RUN FSHA:[712.MASTER.XEQ]FMBVPA
```

REFERENCES:

Anderson, E.D., 1978. An explanation of virtual population analysis. NMFS, NEFC, Woods Hole Lab. Ref. No. 78-09 (mimeo). 5p.

Gulland, J.A., 1965. Estimation of mortality rates. Annex to Arctic Fish Working Group Rpt. ICES C.M. 1965, Doc. No.3, 9p. (mimeo).

Pope, J.G., 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. Res. Bull. Int. Comm. Northw. Atlant. Fish. 9:65-74.

```
$ ASSIGN CATCH.DAT   FOR010
$ ASSIGN WEIGHT.DAT  FOR020
$ ASSIGN EXAMPLE.DAT FOR050
$ ASSIGN EXAMPLE.OUT FOR030
$ ASSIGN SYS$COMMAND FOR005
$ RUN FSHA:[712.MASTER.XEQ]FMBVPA

    VIRTUAL POPULATION ANALYSIS   VERSION 2.6  11/I/85  JACKSON, ALMEIDA

IS THIS RUN INTERACTIVE (ENTER 1), OR
USING A PARAMETER FILE (ENTER 2)?                                  >2
 ENTER TITLE LINE (MAX = 60 BYTES)                                 >  VPA EXAMPLE RUN    POLLOCK DATA
 ENTER FIRST, THEN LAST CALENDAR YEAR (MAX = 45)                   >   1973   1982
 WANT TO OUTPUT AGE SPECIFIC BIOMASS ESTIMATES?  (YES OR NO)       >YES
 WANT TO ADJUST STOCK BIOMASS ESTIMATES? (YES OR NO)               >YES
 ENTER RATIOS, ONE FOR EACH CALENDAR YEAR                          >  0.940  0.900  0.970  1.000  1.000  1.000  1.000  1.000  1.000
                                                                      1.000
 ENTER YOUNGEST, THEN OLDEST TRUE AGE IN DATA SET (MAX = 35)       >      2     11
 IS THERE AN ADDITIONAL PLUS GROUP PRESENT? (YES OR NO)            >YES
 OPTIONS FOR F IN PLUS GROUP INCLUDE:
      WEIGHTED MEAN F (ENTER 1)
      F FOR OLDEST TRUE AGE (ENTER 2)
      USER SUPPLIED (ENTER 3)                                      >      1
 ENTER FORMAT TO READ CATCH-AT-AGE DATA SET                        >(2X,I2,6X,11F5.0)
 ENTER FIRST, THEN LAST COHORT (CALENDAR YEARS)                    >   1962   1980
 WILL M BE CONSTANT?                                               >YES
 ENTER M                                                           >  0.200
 ENTER NUMBER OF STARTING F VALUES                                 >     10
 ENTER STARTING F VALUES                                           >  0.013  0.159  0.200  0.260  0.260  0.260  0.260  0.260  0.260
                                                                      0.260
 ENTER RECRUITMENT ESTIMATE FOR 1983                               >   44500.0
 WANT TO CALCULATE SPAWNING STOCK BIOMASS? (YES OR NO)             >YES
 ENTER PERCENT MATURE-AT-AGE ARRAY (ONE FOR EACH AGE)              >  0.000  0.300  0.750  1.000  1.000  1.000  1.000  1.000  1.000
                                                                      1.000  1.000
 ARE ADDITIONAL SUMMATIONS DESIRED?  (YES OR NO)                   >YES
 ENTER NUMBER OF ADDITIONAL STOCK SUMMATIONS                       >      1
 ENTER AGES TO START SUMMING                                       >      3
 USING A MATRIX OF MEAN WEIGHTS? (YES OR NO)                       >YES
 ENTER FORMAT TO READ MEAN WEIGHT-AT-AGE DATA SET                  >(2X,I2,6X,11F6.3)
 ENTER AGES OF 100% RECRUITMENT, BEGIN WITH EARLIEST YEAR          >      5      5      5      5      5      5      5      5      5
                                                                       5
FORTRAN STOP
$

$ TY EXAMPLE.OUT
```

VPA EXAMPLE RUN POLLOCK DATA

YEAR

FISHING MORTALITY

AGE	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
2	0.036	0.021	0.009	0.011	0.003	0.004	0.019	0.015	0.043	0.013
3	0.102	0.194	0.151	0.097	0.067	0.065	0.099	0.187	0.131	0.159
4	0.387	0.271	0.359	0.240	0.182	0.171	0.190	0.191	0.577	0.200
5	0.689	0.458	0.285	0.326	0.255	0.255	0.212	0.296	0.402	0.260
6	0.401	0.465	0.392	0.305	0.372	0.309	0.254	0.296	0.256	0.260
7	0.589	0.348	0.361	0.415	0.491	0.490	0.191	0.203	0.190	0.260
8	0.574	0.715	0.147	0.284	0.508	0.621	0.184	0.137	0.126	0.260
9	0.756	0.347	0.187	0.040	0.315	0.663	0.365	0.154	0.199	0.260
10	0.799	0.467	0.380	0.158	0.162	0.500	0.266	0.327	0.167	0.260
11	0.624	0.458	0.318	0.321	0.338	0.337	0.222	0.270	0.285	0.260
12+	0.624	0.458	0.318	0.321	0.338	0.337	0.222	0.270	0.285	0.260
MEAN F	0.624	0.458	0.318	0.321	0.338	0.337	0.222	0.270	0.285	0.260
REC AGE	5+	5+	5+	5+	5+	5+	5+	5+	5+	5+

STOCK SIZE

AGE	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
2	57595.2	32685.4	43493.9	52833.6	64325.7	51963.8	13598.2	26873.8	57119.7	25792.6	44500.0
3	18123.9	45492.0	26207.2	35300.7	42791.5	52635.9	42401.8	10923.4	21676.0	44794.1	20844.5
4	19427.8	13401.1	30690.1	18442.7	26240.2	32758.2	40365.4	31446.5	7418.2	15566.6	31283.0
5	9508.2	10804.4	8364.6	17553.1	11875.9	17906.8	22599.8	27332.6	21270.3	3411.6	10434.6
6	3476.9	3907.6	5595.3	5149.2	10370.8	7536.7	11364.5	14972.8	16652.6	11650.4	2153.7
7	1950.5	1905.4	2009.8	3095.8	3107.7	5854.2	4531.4	7215.0	9117.0	10556.4	7354.7
8	908.9	885.7	1101.1	1147.2	1673.3	1557.8	2937.4	3064.3	4824.1	6170.7	6664.1
9	938.7	419.3	354.7	778.0	707.3	824.5	685.3	2001.5	2188.1	3483.6	3895.4
10	833.2	360.8	242.7	240.9	611.7	422.7	348.0	389.6	1405.3	1468.3	2199.1
11	185.8	306.8	185.2	135.9	168.4	426.1	209.9	218.4	230.0	974.1	926.9
12+	72.9	166.8	153.0	279.8	994.9	928.9	618.7	343.8	548.6	935.7	1205.6
TOT NOS	113022.0	110335.5	118397.6	134956.8	162867.4	172815.6	139660.4	124781.9	142449.9	124804.0	131461.7
WGHT ADJ	176091.7	175315.3	206299.7	239370.8	258638.1	275822.6	305856.2	315079.4	321595.4	296739.8	300913.6
SPWN NOS	37883.1	42455.4	48886.1	52802.0	62027.6	75817.1	86289.6	82400.0	68302.5	63763.9	64549.8
WGHT ADJ	104154.6	103644.1	126964.2	148130.8	154639.4	179292.8	237037.0	257622.3	243106.1	229273.5	233675.6
3+ NOS	55426.8	77650.0	74903.6	82123.1	98541.6	120851.8	126062.2	97908.0	85330.3	99011.4	86961.7
WGHT ADJ	133862.9	151487.6	168751.4	196575.5	198815.1	233212.3	295793.5	287130.6	269502.3	279639.3	271410.1

AGE	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
						STOCK BIOMASS AT AGE					
2	42228.8	23827.7	37548.3	42795.2	59822.9	42610.3	10062.7	27948.8	52093.1	17100.5	29503.5
3	26917.6	58957.6	37368.8	54716.0	47926.4	58425.8	55970.4	18569.8	31170.1	58725.0	27327.1
4	43463.8	26293.0	62515.8	40574.0	42509.1	52085.5	78308.9	66037.7	18308.2	37033.0	74422.3
5	27885.7	29852.6	24097.7	52132.7	30639.9	42797.1	65765.5	82271.1	61768.8	11828.1	36176.8
6	11994.7	14419.2	21438.3	19361.1	35468.0	26981.4	42844.0	51356.8	59732.9	45389.9	8390.8
7	8103.8	8745.6	9747.6	13961.9	13766.9	25583.0	21524.2	30663.8	40433.8	45920.2	31993.0
8	4237.5	4870.6	6664.4	5942.3	9672.0	8630.5	17506.7	17864.8	26783.5	32957.6	35592.8
9	5029.7	2520.9	2432.3	4777.0	4766.9	5318.0	4441.0	12769.5	14148.2	21647.1	24206.3
10	4417.4	2361.0	1716.3	1840.2	4318.9	2849.0	2606.7	2852.0	10291.3	10351.5	15504.0
11	1292.5	2212.0	1406.5	1040.8	1320.0	3212.6	1660.3	1729.6	1834.4	7551.0	7185.4
12+	520.2	1255.2	1363.7	2229.6	8427.0	7329.3	5165.8	3015.5	5031.0	8235.8	10611.6

AGE	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
						CATCH AT AGE				
2	1856.0	617.0	372.0	514.0	170.0	196.0	233.0	368.0	2180.0	302.0
3	1595.0	7281.0	3346.0	2952.0	2526.0	3023.0	3628.0	1694.0	2419.0	5984.0
4	5684.0	2899.0	8434.0	3583.0	3972.0	4686.0	6348.0	4971.0	2975.0	2566.0
5	4341.0	3626.0	1890.0	4453.0	2431.0	3665.0	3922.0	6370.0	6424.0	711.0
6	1049.0	1327.0	1655.0	1233.0	2937.0	1824.0	2323.0	3495.0	3422.0	2428.0
7	795.0	511.0	555.0	960.0	1101.0	2071.0	717.0	1203.0	1437.0	2200.0
8	363.0	415.0	137.0	258.0	609.0	660.0	448.0	356.0	517.0	1286.0
9	457.0	112.0	55.0	28.0	174.0	366.0	191.0	259.0	359.0	726.0
10	421.0	123.0	70.0	32.0	83.0	152.0	74.0	99.0	196.0	306.0
11	79.0	103.0	46.0	34.0	44.0	111.0	38.0	47.0	52.0	203.0
12	31.0	56.0	38.0	70.0	260.0	242.0	112.0	74.0	124.0	195.0
TOTAL	16671.0	17070.0	16598.0	14117.0	14307.0	16996.0	18034.0	18936.0	20105.0	16907.0

$

```
$ T CATCH.DAT
  73      1 1856 1595 5684 4341 1049  795  363  457  421   79   31
  74      1  617 7281 2899 3626 1327  511  415  112  123  103   56
  75      1  372 3346 8434 1890 1655  555  137   55   70   46   38
  76      1  514 2952 3583 4453 1233  960  258   28   32   34   70
  77      1  170 2526 3972 2431 2937 1101  609  174   83   44  260
  78      1  196 3023 4686 3665 1824 2071  660  366  152  111  242
  79      9  233 3628 6348 3922 2323  717  448  191   74   38  112
  80     45  368 1694 4971 6370 3495 1203  356  259   99   47   74
  81      1 2180 2419 2975 6424 3422 1437  517  359  196   52  124
  82      1  302 5984 2566  711 2428 2200 1286  726  306  203  195
$

$ T WEIGHT.DAT
  73 0.305 0.780 1.580 2.380 3.120 3.670 4.420 4.960 5.700 5.640 7.400 7.590
  74 0.305 0.810 1.440 2.180 3.070 4.100 5.100 6.110 6.680 7.270 8.010 8.360
  75 0.305 0.890 1.470 2.100 2.970 3.950 5.000 6.240 7.070 7.290 7.830 9.190
  76 0.305 0.810 1.550 2.200 2.970 3.760 4.510 5.180 6.140 7.640 7.660 7.970
  77 0.305 0.930 1.120 1.620 2.580 3.420 4.430 5.780 6.740 7.060 7.840 8.470
  78 0.305 0.820 1.110 1.590 2.390 3.580 4.370 5.540 6.450 6.740 7.540 7.890
  79 0.240 0.740 1.320 1.940 2.910 3.770 4.750 5.960 6.480 7.490 7.910 8.350
  80 0.370 1.040 1.700 2.100 3.010 3.430 4.250 5.830 6.380 7.320 7.920 8.770
  81 0.305 0.912 1.438 2.468 2.904 3.587 4.435 5.552 6.466 7.323 7.974 9.171
  82 0.305 0.663 1.311 2.379 3.467 3.896 4.350 5.341 6.214 7.050 7.752 8.802
$

$ T EXAMPLE.DAT
  VPA EXAMPLE RUN     POLLOCK DATA
1973,1982
YES
YES
.94,.90,.97,7*1.0
2,11
YES
1
(2X,I2,6X,11F5.0)
1962,1980
YES
.2
10
.013,.159,.200,7*.26
44500
YES
.00,.30,.75,8*1.00
YES
1
3
YES
(2X,I2,6X,11F6.3)
10*5
$
```

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PROGRAM NAME: Separable VPA

PROGRAM TYPE: Main

DATE CREATED: Jan 1 1982

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]SVPA.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]SVPA.EXE

AUTHOR: J.G. Shepherd

DOCUMENTED BY: W.L. Gabriel

REVISIONS (Date/Reviser - Description)

February 1983 /J.K. Hunton
Before receipt at NMFS
October 1983 /O.L. Jackson
Expanded dimension, altered I/O, converted for VAX 11
November 1983 /F.P. Almeida
Added I/O options

STATUS: Operational

CLASSIFICATION: Analytical model

PURPOSE OF PROGRAM:

The method determines values of F from a catch-at-age matrix based on the assumption that age-specific patterns of exploitation are constant over time.

DESCRIPTION:

The original guide, Separable VPA: User's Guide (Shepherd and Stevens, 1983) provides a complete description. However, in our version, spawning biomass calculations are not available and I/O instructions are not applicable. The analysis can be applied to 36 years of data containing 36 ages. In extreme situations where the data do not meet the assumptions of separability, the extended analysis may include a zero in the denominator, leading to a fatal execution error.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

Data sets required:

a. Catch at age matrix, one line per year, formatted

b. Weight at age matrix, one line per year, formatted
The remainder of the program is interactive. To run the program, type:

```
$RUN FSHA:[712.MASTER.XEQ]SVPA
```

You will be prompted for answers.
If the output conatins more than 18 age classes, increase the horizontal print density before printing at the terminal.

REFERENCES:

Shepherd, J. G. 1982. Two overall measures of averall fishing mortality. International Council for the Exploration of the Sea. CM 1982/G:28, Demersal Fish Committee. Mimeo.

Shepherd, J. G. and S. M. Stevens. 1983. Separable VPA: User's Guide. Internal Report No. 8., Ministry of Agriculture, Fisheries and Food, Directorate of Fisheries Research, Lowestoft, U. K.

PROGRAM [illegible] VPA VAX VER 1.2 (10/19/83)
NORTH SEA PLAICE - PAST

from data file PLAICEC.DAT
PLAICEW.DAT
14 ages 27 years

YEAR/AGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	PLUS
CATCH AT AGE MATRIX															
1966	[illegible]	[illegible]	964.7	[illegible]	343.5	[illegible]	154.7	101.0	59.3	28.9	19.7	24.6	14.9	11.7	38.0
1967	[illegible]	[illegible]	[illegible]	[illegible]	482.9	279.9	213.4	77.2	[illegible]	28.4	19.7	9.8	15.7	9.5	33.4
1968	[illegible]	[illegible]	[illegible]	[illegible]	1225.6	106.7	86.5	104.5	35.0	48.0	18.7	16.7	8.3	9.9	28.4
1969	7.9	181.0	517.6	373.6	332.3	699.7	90.2	50.0	87.1	29.5	41.1	16.2	12.0	5.8	24.4
1970	21.7	225.6	550.5	593.7	400.8	320.8	717.7	68.6	39.0	51.7	20.5	27.7	10.6	8.4	17.1
1971	4.4	298.3	488.1	333.7	259.0	227.5	166.9	296.8	64.8	46.4	35.1	22.3	20.1	9.5	39.3
1972	25.2	371.7	614.6	[illegible]	234.6	[illegible]	143.1	109.6	183.6	33.9	33.2	28.7	16.0	16.2	35.4
1973	9.7	[illegible]	654.2	731.6	402.4	[illegible]	85.2	97.5	62.5	146.2	21.9	23.3	17.9	17.0	37.2
1974	22.2	231.2	555.5	421.2	410.8	196.7	80.1	63.2	55.7	39.2	101.2	16.3	16.9	12.4	33.7
1975	9.8	261.2	616.2	312.6	254.2	211.9	118.7	59.2	41.1	33.4	17.4	79.4	10.8	14.2	41.8
1976	28.2	336.4	776.5	964.0	137.8	99.0	91.2	63.9	29.5	20.2	21.1	9.1	44.8	3.9	26.4
1977	32.2	259.7	432.9	660.1	837.0	91.4	59.1	50.2	40.6	19.3	13.0	13.6	4.9	22.9	18.3
1978	11.4	[illegible]	623.4	543.4	501.0	355.1	59.4	33.5	24.2	21.8	11.5	6.0	6.9	3.3	25.2
1979	[illegible]	[illegible]	1185.6	409.6	478.9	399.3	242.3	41.6	28.1	23.3	18.5	11.1	7.1	7.1	25.8
1980	9.5	[illegible]	1397.4	775.2	249.7	179.8	137.6	84.6	18.6	13.3	9.5	11.7	4.3	2.8	12.1
1981	2.5	1009.3	1223.0	576.0	357.4	124.1	95.6	80.9	48.7	14.1	11.0	8.3	8.0	4.7	13.1
1982	83.0	473.3	2070.8	669.1	283.9	165.8	75.2	54.2	44.5	36.7	11.2	7.1	5.7	5.1	19.9

PROGRAM HOVPB SEPARABLE VPA VAX VER 1.2 (10/19/83)
NORTH SEA PLACIE, PART 2

from data files PLAICEC.DAT
PLAICEW.DAT
14 ages 17 years

CATCH AT AGE MATRIX

YEAR/AGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	PLUS
1966	0.5	96.9	964.6	595.3	343.5	235.9	154.7	101.0	59.3	28.9	19.7	24.6	14.9	11.7	38.0
1967	0.5	72.6	395.9	1801.3	482.9	279.9	213.4	77.2	86.0	28.4	19.7	9.8	15.7	9.5	33.4
1968	0.5	142.8	519.1	469.3	1228.0	100.7	86.5	104.5	35.0	48.0	18.7	16.7	8.3	9.9	28.4
1969	2.9	181.8	517.8	373.8	332.3	699.7	90.2	50.0	87.1	29.5	41.1	16.2	12.0	5.8	24.4
1970	21.7	225.6	550.5	599.7	400.8	320.8	717.7	68.6	39.0	51.7	20.5	27.7	10.6	8.4	17.1
1971	4.4	298.8	488.1	333.7	259.0	227.5	166.9	290.8	64.8	46.4	35.1	22.3	20.1	9.5	39.3
1972	25.2	371.7	614.6	523.0	234.6	170.8	143.1	109.6	183.6	33.9	30.2	28.7	16.0	16.2	35.4
1973	9.7	311.9	654.2	731.6	402.4	130.2	85.2	97.5	62.5	146.2	21.9	23.3	17.9	17.0	37.2
1974	22.2	231.2	555.5	421.2	410.8	196.7	80.1	63.2	55.7	39.2	101.2	16.3	16.9	12.4	33.7
1975	9.8	281.2	616.2	312.6	254.2	211.9	118.7	59.2	41.1	33.4	17.4	79.4	10.8	14.2	41.8
1976	28.2	336.4	776.5	964.0	137.8	99.0	91.2	63.9	29.5	20.2	21.1	9.1	44.8	3.9	26.4
1977	32.2	569.7	432.9	660.1	837.0	91.4	59.1	50.2	40.6	19.3	13.0	13.6	4.9	22.9	18.3
1978	11.4	605.8	623.4	543.4	501.0	355.1	59.4	33.5	24.2	21.8	11.5	6.0	6.9	3.3	25.2
1979	13.2	589.3	1188.6	489.6	478.9	399.3	242.3	41.6	28.1	23.3	18.5	11.1	7.1	7.1	25.8
1980	9.8	649.0	1337.4	775.2	249.7	179.8	137.6	84.6	18.6	13.3	9.5	11.7	4.3	2.8	12.1
1981	2.5	1009.3	1223.0	576.0	357.4	124.1	95.6	80.9	48.7	14.1	11.0	8.3	8.0	4.7	13.1
1982	33.0	473.3	2070.8	689.1	283.9	165.8	75.2	54.2	44.5	36.7	11.2	7.1	5.7	5.1	19.9

MEAN WEIGHT AT AGE MATRIX

YEAR/AGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	PLUS
1966	0.000	0.232	0.271	0.337	0.439	0.547	0.636	0.700	0.748	0.854	0.930	0.991	1.017	1.131	1.214
1967	0.000	0.235	0.271	0.334	0.439	0.546	0.612	0.681	0.762	0.886	0.957	1.051	1.051	1.074	1.275
1968	0.000	0.234	0.269	0.338	0.442	0.554	0.643	0.682	0.779	0.838	0.899	1.001	1.007	1.095	1.289
1969	0.224	0.277	0.322	0.391	0.457	0.503	0.591	0.634	0.706	0.765	0.850	0.837	1.000	0.917	1.155
1970	0.213	0.275	0.321	0.389	0.459	0.502	0.578	0.639	0.747	0.793	0.837	0.900	0.949	1.021	1.120
1971	0.300	0.338	0.370	0.413	0.459	0.521	0.552	0.613	0.706	0.730	0.803	0.885	0.980	1.085	1.111
1972	0.278	0.316	0.363	0.433	0.496	0.545	0.582	0.656	0.685	0.800	0.872	0.913	0.935	0.982	1.197
1973	0.311	0.333	0.347	0.407	0.494	0.570	0.649	0.667	0.732	0.763	1.042	0.990	0.984	1.075	1.161
1974	0.285	0.311	0.354	0.405	0.476	0.554	0.609	0.693	0.707	0.779	0.849	0.971	1.002	1.040	1.224
1975	0.249	0.300	0.330	0.420	0.495	0.587	0.636	0.703	0.783	0.853	0.854	0.983	0.953	1.138	1.264
1976	0.265	0.295	0.336	0.375	0.513	0.594	0.641	0.705	0.741	0.813	0.851	0.928	1.019	1.009	1.159
1977	0.254	0.323	0.353	0.380	0.418	0.556	0.647	0.721	0.715	0.791	0.898	0.970	0.855	1.063	1.165
1978	0.244	0.315	0.369	0.397	0.438	0.491	0.609	0.687	0.776	0.781	0.886	0.983	1.039	0.933	1.094
1979	0.235	0.311	0.349	0.388	0.429	0.474	0.550	0.675	0.796	0.871	0.818	0.894	1.063	1.044	1.115
1980	0.238	0.286	0.344	0.401	0.473	0.545	0.588	0.662	0.772	0.931	0.943	0.848	1.015	1.308	1.248
1981	0.237	0.274	0.329	0.416	0.505	0.558	0.604	0.642	0.725	0.869	0.950	0.931	0.933	1.179	1.236
1982	0.279	0.262	0.311	0.424	0.514	0.608	0.604	0.712	0.739	0.840	0.984	1.045	1.174	0.971	1.177

Catch data used in Separable Analysis

First year used is 1972,Last year used is 1981
First age used is 2,Last age used is 10

AGE YR	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
2	371.7	311.9	231.2	281.2	336.4	569.7	605.8	580.3	649.0	1009.3
3	614.6	554.2	555.5	615.2	776.5	432.9	623.4	1188.6	1337.4	1223.0
4	523.1	731.6	421.2	312.6	964.0	660.1	543.4	489.6	775.2	576.0
5	234.6	402.4	410.8	254.2	137.8	837.0	501.0	478.9	249.7	357.4
6	170.8	130.2	196.7	211.9	99.0	91.4	355.1	399.3	179.8	124.1
7	143.1	85.2	80.1	118.7	91.2	59.1	59.4	242.3	137.6	95.6
8	109.6	97.5	63.2	59.2	63.9	50.2	33.5	41.6	84.6	80.9
9	183.6	62.5	55.7	41.1	29.5	40.6	24.2	28.1	18.6	48.7
10	33.9	146.2	39.2	33.4	20.2	19.3	21.8	23.3	13.3	14.1

NATURAL MORTALITY = 0.100
TERMINAL F = 0.450
TERMINAL S = 0.600

REFERENCE AGE (FOR UNIT SELECTION) IS 4

NO. OF ITERATIONS CHOSEN IS 30
MINIMUM DIFFERENCE BETWEEN ITERATIONS IS 10**-5

ITERATION	SSQ
1	21.0608
29	3.4506

APPROX. COEFF. VARIATION OF CATCH DATA = 17.6 %

YEAR	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
F(I)	0.3850	0.4221	0.4142	0.4318	0.4152	0.4371	0.4225	0.5720	0.4816	0.4500
S(J)	0.2990	0.7652	1.0000	1.0883	0.9494	0.8284	0.7606	0.6530	0.6000	

LOG CATCH RATIO RESIDUALS

	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81	
2/ 3	0.153	0.027	-0.321	-0.434	0.415	0.494	0.196	-0.431	-0.100	-0.001
3/ 4	-0.268	0.224	0.414	-0.689	0.009	-0.469	0.276	-0.035	0.536	-0.001
4/ 5	-0.080	0.108	0.092	0.324	-0.265	-0.221	-0.098	-0.065	0.206	-0.001
5/ 6	0.034	0.031	0.035	0.232	-0.210	0.145	-0.204	0.022	-0.086	0.000
6/ 7	0.193	-0.144	-0.067	0.188	-0.049	-0.225	0.015	0.179	-0.091	0.000
7/ 8	-0.030	-0.239	-0.178	0.056	0.124	0.005	0.085	0.270	-0.095	0.000
8/ 9	0.116	-0.009	-0.080	0.103	-0.049	0.137	-0.119	0.001	-0.101	-0.001
9/10	-0.117	0.000	0.103	0.220	0.024	0.133	-0.151	0.057	-0.269	-0.001
	0.000	-0.001	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	-0.004

RESULTS FROM SEPARABLE ANALYSIS

POPULATION NUMBERS

AGE	YEAR 1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
2	2266.	1957.	4777.	4188.	3096.	2909.	4469.	4318.	5340.	8415.	????
3	2465.	1527.	1561.	3819.	3330.	2474.	2310.	3564.	3293.	4184.	6655.
4	1812.	1561.	1197.	1029.	2463.	2193.	1602.	1513.	2082.	2061.	2683.
5	808.	1116.	986.	716.	604.	1483.	1282.	950.	772.	1164.	1189.
6	571.	481.	638.	568.	405.	348.	834.	732.	461.	414.	645.
7	550.	359.	291.	389.	341.	247.	208.	505.	385.	264.	244.
8	419.	362.	229.	137.	246.	219.	156.	133.	285.	234.	165.
9	918.	283.	237.	151.	122.	163.	142.	102.	78.	179.	150.
10	172.	646.	194.	164.	103.	84.	111.	98.	64.	51.	120.
11	????	124.	454.	137.	114.	73.	59.	78.	63.	43.	35.

FISHING MORTALITY

AGE	YEAR 1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
2	0.115	0.126	0.124	0.129	0.124	0.131	0.126	0.171	0.144	0.135
3	0.295	0.323	0.317	0.330	0.318	0.334	0.323	0.438	0.369	0.344
4	0.385	0.422	0.414	0.432	0.415	0.437	0.422	0.572	0.482	0.450
5	0.419	0.459	0.451	0.470	0.452	0.476	0.460	0.623	0.524	0.490
6	0.366	0.401	0.393	0.410	0.394	0.415	0.401	0.543	0.457	0.427
7	0.319	0.350	0.343	0.358	0.344	0.362	0.350	0.474	0.399	0.373
8	0.293	0.321	0.315	0.328	0.316	0.332	0.321	0.435	0.366	0.342
9	0.251	0.276	0.271	0.282	0.271	0.285	0.276	0.374	0.315	0.294
10	0.231	0.253	0.249	0.259	0.249	0.262	0.253	0.343	0.289	0.270
$\bar{F}$	0.325	0.351	0.345	0.357	0.346	0.361	0.351	0.448	0.391	0.370
$\bar{F}(2)_P^C$	0.102	0.107	0.106	0.109	0.106	0.109	0.107	0.126	0.115	0.111
A	6.143	6.075	6.089	6.056	6.087	6.049	6.074	5.836	5.974	6.027

RESULTS FROM EXTENDED ANALYSIS (TERMINAL POPULATIONS USED)

POPULATION NUMBERS

AGE \ YEAR	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
1	3305.	3018.	2535.	3321.	3764.	2836.	2291.	5400.	4516.	3295.	3228.	4973.	4983.	5953.	9310.	4532.	28868.	3222
2	3192.	2993.	2731.	2293.	3003.	3385.	2562.	2049.	4877.	4065.	2972.	2894.	4469.	4498.	5374.	8414.	4098.	26089
3	9238.	2796.	2636.	2335.	1902.	2502.	2779.	1965.	1558.	4193.	3411.	2369.	2078.	3469.	3519.	4246.	6655.	3259
4	2049.	7443.	2154.	1893.	1621.	1199.	1801.	1931.	1158.	863.	3209.	2350.	1733.	1290.	2013.	1917.	2683.	4059
5	1322.	1290.	5026.	1504.	1358.	899.	769.	1134.	1055.	649.	503.	1990.	1500.	1053.	703.	1087.	1189.	1774
6	1121.	871.	710.	3383.	1045.	849.	568.	473.	645.	566.	347.	325.	1009.	883.	500.	409.	645.	807
7	593.	791.	523.	490.	2208.	642.	552.	352.	305.	397.	311.	220.	207.	576.	421.	282.	244.	427
8	554.	390.	513.	391.	358.	1318.	423.	364.	238.	200.	247.	195.	143.	131.	292.	251.	165.	150
9	240.	405.	279.	365.	306.	258.	916.	278.	237.	155.	125.	163.	129.	97.	79.	184.	150.	98
10	152.	161.	285.	229.	248.	240.	172.	655.	193.	161.	102.	85.	109.	94.	62.	54.	120.	94
11	101.	110.	118.	212.	171.	175.	173.	124.	454.	137.	114.	73.	59.	78.	63.	43.	35.	74
12	116.	73.	81.	89.	153.	135.	125.	128.	91.	315.	107.	83.	53.	42.	53.	48.	29.	21
13	75.	81.	56.	57.	65.	112.	101.	86.	94.	67.	209.	89.	63.	43.	28.	37.	35.	19
14	61.	54.	59.	43.	40.	49.	82.	76.	61.	69.	50.	147.	76.	50.	32.	21.	26.	26
+	191.	195.	167.	135.	101.	213.	180.	167.	166.	202.	133.	81.	126.	104.	56.	50.	85.	79

** Warning - Results for years later than 1981 and ages older than 10 should be treated with caution **

FISHING MORTALITY

AGE	YEAR 1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	0.000	0.000	0.000	0.001	0.006	0.002	0.012	0.002	0.005	0.003	0.009	0.007	0.002	0.002	0.001	0.001	0.001
2	0.032	0.026	0.056	0.087	0.082	0.097	0.165	0.174	0.051	0.075	0.126	0.231	0.153	0.145	0.136	0.135	0.129
3	0.116	0.161	0.231	0.265	0.361	0.229	0.264	0.429	0.467	0.167	0.273	0.213	0.377	0.444	0.507	0.359	0.394
4	0.363	0.293	0.259	0.232	0.490	0.345	0.363	0.505	0.479	0.463	0.378	0.349	0.398	0.506	0.516	0.378	0.314
5	0.318	0.497	0.296	0.264	0.370	0.359	0.385	0.464	0.523	0.527	0.338	0.580	0.430	0.645	0.465	0.422	0.288
6	0.249	0.411	0.271	0.327	0.386	0.330	0.378	0.340	0.385	0.498	0.356	0.350	0.460	0.640	0.472	0.393	0.314
7	0.319	0.332	0.191	0.215	0.416	0.318	0.317	0.292	0.322	0.376	0.367	0.331	0.358	0.579	0.419	0.438	0.389
8	0.212	0.233	0.240	0.144	0.225	0.263	0.317	0.330	0.326	0.371	0.317	0.314	0.282	0.404	0.361	0.412	0.423
9	0.300	0.252	0.141	0.288	0.144	0.305	0.236	0.268	0.283	0.325	0.285	0.303	0.219	0.360	0.283	0.325	0.372
10	0.223	0.205	0.195	0.152	0.247	0.227	0.231	0.267	0.240	0.245	0.234	0.272	0.236	0.302	0.257	0.320	0.384
11	0.229	0.209	0.181	0.227	0.135	0.236	0.202	0.205	0.266	0.143	0.215	0.208	0.231	0.287	0.173	0.311	0.402
12	0.252	0.153	0.245	0.211	0.211	0.190	0.275	0.212	0.208	0.307	0.093	0.187	0.125	0.324	0.265	0.202	0.302
13	0.234	0.226	0.168	0.249	0.186	0.208	0.182	0.246	0.210	0.185	0.254	0.060	0.123	0.192	0.179	0.260	0.186
14	0.223	0.205	0.195	0.152	0.247	0.227	0.231	0.267	0.240	0.245	0.085	0.178	0.047	0.161	0.097	0.270	0.235
$\bar{F}_C$	0.277	0.319	0.226	0.231	0.364	0.273	0.283	0.376	0.428	0.363	0.288	0.319	0.342	0.439	0.429	0.336	0.314
F(1)	0.059	0.063	0.062	0.066	0.083	0.072	0.082	0.093	0.086	0.074	0.079	0.087	0.088	0.096	0.095	0.085	0.081
P_A	7.788	7.732	6.978	6.638	6.485	6.596	5.945	5.921	6.625	7.097	6.204	5.941	6.040	6.076	6.085	6.199	6.249

TABLE OF F(EXT) - F(SEP)

AGE	YEAR 1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
2	0.050	0.048	-0.073	-0.054	0.002	0.101	0.027	-0.026	-0.008	0.000
3	-0.031	0.106	0.150	-0.163	-0.045	-0.122	0.054	0.007	0.139	0.015
4	-0.022	0.083	0.065	0.031	-0.037	-0.088	-0.024	-0.066	0.034	-0.072
5	-0.034	0.005	0.073	0.057	-0.114	0.104	-0.030	0.022	-0.060	-0.068
6	0.013	-0.061	-0.008	0.088	-0.039	-0.065	0.059	0.097	0.015	-0.034
7	-0.002	-0.057	-0.021	0.018	0.023	-0.031	0.008	0.105	0.020	0.065
8	0.024	0.009	0.011	0.043	0.001	-0.018	-0.039	-0.031	-0.005	0.070
9	-0.016	-0.007	0.013	0.043	0.014	0.018	-0.056	-0.014	-0.032	0.031
10	0.000	0.013	-0.008	-0.015	-0.015	0.010	-0.017	-0.041	-0.032	0.050

RESULTS FROM EXTENDED ANALYSIS (TERMINAL FS USED)

POPULATION NUMBERS

AGE \ YEAR	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
1	3285.	3005.	2542.	3305.	3740.	2821.	2312.	5437.	4601.	3367.	3185.	4792.	4640.	6140.	9310.	4455.	29672.	2222
2	3179.	2972.	2718.	2300.	2988.	3363.	2548.	2068.	4910.	4142.	3038.	2855.	4305.	4187.	5543.	8414.	4029.	26275
3	9300.	2784.	2620.	2324.	1908.	2489.	2759.	1953.	1575.	4223.	3480.	2429.	2043.	3320.	3238.	4399.	6655.	3196
4	2049.	7498.	2143.	1878.	1611.	1205.	1789.	1914.	1147.	899.	3236.	2412.	1787.	1258.	1878.	1664.	2821.	4059
5	1314.	1290.	5076.	1494.	1345.	890.	774.	1123.	1039.	639.	517.	2015.	1557.	1102.	674.	966.	960.	1899
6	1117.	863.	710.	3428.	1037.	837.	560.	478.	635.	551.	338.	337.	1031.	934.	544.	374.	536.	600
7	600.	787.	516.	490.	2249.	634.	541.	345.	309.	388.	298.	212.	219.	596.	467.	322.	221.	327
8	554.	396.	510.	384.	358.	1355.	415.	354.	231.	203.	239.	183.	136.	141.	310.	292.	201.	128
9	238.	405.	285.	362.	300.	258.	950.	272.	228.	149.	128.	155.	118.	91.	89.	200.	188.	130
10	151.	159.	285.	225.	245.	235.	172.	685.	187.	153.	96.	88.	102.	84.	56.	62.	135.	128
11	102.	109.	117.	212.	175.	173.	168.	124.	481.	132.	107.	68.	61.	72.	54.	38.	43.	88
12	116.	74.	80.	88.	153.	139.	123.	124.	91.	340.	103.	77.	49.	44.	47.	40.	24.	28
13	74.	81.	58.	57.	64.	112.	105.	84.	90.	67.	232.	84.	57.	39.	30.	32.	28.	15
14	61.	53.	59.	44.	40.	48.	82.	80.	59.	65.	50.	167.	72.	45.	28.	23.	21.	20
+	191.	195.	166.	135.	101.	212.	180.	174.	161.	192.	126.	83.	118.	93.	51.	58.	79.	68

** Warning - Results for years later than 1981 and ages older than 10 should be treated with caution **

FISHING MORTALITY

AGE	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	0.000	0.000	0.000	0.001	0.006	0.002	0.012	0.002	0.005	0.003	0.009	0.007	0.003	0.002	0.001	0.001	0.001
2	0.033	0.026	0.057	0.087	0.083	0.098	0.166	0.172	0.051	0.074	0.124	0.235	0.160	0.157	0.131	0.135	0.132
3	0.115	0.162	0.233	0.266	0.360	0.230	0.266	0.432	0.461	0.166	0.266	0.207	0.385	0.470	0.566	0.344	0.394
4	0.363	0.290	0.261	0.234	0.493	0.343	0.366	0.511	0.485	0.453	0.374	0.338	0.383	0.523	0.565	0.450	0.296
5	0.320	0.497	0.292	0.266	0.374	0.364	0.382	0.470	0.534	0.538	0.327	0.570	0.411	0.606	0.490	0.490	0.371
6	0.250	0.415	0.271	0.322	0.392	0.335	0.385	0.336	0.392	0.515	0.367	0.334	0.447	0.592	0.425	0.427	0.392
7	0.315	0.334	0.194	0.215	0.407	0.323	0.324	0.300	0.317	0.386	0.386	0.346	0.335	0.553	0.369	0.373	0.441
8	0.212	0.229	0.242	0.147	0.225	0.255	0.324	0.340	0.338	0.364	0.329	0.338	0.300	0.368	0.337	0.342	0.333
9	0.303	0.252	0.138	0.290	0.146	0.305	0.227	0.276	0.296	0.340	0.277	0.320	0.242	0.392	0.249	0.294	0.285
10	0.224	0.208	0.195	0.148	0.250	0.232	0.231	0.253	0.249	0.259	0.249	0.262	0.253	0.343	0.289	0.270	0.335
11	0.226	0.210	0.184	0.227	0.131	0.240	0.208	0.205	0.249	0.149	0.231	0.225	0.220	0.315	0.204	0.365	0.317
12	0.252	0.150	0.247	0.215	0.211	0.184	0.281	0.220	0.208	0.281	0.098	0.205	0.138	0.304	0.300	0.247	0.378
13	0.236	0.226	0.164	0.251	0.190	0.208	0.174	0.253	0.220	0.185	0.226	0.063	0.137	0.214	0.165	0.307	0.239
14	0.224	0.208	0.195	0.148	0.250	0.232	0.231	0.253	0.249	0.259	0.085	0.155	0.050	0.182	0.110	0.245	0.292
$\bar{F}_C$	0.277	0.319	0.227	0.231	0.364	0.274	0.285	0.379	0.428	0.366	0.288	0.316	0.336	0.439	0.467	0.354	0.329
F(1)	0.059	0.064	0.062	0.066	0.083	0.072	0.082	0.094	0.086	0.074	0.078	0.086	0.088	0.098	0.098	0.086	0.083
P_A	7.789	7.731	6.969	6.635	6.482	6.591	5.941	5.928	6.632	7.124	6.242	5.938	5.998	5.983	6.091	6.208	6.238

TABLE OF F(EXT) - F(SEP)

AGE	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
2	0.051	0.046	-0.073	-0.055	-0.001	0.104	0.033	-0.014	-0.013	0.000
3	-0.029	0.109	0.144	-0.164	-0.051	-0.127	0.062	0.032	0.197	0.000
4	-0.019	0.089	0.071	0.021	-0.041	-0.099	-0.039	-0.049	0.083	0.000
5	-0.037	0.011	0.083	0.068	-0.124	0.094	-0.049	-0.017	-0.034	0.000
6	0.019	-0.064	-0.001	0.105	-0.027	-0.081	0.046	0.049	-0.032	0.000
7	0.005	-0.050	-0.026	0.028	0.042	-0.016	-0.015	0.080	-0.030	0.000
8	0.031	0.019	0.023	0.035	0.013	0.006	-0.021	-0.067	-0.030	0.000
9	-0.025	0.000	0.025	0.058	0.006	0.035	-0.034	0.018	-0.066	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

PROGRAM NAME: Multispecies Cohort Analysis

PROGRAM TYPE: Main

DATE CREATED: Oct 1979

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]POPE.FOR

EXECUTE FILE NAME: NONE - see INSTRUCTIONS FOR RUNNING

AUTHOR: J.G. Pope

DOCUMENTED BY: K.L. Foster

REVISIONS (Date/Reviser - Description)

Jun 13 1983 /K.L. Foster -
Revised to allow for species and age specific basal natural mortality rates and converted to FORTRAN77 to run on Vax 11/780

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

This program is an extension of Pope's (1979) multispecies cohort analysis which incorporates species interactions through predation into species, year and age specific calculations of stock size, fishing mortality and total natural mortality.

DESCRIPTION:

Species interaction through predation is incorporated into calculations of stock size (Ni), natural mortality (AM, basal natural mortality plus predation mortality), and fishing mortality (F) for all years, species and ages considered in the model. This program is different from Pope's (1979) original program because it uses a species and age specific basal natural mortality rate instead of a constant rate for all species and ages. This model assumes the fraction of food contributed by fish species remains constant over the years independent of whether prey biomass increases or decreases. There has been criticism of this because it does not allow for contributions of 'other food' not included in the model.

Tables are generated for stock size, natural mortality and fishing mortality by species. Each table contains that species' ages and the years used in the analysis. Foster (1982) describes the analytical procedures used in this analysis.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

A data file must be set up containing the following data: total (U.S. and foreign) catch-at-age data (C) in numbers; instantaneous basal natural mortality (AM), which is mortality due to causes other than predation (ie. disease); terminal fishing mortality (F), which is mortality due to fishing in the last year (terminal) of the analysis, for all ages of each species and mortality for the oldest age of each species in every year considered in the analysis; mean weight at age (W) in kg; annual consumption (FR) in kg/yr; and a predator preference matrix which consists of age specific values determining a predator's preference for a particular species and age of prey. The size of the input data file depends on the number of years of data (consistent for each species), the number of species and the number of ages of each species used in the analysis.

Input into the data file should follow the guidelines used to set up the file [712.MASTER.DATA]POPE.DAT.

Record Number	Record Description
1	Number of species, number of years.
2-7	Number of ages for species, species name.
8	Title: Catch at age (000's) species name.
9	Catch by age for 1968.
10-17	Catch by age for 1969-1976.
18-67	(repeat 8-17 for each species)
68	Title: Natural mortality of species name.
69	Basal natural mortality by age.
70-79	(repeat 68-69 for each species)
80	Title: Terminal fishing mortality (F) of species name.
81	F for all ages in terminal year (1976).
82	F for oldest ages of each species for all years.
83-97	(repeat 80-82 for each species)
98	Title: Food preference of predator species for prey species.
99-108	Predator preference (%) for prey by predator age (horizontal) and prey age (vertical).
109-439	(repeat food preference matrix for all species, the number of lines depends on the number of ages of prey, total number of matrices = 36)
440	Title: Daily ration of predator species (% body weight).
441-450	Rations by age.
451-496	(repeat 440-450 for other species,only predator species will have a ration)
497	Title: Weight at age (kg) species name.

498-507	Weight at age for species by age.
508-553	(repeat 497-507 for each species)

Input data is free formatted, spaces should separate data values.

The Fortran source program must be editted each time a new set of data is analyzed. The 'total number of ages (summed over all species) + 1.' (#) must be input at the following statement:

```
IF (IJ.GT.#) GO TO 2003
```

ie. if total number of ages for all species is 51, then #= 52. You must also edit the following statement which appears three times in the program by substituting 'first year of the analysis - 1.' (#) so the output will be labelled correctly:

```
ITTT=ITT + #
```

ie. if the first year in the analysis is 1969 , then # = 1968. Depending on the number of years, species and total number of ages, the DIMENSION statement may also need to be editted. Presently it can accomadate 9 years, 6 species and a total of 51 ages.

To edit source code type:

```
$COPY [712.MASTER.SOURCE]POPE.FOR *.*
```

to your own directory and do your editting. To run, type:

```
$SET TERMINAL/WIDTH=132
$ASSIGN [directory]datafile.DAT FOR005
$FORT [directory]POPE
$LINK POPE
$RUN POPE
```

REFERENCES:

Pope, J.G. 1979. A modified cohort analysis in which constant natural mortality is replaced by estimates of predation levels. ICES C.M. 1979/H:16 (mimeo).

Foster, K.L. 1982. An application of a multispecies cohort analysis to six fish stocks located on Georges Bank. ICES C.M. 1982/G:37.

```
$ASSIGN FSHA:[712.MASTER.DATA]POPE.DAT  FOR005
$RUN POPE.EXE
 6  9
10 SILVER H
12 COD
 9 MACKEREL
10 HADDOCK
 6 HERRING
 4 BUTTERFI
CATCH AT AGE SILVER HAKE
       0.     1600.     4800.    76100.    56500.     3100.     6200.     1900.      800.      300.
       0.     1200.    12800.    20700.    15200.    14400.     6000.     5300.     1900.     1300.
       0.     3800.    27100.    33000.    37900.    14600.     4200.     3300.     1300.      300.
       0.     3300.    21900.   110400.    98100.    55300.    21600.     8900.     7800.     3800.
       0.    48200.   148400.   102100.    28200.     5700.     3400.     2200.      800.      400.
       0.    20500.   240000.    78400.    12200.     2600.     1600.      900.      300.      100.
       0.    12000.   150300.   122500.    25300.     3500.     3800.     1600.      400.      200.
       0.    17200.   110700.   134400.    42600.    13800.     2000.      700.      100.      300.
       0.     1600.    20000.   114200.    85800.     7900.      900.      100.        1.        1.
CATCH AT AGE COD
       0.      192.    10500.     8220.     3180.     1043.      735.      324.      244.      137.       76.        5.
       0.       68.     9879.     8931.     2914.      817.      612.      267.      201.      105.       59.       15.
       0.       50.     2765.     6600.     3031.      890.      542.      210.      138.       87.       39.       12.
       0.       84.     3200.     4524.     2872.     1168.      868.      354.      217.      124.       56.        4.
       0.      130.     3889.     4927.     2380.      862.      606.      256.      170.       90.       40.        7.
       0.     1084.    15453.     4714.     1272.      450.      316.      124.       89.       58.       28.       11.
       0.      272.     7620.     6368.     1564.      484.      355.      187.      162.      109.       56.       20.
       0.      222.     4134.     4680.     2616.      786.      477.      150.       82.       55.       17.        5.
       0.      334.     4234.     3244.     1614.      796.      578.      175.       96.       30.       19.        2.
                                    .
                                    .
          Remaining age specific catch tables for:  Mackerel
                                                    Haddock
                                                    Herring
                                                    Butterfish
                                    .
                                    .
NATURAL MORTALITY OF SILVER HAKE
.05.05.05.05.30.30.30.30.30.30
NATURAL MORTALITY OF COD
.20.20.20.20.20.20.20.20.20.20.20.20
NATURAL MORTALITY OF MACKEREL
.05.05.05.10.10.10.10.10.10
NATURAL MORTALITY OF HADDOCK
.05.05.05.20.20.20.20.20.20.20
NATURAL MORTALITY OF HERRING
.10.10.05.05.05.05
NATURAL MORTALITY OF BUTTERFISH
.05.05.05.60
```

```
TERMINAL F OF SILVERHAKE
0.00.00.20.30.50.60.80.40.00.0
0.80.80.60.30.20.50.00.00.0
TERMINAL F OF COD
0.00.00.20.60.60.60.60.60.60.60.6
0.6
0.60.60.60.60.60.60.60.60.6
TERMINAL F OF MACKEREL
0.00.00.40.40.30.40.30.40.4
0.00.00.30.10.20.40.30.40.4
TERMINAL F OF HADDOCK
0.00.00.50.20.40.10.00.10.20.2
0.60.50.40.60.40.50.20.30.2
TERMINAL F OF HERRING
0.00.00.00.00.11.5
0.50.70.50.81.61.00.51.21.5
TERMINAL F OF BUTTERFISH
0.00.20.81.0
0.00.50.80.42.60.31.91.01.0
FOOD PREFERENCE OF SILVER HAKE FOR SILVERHAKE
0.00.00.00.00.00.00.00.00.00.0
0.00.20.20.20.20.20.10.10.10.1
0.00.00.20.20.20.20.20.10.10.1
0.00.00.00.20.20.20.10.10.10.1
0.00.00.00.00.00.00.00.00.00.0
0.00.00.00.00.00.00.00.00.00.0
0.00.00.00.00.00.00.00.00.00.0
0.00.00.00.00.00.00.00.00.00.0
0.00.00.00.00.00.00.00.00.00.0
0.00.00.00.00.00.00.00.00.00.0
FOOD PREFERENCE OF SILVER HAKE FOR COD
0.00.00.00.00.00.00.00.00.00.0
0.00.00.00.00.00.00.00.00.00.0
0.00.00.00.00.00.00.00.00.00.0
0.00.00.00.00.00.00.00.00.00.0
0.00.00.00.00.00.00.00.00.00.0
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0.00.00.00.00.00.00.00.00.00.0
0.00.00.00.00.00.00.00.00.00.0
0.00.00.00.00.00.00.00.00.00.0
0.00.00.00.00.00.00.00.00.00.0
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Food preference tables for each remaining species combination
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DAILY RATION OF SILVER HAKE
0.00
0.00
0.05
0.14
0.69
0.93
1.16
1.36
1.53
1.67
DAILY RATION OF COD
0.00
0.00
0.28
0.76
2.32
3.59
5.05
6.62
8.27
9.95

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Remaining age specific daily ration tables for: Mackerel
Haddock
Herring
Butterfish

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WEIGHT AT AGE SILVER HAKE
0.01
0.03
0.10
0.19
0.29
0.39
0.49
0.57
0.64
0.70
WEIGHT AT AGE FOR COD
0.08
0.17
0.62
1.41
2.51
3.88
5.45
7.15
8.93
10.75

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Remaining age specific mean weight tables for: Mackerel
Haddock
Herring
Butterfish

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                0
K=    1   ZSQU=     0.3104E+02
K=    2   ZSQU=     0.1917E-01
K=    3   ZSQU=     0.7065E-03
K=    4   ZSQU=     0.1835E-04
K=    5   ZSQU=     0.4720E-06
K=    6   ZSQU=     0.1400E-07
K=    1   ZSQU=     0.4981E+01
K=    2   ZSQU=     0.3871E-01
K=    3   ZSQU=     0.3846E-02
K=    4   ZSQU=     0.1901E-03
K=    5   ZSQU=     0.9627E-05
K=    6   ZSQU=     0.5683E-06
K=    7   ZSQU=     0.4184E-07
K=    1   ZSQU=     0.5692E+01
K=    2   ZSQU=     0.6589E-01
K=    3   ZSQU=     0.6855E-02
K=    4   ZSQU=     0.3600E-03
K=    5   ZSQU=     0.2059E-04
K=    6   ZSQU=     0.1460E-05
K=    7   ZSQU=     0.1373E-06
K=    8   ZSQU=     0.1703E-07
K=    1   ZSQU=     0.5364E+01
K=    2   ZSQU=     0.6443E-01
K=    3   ZSQU=     0.6246E-02
K=    4   ZSQU=     0.3659E-03
K=    5   ZSQU=     0.2782E-04
K=    6   ZSQU=     0.2570E-05
K=    7   ZSQU=     0.2665E-06
K=    8   ZSQU=     0.2995E-07
K=    1   ZSQU=     0.6073E+01
K=    2   ZSQU=     0.8255E-01
K=    3   ZSQU=     0.1128E-01
K=    4   ZSQU=     0.1018E-02
K=    5   ZSQU=     0.1201E-03
K=    6   ZSQU=     0.1613E-04
K=    7   ZSQU=     0.2290E-05
K=    8   ZSQU=     0.3346E-06
K=    9   ZSQU=     0.4967E-07
```

1SILVER H

POP. 1968	670146.	515870.	2940994.	1429191.	128195.	50240.	62599.	6604.	4671.	625.
POP. 1969	798421.	637462.	424328.	2363388.	1155677.	45765.	34340.	40811.	3242.	2764.
POP. 1970	1248639.	759481.	467310.	297576.	1732278.	836786.	21362.	20168.	25577.	763.
POP. 1971	1243681.	1187742.	404915.	229556.	137092.	1243038.	604541.	12151.	12058.	17787.
POP. 1972	2150457.	1183026.	664314.	153110.	51085.	16765.	868245.	427106.	1326.	2207.
POP. 1973	1611328.	2045578.	778024.	184265.	24973.	13437.	7476.	638111.	313788.	293.
POP. 1974	214787.	1532743.	1234051.	293437.	54936.	7907.	7675.	4145.	470754.	231737.
POP. 1975	287558.	204311.	847861.	579187.	78910.	18655.	2813.	2392.	1686.	347694.
POP. 1976	0.	273534.	116879.	452105.	269941.	21319.	1876.	353.	1161.	1159.

2COD

POP. 1968	24170.	34720.	33956.	17632.	7074.	3239.	1826.	926.	495.	277.	131.	13.
POP. 1969	23432.	19789.	28252.	18300.	6998.	2914.	1708.	830.	465.	184.	103.	39.
POP. 1970	27186.	19185.	16140.	14192.	6902.	3093.	1647.	845.	438.	199.	56.	31.
POP. 1971	50503.	22258.	15662.	10713.	5648.	2908.	1727.	858.	502.	233.	84.	10.
POP. 1972	32734.	41348.	18147.	9927.	4677.	2025.	1324.	629.	382.	214.	79.	18.
POP. 1973	22459.	26801.	33736.	11339.	3670.	1676.	878.	536.	283.	159.	94.	28.
POP. 1974	42479.	18388.	20962.	13638.	5018.	1854.	965.	433.	327.	151.	78.	52.
POP. 1975	24417.	34779.	14809.	10267.	5404.	2693.	1080.	469.	185.	121.	25.	13.
POP. 1976	0.	19991.	28274.	8384.	4171.	2057.	1494.	452.	248.	78.	49.	5.

Remaining age specific population size tables for: Mackerel
Haddock
Herring
Butterfish

1SILVER H

F	1968	0.00	0.00	0.00	0.06	0.72	0.07	0.12	0.41	0.22	0.79
F	1969	0.00	0.00	0.04	0.01	0.02	0.46	0.23	0.16	1.14	0.76
F	1970	0.00	0.01	0.08	0.16	0.03	0.02	0.26	0.21	0.06	0.60
F	1971	0.00	0.00	0.08	0.94	1.79	0.05	0.04	1.91	1.40	0.28
F	1972	0.00	0.05	0.40	1.46	1.03	0.50	0.00	0.01	1.21	0.23
F	1973	0.00	0.01	0.48	0.74	0.84	0.26	0.29	0.00	0.00	0.50
F	1974	0.00	0.01	0.17	0.75	0.77	0.73	0.86	0.60	0.00	0.00
F	1975	0.00	0.11	0.18	0.33	1.00	1.99	1.77	0.42	0.07	0.00
F	1976	0.00	0.01	0.23	0.35	0.46	0.56	0.79	0.39	0.00	0.00

2COD

F	1968	0.00	0.01	0.42	0.72	0.69	0.44	0.59	0.49	0.79	0.79	1.02	0.55
F	1969	0.00	0.00	0.49	0.78	0.62	0.37	0.50	0.44	0.65	1.00	1.00	0.55
F	1970	0.00	0.00	0.21	0.72	0.66	0.38	0.45	0.32	0.43	0.66	1.48	0.55
F	1971	0.00	0.00	0.26	0.63	0.83	0.59	0.81	0.61	0.65	0.88	1.34	0.55
F	1972	0.00	0.00	0.27	0.80	0.83	0.64	0.70	0.60	0.68	0.62	0.82	0.55
F	1973	0.00	0.05	0.71	0.62	0.48	0.35	0.51	0.30	0.43	0.52	0.40	0.55
F	1974	0.00	0.02	0.51	0.73	0.42	0.34	0.52	0.65	0.79	1.60	1.59	0.55
F	1975	0.00	0.01	0.37	0.70	0.77	0.39	0.67	0.44	0.67	0.70	1.38	0.55
F	1976	0.00	0.02	0.18	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

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Remaining age specific fishing mortality tables for: Mackerel
Haddock
Herring
Butterfish

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NATURAL MORTALITY

1SILVER H

1968	0.050	0.192	0.217	0.153	0.309	0.306	0.305	0.304	0.303	0.302
1969	0.050	0.308	0.319	0.300	0.307	0.305	0.305	0.303	0.303	0.302
1970	0.050	0.622	0.630	0.615	0.306	0.305	0.304	0.303	0.302	0.302
1971	0.050	0.577	0.888	0.568	0.308	0.306	0.305	0.304	0.303	0.302
1972	0.050	0.369	0.884	0.358	0.306	0.304	0.303	0.302	0.302	0.301
1973	0.050	0.493	0.490	0.473	0.307	0.305	0.303	0.303	0.302	0.301
1974	0.050	0.582	0.582	0.559	0.309	0.308	0.306	0.303	0.302	0.301
1975	0.050	0.448	0.452	0.431	0.313	0.311	0.309	0.306	0.303	0.302
1976	0.050	0.364	0.359	0.342	0.323	0.319	0.313	0.309	0.306	0.302

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Remaining age specific natural mortality tables for: Mackerel
Haddock
Herring
Butterfish
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FORTRAN STOP
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PROGRAM NAME: Population Estimation from Relative Abundance Data

PROGRAM TYPE: Main

DATE CREATED: Jan 1 1982

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]DELPOP.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]DELPOP.EXE

AUTHOR: J.S. Collie

DOCUMENTED BY: J.S. Collie

REVISIONS (Date/Reviser - Description)

Mar 12 1984 /J.S. Collie -
Combined age-structured and non-age-structured versions into one program. Revised to conform with NERFIS standards.

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

Estimation of catchability coefficients, population size (numbers) and smoothing of relative abundance indices.

DESCRIPTION:

Relative abundance indices (e.g. bottom trawl survey) indices and commercial catch data are used to estimate population size in numbers. The program may be run with or without knowledge of the age composition of the catch. The instantaneous rate of natural mortality (M) is assumed to be known. In addition to estimating catchability coefficients, this method accounts for error in the measurement of relative abundance.

The program, a modification of the DeLury method, consists of two alternate subroutines, one age-structured and the other non-age-structured. The population model is fitted using the non-linear regression subroutine ZXSSQ of the International Mathematics and Statistical Library. Program output includes estimated catchability coefficients, smoothed relative abundance indices, corresponding residuals and standard errors, population estimates and a full parameter summary.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

First decide whether to use the age-structured or non-age-structured subroutine. The non-age-structured subroutine can be run interactively; the age-structured subroutine must be run in batch mode. The switch for the two subroutines is the number of age classes, JEND. To run the non-age-structured subroutine JEND=2; for the age-structured subroutine JEND>2.

It is imperative that the survey data correspond in area, time and ages as closely as possible to the commercial catch data. In the examples given below, the fall survey index is compared to the commercial catch from the following calendar year. In other words, the survey index for fish age a-1 from the fall of year t-1 is used as a relative abundance index for fish age a in year t. If possible the commercial catch data should be compiled to be in phase with the timing of the survey data.

The following parameters are required to initialize the population model and regression. For the non-age-structured subroutine the parameters are entered interactively; for the age-structured routine they should be listed in a separate data file (e.g. params.dat) or listed in the command file used to submit the program to batch.

Record Number	Record Description
1.	Title line (maximum 40 characters).
2.	Number of age classes (maximum is 15) (2 for the non-age-structured subroutine).
3.	Estimate of natural mortality, M.
4.	Initial guess of catchability coefficient, q, scaled to the commercial catch (see below).
5.	Pre-recruit catchability relative to 1 for post-recruits (if in doubt type 1; do not type 0).
6.	Timing of commercial catch, t, such that 0<t<1. t=0 assumes catch occurs at beginning of year t=1 assumes catch occurs at end of year (if in doubt type 0.5).
7.	Weights of pre-recruit and post-recurit errors (if in doubt type 1,1).
8.	EPSILON - convergence criterion satisfied if on successive iterations, the residual sum of squares estimates differ by less than EPSILON. Try 0.00001 to start. EPSILON may be set to 0.
9.	DELTA - convergence criterion satisfied if the norm of the gradient of the sum of squares surface is less than DELTA. Try 0.001 to start.
10.	NSIG - convergence criterion satisfied if on successive iterations the parameter estimates agree component by component to NSIG digits. Try 3 to start.

Convergence is considered achieved if any one of the three conditions is satisfied. The convergence criteria should be varied until an acceptable fit is obtained. All data input, except the title, is free format.

The survey indices and commercial catch must be scaled so that they are roughly the same magnitude. The catchability coefficient, q, will then be scaled by the same factor. The maximum number of years is 30. Output requires a wide carriage terminal.

For the non-age-structured subroutine one data file, 'INFILE', is required with each record consisting of the following:
Year, pre-recruit index, post-recruit index, commercial catch.

To run DELPOP with non-age-structured data, type:

```
$ASSIGN [directory]data.dat   INFILE
$ASSIGN [directory]output.ext OUTFILE
$RUN [712.MASTER.XEQ]DELPOP
```

The age-structured subroutine requires two data files, 'POPFILE' and 'CATFILE'. 'POPFILE' contains the survey catch-at-age data; 'CATFILE' the corresponding commercial catch-at-age.
Each record should consist of:
Year, catch at age 1, catch at age 2, catch at age 3, ...

To run DELPOP with age-structured data submit the following command file:

```
$ASSIGN [directory]params.dat  FOR005
$ASSIGN [directory]survey.dat  POPFILE
$ASSIGN [directory]catch.dat   CATFILE
$ASSIGN [directory]output.ext  OUTFILE
$RUN [712.MASTER.XEQ]DELPOP
```

REFERENCES:

Collie, J.S. and M.P. Sissenwine 1983. Estimating population size from relative abundance data measured with error. Can. J. Fish. Aquat. Sci. 40:1871-1879.

International Mathematical and Statistical Library, 1982. 9th edition, Houston Texas. Volume 4, subroutine ZXSSQ.

```
$ ASSIGN DELAGEPRM.DAT     FOR005
$ ASSIGN DELAGESTK.DAT     POPFILE
$ ASSIGN DELAGECAT.DAT     CATFILE
$ ASSIGN OUTPUT.DAT        OUTFILE
$ RUN FSHA:[712.MASTER.XEQ]DELPOP

*** DELPOP - VERSION 2.2 - APR 1984 - J.S. COLLIE ***

ENTER TITLE LINE (MAX = 40 CHARACTERS)
                                      :
ENTER THE NUMBER OF AGE CLASSES
THE AGE-STRUCTURED MODEL SHOULD BE RUN IN BATCH
TYPE "2" TO RUN THE NON-AGE-STRUCTURED MODEL                    :
ENTER ESTIMATE OF NATURAL MORTALITY (M)                         :
ENTER GUESS OF q SCALED TO COMMERCIAL CATCH                     :
ENTER PRE-RECRUIT CATCHABILITY RELATIVE TO 1 FOR POST-RECRUITS
IF IN DOUBT TYPE "1"; DO NOT TYPE "0"!                          :
ENTER TIMING OF CATCH, T, SUCH THAT 0<T<1
IF IN DOUBT TYPE "0.5"                                          :
ENTER WEIGHTS OF PRE-RECRUIT AND POST-RECRUIT ERRORS
RELATIVE TO EQUATION ERROR.  IF IN DOUBT TYPE 1,1               :
FINALLY, CHOOSE THE FITTING CRITERIA
ENTER EPSILON (TRY 0.00001 TO START)                            :
ENTER DELTA (TRY 0.001 TO START)                                :
ENTER NUMBER OF SIGNIFICANT DIGITS (TRY 3)                      :
IF YOU ARE CONFUSED BY ALL THIS CALL THE SAMARITANS
$
```

$ T OUTPUT.DAT

ELPOP TEST RUN WITH AGE DATA

RELATIVE ABUNDANCE ESTIMATES

YEAR	AGE CLASS 2	3	4	5	6	7	8	9	10	11	12	13	14	15
1964	30.23	4.58	3.31	5.13	3.14	1.23	0.84	0.83						
1965	78.74	21.67	2.79	1.66	2.47	1.35	0.49	0.48						
1966	4.11	39.94	9.06	0.99	0.60	0.67	0.49	0.34						
1967	0.58	1.88	13.04	3.71	0.36	0.31	0.23	0.14						
1968	2.20	0.25	0.77	6.65	1.23	0.31	0.14	0.32						
1969	0.04	0.81	0.09	0.22	2.68	0.69	0.18	0.34						
1970	0.02	0.00	0.20	0.09	0.11	1.13	0.35	0.25						
1971	1.39	0.14	0.01	0.19	0.17	0.30	0.70	0.49						
1972	0.00	0.26	0.05	0.01	0.15	0.02	0.06	0.29						
1973	1.61	0.00	0.32	0.06	0.00	0.06	0.04	0.62						
1974	2.96	0.87	0.00	0.13	0.03	0.00	0.05	0.45						
1975	1.06	1.77	0.25	0.00	0.01	0.00	0.00	0.16						
1976	0.43	0.53	1.43	0.49	0.00	0.02	0.00	0.21						
1977	22.27	0.35	0.38	0.70	0.21	0.00	0.03	0.23						
1978	1.50	17.00	0.41	0.42	0.52	0.26	0.03	0.08						
1979		0.96	11.67	0.15	0.21	0.36	0.01	0.01						

ABUNDANCE RESIDUALS

1964	-0.57	0.30	0.32	0.09	0.24	0.11	0.29	0.29
1965	-0.04	0.68	0.34	-0.32	0.04	-0.25	-0.06	-0.21
1966	0.51	0.26	-0.33	-0.32	-0.10	-0.10	0.10	0.04
1967	0.09	0.03	-0.06	-0.50	-0.04	0.08	-0.03	-0.05
1968	0.72	-0.05	-0.14	-0.38	-0.12	0.06	-0.01	0.05
1969	0.00	-0.24	-0.01	-0.02	-0.03	0.20	0.01	0.08
1970	0.00	0.00	-0.05	0.00	-0.02	-0.10	-0.03	-0.05
1971	0.69	0.02	0.00	0.02	0.03	0.11	0.28	0.19
1972	0.00	-0.20	0.00	0.00	0.01	0.00	-0.04	-0.20
1973	0.05	0.00	0.08	0.00	0.00	0.00	0.00	0.36
1974	0.71	0.21	0.00	0.00	0.00	0.00	0.01	0.07
1975	0.12	-0.99	-0.16	0.00	0.00	0.00	0.00	-0.04
1976	-0.03	-0.10	0.82	0.24	0.00	0.00	0.00	0.01
1977	0.66	-0.01	-0.05	-0.24	-0.06	0.00	0.00	0.04
1978	0.15	-0.10	0.11	0.11	0.01	0.08	0.00	0.00
1979		-0.12	-0.43	-0.02	0.00	0.02	0.00	0.00

STANDARD ERROR OF ESTIMATES

1964	2.70	0.62	0.51	0.64	0.49	0.29	0.23	0.23
1965	6.92	1.94	0.41	0.32	0.38	0.28	0.14	0.14
1966	0.56	3.47	0.91	0.23	0.16	0.18	0.14	0.10
1967	0.17	0.35	1.22	0.50	0.11	0.09	0.07	0.04
1968	0.39	0.08	0.19	0.72	0.28	0.09	0.04	0.09
1969	0.01	0.20	0.03	0.07	0.42	0.18	0.05	0.10
1970	0.01	0.00	0.06	0.03	0.03	0.26	0.10	0.08
1971	0.29	0.04	0.00	0.06	0.05	0.09	0.18	0.13
1972	0.00	0.08	0.02	0.00	0.05	0.01	0.02	0.09
1973	0.35	0.00	0.09	0.02	0.00	0.02	0.01	0.16
1974	0.51	0.21	0.00	0.04	0.01	0.00	0.02	0.12
1975	0.26	0.35	0.07	0.00	0.00	0.00	0.00	0.05
1976	0.13	0.14	0.27	0.13	0.00	0.01	0.00	0.06
1977	3.62	0.10	0.11	0.18	0.06	0.00	0.01	0.07
1978	0.35	2.95	0.11	0.12	0.14	0.08	0.01	0.03
1979		0.26	2.42	0.05	0.06	0.11	0.00	0.00

EQUATION RESIDUALS

1965	0.02	-0.08	-0.12	-0.02	-0.09	-0.11	-0.42
1966	0.00	-0.01	-0.25	0.09	-0.04	0.12	0.02
1967	-0.15	-0.01	0.03	0.09	0.32	0.13	-0.12
1968	-0.19	-0.21	0.00	0.21	0.25	0.09	0.34
1969	-0.40	0.02	-0.03	0.07	0.37	0.06	0.21
1970	-0.03	-0.13	0.10	0.06	0.10	0.09	-0.02
1971	0.15	0.01	0.13	0.14	0.25	0.23	0.23
1972	-0.62	-0.02	0.01	0.05	-0.07	-0.13	-0.21
1973	0.00	0.20	0.03	0.00	-0.04	0.04	0.58
1974	-0.04	0.00	-0.06	-0.01	0.01	0.02	0.00
1975	-0.30	-0.34	0.00	-0.08	-0.02	0.00	-0.20
1976	-0.14	0.34	0.36	0.00	0.02	0.00	0.10
1977	0.09	0.05	-0.30	-0.15	0.00	0.02	0.08
1978	-0.04	0.16	0.24	0.05	0.16	0.03	-0.10
1979	-0.12	-0.04	-0.13	-0.02	0.04	-0.18	-0.06

POPULATION ESTIMATES BY AGE

1964	126.96	19.25	13.91	21.55	13.20	5.15	3.54	3.47
1965	330.73	91.00	11.70	6.97	10.37	5.68	2.06	2.03
1966	17.26	167.77	38.04	4.16	2.51	2.83	2.04	1.41
1967	2.45	7.89	54.79	15.59	1.53	1.28	0.96	0.58
1968	9.23	1.06	3.23	27.92	5.16	1.30	0.60	1.35
1969	0.17	3.41	0.38	0.94	11.25	2.91	0.75	1.44
1970	0.08	0.02	0.84	0.38	0.47	4.73	1.48	1.06
1971	5.85	0.57	0.04	0.78	0.73	1.28	2.93	2.04
1972	0.02	1.08	0.21	0.04	0.62	0.08	0.26	1.23
1973	6.74	0.02	1.36	0.25	0.02	0.25	0.17	2.61
1974	12.45	3.67	0.02	0.55	0.13	0.02	0.21	1.91
1975	4.44	7.44	1.03	0.02	0.04	0.02	0.02	0.66
1976	1.82	2.22	6.01	2.06	0.02	0.08	0.02	0.88
1977	93.52	1.49	1.60	2.92	0.89	0.02	0.13	0.97
1978	6.31	71.40	1.73	1.77	2.17	1.09	0.13	0.34
1979		4.02	49.03	0.64	0.89	1.53	0.04	0.04

SUMMED POPULATION ESTIMATES

1964	207.04
1965	460.54
1966	236.02
1967	85.07
1968	49.85
1969	21.24
1970	9.06
1971	14.24
1972	3.55
1973	11.42
1974	18.95
1975	13.66
1976	13.11
1977	101.53
1978	84.93
1979	59.10

```
          PARAMETER SUMMARY

NUMBER OF YEARS = 16
NUMBER OF AGE CLASSES =  8
NUMBER OF RESIDUALS =232
NUMBER OF PARAMETERS TO BE ESTIMATED =128
DEGREES OF FREEDOM =104

          FUDGE FACTORS
PRE-RECRUIT CATCHABILITY = 1.00 TIMES ADULT CATCHABILITY
COMMERCIAL CATCH OCCURS AT: 0.00
NATURAL MORTALITY = 0.2

                    RELATIVE ERROR WEIGHTS
EQUATION ERROR                      1.0
PRE-RECRUIT OBSERVATION ERROR       1.0
POST-RECRUIT OBSERVATION ERROR      1.0

           NON-LINEAR LEAST-SQUARES FIT
ERROR CHECK =   0 (IF IER.NE.0 CHECK PROGRAM DOCUMENTATION)
MARQUARDT PARAMETER = 0.544E-03 (YOU WANT THIS TO BE LOW)

          FITTING CRITERIA
                         INITIAL        FINAL
1. SIGNIFICANT DIGITS      3              2.9
2. EPSILON               0.100E-04
3. NORM OF GRADIENT      0.0010         0.0731

INFER =  2 CHECK DOCUMN TO SEE WHICH CRITERIA WERE SATISFIED
NUMBER OF ITERATIONS = 10.
SUM OF SQUARES = 10.24

                    CATCHABILITY COEFFICIENT
INITIAL                       0.20000
FINAL                         0.23808
ESTIMATED STANDARD ERROR      0.02190
$
```

```
$ T DELAGESTK.DAT

1964     17.04     6.19     4.57     5.60     3.99     1.37     1.13     1.10
1965     75.75    42.78     3.91     1.20     2.56     1.05      .46      .39
1966      6.82    51.91     6.51      .72      .54      .61      .54      .35
1967       .64     1.94    12.34     2.25      .35      .33      .22      .13
1968      4.51      .24      .67     4.54     1.09      .33      .14      .34
1969       .04      .64      .09      .22     2.59      .85      .18      .37
1970       .02      .00      .19      .09      .11     1.02      .34      .24
1971      2.77      .14      .01      .19      .18      .34      .92      .59
1972       .00      .21      .05      .01      .15      .02      .06      .24
1973      1.69      .00      .35      .06      .00      .06      .04      .89
1974      6.04     1.08      .00      .13      .03      .00      .05      .49
1975      1.19      .66      .21      .00      .01      .00      .00      .15
1976       .42      .48     3.26      .62      .00      .02      .00      .21
1977     43.07      .35      .36      .55      .20      .00      .03      .24
1978      1.75    15.33      .46      .47      .52      .28      .03      .08
1979       .69      .85     7.59      .15      .21      .37      .01      .01
$

$ T DELAGECAT.DAT

1964     15.935    4.544    4.776    8.772    5.794    2.082    1.028    1.332
1965    125.818   44.496    5.356    4.391    6.690    3.772    1.094    1.366
1966      6.843  100.810   19.167    2.768    2.591    2.332    1.268     .867
1967       .168    2.891   20.667   10.338    1.209     .993     .917     .698
1968      2.994     .709    1.921   14.519    3.499     .677     .453     .842
1969       .011    1.698     .448     .654    5.954    1.574     .225     .570
1970       .158     .016     .570     .186     .214    2.308     .746     .464
1971      1.375     .223     .040     .289     .246     .285    1.469     .928
1972       .002     .450     .081     .032     .120     .078     .066    1.236
1973      2.057     .003     .386     .053     .030     .077     .015     .447
1974      1.820     .657     .002     .070     .002     .002     .053     .249
1975      1.034    1.864     .375     .004     .042     .004     .004     .088
1976       .473     .550     .880     .216     .000     .023     .004     .112
1977      6.130     .187     .680     .515     .357     .004     .039     .111
1978       .761   11.315     .305     .567     .517     .139     .014     .067
1979       .026    1.726    7.169     .525     .410     .315     .096     .046
$

$ T DELAGEPRM.DAT

DELPOP TEST RUN WITH AGE DATA
8
.2
.2
1
0
1,1
.00001
.001
3
$
```

```
$ ASSIGN  DELNOAGES.DAT  INFILE
$ ASSIGN  OUTPUT.DAT     OUTFILE
$ RUN FSHA:[712.MASTER.XEQ]DELPOP


*** DELPOP - VERSION 2.2 - APR 1984 - J.S. COLLIE ***

ENTER TITLE LINE (MAX = 40 CHARACTERS)
                                : DELPOP TEST RUN WITHOUT AGE DATA
ENTER THE NUMBER OF AGE CLASSES
THE AGE-STRUCTURED MODEL SHOULD BE RUN IN BATCH
TYPE "2" TO RUN THE NON-AGE-STRUCTURED MODEL                    : 2
ENTER ESTIMATE OF NATURAL MORTALITY (M)                         : .2
ENTER GUESS OF q SCALED TO COMMERCIAL CATCH                     : .2
ENTER PRE-RECRUIT CATCHABILITY RELATIVE TO 1 FOR POST-RECRUITS
IF IN DOUBT TYPE "1"; DO NOT TYPE "0"!                          : 1
ENTER TIMING OF CATCH, T, SUCH THAT 0<T<1
IF IN DOUBT TYPE "0.5"                                          : 0
ENTER WEIGHTS OF PRE-RECRUIT AND POST-RECRUIT ERRORS
RELATIVE TO EQUATION ERROR.  IF IN DOUBT TYPE 1,1               : 1,1
FINALLY, CHOOSE THE FITTING CRITERIA
ENTER EPSILON (TRY 0.00001 TO START)                            : 0
ENTER DELTA (TRY 0.001 TO START)                                : .001
ENTER NUMBER OF SIGNIFICANT DIGITS (TRY 3)                      : 4
IF YOU ARE CONFUSED BY ALL THIS CALL THE SAMARITANS
SUCCESSFUL RUN
$ T OUTPUT.DAT

DELPOP TEST RUN WITHOUT AGE DATA
```

ESTIMATED RELATIVE ABUNDANCE

YEAR	PRE-RECRUITS				POST-RECRUITS				EQUATION
	OBSERVED	ESTIMATED	RESIDUAL	EST SE	OBSERVED	ESTIMATED	RESIDUAL	EST SE	ERROR
1964	17.04	21.39	-0.23	10.59	23.95	34.61	-0.37	14.77	
1965	75.75	81.49	-0.07	26.15	52.35	34.50	0.42	12.28	0.01
1966	6.82	6.74	0.01	3.56	61.21	52.59	0.15	11.66	0.00
1967	0.65	0.65	0.00	0.35	17.56	19.96	-0.13	4.41	0.00
1968	4.51	5.12	-0.13	2.47	7.35	8.72	-0.17	2.65	0.01
1969	0.04	0.04	0.00	0.02	4.94	5.99	-0.19	1.22	0.03
1970	0.02	0.02	0.00	0.01	1.99	2.69	-0.30	0.80	0.08
1971	2.77	2.21	0.22	0.89	2.37	1.46	0.48	0.60	0.23
1972	0.00	0.00	0.00	0.00	1.19	1.87	-0.45	0.60	-0.12
1973	1.69	1.77	-0.04	0.75	1.40	1.21	0.14	0.48	0.14
1974	6.04	3.09	0.67	1.15	1.78	1.29	0.32	0.56	0.03
1975	1.19	1.35	-0.13	0.67	1.03	2.72	-0.97	0.87	-0.26
1976	0.42	0.41	0.03	0.21	4.59	2.69	0.53	0.77	0.11
1977	43.01	18.30	0.85	4.47	1.73	1.93	-0.11	0.70	-0.10
1978	1.75	1.57	0.11	0.83	17.17	14.83	0.15	3.51	-0.06
1979	0.69	0.66	0.05	0.35	9.19	10.49	-0.13	2.80	-0.08
1980	37.29	23.85	0.45	9.52	4.38	6.88	-0.45	2.35	-0.08
1981	2.22				13.21	21.71	-0.50	7.83	-0.02

POPULATION ESTIMATES SCALED TO COMMERCIAL CATCH

YEAR	AGE 1	AGE 2+	TOTAL
1964	83.73	135.45	219.18
1965	318.96	135.03	453.99
1966	26.37	205.84	232.21
1967	2.55	78.14	80.69
1968	20.04	34.13	54.17
1969	0.16	23.46	23.61
1970	0.08	10.51	10.59
1971	8.66	5.72	14.38
1972	0.02	7.31	7.33
1973	6.92	4.75	11.66
1974	12.11	5.06	17.17
1975	5.28	10.65	15.93
1976	1.59	10.53	12.12
1977	71.64	7.55	79.19
1978	6.16	58.04	64.21
1979	2.58	41.05	43.63
1980	93.35	26.94	120.30
1981		84.97	

PARAMETER SUMMARY

NUMBER OF YEARS = 18
NUMBER OF AGE CLASSES = 2
NUMBER OF RESIDUALS = 52
NUMBER OF PARAMETERS TO BE ESTIMATED = 36
DEGREES OF FREEDOM = 16

FUDGE FACTORS
PRE-RECRUIT CATCHABILITY = 1.00 TIMES ADULT CATCHABILITY
COMMERCIAL CATCH OCCURS AT: 0.00
NATURAL MORTALITY = 0.2

RELATIVE ERROR WEIGHTS

EQUATION ERROR	1.0
PRE-RECRUIT OBSERVATION ERROR	1.0
POST-RECRUIT OBSERVATION ERROR	1.0

NON-LINEAR LEAST-SQUARES FIT
ERROR CHECK = 0 (IF IER.NE.0 CHECK IMSL DOCUMENTATION)
MARQUARDT PARAMETER = 0.629E-05 (YOU WANT THIS TO BE LOW)

FITTING CRITERIA

	INITIAL	FINAL
1. SIGNIFICANT DIGITS	4	3.1
2. EPSILON	0.000E+00	
3. NORM OF GRADIENT	0.0010	0.0023

INFER = 2 (CHECK IMSL DOCUMENTATION TO SEE WHICH CRITERIA WERE SATISFIED)
NUMBER OF ITERATIONS = 14.
SUM OF SQUARES = 4.54

CATCHABILITY COEFFICIENT

INITIAL GUESS	0.20000
FINAL ESTIMATE	0.25550
ESTIMATED STANDARD ERROR	0.05103

$

```
$ T [712.MASTER.DATA]DELNOAGES.DAT
1964     17.04    23.95    54.324
1965     75.75    52.35   202.584
1966      6.82    61.21   136.760
1967       .65    17.56    39.031
1968      4.51     7.35    25.662
1969       .04     4.94    11.136
1970       .02     1.99     4.708
1971      2.77     2.37     4.855
1972       .00     1.19     2.211
1973      1.69     1.40     5.628
1974      6.04     1.78     2.901
1975      1.19     1.03     3.607
1976       .42     4.59     2.402
1977     43.01     1.73     8.023
1978      1.75    17.17    13.685
1979       .69     9.19    10.313
1980     37.29     4.38    16.400
1981      2.22    13.21    16.400
$
```

PROGRAM NAME: Analysis of a Catch Curve

PROGRAM TYPE: Main

DATE CREATED: Jan 1 1964

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]CATCURV.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]CATCURV.EXE

AUTHOR: L.E. Gales

DOCUMENTED BY: S.H. Clark

REVISIONS (Date/Reviser - Description)

Jan 16 1984 /F.P. Almeida, S.H. Clark
Converted to FORTRAN77 to run on VAX11/780

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

The program analyzes a vector of catch at age data and provides estimates of the survival rate (S), the instantaneous total mortality rate (Z), and associated statistical measures (variances, standard errors and confidence limits). Options are available to evaluate assumptions concerning age at full recruitment, to combine data for which ages are uncertain, and to subdivide the catch curve and analyze resulting segments separately.

DESCRIPTION:

The program employs a series of algorithms to analyze catch curve data as presented by Chapman and Robson (1960) and Robson and Chapman (1961). The user should consult these papers before running CATCURV. A description of each option and the algorithms used is given in the following sections.

Option 1: Assumes constant recruitment and survival, that all ages in the catch vector are fully available to the fishing/sampling gear, and all ages are known. Let N(0), N(1), N(2).... be the numbers of fish caught at (coded) ages 0, 1, 2...I; let n = total number summed over all ages, and let T = N(1) + 2N(2) + 3N(3) + ... + IN(I). Then S = T/(T + n - 1) and the variance, standard error, and confidence interval about this estimate are calculated. An estimate is also provided for the instantaneous total mortality rate (Z) together with

variance, standard error, and confidence interval, as for S:

S (survival rate) = T/(T + n - 1)

variance of S = S[S - (T - 1)/(n + T - 2)]

standard error of S = SQRT(Variance of S)

confidence interval about S = S + 2(Standard error of S) to
S - 2(Standard error of S)

Option 2: Tests the hypothesis that the relative frequency in the first age group does not deviate significantly from that observed for older ages, i.e. that the first age group is fully available. Heinke's estimate of S (n - N(0))/n is calculated and used with the estimate of S derived in Option 1. If Chi exceeds the tabular value (use 3.84) with 1 degree of freedom, then a significant deficit in N(0) is implied, which could result from incomplete vulnerability or other factors (Robson and Chapman 1961). Data are recoded (N(1) to N(0), N(2) to N(1), etc.) and calculations repeated until the statistic is less than the value of Chi entered, after which computations and output are then the same as under Option 1.

Option 3: May be used when ages for older groups are uncertain. If ages above N(K) are uncertain, data for the N(K + 1) group and all older groups are combined, viz. m = N(K + 1) + ... N(I) where N(I) is the last observation in the data set. Calculations are then performed as under Option 1 using the vector N(1), N(2), N(3) ... m. The user enters the K value corresponding to the last known age (K = 1, N).

Option 4: Computes the same output as Option 1 for each segment of the catch vector defined by the user, e.g. K values 1 to 3, 2 to 4, etc. The program allows use of overlapping segments, i.e. one age group may appear in more than one segment. The user specifies the K values corresponding to the derived segment endpoints.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

Input values are free - formatted; data values should be entered separated by commas. Program output requires a wide carriage terminal. To run the program, type:

$RUN FSHA:[712.MASTER.XEQ]CATCURV

The user is then prompted for an identifier title (40 byte maximum), catch values, and option number and age at full recruitment (may be different from the first value entered). Following each run, the user may rerun the program with a different option and/or new catch values. A different age at

full recruitment can also be requested by changing the appropiate value on the "option" record.

The user may also choose to create a data file and use the following:

```
$ASSIGN datafile.DAT FOR005
$RUN FSHA:[712.MASTER.XEQ]CATCURV
```

Restrictions: Number of age groups less than or equal to 1000 and number of segments less than or equal to 10.

REFERENCES:

Chapman, D.G. and D.S. Robson 1960. The analysis of a catch curve. Biometrics 16:354-368.

Robson, D.S. and D.G. Chapman 1961. Catch curves and mortality rates. Trans. Am. Fish. Soc. 90:181-189.

```
$RUN FSHA:[712.MASTER.XEQ]CATCURV
   Catcurv analysis of a catch curve program '     FRG 705 I/13/84/ L.E.Gales-S.Clark


 Input identifier title (maximum of 40 bytes)
TEST RUN ROBSON-CHAPMAN DATA
 Input number of catch values (maximum of 1000)
6
 Input catch values
118,73,36,14,1,1
 Input option number and age at full recruitment
1,6


*****************************************************************************************************************
O P T I O N  1    6. IS YOUNGEST AGE FULLY AVAILABLE      TEST RUN ROBSON-CHAPMAN DATA
*****************************************************************************************************************


                                        (AGE,NUMBER)

 (   6,   118.0)  (   7,    73.0)  (   8,    36.0)  (   9,    14.0)  (  10,     1.0)  (  11,     1.0)  (

ESTIMATE OF SURVIVAL RATE =  0.447488576
VARIANCE O       F SURVIVAL RATE =  0.000565775
STANDARD ERROR OF SURVIVAL            RATE =  0.023786023
95 PER CENT CONFIDENCE INTERVAL FOR              SURVIVAL RATE =  0.39991653   0.49506062
INSTANTANEOUS MORTALITY        RATE =   0.801323
VARIANCE OF INSTANTANEOUS MORTALITY RATE =  0.00280734
STANDARD ERROR OF Z =  0.05298430
95 PER CENT CONFIDENCE     INTERVAL FOR Z =   0.695354    0.907291
Z INTERVAL OBTAINED FROM S INTERVAL =  0.70307505   0.91649944


 Want to restart with new catch values (enter 1),  rerun with different options (enter 2),  or stop (enter 3)?
2
 Input option number and age at full recruitment
2
,6
 Option 2 selected, input CHI SQUARE value
3.84
```

```
*****************************************************************************************************************
O P T I O N  2  USING CHI SQUARE VALUE OF   3.840 AND AFR= 6.0      TEST RUN ROBSON-CHAPMAN DATA
*****************************************************************************************************************


                                        (AGE,NUMBER)

 (   6,   118.0)  (   7,    73.0)  (   8,    36.0)  (   9,    14.0)  (  10,     1.0)  (  11,     1.0)  (


AGE AT FULL RECRUITMENT IS  6.

ESTIMATE OF   SURVIVAL RATE =  0.44748858
HEINCKES SURVIVAL EST. =  0.51440328
CHI-SQUARE STATISTIC =     9.8622


AGE AT FULL RECRUITMENT IS  7.

ESTIMATE OF   SURVIVAL RATE =  0.36410257
HEINCKES SURVIVAL EST. =  0.41600001
CHI-SQUARE STATISTIC =     4.0299


AGE AT FULL RECRUITMENT IS  8.

ESTIMATE OF   SURVIVAL RATE =  0.27142859
HEINCKES SURVIVAL EST. =  0.30769232
CHI-SQUARE STATISTIC =     1.3256


ESTIMATE OF SURVIVAL RATE =  0.271428585
VARIANCE O       F SURVIVAL RATE =  0.002866020
STANDARD ERROR OF SURVIVAL            RATE =  0.053535227
95 PER CENT CONFIDENCE INTERVAL FOR              SURVIVAL RATE =  0.16435814   0.37849903
INSTANTANEOUS MORTALITY        RATE =   1.269029
VARIANCE OF INSTANTANEOUS MORTALITY RATE =  0.03760844
STANDARD ERROR OF Z =  0.19392896
95 PER CENT CONFIDENCE     INTERVAL FOR Z =   0.881171    1.656887
Z INTERVAL OBTAINED FROM S INTERVAL =  0.97154176   1.80570745



 Want to restart with new catch values (enter 1),  rerun with different options (enter 2),  or stop (enter 3)?
2
 Input option number and age at full recruitment
3,6
 Option 3 selected,inputlast data point for known ages
3
```

```
*****************************************************************************************************************
O P T I O N  3    OLDER AGES COMBINED.   6. IS YOUNGEST AGE FULLY AVAILABLE      TEST RUN ROBSON-CHAPMAN DATA
*****************************************************************************************************************


                                        (AGE,NUMBER)

 (   6,   118.0)  (   7,    73.0)  (   8,    36.0)  (   9,    14.0)  (  10,     1.0)  (  11,     1.0)  (

COMBINED AGE VECTOR
      118.00        73.00        36.00        16.00


ESTIMATE OF SURVIVAL RATE =  0.459523797
VARIANCE O       F SURVIVAL RATE =  0.000611763
STANDARD ERROR OF SURVIVAL            RATE =  0.024733853
95 PER CENT CONFIDENCE INTERVAL FOR              SURVIVAL RATE =  0.41005608   0.50899148
INSTANTANEOUS MORTALITY        RATE =   0.774667
VARIANCE OF INSTANTANEOUS MORTALITY RATE =  0.00289713
STANDARD ERROR OF Z =  0.05382496
95 PER CENT CONFIDENCE     INTERVAL FOR Z =   0.667017    0.882317
Z INTERVAL OBTAINED FROM S INTERVAL =  0.67532402   0.89146131

 Want to restart with new catch values (enter 1),  rerun with different options (enter 2),  or stop (enter 3)?
2
 Input option number and age at full recruitment
4
,6
 Option 4 selected,input number of segments(max 10)
2
nput segment endpoints
1,4,2,5
```

```
*****************************************************************************************************
O P T I O N  4   SURVIVAL ESTIMATES FOR A SEGMENTED CATCH CURVE      TEST RUN ROBSON-CHAPMAN DATA
*****************************************************************************************************


                                        (AGE,NUMBER)

 (   6,   118.0)  (   7,    73.0)  (   8,    36.0)  (   9,    14.0)  (  10,     1.0)  (  11,     1.0)  (


-----------------------------------------------------------------------------------------------------
SEGMENT  1     N(  1)  TO  N(  4)   INCLUDES AGES    6  TO    9


ITERATION NO. (   1)  S=   0.524717E+00   X=   0.775934E+00  0.369177E-01
ITERATION NO. (   2)  S=   0.524727E+00   X=   0.775934E+00  0.281036E-04
ITERATION NO. (   3)  S=   0.524727E+00   X=   0.775934E+00  0.149012E-06

 0.524726927 0.001265425 0.035572819 0.453581303 0.595872581

 0.524726927 0.001265425 0.035572819 0.453581303 0.595872581 0.517728448


ESTIMATE OF SURVIVAL RATE =  0.524726927
VARIANCE O       F SURVIVAL RATE =  0.001265425
STANDARD ERROR OF SURVIVAL            RATE =  0.035572819
95 PER CENT CONFIDENCE INTERVAL FOR              SURVIVAL RATE =  0.45358130   0.59587258
INSTANTANEOUS MORTALITY        RATE =   0.640281
VARIANCE OF INSTANTANEOUS MORTALITY RATE =  0.00459589
STANDARD ERROR OF Z =  0.06779301
95 PER CENT CONFIDENCE     INTERVAL FOR Z =   0.504695    0.775867
Z INTERVAL OBTAINED FROM S INTERVAL =  0.51772845   0.79058075
-----------------------------------------------------------------------------------------------------


-----------------------------------------------------------------------------------------------------
SEGMENT  2     N(  2)  TO  N(  5)   INCLUDES AGES    7  TO   10


ITERATION NO. (   1)  S=   0.387559E+00   X=   0.540323E+00  0.253430E-01
ITERATION NO. (   2)  S=   0.387463E+00   X=   0.540323E+00  0.938773E-04
ITERATION NO. (   3)  S=   0.387463E+00   X=   0.540323E+00  0.149012E-06

 0.387463003 0.001847715 0.042985056 0.301492900 0.473433107

 0.387463003 0.001847715 0.042985056 0.301492900 0.473433107 0.747744679
```

```
ESTIMATE OF SURVIVAL RATE =  0.387463003
VARIANCE O       F SURVIVAL RATE =  0.001847715
STANDARD ERROR OF SURVIVAL            RATE =  0.042985056
95 PER CENT CONFIDENCE INTERVAL FOR              SURVIVAL RATE =  0.30149290   0.47343311
INSTANTANEOUS MORTALITY        RATE =   0.935827
VARIANCE OF INSTANTANEOUS MORTALITY RATE =  0.01230763
STANDARD ERROR OF Z =  0.11093977
95 PER CENT CONFIDENCE     INTERVAL FOR Z =   0.713948    1.157707
Z INTERVAL OBTAINED FROM S INTERVAL =  0.74774468   1.19900882
-----------------------------------------------------------------------------------------------------

 Want to restart with new catch values (enter 1),  rerun with different options (enter 2),  or stop (enter 3)?
3
FORTRAN STOP
$ LO
```

PROGRAM NAME: Leslie Matrix - Population Simulator

PROGRAM TYPE: Main

DATE CREATED: Oct 1 1974

SOURCE FILE NAME: FSHA:[712.MASTER SOURCE]LESLIE.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]LESLIE.EXE

AUTHOR: S. Miller

DOCUMENTED BY: G.T. Waring

REVISIONS (Date/Reviser - Description)

Jul 19 1983 /G.T. Waring -
Converted to FORTRAN 77 to run on VAX 11/780, replaced the UMPLOT plotting routine by DISSPLA subroutines.

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

Program LESLIE simulates the growth of the female portion of a population, utilizing the matrix model developed by P.H. Leslie. Each individual female is assumed to have age specific rates of fecundity and survival, which remain constant over time.

DESCRIPTION:

The matrix equation which describes the age distribution of the population after one unit's time interval are:

$$
\begin{bmatrix} F(o) & F(1) & F(2) & \cdots & F(m) \\ P(o) & 0 & 0 & \cdots & 0 \\ 0 & P(1) & & & \vdots \\ 0 & 0 & P(2) & \cdots & 0 \\ \vdots & & & & \vdots \\ 0 & 0 & 0 & \cdots & P(m-1)\ 0 \end{bmatrix}
\begin{bmatrix} N(ot) \\ N(1t) \\ N(2t) \\ \vdots \\ \vdots \\ N(mt) \end{bmatrix}
=
\begin{bmatrix} N(ot+1) \\ N(1t+1) \\ N(2t+1) \\ \vdots \\ \vdots \\ N(mt+1) \end{bmatrix}
$$

where:

N(xt) = the number of females alive in the age group x to x+1 at time t.

F(x) = the number of female offspring born in the interval t to t+1 per female aged x to x+1 at

time t, who will be alive in the age group 0 to 1 at time t+1.

P(x) = is the probability that a female aged x to x+1 at time t will be alive in the age group x+1 to x+2 at time t+1.

(m+1) = the number of age classes of the female portion of the population.

The total size of the female portion of the population and its corresponding age distribution is calculated for each unit of time from time t=1 until time t=T(f).

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

For each population to be simulated, the user must provide a data file containing four data records. Input data data is assigned to unit FOR001. Output is to unit FOR002, graphics output is to a standard DISSMETA.DAT file created by DISSPLA subroutines. The format for the data records is as follows:

Record Number		Record Description
1	Cols. 1-5	T - the final time interval, integer values,
	6-10	m+1 - the number of age groups in the population, maximum = 10,
	11-15	T - the first time interval for which a histogram of the age distribution is desired. Enter 0 if no histogram is desired,
	16-20	T - the second time interval for which a histogram of the age distribution is desired. Enter 0 if no histogram is desired.
	.	.
	.	.
	.	.
	31-35	T - the fifth time.....
2	Cols. 1-5	F - fecundity rate of the 0 to 1 age class, include decimal,
	6-10	F - fecundity rate of the 1 to 2 age class,
	.	.
	.	.
	.	.
	46-50	F - fecundity rate of the 9 to 10 age class.
3	Cols. 1-5	P - survival rate of the 0 to 1 age class, include decimal,
	5-10	P - survival rate of the 1 to 2 age

		class,
	.	.
	.	.
	.	.
	46-50	P - survival rate of the 9 to 10 age class.
4	Cols. 1-5	N - number of females aged 0 to 1 at time t=1, integer values,
	6-10	N - number of females aged 1 to 2 at time t=1,
	.	.
	.	.
	.	.
	46-50	N - number of females aged 9 to 10 at time t=1.

Input, interactively, the scaling factor for the Y-axis of the total population size plot. To determine a reasonable factor, examine the total sizes of each time interval from the tabular output.

Records 2, 3 and 4 should contain m+1 data values each. All data must be right justified in the fields of columns indicated.

To run the program enter the following commands:

```
$ASSIGN [directory]datafile.DAT FOR001
$ASSIGN SYS$OUTPUT FOR002
$RUN DSKA:[712.MASTER.XEQ]LESLIE
```

The output from the program consists of tables of age-specific population sizes for each time interval. Graphic output is of two forms:

(1) A histogram of the percent of the total population size in each age class and a listing of the number of females in each age class is printed at time t=1, T(1), T(2), T(3), T(4), T(5), and T(f). This allows the user to select up to five time intervals for which a histogram is desired. The program automatically produces a histogram at time t=1 and t=T(f).

(2) A graph plotting the total population size versus time is printed for time t=1 until time t=T(f).

REFERENCES:

Leslie, P.H. 1945. On the use of matrices in certain population mathematics. Biometrika 23:183-212

Pielou, E.C. 1969. An introduction to mathematical ecology. Wiley, New York

```
$ SET DEFAULT SPAK
$ ASSIGN DSKA:[712.MASTER.DATA]LESLIE.DAT FOR001
$ ASSIGN SYS$OUTPUT FOR002
$ RUN DSKA:[712.MASTER.EXE]LESLIE

      Leslie Matrix - Population Simulator
   Written by S. Miller, Univ. Wash. Oct 1974
VAX 11/780 Version 2.0  4 June 1984  G.T. Waring
```

****

LESLIE MATRIX MODEL - TIME INTERVAL 1.

****

AGE	NUMBER	FECUNDITY	SURVIVAL
1	24.	0.0000	0.7400
2	13.	0.0000	0.7400
3	9.	0.0000	0.7400
4	8.	0.0000	0.7400
5	3.	1.1000	0.7400
6	5.	3.8000	0.7400
7	5.	4.5000	0.7400
8	6.	4.5000	0.7400
9	7.	5.3000	0.7400
10	8.	5.3000	0.7400
TOTAL	88.		

****

****

LESLIE MATRIX MODEL - TIME INTERVAL 10.

****

AGE	NUMBER	FECUNDITY	SURVIVAL
1	250.	0.0000	0.7400
2	177.	0.0000	0.7400
3	107.	0.0000	0.7400
4	41.	0.0000	0.7400
5	16.	1.1000	0.7400
6	13.	3.8000	0.7400
7	12.	4.5000	0.7400
8	12.	4.5000	0.7400
9	13.	5.3000	0.7400
10	1.	5.3000	0.7400
TOTAL	642.		

****

LESLIE MATRIX MODEL - TIME INTERVAL 15.

AGE	NUMBER	FECUNDITY	SURVIVAL
1	530.	0.0000	0.7400
2	295.	0.0000	0.7400
3	161.	0.0000	0.7400
4	107.	0.0000	0.7400
5	75.	1.1000	0.7400
6	56.	3.8000	0.7400
7	39.	4.5000	0.7400
8	24.	4.5000	0.7400
9	9.	5.3000	0.7400
10	4.	5.3000	0.7400
TOTAL	1300.		

LESLIE MATRIX MODEL - TIME INTERVAL 20.

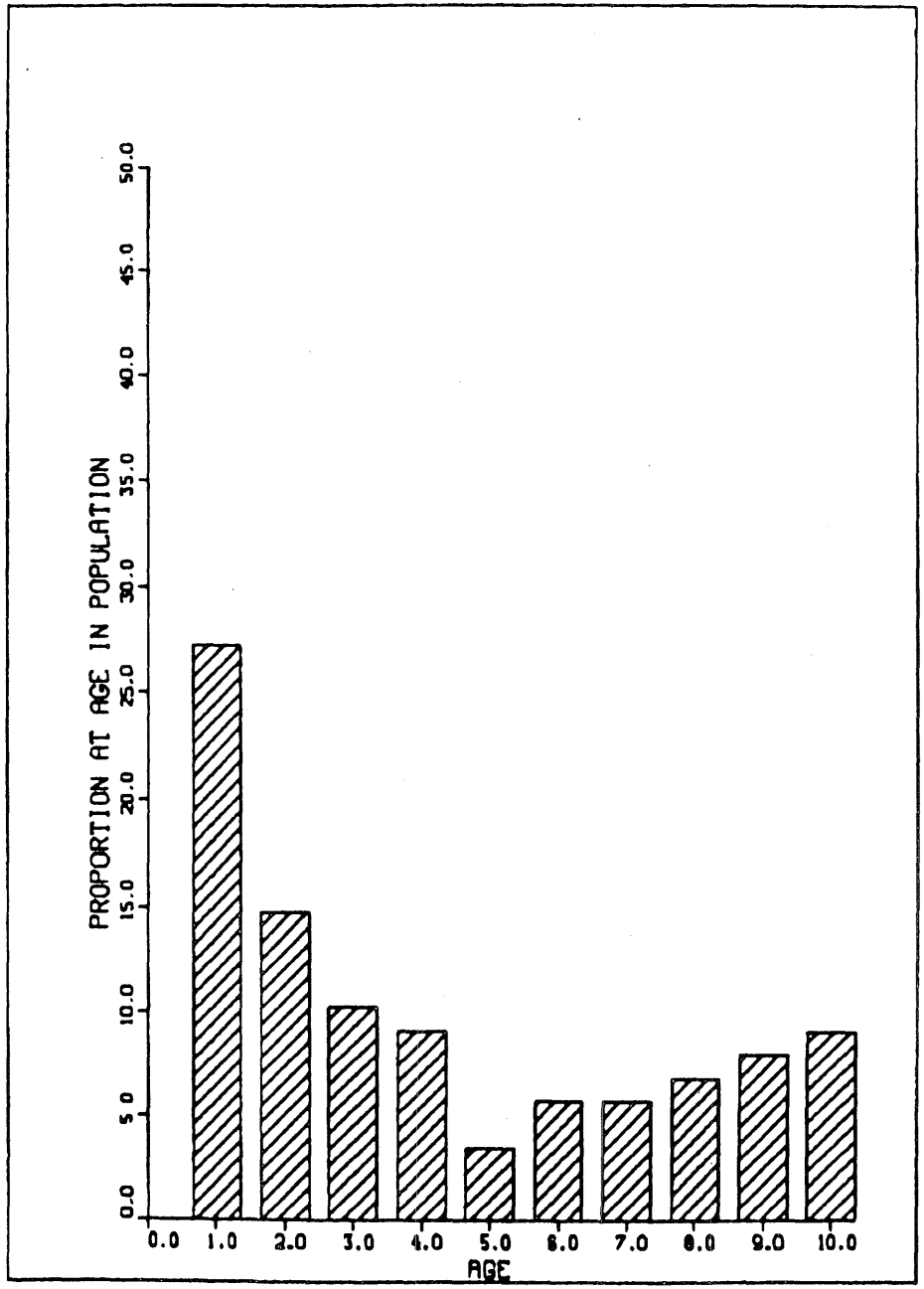
AGE	NUMBER	FECUNDITY	SURVIVAL
1	1071.	0.0000	0.7400
2	672.	0.0000	0.7400
3	448.	0.0000	0.7400
4	303.	0.0000	0.7400
5	195.	1.1000	0.7400
6	118.	3.8000	0.7400
7	65.	4.5000	0.7400
8	36.	4.5000	0.7400
9	24.	5.3000	0.7400
10	16.	5.3000	0.7400
TOTAL	2948.		

LESLIE MATRIX MODEL - TIME INTERVAL 30.

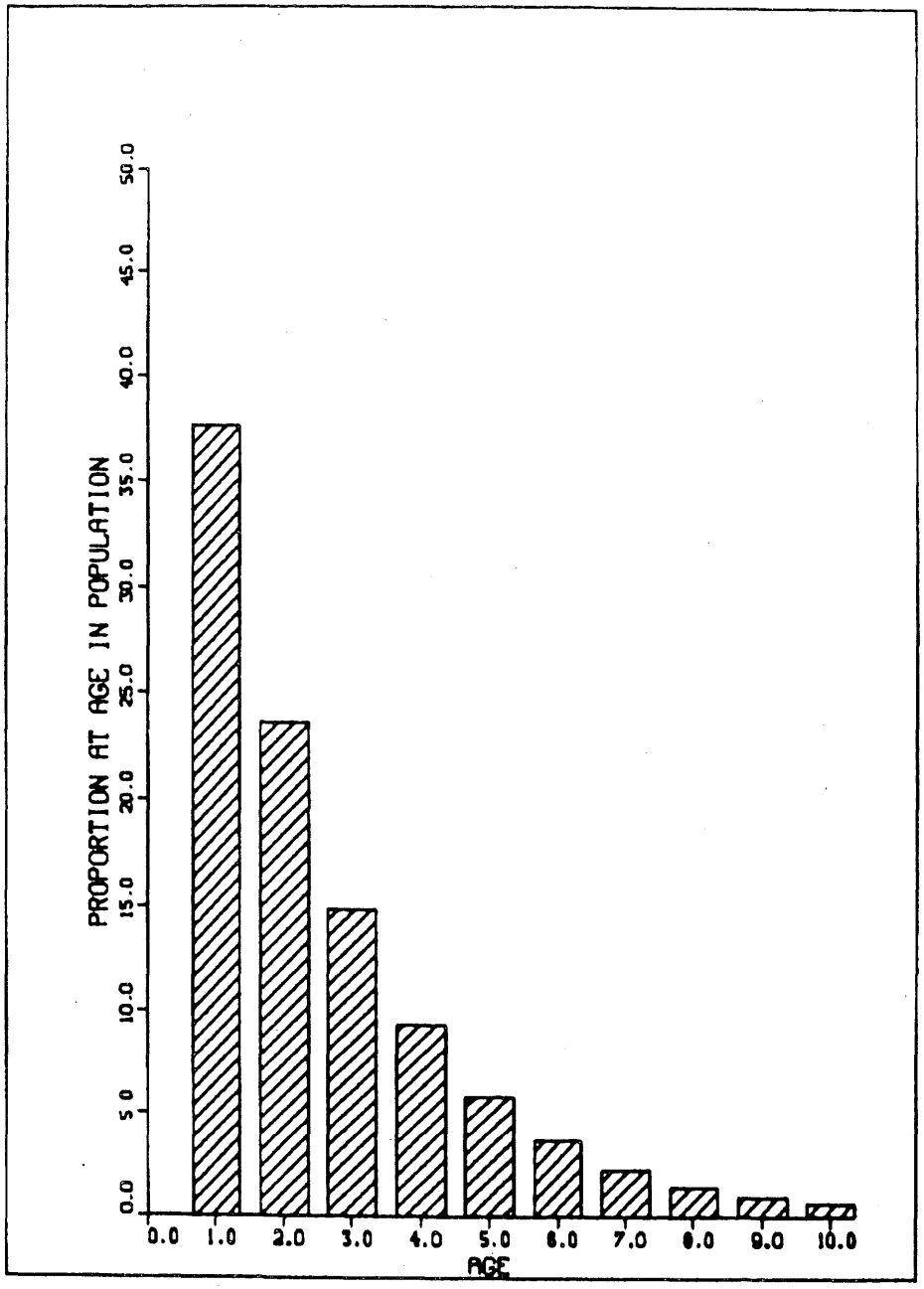
AGE	NUMBER	FECUNDITY	SURVIVAL
1	6153.	0.0000	0.7400
2	3832.	0.0000	0.7400
3	2365.	0.0000	0.7400
4	1461.	0.0000	0.7400
5	913.	1.1000	0.7400
6	583.	3.8000	0.7400
7	376.	4.5000	0.7400
8	239.	4.5000	0.7400
9	147.	5.3000	0.7400
10	88.	5.3000	0.7400
TOTAL	16157.		

```
*****************************************************************
                LESLIE MATRIX MODEL - TIME INTERVAL 35.
 ****************************************************************
    AGE                NUMBER         FECUNDITY         SURVIVAL
      1               13937.            0.0000           0.7400
      2                8683.            0.0000           0.7400
      3                5441.            0.0000           0.7400
      4                3430.            0.0000           0.7400
      5                2168.            1.1000           0.7400
      6                1365.            3.8000           0.7400
      7                 850.            4.5000           0.7400
      8                 525.            4.5000           0.7400
      9                 324.            5.3000           0.7400
     10                 203.            5.3000           0.7400
  TOTAL               36926.
*****************************************************************


*****************************************************************
                LESLIE MATRIX MODEL - TIME INTERVAL 40.
 ****************************************************************
    AGE                NUMBER         FECUNDITY         SURVIVAL
      1               32076.            0.0000           0.7400
      2               20132.            0.0000           0.7400
      3               12653.            0.0000           0.7400
      4                7941.            0.0000           0.7400
      5                4963.            1.1000           0.7400
      6                3093.            3.8000           0.7400
      7                1927.            4.5000           0.7400
      8                1207.            4.5000           0.7400
      9                 761.            5.3000           0.7400
     10                 481.            5.3000           0.7400
  TOTAL               85234.
*****************************************************************


*****************************************************************
                LESLIE MATRIX MODEL - TIME INTERVAL  0.
*****************************************************************

Input scaling factor for total population plot:10000.

END OF DISSPLA 9.2 -- 11518 VECTORS IN 8 PLOTS.
RUN ON 7/24/84 USING SERIAL NUMBER 60 AT  WHOI
PROPRIETARY SOFTWARE PRODUCT OF ISSCO, SAN DIEGO, CA.
3727 VIRTUAL STORAGE REFERENCES; 4 READS; 0 WRITES.
FORTRAN STOP
$SPAK/RELEASE

$ T DSKA:[712.MASTER.DATA]LESLIE.DAT
   40   10   10   15   20   30   35
    0    0    0    0  1.1  3.8  4.5  4.5  5.3  5.3
  .74  .74  .74  .74  .74  .74  .74  .74  .74  .74
   24   13    9    8    3    5    5    6    7    8
$
```

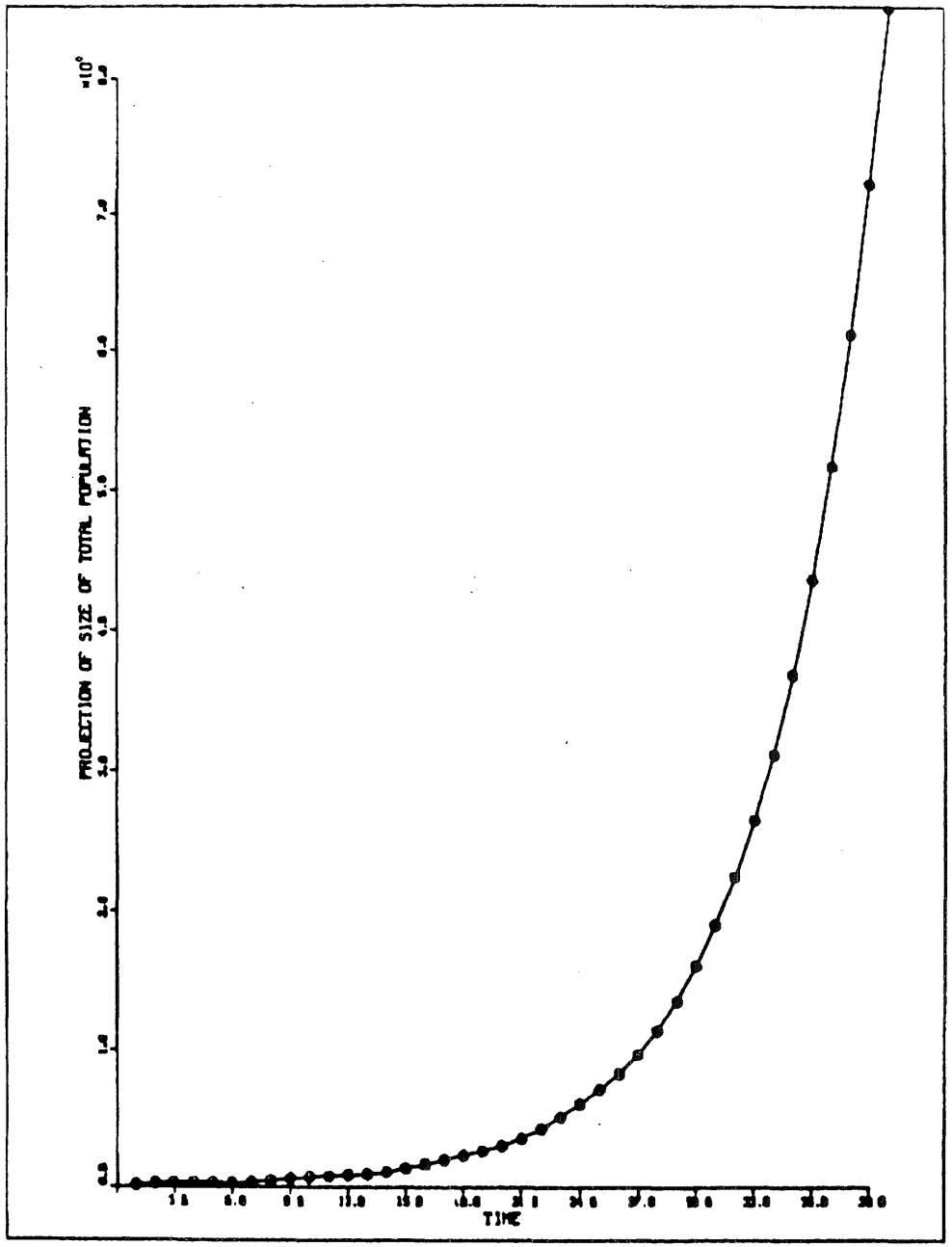
Time Interval 1



Time Interval 40



Total Population



PROGRAM NAME: Catch and Stock Size Prediction

PROGRAM TYPE: Main

DATE CREATED: May 1 1974

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]FMBPRED.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]FMBPRED.EXE

AUTHOR: R.K. Mayo

DOCUMENTED BY: R.K. Mayo

REVISIONS (Date/Reviser - Description)

Jul 1 1980 /D.L. Eslinger. -
Input - Output Section Restructured.
Jan 1 1982 /R.K. Mayo -
Revised to conform with VAX 11/780 compatable FORTRAN 77.
Oct 1 1983 /R.K. Mayo -
Memory updated to allow 30 ages and 30 years.
Mar 26 1984 /R.K. Mayo -
Documented to conform with NERFIS standards.

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

This program computes catch and remaining stock size, given various levels of instantaneous fishing (F) and natural (M) mortality, initial stock size, and recruitment, according to the Murphy catch equation (JFRBC 27: 821-825).

Age-specific values of F and M, partial selection coefficients, and separate average weights at age for the stock and catch may be entered. The program accepts data for up to 30 age groups, and will predict catches and stock sizes up to 30 years ahead.

DESCRIPTION:

The program accepts information from the user on an interactive basis, and can be instructed to display results in either age-specific or summary form. Input parameter(s) may be changed during execution without affecting remaining values.

In general, tables of age-specific stock size and catch would be displayed if projections are to be run for a few years ahead. Summary results only would be displayed for equilibrium modelling, when projections are to be run for up to 30 years ahead.

A HELP section is accessible during execution with a menu for selecting variable names which may be entered to initiate a parameter change, a print option change, or to terminate the program in a proper and orderly manner.

Calculations:

The reference for calculations is Tomlinson (1970). Equations are as follows:

1.0 Catch in numbers at age j in year i is calculated as:

$$NC(i,j) = NS(i,j)*[F(i,j)/(F(i,j)+M(i,j))]*[1-EXP(-(F(i,j)+M(i,j)))]$$

where:
NC = Catch in numbers,
NS = Stock size in numbers,
F = Instantaneous fishing mortality (fishing mortality * selection coefficient),
M = Instantaneous natural mortality (natural mortality * selection coefficient).

2.0 Catch in weight at age j in year i is calculated as:

$$WC(i,j) = NC(i,j)*AWC(j)$$

where:
WC = Catch in weight,
AWC = Average weight of a fish at age in the catch.

3.0 Stock size in numbers at age j+1 in year i+1 is calculated as:

$$NS(i+1,j+1) = NS(i,j)*[EXP(-(F(i,j)+M(i,j)))]$$

and,

$$NS(i+1,1) = R(i+1)$$

where:
NS = Stock size in numbers,
R = Recruitment estimate for year i+1.

4.0 Stock size in weight at age j in year i is calculated as:

$$WS(i,j) = NS(i,j)*AWS(j)$$

where:
WS = Stock weight,
AWS = Average weight of a fish at age in the stock.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

Input Description:

Input to the program is on an interactive basis in response to a series of prompts. Responses will be in one of three forms:

1. Y or N for Yes/No questions. These responses set up the I/O environment and option selection scheme.

2. CHANGE questions. These allow the user to change the value(s) of one or more input variables. A HELP section is included for displaying a menu of acceptable variables which can be changed before initiating a new analysis. An initial menu for changing PRINT options can be accessed immediately and a full menu for changing all options and data values can be accessed between analyses.

3. Data questions. The following data are required to initiate an analysis.

   A. Initial year
   B. Number of years
   C. Fishing mortality in each year
   D. Number of recruits in each year
   E. Natural mortality
   F. Number of age groups
   G. Age at recruitment
   H. Initial stock sizes
   I. Selection coefficients
   J. Average weights at age

Options:

1. Selection Coefficients

The user may enter age-specific fishing mortality selection coefficients which describe an appropriate partial recruitment vector for the selected species. An additional vector of age-specific natural mortality selection coefficients may be entered.

2. Natural Mortality

The user may enter different natural mortality rates for each year or may elect to use the same value for all years.

3. Average Weights at Age

The user may elect to use separate average weights at age to calculate catch weights and stock weights, or may use the same weights at age for catch and stock.

Menus:

The following menus of PRINT and CHANGE options may be viewed by entering HELP in response to a CHANGE question:

1. Initial PRINT Options

```
ENTER:        TO:

S...........STOP MAKING CHANGES
PRQU........PRINT QUESTIONS
NOQU........DO NOT PRINT QUESTIONS
TOT.........PRINT ONLY TOTALS
TABL........PRINT FULL TABLE
PRSC........PRINT SEL COEF AND WEIGHTS
NOSC........DO NOT PRINT SEL COEF AND WEIGHTS

WHAT DO YOU WANT TO CHANGE ? (HELP FOR OPTIONS)
```

2. Complete PRINT and CHANGE Options

```
ENTER:        TO:

S...........STOP MAKING CHANGES
PRQU........PRINT QUESTIONS
NOQU........DO NOT PRINT QUESTIONS
TOT.........PRINT ONLY TOTALS
TABL........PRINT FULL TABLE
PRSC........PRINT SEL COEF AND WEIGHTS
NOSC........DO NOT PRINT SEL COEF AND WEIGHTS
F...........CHANGE FISHING MORTALITY
M...........CHANGE NATURAL MORTALITY
SCF.........CHANGE FISHING SELECTION COEFFICIENTS
SCM.........CHANGE NATURAL MORT SELECTION COEF
YRS.........CHANGE NUMBER OF YEARS TO RUN
AGE.........CHANGE AGE OF RECRUITS
NOGP........CHANGE NUMBER OF AGE GROUPS
REC.........CHANGE NUMBER OF RECRUITS
STOK........CHANGE INITIAL STOCK SIZES
WTS.........CHANGE AVE WTS OF STOCK AND/OR CATCH
INYR........CHANGE INITIAL YEAR

WHAT DO YOU WANT TO CHANGE ? (HELP FOR FULL OPTIONS)
```

Error Conditions:

The program compares user responses with the acceptable menu list and displays the following error message if an unacceptable response is entered by the user:

PLEASE RETYPE RESPONSE OR TYPE HELP FOR RESPONSES

Prompts:

The following initial parameters are set by default:

PRINT PROMPT QUESTIONS ? YES
PRINT TABLE OF SELECTION COEFFICIENTS AND WEIGHTS ? YES
PRINT TABLE OF AGE BREAKDOWN FOR EACH YEAR ? YES

Initial default PRINT parameters may be changed immediately by answering the following question:

1. DO YOU WANT TO CHANGE INITIALIZED VALUES ?
   Enter Y (YES) or N (NO).
   If YES, answer the following:

   1a. WHAT DO YOU WANT TO CHANGE ? (HELP FOR OPTIONS)
   Enter HELP to view initial CHANGE option menu.
   Enter one of the acceptable menu names to change an initial PRINT option.
   Enter another menu name or S to stop making changes.

   If NO, default PRINT parameters are retained.

The following questions are then asked of the user:

2. WHAT IS THE INITIAL YEAR ?
   Enter the year for which stock size estimates are to be entered.

3. HOW MANY YEARS DO YOU WANT TO RUN ?
   Enter the number of years, including the initial year, for which you wish to compute catch and stock sizes.

4. ENTER FISHING MORT FOR EACH YEAR.
   Enter fishing mortality values corresponding to each year for which you requested catch and stock size computations.

5. ENTER NUMBER OF RECRUITS IN EACH YEAR.
   Enter number of recruits corresponding to each year for which you requested catch and stock size computations.

6. DO YOU WANT NATURAL MORT TO CHANGE OVER TIME ?
Enter Y (YES) or N (NO).
If YES, answer the following:

6a. ENTER NAT MORTALITY FOR EACH YEAR.
Enter natural mortality values corresponding to each year for which you requested catch and stock size computations.

If NO, enter one natural mortality value which will be applied to each year for which you requested catch and stock size computations.

7. HOW MANY AGE GROUPS DO YOU WANT TO RUN ?
Enter the number of age groups, including recruits, in the stock.

8. INITIAL AGE OF RECRUITS ?
Enter the age at first recruitment.

9. ENTER nn INITIAL STOCK SIZES FOR AGES n TO n.
Enter the age-specific stock sizes, excluding recruits, which exist in the initial year of the analysis.

10. DO YOU WANT TO CHANGE FISHING MORT SEL COEF ?
Enter Y (YES) or N (NO).
If YES, answer the following:

10a. ENTER nn FISHING MORT SEL COEFS FOR AGES n TO n.
Enter age-specific fishing mortality selection coefficients which describe the partial recruitment vector for this species.

If NO, default values of 1.000, stored in memory, are applied to F for each age group.

11. DO YOU WANT TO CHANGE NATURAL MORT SEL COEF ?
Enter Y (YES) or N (NO).
If YES, answer the following:

11a. ENTER nn NATURAL MORT SEL COEFS FOR AGES n TO n.
Enter age-specific natural mortality selection coefficients which describe changes in natural mortality with age.

If NO, default values of 1.000, stored in memory, are applied to M for each age group.

12. DO YOU WANT TO CHANGE AVE WEIGHTS FOR STOCK OR CATCH ?
Enter Y (YES) or N (NO).
If YES, answer the following:

12a. DO YOU WANT TO USE THE SAME WEIGHTS FOR STOCK AND CATCH ?
Enter Y (YES) or N (NO).

If YES, answer the following:

ENTER nn AVE WEIGHTS FOR STOCK AND CATCH.
Enter age-specific mean weights to be applied in computing weight at age of the stock and catch. The same mean weights-at-age will be used for both stock and catch weight computations.

If NO, answer the following:

12a-1. DO YOU WANT TO CHANGE AVE WEIGHTS OF STOCK ?
Enter Y (YES) or N (NO).
If YES, answer the following:

ENTER nn AVE WEIGHTS FOR STOCK AGES n - n.
Enter age-specific mean weights to be applied in computing weight at age of the stock.

If NO, default values of 1.000, stored in memory, will be used in computing weight at age of the stock.

12a-2. DO YOU WANT TO CHANGE AVE WEIGHTS OF CATCH ?
If YES, answer the following:

ENTER nn AVE WEIGHTS FOR CATCH AGES n - n.
Enter age specific mean weights to be applied in computing weight at age of the catch.

If NO, default values of 1.000, stored in memory, will be used in computing weight at age of the catch.

If NO, default values of 1.000, stored in memory, will be applied in computing weights at age of the stock and catch.

13. DO YOU WANT TO MAKE ANY MORE CHANGES BEFORE RUNNING ?
Enter Y (YES) or N (NO).
If YES, answer the following:

13a. WHAT DO YOU WANT TO CHANGE ? (HELP FOR FULL OPTIONS)
Enter HELP to view full CHANGE option menu.
Enter one of the acceptable menu names to select a PRINT option or data variable to be changed.
After selecting the option name, answer the following:

13a-1. ENTER DATA.
Enter the correct amount of data values to replace previously entered data.
Enter S to stop making changes and commence analysis.

If NO, analysis commences.

After each analysis has been completed, the following prompt will be displayed:

14. DO YOU WANT TO MAKE ANY FURTHER CHANGES ?
    Enter Y (YES) or N (NO).
    If YES, answer the following:

    14a. WHAT DO YOU WANT TO CHANGE ? (HELP FOR FULL OPTIONS)
         Enter HELP to view full CHANGE option menu.
         Enter one of the acceptable menu names to select a PRINT option or data variable to be changed.
         After selecting the option name, answer the following:

         14a-1. ENTER DATA.
                Enter the correct amount of data values to replace previously entered data.
                Enter S to stop making changes and commence analysis.

    If NO, program terminates.

To run the program interactively, type:

```
$RUN FSHA:[712.MASTER.XEQ]FMBPRED
```

and you will be prompted for input.

Output Description:

By default, all questions which require a response are displayed at the user's terminal. However, if the user is familiar with the program, the prompting may be suppressed by invoking a CHANGE menu. Selection coefficients and mean weights at age used in the calculations are also displayed by default. These may be suppressed by invoking a CHANGE menu.

Full tables of catch and stock size at age are also displayed by default. The user may elect to view only totals by invoking a CHANGE menu. The user may wish to display full age composition tables when projecting only a few years ahead. For equilibrium modelling, when projections are run for up to 30 years ahead, it is recommended that only stock and catch totals be displayed.

References:

Tomlinson, P.K. 1970. A generalization of the Murphy catch equation. J. Fish. Res. Bd. Canada. 27: 821-825.

```
$ RUN FSHA:[712.MASTER.XEQ]FMBPRED



Catch and Stock Size Prediction - RK Mayo - Mar 22 84
(VAX Ver. 2.0) (30 Age Groups and 31 Year Projections)

THIS PROGRAM IS INITIALIZED TO:
 PRINT PROMPT QUESTIONS? YES
 PRINT TABLE OF SELECTION COEFFICIENTS AND WEIGHTS? YES
 PRINT TABLE OF AGE BREAKDOWN FOR EACH YEAR? YES
DO YOU WANT TO CHANGE INITIALIZED VALUES?
Y
WHAT DO YOU WANT TO CHANGE? ( HELP FOR OPTIONS)
HELP


INITIAL OPTIONS:
-----------------------------------------------
 ENTER:   TO:

  S........STOP MAKING CHANGES
  PRQU.....PRINT QUESTIONS
  NOQU.....DO NOT PRINT QUESTIONS
  TOT......PRINT  ONLY TOTALS
  TABL.....PRINT FULL TABLE
  PRSC.....PRINT SEL COEF AND WEIGHTS
  NOSC.....DO NOT PRINT SEL COEF AND WEIGHTS
WHAT DO YOU WANT TO CHANGE? ( HELP FOR OPTIONS)
S
WHAT IS THE INITIAL YEAR?
1983
HOW MANY YEARS DO YOU WANT TO RUN?
3
ENTER FISHING MORT FOR EACH YEAR (MAX OF 10 PER LINE)
0.25,0.20,0.25
ENTER NUMBER OF RECRUITS IN EACH YEAR (MAX OF 10 PER LINE)
10000,15000,20000
DO YOU WANT NATURAL MORT. TO CHANGE OVER TIME?
Y
ENTER NAT MORTALITY FOR EACH YEAR (MAX OF 10 VALUES PER LINE)
0.10,0.05,0.10
HOW MANY AGE GROUPS DO YOU WANT TO RUN?
30
INITIAL AGE OF RECRUITS?
1
ENTER 29 INITIAL STOCK SIZES FOR AGES  2 TO 30(MAX OF 10 PER LINE)
23222,1196,1138,1082,781,1036,6571,100048,1231,260
272,1285,2907,4914,7228,5091,3931,3339,2676,2800
2190,2066,1740,1569,1450,1200,900,800,700
```

```
DO YOU WANT TO CHANGE FISHING MORT SEL COEF?
Y
ENTER 30 FISHING MORT SEL COEFS FOR AGES  1 TO 30
MAX OF 10 PER LINE)
.010,.025,.050,.100,.250,.500,.700,.800,1.000,1.000
20*1.000
DO YOU WANT TO CHANGE NATURAL MORT SEL COEF?
N
DO YOU WANT TO CHANGE AVE WEIGHTS FOR STOCK OR CATCH?
Y
DO YOU WANT TO USE THE SAME WEIGHTS FOR CATCH AND STOCK?
N
DO YOU WANT TO CHANGE AVE WEIGHTS OF STOCK?
Y
ENTER 30 AVE WEIGHTS FOR STOCK AGES  1 - 30
MAX OF 10 PER LINE)
.010,.020,.052,.092,.135,.171,.195,.245,.277,.297
.333,.377,.404,.420,.441,.465,.494,.498,.538,.560
.549,.572,.595,.570,.589,.600,.600,.600,.600,.600
DO YOU WANT TO CHANGE AVE WEIGHTS OF CATCH?
Y
ENTER 30 AVE WEIGHTS FOR CATCH AGES  1 - 30
MAX OF 10 PER LINE)
.010,.020,.052,.092,.135,.108,.175,.188,.283,.371
.421,.362,.424,.454,.506,.478,.499,.518,.554,.595
.647,.664,.629,.599,.681,.695,.695,.695,.695,.695
DO YOU WANT TO MAKE ANY CHANGES BEFORE RUNNING?
N
```

AGE	FISHING SEL COEF	NATURAL SEL COEF	AVE WEIGHT STOCK	AVE WEIGHT CATCH
1	0.0100	1.0000	0.010	0.010
2	0.0250	1.0000	0.020	0.020
3	0.0500	1.0000	0.052	0.052
4	0.1000	1.0000	0.092	0.092
5	0.2500	1.0000	0.135	0.135
6	0.5000	1.0000	0.171	0.108
7	0.7000	1.0000	0.195	0.175
8	0.8000	1.0000	0.245	0.188
9	1.0000	1.0000	0.277	0.283
10	1.0000	1.0000	0.297	0.371
11	1.0000	1.0000	0.333	0.421
12	1.0000	1.0000	0.377	0.362
13	1.0000	1.0000	0.404	0.424
14	1.0000	1.0000	0.420	0.454
15	1.0000	1.0000	0.441	0.506
16	1.0000	1.0000	0.465	0.478
17	1.0000	1.0000	0.494	0.499
18	1.0000	1.0000	0.498	0.518
19	1.0000	1.0000	0.538	0.554
20	1.0000	1.0000	0.560	0.595
21	1.0000	1.0000	0.549	0.647
22	1.0000	1.0000	0.572	0.664
23	1.0000	1.0000	0.595	0.629
24	1.0000	1.0000	0.570	0.599
25	1.0000	1.0000	0.589	0.681
26	1.0000	1.0000	0.600	0.695
27	1.0000	1.0000	0.600	0.695
28	1.0000	1.0000	0.600	0.695
29	1.0000	1.0000	0.600	0.695
30	1.0000	1.0000	0.600	0.695

YEAR: 1983 F= 0.2500 M= 0.1000 Z= 0.3500

AGE	STOCK SIZE (NUMBER)	STOCK SIZE (WEIGHT)	CATCH SIZE (NUMBER)	CATCH SIZE (WEIGHT)
1	10000.000	100.000	23.761	0.238
2	23222.000	464.440	137.693	2.754
3	1196.000	62.192	14.140	0.735
4	1138.000	104.696	26.744	2.460
5	1082.000	146.070	62.416	8.426
6	781.000	133.551	87.422	9.442
7	1036.000	202.020	158.508	27.739
8	6571.000	1609.895	1135.389	213.453
9	100048.000	27713.297	21103.834	5972.385
10	1231.000	365.607	259.664	96.335
11	260.000	86.580	54.844	23.089
12	272.000	102.544	57.375	20.770
13	1285.000	519.140	271.054	114.927
14	2907.000	1220.940	613.194	278.390
15	4914.000	2167.074	1036.545	524.492
16	7228.000	3361.020	1524.653	728.784
17	5091.000	2514.954	1073.881	535.867
18	3931.000	1957.638	829.194	429.522
19	3339.000	1796.382	704.319	390.193
20	2676.000	1498.560	564.468	335.858
21	2800.000	1537.200	590.624	382.134
22	2190.000	1252.680	461.952	306.736
23	2066.000	1229.270	435.796	274.116
24	1740.000	991.800	367.031	219.851
25	1569.000	924.141	330.960	225.384
26	1450.000	870.000	305.859	212.572
27	1200.000	720.000	253.125	175.922
28	900.000	540.000	189.843	131.941
29	800.000	480.000	168.750	117.281
30	700.000	420.000	147.656	102.621

TOTAL SIZE STOCK 2-30	TOTAL WEIGHT STOCK 2-30	TOTAL SIZE CATCH 1-30	TOTAL WEIGHT CATCH 1-30
183623.000	54991.688	32990.695	11864.418

YEAR: 1984 F= 0.2000 M= 0.0500 Z= 0.2500

AGE	STOCK SIZE (NUMBER)	STOCK SIZE (WEIGHT)	CATCH SIZE (NUMBER)	CATCH SIZE (WEIGHT)
1	15000.000	150.000	29.233	0.292
2	9025.782	180.516	43.910	0.878
3	20881.219	1085.823	202.671	10.539
4	1068.742	98.324	20.644	1.899
5	1004.281	135.578	47.785	6.451
6	919.717	157.272	85.406	9.224
7	623.641	121.610	79.517	13.915
8	786.917	192.795	113.565	21.350
9	4867.917	1348.413	861.423	243.783
10	70502.633	20939.281	12476.102	4628.634
11	867.471	288.868	153.507	64.627
12	183.219	69.074	32.422	11.737
13	191.675	77.437	33.919	14.382
14	905.524	380.320	160.241	72.749
15	2048.528	903.401	362.506	183.428
16	3462.837	1610.219	612.781	292.910
17	5093.485	2516.182	901.340	449.769
18	3587.567	1786.608	634.854	328.854
19	2770.129	1490.329	490.200	271.571
20	2352.953	1317.654	416.377	247.744
21	1885.745	1035.274	333.700	215.904
22	1973.127	1128.628	349.163	231.844
23	1543.267	918.244	273.096	171.777
24	1455.885	829.855	257.633	154.322
25	1226.157	722.207	216.980	147.763
26	1105.656	663.393	195.656	135.981
27	1021.798	613.079	180.817	125.668
28	845.626	507.375	149.641	104.001
29	634.219	380.532	112.231	78.001
30	563.750	338.250	99.761	69.334

TOTAL SIZE STOCK 2-30	TOTAL WEIGHT STOCK 2-30	TOTAL SIZE CATCH 1-30	TOTAL WEIGHT CATCH 1-30
143399.469	41836.535	19927.084	8309.331

YEAR: 1985 F= 0.2500 M= 0.1000 Z= 0.3500

AGE	STOCK SIZE (NUMBER)	STOCK SIZE (WEIGHT)	CATCH SIZE (NUMBER)	CATCH SIZE (WEIGHT)
1	20000.000	200.000	47.523	0.475
2	14239.933	284.799	84.435	1.689
3	8542.769	444.224	100.997	5.252
4	19665.191	1809.198	462.144	42.517
5	996.489	134.526	57.484	7.760
6	908.711	155.390	101.717	10.985
7	791.608	154.364	121.116	21.195
8	515.726	126.353	89.111	16.753
9	637.862	176.688	134.549	38.077
10	3791.137	1125.968	799.691	296.686
11	54907.504	18284.199	11582.029	4876.034
12	675.587	254.696	142.506	51.587
13	142.691	57.647	30.099	12.762
14	149.277	62.696	31.488	14.296
15	705.223	311.003	148.758	75.271
16	1595.396	741.859	336.528	160.860
17	2696.860	1332.249	568.868	283.865
18	3966.810	1975.472	836.747	433.435
19	2794.000	1503.172	589.358	326.504
20	2157.379	1208.132	455.071	270.767
21	1832.482	1006.033	386.538	250.090
22	1468.620	840.051	309.786	205.698
23	1536.672	914.320	324.141	203.885
24	1201.897	685.082	253.525	151.861
25	1133.845	667.835	239.170	162.875
26	954.932	572.959	201.431	139.994
27	861.086	516.651	181.635	126.236
28	795.777	477.466	167.859	116.662
29	658.574	395.144	138.918	96.548
30	493.930	296.358	104.188	72.411

TOTAL SIZE STOCK 2-30	TOTAL WEIGHT STOCK 2-30	TOTAL SIZE CATCH 1-30	TOTAL WEIGHT CATCH 1-30
130817.984	36514.539	19027.412	8473.033

```
DO YOU WANT TO MAKE ANY FURTHER CHANGES?
Y
WHAT DO YOU WANT TO CHANGE? (HELP FOR FULL OPTIONS)
HELP


FULL TABLE
-----------------------------------------------
 ENTER:   TO:

  S........STOP MAKING CHANGES
  PRQU.....PRINT QUESTIONS
  NOQU.....DO NOT PRINT QUESTIONS
  TOT......PRINT  ONLY TOTALS
  TABL.....PRINT FULL TABLE
  PRSC.....PRINT SEL COEF AND WEIGHTS
  NOSC.....DO NOT PRINT SEL COEF AND WEIGHTS
  F........CHANGE FISHING MORTALITY
  M........CHANGE NATURAL MORTALITY
  SCF......CHANGE FISHING SELECTION COEFFICIENTS
  SCM......CHANGE NATURAL MORT SELECTION COEF
  YRS......CHANGE NUMBER OF YEARS TO RUN
  AGE......CHANGE AGE OF RECRUITS
  NOGP.....CHANGE NUMBER OF AGE GROUPS
  REC......CHANGE NUMBER OF RECUITS
  STOK.....CHANGE INITIAL STOCK SIZE
  WTS......CHANGE AVE WEIGHTS OF STOCK AND/OR CATCH
  INYR.....CHANGE INITIAL YEAR
-----------------------------------------------
WHAT DO YOU WANT TO CHANGE? (HELP FOR FULL OPTIONS)
TOT
WHAT DO YOU WANT TO CHANGE? (HELP FOR FULL OPTIONS)
NOSC
WHAT DO YOU WANT TO CHANGE? (HELP FOR FULL OPTIONS)
YRS
HOW MANY YEARS DO YOU WANT TO RUN?
30
ENTER FISHING MORT FOR EACH YEAR (MAX OF 10 PER LINE)
30*0.15
ENTER NUMBER OF RECRUITS IN EACH YEAR (MAX OF 10 PER LINE)
30*50000
DO YOU WANT NATURAL MORT. TO CHANGE OVER TIME?
N
ENTER NATURAL MORTALITY (1 VALUE).
0.05
WHAT DO YOU WANT TO CHANGE? (HELP FOR FULL OPTIONS)
S
```

YEAR	F	TOTAL STOCK (NUMBER) AGES 2-30	TOTAL STOCK (WEIGHT) AGES 2-30	TOTAL CATCH (NUMBER) AGES 1-30	TOTAL CATCH (WEIGHT) AGES 1-30
1983	0.150	183623.000	54991.691	21304.996	7645.381
1984	0.150	200891.891	49148.359	17912.219	7411.874
1985	0.150	220661.906	46592.781	15257.325	6669.051
1986	0.150	242097.344	46491.898	13689.842	5235.129
1987	0.150	263969.219	47043.055	13524.236	4947.799
1988	0.150	284940.906	48194.859	14579.512	4718.974
1989	0.150	303921.531	50502.684	16197.189	4790.934
1990	0.150	320442.813	53593.879	18082.643	4798.156
1991	0.150	334332.625	56724.180	19970.986	5261.814
1992	0.150	345759.719	59264.387	21524.527	5809.152
1993	0.150	355098.500	62316.344	22794.150	6282.868
1994	0.150	362826.813	64997.164	23844.838	6660.590
1995	0.150	369148.000	67039.273	24704.201	7029.899
1996	0.150	374334.125	69103.398	25409.271	7325.575
1997	0.150	378562.625	70900.531	25984.145	7532.895
1998	0.150	381974.281	72213.398	26447.973	7699.850
1999	0.150	384927.188	73647.773	26849.416	7928.523
2000	0.150	387448.031	74919.023	27192.131	8102.081
2001	0.150	389573.781	76049.617	27481.139	8256.368
2002	0.150	391343.281	77008.797	27721.707	8399.228
2003	0.150	392793.406	77801.438	27918.848	8525.834
2004	0.150	393966.875	78477.547	28078.385	8627.129
2005	0.150	393717.781	78308.430	28044.521	8590.120
2006	0.150	394674.156	78859.648	28174.539	8671.922
2007	0.150	395515.969	79359.438	28288.992	8750.544
2008	0.150	396208.313	79774.828	28383.115	8815.961
2009	0.150	396773.469	80113.945	28459.953	8869.363
2010	0.150	397236.344	80391.648	28522.877	8913.096
2011	0.150	397615.344	80619.055	28574.402	8948.907
2012	0.150	397793.594	80726.008	28598.637	8965.749

```
DO YOU WANT TO MAKE ANY FURTHER CHANGES?
N
FORTRAN STOP
$
```

PROGRAM NAME: Yield Per Recruit

PROGRAM TYPE. Main

DATE CREATED: May 17 1984

SOURCE FILE NAME FSHA:[712.MASTER.SOURCE]YR.FOR

EXECUTE FILE NAME. FSHA:[712.MASTER.XEQ]YR.EXE

AUTHOR. J.W. Hauser

DOCUMENTED BY J.W Hauser
S A. Murawski

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM.

The program computes equilibrium yield and spawning stock biomass per recruit (in numbers and weight), and values of F(0.1) and F(max). The algorithm of Thompson and Bell (1934) is used to sum yields from the various age groups. The last age can be specified as a plus-group.

DESCRIPTION:

Program YR computes equilibrium yields, total stock, and spawning stock per recruit (in numbers and weight) for exploited fishery populations. The basic computational algorithm is that of Thompson and Bell (1934) modified to allow partial selection by the fishery by age class. Partial selection is simulated by the use of a selection multiplier (FFACTOR) on the instantaneous fishing mortality rate on each age class. Spawning stock biomass and numbers are calculated by multiplying the stock biomass and numbers at age by a maturity factor (the proportion of each age group that will spawn) Seasonality of spawning is accounted for in the analysis by assuming a certain portion of fishing and natural mortality occuring before spawning stock calculations for the age group are performed. For example if spawning is assumed to occur on 1 January, then none of the fishing or natural mortality takes place before spawning. However, if spawning takes place on 1 July, and there are no seasonal changes in F and M, then the population numbers and weights are decremented by half of the fishing and natural mortality rates before spawning.

The program allows for a 'plus-group' calculation to include yields from those age groups that may not be adequately sampled for age and growth information. Contri-

butions of the plus group to total yield per recruit are derived by multiplying the stock numbers alive at the first plus-group age (i.e. for a plus group of 10+, age 10), by the ratio F/Z. The resulting number is the catch from the plus group over its entire age span (whatever it may be). The catch in numbers is then multiplied by an appropriate mean weight (over all plus-group ages). Plus-group calculations are strongly recommended for yield per recruit calculations as the position of F(max) and F(0.1) appear to be sensitive to the number of age groups included in the analysis (ICES 1984). The program computes the slope of the yield curve at F=0.0, F(max), F(0.1), and for a given harvesting scenario.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

An input file created by program YRPREP (documentation follows immediately) contains the input data for the particular yield per recruit analysis desired. This information includes the first age to be analyzed, the last age to be analyzed , whether or not the last age is to include data for all subsequent ages, the proportion of fishing mortality before the spawning season, and the proportion of natural mortality before the spawning season. For each age, it also includes (1) data for the weight of a fish in the catch and in the stock and (2) age specific factors for fishing mortality, natural mortality, and maturity.

The program utilizes the Dynamic Model Processor (DMP) to simulate the progress of a year class through time. Macros are used to perform multiple simulations with one command. Other macros are used to display input, output, and summary information and to produce graphs.

The values of the following variables are accessible online:

AGE	The age corresponding to the current timestep.
FFACTOR	A factor to be multiplied by the age specific fishing mortality input factor to produce F.
F	The fishing mortality.
MFACTOR	A factor to be multiplied by the age specific natural mortality input factor to produce M.
M	The natural mortality.
CATCHN	The number of fish caught.
CATCHW	The weight of fish caught.
STOCKN	The number of fish in the stock.
STOCKW	The weight of fish in the stock.
SPAWNN	The number of fish in the spawning stock.
SPAWNW	The weight of fish in the spawning stock.

The following macros are available:

INPUT	Displays values of the input variables.
SUMMARY	Calculates and displays summary data concering the

```
                yield per recruit (total CATCHW vs FFACTOR) curve.
RUNS.1        One of these RUNS commands can be used to perform a
RUNS.2         series of simulations varying the fishing intensity
RUNS.5         (FFACTOR) up to the specified maximum value. The
RUNS1          sums of each simulation are saved.
RUNS2
RUNS5
RUNS10
OUTPUT        Displays the saved sums.
DRAW          Draws the yield per recruit curve (same as CATCHW).
CATCHN        Draws graph of total CATCHN vs FFACTOR.
CATCHW        Draws graph of total CATCHW vs FFACTOR.
STOCKN        Draws graph of total STOCKN and SPAWNN vs FFACTOR.
STOCKW        Draws graph of total STOCKW and SPAWNW vs FFACTOR.
DELETE        Clears the saved sums.  New sums may then be saved.
SHOWOUT       Shows result of single simulation.
SAVEOUT       Shows result of single simulation and saves sums.
```

To run the program, prepare a command file similar to the following (an example is provided in DSKA:[712.MASTER.COM]YR.COM). Input files are on units FOR001, FOR004, and FOR011. The user must provide the file for FOR011; program YRPREP will help you prepare this file.

```
$ASSIGN FSHA:[712.MASTER.DATA]  MDATA
$ASSIGN MDATA:YRVAR.DAT     FOR001  DMP variable name file
$ASSIGN SYS$COMMAND         FOR002  Used by DISSPLA
$ASSIGN yrtable.dat         FOR003  DMP TABLE output
$ASSIGN MDATA:YRMACRO.DAT   FOR004  DMP macro file for YR
$ASSIGN NL:                 FOR009  DMP unneeded data
$ASSIGN yrprepout.dat       FOR011  Initialization parameter file
                                      (created by YRPREP program)
$ASSIGN yrsum.dat           FOR012  File containing saved sums
$ASSIGN yrdtl.dat           FOR013  Detailed output
$ASSIGN yrrun.dat           FOR022  DMP record of most recent run
$ASSIGN SYS$COMMAND      SYS$INPUT  Accepts replies from terminal
$ASSIGN yrgraph.dat       DISSMETA  DMP graphical output
$RUN FSHA:[712.MASTER.XEQ]YR        Run the YR program
```

Execute the command file and you will be prompted to provide interactive replies such as the following example:

```
INPUT
SUMMARY
RUNS5     (or some other one of the RUNSx commands.
           Try a value for x about two times the value
           of F-MAX shown by the SUMMARY command.)
N
OUTPUT
CATCHN
Y
CATCHW
Y
STOCKN
Y
```

```
STOCKW
Y
EXIT
```

Deferred graphical output is accessed using DISSPLOT.

REFERENCES:

International Council for the Exploration of the Sea. 1984. Report of the Working Group on Methods of Fish Stock Assessment. ICES Cooperative Research Report 129. 134p.

Thompson, W.F., and F.H. Bell. 1934. Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity upon total yield and yield per unit of gear. Rep. Int. Fish. (Pacific Hilibut) Comm. 8:49p.

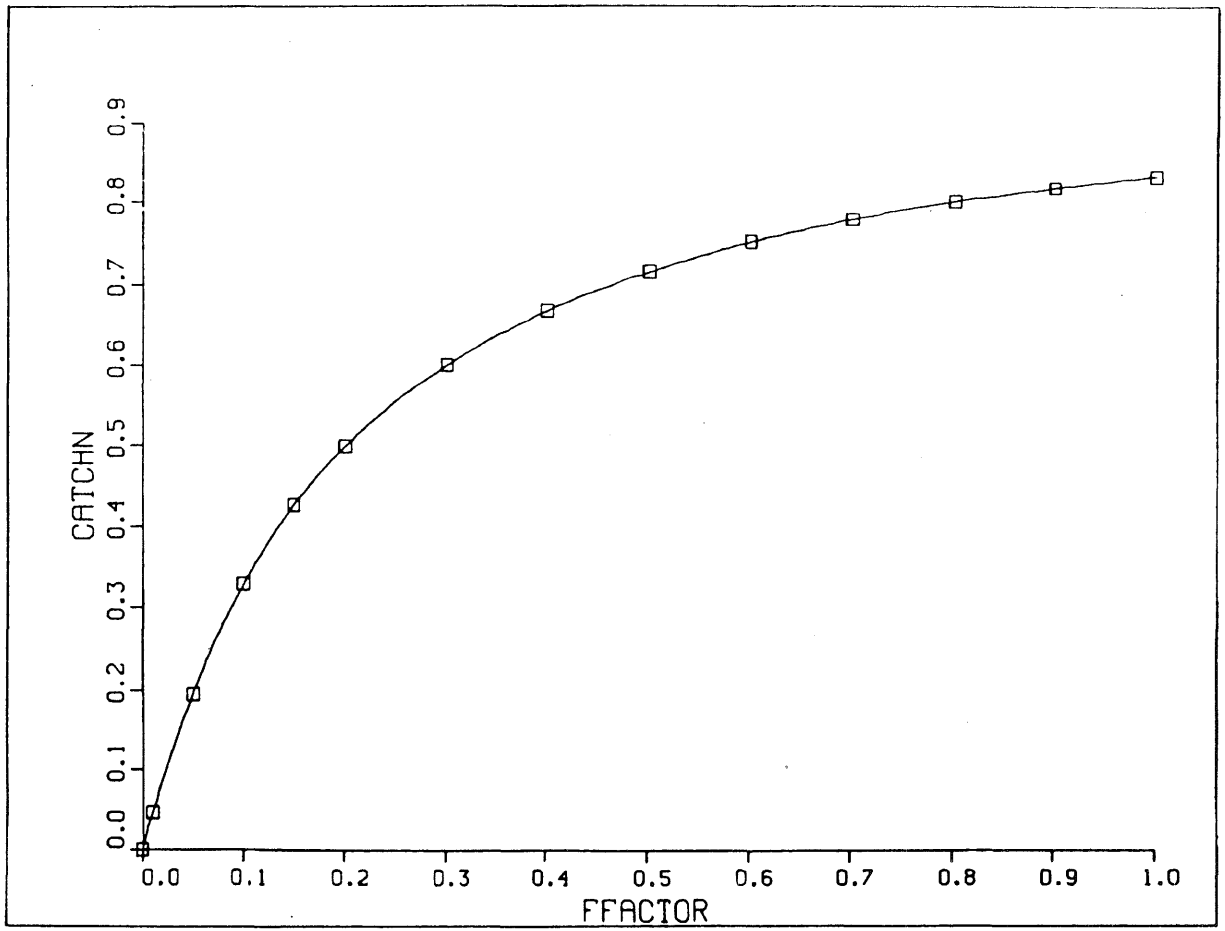
```
$ SET DEFAULT SPAK
$
$ASSIGN DSKA:[712.MASTER.DATA]YRVAR.DAT FOR001
$ASSIGN SYS$COMMAND FOR002
$ASSIGN YRTABLE.DAT FOR003
$ASSIGN DSKA:[712.MASTER.DATA]YRMACRO.DAT FOR004
$ASSIGN NL: FOR009
$ASSIGN DSKA:[712.MASTER.DATA]YR.DAT FOR011
$ASSIGN YRSUM.DAT FOR012
$ASSIGN YRDTL.DAT FOR013
$ASSIGN YRRUN.DAT FOR022
$ASSIGN SYS$COMMAND SYS$INPUT
Previous logical name assignment replaced
$ASSIGN YRGRAPH.DAT DISSMETA
$RUN DSKA:[712.MASTER.XEQ]YR


NMFS/NEFC    YIELD PER RECRUIT PROGRAM
VERSION 1.0       RUN: 11:02  1-AUG-84
DYNAMIC MODEL PROCESSOR BEGINS
ENTER COMMAND
  :>INPUT

CURRENT VALUES OF INPUT DATA FOLLOW
TITLE:YELLOWTAIL FLOUNDER
FIRST AGE GROUP:                  1
LAST AGE GROUP:                  15
LAST GROUP IS PLUS:               F
F MORTALITY FACTOR:          1.0000
M MORTALITY FACTOR:          1.0000
F FRACTION BEFORE SPAWN:     0.2000
M FRACTION BEFORE SPAWN:     0.2000
```

AGE	FPATTERN	MPATTERN	MATURITY	WEIGHT IN THE CATCH	WEIGHT IN THE STOCK
1	1.0000	0.2000	0.0000	0.1000	0.0360
2	1.0000	0.2000	0.5200	0.2400	0.1550
3	1.0000	0.2000	0.6700	0.3500	0.3310
4	1.0000	0.2000	1.0000	0.5300	0.5210
5	1.0000	0.2000	1.0000	0.7700	0.6960
6	1.0000	0.2000	1.0000	0.9000	0.8460
7	1.0000	0.2000	1.0000	1.0110	0.9650
8	1.0000	0.2000	1.0000	1.0900	1.0570
9	1.0000	0.2000	1.0000	1.1500	1.1270
10	1.0000	0.2000	1.0000	1.2000	1.1790
11	1.0000	0.2000	1.0000	1.2300	1.2170
12	1.0000	0.2000	1.0000	1.2600	1.2450
13	1.0000	0.2000	1.0000	1.2700	1.2650
14	1.0000	0.2000	1.0000	1.2800	1.2800
15	1.0000	0.2000	1.0000	1.2900	1.2900

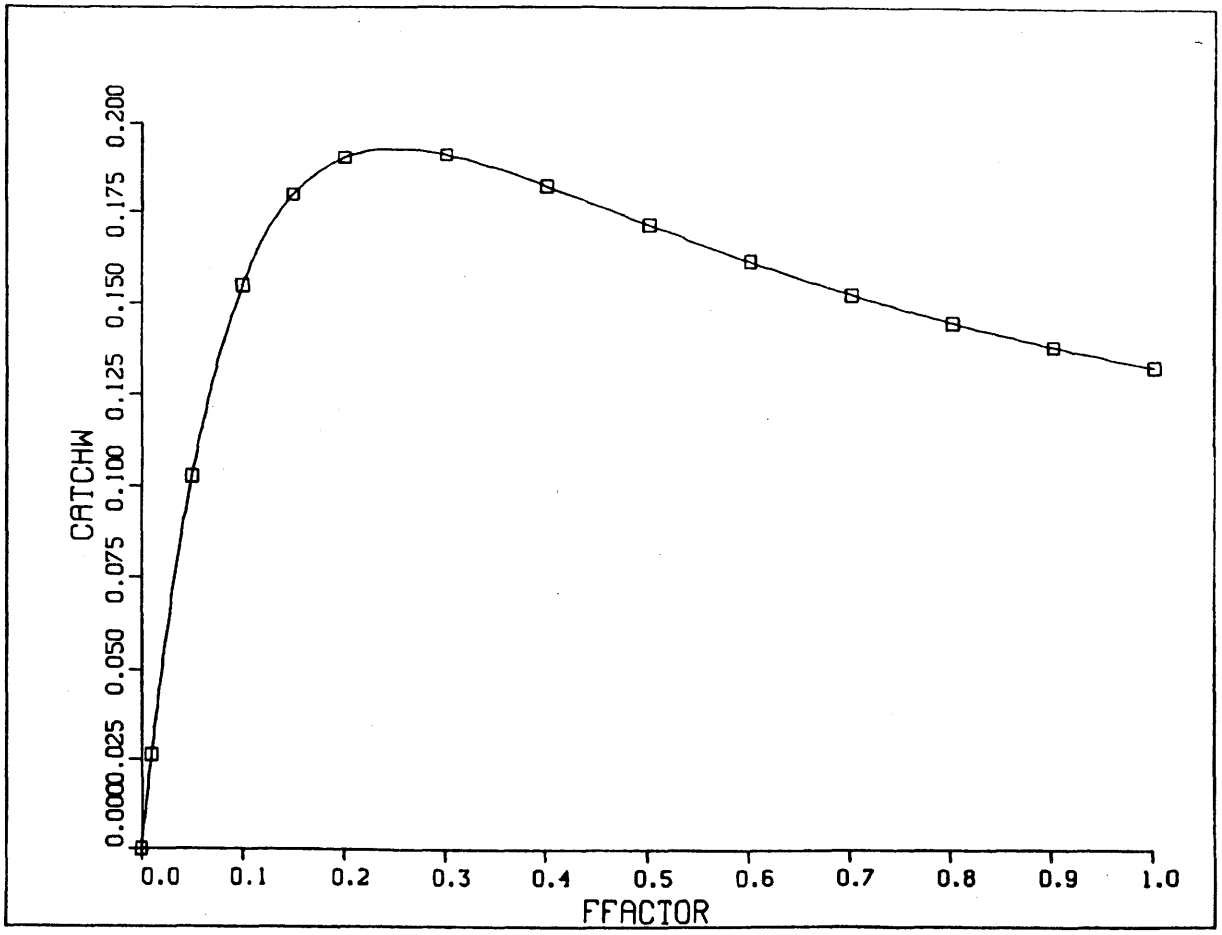
```
ENTER COMMAND
  :>SUMMARY

SLOPE OF THE Y/R (CATCHWvsFFACTOR) CURVE AT FFACTOR=0:    2.807
FFACTOR AT SLOPE=1/10 OF THE ABOVE SLOPE (F-0.1):         0.158
FFACTOR TO PRODUCE MAXIMUM CATCHW (F-MAX):                0.249

ENTER COMMAND
  :>RUNS5
DO YOU WISH DETAILED OUTPUT TO BE SENT TO A DISK FILE?
(Y or N)  IF NOT IT WILL BE SENT TO YOUR TERMINAL
  :>Y
ENTER COMMAND
  :>OUTPUT
```

FFACTOR	MFACTOR	CATCHN	CATCHW	STOCKN	STOCKW	SPAWNN	SPAWNW
0.000000	1.000000	0.000000	0.000000	5.241998	2.859326	3.485553	2.583749
0.050000	1.000000	0.195296	0.102686	4.414493	2.108848	2.701980	1.853617
0.250000	1.000000	0.554905	0.192506	2.756365	0.804277	1.202857	0.618208
0.500000	1.000000	0.714266	0.171275	1.986379	0.357112	0.579550	0.223625
0.750000	1.000000	0.789473	0.148435	1.630632	0.204016	0.327177	0.101638
1.000000	1.000000	0.833333	0.132890	1.431013	0.135843	0.201772	0.053117
1.500000	1.000000	0.882353	0.115273	1.223516	0.079531	0.088840	0.018715
2.000000	1.000000	0.909091	0.106497	1.124610	0.058068	0.043391	0.008040
2.500000	1.000000	0.925926	0.101820	1.072048	0.048085	0.022318	0.003841
3.000000	1.000000	0.937500	0.099283	1.042494	0.042905	0.011801	0.001946
3.500000	1.000000	0.945946	0.097935	1.025350	0.040043	0.006337	0.001019
4.000000	1.000000	0.952381	0.097262	1.015224	0.038401	0.003433	0.000544
4.500000	1.000000	0.957447	0.096973	1.009179	0.037438	0.001869	0.000294
5.000000	1.000000	0.961538	0.096900	1.005547	0.036865	0.001021	0.000160

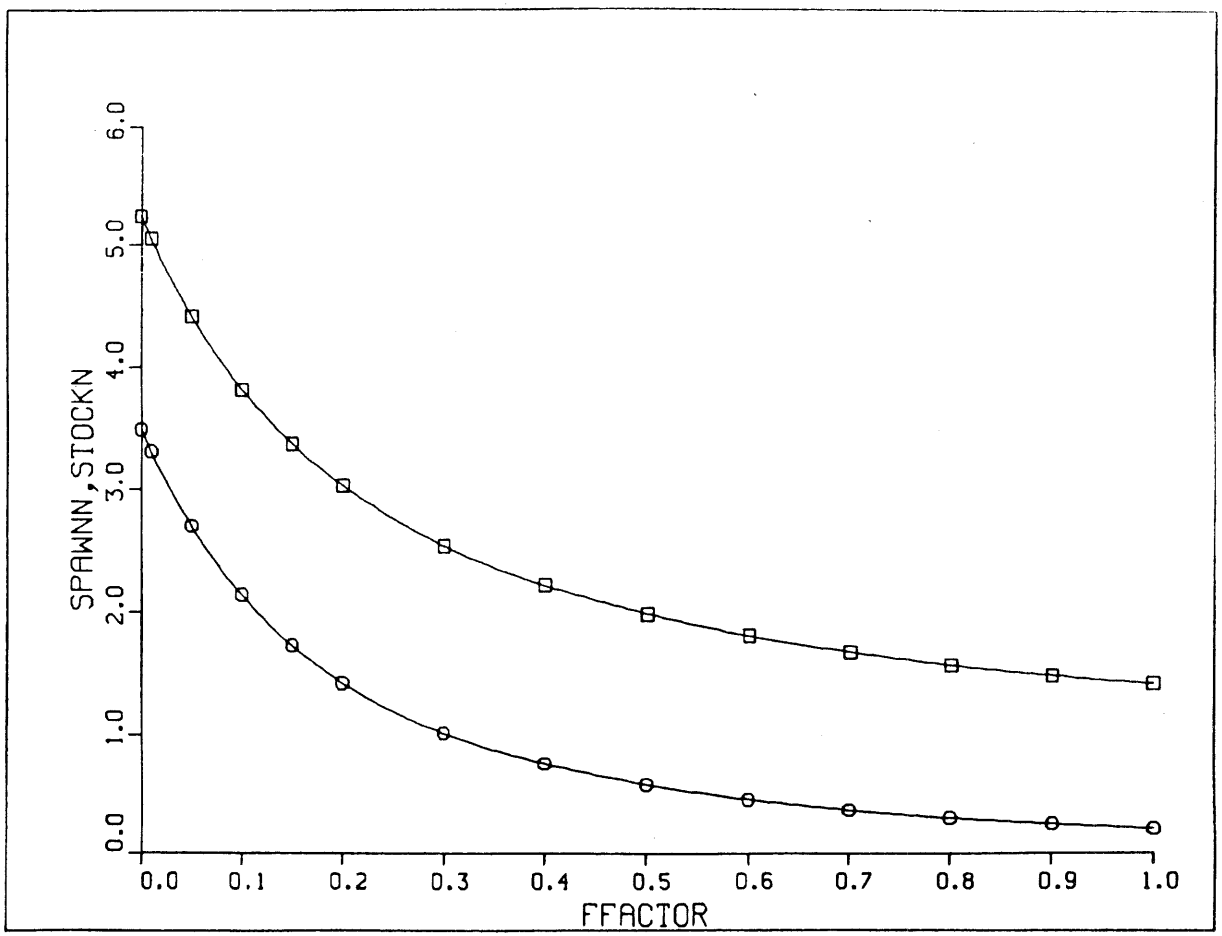
```
ENTER COMMAND
  :>CATCHN
DO YOU WISH TO DEFER GRAPHICAL OUTPUT SO THAT IT
CAN BE PRODUCED LATER ON ANOTHER DEVICE?  (Y or N)
IF NOT OUTPUT WILL BE TO YOUR GRAPHICS TERMINAL
  :>N
```



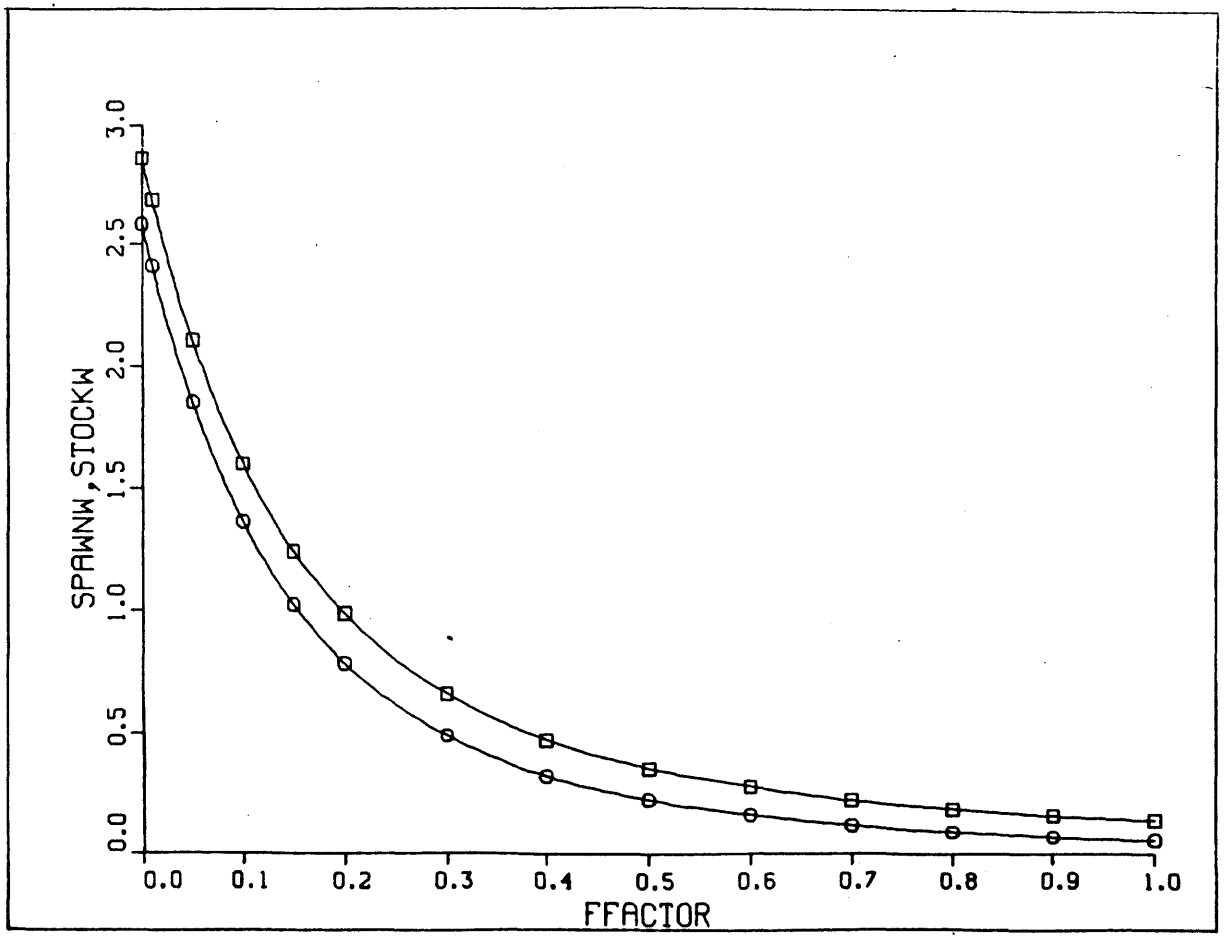
```
ENTER COMMAND
  :>CATCHW
DO YOU WISH TO DEFER GRAPHICAL OUTPUT SO THAT IT
CAN BE PRODUCED LATER ON ANOTHER DEVICE?  (Y or N)
IF NOT OUTPUT WILL BE TO YOUR GRAPHICS TERMINAL
  :>N
```



```
ENTER COMMAND
  :>STOCKN
DO YOU WISH TO DEFER GRAPHICAL OUTPUT SO THAT IT
CAN BE PRODUCED LATER ON ANOTHER DEVICE?  (Y or N)
IF NOT OUTPUT WILL BE TO YOUR GRAPHICS TERMINAL
  :>N
```



```
ENTER COMMAND
  :>STOCKW
DO YOU WISH TO DEFER GRAPHICAL OUTPUT SO THAT IT
CAN BE PRODUCED LATER ON ANOTHER DEVICE?  (Y or N)
IF NOT OUTPUT WILL BE TO YOUR GRAPHICS TERMINAL
  :>N
```




```
ENTER COMMAND
  :>EXIT
END OF DISSPLA 9.0 -- 5840 VECTORS GENERATED IN 4 PLOT FRAMES.
    PROPRIETARY SOFTWARE PRODUCT OF ISSCO, SAN DIEGO, CA.
9930 VIRTUAL STORAGE REFERENCES; 4 READS; 0 WRITES.
DYNAMIC MODEL PROCESSOR ENDS
FORTRAN STOP

$SPAK/RELEASE
```

$ T YRDTL.DAT

FFACTOR= 0.0000000 MFACTOR= 1.0000000

AGE	F	M	CATCHN	CATCHW	STOCKN	STOCKW	SPAWNN	SPAWNW
1	0.000000	0.200000	0.000000	0.000000	1.000000	0.036000	0.000000	0.000000
2	0.000000	0.200000	0.000000	0.000000	0.818731	0.126903	0.409046	0.063402
3	0.000000	0.200000	0.000000	0.000000	0.670320	0.221876	0.431504	0.142828
4	0.000000	0.200000	0.000000	0.000000	0.548812	0.285931	0.527292	0.274719
5	0.000000	0.200000	0.000000	0.000000	0.449329	0.312733	0.431711	0.300471
6	0.000000	0.200000	0.000000	0.000000	0.367879	0.311226	0.353455	0.299023
7	0.000000	0.200000	0.000000	0.000000	0.301194	0.290652	0.289384	0.279256
8	0.000000	0.200000	0.000000	0.000000	0.246597	0.260653	0.236928	0.250433
9	0.000000	0.200000	0.000000	0.000000	0.201897	0.227537	0.193980	0.218616
10	0.000000	0.200000	0.000000	0.000000	0.165299	0.194887	0.158817	0.187246
11	0.000000	0.200000	0.000000	0.000000	0.135335	0.164703	0.130029	0.158245
12	0.000000	0.200000	0.000000	0.000000	0.110803	0.137950	0.106459	0.132541
13	0.000000	0.200000	0.000000	0.000000	0.090718	0.114758	0.087161	0.110258
14	0.000000	0.200000	0.000000	0.000000	0.074274	0.095070	0.071361	0.091342
15	0.000000	0.200000	0.000000	0.000000	0.060810	0.078445	0.058426	0.075369
TOTAL			0.000000	0.000000	5.241998	2.859326	3.485553	2.583749

FFACTOR= 0.0500000 MFACTOR= 1.0000000

AGE	F	M	CATCHN	CATCHW	STOCKN	STOCKW	SPAWNN	SPAWNW
1	0.050000	0.200000	0.044240	0.004424	1.000000	0.036000	0.000000	0.000000
2	0.050000	0.200000	0.034454	0.008269	0.778801	0.120714	0.385225	0.059710
3	0.050000	0.200000	0.026833	0.009391	0.606531	0.200762	0.386556	0.127950
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
12	0.050000	0.200000	0.002828	0.003563	0.063928	0.079590	0.060810	0.075709
13	0.050000	0.200000	0.002203	0.002797	0.049787	0.062981	0.047359	0.059909
14	0.050000	0.200000	0.001715	0.002196	0.038774	0.049631	0.036883	0.047210
15	0.050000	0.200000	0.001336	0.001723	0.030197	0.038955	0.028725	0.037055
TOTAL			0.195296	0.102686	4.414493	2.108848	2.701980	1.853617
.	.	.						
.	.	.						
.	.	.						
.	.	.						

FFACTOR= 5.0000000 MFACTOR= 1.0000000

AGE	F	M	CATCHN	CATCHW	STOCKN	STOCKW	SPAWNN	SPAWNW
1	5.000000	0.200000	0.956234	0.095623	1.000000	0.036000	0.000000	0.000000
2	5.000000	0.200000	0.005275	0.001266	0.005517	0.000855	0.001014	0.000157
3	5.000000	0.200000	0.000029	0.000010	0.000030	0.000010	0.000007	0.000002
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
12	5.000000	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
13	5.000000	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
14	5.000000	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15	5.000000	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
TOTAL			0.961538	0.096900	1.005547	0.036865	0.001021	0.000160

$

PROGRAM NAME: Yield per recruit parameter preparation program

PROGRAM TYPE: Main

DATE CREATED: May 17 1984

SOURCE FILE NAME: RED::DSKA:[712.MASTER.SOURCE]YRPREP.FOR

EXECUTE FILE NAME: RED::DSKA:[712.MASTER.XEQ]YRPREP.EXE

AUTHOR: J.W. Hauser

DOCUMENTED BY: J.W. Hauser

CLASSIFICATION: Data entry and preparation

PURPOSE OF PROGRAM:

This program may be used to create or revise the input file necessary to run the YR (yield per recruit) program. The file contains data for the particular yield per recruit model desired. Use of YRPREP is not manditory; the input file may be revised or even created using an editor. However, use of YRPREP simplifies the process of file creation and insures correct file format.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

The program first asks the user if a new file is to be created or an old one revised. If a new file is desired the the program prompts for all necessary information. If an old file is to be revised, the user may select items to be changed. The program displays current values on request. The old file must be in proper format or it will be rejected. If a change makes additional information necessary, the program automatically prompts for that information.

If an old file is to be revised, assign the old file to FOR001. Program output is to unit FOR002. To run the program, enter the following commands:

```
$ASSIGN old-file-name FOR001
$ASSIGN new-file-name FOR002
$RUN DSKA:[712.MASTER.XEQ]YRPREP
```

and you will be prompted for responses by the program.

```
$ ASSIGN YR.DAT FOR002
$ RUN [712.MASTER.XEQ]YRPREP


NMFS/NEFC   YRPREP PROGRAM   VERSION 1.0   RUN: 12:03  1-AUG-84
DO YOU WISH TO CHANGE AN OLD FILE? (Y or N)
IF NOT YOU WILL BE PROMPTED FOR ALL INFORMATION FOR A NEW FILE.
   >N
ENTER TITLE
   >YELLOWTAIL FLOUNDER
ENTER FIRST AGE GROUP
   >1
ENTER LAST AGE GROUP
   >15
IS LAST AGE GROUP A PLUS GROUP? (Y or N)
   >N
ENTER PROPORTION OF F MORTALITY BEFORE SPAWNING SEASON
   >.2
ENTER PROPORTION OF M MORTALITY BEFORE SPAWNING SEASON
   >.2
ENTER DATA FOR AGE =  1
   FPATTERN        >1
   MPATTERN        >.2
   MATURITY        >0.
   WEIGHT IN CATCH >.1
   WEIGHT IN STOCK >.0360
ENTER DATA FOR AGE =  2
   FPATTERN        >1.
   MPATTERN        >.2
   MATURITY        >.52
   WEIGHT IN CATCH >.24
   WEIGHT IN STOCK >.155
ENTER DATA FOR AGE =  3
   FPATTERN        >1.
   MPATTERN        >.2
   MATURITY        >.67
   WEIGHT IN CATCH >.35
   WEIGHT IN STOCK >.331
ENTER DATA FOR AGE =  4
   FPATTERN        >1.
   MPATTERN        >.2
   MATURITY        >1.
   WEIGHT IN CATCH >.53
   WEIGHT IN STOCK >.521
ENTER DATA FOR AGE =  5
   FPATTERN        >1.
   MPATTERN        >.2
   MATURITY        >1.
   WEIGHT IN CATCH >.77
   WEIGHT IN STOCK >.696
ENTER DATA FOR AGE =  6
   FPATTERN        >1.
   MPATTERN        >.2
   MATURITY        >1.
   WEIGHT IN CATCH >.9
   WEIGHT IN STOCK >.846
```

```
ENTER DATA FOR AGE =  7
   FPATTERN         >1.
   MPATTERN         >.2
   MATURITY         >1.
   WEIGHT IN CATCH >1.011
   WEIGHT IN STOCK >.965
ENTER DATA FOR AGE =  8
   FPATTERN         >1.
   MPATTERN         >.2
   MATURITY         >1.
   WEIGHT IN CATCH >1.09
   WEIGHT IN STOCK >1.057
ENTER DATA FOR AGE =  9
   FPATTERN         >1.
   MPATTERN         >.2
   MATURITY         >1.
   WEIGHT IN CATCH >1.15
   WEIGHT IN STOCK >1.127
ENTER DATA FOR AGE = 10
   FPATTERN         >1.
   MPATTERN         >.2
   MATURITY         >1.
   WEIGHT IN CATCH >1.20
   WEIGHT IN STOCK >1.179
ENTER DATA FOR AGE = 11
   FPATTERN         >1.
   MPATTERN         >.2
   MATURITY         >1.
   WEIGHT IN CATCH >1.23
   WEIGHT IN STOCK >1.217
ENTER DATA FOR AGE = 12
   FPATTERN         >1.
   MPATTERN         >.2
   MATURITY         >1.
   WEIGHT IN CATCH >1.26
   WEIGHT IN STOCK >1.245
ENTER DATA FOR AGE = 13
   FPATTERN         >1.
   MPATTERN         >.2
   MATURITY         >1.
   WEIGHT IN CATCH >1.27
   WEIGHT IN STOCK >1.265
ENTER DATA FOR AGE = 14
   FPATTERN         >1.
   MPATTERN         >.2
   MATURITY         >1.
   WEIGHT IN CATCH >1.28
   WEIGHT IN STOCK >1.28
ENTER DATA FOR AGE = 15
   FPATTERN         >1.
   MPATTERN         >.2
   MATURITY         >1.
   WEIGHT IN CATCH >1.29
   WEIGHT IN STOCK >1.29
FORTRAN STOP
$
```

```
$ T YR.DAT
TITLE:
YELLOWTAIL FLOUNDER
FIRST AGE GROUP:  LAST AGE GROUP:  LAST GROUP IS PLUS:
                1               15                  NO
PROPORTION OF F MORTALITY BEFORE SPAWNING SEASON:
0.2000
PROPORTION OF M MORTALITY BEFORE SPAWNING SEASON:
0.2000
```

AGE	FPATTERN	MPATTERN	MATURITY	WEIGHT IN THE CATCH	WEIGHT IN THE STOCK
1	1.0000	0.200	0.0000	0.1000	0.0360
2	1.0000	0.200	0.5200	0.2400	0.1550
3	1.0000	0.200	0.6700	0.3500	0.3310
4	1.0000	0.200	1.0000	0.5300	0.5210
5	1.0000	0.200	1.0000	0.7700	0.6960
6	1.0000	0.200	1.0000	0.9000	0.8460
7	1.0000	0.200	1.0000	1.0110	0.9650
8	1.0000	0.200	1.0000	1.0900	1.0570
9	1.0000	0.200	1.0000	1.1500	1.1270
10	1.0000	0.200	1.0000	1.2000	1.1790
11	1.0000	0.200	1.0000	1.2300	1.2170
12	1.0000	0.200	1.0000	1.2600	1.2450
13	1.0000	0.200	1.0000	1.2700	1.2650
14	1.0000	0.200	1.0000	1.2800	1.2800
15	1.0000	0.200	1.0000	1.2900	1.2900

```
$
```

PROGRAM NAME: Beverton and Holt Yield per Recruit

PROGRAM TYPE: Main

DATE CREATED: Jan 1 1975

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]FMBYPCTC.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]FMBYPCTC.EXE

AUTHOR: M. Parrack

DOCUMENTED BY: F.P. Almeida

REVISIONS (Date/Reviser - Description)

Nov 14 1983 /F.P. Almeida -
Revised to conform with VAX 11/780 compatible FORTRAN77
Jan 30 1984 /F.P.Almeida
Documented to conform with NERFIS standards

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

The program provides equilibrium yield values for a given recruitment according to Beverton and Holt's formula. The model assumes constant fishing mortality over the fishable life span with 'knife-edge' selection and a value of 3.0 for b in the length-weight equation. It will also allow for the creation of an output matrix of yield values for use in plotting routines.

DESCRIPTION:

The program requires ranges of natural mortality (M), fishing mortality (F), age at entry into the fishery (tp'), the parameters of the relevant von Bertalanffy equation, and the maximum weight the fish will attain. The program will pass through an inner loop of different ages at entry to the exploited phase within two successive outer loops representing varying levels of F and M. The yield formula is:

$$Y_W = FRW_\infty e^{-M(t_p'-t_p)} \sum_{n=o}^{3} \frac{\Omega_n e^{-nK(t_{p'}-t_o)}}{F+M+nK} (1-e^{-(F+M+nK)(t_\lambda-t_p')})$$

where:

Y_W = yield in weight,
W_∞ = asymptotic weight,

R = number of recruits at age tp, that is, the number entering the area where fishing is in progress and becoming liable to encounters with the gear,
F = instantaneous rate of fishing mortality,
M = instantaneous rate of natural mortality,
K = von Bertalanffy's coefficient of catabolism,
t_o = hypothetical time at which the fish would have been 0 length according to the equation,
t_p = age at recruitment, i.e. age at which fish become liable to encounters with the gear (Gulland's tr), T(P) in program output,
$t_{p'}$ = age at entry to the exploited phase; corresponding to 50% on the mesh selection ogive (Gulland's tc), T(P') in program output,
t_λ = end of the life span; corresponds to the maximum age for which adequate age data are available.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

The program is completely interactive and to run, the user simply enters:

```
$RUN FSHA:[712.MASTER.XEQ]FMBYPCTC
```

If a plot file is desired, assign FOR004 to some file name before running the program i.e.:

```
$ASSIGN plotfile.DAT FOR004
$RUN FSHA:[712.MASTER.XEQ]FMBYPCTC
```

**Restrictions:
An 'output conversion error' will result if yield values in your created plot file exceed 9999 units.

REFERENCES:

Beverton, R.J.H., and S.J. Holt. 1957. On the dynamics of exploited fish populations. Fish. Invest. Minist. Agric. Fish. Food (GB), Ser. II, 19, 533p.

```
$ RUN FSHA:[712.MASTER.XEQ]FMBYPCTC

     Beverton and Holt Yield per Recruit
      Version 1.0  Jan 1975  M. Parrack
VAX 11/780 Version 1.0 14/XI/83 F.P. Almeida

WANT EXPLANATION OF PROGRAM? (YES OR NO)
NO
WANT TO CREATE A PLOT FILE? (YES OR NO)
NO
TYPE TITLE UP TO 80 CHARACTERS
TEST RUN VAX VERSION 1.0

LOWEST INSTANTANEOUS NATURAL MORTALITY RATE(M),
HIGHEST INSTANTANEOUS NATURAL MORTALITY RATE(M) AND
INCREMENT THROUGH WHICH LOOP TRAVERSES (>0)
.4
.4
.1

LOWEST INSTANTANEOUS FISHING MORTALITY RATE(F),
HIGHEST INSTANTANEOUS FISHING MORTALITY RATE(F) AND
INCREMENT THROUGH WHICH LOOP TRAVERSES
.05
1.00
.05

LOWEST AGE OF ENTRY TO EXPLOITED PHASE(TP'),
HIGHEST AGE OF ENTRY TO EXPLOITED PHASE(TP') AND
INCREMENT THROUGH WHICH LOOP TRAVERSES
  ...MAXIMUM NUMBER OF AGES = 40...
1.00
4.00
.25

HYPOTHETICAL TIME OF ZERO LENGTH(TO), AGE AT RECRUITMENT(T(P)),
END OF LIFE SPAN(TLAMBDA), COEFFICIENT OF CATABOLISM(K),
ASYMPTOTIC WEIGHT(W(INFINITY)), AND NUMBER OF RECRUITS AT AGE T(P)
.273,1.00
12.0,.4156
.703,10000.0
```

```
    TEST RUN
T(O)------------ 0.2730
T(P)------------ 1.0000
T(LAMBDA)-------12.0000
K-VALUE--------- 0.4156
W-INFINITY------ 0.7030


  FOLLOWING YIELDS IN
WEIGHT PER   10000.  FISH


 M = 0.4000

  F                                    T(P")

      1.00  1.25  1.50  1.75  2.00  2.25  2.50  2.75  3.00  3.25  3.50  3.75  4.00
0.05   241.  242.  241.  239.  235.  229.  222.  213.  204.  194.  183.  172.  162.
0.10   401.  406.  409.  408.  404.  397.  387.  374.  359.  343.  326.  307.  289.
0.15   505.  518.  526.  530.  528.  522.  511.  497.  479.  459.  437.  414.  390.
0.20   573.  593.  608.  617.  620.  616.  607.  592.  573.  551.  526.  500.  472.
0.25   615.  643.  665.  680.  687.  687.  680.  666.  648.  625.  598.  569.  539.
0.30   639.  675.  705.  726.  738.  742.  737.  725.  707.  684.  657.  627.  594.
0.35   652.  695.  731.  758.  776.  783.  782.  772.  755.  732.  705.  674.  640.
0.40   656.  706.  748.  782.  804.  816.  818.  810.  795.  772.  745.  714.  679.
0.45   653.  710.  759.  798.  825.  841.  846.  841.  827.  806.  779.  747.  712.
0.50   647.  710.  765.  809.  841.  861.  869.  866.  854.  834.  807.  776.  741.
0.55   638.  706.  767.  816.  852.  876.  887.  887.  877.  858.  832.  801.  765.
0.60   628.  701.  766.  820.  860.  888.  902.  904.  896.  878.  853.  822.  787.
0.65   616.  693.  763.  821.  866.  897.  914.  919.  912.  895.  871.  841.  805.
0.70   603.  685.  759.  821.  870.  904.  924.  931.  926.  910.  887.  857.  822.
0.75   590.  676.  754.  820.  872.  909.  932.  941.  937.  923.  901.  871.  836.
0.80   577.  666.  748.  817.  873.  913.  938.  949.  947.  935.  913.  884.  849.
0.85   564.  656.  741.  814.  873.  916.  943.  956.  956.  945.  924.  896.  861.
0.90   552.  646.  734.  810.  872.  918.  947.  962.  964.  954.  934.  906.  872.
0.95   539.  636.  727.  806.  870.  919.  951.  968.  970.  961.  942.  915.  881.
1.00   527.  627.  720.  802.  869.  919.  953.  972.  976.  968.  950.  923.  890.
WANT TO RERUN PROGRAM?
YES
WANT TO CREATE A PLOT FILE? (YES OR NO)
YES
     INPUT FORMAT FOR 3D PLOT WILL BE (5X,__F6.0)
     __=TOTAL NUMBER OF T(P") IN OUTPUT MATRIX

     IF YOU DID NOT DESIGNATE A PLOT FILE NAME
     ie. ASSIGN AN FOR004 FILE, THE PROGRAM WILL
     CREATE ONE FOR YOU (FOR004.DAT).

TYPE TITLE UP TO 80 CHARACTERS
TEST RUN WITH PLOT FILE

LOWEST INSTANTANEOUS NATURAL MORTALITY RATE(M),
HIGHEST INSTANTANEOUS NATURAL MORTALITY RATE(M) AND
INCREMENT THROUGH WHICH LOOP TRAVERSES (>0)
.4
.4
.1
```

```
LOWEST INSTANTANEOUS FISHING MORTALITY RATE(F),
HIGHEST INSTANTANEOUS FISHING MORTALITY RATE(F) AND
INCREMENT THROUGH WHICH LOOP TRAVERSES
.05
1.00
.05

LOWEST AGE OF ENTRY TO EXPLOITED PHASE(TP'),
HIGHEST AGE OF ENTRY TO EXPLOITED PHASE(TP') AND
INCREMENT THROUGH WHICH LOOP TRAVERSES
  ...MAXIMUM NUMBER OF AGES = 40...
1.00
4.00
.25

HYPOTHETICAL TIME OF ZERO LENGTH(TO),AGE AT RECRUITMENT (T(P)
END OF LIFE SPAN(TLAMBDA),COEFFICIENT OF CATABOLISM(K),
ASYMPTOTIC WEIGHT(WINFINITY) AND NUMBER OF RECRUITS AT AGE TP)
.273,1.00
12.00,.4156
.703,10000.
    TEST RUN WITH PLOT FILE
T(O)------------ 0.2730
T(P)------------ 1.0000
T(LAMBDA)-------12.0000
K-VALUE--------- 0.4156
W-INFINITY------ 0.7030


  FOLLOWING YIELDS IN
WEIGHT PER   10000.  FISH


 M = 0.4000

  F                                    T(P")

     1.00  1.25  1.50  1.75  2.00  2.25  2.50  2.75  3.00  3.25  3.50  3.75  4.00
WANT TO RERUN PROGRAM?
NO
FORTRAN STOP
```

```
$ T FOR004.DAT

0.05  241.  242.  241.  239.  235.  229.  222.  213.  204.  194.  183.  172.  162.
0.10  401.  406.  409.  408.  404.  397.  387.  374.  359.  343.  326.  307.  289.
0.15  505.  518.  526.  530.  528.  522.  511.  497.  479.  459.  437.  414.  390.
0.20  573.  593.  608.  617.  620.  616.  607.  592.  573.  551.  526.  500.  472.
0.25  615.  643.  665.  680.  687.  687.  680.  666.  648.  625.  598.  569.  539.
0.30  639.  675.  705.  726.  738.  742.  737.  725.  707.  684.  657.  627.  594.
0.35  652.  695.  731.  758.  776.  783.  782.  772.  755.  732.  705.  674.  640.
0.40  656.  706.  748.  782.  804.  816.  818.  810.  795.  772.  745.  714.  679.
0.45  653.  710.  759.  798.  825.  841.  846.  841.  827.  806.  779.  747.  712.
0.50  647.  710.  765.  809.  841.  861.  869.  866.  854.  834.  807.  776.  741.
0.55  638.  706.  767.  816.  852.  876.  887.  887.  877.  858.  832.  801.  765.
0.60  628.  701.  766.  820.  860.  888.  902.  904.  896.  878.  853.  822.  787.
0.65  616.  693.  763.  821.  866.  897.  914.  919.  912.  895.  871.  841.  805.
0.70  603.  685.  759.  821.  870.  904.  924.  931.  926.  910.  887.  857.  822.
0.75  590.  676.  754.  820.  872.  909.  932.  941.  937.  923.  901.  871.  836.
0.80  577.  666.  748.  817.  873.  913.  938.  949.  947.  935.  913.  884.  849.
0.85  564.  656.  741.  814.  873.  916.  943.  956.  956.  945.  924.  896.  861.
0.90  552.  646.  734.  810.  872.  918.  947.  962.  964.  954.  934.  906.  872.
0.95  539.  636.  727.  806.  870.  919.  951.  968.  970.  961.  942.  915.  881.
1.00  527.  627.  720.  802.  869.  919.  953.  972.  976.  968.  950.  923.  890.
$
```

PROGRAM NAME: Piece-wise Integration of Yield Curves

PROGRAM TYPE: Main

DATE CREATED: Apr 1 1964

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]FMBRIKR.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]FMBRIKR.EXE

AUTHOR: L.E. Gales

DOCUMENTED BY: G.T. Waring

REVISIONS (Date/Reviser - Description)

Feb 01 1982 /G.T. Waring -
Revised to conform with VAX 11/780 FORTRAN 77

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

This program will compute an approximate yield isopleth for a given number of recruits to a fishery when both growth and natural mortality are estimated empirically. The calculations are carried out using a modified form of Ricker's method for estimating equilibrium yield (see Ricker, 1958, pp. 238-239).

The program is extremely general in that growth, natural mortality and fishing mortality rates need not be measured using the same time intervals. Fishing mortality rates can be age specific (up to 400 different rates can be applied during the life of the fish) but the over-all level of fishing mortality can be varied by means of multipliers which apply to all of the individual age specific rates. The range and the intervals between ages at first capture can also be varied by the user.

DESCRIPTION:

The program has two approximation options: 1) an exponential mode which assumes that the biomass of the stock changes in a strickly exponential manner during any interval when growth, natural mortality and fishing rates are all constant (see equation 10.4 Ricker,1958); or, 2) an arithmetic mode which uses the arithmetic mean of the stock biomass at the start and at the end of any interval during which all three rates are constant as an estimate of the average biomass

present during the interval (see equation 10.3 Ricker,1958).

Input to the program can be given in the form of instantaneous rates for growth, natural mortality and fishing mortality or the program can compute the instantaneous growth and natural mortality rates frow weight-at-time input and from numbers-at-time input. If the lstter form of input is employed the instantaneous average growth rate during the i period is calculated from the formula:

$$g_i = \ln (W_{t_{i+1}} / W_{t_i}) / (t_{i+1} - t_i)$$

where t_i = time at which the weight of an individual fish is exactly W_{t_i} weight units,

W_{t_i} = weight of an individual fish at time t_i.

Instantaneous natural mortality rates are calculated similarly from the formula:

$$M_i = -\ln (N_{t!_{i+1}} / N_{t!_i}) / (t!_{i+1} - t!_i)$$

where $t!_i$ = time at which the number of fish in the stock is exactly N pieces if natural mortality is the only source of mortality present,

M_i = instantaneous natural mortality rate during the ith time interval,

$N_{t!_i}$ = number of fish in the stock at time $t!_i$ when natural mortality is the only source of mortality.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

The program is completely interactive, input is free formatted with question prompts. The user must answer the following questions to set the control parameters:

Record Number	Record Description
1	Weight at growth scale divisions (enter 1) or instantaneous growth rates (enter 2)?
2	Numbers for natural mortality computations (enter 1) or instantaneous natural mortality rates (enter 2)?
3	Yield in arithmetic mode (enter 1) or in exponential mode (enter 2)?
4	Output biomass only (enter 1) or biomass and yield matrix (enter 2) or yield matrix only (enter 3)?
5	Enter title (80 character maximum)

After answering the five questions for setting the control parameters, the user will have to provide values on

growth, natural mortality and fishing mortality in response to a series of questions (see example).

To run the program, simply type:

```
$RUN FSHA:[712.MASTER.XEQ]FMBRIKR
```

and you will be prompted for values, or create a data file and run using:

```
$ASSIGN datafile.DAT FOR005
$RUN FSHA:[712.MASTER.XEQ]FMBRIKR
```

REFERENCES:

Paulik, G.J. and Bayliff, W.F. 1967. A generalized computer program for the Ricker model of equilibrium yield per recruitment. J. Fish. Res. Bd. Canada, 24(2) 249-259.

Ricker, W.E. 1958. Handbook of computations for biological statistics of fish populations. Bull. Fish. Res. Board Can. 119:300p.

```
$ RUN [712.MASTER.XEQ]FMBRIKR

   Piece-wise Integration of Yield Curves    Version 2.1 24/I/84  L. E. Gales

WANT EXPLANATION OF PROGRAM ?(YES OR NO)
NO


                                  ---------------------------
                                      CONTROL PARAMETERS
                                  ---------------------------


WEIGHT AT GROWTH SCALE DIVISIONS(ENTER 1)
OR INSTANTANEOUS GROWTH RATES?(ENTER 2)
1
NUMBERS FOR NATURAL MORTALITY COMPUTATIONS(ENTER 1)
ORINSTANTANEOUS NATURAL MORTALITY RATES(ENTER 2)?
2
YIELD IN ARITHMETICMODE(ENTER 1)
OR IN EXPONENTIAL    MODE(ENTER 2)?
2
OUTPUT BIOMASS ONLY(ENTER 1)
OR BIOMASS AND YIELD     MATRIX (ENTER 2)
OR YIELD MATRIX ONLY(ENTER 3)?
2
INPUT TITLE(UP TO 80 CHARACTERS)
TEST RUN  BUTTERFISH DATA
```

```
*****************************************************************************************************
TEST RUN  BUTTERFISH DATA
PIECE-WISE INTEGRATION OF THE YIELD CURVE

                                  ----------------------------
                                       I N P U T   D A T A
                                  ----------------------------


DIVISIONS OF GROWTH SCALE  9 PER LINE

-------------------------------------------------------------
INPUT THE NUMBER OF DATA POINTS TO BE READ IN THIS SET
4
INPUT DATA POINTS FOR THIS SET
0,1,2,3
     0.0000      1.0000      2.0000      3.0000


WEIGHTS AT GROWTH SCALE DIVISION, 9 PER LINE/
-------------------------------------------------------------
INPUT THE NUMBER OF DATA POINTS TO BE READ IN THIS SET
4
INPUT DATA POINTS FOR THIS SET
28,65,123,172
 0.2800E+02  0.6500E+02  0.1230E+03  0.1720E+03


INSTANTANEOUS GROWTH RATES, 9 PER LINE

-------------------------------------------------------------
 0.8422E+00  0.6378E+00  0.3353E+00


DIVISIONS OF NATURAL MORTALITY SCALE,  9 PER LINE

-------------------------------------------------------------
INPUT THE NUMBER OF DATA POINTS TO BE READ IN THIS SET
4
INPUT DATA POINTS FOR THIS SET
0,1,2,3
     0.0000      1.0000      2.0000      3.0000


INSTANTANEOUS NATURAL MORTALITY RATES, 9 PER LINE

-------------------------------------------------------------
INPUT THE NUMBER OF DATA POINTS TO BE READ IN THIS SET
3
INPUT DATA POINTS FOR THIS SET
.4,.8,.8
 0.4000E+00  0.8000E+00  0.8000E+00


DIVISIONS OF FISHING SCALE, 9 PER LINE

-------------------------------------------------------------
INPUT THE NUMBER OF DATA POINTS TO BE READ IN THIS SET
4
INPUT DATA POINTS FOR THIS SET
0,1,2,3
     0.0000      1.0000      2.0000      3.0000
```

```
INSTANTANEOUS FISHING MORTALITY RATES, 9 PER LINE

-----------------------------------------------------------
INPUT THE NUMBER OF DATA POINTS TO BE READ IN THIS SET
4
INPUT DATA POINTS FOR THIS SET
.2,.5,1.0,1.0
 0.2000E+00  0.5000E+00  0.1000E+01  0.1000E+01


MULTIPLIERS,  9 PER LINE

-----------------------------------------------------------
INPUT THE NUMBER OF DATA POINTS TO BE READ IN THIS SET
20
INPUT DATA POINTS FOR THIS SET
.2,.4,.6,.8,1.0,1.2,1.4,1.6,1.8
2.0,2.2,2.4,2.6,2.8,3.0,3.2,3.4,3.6
3.8,4.0
 0.2000E+00  0.4000E+00  0.6000E+00  0.8000E+00  0.1000E+01  0.1200E+01  0.1400E+01  0.1600E+01  0.1800E+01
 0.2000E+01  0.2200E+01  0.2400E+01  0.2600E+01  0.2800E+01  0.3000E+01  0.3200E+01  0.3400E+01  0.3600E+01
 0.3800E+01  0.4000E+01


VALUES OF TAU, 9 PER LINE

-----------------------------------------------------------
INPUT THE NUMBER OF DATA POINTS TO BE READ IN THIS SET
4
INPUT DATA POINTS FOR THIS SET
0,1,2,3
     0.0000      1.0000      2.0000      3.0000
INPUT NUMBER AT START AND AVERAGE WEIGHT AT START
1,28


NUMBER AT START=   0.100000E+01   AVERAGE WEIGHT AT START=   0.280000E+02
*****************************************************************************************************



-----------------------------------------------------------------------------------------------------
BIO-MASS VECTOR NO HARVEST

NUMBER    TIME            BIO-MASS

     1   0.000000E+00    0.280000E+02
     2   0.100000E+01    0.435708E+02
     3   0.200000E+01    0.370469E+02
     4   0.300000E+01    0.232777E+02

-----------------------------------------------------------------------------------------------------
```

```
*****************************************************************************************************************

                                        -------------------------------
                                            Y I E L D   M A T R I X
                                        -------------------------------


                 /
                 /
T( 4)=    3.000 /  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
                 /  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
                 /  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
                 /
                 /
T( 3)=    2.000 /  0.54127E+01  0.99196E+01  0.13678E+02  0.16818E+02  0.19447E+02  0.21651E+02  0.23505E+02
                 /  0.25067E+02  0.26387E+02  0.27506E+02  0.28457E+02  0.29268E+02  0.29963E+02  0.30560E+02
                 /  0.31075E+02  0.31521E+02  0.31909E+02  0.32248E+02  0.32546E+02  0.32809E+02
                 /
                 /
T( 2)=    1.000 /  0.87303E+01  0.15432E+02  0.20600E+02  0.24605E+02  0.27727E+02  0.30176E+02  0.32110E+02
                 /  0.33649E+02  0.34883E+02  0.35882E+02  0.36697E+02  0.37368E+02  0.37927E+02  0.38396E+02
                 /  0.38793E+02  0.39133E+02  0.39427E+02  0.39682E+02  0.39906E+02  0.40105E+02
                 /
                 /
T( 1)=    0.000 /  0.97667E+01  0.16945E+02  0.22235E+02  0.26143E+02  0.29038E+02  0.31185E+02  0.32780E+02
                 /  0.33965E+02  0.34843E+02  0.35492E+02  0.35968E+02  0.36312E+02  0.36556E+02  0.36724E+02
                 /  0.36832E+02  0.36893E+02  0.36919E+02  0.36917E+02  0.36893E+02  0.36851E+02
                 ---------------------------------------------------------------------------------------------
MULTIPLIER ...      M( 1)        M( 2)        M( 3)        M( 4)        M( 5)        M( 6)        M( 7)
                    M( 8)        M( 9)        M(10)        M(11)        M(12)        M(13)        M(14)
                    M(15)        M(16)        M(17)        M(18)        M(19)        M(20)

          WHERE M( 1)=  0.20000E+00
                M( 2)=  0.40000E+00
                M( 3)=  0.60000E+00
                M( 4)=  0.80000E+00
                M( 5)=  0.10000E+01
                M( 6)=  0.12000E+01
                M( 7)=  0.14000E+01
                M( 8)=  0.16000E+01
                M( 9)=  0.18000E+01
                M(10)=  0.20000E+01
                M(11)=  0.22000E+01
                M(12)=  0.24000E+01
                M(13)=  0.26000E+01
                M(14)=  0.28000E+01
                M(15)=  0.30000E+01
                M(16)=  0.32000E+01
                M(17)=  0.34000E+01
                M(18)=  0.36000E+01
                M(19)=  0.38000E+01
                M(20)=  0.40000E+01
WANT TO RERUN PROGRAM ?(YES OR NO)
NO
FORTRAN STOP
```

PROGRAM NAME: Yield per recruit using incomplete beta function

PROGRAM TYPE: Main

DATE CREATED: Jan 1 1964

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]YPIB.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]YPIB.EXE

AUTHOR: L.E. Gales

DOCUMENTED BY: S.A. Murawski
R.K. Mayo

REVISIONS (Date/Reviser - Description)

Jan 1 1982 /S.A. Murawski -
Converted from Sigma 7 to Vax 11/780.
Jul 31 1984 /R.K. Mayo -
Enhanced with DISSPLA graphics options.

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

Program YPIB uses the incomplete Beta function in the Beverton-Holt yield equation to produce an array of coordinates for plotting yield isopleths.

DESCRIPTION:

The program accepts up to 50 values of F (instantaneous fishing mortality) and tp´ (age at entry to the exploited phase); the yield, Yw, is evaluated at each pair of F and tp´ to produce each coordinate. The model assumes constant fishing mortality over the fishable life span; it allows for a b value (in the length-weight equation) of other than 3.0.

The user may select among conditional yield per recruit curves, yield isopleths, and 3 dimensional plots of the yield surface to graphically represent the yield matrix if desired.

The model equations are:

$$Y_w = RW_\infty e^{M(t_p - t_o)}\, g(1-c)^{-g} \int_o^{1-c} y^{(m+g-1)} (1-y)^b \, dy$$

Modified to: $Y_w = RW_\infty e^{M(t_p - t_o)}\, g(1-c)^{-g}\, B_{1-c}(m+g,\ b+1)$

by expressing the integral as an incomplete beta function.

$$g = F/_K \qquad 1-c = e^{-K(t_p'-t_o)}$$

$$m = M/_K \qquad y = e^{-K(t-t_o)}$$

Input parameters are:

W infinity	=	asymptotic weight
R	=	number of recruits at age tp
tp	=	age at recruitment
tp´	=	age at entry to the exploited phase
t0	=	hypothetical age of zero length
F	=	instantaneous fishing mortality rate
M	=	instantaneous natural mortality rate
K	=	coefficient of catabolism
b	=	exponent in length-weight equation

Since the yield values are determined by integration of four third degree polynomials, an initial limit of integration must be calculated. This is given by:

S = exp(-K(T lambda - t0))

where T lambda is the end of the fishable life span.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

A. Control Records

Input consists of two control records in (8F8.0) format, thus, decimals must be included. Values are arranged as follows:

Record Number		Record Description
1.	Cols. 1-8	Initial value of F (F0).
	9-16	Initial value of tp´ (TPP0).
	17-24	Final value of F (RANGE).
	25-32	Final value of tp´ (UPPER).
	33-40	Increment in F (FDELT).
	41-48	Increment in tp´ (DELTAT).
	49-56	b-length-weight exponent (DELTA).
	57-64	A second exponent (DDELTA) This is used to compare results of the first computation to the second where b is not equal to 3.0. If no comparison is desired set this equal to 0.
2.	Cols. 1-8	R-number of recruits at tp (R).
	9-16	W infinity - asymptotic weight (W).

17-24	M - instantaneous natural mortality (AM).
25-32	K - coefficeint of catabolism (AK).
33-40	tp - age at recruitment (TP).
41-48	to - age at 0 length (TO).
49-56	t lambda - maximum age (T LAMBA).
57-64	S - initial limit of integration (XINTO).

Input must be from a file on input device FOR001. Tabular output of the computed yield matrix is produced on an output file ASSIGNed to device FOR007.

B. Interactive Graphics Option

Graphic representation of the two-dimensional yield per recruit (YPR) matrix may be obtained interactively during program execution. Before attempting any plots, the user must examine the tabular output matrix to determine the minimum and maximum bounds of the computed yield values.

The graphics mode is entered by responding to the following question:

1.0. Do You Want to Plot Results ? Enter Y or N.

Enter Y to proceed with the graphics option.
Enter N to terminate program execution.

The following questions allow the user to select among various plot types, axis annotation and plot parameter features.

2.0. Enter Descriptive Label (max = 64 Characters).

Enter a name or other descriptive label to appear at the top of the plots.

3.0. Enter: COND for conditional Curves
: ISOP for Isopleths
: 3DEE for 3 Dimensional Plots

3.1. COND produces 1 or more conditional YPR curves taken through the yield matrix at user-specified level(s) of Tp´. The axis coordinate system for this plot type is:

X axis - Instantaneous Fishing Mortality (F)
Y axis - Yield per Recruit

Axis annotation must be set up by responding to the following prompts:

3.1.1. Enter X axis Increment of F.
The user must specify the increment along the X axis.

3.1.2. Enter Minimum YPR, Maximum YPR, and Increment of YPR.
The user must specify the lower and upper bounds of

the computed yield values, and the increment along the Y axis.

Plot parameters must be set up by responding to the following prompts:

3.1.3. How Many Curves Do You Want to Plot ?
The number of curves must not exceed the number of age at entry values indicated on the first control record.

3.1.4. Enter nn Ages Between nn and nn.
The ages must be within the range indicated on the first control record.

3.2. ISOP produces a contoured Yield isopleth of the lattice points at the intersections of F and Tp´, as indicated on the first control record. The axis coordinate system for this plot type is:

X axis - Instantaneous Fishing Mortality (F)
Y axis - Age at Entry (Tp´)

Axis annotation must be set up by responding to the following prompts:

3.2.1. Enter X axis Increment of F.
The user must specify the increment along the X axis.

3.2.2. Enter Y axis Increment of Tp´.
The user must specify the increment along the Y axis.

Plot parameters must be set up by responding to the following prompt:

3.2.3. Enter Contour Resolution (YPR Units).
The user must specify the distance between contour lines in units of computed Yield per Recruit.

3.3. 3DEE produces a 3 dimensional representation of the yield per recruit surface. The user may select any viewing angle in the X-Y (Horizontal) and Z (Vertical) planes. The axis coordinate system for this plot type is:

X axis - Instantaneous Fishing Mortality (F)
Y axis - Age at Entry (Tp´)
Z axis - Yield per Recruit (YPR)

Axis annotation must be set up by responding to the following prompts:

3.3.1. Enter X axis Increment of F.
The user must specify the increment along the X axis.

3.3.2. Enter Y axis Increment of Tp´.

The user must specify the increment along the Y axis.

3.3.3. Enter Minimum YPR, Maximum YPR, and Increment of YPR. The user must specify the lower and upper bounds of the computed yield values, and the increment along the Z axis.

Plot parameters must be set up by responding to the following prompt:

3.3.4. Enter X-Y View Angle, Z View Angle, View Distance.

The X-Y view angle allows the entire axis system to be rotated about a 360 degree arc in the horizontal (X-Y) plane as illustrated below:

```
                    Y Axis

                     +90
                      |
                      |
                      |
                      |
-180  <---------------------------> 0    X Axis
                      |
                      |
                      |
                      |
                     -90
```

The Z view angle represents the vertical angle in degrees above (1 to 90) or below (-1 to -90) the horizontal (X-Y) plane from which the plot is viewed.

The view distance is the distance from the center of the 3-D work space in absolute -D units from which the plot is viewed. (Try 5 for starters)

Optional replotting capability is allowed within each plot type, allowing the user to adjust the existing plot parameters of the current plot. After each plot is completed, the program pauses to allow the user to examine the results and/or obtain a hard copy. At this point, the user MUST enter a Carriage Return to proceed. The user may then elect to replot the data in the current form, select another plot type, or terminate the program by responding to the following prompt:

4.0. Enter: C for Current plot type.
: N for New plot type.

Enter C to adjust the existiog plot parameters and replot the data. When Current (C) is elected, the user will be asked to supply the plot parameters appropriate

for the current plot type as specified in parts 3.1, 3.2 or 3.3 above.

Enter N to select another plot type. When New (N) is elected, the prompt sequence will be restarted at 3.0 above. At this point, the user may continue with the graphics option or elect to terminate program execution by responding to the following question:

5.0. Do You Want Any More Plots ? Enter Y or N.

Enter Y to continue with graphics option.
Enter N to terminate program execution.

Proper termination of the program is indicated by the following message:

:: TABULAR RESULTS SENT TO FOR007 DEVICE

To run the program, enter the following commands:

```
$ASSIGN [directory]datafile.DAT  FOR001
$ASSIGN tabular output           FOR007
$RUN DSKA:[712.MASTER.XEQ]YPIB
```

REFERENCES:

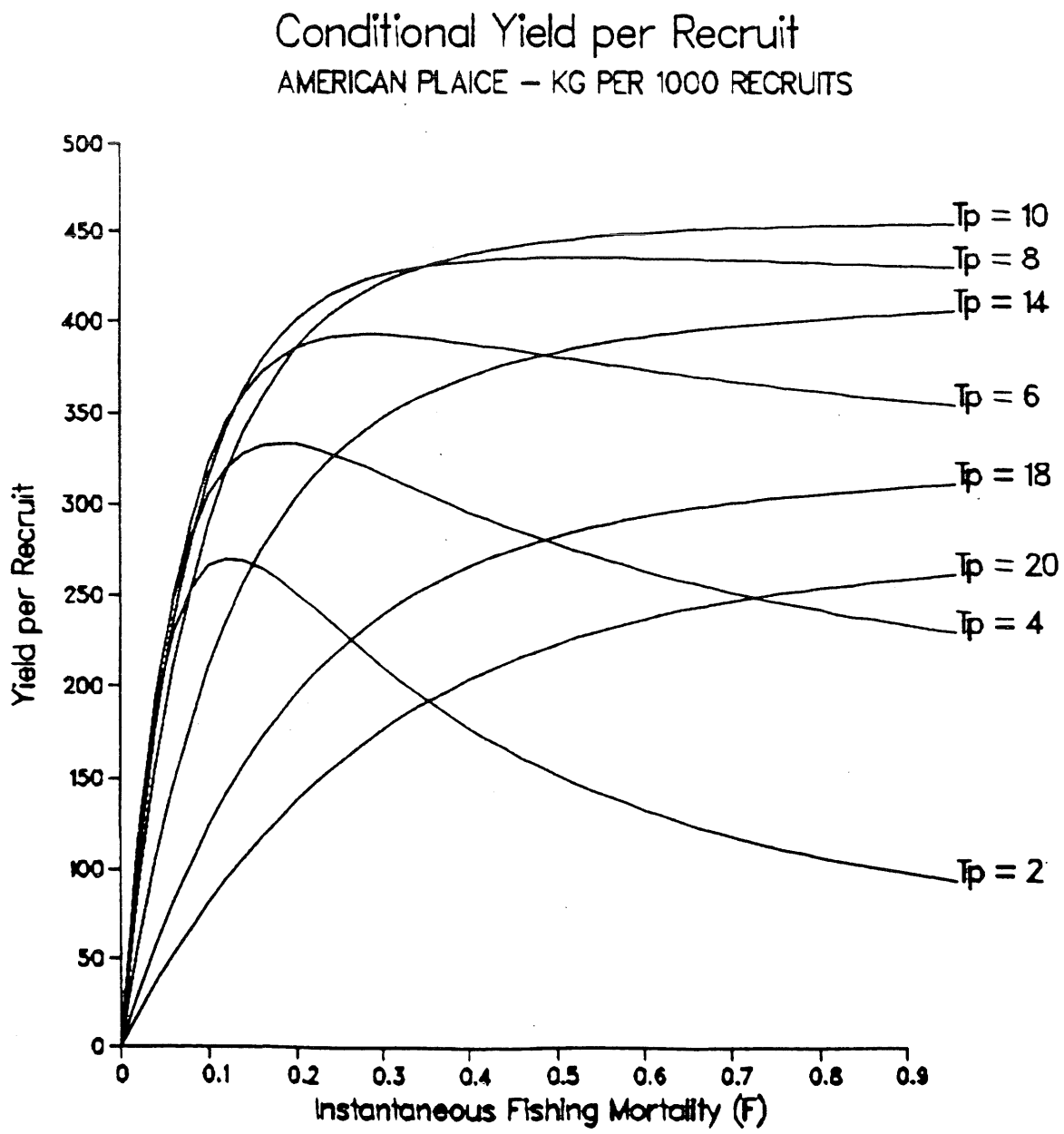
Paulik, G.J., and L.E. Gales. 1964. Allometric growth and the Beverton-Holt yield equation. Trans. Amer. Fish. Soc. 93 (4):369-381.

```
$ ASSIGN DSKA:[712.MASTER.DATA]YPIB.DAT  FOR001
$ ASSIGN SYS$INPUT FOR005
$ ASSIGN SYS$OUTPUT FOR006
$ ASSIGN YPIB.OUT FOR007
$ RUN DSKA:[712.MASTER.XEQ]YPIB
Do You Want to Plot Results ? Enter Y or N.
NO
:: TABULAR RESULTS SENT TO FOR007 DEVICE


$ TYPE YPIB.OUT
  YIELD PER RECRUIT USING INCOMPLETE BETA FUNCTION
  VERSION 2.1 23/II/84 L.E.GALES


*************************************************************************************************************
INPUT DATA
*************************************************************************************************************


    FO          TPPO        RANGE       UPPER       FDELT       DELTAT      DELTA       DDELTA
  0.0000E+00  0.2000E+01  0.9600E+00  0.2000E+02  0.2000E-01  0.1000E+01  0.3345E+01  0.0000E+00

    R           W           AM          AK          TP          TO          TLAMBA      XINTO
  0.1000E+04  0.2157E+01  0.1000E+00  0.1712E+00  0.1000E+01 -0.4400E-01  0.2400E+02  0.1630E-01


OUTPUT BLOCK WITH INITIAL DELTA=   3.3450
THE T IN THE FIRST COLUMN REPRESENTS DISTANCE ALONG THE T-AXIS (FOR THE BETA-INTEGRAL).
THE 49 NUMBERS OPPOSITE THE T-COLUMN ARE THE EVALUATIONS OF THE FUNCTION AT THE LATTICE POINTS (F,T)
WHERE F GOES FROM   0.0000 TO   0.9600

(T= 2.000)      0.00000E+00  0.11510E+03  0.18685E+03  0.23001E+03  0.25436E+03  0.26639E+03  0.27040E+03
                0.26928E+03  0.26493E+03  0.25862E+03  0.25119E+03  0.24320E+03  0.23500E+03  0.22684E+03
                0.21886E+03  0.21115E+03  0.20377E+03  0.19673E+03  0.19004E+03  0.18372E+03  0.17774E+03
                0.17209E+03  0.16676E+03  0.16173E+03  0.15698E+03  0.15250E+03  0.14826E+03  0.14426E+03
                0.14047E+03  0.13689E+03  0.13350E+03  0.13029E+03  0.12724E+03  0.12435E+03  0.12160E+03
                0.11899E+03  0.11650E+03  0.11414E+03  0.11188E+03  0.10973E+03  0.10768E+03  0.10572E+03
                0.10385E+03  0.10206E+03  0.10034E+03  0.98704E+02  0.97131E+02  0.95623E+02  0.94177E+02

(T= 3.000)      0.00000E+00  0.11625E+03  0.19212E+03  0.24067E+03  0.27075E+03  0.28835E+03  0.29755E+03
                0.30113E+03  0.30096E+03  0.29835E+03  0.29417E+03  0.28902E+03  0.28331E+03  0.27733E+03
                0.27125E+03  0.26521E+03  0.25928E+03  0.25352E+03  0.24797E+03  0.24263E+03  0.23751E+03
                0.23262E+03  0.22796E+03  0.22352E+03  0.21928E+03  0.21525E+03  0.21141E+03  0.20775E+03
                0.20426E+03  0.20094E+03  0.19778E+03  0.19475E+03  0.19187E+03  0.18912E+03  0.18649E+03
                0.18397E+03  0.18156E+03  0.17926E+03  0.17705E+03  0.17494E+03  0.17291E+03  0.17096E+03
                0.16910E+03  0.16730E+03  0.16557E+03  0.16391E+03  0.16232E+03  0.16078E+03  0.15930E+03
                    .            .            .
                    .            .            .
                    .            .            .
```

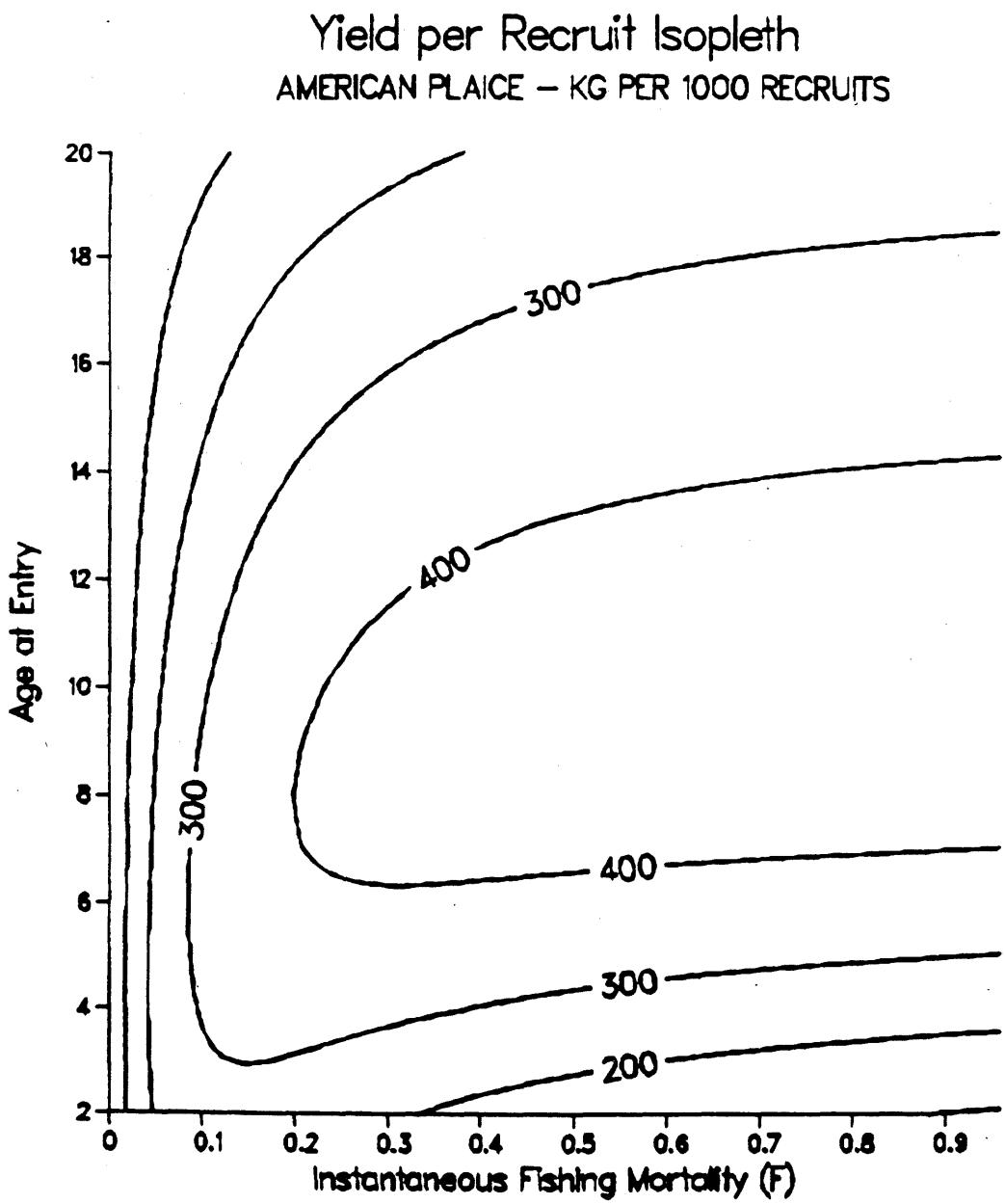
```
                    .            .            .
                    .            .            .
                    .            .            .
(T=18.000)     0.00000E+00  0.30431E+02  0.57705E+02  0.82164E+02  0.10411E+03  0.12381E+03  0.14152E+03
               0.15743E+03  0.17175E+03  0.18465E+03  0.19627E+03  0.20675E+03  0.21621E+03  0.22475E+03
               0.23248E+03  0.23948E+03  0.24583E+03  0.25158E+03  0.25681E+03  0.26157E+03  0.26590E+03
               0.26985E+03  0.27345E+03  0.27675E+03  0.27976E+03  0.28253E+03  0.28507E+03  0.28741E+03
               0.28956E+03  0.29155E+03  0.29338E+03  0.29508E+03  0.29666E+03  0.29812E+03  0.29948E+03
               0.30075E+03  0.30193E+03  0.30303E+03  0.30407E+03  0.30504E+03  0.30595E+03  0.30681E+03
               0.30762E+03  0.30838E+03  0.30911E+03  0.30979E+03  0.31044E+03  0.31105E+03  0.31164E+03

(T=19.000)     0.00000E+00  0.24481E+02  0.46796E+02  0.67143E+02  0.85703E+02  0.10264E+03  0.11810E+03
               0.13222E+03  0.14512E+03  0.15690E+03  0.16768E+03  0.17755E+03  0.18658E+03  0.19484E+03
               0.20242E+03  0.20937E+03  0.21574E+03  0.22159E+03  0.22697E+03  0.23191E+03  0.23645E+03
               0.24064E+03  0.24449E+03  0.24805E+03  0.25133E+03  0.25435E+03  0.25715E+03  0.25975E+03
               0.26214E+03  0.26437E+03  0.26643E+03  0.26835E+03  0.27013E+03  0.27179E+03  0.27333E+03
               0.27478E+03  0.27612E+03  0.27738E+03  0.27856E+03  0.27966E+03  0.28070E+03  0.28167E+03
               0.28258E+03  0.28345E+03  0.28426E+03  0.28502E+03  0.28575E+03  0.28643E+03  0.28708E+03

(T=20.000)     0.00000E+00  0.18897E+02  0.36424E+02  0.52684E+02  0.67770E+02  0.81771E+02  0.94767E+02
               0.10683E+03  0.11804E+03  0.12844E+03  0.13811E+03  0.14710E+03  0.15545E+03  0.16321E+03
               0.17043E+03  0.17715E+03  0.18340E+03  0.18922E+03  0.19464E+03  0.19969E+03  0.20439E+03
               0.20877E+03  0.21286E+03  0.21667E+03  0.22023E+03  0.22355E+03  0.22665E+03  0.22955E+03
               0.23226E+03  0.23479E+03  0.23716E+03  0.23938E+03  0.24146E+03  0.24340E+03  0.24523E+03
               0.24694E+03  0.24855E+03  0.25006E+03  0.25148E+03  0.25282E+03  0.25407E+03  0.25525E+03
               0.25637E+03  0.25742E+03  0.25841E+03  0.25934E+03  0.26023E+03  0.26106E+03  0.26185E+03
```

```
$ TYPE DSKA:[712.MASTER.DATA]YPIB.DAT
0.0,2.,0.96,20.,.02,1.,3.345,0.
1000.,2.157,.1,.1712,1.,-.0440,24.,.0163
```

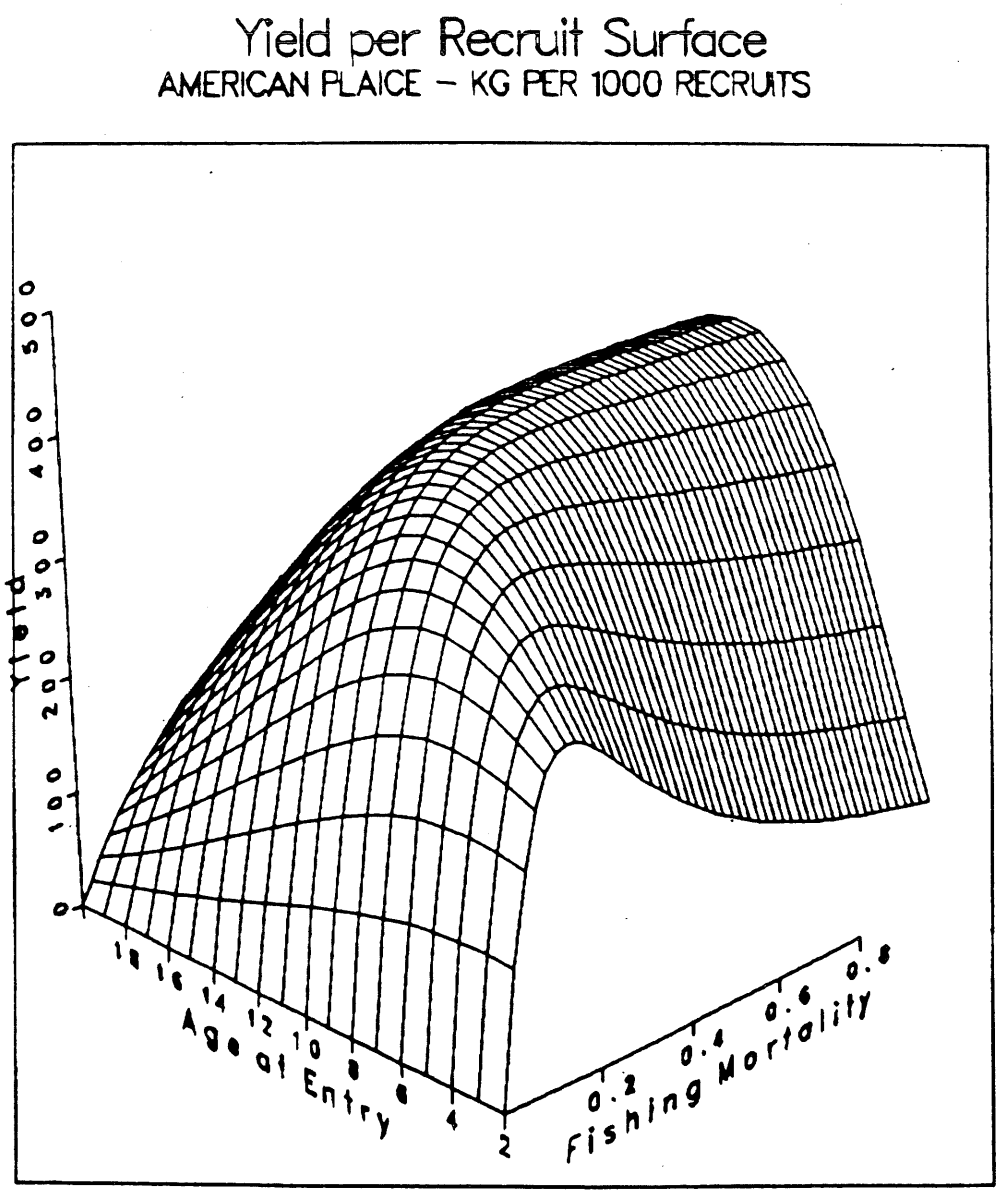
```
$ RUN DSKA:[712.MASTER.XEQ]YPIB.EXE

Do You Want to Plot Results ? Enter Y or N.
Y
Enter Descriptive Label (LE. 64 Characters).
AMERICAN PLAICE - KG PER 1000 RECRUITS
Enter : COND for Conditional Curves
      : ISOP for Isopleths
      : 3DEE for 3 Dimensional Plots
COND
Enter X Axis Increment of F.
0.1
Enter Minimum YPR, Maximum YPR, Increment of YPR.
0,500,50
How Many Curves Do You Want to Plot ?
8
Enter  8 Ages Between  2 and 20
2,4,6,8,10,14,18,20
```



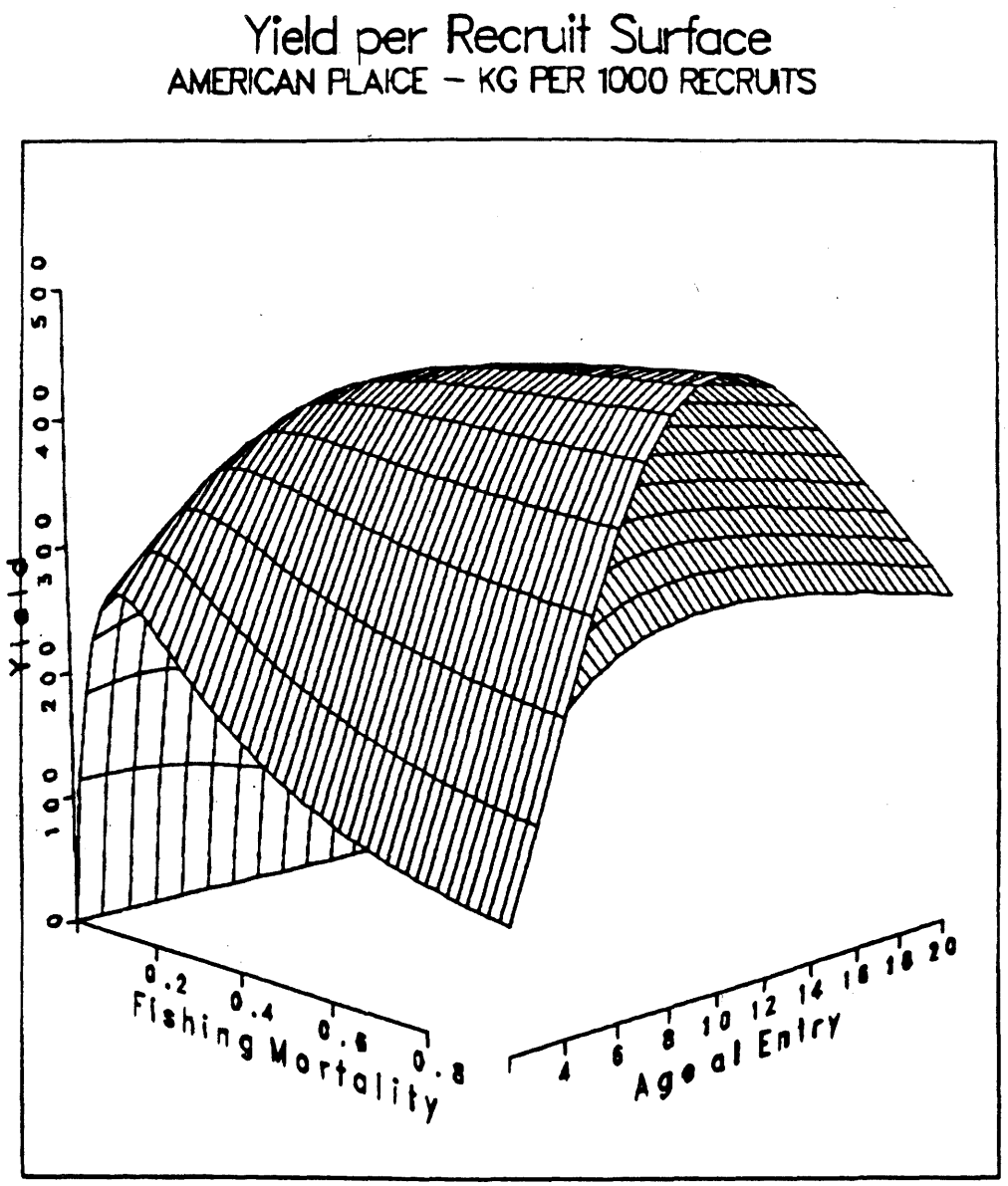
```
Enter : C for Current plot type
      : N for New plot type
N

Do You Want Any More Plots ? Enter Y or N.
Y
Enter : COND for Conditional Curves
      : ISOP for Isopleths
      : 3DEE for 3 Dimensional Plots
ISOP
Enter X Axis Increment of F.
0.1
Enter Y Axis Increment of Tp.
2
Enter Contour Resolution (YPR Units).
100
```



```
Enter : C for Current plot type
      : N for New plot type
N

Do You Want Any More Plots ? Enter Y or N.
Y
Enter : COND for Conditional Curves
      : ISOP for Isopleths
      : 3DEE for 3 Dimensional Plots
3DEE
Enter X Axis Increment of F.
0.2
Enter Y Axis Increment of Tp.
2
Enter Minimum YPR, Maximum YPR, Increment of YPR.
0,500,100
Enter X-Y View Angle, Z View Angle, View Distance.
-135,20,5
```



```
Enter : C for Current plot type
      : N for New plot type
C

Enter X-Y View Angle, Z View Angle, View Distance.
-45,10,5
```




```
Enter : C for Current plot type
      : N for New plot type
N

Do You Want Any More Plots ? Enter Y or N.
N
:: TABULAR RESULTS SENT TO FOR007 DEVICE
$
```

PROGRAM NAME: Relative yield per recruit isopleth generator

PROGRAM TYPE: Main

DATE CREATED: Jan 1 1974

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]YPER.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]YPER.EXE

AUTHOR: W.H. Lenarz

DOCUMENTED BY: F.P Almeida

REVISIONS (Date/Reviser - Description)

Sep 21 1983 /F.P. Almeida -
Converted to FORTRAN77 to run on VAX 11/780

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

The program uses a modification of the Beverton-Holt yield equation to produce relative yield per recruit isopleths for different E (F/F+M) and C (lc/l(infinity)) values as a function of M and K.

DESCRIPTION:

Yield isopleths are computed as a function of 3 M/K values specified by the user to cover the range of conditions under consideration. The program utilizes the modified form of the Beverton-Holt yield equation (Gulland 1969) to produce relative yield per recruit isopleths for different E and C values where:

E = exploitation rate, F/F+M and
C = lc/l(infinity) ,lc being the mean selection length at age tp´ = tc.

Thus, C is the proportion of the total growth in length made before the fish enters the exploited phase.

It generates tables of optimal length at first capture produced at specified l(infinity) values. Note that the parameter C (vertical axis) decreases from the top of the page to the foot; in consequence, each page represents the numerical equivalent of the yield-isopleth diagram for the M/K value specified. The model assumes constant fishing mortality over the fishable lifespan with ´knife-edge´ selection and a value of

3.0 for b in the length-weight equation.

The equation is:

$$Y' = E(1-c)^{M/K} \sum_{o}^{3} \frac{U_n(1-c)^n}{1 + nK/_M \ (1-E)}$$

where Y' = relative yield value independent of units
E = F/F+M (instantaneous fishing and natural mortality coefficients)
c = lc/l(infinity)
K = coefficient of catabolism, and
Un = summation variable, using 1,-3,3,-1 for n = 0,1,2,3 respectively.

Y' may be converted to weight units (ie. gm per recruit at age tp (=tr) by multiplying by $W_\infty e^{M(t_r-t_o)}$ and from this to absolute yield Y by multiplying by R = number of recruits at age tr. Such conversions should be unnecessary for most applications.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

For each series of isopleths desired, the program needs a title record with alphanumeric information identifying the run followed by a control record and parameter records. As many data sets as desired may be read; two blank records following the last data set will terminate the program normally. Data records are required as follows:

Record Number	Record Description
1	Title (maximim of 80 bytes)
2	Lowest exploitation rate on isopleth (with decimal point) (suggest 0.05), Increment size for exploitation rates on isopleths (suggest 0.05), Largest c value on isopleth (suggest 1.0), Increment size for c values on isopleths (suggest 0.02), Number of different M/K values for optimum length tables (less than or equal to 10), Number of different E values for optimum length tables (less than or equal to 10), Scaling factor for isopleths, set at: 5. M/K <3 6. 3≤ M/K ≤10 7. 10≤ M/K (default = 5.)
3	Low, best, and high M/K, low, best, and high L(infinity)
4	M/K record; M/K values for optimum length tables
5	E record; E values for optimum length tables

Input is free formatted, data values should be separated by commas. Program output requires a wide carriage terminal. To run the program, simply type:

```
$RUN FSHA:[712.MASTER.XEQ]YPER
```

and you will be prompted for values, or create a data file with the above data and use:

```
$ASSIGN datafile.DAT FOR005
$RUN FSHA:[712.MASTER.XEQ]YPER
```

REFERENCES:

Lenarz, W.H., W.W. Fox, Jr., G.T. Sakagawa, and B.J. Rothschild 1974. An estimation of the yield per recruit basis for a minimum size regulation for Atlantic yellowfin tuna, Thunnis albacares. Fish. Bull. 72(1):37-61.

Gulland, J.A. 1969. Manual of methods for fish stock assessment. F.A.O. Manual in Fishery Science #4.

```
$ RUN [712.MASTER.XEQ]YPER
   *This program"s output requires a wide carriage*

   Relative Yield per Recruit Isopleth Generator    Version 2.1  21/IX/83  W.H. Lenarz

 Input title (maximum of 80 bytes)                              : TEST RUN - DICKIE-MCCRAKEN WINTER FLOUNDER DATA
 Input lowest exploitation rate, exploitation rate increment,
  largest c value, c value increment,
  number of M/K values for optimum length tables,
  number of E values for optimum length tables,
  and isopleth scaling factor (exponent of 10)                  : .05,.05,1,.02,8,8,5
 Input low, best, and high M/K                                  : .3,.625,.9
 Input low, best, and high L(infinity)                          : 45,50,55
```

TEST RUN - DICKIE-MCCRAKEN WINTER FLOUNDER DATA

RELATIVE YIELD-PER-RECRUIT ISOPLETH (10**-5.)

M/K = 0.3000

EXPLOITATION RATE

C	0.050	0.100	0.150	0.200	0.250	0.300	0.350	0.400	0.450	0.500	0.550	0.600	0.650	0.700	0.750	0.800	0.850	0.900	0.950	1.000
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.980	1524	3047	4567	6085	7600	9112	10621	12126	13625	15119	16606	18084	19552	21007	22445	23862	25250	26600	27894	29106
0.960	1850	3696	5536	7371	9199	11020	12832	14635	16425	18201	19960	21699	23412	25094	26737	28327	29850	31279	32578	33685
0.940	2060	4113	6157	8192	10216	12227	14224	16204	18164	20101	22009	23883	25716	27496	29211	30840	32357	33720	34871	35713
0.920	2215	4419	6611	8789	10952	13096	15220	17320	19391	21429	23427	25376	27265	29080	30801	32401	33842	35068	35995	36500
0.900	2336	4657	6962	9250	11517	13760	15976	18160	20307	22410	24459	26445	28352	30163	31850	33380	34703	35747	36409	36537
0.880	2433	4849	7245	9618	11965	14283	16567	18811	21009	23151	25228	27225	29124	30903	32530	33961	35138	35973	36343	36075
0.860	2514	5007	7476	9918	12329	14704	17038	19324	21554	23718	25803	27793	29665	31393	32940	34254	35264	35872	35935	35264
0.840	2582	5139	7668	10165	12626	15045	17416	19731	21980	24152	26231	28199	30030	31693	33145	34327	35158	35527	35275	34204
0.820	2640	5251	7830	10372	12872	15324	17721	20054	22312	24480	26543	28478	30257	31844	33191	34230	34873	34995	34426	32963
0.800	2689	5346	7966	10544	13075	15553	17967	20309	22566	24723	26761	28654	30373	31876	33109	33999	34448	34319	33435	31592
0.780	2731	5427	8081	10689	13244	15739	18164	20509	22759	24897	26902	28748	30399	31811	32925	33660	33911	33532	32336	30131
0.760	2768	5496	8179	10811	13384	15891	18321	20662	22899	25012	26980	28772	30351	31667	32657	33235	33286	32657	31158	28609
0.740	2800	5556	8262	10913	13499	16013	18443	20776	22995	25079	27005	28739	30241	31459	32322	32740	32591	31716	29922	27051
0.720	2827	5607	8333	10998	13594	16111	18536	20857	23054	25106	26985	28658	30080	31196	31931	32189	31842	30725	28646	25477
0.700	2851	5651	8392	11068	13670	16186	18605	20909	23081	25097	26928	28537	29877	30889	31495	31593	31049	29696	27345	23902
0.680	2872	5688	8442	11127	13731	16244	18652	20938	23082	25059	26839	28382	29639	30546	31023	30961	30225	28642	26033	22339
0.660	2890	5720	8485	11174	13778	16285	18680	20945	23060	24997	26723	28199	29371	30173	30521	30302	29376	27572	24717	20801
0.640	2905	5747	8519	11212	13814	16313	18693	20935	23018	24912	26585	27992	29079	29776	29995	29622	28512	26494	23409	19294
0.620	2918	5771	8548	11242	13840	16328	18692	20910	22959	24810	26427	27765	28766	29360	29452	28927	27637	25414	22114	17828
0.600	2930	5790	8571	11264	13856	16334	18679	20871	22886	24693	26254	27522	28438	28928	28896	28222	26758	24339	20839	16409
0.580	2940	5806	8590	11281	13866	16330	18655	20821	22801	24562	26067	27266	28097	28484	28330	27511	25879	23274	19590	15040
0.560	2948	5819	8604	11291	13868	16318	18623	20761	22705	24421	25869	26999	27746	28033	27758	26798	25005	22223	18371	13728
0.540	2955	5830	8615	11297	13865	16300	18584	20694	22601	24271	25663	26724	27388	27575	27183	26086	24138	21190	17185	12474
0.520	2961	5839	8622	11299	13856	16276	18538	20619	22489	24114	25450	26442	27024	27114	26607	25378	23281	20178	16037	11282
0.500	2966	5845	8627	11297	13843	16247	18487	20538	22372	23951	25231	26156	26658	26652	26034	24677	22438	19189	14928	10153
0.480	2970	5850	8629	11293	13827	16213	18431	20453	22250	23783	25008	25866	26289	26191	25465	23985	21611	18227	13860	9089
0.460	2974	5854	8629	11285	13807	16176	18371	20364	22124	23612	24782	25575	25921	25732	24901	23303	20802	17292	12836	8091
0.440	2976	5856	8627	11275	13785	16136	18308	20272	21995	23439	24555	25284	25554	25276	24344	22633	20011	16387	11857	7158
0.420	2978	5857	8623	11263	13760	16094	18242	20177	21864	23264	24327	24993	25189	24826	23796	21977	19241	15513	10923	6292
0.400	2980	5857	8618	11249	13733	16050	18175	20080	21732	23088	24099	24704	24828	24382	23258	21335	18493	14670	10036	5491
0.380	2981	5856	8612	11234	13705	16004	18106	19982	21598	22912	23872	24417	24471	23945	22731	20709	17768	13861	9196	4754
0.360	2982	5855	8605	11218	13676	15956	18036	19884	21465	22737	23647	24133	24120	23516	22215	20100	17066	13084	8403	4081
0.340	2982	5852	8597	11201	13645	15908	17965	19785	21332	22562	23424	23853	23774	23095	21711	19508	16388	12341	7656	3470
0.320	2982	5850	8589	11183	13614	15860	17894	19686	21199	22390	23204	23577	23434	22683	21220	18934	15735	11633	6956	2919
0.300	2982	5847	8580	11164	13582	15811	17823	19588	21068	22219	22986	23306	23102	22281	20742	18378	15107	10957	6302	2426
0.280	2982	5843	8570	11146	13550	15761	17752	19490	20938	22050	22773	23041	22776	21889	20278	17840	14503	10316	5694	1989
0.260	2981	5840	8560	11126	13518	15712	17681	19393	20810	21885	22563	22780	22458	21507	19828	17321	13925	9708	5129	1606
0.240	2981	5836	8550	11107	13486	15663	17612	19298	20683	21722	22358	22526	22148	21136	19392	16821	13371	9133	4608	1273
0.220	2980	5832	8540	11088	13454	15615	17543	19204	20559	21562	22156	22277	21846	20776	18970	16339	12842	8591	4128	988
0.200	2979	5827	8530	11068	13422	15567	17475	19111	20437	21405	21960	22034	21552	20426	18562	15876	12338	8081	3689	748
0.180	2978	5823	8519	11049	13390	15520	17408	19020	20318	21252	21768	21798	21267	20087	18168	15431	11857	7601	3289	550
0.160	2977	5819	8509	11030	13359	15473	17342	18931	20200	21102	21580	21568	20989	19759	17788	15005	11400	7151	2927	389
0.140	2976	5815	8499	11011	13329	15427	17277	18844	20086	20956	21398	21344	20720	19441	17422	14596	10966	6731	2600	262
0.120	2975	5810	8489	10992	13299	15382	17214	18758	19974	20814	21220	21127	20459	19134	17070	14205	10553	6339	2307	166
0.100	2974	5806	8479	10974	13269	15338	17152	18675	19865	20675	21047	20915	20206	18838	16731	13830	10163	5973	2045	97
0.080	2973	5802	8469	10956	13240	15295	17091	18593	19758	20539	20878	20710	19961	18551	16404	13472	9793	5633	1812	50
0.060	2972	5798	8460	10938	13212	15253	17032	18513	19655	20407	20715	20511	19724	18274	16090	13130	9442	5317	1607	21
0.040	2971	5794	8450	10921	13184	15212	16975	18436	19553	20279	20555	20318	19494	18007	15789	12802	9111	5024	1427	6
0.020	2970	5790	8441	10904	13157	15172	16918	18360	19455	20154	20401	20130	19271	17749	15498	12490	8797	4752	1269	1

TEST RUN - DICKIE-MCCRAKEN WINTER FLOUNDER DATA

RELATIVE YIELD-PER-RECRUIT ISOPLETH (10**-5.)

M/K = 0.6250

EXPLOITATION RATE

C	0.050	0.100	0.150	0.200	0.250	0.300	0.350	0.400	0.450	0.500	0.550	0.600	0.650	0.700	0.750	0.800	0.850	0.900	0.950	1.000
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.980	423	846	1268	1689	2110	2529	2947	3364	3780	4194	4606	5016	5423	5828	6230	6628	7021	7409	7790	8162
0.960	638	1273	1907	2538	3166	3791	4413	5031	5645	6254	6857	7454	8044	8626	9198	9758	10305	10835	11346	11833
0.940	802	1601	2395	3185	3969	4748	5520	6285	7042	7790	8527	9253	9965	10661	11339	11995	12626	13227	13792	14313
0.920	938	1870	2795	3713	4623	5523	6414	7294	8160	9013	9849	10667	11464	12236	12979	13690	14362	14987	15557	16062
0.900	1053	2098	3133	4158	5171	6172	7158	8129	9081	10014	10924	11808	12662	13482	14263	14997	15677	16293	16835	17287
0.880	1153	2294	3423	4539	5639	6722	7787	8830	9851	10844	11808	12738	13629	14475	15269	16004	16668	17250	17736	18111
0.860	1240	2465	3675	4868	6041	7194	8322	9425	10497	11537	12539	13498	14408	15263	16053	16769	17398	17926	18337	18613
0.840	1317	2616	3896	5155	6390	7600	8781	9929	11042	12115	13141	14116	15032	15881	16652	17333	17911	18369	18690	18854
0.820	1385	2748	4089	5405	6693	7950	9173	10358	11501	12595	13635	14615	15524	16355	17094	17729	18243	18619	18837	18879
0.800	1445	2865	4259	5624	6956	8253	9509	10721	11884	12991	14036	15010	15903	16705	17402	17980	18420	18704	18811	18725
0.780	1499	2969	4409	5816	7185	8513	9796	11028	12203	13315	14355	15315	16184	16949	17595	18107	18465	18650	18640	18420
0.760	1546	3061	4541	5983	7383	8737	10039	11284	12465	13574	14604	15543	16379	17100	17688	18127	18397	18476	18345	17992
0.740	1589	3142	4657	6129	7554	8927	10243	11495	12676	13777	14789	15701	16499	17169	17694	18055	18231	18201	17947	17460
0.720	1627	3214	4759	6256	7701	9089	10414	11668	12843	13931	14920	15799	16554	17168	17624	17903	17981	17840	17462	16845
0.700	1661	3278	4848	6366	7827	9225	10554	11805	12970	14039	15001	15843	16550	17105	17489	17681	17660	17406	16905	16162
0.680	1691	3334	4926	6461	7934	9338	10666	11911	13062	14109	15040	15841	16496	16987	17295	17399	17277	16911	16289	15426
0.660	1717	3383	4993	6542	8023	9430	10755	11989	13122	14144	15040	15796	16397	16822	17053	17067	16843	16365	15627	14649
0.640	1741	3426	5051	6610	8097	9503	10821	12042	13155	14147	15006	15716	16259	16616	16767	16691	16366	15778	14927	13843
0.620	1761	3464	5101	6668	8156	9560	10868	12073	13162	14124	14942	15603	16087	16375	16445	16278	15853	15158	14199	13018
0.600	1780	3496	5143	6715	8204	9601	10898	12084	13148	14076	14852	15462	15885	16103	16093	15835	15311	14513	13453	12183
0.580	1796	3524	5179	6753	8240	9629	10912	12078	13114	14006	14740	15297	15658	15804	15714	15367	14747	13849	12694	11345
0.560	1810	3548	5208	6784	8266	9645	10913	12056	13063	13918	14606	15110	15410	15485	15314	14879	14166	13174	11930	10513
0.540	1822	3568	5232	6807	8283	9651	10901	12020	12996	13814	14456	14906	15143	15147	14897	14376	13572	12491	11166	9692
0.520	1832	3585	5251	6823	8291	9647	10878	11972	12916	13695	14291	14686	14860	14794	14467	13862	12972	11806	10409	8888
0.500	1841	3599	5266	6834	8293	9634	10845	11913	12825	13564	14113	14453	14566	14430	14026	13341	12368	11124	9662	8105
0.480	1849	3610	5277	6839	8289	9614	10804	11846	12724	13422	13924	14211	14261	14057	13579	12816	11765	10449	8931	7349
0.460	1855	3619	5284	6840	8278	9588	10756	11770	12614	13272	13727	13959	13949	13678	13129	12290	11166	9784	8218	6622
0.440	1861	3626	5288	6837	8263	9556	10702	11687	12497	13115	13523	13702	13632	13296	12677	11767	10574	9133	7528	5929
0.420	1865	3631	5289	6830	8244	9519	10642	11599	12374	12952	13313	13439	13311	12911	12226	11249	9992	8498	6863	5271
0.400	1868	3634	5288	6820	8221	9477	10577	11506	12247	12784	13100	13174	12989	12528	11778	10737	9422	7882	6225	4651
0.380	1871	3635	5284	6808	8194	9433	10509	11409	12116	12613	12883	12907	12667	12146	11335	10235	8866	7287	5617	4070
0.360	1873	3636	5279	6793	8165	9385	10438	11309	11982	12440	12666	12640	12346	11768	10900	9743	8327	6715	5040	3530
0.340	1874	3635	5272	6776	8134	9335	10364	11206	11846	12266	12448	12374	12028	11396	10472	9265	7805	6168	4496	3031
0.320	1875	3633	5264	6757	8101	9283	10288	11102	11709	12091	12230	12110	11713	11029	10054	8799	7302	5646	3986	2575
0.300	1876	3631	5255	6738	8067	9229	10211	10997	11571	11916	12014	11848	11404	10671	9648	8350	6820	5152	3511	2160
0.280	1876	3627	5245	6717	8031	9175	10134	10892	11434	11743	11800	11591	11100	10321	9253	7916	6360	4685	3070	1788
0.260	1876	3624	5234	6695	7994	9119	10055	10787	11298	11571	11589	11338	10804	9980	8870	7499	5921	4246	2665	1456
0.240	1875	3619	5222	6672	7957	9064	9977	10682	11162	11401	11382	11090	10514	9649	8501	7099	5505	3837	2294	1164
0.220	1874	3615	5210	6650	7920	9008	9899	10578	11029	11234	11179	10848	10233	9329	8146	6718	5112	3455	1958	912
0.200	1874	3610	5198	6626	7883	8953	9822	10476	10897	11070	10980	10613	9960	9020	7806	6355	4742	3103	1657	696
0.180	1872	3605	5185	6603	7845	8898	9746	10375	10768	10910	10786	10384	9695	8722	7480	6011	4395	2778	1388	515
0.160	1871	3599	5173	6580	7808	8843	9671	10275	10641	10753	10597	10161	9440	8436	7169	5685	4072	2482	1151	367
0.140	1870	3594	5160	6557	7771	8790	9597	10178	10518	10601	10414	9946	9194	8162	6873	5377	3771	2212	944	250
0.120	1869	3589	5148	6534	7735	8737	9524	10083	10397	10453	10236	9739	8957	7899	6591	5088	3492	1968	767	160
0.100	1868	3583	5135	6512	7700	8685	9454	9990	10280	10309	10064	9538	8730	7648	6324	4817	3234	1749	616	94
0.080	1866	3578	5123	6490	7665	8635	9385	9900	10166	10169	9898	9345	8511	7409	6072	4563	2997	1554	490	49
0.060	1865	3572	5111	6468	7631	8585	9317	9812	10055	10034	9737	9159	8302	7182	5833	4326	2780	1380	387	21
0.040	1864	3567	5099	6447	7597	8537	9251	9726	9947	9903	9582	8980	8102	6965	5608	4105	2581	1228	304	6
0.020	1862	3562	5088	6426	7565	8490	9187	9643	9843	9776	9432	8809	7911	6759	5395	3899	2399	1093	239	1

TEST RUN - DICKIE-MCCRAKEN WINTER FLOUNDER DATA

RELATIVE YIELD-PER-RECRUIT ISOPLETH (10**-5.)

M/K = 0.9000

EXPLOITATION RATE

C	0.050	0.100	0.150	0.200	0.250	0.300	0.350	0.400	0.450	0.500	0.550	0.600	0.650	0.700	0.750	0.800	0.850	0.900	0.950	1.000
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.980	144	287	430	573	716	858	1000	1141	1282	1423	1563	1702	1841	1979	2116	2252	2387	2521	2653	2784
0.960	260	520	778	1036	1292	1547	1801	2053	2304	2553	2800	3045	3287	3527	3763	3996	4225	4450	4669	4883
0.940	364	726	1086	1444	1800	2153	2504	2851	3195	3535	3871	4202	4528	4849	5163	5470	5768	6058	6336	6603
0.920	458	913	1364	1812	2256	2695	3130	3559	3983	4401	4811	5214	5608	5993	6366	6728	7076	7409	7724	8019
0.900	544	1082	1616	2144	2667	3183	3691	4192	4685	5168	5640	6101	6550	6984	7402	7802	8183	8541	8873	9178
0.880	622	1237	1845	2446	3039	3622	4196	4758	5309	5848	6371	6879	7370	7840	8290	8714	9112	9480	9813	10109
0.860	694	1379	2054	2720	3375	4018	4648	5264	5865	6449	7014	7558	8080	8576	9044	9481	9883	10246	10567	10840
0.840	759	1508	2245	2969	3679	4375	5054	5716	6358	6979	7576	8148	8691	9202	9678	10116	10511	10858	11153	11391
0.820	820	1626	2418	3194	3954	4696	5417	6117	6793	7443	8065	8655	9211	9728	10203	10632	11009	11330	11589	11781
0.800	875	1734	2576	3399	4202	4983	5741	6472	7176	7848	8486	9088	9648	10163	10628	11039	11390	11675	11889	12028
0.780	925	1832	2719	3583	4424	5240	6028	6785	7509	8197	8846	9451	10009	10514	10962	11347	11664	11906	12068	12147
0.760	972	1921	2848	3750	4624	5468	6281	7058	7798	8496	9148	9751	10300	10789	11212	11565	11841	12034	12138	12152
0.740	1014	2003	2965	3899	4801	5670	6503	7295	8045	8747	9398	9993	10526	10993	11387	11702	11931	12068	12110	12055
0.720	1052	2076	3071	4032	4959	5848	6695	7498	8253	8955	9599	10181	10694	11134	11492	11764	11941	12020	11996	11870
0.700	1087	2143	3165	4151	5098	6003	6861	7671	8426	9123	9756	10320	10809	11216	11535	11758	11881	11897	11805	11607
0.680	1119	2203	3250	4256	5220	6136	7003	7814	8566	9254	9872	10414	10874	11245	11520	11693	11757	11709	11547	11276
0.660	1147	2256	3325	4349	5325	6251	7121	7931	8676	9351	9950	10467	10894	11226	11454	11573	11577	11462	11230	10888
0.640	1173	2304	3391	4430	5416	6347	7218	8024	8759	9418	9994	10482	10874	11163	11342	11405	11346	11164	10863	10452
0.620	1196	2347	3449	4500	5494	6427	7296	8094	8816	9456	10007	10463	10817	11061	11189	11194	11072	10823	10453	9977
0.600	1217	2385	3500	4560	5558	6492	7355	8143	8849	9468	9992	10414	10727	10925	10999	10945	10760	10445	10008	9469
0.580	1235	2418	3544	4610	5611	6543	7399	8174	8862	9456	9951	10337	10608	10757	10777	10664	10416	10035	9534	8937
0.560	1252	2447	3582	4653	5654	6580	7427	8187	8855	9424	9886	10235	10462	10562	10527	10355	10044	9600	9038	8388
0.540	1266	2472	3614	4687	5686	6606	7441	8185	8831	9372	9802	10111	10294	10343	10253	10022	9650	9145	8526	7828
0.520	1279	2494	3640	4714	5710	6622	7444	8169	8792	9304	9698	9968	10105	10104	9959	9669	9237	8674	8003	7263
0.500	1290	2512	3662	4735	5725	6627	7434	8140	8738	9220	9579	9808	9899	9847	9648	9301	8812	8194	7474	6699
0.480	1299	2527	3679	4750	5733	6624	7415	8100	8672	9123	9446	9633	9678	9576	9323	8921	8377	7707	6944	6139
0.460	1307	2540	3692	4759	5735	6613	7387	8050	8595	9014	9300	9446	9445	9293	8988	8532	7935	7218	6417	5590
0.440	1314	2550	3702	4764	5730	6595	7351	7991	8509	8895	9144	9248	9201	9001	8645	8137	7492	6731	5898	5055
0.420	1320	2558	3708	4764	5721	6571	7308	7925	8414	8768	8979	9042	8950	8702	8296	7740	7049	6250	5389	4538
0.400	1325	2564	3711	4760	5706	6541	7259	7852	8312	8633	8807	8829	8693	8398	7945	7343	6609	5776	4895	4041
0.380	1329	2568	3711	4753	5688	6507	7204	7773	8205	8493	8630	8611	8433	8092	7594	6949	6176	5314	4417	3569
0.360	1332	2570	3709	4743	5665	6468	7145	7689	8092	8348	8449	8390	8170	7786	7245	6559	5752	4865	3959	3122
0.340	1334	2571	3706	4731	5640	6426	7083	7602	7976	8199	8264	8167	7906	7481	6899	6176	5339	4432	3523	2704
0.320	1336	2571	3700	4716	5612	6382	7017	7511	7857	8048	8078	7944	7643	7179	6559	5802	4938	4017	3111	2316
0.300	1337	2570	3693	4699	5582	6334	6949	7419	7736	7896	7892	7721	7382	6881	6226	5438	4553	3622	2724	1959
0.280	1337	2568	3684	4681	5550	6285	6879	7324	7614	7743	7706	7500	7125	6588	5901	5087	4183	3248	2363	1633
0.260	1338	2565	3675	4661	5517	6235	6808	7229	7492	7591	7521	7281	6873	6303	5586	4748	3831	2896	2031	1340
0.240	1337	2561	3664	4640	5483	6183	6736	7134	7370	7439	7339	7066	6626	6025	5282	4424	3497	2567	1726	1080
0.220	1337	2557	3653	4619	5447	6131	6664	7038	7248	7290	7159	6856	6385	5757	4989	4115	3182	2262	1449	851
0.200	1336	2552	3642	4597	5412	6079	6592	6943	7128	7142	6983	6651	6152	5497	4709	3822	2887	1981	1201	654
0.180	1335	2547	3630	4575	5376	6027	6520	6850	7010	6998	6811	6452	5926	5248	4442	3545	2613	1725	982	488
0.160	1334	2542	3617	4552	5340	5975	6449	6757	6894	6857	6644	6258	5709	5010	4188	3285	2359	1492	789	350
0.140	1333	2537	3605	4530	5305	5924	6379	6667	6781	6719	6481	6072	5500	4782	3949	3042	2125	1284	624	240
0.120	1332	2532	3592	4507	5270	5873	6311	6578	6670	6585	6324	5892	5300	4566	3723	2816	1911	1099	483	154
0.100	1331	2526	3580	4485	5235	5823	6244	6491	6563	6456	6173	5720	5109	4361	3511	2606	1717	936	367	91
0.080	1329	2521	3568	4463	5201	5775	6178	6407	6458	6331	6027	5555	4927	4168	3312	2413	1542	794	273	48
0.060	1328	2515	3556	4442	5168	5727	6115	6326	6357	6210	5887	5397	4754	3985	3127	2236	1386	672	199	20
0.040	1327	2510	3544	4421	5136	5681	6053	6246	6260	6094	5753	5246	4590	3813	2955	2073	1246	569	142	6
0.020	1325	2505	3532	4401	5104	5636	5993	6170	6166	5982	5624	5102	4435	3652	2795	1925	1122	482	101	1

Input M/K values for optimum length tables
.3, .4, .5, .6, .7, .8, .9, 1
Input E values for optimum length tables
.44, .62, .71, .76, .80, .83, .85, .86

TABLE OF OPTIMUM LENGTHS AT FIRST CAPTURE RELATIVE TO L(INFINITY)

EXPLOITATION RATE

M/K	0.440	0.620	0.710	0.760	0.800	0.830	0.850	0.860
0.300	0.684	0.771	0.808	0.827	0.842	0.853	0.860	0.863
0.400	0.662	0.747	0.784	0.803	0.817	0.828	0.835	0.838
0.500	0.642	0.725	0.761	0.779	0.794	0.804	0.811	0.814
0.600	0.623	0.704	0.739	0.757	0.771	0.781	0.788	0.791
0.700	0.605	0.685	0.719	0.737	0.750	0.760	0.767	0.770
0.800	0.588	0.666	0.700	0.717	0.731	0.740	0.746	0.749
0.900	0.572	0.649	0.682	0.699	0.712	0.721	0.727	0.730
1.000	0.557	0.632	0.665	0.681	0.694	0.703	0.709	0.712

TABLE OF OPTIMUM LENGTHS AT FIRST CAPTURE -- L(INFINITY) = 0.450000E+02

	EXPLOITATION RATE							
M/K	0.44	0.62	0.71	0.76	0.80	0.83	0.85	0.86
0.300	30.78	34.69	36.36	37.21	37.89	38.38	38.70	38.83
0.400	29.79	33.61	35.28	36.13	36.76	37.26	37.57	37.71
0.500	28.89	32.62	34.24	35.05	35.73	36.18	36.49	36.63
0.600	28.03	31.68	33.25	34.06	34.69	35.14	35.46	35.59
0.700	27.22	30.82	32.35	33.16	33.75	34.20	34.51	34.65
0.800	26.46	29.97	31.50	32.26	32.89	33.30	33.57	33.70
0.900	25.74	29.20	30.69	31.45	32.04	32.44	32.71	32.85
1.000	25.06	28.44	29.92	30.64	31.23	31.63	31.90	32.04

TABLE OF OPTIMUM LENGTHS AT FIRST CAPTURE -- L(INFINITY) = 0.500000E+02

	EXPLOITATION RATE							
M/K	0.44	0.62	0.71	0.76	0.80	0.83	0.85	0.86
0.300	34.20	38.55	40.40	41.35	42.10	42.65	43.00	43.15
0.400	33.10	37.35	39.20	40.15	40.85	41.40	41.75	41.90
0.500	32.10	36.25	38.05	38.95	39.70	40.20	40.55	40.70
0.600	31.15	35.20	36.95	37.85	38.55	39.05	39.40	39.55
0.700	30.25	34.25	35.95	36.85	37.50	38.00	38.35	38.50
0.800	29.40	33.30	35.00	35.85	36.55	37.00	37.30	37.45
0.900	28.60	32.45	34.10	34.95	35.60	36.05	36.35	36.50
1.000	27.85	31.60	33.25	34.05	34.70	35.15	35.45	35.60

TABLE OF OPTIMUM LENGTHS AT FIRST CAPTURE -- L(INFINITY) = 0.550000E+02

	EXPLOITATION RATE							
M/K	0.44	0.62	0.71	0.76	0.80	0.83	0.85	0.86
0.300	37.62	42.40	44.44	45.48	46.31	46.91	47.30	47.46
0.400	36.41	41.08	43.12	44.16	44.93	45.54	45.92	46.09
0.500	35.31	39.87	41.85	42.84	43.67	44.22	44.60	44.77
0.600	34.26	38.72	40.64	41.63	42.40	42.95	43.34	43.50
0.700	33.27	37.67	39.54	40.53	41.25	41.80	42.18	42.35
0.800	32.34	36.63	38.50	39.43	40.20	40.70	41.03	41.19
0.900	31.46	35.69	37.51	38.44	39.16	39.65	39.98	40.15
1.000	30.63	34.76	36.57	37.45	38.17	38.66	38.99	39.16

Want to rerun (yes or no)?
NO
FORTRAN STOP

PROGRAM NAME: Yield per Recruit for Multiple Gear Fisheries

PROGRAM TYPE: Main

DATE CREATED: 1974

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]MGEAR.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]MGEAR.EXE

AUTHOR: W.H. Lenarz

DOCUMENTED BY: F.P. Almeida

REVISIONS (Date/Reviser - Description)

1983 /F.P. Almeida -
Modified to conform with VAX 11/780 FORTRAN77.

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

The program computes estimates of yield per recruit and several realted parameters for fisheries that are exploited by several gears which may have differing vectors of age specific fishing mortality. The Ricker (1958) yield equation is used for cumputations.

DESCRIPTION:

Besides tables of yield per recruit, landings per recruit when fish below a minimum size are caught and then discarded dead, average weight of fish in the catch, and yield per reccruit per effort as functions of minimum size and amount of fishing effort are contained in the output for each gear and the entire fishery. (Lenarz et al. (1974) found the output useful for evaluating proposed minimum size regulations for the yellowfin tuna fishery of the tropical Atlantic Ocean. The fishery is exploited by four types of vessels, bait boats, small purse seiners, and longliners, having quite different vectors of age specific fishing mortality.) Input to the program is limited to 4 types of gear, 30 age intervals, and 10 levels of fishing mortality.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

Input data are formatted, the number of records is determined by the number of gears and ages to be analyzed.

Record Number		Record Description
1	Cols. 1-4	Value of coefficient of instantaneous natural mortality (M) under the assumption that M is constant (F4.0).
	5-8	First multiplier of vector of coefficients of age specific fishing mortality (F4.0). Yield per recruit isopleths and related parameters are output as functions of the multiplier and minimum size.
	9-12	
	.	. . . .
	.	. . . .
	.	. . . .
	41-44	Tenth multiplier of vector of coefficients of age specific fishing mortality (F4.0).
	45-46	Number of age intervals. 30 or less. (I2).
	47	Number of fishing gears. 4 or less. (I1).
	48-57	Scaling factor for vector of coefficients of fishing mortality (SCALE) (F10.0). Each value of FI is multiplied by SCALE at the beginning of the program. F(I,J) = FI(I,J)*SCALE. where FI(I,J)= input value of F for Ith age interval and Jth gear. F(I,J) = value of F used in remainder of calculations.
	58-66	Value of A in the length-weight relation (F9.3).
	67-75	Value of B in the length-weight relation (F9.3).
	76-77	Number of multipliers of fishing mortality. Must be 10 or less. (I2).
	78	= 1 when natural mortality is age specific, any other value when M is constant.
	79	= 0 when Tables (1) yeild per recruit, (2) yield per recruit when fish below the minimum size are caught and discarded dead, (3) average weight of the catch, and (4) yield per recruit per effort are desired. = 1 when only Tables (1), (2), and (3) are desired. = 2 when only Tables (1) and (2) are desired. = 3 when only Table (1) is desired.
	80	= 0 when tables for each gear are desired. = 1 when only tables for the entire fishery are desired.

2	Cols.	1-78	Title for output (50 character maximum).
3	Cols.	1-4	Length at beginning of first interval. Used to label tables (20F4.1).
		5-8	Length at beginning of second interval.
		.	. . .
		.	. . .
		.	. . .
			(If number of ages is 20 or less, only one card is necessary.)
4	Cols.	1-16	Label for first gear (4A4).
		.	. . .
			repeat for as many gears as specified
5	Cols.	1-5	Coefficient of instantaneous natural mortality for first age interval (F5.0).
		6-10	Coefficient of instantaneous natural mortality for second age interval (F5.0).
		.	. . .
		.	. . .
		.	. . .
			(If number of ages is 15 or less, only one card is necessary.)
6	Cols.	1-5	Coefficient of instantaneous fishing mortality for first gear and first age (F5.0).
		6-10	Coefficient of instantaneous fishing mortality for first gear and second age (F5.0).
		.	. . .
		.	. . .
		.	. . .
			(If number of ages is 15 or less, only one card is necessary.)
7	Cols.	1-5	Coefficient of instantaneous fishing mortality for second gear and first age (F5.0).
		6-10	Coefficient of instantaneous fishing mortality for second gear and second age (F5.0).
		.	. . .
		.	. . .
		.	. . .
			(If number of ages is 15 or less, only one card is necessary.)
			Repeat for as many gears as specified.
8	Cols.	1-4	Age at beginning of first interval (F4.3).
		5-8	Age at beginning of second interval (F4.3).
		.	. . .
		.	. . .
		.	. . .
		.	Age at end of last interval (F4.3).
			(If number of ages is 20 or less, only one card is necessary.)
9	Cols.	1-4	Weight at beginning of first interval (F4.1).
		5-8	Weight at beginning of second interval (F4.1).

```
                .          .          .          .
                .          .          .          .
                .          .          .          .
                .      Weight at end of last interval (F4.1).
                       (If number of Weights is 20 or less, only
                        one card is necessary.)
    10                 This card may be repeated as often as desired.

        Cols. 1-10     = 0.0 if run is to be terminated,
                       = 999.99 when new set of values starting
                         with card 1 are to be used, otherwise,
                       = factor for first gear (F10.2).
              11-20    = factor for second gear (F10.2).
              21-30    = factor for third gear (F10.2).
              31-40    = factor for fourth gear (F10.2)
                         Each factor of F for gear I is multiplied
                         by these factors.  This allows fishing
                         effort to be varied independently for each
                         gear.
```

To run the program, enter the following:

```
$ASSIGN [directory]datafile.DAT FOR005
$RUN FSHA:[712.MASTER.XEQ]MGEAR
```

REFERENCES:

Lenarz, W.H., W.W. Fox, Jr., G.T. Sakagawa, and B.J. Rothschild. 1974. An examination of the yield per recruit basis for a minimum size regulation for Atlantic yellowfin tuna, Thunnis albacares. Fish. Bull. (US) 72(1):37-61.

Paulik, G.J., and W.H. Bayliff. 1967. A generalized computer program for the Ricker model of equilibrium yield per recruit. J. Fish. Res. Board Can. 24:249-259.

Ricker, W. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Board Can., Bull. 119, 300p.

YEILD PER RECRUIT FOR MULTI-GEAR FISHERIES
Written by W.H. LENARZ 1974
VAX 11/780 Ver. 1.0 Feb 1984

VALUES OF F FOR GEAR 1

MGEAR.LOG;1 7-FEB-1984 19:57 Page 2

0.00260 0.02050 0.10510 0.37220 0.39640 0.44040 0.61080 0.39700 0.30870 0.29390 0.21750 0.16460 0.19130 0.18420 0.14230 0.10930
0.07730 0.10120 0.07860 0.04260 0.02890 0.02880 0.03840 0.02330 0.01800 0.02240

VALUES OF F FOR GEAR 2
0.00000 0.00000 0.00000 0.00000 0.00000 0.00050 0.00080 0.00290 0.00790 0.00890 0.02010 0.02330 0.02230 0.03110 0.07660 0.12110
0.13100 0.19780 0.23260 0.20710 0.28620 0.37790 0.40770 0.48740 0.44900 0.38940

TABLE . ESTIMATES OF YIELD PER RECRUIT (KG).
TEST RUN ATLANTIC YELLOWFIN TUNA DATA

BAIT BOATS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
152.5	66.5	0.01	0.02	0.03	0.05	0.07	0.08	0.09	0.10	0.12	0.13
147.5	60.2	0.02	0.03	0.05	0.08	0.10	0.12	0.13	0.15	0.16	0.18
142.5	54.3	0.03	0.05	0.08	0.12	0.16	0.19	0.20	0.24	0.26	0.29
137.5	48.9	0.04	0.07	0.10	0.15	0.19	0.23	0.25	0.28	0.31	0.34
132.5	43.8	0.04	0.08	0.12	0.18	0.23	0.27	0.29	0.33	0.37	0.39
127.5	39.0	0.05	0.10	0.15	0.23	0.29	0.35	0.37	0.43	0.48	0.52
122.5	34.6	0.07	0.14	0.20	0.31	0.40	0.49	0.52	0.61	0.68	0.75
117.5	30.6	0.10	0.18	0.27	0.41	0.54	0.65	0.71	0.82	0.93	1.02
112.5	26.9	0.11	0.22	0.31	0.49	0.64	0.77	0.83	0.97	1.09	1.20
107.5	23.5	0.13	0.26	0.37	0.58	0.76	0.92	1.00	1.16	1.31	1.44
102.5	20.4	0.16	0.31	0.45	0.70	0.91	1.11	1.20	1.40	1.59	1.75
97.5	17.6	0.19	0.37	0.53	0.83	1.10	1.33	1.44	1.69	1.92	2.12
92.5	15.0	0.22	0.42	0.61	0.96	1.26	1.53	1.65	1.94	2.20	2.43
87.5	12.7	0.24	0.46	0.67	1.05	1.38	1.67	1.81	2.12	2.39	2.64
82.5	10.7	0.27	0.51	0.74	1.15	1.51	1.83	1.97	2.30	2.59	2.85
77.5	8.9	0.29	0.57	0.82	1.27	1.66	2.00	2.15	2.50	2.80	3.06
72.5	7.3	0.32	0.61	0.88	1.36	1.77	2.13	2.29	2.64	2.94	3.20
67.5	5.9	0.35	0.67	0.95	1.46	1.89	2.25	2.41	2.76	3.05	3.29
62.5	4.7	0.38	0.73	1.04	1.57	2.01	2.37	2.52	2.85	3.11	3.32
57.5	3.7	0.40	0.76	1.08	1.62	2.05	2.40	2.55	2.86	3.09	3.27
52.5	2.8	0.42	0.78	1.11	1.65	2.07	2.40	2.54	2.82	3.03	3.17
47.5	2.1	0.43	0.80	1.12	1.66	2.07	2.38	2.51	2.76	2.93	3.05
42.5	1.5	0.43	0.80	1.13	1.66	2.06	2.37	2.49	2.73	2.90	3.01
37.5	1.0	0.43	0.80	1.13	1.66	2.06	2.36	2.49	2.73	2.89	3.00
32.5	0.7	0.43	0.80	1.13	1.66	2.06	2.36	2.49	2.73	2.89	2.99

TABLE . CONTINUED

LONG LINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
152.5	66.5	0.23	0.45	0.66	1.05	1.40	1.73	1.88	2.22	2.53	2.81
147.5	60.2	0.37	0.70	1.02	1.58	2.07	2.49	2.68	3.11	3.47	3.78
142.5	54.3	0.47	0.91	1.30	1.98	2.55	3.03	3.24	3.69	4.05	4.35
137.5	48.9	0.57	1.08	1.54	2.33	2.96	3.48	3.70	4.17	4.53	4.83
132.5	43.8	0.64	1.21	1.72	2.57	3.24	3.78	4.00	4.47	4.84	5.12
127.5	39.0	0.69	1.30	1.83	2.72	3.41	3.95	4.18	4.64	4.98	5.25
122.5	34.6	0.74	1.39	1.95	2.86	3.56	4.09	4.31	4.75	5.06	5.30
117.5	30.6	0.78	1.45	2.03	2.96	3.65	4.16	4.37	4.77	5.05	5.24
112.5	26.9	0.81	1.49	2.08	3.01	3.69	4.19	4.39	4.76	5.02	5.19
107.5	23.5	0.83	1.53	2.12	3.04	3.70	4.17	4.35	4.69	4.91	5.04
102.5	20.4	0.84	1.54	2.12	3.02	3.65	4.09	4.25	4.54	4.71	4.79
97.5	17.6	0.84	1.53	2.10	2.97	3.55	3.94	4.08	4.30	4.41	4.45
92.5	15.0	0.84	1.52	2.08	2.91	3.45	3.79	3.91	4.08	4.14	4.13
87.5	12.7	0.84	1.51	2.07	2.87	3.37	3.68	3.77	3.91	3.93	3.88
82.5	10.7	0.83	1.50	2.04	2.81	3.27	3.53	3.61	3.69	3.67	3.59
77.5	8.9	0.83	1.49	2.01	2.72	3.14	3.35	3.40	3.42	3.35	3.23
72.5	7.3	0.82	1.47	1.97	2.64	3.01	3.17	3.20	3.18	3.06	2.91
67.5	5.9	0.82	1.45	1.93	2.54	2.85	2.96	2.95	2.89	2.73	2.55
62.5	4.7	0.81	1.42	1.86	2.41	2.63	2.67	2.65	2.51	2.31	2.09
57.5	3.7	0.80	1.39	1.82	2.31	2.49	2.49	2.45	2.28	2.06	1.83
52.5	2.8	0.80	1.38	1.78	2.24	2.38	2.35	2.29	2.09	1.86	1.62
47.5	2.1	0.79	1.36	1.75	2.17	2.28	2.22	2.15	1.94	1.70	1.46
42.5	1.5	0.79	1.35	1.74	2.15	2.25	2.19	2.12	1.90	1.65	1.42
37.5	1.0	0.79	1.35	1.74	2.15	2.25	2.18	2.11	1.89	1.65	1.41
32.5	0.7	0.79	1.35	1.74	2.15	2.25	2.18	2.11	1.89	1.64	1.41

TABLE . CONTINUED

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
152.5	66.5	0.24	0.47	0.69	1.10	1.47	1.81	1.96	2.32	2.65	2.94
147.5	60.2	0.38	0.74	1.07	1.66	2.17	2.61	2.81	3.25	3.63	3.96
142.5	54.3	0.50	0.96	1.38	2.10	2.71	3.22	3.44	3.92	4.32	4.64
137.5	48.9	0.61	1.15	1.64	2.48	3.15	3.71	3.94	4.45	4.84	5.16
132.5	43.8	0.69	1.30	1.84	2.75	3.47	4.05	4.30	4.81	5.20	5.52
127.5	39.0	0.75	1.40	1.98	2.95	3.70	4.30	4.55	5.07	5.46	5.77
122.5	34.6	0.82	1.53	2.15	3.13	3.97	4.58	4.84	5.36	5.75	6.05
117.5	30.6	0.88	1.64	2.30	3.37	4.19	4.82	5.07	5.59	5.98	6.26
112.5	26.9	0.92	1.71	2.40	3.50	4.33	4.96	5.22	5.73	6.11	6.39
107.5	23.5	0.96	1.78	2.49	3.62	4.46	5.09	5.35	5.85	6.22	6.49
102.5	20.4	1.00	1.84	2.57	3.72	4.57	5.19	5.45	5.94	6.29	6.54
97.5	17.6	1.03	1.90	2.64	3.80	4.65	5.27	5.52	6.00	6.33	6.57
92.5	15.0	1.05	1.94	2.70	3.87	4.71	5.32	5.55	6.02	6.34	6.56
87.5	12.7	1.08	1.98	2.74	3.91	4.75	5.35	5.58	6.03	6.32	6.52
82.5	10.7	1.10	2.02	2.78	3.96	4.78	5.36	5.58	6.00	6.26	6.44
77.5	8.9	1.12	2.05	2.82	3.99	4.79	5.34	5.55	5.92	6.15	6.29
72.5	7.3	1.15	2.08	2.86	4.01	4.78	5.30	5.49	5.82	6.01	6.11
67.5	5.9	1.17	2.11	2.88	4.01	4.74	5.21	5.38	5.65	5.79	5.84
62.5	4.7	1.19	2.14	2.90	3.97	4.64	5.04	5.17	5.36	5.42	5.41
57.5	3.7	1.21	2.16	2.90	3.94	4.55	4.90	5.00	5.13	5.15	5.09
52.5	2.8	1.21	2.16	2.89	3.89	4.45	4.75	4.83	4.92	4.89	4.80
47.5	2.1	1.22	2.16	2.87	3.83	4.35	4.60	4.66	4.70	4.63	4.51
42.5	1.5	1.22	2.15	2.87	3.81	4.31	4.56	4.61	4.63	4.55	4.42
37.5	1.0	1.22	2.15	2.87	3.80	4.31	4.55	4.60	4.62	4.54	4.40
32.5	0.7	1.22	2.15	2.87	3.80	4.31	4.55	4.60	4.62	4.53	4.40

TABLE . LANDINGS PER RECRUIT (KG) WHEN FISH LESS THAN THE MINIMUM SIZE ARE CAUGHT AND DISCARDED DEAD.
TEST RUN ATLANTIC YELLOWFIN TUNA DATA

BAIT BOATS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
152.5	66.5	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00
147.5	60.2	0.01	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01
142.5	54.3	0.02	0.04	0.05	0.06	0.05	0.05	0.04	0.04	0.03	0.02
137.5	48.9	0.03	0.05	0.07	0.08	0.08	0.07	0.06	0.05	0.04	0.03
132.5	43.8	0.04	0.06	0.08	0.10	0.10	0.09	0.09	0.07	0.06	0.05
127.5	39.0	0.05	0.08	0.11	0.13	0.13	0.13	0.12	0.11	0.09	0.07
122.5	34.6	0.07	0.11	0.15	0.19	0.20	0.19	0.19	0.17	0.15	0.13
117.5	30.6	0.09	0.15	0.20	0.26	0.28	0.28	0.28	0.26	0.23	0.20
112.5	26.9	0.10	0.18	0.24	0.32	0.35	0.35	0.35	0.33	0.30	0.27
107.5	23.5	0.12	0.22	0.29	0.39	0.44	0.45	0.45	0.43	0.40	0.36
102.5	20.4	0.15	0.27	0.36	0.48	0.54	0.57	0.57	0.56	0.52	0.48
97.5	17.6	0.18	0.32	0.43	0.59	0.68	0.72	0.73	0.72	0.68	0.64
92.5	15.0	0.21	0.37	0.51	0.70	0.81	0.86	0.88	0.88	0.85	0.80
87.5	12.7	0.23	0.41	0.56	0.78	0.91	0.98	1.00	1.01	0.98	0.93
82.5	10.7	0.25	0.46	0.63	0.88	1.03	1.12	1.15	1.17	1.15	1.10
77.5	8.9	0.28	0.51	0.71	1.00	1.19	1.30	1.33	1.37	1.37	1.32
72.5	7.3	0.31	0.57	0.78	1.11	1.33	1.46	1.51	1.57	1.58	1.55
67.5	5.9	0.34	0.62	0.86	1.23	1.49	1.66	1.72	1.81	1.84	1.82
62.5	4.7	0.37	0.70	0.97	1.40	1.71	1.93	2.01	2.15	2.22	2.23
57.5	3.7	0.40	0.74	1.03	1.51	1.85	2.10	2.20	2.37	2.47	2.52
52.5	2.8	0.41	0.77	1.08	1.58	1.96	2.23	2.34	2.55	2.68	2.75
47.5	2.1	0.43	0.79	1.12	1.64	2.04	2.34	2.45	2.69	2.84	2.94
42.5	1.5	0.43	0.80	1.12	1.65	2.06	2.36	2.48	2.72	2.88	2.99
37.5	1.0	0.43	0.80	1.13	1.66	2.06	2.36	2.49	2.73	2.89	2.99
32.5	0.7	0.43	0.80	1.13	1.66	2.06	2.36	2.49	2.73	2.89	2.99

TABLE . CONTINUED

LONG LINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
152.5	66.5	0.19	0.30	0.36	0.39	0.34	0.28	0.25	0.18	0.12	0.08
147.5	60.2	0.31	0.50	0.61	0.66	0.61	0.52	0.47	0.36	0.26	0.18
142.5	54.3	0.41	0.67	0.82	0.93	0.88	0.77	0.71	0.55	0.41	0.30
137.5	48.9	0.50	0.83	1.03	1.19	1.16	1.04	0.95	0.78	0.60	0.46
132.5	43.8	0.57	0.95	1.19	1.40	1.38	1.26	1.13	0.98	0.78	0.61
127.5	39.0	0.62	1.04	1.31	1.55	1.55	1.43	1.35	1.13	0.92	0.73
122.5	34.6	0.67	1.13	1.44	1.72	1.74	1.63	1.55	1.33	1.10	0.89
117.5	30.6	0.71	1.21	1.54	1.86	1.91	1.81	1.73	1.50	1.26	1.04
112.5	26.9	0.74	1.26	1.61	1.96	2.02	1.93	1.85	1.62	1.37	1.14
107.5	23.5	0.76	1.30	1.67	2.04	2.12	2.03	1.96	1.73	1.48	1.25
102.5	20.4	0.78	1.32	1.70	2.09	2.17	2.10	2.03	1.80	1.55	1.31
97.5	17.6	0.78	1.33	1.71	2.11	2.20	2.12	2.05	1.82	1.58	1.34
92.5	15.0	0.78	1.34	1.72	2.12	2.21	2.14	2.07	1.84	1.60	1.36
87.5	12.7	0.79	1.35	1.73	2.13	2.23	2.16	2.09	1.86	1.61	1.38
82.5	10.7	0.79	1.35	1.74	2.14	2.24	2.17	2.10	1.88	1.63	1.39
77.5	8.9	0.79	1.35	1.74	2.14	2.24	2.18	2.11	1.88	1.64	1.40
72.5	7.3	0.79	1.35	1.74	2.15	2.25	2.18	2.11	1.89	1.64	1.40
67.5	5.9	0.79	1.35	1.74	2.15	2.25	2.18	2.11	1.89	1.64	1.41
62.5	4.7	0.79	1.35	1.74	2.15	2.25	2.18	2.11	1.89	1.64	1.41
57.5	3.7	0.79	1.35	1.74	2.15	2.25	2.18	2.11	1.89	1.64	1.41
52.5	2.8	0.79	1.35	1.74	2.15	2.25	2.18	2.11	1.89	1.64	1.41
47.5	2.1	0.79	1.35	1.74	2.15	2.25	2.18	2.11	1.89	1.64	1.41
42.5	1.5	0.79	1.35	1.74	2.15	2.25	2.18	2.11	1.89	1.64	1.41
37.5	1.0	0.79	1.35	1.74	2.15	2.25	2.18	2.11	1.89	1.64	1.41
32.5	0.7	0.79	1.35	1.74	2.15	2.25	2.18	2.11	1.89	1.64	1.41

TABLE . CONTINUED

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
152.5	66.5	0.20	0.32	0.38	0.40	0.36	0.30	0.26	0.19	0.13	0.09
147.5	60.2	0.32	0.52	0.63	0.70	0.64	0.55	0.50	0.37	0.27	0.19
142.5	54.3	0.43	0.71	0.87	0.98	0.93	0.82	0.75	0.59	0.44	0.32
137.5	48.9	0.53	0.88	1.10	1.26	1.23	1.11	1.03	0.83	0.64	0.49
132.5	43.8	0.61	1.01	1.27	1.49	1.48	1.35	1.27	1.05	0.84	0.65
127.5	39.0	0.67	1.12	1.41	1.68	1.68	1.56	1.47	1.24	1.01	0.80
122.5	34.6	0.74	1.25	1.58	1.91	1.94	1.83	1.74	1.50	1.24	1.01
117.5	30.6	0.80	1.36	1.74	2.12	2.19	2.09	2.01	1.76	1.49	1.24
112.5	26.9	0.84	1.44	1.85	2.27	2.37	2.28	2.20	1.95	1.67	1.41
107.5	23.5	0.89	1.52	1.96	2.43	2.55	2.48	2.41	2.16	1.88	1.60
102.5	20.4	0.92	1.59	2.06	2.57	2.72	2.67	2.60	2.35	2.07	1.79
97.5	17.6	0.96	1.65	2.15	2.70	2.88	2.84	2.78	2.54	2.26	1.98
92.5	15.0	0.99	1.71	2.23	2.82	3.02	3.00	2.95	2.72	2.44	2.16
87.5	12.7	1.01	1.76	2.29	2.91	3.14	3.14	3.09	2.87	2.60	2.31
82.5	10.7	1.04	1.81	2.36	3.02	3.27	3.29	3.25	3.05	2.78	2.50
77.5	8.9	1.07	1.87	2.45	3.14	3.43	3.47	3.44	3.26	3.00	2.72
72.5	7.3	1.10	1.92	2.52	3.25	3.57	3.64	3.62	3.46	3.22	2.95
67.5	5.9	1.13	1.98	2.60	3.38	3.74	3.84	3.83	3.70	3.48	3.23
62.5	4.7	1.17	2.05	2.71	3.55	3.96	4.11	4.12	4.04	3.86	3.64
57.5	3.7	1.19	2.09	2.77	3.65	4.10	4.28	4.31	4.26	4.12	3.93
52.5	2.8	1.20	2.12	2.82	3.73	4.21	4.42	4.46	4.44	4.32	4.16
47.5	2.1	1.22	2.15	2.86	3.79	4.29	4.52	4.57	4.58	4.49	4.35
42.5	1.5	1.22	2.15	2.86	3.80	4.30	4.54	4.60	4.61	4.53	4.40
37.5	1.0	1.22	2.15	2.87	3.80	4.31	4.55	4.60	4.62	4.53	4.40
32.5	0.7	1.22	2.15	2.87	3.80	4.31	4.55	4.60	4.62	4.53	4.40

TABLE . ESTIMATES OF AVERAGE WEIGHT OF CATCH (KG).
TEST RUN ATLANTIC YELLOWFIN TUNA DATA

BAIT BOATS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
152.5	66.5	73.04	72.94	72.85	72.66	72.47	72.29	72.19	71.97	71.74	71.52
147.5	60.2	68.89	68.71	68.54	68.20	67.87	67.54	67.38	66.98	66.60	66.23
142.5	54.3	63.71	63.46	63.22	62.74	62.29	61.86	61.66	61.17	60.71	60.29
137.5	48.9	60.45	60.15	59.86	59.30	58.78	58.28	58.04	57.49	56.97	56.50
132.5	43.8	57.21	56.86	56.52	55.86	55.24	54.67	54.40	53.76	53.17	52.64
127.5	39.0	52.96	52.55	52.15	51.41	50.72	50.08	49.78	49.09	48.46	47.90
122.5	34.6	47.32	46.89	46.48	45.71	45.02	44.39	44.10	43.43	42.84	42.32
117.5	30.6	42.54	42.12	41.73	41.00	40.35	39.78	39.51	38.91	38.38	37.92
112.5	26.9	39.66	39.25	38.86	38.16	37.54	36.99	36.73	36.16	35.66	35.22
107.5	23.5	36.17	35.77	35.40	34.72	34.12	33.59	33.34	32.79	32.31	31.88
102.5	20.4	32.63	32.25	31.90	31.25	30.67	30.17	29.93	29.40	28.94	28.53
97.5	17.6	29.15	28.79	28.46	27.85	27.31	26.84	26.62	26.12	25.69	25.30
92.5	15.0	26.37	26.03	25.71	25.14	24.63	24.18	23.98	23.51	23.10	22.73
87.5	12.7	24.32	23.99	23.69	23.13	22.64	22.21	22.01	21.56	21.16	20.80
82.5	10.7	21.99	21.68	21.38	20.85	20.37	19.95	19.76	19.31	18.92	18.57
77.5	8.9	19.45	19.15	18.86	18.34	17.89	17.48	17.29	16.85	16.46	16.11
72.5	7.3	17.34	17.05	16.77	16.27	15.82	15.42	15.24	14.81	14.43	14.08
67.5	5.9	15.18	14.90	14.63	14.14	13.70	13.31	13.13	12.71	12.33	11.99
62.5	4.7	12.77	12.49	12.23	11.76	11.34	10.95	10.78	10.37	10.00	9.67
57.5	3.7	11.44	11.17	10.92	10.45	10.04	9.66	9.49	9.09	8.73	8.40
52.5	2.8	10.41	10.14	9.88	9.42	9.01	8.63	8.45	8.06	7.71	7.39
47.5	2.1	9.53	9.26	9.01	8.55	8.14	7.76	7.59	7.19	6.84	6.52
42.5	1.5	9.29	9.02	8.77	8.31	7.89	7.52	7.35	6.95	6.59	6.27
37.5	1.0	9.24	8.97	8.72	8.25	7.84	7.47	7.29	6.90	6.54	6.22
32.5	0.7	9.23	8.96	8.71	8.25	7.83	7.46	7.29	6.89	6.53	6.21

TABLE . CONTINUED

LONG LINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
152.5	66.5	72.42	72.33	72.24	72.05	71.87	71.69	71.60	71.38	71.17	70.96
147.5	60.2	68.54	68.38	68.22	67.91	67.60	67.30	67.15	66.78	66.43	66.09
142.5	54.3	65.30	65.07	64.84	64.39	63.95	63.52	63.31	62.81	62.33	61.87
137.5	48.9	62.19	61.88	61.58	60.98	60.40	59.84	59.57	58.92	58.31	57.74
132.5	43.8	59.68	59.29	58.92	58.19	57.49	56.82	56.49	55.72	55.01	54.34
127.5	39.0	57.65	57.20	56.77	55.92	55.11	54.34	53.97	53.09	52.28	51.53
122.5	34.6	55.18	54.66	54.14	53.14	52.19	51.29	50.86	49.84	48.90	48.03
117.5	30.6	52.98	52.38	51.80	50.66	49.58	48.56	48.07	46.92	45.87	44.90
112.5	26.9	51.43	50.77	50.13	48.89	47.71	46.60	46.07	44.83	43.69	42.65
107.5	23.5	49.86	49.14	48.44	47.09	45.81	44.60	44.03	42.68	41.45	40.33
102.5	20.4	48.79	48.03	47.28	45.85	44.49	43.22	42.61	41.18	39.88	38.69
97.5	17.6	48.30	47.52	46.76	45.28	43.88	42.56	41.94	40.47	39.12	37.90
92.5	15.0	47.92	47.12	46.33	44.81	43.38	42.02	41.38	39.86	38.47	37.21
87.5	12.7	47.47	46.65	45.83	44.27	42.78	41.38	40.71	39.13	37.68	36.35
82.5	10.7	47.06	46.20	45.37	43.75	42.21	40.76	40.05	38.41	36.90	35.51
77.5	8.9	46.86	45.99	45.14	43.49	41.93	40.44	39.73	38.05	36.49	35.06
72.5	7.3	46.66	45.78	44.92	43.24	41.64	40.13	39.40	37.67	36.07	34.59
67.5	5.9	46.59	45.70	44.83	43.14	41.53	39.99	39.25	37.51	35.88	34.38
62.5	4.7	46.56	45.68	44.80	43.11	41.49	39.95	39.21	37.45	35.82	34.31
57.5	3.7	46.55	45.66	44.78	43.09	41.46	39.92	39.18	37.41	35.77	34.25
52.5	2.8	46.55	45.66	44.78	43.09	41.46	39.92	39.18	37.41	35.77	34.25
47.5	2.1	46.55	45.66	44.78	43.09	41.46	39.92	39.18	37.41	35.77	34.25
42.5	1.5	46.55	45.66	44.78	43.09	41.46	39.92	39.18	37.41	35.77	34.25
37.5	1.0	46.55	45.66	44.78	43.09	41.46	39.92	39.18	37.41	35.77	34.25
32.5	0.7	46.55	45.66	44.78	43.09	41.46	39.92	39.18	37.41	35.77	34.25

TABLE . CONTINUED

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
152.5	66.5	72.45	72.36	72.27	72.08	71.90	71.72	71.63	71.41	71.19	70.98
147.5	60.2	68.56	68.40	68.24	67.92	67.61	67.31	67.16	66.79	66.44	66.10
142.5	54.3	65.21	64.97	64.74	64.29	63.85	63.42	63.21	62.71	62.23	61.77
137.5	48.9	62.09	61.78	61.47	60.87	60.29	59.74	59.47	58.83	58.23	57.66
132.5	43.8	59.52	59.13	58.76	58.03	57.33	56.67	56.35	55.58	54.87	54.22
127.5	39.0	57.28	56.83	56.40	55.55	54.74	53.97	53.60	52.73	51.92	51.18
122.5	34.6	54.37	53.84	53.32	52.31	51.36	50.46	50.03	49.02	48.09	47.24
117.5	30.6	51.60	50.98	50.38	49.24	48.16	47.15	46.67	45.54	44.52	43.59
112.5	26.9	49.62	48.95	48.30	47.05	45.88	44.80	44.28	43.08	42.00	41.02
107.5	23.5	47.35	46.61	45.90	44.54	43.28	42.10	41.55	40.27	39.11	38.08
102.5	20.4	45.19	44.39	43.63	42.17	40.81	39.56	38.98	37.62	36.41	35.33
97.5	17.6	43.05	42.20	41.38	39.82	38.39	37.07	36.45	35.04	33.78	32.66
92.5	15.0	40.96	40.06	39.19	37.55	36.04	34.67	34.03	32.56	31.25	30.11
87.5	12.7	39.13	38.18	37.27	35.56	34.00	32.58	31.92	30.41	29.08	27.92
82.5	10.7	36.89	35.89	34.94	33.15	31.53	30.06	29.39	27.84	26.49	25.30
77.5	8.9	34.21	33.16	32.16	30.30	28.62	27.12	26.43	24.86	23.49	22.31
72.5	7.3	31.67	30.59	29.55	27.64	25.93	24.41	23.71	22.14	20.79	19.62
67.5	5.9	28.80	27.68	26.62	24.67	22.95	21.43	20.74	19.19	17.88	16.75
62.5	4.7	25.17	24.02	22.95	21.00	19.30	17.82	17.15	15.68	14.44	13.39
57.5	3.7	22.99	21.85	20.77	18.84	17.17	15.73	15.09	13.68	12.50	11.52
52.5	2.8	21.24	20.10	19.03	17.13	15.49	14.09	13.47	12.11	10.99	10.05
47.5	2.1	19.75	18.61	17.55	15.67	14.07	12.70	12.10	10.79	9.72	8.83
42.5	1.5	19.34	18.20	17.14	15.27	13.67	12.32	11.72	10.43	9.37	8.49
37.5	1.0	19.26	18.12	17.06	15.19	13.60	12.24	11.65	10.35	9.30	8.42
32.5	0.7	19.25	18.11	17.05	15.18	13.58	12.23	11.64	10.34	9.29	8.42

TABLE . ESTIMATES OF YIELD PER RECRUIT PER EFFORT (KG).
TEST RUN ATLANTIC YELLOWFIN TUNA DATA

BAIT BOATS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
152.5	66.5	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04
147.5	60.2	0.09	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.05
142.5	54.3	0.14	0.14	0.13	0.12	0.11	0.10	0.10	0.09	0.09	0.08
137.5	48.9	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.11	0.10	0.10
132.5	43.8	0.22	0.21	0.20	0.18	0.16	0.15	0.15	0.13	0.12	0.11
127.5	39.0	0.27	0.26	0.25	0.23	0.21	0.19	0.19	0.17	0.16	0.15
122.5	34.6	0.37	0.35	0.34	0.31	0.29	0.27	0.26	0.24	0.23	0.21
117.5	30.6	0.48	0.46	0.44	0.41	0.39	0.36	0.35	0.33	0.31	0.29
112.5	26.9	0.56	0.54	0.52	0.49	0.45	0.43	0.41	0.39	0.36	0.34
107.5	23.5	0.67	0.65	0.62	0.58	0.54	0.51	0.50	0.47	0.44	0.41
102.5	20.4	0.80	0.77	0.74	0.70	0.65	0.62	0.60	0.56	0.53	0.50
97.5	17.6	0.95	0.92	0.89	0.83	0.78	0.74	0.72	0.68	0.64	0.60
92.5	15.0	1.10	1.06	1.02	0.96	0.90	0.85	0.83	0.78	0.73	0.69
87.5	12.7	1.20	1.16	1.12	1.05	0.99	0.93	0.90	0.85	0.80	0.75
82.5	10.7	1.33	1.28	1.23	1.15	1.08	1.02	0.99	0.92	0.86	0.81
77.5	8.9	1.47	1.42	1.36	1.27	1.18	1.11	1.08	1.00	0.93	0.87
72.5	7.3	1.60	1.54	1.47	1.36	1.27	1.18	1.14	1.06	0.98	0.91
67.5	5.9	1.74	1.66	1.59	1.46	1.35	1.25	1.21	1.10	1.02	0.94
62.5	4.7	1.92	1.82	1.73	1.57	1.43	1.31	1.26	1.14	1.04	0.95
57.5	3.7	2.01	1.90	1.80	1.62	1.47	1.34	1.28	1.14	1.03	0.93
52.5	2.8	2.08	1.96	1.85	1.65	1.48	1.34	1.27	1.13	1.01	0.91
47.5	2.1	2.13	1.99	1.87	1.66	1.48	1.32	1.25	1.10	0.98	0.87
42.5	1.5	2.14	2.00	1.88	1.66	1.47	1.32	1.25	1.09	0.97	0.86
37.5	1.0	2.14	2.00	1.88	1.66	1.47	1.31	1.24	1.09	0.96	0.86
32.5	0.7	2.14	2.00	1.88	1.66	1.47	1.31	1.24	1.09	0.96	0.86

TABLE . CONTINUED

LONG LINERS

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
152.5	66.5	1.16	1.13	1.10	1.05	1.00	0.96	0.94	0.89	0.84	0.80
147.5	60.2	1.83	1.76	1.70	1.58	1.48	1.38	1.34	1.24	1.16	1.08
142.5	54.3	2.37	2.26	2.15	1.98	1.82	1.68	1.62	1.47	1.35	1.24
137.5	48.9	2.86	2.71	2.57	2.33	2.12	1.93	1.85	1.67	1.51	1.38
132.5	43.8	3.21	3.03	2.86	2.57	2.31	2.10	2.00	1.79	1.61	1.46
127.5	39.0	3.46	3.25	3.06	2.72	2.44	2.20	2.09	1.86	1.66	1.50
122.5	34.6	3.71	3.47	3.25	2.86	2.54	2.27	2.15	1.90	1.69	1.51
117.5	30.6	3.91	3.64	3.39	2.96	2.61	2.31	2.18	1.91	1.68	1.50
112.5	26.9	4.03	3.74	3.47	3.01	2.64	2.33	2.19	1.91	1.67	1.48
107.5	23.5	4.13	3.81	3.53	3.04	2.64	2.32	2.18	1.88	1.64	1.44
102.5	20.4	4.18	3.84	3.54	3.02	2.61	2.27	2.12	1.81	1.57	1.37
97.5	17.6	4.18	3.83	3.51	2.97	2.54	2.19	2.04	1.72	1.47	1.27
92.5	15.0	4.18	3.80	3.47	2.91	2.47	2.11	1.95	1.63	1.38	1.18
87.5	12.7	4.18	3.79	3.44	2.87	2.41	2.04	1.89	1.56	1.31	1.11
82.5	10.7	4.17	3.76	3.40	2.81	2.34	1.96	1.80	1.48	1.22	1.03
77.5	8.9	4.15	3.72	3.34	2.72	2.24	1.86	1.70	1.37	1.12	0.92
72.5	7.3	4.12	3.68	3.28	2.64	2.15	1.76	1.60	1.27	1.02	0.83
67.5	5.9	4.09	3.62	3.21	2.54	2.04	1.64	1.48	1.15	0.91	0.73
62.5	4.7	4.05	3.54	3.10	2.41	1.88	1.49	1.32	1.00	0.77	0.60
57.5	3.7	4.02	3.49	3.03	2.31	1.78	1.39	1.23	0.91	0.69	0.52
52.5	2.8	3.99	3.44	2.97	2.24	1.70	1.30	1.15	0.84	0.62	0.46
47.5	2.1	3.96	3.40	2.92	2.17	1.63	1.23	1.08	0.78	0.57	0.42
42.5	1.5	3.96	3.39	2.90	2.15	1.61	1.22	1.06	0.76	0.55	0.40
37.5	1.0	3.96	3.38	2.90	2.15	1.61	1.21	1.06	0.76	0.55	0.40
32.5	0.7	3.96	3.38	2.90	2.15	1.61	1.21	1.06	0.76	0.55	0.40

TABLE . CONTINUED

MINIMUM SIZE		MULTIPLIER OF EFFORT									
CM	KG	0.2	0.4	0.6	1.0	1.4	1.8	2.0	2.5	3.0	3.5
152.5	66.5	1.22	1.18	1.16	1.10	1.05	1.00	0.98	0.93	0.88	0.84
147.5	60.2	1.91	1.84	1.78	1.66	1.55	1.45	1.41	1.30	1.21	1.13
142.5	54.3	2.51	2.40	2.29	2.10	1.93	1.79	1.72	1.57	1.44	1.33
137.5	48.9	3.04	2.88	2.74	2.48	2.25	2.06	1.97	1.78	1.61	1.48
132.5	43.8	3.43	3.24	3.06	2.75	2.48	2.25	2.15	1.92	1.73	1.58
127.5	39.0	3.73	3.51	3.30	2.95	2.64	2.39	2.28	2.03	1.82	1.65
122.5	34.6	4.08	3.82	3.59	3.18	2.83	2.55	2.42	2.14	1.92	1.73
117.5	30.6	4.39	4.10	3.83	3.37	2.99	2.68	2.54	2.24	1.99	1.79
112.5	26.9	4.60	4.28	3.99	3.50	3.09	2.76	2.61	2.29	2.04	1.82
107.5	23.5	4.80	4.46	4.15	3.62	3.19	2.83	2.57	2.34	2.07	1.85
102.5	20.4	4.98	4.61	4.28	3.72	3.26	2.89	2.72	2.38	2.10	1.87
97.5	17.6	5.14	4.75	4.40	3.80	3.32	2.93	2.75	2.40	2.11	1.88
92.5	15.0	5.27	4.86	4.49	3.87	3.37	2.96	2.78	2.41	2.11	1.87
87.5	12.7	5.38	4.95	4.56	3.91	3.39	2.97	2.79	2.41	2.11	1.86
82.5	10.7	5.50	5.04	4.64	3.96	3.41	2.98	2.79	2.40	2.09	1.84
77.5	8.9	5.62	5.13	4.71	3.99	3.42	2.97	2.78	2.37	2.05	1.80
72.5	7.3	5.73	5.21	4.76	4.01	3.41	2.94	2.74	2.33	2.00	1.74
67.5	5.9	5.83	5.28	4.80	4.01	3.38	2.89	2.69	2.26	1.93	1.67
62.5	4.7	5.96	5.36	4.83	3.97	3.31	2.80	2.58	2.14	1.81	1.55
57.5	3.7	6.03	5.39	4.83	3.94	3.25	2.72	2.50	2.05	1.72	1.46
52.5	2.8	6.07	5.40	4.82	3.89	3.18	2.64	2.42	1.97	1.63	1.37
47.5	2.1	6.09	5.39	4.79	3.83	3.11	2.56	2.33	1.88	1.54	1.29
42.5	1.5	6.10	5.39	4.78	3.81	3.08	2.53	2.31	1.85	1.52	1.26
37.5	1.0	6.10	5.39	4.78	3.80	3.08	2.53	2.30	1.85	1.51	1.26
32.5	0.7	6.10	5.38	4.78	3.80	3.08	2.53	2.30	1.85	1.51	1.26

```
FORTRAN STOP
        0.2735 C.U. USED
$set noverify
  712_FPA1     job terminated at  7-FEB-1984 19:57:26.32

  Accounting information:
  Buffered I/O count:          101      Peak working set size:   403
  Direct I/O count:            123      Peak page file size:     707
  Page faults:                1857      Mounted volumes:           0
  Elapsed CPU time:     0 00:00:08.70   Elapsed time:     0 00:00:25.76
```

PROGRAM NAME: Single species proportion of total landings

PROGRAM TYPE: Main

DATE CREATED: May 1 1975

SOURCE FILE NAME: [712.MASTER.SOURCE]PCNT.FOR

EXECUTE FILE NAME: [712.MASTER.XEQ]PCNT.EXE

AUTHOR: R.K. Mayo

DOCUMENTED BY: R.K. Mayo

REVISIONS (Date/Reviser - Description)

May 1 1982 /R.K. Mayo
Revised to conform with VAX 11/780 compatible FORTRAN 77.
Jan 17 1984 /R.K. Mayo
Revised to conform with NERFIS Standards.
Nov 9 1984 /F.P. Almeida
Revised to include plot file option.

STATUS: Operational

CLASSIFICATION: Report Summary

PURPOSE OF PROGRAM:

This program computes the percentage composition of a single species in the total commercial landings of a series of fishing trips on a trip by trip landed weight basis. Summary data are displayed on the output device arrayed in 5-percent intervals by month. The number of trips, days fished, landings, and landings per day fished are given by month for all trips in the data set and for those trips which meet a minimum percentage requirement specified by the user.

DESCRIPTION:

As each trip record is read, PCNT computes the proportion of target species landings to the total landings of all species. The corresponding trip days fished as well as landings are accumulated in a two-way matrix by 5-percent interval and month.

Row totals of the number of trips and species landings are computed for each 5-percent interval over all months.

Column totals of the number of trips, days fished, and landings are computed by month over all 5-percent intervals. Landings per day fished values are then computed by month from the column totals of landings and days fished.

Additional column sub-totals of the above values are also

computed by month over those 5-percent intervals which meet the minimun percentage criterion specified by the user. Additional landings per day fished values are computed by month from the column sub-totals of landings and days fished.

Note that the target species percentages are based on landed weights for compatability with total species landings, while landings summaries displayed on the output device are in terms of live weight equivalents.

ERROR CONDITIONS.

An error condition is detected by PCNT when the target species landings exceed the sum of all species landings. This condition is an artifact of the editing procedure which may occur due to incomplete separation of unique trips in the master data files. The following message is written on the FOR008 output device along with the year, month and landings of the detected trip record :

BAD RECORD, SPPLBS GT TRPLBS

When an error condition is detected the ratio of target species landings to total landings is set equal to 1.000, and the landings and effort data are included in the analysis.

DATA USED: User-edited WODTL73 format commercial data

Detail trip commercial landings records residing in master files in WODTL73, WODTL75, or WODETS formats may be accessed by DTR32 or a similar utility. Records to be read by PCNT must then be converted to WODTL73 format and modified to delete duplicate effort entries on trips landing multiple market categories. Therefore, data to be edited must remain in the original trip sort order as in the master file. User data must be edited in the above manner using one of the following command procedures:

Command File Name	Input Format	Years
FSHA:[712.MASTER.COM]FLEDIT73.COM	WO.WODTL73_REC	1964-1974
FSHA:[712.MASTER.COM]FLEDIT75.COM	WO.WODTL75_REC	1975-1981
FSHA:[712.MASTER.COM]FLEDIT82.COM	WO.WODETS_REC	1982+

INSTRUCTIONS FOR RUNNING:

Program PCNT will assimilate all data records residing in the user-specified input file. Therefore, a pre-processing utility such as DTR32 must be executed prior to running PCNT to select the appropriate categories of data (eg. Area, Port, Vessel tonnage, etc.) to include in the summary output. There is no need to re-sort data for input to PCNT.

PCNT does discriminate among years and the program will process up to 25 consecutive years separately in a single pass

through the data.

INPUT.

Landings records are read by PCNT on device FOR004. The user must also supply a control record and a title record to be read on device FOR005 as follows:

Record Number			Record Description
1			FORMAT(5X,I2,3X,I2,3X,I2,3X,I1)
	Cols	6-7	Enter number of years to be processed.
		11-12	Enter initial year to be processed.
		16-17	Enter minimum percentage criterion for target species.
		21	Enter 1 if plot file is desired, else, leave blank.
2			FORMAT(20A4)
	Cols	2-80	Enter user-specified descriptive title for data set to be processed.

Program PCNT may be run on-line or in batch mode. In either case, the user is advised to build a command file containing DTR32 specifications and FORTRAN device ASSIGN statements. An example command file may be found in :

FSHA:[712.MASTER.COM]PCNTDTR.COM

Since PCNT analyses are generally performed on several subsets of the user's edited data, a DTR32 domain must be defined in the user's Datatrieve default directory using the WO.WODTL73_REC record definition. This domain can be readied in the PCNT command file, and the appropriate DTR32 selection criteria may be specified to obtain the data subset to be analyzed by PCNT.

OUTPUT.

Program PCNT displays output in 132 character tabular form through device FOR006. An optional file containing total frequencies of trip (records 1-20) and catch (records 21-40) data in 5-percent intervals is written on device FOR007. Error messages are written on device FOR008 when an error condition is detected.

EXAMPLE COMMAND PROCEDURE

```
$ TY PCNTDTR.COM
$DTR32
SET DIC CDD$TOP.NMFS.WORK.RKM1
READY POI182ED
SET C_P = 96
PRINT ALL IMAGE (-) OF
POI182ED WITH AREA GE 410 AND
NEGEAR EQ 05 AND
TONNAGE BT 22 AND 25 ON
POITMP2.DAT
EXIT
$ASSIGN POITMP2.DAT FOR004      ! INPUT LANDINGS DATA
$ASSIGN SYS$INPUT FOR005        ! INPUT CONTROL RECORD
$ASSIGN SYS$OUTPUT FOR006       ! OUTPUT SUMMARY TABLE
$ASSIGN PCNTERR.DAT FOR008      ! OUTPUT ERROR MESSAGES
$RUN [712.NERFIS.XEQ]PCNT
     01   82   50
     POILOCK 1982 DIVS 4VWX + SA5; GEAR 05; ALL PORTS; TC 2.
$DELETE POITMP2.DAT.*
$
```

```
@PCNTDTR.COM
VAX-11 Datatrieve V2.0
DEC Query and Report System
Type HELP for help
[looking for name of domain, collection, or list]
[looking for Boolean expression]
[looking for Boolean expression]
[looking for file name]
```

```
SINGLE SPECIES PROPORTION OF TOTAL LANDINGS
            -- PROGRAM:  PCNT --
Written by R.K. Mayo, May 01 1975
VAX 11/780 Ver. 1.0  17 JAN 1984  R.K. Mayo
```

NUMBER OF TRIPS AND CATCH IN 1000S OF POUNDS
POLLOCK 1982 DIVS 4VWX + SA5; GEAR 05; ALL PORTS; TC 2.
YEAR: 82

MONTH

UPP PC VAL	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	FREQ	POUNDS	FREQ
5	108.	72.	95.	91.	271.	191.	146.	118.	123.	109.	183.	197.	1704.	0.762	222.	0.132
10	12.	3.	8.	14.	32.	13.	15.	7.	17.	12.	20.	28.	181.	0.081	94.	0.056
15	3.	0.	3.	2.	7.	1.	5.	6.	8.	2.	12.	13.	62.	0.028	45.	0.027
20	1.	0.	3.	5.	8.	10.	2.	7.	10.	0.	3.	7.	56.	0.025	118.	0.070
25	4.	0.	2.	6.	3.	1.	2.	2.	3.	2.	2.	6.	33.	0.015	60.	0.036
30	2.	0.	1.	3.	2.	2.	2.	1.	3.	2.	6.	4.	28.	0.013	58.	0.034
35	0.	0.	2.	0.	3.	0.	0.	1.	5.	4.	1.	1.	17.	0.008	44.	0.026
40	1.	0.	1.	0.	0.	1.	1.	1.	3.	1.	1.	5.	15.	0.007	49.	0.029
45	1.	0.	0.	3.	1.	1.	2.	0.	2.	1.	1.	2.	14.	0.006	45.	0.027
50	0.	0.	2.	0.	3.	0.	0.	0.	4.	1.	1.	0.	11.	0.005	33.	0.020
55	0.	0.	0.	0.	0.	1.	0.	0.	3.	0.	2.	0.	6.	0.003	11.	0.007
60	0.	0.	0.	0.	0.	0.	2.	2.	3.	0.	0.	2.	9.	0.004	28.	0.017
65	0.	0.	2.	0.	1.	0.	1.	0.	4.	1.	2.	0.	11.	0.005	163.	0.097
70	1.	0.	1.	1.	0.	0.	2.	0.	5.	2.	2.	2.	16.	0.007	114.	0.068
75	0.	0.	1.	1.	0.	0.	0.	1.	2.	1.	1.	1.	8.	0.004	45.	0.027
80	1.	0.	0.	0.	0.	0.	0.	1.	1.	0.	4.	1.	8.	0.004	31.	0.019
85	0.	0.	1.	0.	0.	0.	0.	0.	2.	5.	6.	2.	16.	0.007	119.	0.071
90	0.	0.	1.	1.	1.	0.	0.	0.	4.	1.	3.	3.	14.	0.006	142.	0.084
95	1.	0.	0.	0.	1.	0.	0.	1.	5.	2.	4.	5.	19.	0.008	203.	0.121
100	1.	0.	0.	0.	1.	0.	0.	0.	1.	0.	2.	3.	8.	0.004	51.	0.030
TOTNO	136.	75.	123.	127.	334.	221.	180.	148.	208.	146.	256.	282.	2236.			
FREQ	0.061	0.034	0.055	0.057	0.149	0.099	0.081	0.066	0.093	0.065	0.114	0.126		1.000		
LBS	52.	7.	148.	97.	129.	73.	134.	92.	333.	231.	223.	160.			1677.	
FREQ	0.031	0.004	0.089	0.058	0.077	0.043	0.080	0.055	0.199	0.137	0.133	0.095				1.000
DYSFH	149.6	92.1	176.0	152.2	369.9	299.2	250.1	222.7	203.4	191.1	201.5	241.5	2549.3			
C/DAY	0.35	0.07	0.84	0.64	0.35	0.24	0.54	0.41	1.64	1.21	1.10	0.66			0.66	

CATCH AND EFFORT FOR 50 PC TRIPS OR GREATER

TOTNO	4.	0.	6.	3.	4.	1.	5.	5.	30.	12.	26.	19.	115.			
LBS	17.	0.	98.	33.	24.	5.	31.	16.	246.	188.	168.	82.			908.	
DYSFH	1.5	0.0	10.8	2.8	0.9	0.8	5.1	1.7	12.8	7.5	6.9	4.9	55.7			
C/DAY	11.57	0.00	9.06	11.70	26.71	5.93	6.12	9.63	19.22	25.00	24.41	16.69			16.30	

FORTRAN STOP
$

PROGRAM NAME: Relative Fishing Power Estimator

PROGRAM TYPE: Main

DATE CREATED: Jan 1 1971

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]FPOW.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]FPOW.EXE

AUTHOR: C. Berude and N.J. Abramson

DOCUMENTED BY: S.A. Murawski

REVISIONS (Date/Reviser - Description)

May 30 1984 /S.A. Murawski -
Revised to conform with VAX 11/780 FORTRAN77

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

Estimates of relative fishing power and relative population density are obtained utilizing analysis of variance.

DESCRIPTION:

Analysis of variance as a method for estimating relative fishing power was suggested by Robson (1966). FPOW utilizes this method in estimating relative fishing power, relative population density, approximate confidence intervals and corrections for bias in the parameter estimates.

A simple development of the method may be outlined as follows. The basic model assumed is:

$$C(ij) = q(i)f(ij)\bar{P}(j)E(ij) \qquad (1)$$

where: $C(ij)$ = the catch of the ith fishing treatment in the jth area-date stratum,
$q(i)$ = the catchability coefficient of the ith treatment,
$f(ij)$ = the amount of fishing effort expended by the ith treatment in the jth area-date,
$\bar{P}(j)$ = the average population size in the jth area-date,
$E(ij)$ = a log-normally distributed random variable.

The i treatments may be different vessels, horsepower, vessel types or their attributes (e.g. length, horsepower, tonnage), gear types or characteristics (e.g. gill nets, purse seines, soak times, trawl footrope lengths), or any other way of designating

classes within the fishing fleet. It is assumed that (1) effort is measured such that within each treatment q(i) is constant, (2) the units of effort operate independently, and (3) there is no interaction between the treatments and area-dates.

Dividing through equation (1) by effort and taking natural logarithms we have:

$$\ln(C(ij) / f(ij)) = \ln q(i) + \ln\bar{P}(j) + \ln E(ij)$$

which may be written as:

$$Y(ij) = alpha(i) + beta(j) + E'(ij) \qquad (2)$$

Equation (2) may be recognized as a linear two-factor analysis of variance model where the E'(ij) are assumed to be approximately N(0,var). If the alpha(i) and beta(j) were estimable one would have estimates of the logarithms of the catchability coefficients and population densities directly. Since the design matrix is singular and therefore no solution exists, one must re-parameterize the model and obtain estimates of relative catchability, called relative fishing power, rho(i); and relative population density, D(j), where:

$$rho(i) = q(i) / q(s)$$

$$D(j) = \bar{P}(j) / \bar{P}(s)$$

and s designates the treatment and area-date selected to be the standard. Standardized fishing effort is obtained by:

$$f(sj) = \sum_i rho(i)f(ij)$$

such that: $$C(j) = q(s)f(sj)\bar{P}(j),$$

the desired relation with a single catchability coefficient. Detailed descriptions of the equations on which the method is based are given in the FAO manual on computer programs for fish stock assessment.

DATA USED: Catch/effort data by vessel and area-date

INSTRUCTIONS FOR RUNNING:
---

(1) a) The treatments (called Boats by FPOW) may be given any numeric designation. However, FPOW will always select the smallest numeric value as standard.

b) The AREA-DATES also may be given any numeric designation. FPOW will select as the standard that AREA-DATE with the lowest numeric value in which the standard BOAT first occurs.

c) Since the variances of the estimates include the variance of the standard, that BOAT which appears in the most AREA-DATES should be selected as the standard and be given the lowest numeric designation in order to

obtain the smallest variances of estimates.

(2) Each BOAT need not appear in every AREA-DATE and zero catch observations may be entered.

(3) CATCH PER UNIT EFFORT values are the data entered into the program, but FPOW calls them CATCH.

(4) FPOW computes the expected catch per unit effort for the standard BOAT in the standard AREA-BOAT. Therefore, standardized catch per unit effort may be obtained by multiplying the expected value times each of the estimates of relative density. However, unless the amount of effort for each BOAT-type is relatively uniform within each AREA-DATE, this procedure is not recommended. The major drawback to this program is that the estimates are not weighted by the amount of effort. With greater effort the variance of the observation is likely to be smaller. One can do nothing about the estimates of relative fishing power, but better estimates of standardized catch per unit of effort may be obtained in the long manner of multiplying each BOAT's effort by its relative fishing power estimate, summing up the standardized effort and dividing it into the catch.

(5) Another drawback is that an analysis of variance is not performed and there is no provision for testing for interaction. Also one cannot use alternative ANOVA models such as nested designs which often may be the appropriate ones. BMDP or SPSS ANOVA programs may be used prior to FPOW to examine interaction or alternative designs.

(6) Input data can be from a file (recommended) or can be entered interactivly. Input data files are assigned to device FOR005. Output is to device FOR006. The following records are included in the input file:

Record Number		Record Description
1	Cols. 1-80	Title record, appears on each table.
2	Cols. 1-80	Sub-title record, appears only above summary.
3	Cols. 1-3	YES for covariance matrix, NO otherwise, left-justified,
	5-7	YES if want biased estimates, NO otherwise, left-justified,
4	Cols. 1-80	Data format (variable 'F' format),
5	Data records, agree with 4	as many as necessary, (format must above)
	Field 1	An alpha(i), where i=1,2,...k BOATS,
	Field 2	A beta(j), where j=1,2,...n AREA-DATES,
	Field 3	A catch per unit effort.
6		A blank card to end run.

To run the program, submit the following commands:

```
$ASSIGN [directory]datafile.DAT FOR005
$ASSIGN SYS$OUTPUT              FOR006
$RUN FSHA:[712.MASTER.XEQ]FPOW
```

REFERENCES:

Robson, D.S. 1966. Estimation of the relative fishing power of individual ships. ICNAF Res. Bull. 3:5-14.

```
$ T FSHA:[712.MASTER.DATA]FPOW.DAT

 TEST RUN
 FIELD 1 IS BOAT, FIELD 2 IS AREA-DATE (BLOCK-YR-MO), FIELD 3 IS CATCH (POUNDS)
YES YES
(2F10.0,F7.0)
      3621    2006501     945000
      3621    2566507     216045
     10043    2406501    1332000
       592    2566507     843600
      3621    2006501     720000
      3621    2006501     837000
      3621    2566507     197000
      3621    2566507     320000
     10043    2006501     100000
     10043    2006501     135670
     10043    2006501     125690
     10043    2566507      14670
     10043    2566507      32900
     10043    2566507      23900
     10043    2466507     360000
     10043    2466507     329000
      3621    2406501     100000
      3621    2406501     128970
      3621    2406501     115900
       592    2566507     789000
       592    2566507     657000
       592    2006501    1298000
       592    2006501    1568999
       592    2006501    1789600
       592    2466507     345678
       592    2466507     283456
       592    2466507     187900

$
```

```
$ ASSIGN FSHA:[712.MASTER.DATA]FPOW.DAT  FOR005
$ RUN FSHA:[712.MASTER.XEQ]FPOW
```

Relative Fishing Power Calculator (FPOW)
C.L Berude VAX 11/780 Ver 1.0 S.A. Murawski

TEST RUN
FIELD 1 IS BOAT, FIELD 2 IS AREA-DATE (BLOCK-YR-MO), FIELD 3 IS CATCH (POUNDS)

CATCH BY AREA-DATE BY BOAT

NUMBER OF OBSERVATIONS - 27 NUMBER OF DISTINCT BOATS - 3 NUMBER OF DISTINCT AREA-DATES - 4

BOAT	AREA-DATE	CATCH	***	BOAT	AREA-DATE	CATCH	***	BOAT	AREA-DATE	CATCH
			***				***			
592.	2006501.	1298.0000	***	592.	2006501.	1568.0000	***	592.	2006501.	1789.0000
592.	2466507.	345.0000	***	592.	2466507.	187.0000	***	592.	2466507.	283.0000
592.	2566507.	843.0000	***	592.	2566507.	657.0000	***	592.	2566507.	789.0000
3621.	2006501.	837.0000	***	3621.	2006501.	945.0000	***	3621.	2006501.	720.0000
3621.	2406501.	128.0000	***	3621.	2406501.	115.0000	***	3621.	2406501.	100.0000
3621.	2566507.	197.0000	***	3621.	2566507.	216.0000	***	3621.	2566507.	320.0000
10043.	2006501.	125.0000	***	10043.	2006501.	135.0000	***	10043.	2006501.	100.0000
10043.	2406501.	1332.0000	***	10043.	2466507.	360.0000	***	10043.	2466507.	329.0000
10043.	2566507.	14.0000	***	10043.	2566507.	32.0000	***	10043.	2566507.	23.0000

TEST RUN

ESTIMATED RELATIVE FISHING POWERS AND RELATIVE DENSITIES

BOAT	RELATIVE FISHING POWER	STANDARD ERROR OF LOG FISHING POWER	0.95 CONFIDENCE LIMITS ON FISHING POWER	
3621.	0.352	0.54358	0.141	1.187
10043.	0.146	0.48568	0.063	0.426

AREA-DATE	RELATIVE DENSITY	STANDARD ERROR OF LOG DENSITY	0.95 CONFIDENCE LIMITS ON DENSITY	
2406501.	0.400	0.64394	0.139	1.740
2466507.	0.386	0.58959	0.145	1.461
2566507.	0.264	0.47795	0.116	0.756

*** C= 1184.216 IS EXPECTED CATCH OF STANDARD BOAT 592. IN STANDARD AREA-DATE 2006501..

TEST RUN

BOAT	BIASED ESTIMATE FISHING POWER	BIAS	TRUNCATION ERROR	***	AREA-DATE	BIASED ESTIMATE DENSITY	BIAS	TRUNCATION ERROR
				***				
3621.	0.409	0.05651	0.31644E-30	***	2406501.	0.493	0.09300	0.86262E-28
10043.	0.164	0.01839	0.34642E-32	***	2466507.	0.460	0.07390	0.47931E-29
				***	2566507.	0.296	0.03212	0.37324E-32

*** C= 1311.720 IS BIASED EXPECTED CATCH OF STANDARD BOAT 592. IN STANDARD AREA-DATE 2006501..

TEST RUN

VARIANCE-COVARIANCE TABLE

VARIANCE-COVARIANCE MATRIX FOLLOWS IN TABULAR FORM. EACH SECTION LISTS ELEMENTS OF ONE ROW OF THE SYMMETRIC MATRIX. ONLY ELEMENTS OF THE UPPER TRIANGLE ARE PRINTED--THE FIRST VALUE LISTED FOR EACH SECTION IS AN ELEMENT OF THE MAIN DIAGONAL. MATRIX COLUMN NUMBERS IN MULTIPLES OF 8 ELEMENTS PER OUTPUT ROW ARE INDICATED IN THE LEFTMOST COLUMN OF OUTPUT. BOAT OR AREADATE NUMBERS LABELING ELEMENT VALUES PRINTED ARE PRECEDED BY A B IF THE LABEL IS A BOAT NUMBER, OR BY AN A IF AREADATE.

MATRIX E

	(592.)	(3621.)	(10043.)	(2406501.)	(2466507.)	(2566507.)
1- 6	0.20361E+00	-0.14401E+00	-0.12415E+00	-0.64558E-01	-0.15395E+00	-0.11422E+00

MATRIX bFP

		(3621.)	(10043.)	(2406501.)	(2466507.)	(2566507.)
2- 6		0.29548E+00	0.13657E+00	-0.11174E+00	0.89388E-01	0.19147E-08

MATRIX G1

			(10043.)	(2406501.)	(2466507.)	(2566507.)
3- 6			0.23589E+00	-0.37245E-01	0.29796E-01	0.38295E-08

MATRIX AKa

				(2406501.)	(2466507.)	(2566507.)
4- 6				0.41466E+00	0.79456E-01	0.11422E+00

MATRIX AK,

					(2466507.)	(2566507.)
5- 6					0.34762E+00	0.11422E+00

MATRIX AK,%

						(2566507.)
6- 6						0.22844E+00

RESIDUAL VARIANCE - 0.10280E+01

DEGREES OF FREEDOM - 21

*** PROGRAMMED BY BIOMETRICAL ANALYSIS UNIT, MRO, CALIF. DEPT. FISH AND GAME, JANUARY 1969.

PROGRAM NAME: Estimation of Relative Fishing Power

PROGRAM TYPE: Main

DATE CREATED: May 1 1972

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]ESP3.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]ESP3.EXE

AUTHOR: K. Paine

DOCUMENTED BY: M.J. Fogarty

REVISIONS (Date/Reviser - Description)

/ -

STATUS: Operational

CLASSIFICATION: Statistical Analysis

PURPOSE OF PROGRAM:

The program provides an estimation procedure for determining relative fishing power coefficients using a two-way classification model with no interaction. Fishing effort is adjusted to an arbitrarily selected standard (e.g. gear-tonnage class combination).

DESCRIPTION:

Fishing power coeffifients are determined by the method of Robson (1966) based on a general linear model with no interaction. The model may be expressed:

$$X_{ij} = \mu + \alpha_i + \beta_j + e_{ij} \qquad i = 1...r \quad j = 1...c$$

where:

μ = the overall mean,
α_i = the effect of the first factor,
β_j = the effect of the second factor, and
e_{ij} = independent, normally distributed error terms with mean = 0, and variance σ^2.

Generally a multiplicative model is assumed; accordingly, the data are typically transformed to natural logarithms prior to analysis. The procedure may accomodate unequal cell frequencies (ie. an unbalanced design) following Snedecor and Cochran (1967) A ´standard´ is designated by the user and all remaining cells are adjusted to the standard cell. The program provides (in addition to intermediate results): cell estimates for the r x c matrix, standardized fishing power coefficients, total standard-

ized effort, and landings per standardized day fished. An analysis of variance table is also provided.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

A set of eight control records is required as follows:

Record Number		Record Description
1	Cols. 2-80	Identification title, to be printed at the top of each page.
2	Cols. 1-5	R - the number of A-factor levels, ie. number of rows in the data matrix.
	6-10	C - The number of B-factor levels, ie. number of columns in the data matrix.
	11-15	N - the number of factors to describe a data block.
	19-20	The number of K levels to retain in calculating fishing power at each K level (optional).
	25	Enter 1 to get each input record printed.
3	Cols. 5	Fishing power equation: = 0, do not compute, = 1, compute, data transformed to natural logarithm, = 2, compute, data not transformed.
		The next 7 fields specify the printout options for the seven pages possible: = 108, print = 0, do not print, = n, write on device assigned (n must not = 8).
	8-10	Analysis of variance.
	13-15	Estimators.
	18-20	Fishing power and standardization.
	23-25	Equations.
	28-30	Data matrix 1.
	33-35	Data matrix 2.
	39-40	At each K level, the standardized effort.
4.1	Cols. 1-8	Name of first block factor, left-justified.
4.2	1-8	Name of second block factor, left-justified.
4.3	1-8	Name of last block factor, left-justified.
5	Cols. 1-5	Value of first A-factor level.
	6-10	Value of second A-factor level, etc.

			for all levels, 12 to a record. Continue on more records if necessary. After the last A-factor level, in the next 5 column field, specify the value of the A-factor of the standard cell in fishing power estimates.
6	Cols.	1-5	Value of first B-factor level.
		6-10	Value of second B-factor level, etc. as above for A-factor levels. After last B-factor level, in the next 5 column field, specify the the value of the B-factor of the standard cell in fishing power estimates.
6A	Cols.	1-60	Values of K. Data saved at each K level in recalculating fishing power. (5 column fields, 12/record)
7	Col.	5	Compress matrix option. If = 0, the matrix is not compressed and empty columns will cause the matrix to be singular. If = 1, empty rows and columns are excluded from calculations.
		10	= 0, no action. = 1, if there is any row or column with only 1 observation, that observation will be excluded from the calculations, and the row or column excluded.
		15	n = 0, no action. n > 0, any data block with less than n observations will not be calculated.
		20	n = 0, no action. n > 0, any data block with observations for less than n B-levels will no be calculated.
8	Cols.	2	= 1, y = ln(tons/day fished). = 2, y = tons/day fished. = 3, y = ln(catch); days fished = 1. = 4, y = catch; days fished = 1.
		4	n = 0, 1 observation per record. n > 0, the number of observations specified per data record.
		5-80	Data record format, for the following list of variables, in order: 1) A-factor level. 2) B-factor level. 2a) K-level (indicate dummy if not used). 3) number of days fished (indicate dummy if not used). 4) catch. 5) block factors, in same order as type 4 records. 6) number of observations (even if col. 4 = 0, provision must be made. In-

dicate dummy if not used).

NOTE: All fields must be real, ie. F or E format. Use tab specification when data in records does not conform to order of list.

The data file must be sorted by blocks if separate blocks are designated, but the main effects factors within a block need not be sorted.

The program should be run in batch mode. To run the program, create a command file with the following records, or copy the example file FSHA:[712.MASTER.COM]ESP3.COM to your directory and modify it to fit your needs.

```
$ASSIGN SYS$INPUT      FOR001
$ASSIGN datafile.DAT   FOR002
$RUN FSHA:[712.MASTER.XEQ]ESP3
...control records...
```

REFERENCES:

Robson, D.S. 1966. Estimation of the relative fishing power of individual ships. Int. Comm. Northw. Atlant. Fish. Res. Bull 3:5-14.

Snedecor, G.W. and W.G. Cochran. 1967. Statistical Methods (6th ed). Iowa State Univ. Press, Ames, Iowa. 593p.

```
$ T FSHA:[712.MASTER.COM]ESP3.COM

$SET VERIFY
$ASSIGN FSHA:[712.MASTER.DATA]ESP3.DAT FOR002
$ASSIGN SYS$INPUT    FOR001
$RUN FSHA:[712.MASTER.XEQ]ESP3
STANDARDIZED U.S. ANNUAL  COMMERCIAL C/E INDEX   MACKEREL SA5&6
    8    3    1    1    0
    1    6    6    6    6    6    6    6    6
YEAR
    1    2    5    8   10   11   12   14    8
    2    3    4    2
   80
    1    0    0    0    0
 1 0(T14,F2.0,T17,F1.0,T1,F2.0,T56,F4.1,T41,F8.0,T1,F2.0,F1.0)
$


$ T FSHA:[712.MASTER.DATA]ESP3.DAT

803070224190701029 998514090103122120535000002000000040001000100010000200     20042704000001000
801010033092702023 257615090103122120535000016130000629000500200020000163 2   16133973400000 988
801010033092702023 483615090103122120535000004900000192000200100010000056 6    4903973400000 866
802062924190702029 998514090103112120535000180950004761009909900990001844 3  180954270400000 979
802061124190702022 349514010103122120535000003100000078000100100010000031 0   31042704000001000
802062424020702029 998514090103112120535000025750000773002000500050000311 5   25754270400000 804
803073122020702029 998512090103112120535000002750000055000600300030000027 5   27544691000001000
803070924190702029 998514090103112120535000035340000636004000400040000353 4  353442704000001000
803083122020702029 998512090103112120535000001320000033001000500050000013 2   13244691000001000
803082724020702029 998514090103112120535000006300000240003501000100000105 8    6304270400000 574
803073124020702029 998514090103112120535000034350000837006001600160000411 9   34354270400000 825
804102924020702029 998514010103112120535000026750000781003001100110000421 0   26754270401100 602
804110624020702029 998514010103112120535000003150000087001000400040000031 5   31542704004001000
801010033092702032 308615090103122120535000018810000734000500200020000227 7   18813973400000 826
801020033092502039 998612090103122120535000006200000310000400200020000062 0    6204073200000 1000
     .
     .
     .
     .
$
```

```
$ @FSHA:[712.MASTER.COM]ESP3
$ASSIGN FSHA:[712.MASTER.DATA]ESP3.DAT FOR002
$ASSIGN SYS$INPUT    FOR001
$RUN FSHA:[712.MASTER.XEQ]ESP3

  Estimation of Relative Fishing Power
      Version 1.0 K. Paine 1/V/72
   Vax Version 1.3 D.Jackson  11/I/84
```

```
                                                                                                                                ESP3 VER 1.3 (01/11/84)
STANDARDIZED U.S. ANNUAL  COMMERCIAL C/E INDEX   MACKEREL SA5&6
   8    3    1    1    0
   1    6    6    6    6    6    6    6    6
 ZERO OBSERVATIONS INCLUDED IN ANALYSIS
 BLOCK DESIGNATORS
YEAR

 A-FACTOR LEVELS (ROWS)
  1.   2.   5.   8.  10.  11.  12.  14.   8.
 B-FACTOR LEVELS (COLS)
  2.   3.   4.   2.
 K-LEVELS
 80.
   1    0    0    0    0
1 0(T14,F2.0,T17,F1.0,T1,F2.0,T56,F4.1,T41,F8.0,T1,F2.0,F1.0)
REC.NO.=   1 A=      1. B=      2. Y= 0.52983E+01 DYS.FSHD=     1.0 K=     80. BLK LEVELS=     80.
```

STANDARDIZED U.S. ANNUAL COMMERCIAL C/E INDEX MACKEREL SA5&6 ESP3

YEAR = 80

ANALYSIS OF VARIANCE FOR YBAR(I,J,.)= M+A(I)+B(J)+E(I,J,.)

	TOTAL	BETWN SUBCL	ROWS	COLUMNS	INTERACTION	ERROR
DEG FREEDOM	113.0000	12.00000	7.000000	2.000000	3.000000	101.0000
SUMSQ (UNADJ)	634.0215	474.6162	410.8926	306.7051		
SUM SQ (ADJ)			163.0048	58.81733	4.906303	159.4053
MEAN SQ			23.28641	29.40866	1.635435	1.578270
F VALUE			14.75439	18.63348	1.036220	

RAW SUMSQ	CORRECTION TERM	WGHTED MEAN	DIFF (GND MN-WTD MEAN)
10066.04	9432.021	10.31314	-1.217145

MATRIX WITH J=NUMBER OF COLUMNS-1

B(J)

	2	3
1	-2.4139447	-0.14968836

ROW MEAN (I)-SUM B(J)*P(I,J)

M+A(I)

	1	2	5	8	10	11	12	14
1	7.7122622	8.9515476	10.298117	10.131317	8.7598572	9.6914949	12.976028	11.261518

ADJUSTED MEANS A

M+A(I)+DIFF

	1	2	5	8	10	11	12	14
1	6.4951172	7.7344027	9.0809717	8.9141722	7.5427122	8.4743500	11.758883	10.044374

ADJUSTED MEANS B=WEIGHTED MEAN + B(J)-DIFF

	2	3	4
1	9.1163359	11.380591	11.530280

STANDARDIZED U.S. ANNUAL COMMERCIAL C/E INDEX MACKEREL SA5&6 ESP3

YEAR = 80

MATRIX WITH J=NUMBER OF COLUMNS

COL MEANS OF CELL ESTIMATES
B BAR (J)

	2	3	4
1	7.5588231	9.8230801	9.9727688

B(J)PRIME

	2	3	4
1	-1.5594004	0.70485604	0.85454440

ROW MEAN(I)-SUM B(J)PRIME*P(I,J)
A(I)+M

	1	2	5	8	10	11	12	14
1	6.8577180	8.0970039	9.4435720	9.2767725	7.9053130	8.8369503	12.121484	10.406974

ROW ESTIMATORS=A(I)+M-MEAN OF EST(I,J)
A(I)

	1	2	5	8	10	11	12	14
1	-2.2605052	-1.0212193	0.32534885	0.15854931	-1.2129102	-0.28127289	3.0032606	1.2887506

CELL ESTMATES=A(I)+M+B(J) PRIME
EST(I,J)

	2	3	4
1	5.2983174	7.5625739	7.7122626
2	6.5376034	8.8018599	8.9515486
5	7.8841715	10.148428	10.298117
8	7.7173719	9.9816284	10.131317
10	6.3459125	8.6101694	8.7598572
11	7.2775497	9.5418062	9.6914949
12	10.562083	12.826340	12.976028
14	8.8475733	11.111830	11.261518

GRAND MEAN OF DATA= 9.095990

STANDARDIZED U.S. ANNUAL COMMERCIAL C/E INDEX MACKEREL SA5&6 ESP3

YEAR = 80

FISHING POWER AND STANDARDIZATION

FISH POWER=EST(I,J)-EST(STANDARD CELL)
FP(IJ)

	2	3	4
1	0.89005731E-01	0.85658818	0.99490374
2	0.30734986	2.9579246	3.4355485
5	1.1815174	11.370884	13.206970
8	1.0000000	9.6239662	11.177974
10	0.25373638	2.4419513	2.8362570
11	0.64415097	6.1992869	7.2003021
12	17.196592	165.49944	192.22307
14	3.0962799	29.798492	34.610134

TOTAL STANDARDIZED DAYS FISHED= 1049.55 (SUM FP(I,J)*EFFORT(I,J))
TOTAL LANDINGS PER STANDARD DAYS FISHED= 3122.62

STANDARD CELL VALUE (EST(I,J)) = 7.717372

STANDARDIZED U.S. ANNUAL COMMERCIAL C/E INDEX MACKEREL SA5&6 ESP3

YEAR = 80

EQUATIONS

LEFT EQUATION

A(J,J)

	2	3	4
2	10.904327	-7.0491276	-3.8552036
3	-7.0491271	16.542339	-9.4932127
4	-3.8552036	-9.4932127	13.348416

RIGHT EQUATION

Y(J)

	2	3	4
1	-25.267273	14.540009	10.727219

INVERSE

C(J,J)

	2	3
2	0.12657413	0.53936578E-01
3	0.53936575E-01	0.83434738E-01

DETERMINENT= 130.69289

STANDARDIZED U.S. ANNUAL COMMERCIAL C/E INDEX MACKEREL SA5&6 ESP3

YEAR = 80

DATA MATRICES 1

OBSERVATION VALUES

	Y(I,J)			TOT
	2	3	4	
1	5.2983174	0.00000000E+00	0.00000000E+00	5.2983174
2	80.476234	15.578716	0.00000000E+00	96.054955
5	44.202019	348.32617	123.40074	515.92896
8	61.738979	0.00000000E+00	0.00000000E+00	61.738979
10	95.188690	0.00000000E+00	0.00000000E+00	95.188690
11	21.832649	0.00000000E+00	0.00000000E+00	21.832649
12	64.450508	50.050735	91.008804	205.51006
14	35.390293	0.00000000E+00	0.00000000E+00	35.390293
1	408.57770	413.95563	214.40955	1036.9429

ROW MEANS=Y(I,.)/N(I,.)

	1	2	5	8	10	11	12	14
1	5.2983174	6.8610682	9.9217110	7.7173724	6.3459125	7.2775497	12.088827	8.8475733

NO. OBSERVATIONS

	N(I,J)			TOT
	2	3	4	
1	1.0000000	0.00000000E+00	0.00000000E+00	1.0000000
2	12.000000	2.0000000	0.00000000E+00	14.000000
5	6.0000000	34.000000	12.000000	52.000000
8	8.0000000	0.00000000E+00	0.00000000E+00	8.0000000
10	15.000000	0.00000000E+00	0.00000000E+00	15.000000
11	3.0000000	0.00000000E+00	0.00000000E+00	3.0000000
12	6.0000000	4.0000000	7.0000000	17.000000
14	4.0000000	0.00000000E+00	0.00000000E+00	4.0000000
1	55.000000	40.000000	19.000000	114.00000

STANDARDIZED U.S. ANNUAL COMMERCIAL C/E INDEX MACKEREL SA5&6 ESP3

YEAR = 80

DATA MATRICES 2

PROPORTION N

P(I,J)

	2	3	4
1	1.0000000	0.00000000E+00	0.00000000E+00
2	0.85714287	0.14285715	0.00000000E+00
5	0.11538462	0.65384614	0.23076923
8	1.0000000	0.00000000E+00	0.00000000E+00
10	1.0000000	0.00000000E+00	0.00000000E+00
11	1.0000000	0.00000000E+00	0.00000000E+00
12	0.35294119	0.23529412	0.41176471
14	1.0000000	0.00000000E+00	0.00000000E+00

LANDINGS

L(I,J) TOT

	2	3	4	
1	200.00000	0.00000000E+00	0.00000000E+00	200.00000
2	34079.000	2501.0000	0.00000000E+00	36580.000
5	15247.000	844693.00	345875.00	1205815.0
8	202944.00	0.00000000E+00	0.00000000E+00	202944.00
10	388097.00	0.00000000E+00	0.00000000E+00	388097.00
11	27854.000	0.00000000E+00	0.00000000E+00	27854.000
12	100905.00	257500.00	934692.00	1293097.0
14	122750.00	0.00000000E+00	0.00000000E+00	122750.00
1	892076.00	1104694.0	1280567.0	3277337.0

EFFORT

E(I,J) TOT

	2	3	4	
1	1.0000000	0.00000000E+00	0.00000000E+00	1.0000000
2	31.800001	0.90000004	0.00000000E+00	32.700001
5	3.3000002	21.300003	9.0000000	33.600006
8	110.70000	0.00000000E+00	0.00000000E+00	110.70000
10	218.00000	0.00000000E+00	0.00000000E+00	218.00000
11	23.799999	0.00000000E+00	0.00000000E+00	23.799999
12	2.3000000	0.40000001	1.6000001	4.3000002
14	25.000000	0.00000000E+00	0.00000000E+00	25.000000
1	415.89999	22.600002	10.600000	449.10001

STANDARDIZED U.S. ANNUAL COMMERCIAL C/E INDEX MACKEREL SA5&6 ESP3

YEAR = 80
KLEVEL = 80.

DAYS FISHED

	2	3	4
1	1.0000000	0.00000000E+00	0.00000000E+00
2	31.800001	0.90000004	0.00000000E+00
5	3.3000002	21.300003	9.0000000
8	110.70000	0.00000000E+00	0.00000000E+00
10	218.00000	0.00000000E+00	0.00000000E+00
11	23.799999	0.00000000E+00	0.00000000E+00
12	2.3000000	0.40000001	1.6000001
14	25.000000	0.00000000E+00	0.00000000E+00

STANDARDIZED FISHING EFFORT FOR K LEVEL= 80.

	2	3	4	TOT
1	0.89005731E-01	0.00000000E+00	0.00000000E+00	0.89005731E-01
2	9.7737255	2.6621323	0.00000000E+00	12.435858
5	3.8990076	242.19986	118.86273	364.96161
8	110.70000	0.00000000E+00	0.00000000E+00	110.70000
10	55.314529	0.00000000E+00	0.00000000E+00	55.314529
11	15.330792	0.00000000E+00	0.00000000E+00	15.330792
12	39.552162	66.199776	307.55695	413.30890
14	77.406998	0.00000000E+00	0.00000000E+00	77.406998
1	312.06625	311.06177	426.41968	1049.5477

PROGRAM NAME: Generalized Stock Production Model

PROGRAM TYPE: Main

DATE CREATED: Jan 1 1969

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]GENPROD.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]GENPROD.EXE

AUTHOR: J.J. Pella and P.K. Tomlinson

DOCUMENTED BY: F.P. Almeida

REVISIONS (Date/Reviser - Description)

Nov 14 1983 /F.P. Almeida -
Modified to VAX 11/780 FORTRAN77

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

The program fits the generalized stock production model to catch and effort data and estimates equilibrium yield as a function of effort.

DESCRIPTION:

GENPROD fits the generalized stock production model:

$$dp/dt = HP(\exp(m)) - KP - FP$$

where:

P = average stock biomass,
K = instantaneous rate of stock increase at densities approaching zero,
F = qf, catchability multiplied by fishing effort,
H = K/P(max), where P(max) equals maximum stock size,
m = an arbitrarily selected exponent determining the shape of the yield curve.

An iterative procedure is used in which trial values of f(opt) (optimum fishing effort), q (catchability), r (simple correlation coefficient), and U(max) (maximum catch/effort) are read and changed in steps (delta) determined by the user until the sum of squares is minimized.

Note that fitting the above model requires estimation of a number of parameters; consequently, numerous iterations are necessary and unless reasonable constraints are placed on m

the estimates obtained may be completely unrealistic (Ricker 1975). This is particularly true for estimates of q (which may be suspect no matter what constraints are placed on m). The user should consult Pella and Tomlinson (1969) before attempting to run GENPROD.

Hints on running -

When the addition or subtraction of f, q, r, or U fails to reduce the sum of squares, the 's are divided by 10 and the process repeated. The number of times the 's are divided by 10 is controlled by the user. The best estimate of the parameters f(opt), q, r, and U(max) are those corresponding to the minimum value of the sum of squares found.

Since guesses are required when using GENPROD, some hints for evaluating these are appropriate. The general situation is depicted as one in which data (catch and effort) are distributed over a range of population sizes, including the optimum. The technique suggested is to choose f(opt) equal to the mean of the observed efforts, choose U(max) equal to the maximum observed catch-per-effort, choose q equal to the maximum observed catch-per-effort divided by 4 times the maximum observed catch, and r equal to .8. The lower bounds of f(opt) and U(max) are set at 1/10 the guesses and the upper bounds are set at 10 times the guesses. The bounds of q should be more liberal, say 1/100 and 100 times. The bounds of r are obviously 0 and 1. The values for are simply set equal to the guesses.

Of course, if it is known that the catch-effort data were obtained from a segment of the range of the population sizes, then the guessing process must be modified, If serious doubts exist, make guesses as suggested and at the same time set very wide bounds and utilize relatively large 's for a quick search across the range. If any of the final estimates equal a bound, the data should be rerun with wider bounds. As for the values of m, it is appropriate to choose a range of values greater than 0 but less than 4 (m = 1 must be excluded). If little is known about the shape of the production curve, try .4, .8, 1.2, 1.6, 2.0, 2.4, 2.8, and 3.2 for a first run, then try additional values when the approximate range is determined by examining the values of S.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

The program is completely interactive, input is free formatted with question prompts. The user enters alphanumeric information, control values, catch and effort data, and best guesses and limits for f(opt), q, r, and U(max) as suggested above. To

run the program, type:

```
$RUN FSHA:[712.MASTER.XEQ]GENPROD
```

Data records are required as follows:

Record Number	Record Description
1	Title (maximum of 80 bytes),
2	Number of catch intervals, Number of parameters to be estimated (4), Number of times step intervals are to be divided by 10. The larger this value, the greater the execution time but answers contain more significant digits. (suggest 3),
3	Starting step for f(opt), if in doubt, leave blank, Starting step for q, if in doubt, leave blank, Starting step for r, if in doubt, leave blank, Starting step for U(max), if in doubt, leave blank,
4	Catch values (max = 1000),
5	Effort value used to make its respective catch,
6	Length of time associated with its respective catch,
7	Lower limits of f(opt), q, r, and U(max),
8	Upper limits of f(opt), q, r, and U(max),
9	Best guess of f(opt); try observed average, Best guess of q; try maximum observed catch-per-effort divided by 4 times maximum observed catch, Best guess of r; try r = 0.8, Best guess of U(max); try observed maximum(?),
10	Number of m values, Number of subintervals each time interval is to be divided into, if in doubt, try 1,
11	Trial values of m (max = 24).

When finished, the program will ask whether or not you want to repeat the run with different values of m, and if not, whether or not you want to rerun entirely. Note that the output requires a wide carriage terminal.

REFERENCES:

Pella, J.J. and P.K. Tomlinson. 1969. A generalized stock production model. Bull. Inter-Am. Trop. Tuna Comm. 13:419-496.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191. 382pp.

```
$ RUN FSHA:[712.MASTER.XEQ]GENPROD


        Generalized Stock Production Model Version 2.0  14/XI/83  J.J. Pella and P.K. Tomlinson

 Want explanation of program? (YES or NO)
NO
 Input title (max = 80 characters)
GENPROD TEST RUN   SCHAEFFER TUNA DATA
 Input number of catch intervals, number of parameters to be estimated,
       and number of times step intervals are tobe divided by 10
34,4,3
 Input starting steps for FOPT,Q,R,UMAX ("0." for each unknown value)
0.,0.,0.,0.
 Input catch values
60913,72294,78353,91522,78288,110418,114590,76841,41965,
50058,64869,89194,129701,160151,200993,200070,224810,186015,
195277,140042,140033,140865,177026,163020,148450,140484,244331,
230886,174063,145469,203882,180086,182294,178994
 Input effort values
5879,6295,6771,8233,6830,10488,10881,9584,5961,
5930,6475,9377,13958,20383,24781,23923,31856,18403,
34834,36356,26228,17198,27205,26768,31135;28198,
35841,41646,42248,33333,42090,43228,40393,33834
 Input time intervals associated with above catch and effort values
1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1
 Input lower limits of FOPT,Q,R, and UMAX
2254,.000000118,0,1.2
 Input upper limits of FOPT,Q,R, and UMAX
225400,.001184,1,116
 Input best estimates of FOPT,Q,R, and UMAX
22542,.00001184,.8,11.57
 Input number of M values and number of subintervals
       each time interval is to be divided into
3,1
 Input M values
1.0001,1.5,2
```

GENPROD TEST RUN SCHAEFFER TUNA DATA

GENERALIZED PRODUCTION MODEL M= 1.00

****

OPTIMUM EFFORT (FOPT)	MAX. CATCH/EFFORT (UMAX)	CATCHABILITY COEFF. (Q)	INITIAL POP./MAX. POP. (P(0)/PMAX)
0.4125183E+05	0.12148499E+02	0.94720024E-04	0.83999985E+00

****

MAXIMUM EQUIL. CATCH (CMAX)	OPTIMUM POPULATION (POPT)	MAX. POPULATION (PMAX)	CONSTANT (H)	CONSTANT (K)
0.18437119E+06	0.47185445E+05	0.12826469E+06	-0.3903E+05	-0.3907E+05

****

SUM OF SQUARES	R	TOTAL CATCH	AVERAGE CATCH
0.17754100E+11	0.8287E+00	0.4816247E+07	0.1416543E+06

****

AT TIME	POPULATION SIZE	APPLIED EFFORT	OBSERVED CATCH	EXPECTED CATCH	OBSERVED CATCH/EFFORT	EXPECTED CATCH/EFFORT
1.00	0.1111668E+06	0.5879000E+04	0.6091300E+05	0.6095075E+05	0.1036112E+02	0.1036754E+02
2.00	0.1101105E+06	0.6295000E+04	0.7229400E+05	0.6596968E+05	0.1148435E+02	0.1047970E+02
3.00	0.1089343E+06	0.6771000E+04	0.7835300E+05	0.7024211E+05	0.1157185E+02	0.1037396E+02
4.00	0.1051663E+06	0.8233000E+04	0.9152200E+05	0.8348104E+05	0.1111648E+02	0.1013981E+02
5.00	0.1086747E+06	0.6830000E+04	0.7828800E+05	0.6917091E+05	0.1146237E+02	0.1012751E+02
6.00	0.9972769E+05	0.1048800E+05	0.1104180E+06	0.1035159E+06	0.1052803E+02	0.9869939E+01
7.00	0.9854467E+05	0.1088100E+05	0.1145900E+06	0.1021746E+06	0.1053120E+02	0.9390182E+01
8.00	0.1017106E+06	0.9584000E+04	0.7684100E+05	0.9089556E+05	0.8017633E+01	0.9484095E+01
9.00	0.1108356E+06	0.5961000E+04	0.4196500E+05	0.6000459E+05	0.7039926E+01	0.1006619E+02
10.00	0.1111004E+06	0.5930000E+04	0.5005800E+05	0.6232961E+05	0.8441484E+01	0.1051090E+02
11.00	0.1097171E+06	0.6475000E+04	0.6486900E+05	0.6771504E+05	0.1001838E+02	0.1045792E+02
12.00	0.1023804E+06	0.9377000E+04	0.8919400E+05	0.9419140E+05	0.9511997E+01	0.1004494E+02
13.00	0.9173599E+05	0.1395800E+05	0.1297010E+06	0.1283208E+06	0.9292233E+01	0.9193354E+01
14.00	0.7855445E+05	0.2038300E+05	0.1601510E+06	0.1643880E+06	0.7857087E+01	0.8064958E+01
15.00	0.7055564E+05	0.2478100E+05	0.2009930E+06	0.1749998E+06	0.8110770E+01	0.7061856E+01

16.00	0.7182979E+05	0.2392300E+05	0.2000700E+06	0.1613218E+06	0.8363082E+01	0.6743376E+01
17.00	0.5952332E+05	0.3185600E+05	0.2248100E+06	0.1981725E+06	0.7057069E+01	0.6220885E+01
18.00	0.8161191E+05	0.1840300E+05	0.1860150E+06	0.1230087E+06	0.1010786E+02	0.6684166E+01
19.00	0.5557641E+05	0.3483400E+05	0.1952770E+06	0.2263249E+06	0.5605931E+01	0.6497241E+01
20.00	0.5320793E+05	0.3635600E+05	0.1400420E+06	0.1873071E+06	0.3851964E+01	0.5152028E+01
21.00	0.6762930E+05	0.2622800E+05	0.1400330E+06	0.1500990E+06	0.5339065E+01	0.5722853E+01
22.00	0.8418369E+05	0.1719800E+05	0.1408650E+06	0.1236513E+06	0.8190778E+01	0.7189865E+01
23.00	0.6666791E+05	0.2720500E+05	0.1770260E+06	0.1943616E+06	0.6507113E+01	0.7144334E+01
24.00	0.6706680E+05	0.2676800E+05	0.1630200E+06	0.1695399E+06	0.6090107E+01	0.6333678E+01
25.00	0.6048986E+05	0.3113500E+05	0.1484500E+06	0.1880892E+06	0.4767946E+01	0.6041085E+01
26.00	0.6470852E+05	0.2819800E+05	0.1404840E+06	0.1671971E+06	0.4982056E+01	0.5929397E+01
27.00	0.5403965E+05	0.3584100E+05	0.2443310E+06	0.2015667E+06	0.6817081E+01	0.5623915E+01
28.00	0.4688648E+05	0.4164600E+05	0.2308860E+06	0.1990622E+06	0.5544014E+01	0.4779862E+01
29.00	0.4613726E+05	0.4224800E+05	0.1740630E+06	0.1861280E+06	0.4120029E+01	0.4405605E+01
30.00	0.5698658E+05	0.3333300E+05	0.1454690E+06	0.1627966E+06	0.4364114E+01	0.4883946E+01
31.00	0.4644106E+05	0.4209000E+05	0.2038820E+06	0.2061709E+06	0.4843954E+01	0.4898335E+01
32.00	0.4504932E+05	0.4322800E+05	0.1800860E+06	0.1873063E+06	0.4165957E+01	0.4332986E+01
33.00	0.4816228E+05	0.4039300E+05	0.1822940E+06	0.1783150E+06	0.4513010E+01	0.4414503E+01
34.00	0.5637791E+05	0.3383400E+05	0.1789940E+06	0.1675130E+06	0.5290359E+01	0.4951025E+01

GENPROD TEST RUN SCHAEFFER TUNA DATA

GENERALIZED PRODUCTION MODEL M= 1.50

OPTIMUM EFFORT (FOPT)	MAX. CATCH/EFFORT (UMAX)	CATCHABILITY COEFF. (Q)	INITIAL POP./MAX. POP. (P(0)/PMAX)
0.3606716E+05	0.11454298E+02	0.29777625E-03	0.91199982E+00

MAXIMUM EQUIL. CATCH (CMAX)	OPTIMUM POPULATION (POPT)	MAX. POPULATION (PMAX)	CONSTANT (H)	CONSTANT (K)
0.18361067E+06	0.17096055E+05	0.38466125E+05	-0.1643E+00	-0.3222E+02

SUM OF SQUARES	R	TOTAL CATCH	AVERAGE CATCH
0.17628641E+11	0.8299E+00	0.4816247E+07	0.1416543E+06

AT TIME	POPULATION SIZE	APPLIED EFFORT	OBSERVED CATCH	EXPECTED CATCH	OBSERVED CATCH/EFFORT	EXPECTED CATCH/EFFORT
1.00	0.3439965E+05	0.5879000E+04	0.6091300E+05	0.6081742E+05	0.1036112E+02	0.1034486E+02
2.00	0.3412053E+05	0.6295000E+04	0.7229400E+05	0.6422059E+05	0.1148435E+02	0.1020184E+02
3.00	0.3380251E+05	0.6771000E+04	0.7835300E+05	0.6847467E+05	0.1157185E+02	0.1011293E+02
4.00	0.3283509E+05	0.8233000E+04	0.9152200E+05	0.8168410E+05	0.1111648E+02	0.9921548E+01
5.00	0.3376320E+05	0.6830000E+04	0.7828800E+05	0.6772420E+05	0.1146237E+02	0.9915695E+01
6.00	0.3137047E+05	0.1048800E+05	0.1104180E+06	0.1017088E+06	0.1052803E+02	0.9697632E+01
7.00	0.3111863E+05	0.1088100E+05	0.1145900E+06	0.1012356E+06	0.1053120E+02	0.9303885E+01
8.00	0.3195362E+05	0.9584000E+04	0.7684100E+05	0.9000055E+05	0.8017633E+01	0.9390709E+01
9.00	0.3434455E+05	0.5961000E+04	0.4196500E+05	0.5884109E+05	0.7039926E+01	0.9871011E+01
10.00	0.3436539E+05	0.5930000E+04	0.5005800E+05	0.6066445E+05	0.8441484E+01	0.1023009E+02
11.00	0.3400008E+05	0.6475000E+04	0.6486900E+05	0.6590777E+05	0.1001838E+02	0.1017881E+02
12.00	0.3208789E+05	0.9377000E+04	0.8919400E+05	0.9226700E+05	0.9511997E+01	0.9839714E+01
13.00	0.2918197E+05	0.1395800E+05	0.1297010E+06	0.1273298E+06	0.9292233E+01	0.9122355E+01
14.00	0.2533867E+05	0.2038300E+05	0.1601510E+06	0.1654585E+06	0.7857087E+01	0.8117476E+01
15.00	0.2286429E+05	0.2478100E+05	0.2009930E+06	0.1778495E+06	0.8110770E+01	0.7176849E+01

16.00	0.2333703E+05	0.2392300E+05	0.2000700E+06	0.1645622E+06	0.8363082E+01	0.6878828E+01
17.00	0.1915049E+05	0.3185600E+05	0.2248100E+06	0.2015174E+06	0.7057069E+01	0.6325886E+01
18.00	0.2649414E+05	0.1840300E+05	0.1860150E+06	0.1250658E+06	0.1010786E+02	0.6795944E+01
19.00	0.1768570E+05	0.3483400E+05	0.1952770E+06	0.2291330E+06	0.5605931E+01	0.6577855E+01
20.00	0.1695944E+05	0.3635600E+05	0.1400420E+06	0.1875333E+06	0.3851964E+01	0.5158250E+01
21.00	0.2207793E+05	0.2622800E+05	0.1400330E+06	0.1524424E+06	0.5339065E+01	0.5812201E+01
22.00	0.2720995E+05	0.1719800E+05	0.1408650E+06	0.1262055E+06	0.8190778E+01	0.7338380E+01
23.00	0.2155486E+05	0.2720500E+05	0.1770260E+06	0.1975219E+06	0.6507113E+01	0.7260501E+01
24.00	0.2178802E+05	0.2676800E+05	0.1630200E+06	0.1727403E+06	0.6090107E+01	0.6453240E+01
25.00	0.1951388E+05	0.3113500E+05	0.1484500E+06	0.1914604E+06	0.4767946E+01	0.6149363E+01
26.00	0.2102953E+05	0.2819800E+05	0.1404840E+06	0.1702153E+06	0.4982056E+01	0.6036433E+01
27.00	0.1720349E+05	0.3584100E+05	0.2443310E+06	0.2040229E+06	0.6817081E+01	0.5692443E+01
28.00	0.1455402E+05	0.4164600E+05	0.2308860E+06	0.1969155E+06	0.5544014E+01	0.4728317E+01
29.00	0.1429184E+05	0.4224800E+05	0.1740630E+06	0.1814470E+06	0.4120029E+01	0.4294806E+01
30.00	0.1841655E+05	0.3333300E+05	0.1454690E+06	0.1623280E+06	0.4364114E+01	0.4869890E+01
31.00	0.1436056E+05	0.4209000E+05	0.2038820E+06	0.2054043E+06	0.4843954E+01	0.4880122E+01
32.00	0.1387029E+05	0.4322800E+05	0.1800860E+06	0.1816976E+06	0.4165957E+01	0.4203238E+01
33.00	0.1510701E+05	0.4039300E+05	0.1822940E+06	0.1742706E+06	0.4513010E+01	0.4314376E+01
34.00	0.1817093E+05	0.3383400E+05	0.1789940E+06	0.1676370E+06	0.5290359E+01	0.4954690E+01

GENPROD TEST RUN SCHAEFFER TUNA DATA

GENERALIZED PRODUCTION MODEL M= 2.00

OPTIMUM EFFORT (FOPT)	MAX. CATCH/EFFORT (UMAX)	CATCHABILITY COEFF. (Q)	INITIAL POP./MAX. POP. (P(0)/PMAX)
0.3358758E+05	0.10991503E+02	0.12041677E-03	0.97599995E+00

MAXIMUM EQUIL. CATCH (CMAX)	OPTIMUM POPULATION (POPT)	MAX. POPULATION (PMAX)	CONSTANT (H)	CONSTANT (K)
0.18458898E+06	0.45639418E+05	0.91278797E+05	-0.8862E-04	-0.8089E+01

SUM OF SQUARES	R	TOTAL CATCH	AVERAGE CATCH
0.18021288E+11	0.8261E+00	0.4816247E+07	0.1416543E+06

AT TIME	POPULATION SIZE	APPLIED EFFORT	OBSERVED CATCH	EXPECTED CATCH	OBSERVED CATCH/EFFORT	EXPECTED CATCH/EFFORT
1.00	0.8329366E+05	0.5879000E+04	0.6091300E+05	0.6101713E+05	0.1036112E+02	0.1037883E+02
2.00	0.8272542E+05	0.6295000E+04	0.7229400E+05	0.6292319E+05	0.1148435E+02	0.9995741E+01
3.00	0.8207867E+05	0.6771000E+04	0.7835300E+05	0.6718584E+05	0.1157185E+02	0.9922588E+01
4.00	0.8009326E+05	0.8233000E+04	0.9152200E+05	0.8038792E+05	0.1111648E+02	0.9764111E+01
5.00	0.8199668E+05	0.6830000E+04	0.7828800E+05	0.6665516E+05	0.1146237E+02	0.9759173E+01
6.00	0.7703257E+05	0.1048800E+05	0.1104180E+06	0.1004215E+06	0.1052803E+02	0.9574894E+01
7.00	0.7649406E+05	0.1088100E+05	0.1145900E+06	0.1005795E+06	0.1053120E+02	0.9243591E+01
8.00	0.7825409E+05	0.9584000E+04	0.7684100E+05	0.8929544E+05	0.8017633E+01	0.9317137E+01
9.00	0.8317563E+05	0.5961000E+04	0.4196500E+05	0.5793748E+05	0.7039926E+01	0.9719423E+01
10.00	0.8322101E+05	0.5930000E+04	0.5005800E+05	0.5940955E+05	0.8441484E+01	0.1001847E+02
11.00	0.8248090E+05	0.6475000E+04	0.6486900E+05	0.6459877E+05	0.1001838E+02	0.9976645E+01
12.00	0.7854074E+05	0.9377000E+04	0.8919400E+05	0.9090863E+05	0.9511997E+01	0.9694853E+01
13.00	0.7232188E+05	0.1395800E+05	0.1297010E+06	0.1267832E+06	0.9292233E+01	0.9083196E+01
14.00	0.6360945E+05	0.2038300E+05	0.1601510E+06	0.1668187E+06	0.7857087E+01	0.8184206E+01
15.00	0.5763891E+05	0.2478100E+05	0.2009930E+06	0.1809055E+06	0.8110770E+01	0.7300168E+01

16.00	0.5876548E+05	0.2392300E+05	0.2000700E+06	0.1676648E+06	0.8363082E+01	0.7008520E+01
17.00	0.4811775E+05	0.3185600E+05	0.2248100E+06	0.2050019E+06	0.7057069E+01	0.6435267E+01
18.00	0.6620218E+05	0.1840300E+05	0.1860150E+06	0.1266682E+06	0.1010786E+02	0.6883018E+01
19.00	0.4424853E+05	0.3483400E+05	0.1952770E+06	0.2316482E+06	0.5605931E+01	0.6650059E+01
20.00	0.4193256E+05	0.3635600E+05	0.1400420E+06	0.1886449E+06	0.3851964E+01	0.5188824E+01
21.00	0.5550867E+05	0.2622800E+05	0.1400330E+06	0.1538739E+06	0.5339065E+01	0.5866779E+01
22.00	0.6787295E+05	0.1719800E+05	0.1408650E+06	0.1277572E+06	0.8190778E+01	0.7428608E+01
23.00	0.5440042E+05	0.2720500E+05	0.1770260E+06	0.2002800E+06	0.6507113E+01	0.7361883E+01
24.00	0.5490201E+05	0.2676800E+05	0.1630200E+06	0.1761581E+06	0.6090107E+01	0.6580923E+01
25.00	0.4904106E+05	0.3113500E+05	0.1484500E+06	0.1948505E+06	0.4767946E+01	0.6258245E+01
26.00	0.5292413E+05	0.2819800E+05	0.1404840E+06	0.1731120E+06	0.4982056E+01	0.6139159E+01
27.00	0.4276956E+05	0.3584100E+05	0.2443310E+06	0.2065002E+06	0.6817081E+01	0.5761562E+01
28.00	0.3499513E+05	0.4164600E+05	0.2308860E+06	0.1949902E+06	0.5544014E+01	0.4682086E+01
29.00	0.3392562E+05	0.4224800E+05	0.1740630E+06	0.1753126E+06	0.4120029E+01	0.4149607E+01
30.00	0.4570929E+05	0.3333300E+05	0.1454690E+06	0.1598214E+06	0.4364114E+01	0.4794689E+01
31.00	0.3451417E+05	0.4209000E+05	0.2038820E+06	0.2033000E+06	0.4843954E+01	0.4830125E+01
32.00	0.3264425E+05	0.4322800E+05	0.1800860E+06	0.1747924E+06	0.4165957E+01	0.4043500E+01
33.00	0.3622674E+05	0.4039300E+05	0.1822940E+06	0.1674941E+06	0.4513010E+01	0.4146611E+01
34.00	0.4510061E+05	0.3383400E+05	0.1789940E+06	0.1656712E+06	0.5290359E+01	0.4896588E+01

```
 Do you wish to run with different M values? (YES or NO)
NO
 Do you wish to rerun program? (YES or NO)
NO
FORTRAN STOP
$
```

PROGRAM NAME: Generalized Stock Production Model

PROGRAM TYPE: Main

DATE CREATED: Unknown

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]PRODFIT.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]PRODFIT.EXE

AUTHOR: W.W. Fox, Jr.

DOCUMENTED BY: S.H. Clark

REVISIONS (Date/Reviser - Description)

Dec 1983 /F.P. Almeida -
Converted to FORTRAN77 to run on VAX11/780

STATUS: Operational

CLASSIFICATION: Analytical Model

PURPOSE OF PROGRAM:

The program fits the generalized stock production model to fishery catch and effort data by least squares using an equilibrium approximation approach.

DESCRIPTION:

This program fits the generalized stock production model

$$dP/dt = HP_t^{\,m} - KP_t - qf_tP_t$$

where

P = population size (usually in terms of weight);
f = effective fishing effort (standardized so as to be proportional to F);
q = constant of proportionality or catchability coefficient,
and H, K, and m are constants. At equilibrium (i.e. dP/dt = 0),

$$P^{m-1} = (K/H+q/H)f$$

or

$$U^{m-1} = (Kq^{m-1}/H) + (q^m/H)f$$

and

$$U = (\alpha+bf)^{\frac{1}{m-1}}$$

where U is the catch per unit effort.

The program also estimates the following:

$$Umax = \alpha^{\frac{1}{m-1}}$$

$$Uopt = (\alpha/m)^{\frac{1}{m-1}}$$

$$Fopt = (\alpha/b)(1/m-1)$$

$$Ymax = (\alpha/b)(1/m-1)(\alpha/m)^{\frac{1}{m-1}}$$

where:

Umax = relative poulation density before exploitation;
Uopt = relative population density providing maximum sustainable yield;
fopt = amount of fishing effort providing maximum sustainable yield, and
Ymax = maximum sustainable yield.

The program first adjusts fishing effort to approximate equilibrium conditions by computing weighted or unweighted averages by year over some previous number of years (K) corresponding to the number of year classes making a significant contribution to the catch. The resulting $\overline{f}i$ values are used with corresponding catch values to derive a data set of (Ui, $\overline{f}i$) pairs which are then utilized to estimate the parameters in the model. Note that K - 1 data points at the beginning of the data set are lost unless some information about these years prior to the data set can be entered and that K can vary throughout the time series. PRODFIT provides least-squares estimates for the parameters a, b, and m by minimizing the function:

$$S = \sum_{i=1}^{n} W_i \, (U_i - \hat{U}_i)^2$$

where the Wi values are statistical weights derived by assuming a multiplicative error structure and the Ui values are predicted from the fitted model.

Output from PRODFIT includes a listing of the input data, initial parameter estimates, final estimates for a, b, m, Umax, Uopt, fopt, and Ymax and their variability indices, observed and predicted values and error terms, estimates of the catchability coefficient q and a tables of equilibrium values.

Program PRODFIT provides the user with different options for data entry, calculation of parameter estimates, model configuration and weighting of effort data. These

can be summarized as follows:

Data Entry: The user may enter catch (Ci) and fishing effort (fi) values for i = 1 ... n years together with a vector of significant year class contribution numbers for averaging purposes (zero values are permitted if they are real and do not simply reflect a lack of information). Alternatively, a constant number of years may be entered for averaging purposes. If the data represent an equilibrium situation, or if the user wishes to calculate the averaged effort vector by procedures other than those used by the program, then catch per unit effort (Ui) and effort (fi) values are entered directly. No estimate of q can be made in the latter option.

Parameter Estimation: Parameter estimates may be calculated directly by the program without use of trial values in the majority of cases. Occasionally the data are so variable that compatible starting values cannot be obtained, and in this case (or in any case) the user may opt to enter initial parameter estimates directly.

Model Configuration: The user may allow PRODFIT to estimate m to any desired precision. Frequently, however, data are so variable that no significant reduction in the residual sum of squares can be obtained by varying m. The user then has the option to fix m at 2, the logistic model (Schaefer 1957); at 1, the Gompertz model (Fox 1970); or at zero, the asymptotic yield model.

Weighting: The user may select statistical weights assuming a multiplicative error structure or may choose not to weight the individual observations, i.e. Wi = 1 for all i.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

Input values are free - formatted; data values should be entered separated by commas. Output requires a wide carriage terminal. To run the program, type:

```
$RUN FSHA:[712.MASTER.XEQ]PRODFIT
```

The user is then prompted for an identifier title (80 byte maximum), control data/specifications, and catch and effort data (or catch per unit effort and effort data if data represent equilibrium). In the former case numbers of significant year classes must also be entered. Alternatively, the user may create a data file and use the following:

```
$ASSIGN datafile.DAT FOR005
$RUN FSHA:[712.MASTER.XEQ]PRODFIT
```

Restrictions: Number of data points cannot exceed 99.

REFERENCES:

Fox, W.W., Jr. 1970. An exponential surplus - yield model for optimizing exploited fish populations. Trans. Am. Fish. Soc. 99:80-88.

Fox, W. W., Jr. 1975. Fitting the generalized stock production model by least squares and equilibrium approximation. Fish. Bull., U.S., 73:23-37.

Schaefer, M. B. 1957. A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Inter - Am. Trop. Tuna Comm., Bull. 2:245-285.

Example 1. Natural mortality(M) fixed, fishing effort averaged.

```
$RUN FSHA:[712.MASTER.XEQ]PRODFIT
   Generalized Stock Production Model     W.W.Fox,Jr.-S.Clark


INPUT TITLE UP TO 80 CHARACTERS
TEST RUN

NUMBER OF DATA POINTS  + STARTING VALUE FOR M(0.,1.,2.)
34,2.0

IS M TO BE FITTED(ENTER 0) OR FIXED AT STARTING VALUE(ENTER 1)?
1

ARE OBSERVATIONS TO BE UNWEIGHTED(ENTER 0) OR WEIGHTED(ENTER 1)?
1

CATCH VALUES OR CATCH PER EFFORT VALUES AT EQUILIBRIUM
60913,72294,78353,91522,78288,110418,114590,76841
41965,50058,64869,89194,129701,160151,206993,200070
224810,186015,195277,140042,140033,140865,177026,163020
148450,140484,244331,230886,174063,145469,203882,180086
182294,178994
FISHING EFFORT VALUES
5879,6295,6771,8233,6830,10488,10801,9584
5961,5930,6475,9377,13958,20383,24781,23923
31856,18403,34834,36356,26228,17198,27205,26768
31158,28198,35841,41646,42248,33303,42090,43228
40393,33834

ARE EFFORT VALUES TO BE AVERAGED(ENTER 0) OR DO DATA REPRESENT EQUILIBRIUM(ENTER 1)?
0

WILL EFFORT VALUES BE AVERAGED BY A CONSTANT FIGURE THOUGHOUT THE DATA SET(ENTER 0)
OR ARE SEPARATE VALUES USED FOR EACH YEAR(ENTER 1)?
0

CONSTANT FOR AVERAGING EFFORT
3.0
```

RAW DATA

CATCH	EFFORT	NO. YEAR CLASSES
0.609130E+05	0.587900E+04	0.300000E+01
0.722940E+05	0.629500E+04	0.300000E+01
0.783530E+05	0.677100E+04	0.300000E+01
0.915220E+05	0.823300E+04	0.300000E+01
0.782880E+05	0.683000E+04	0.300000E+01
0.110418E+06	0.104880E+05	0.300000E+01
0.114590E+06	0.108010E+05	0.300000E+01
0.768410E+05	0.958400E+04	0.300000E+01
0.419650E+05	0.596100E+04	0.300000E+01
0.500580E+05	0.593000E+04	0.300000E+01
0.648690E+05	0.647500E+04	0.300000E+01
0.891940E+05	0.937700E+04	0.300000E+01
0.129701E+06	0.139580E+05	0.300000E+01
0.160151E+06	0.203830E+05	0.300000E+01
0.206993E+06	0.247810E+05	0.300000E+01
0.200070E+06	0.239230E+05	0.300000E+01
0.224810E+06	0.318560E+05	0.300000E+01
0.186015E+06	0.184030E+05	0.300000E+01
0.195277E+06	0.348340E+05	0.300000E+01
0.140042E+06	0.363560E+05	0.300000E+01
0.140033E+06	0.262280E+05	0.300000E+01
0.140865E+06	0.171980E+05	0.300000E+01
0.177026E+06	0.272050E+05	0.300000E+01
0.163020E+06	0.267680E+05	0.300000E+01
0.148450E+06	0.311580E+05	0.300000E+01
0.140484E+06	0.281980E+05	0.300000E+01
0.244331E+06	0.358410E+05	0.300000E+01
0.230886E+06	0.416460E+05	0.300000E+01
0.174063E+06	0.422480E+05	0.300000E+01
0.145469E+06	0.333030E+05	0.300000E+01
0.203882E+06	0.420900E+05	0.300000E+01
0.180086E+06	0.432280E+05	0.300000E+01
0.182294E+06	0.403930E+05	0.300000E+01
0.178994E+06	0.338340E+05	0.300000E+01

DATA FOR FITTING

CATCH/EFFORT	AVERAGE EFFORT
0.115719E+02	0.646367E+04
0.111165E+02	0.742267E+04
0.114624E+02	0.728783E+04
0.105280E+02	0.889283E+04
0.106092E+02	0.100348E+05
0.801763E+01	0.101403E+05
0.703993E+01	0.797533E+04
0.844148E+01	0.654933E+04
0.100184E+02	0.620767E+04
0.951200E+01	0.783517E+04
0.929223E+01	0.111838E+05
0.785709E+01	0.164070E+05
0.835289E+01	0.215112E+05
0.836308E+01	0.236190E+05
0.705707E+01	0.280325E+05
0.101079E+02	0.238073E+05
0.560593E+01	0.288607E+05
0.385196E+01	0.328565E+05
0.533907E+01	0.310383E+05
0.819078E+01	0.234010E+05
0.650711E+01	0.237065E+05
0.609011E+01	0.253187E+05
0.476443E+01	0.290358E+05
0.498206E+01	0.289463E+05
0.681708E+01	0.325128E+05
0.554401E+01	0.374697E+05
0.412003E+01	0.409795E+05
0.436804E+01	0.376752E+05
0.484395E+01	0.391873E+05
0.416596E+01	0.411945E+05
0.451301E+01	0.416208E+05
0.529036E+01	0.375860E+05

```
ARE VALUES FOR A,B,M AND RESIDUAL SUM OF SQUARES TO BEFITTED WITH THE PROGRAM
ENTER 0) OR ENTERED (ENTER 1)?
0

 STARTING VALUES      A =  0.112341E+02      B = -0.170329E-03      M =  0.200000E+01      RESIDUAL SUM OF SQUARES =  0.100000E+

RE-PARAMETERIZED STARTING VALUES AND LIMITS

           VALUE           LOWER           UPPER


UMAX =   0.112341E+02   0.842561E+01   0.140427E+02
YMAX =   0.185238E+06   0.138929E+06   0.231548E+06
M =  0.200000E+01      UMAX =  0.115140E+02      YMAX =  0.189788E+06      SSQ =  0.764476E+00

*****************************************************************************************************************************
```

*** FINAL ESTIMATES ***

```
RESIDUAL SUM OF SQUARES MINIMIZED WITHIN PARAMETER PRECISION OF

     NO.  DECIMAL  PLACES  FOR  M =  2

     NO. DIGITS FOR UMAX AND YMAX =  5

WEIGHTED ESTIMATES


A = 0.115140E+02          VAR. INDEX  A = 0.287412E+00

B =-0.174633E-03          VAR. INDEX  B = 0.281217E-09

M = 0.200000E+01          VAR. INDEX  M = 0.000000E+00

                 RESIDUAL SUM OF SQUARES = 0.764476E+00

                      DEGREES OF FREEDOM = 0.300000E+02

                    RESIDUAL VAR. INDEX = 0.254825E-01

                    DEGREE OF FIT INDEX = 0.776090E+00


VARIABILITY INDEX MATRIX

    0.287412E+00   -0.843643E-05    0.000000E+00

   -0.843643E-05    0.281217E-09    0.000000E+00

    0.000000E+00    0.000000E+00    0.000000E+00
```

AVERAGE EFFORT	CATCH/EFFORT	PRED. C/E	ERROR TERM
0.646367E+04	0.115719E+02	0.103853E+02	0.114255E+00
0.742267E+04	0.111165E+02	0.102178E+02	0.879523E-01
0.728783E+04	0.114624E+02	0.102414E+02	0.119224E+00
0.889283E+04	0.105280E+02	0.996107E+01	0.569183E-01
0.100348E+05	0.106092E+02	0.976163E+01	0.868264E-01
0.101403E+05	0.801763E+01	0.974321E+01	-0.177106E+00
0.797533E+04	0.703993E+01	0.101213E+02	-0.304444E+00
0.654933E+04	0.844148E+01	0.103703E+02	-0.185996E+00
0.620767E+04	0.100184E+02	0.104300E+02	-0.394638E-01
0.783517E+04	0.951200E+01	0.101458E+02	-0.624667E-01
0.111838E+05	0.929223E+01	0.956098E+01	-0.281088E-01
0.164070E+05	0.785709E+01	0.864884E+01	-0.915446E-01
0.215112E+05	0.835289E+01	0.775748E+01	0.767525E-01
0.236190E+05	0.836308E+01	0.738939E+01	0.131769E+00
0.280325E+05	0.705707E+01	0.661864E+01	0.662410E-01
0.238073E+05	0.101079E+02	0.735650E+01	0.374005E+00
0.288607E+05	0.560593E+01	0.647402E+01	-0.134088E+00
0.328565E+05	0.385196E+01	0.577621E+01	-0.333133E+00
0.310383E+05	0.533907E+01	0.609373E+01	-0.123842E+00
0.234010E+05	0.819078E+01	0.742746E+01	0.102770E+00
0.237065E+05	0.650711E+01	0.737411E+01	-0.117573E+00
0.253187E+05	0.609011E+01	0.709257E+01	-0.141340E+00
0.290358E+05	0.476443E+01	0.644343E+01	-0.260576E+00
0.289463E+05	0.498206E+01	0.645906E+01	-0.228671E+00
0.325128E+05	0.681708E+01	0.583623E+01	0.168063E+00
0.374697E+05	0.554401E+01	0.497060E+01	0.115361E+00
0.409795E+05	0.412003E+01	0.435767E+01	-0.545332E-01
0.376752E+05	0.436804E+01	0.493471E+01	-0.114833E+00
0.391873E+05	0.484395E+01	0.467064E+01	0.371072E-01
0.411945E+05	0.416596E+01	0.432012E+01	-0.356849E-01
0.416208E+05	0.451301E+01	0.424567E+01	0.629678E-01
0.375860E+05	0.529036E+01	0.495028E+01	0.686979E-01

****

*** MANAGEMENT IMPLICATIONS OF THE FITTED MODEL ***

	VALUE	VARIABILITY INDEX	ERROR INDEX (PERCENT)
PRE-EXPLOITATION CATCH/EFFORT =	0.115140E+02	0.287412E+00	4.656118
OPTIMUM CATCH/EFFORT =	0.575702E+01	0.718529E-01	4.656118
OPTIMUM FISHING EFFORT =	0.329664E+05	0.325791E+07	5.475181
MAXIMUM SUSTAINABLE YIELD =	0.189788E+06	0.399890E+08	3.331969

****

** ESTIMATES OF THE CATCHABILITY COEFFICIENT AND POPULATION SIZE **

** BY THE INTEGRAL METHOD **

TIME	CATCHABILITY COEFFICIENT
(1, 2)	0.390742E-04
(2, 3)	0.114827E-05
(3, 4)	0.624094E-05
(4, 5)	0.495205E-05
(5, 6)	0.163414E-04
(6, 7)	0.146938E-05
(7, 8)	0.171108E-04
(8, 9)	0.870823E-05
(9,10)	0.117638E-04
(10,11)	0.292079E-04
(11,12)	0.304092E-04
(12,13)	0.307895E-04
(13,14)	0.517745E-07
(14,15)	0.217547E-04
(15,16)	0.194171E-06
(16,17)	0.330000E-04
(17,18)	0.836654E-04
(18,19)	0.905427E-05
(19,20)	0.633490E-04
(20,21)	0.420243E-04
(21,22)	0.464617E-04
(22,23)	0.215643E-04
(23,24)	0.243653E-04
(24,25)	0.480460E-04
(25,26)	0.535666E-05
(26,27)	0.107134E-04
(27,28)	0.275346E-04
(28,29)	0.111961E-03
(29,30)	0.153121E-04
(30,31)	0.697790E-04
(31,32)	0.810808E-04
(32,33)	0.739542E-04
(33,34)	0.298789E-04

UNWEIGHTED GEOMETRIC MEAN

Q = 0.151621E-04

COND. VARIANCE Q = 0.199640E-10

VIRGIN POPL. SIZE = 0.759396E+06

OPTIMUM POPL. SIZE = 0.379698E+06

UNWEIGHTED ARITHMETIC MEAN

Q = 0.307975E-04

COND. VARIANCE Q = 0.238819E-10

VIRGIN POPL. SIZE = 0.373863E+06

OPTIMUM POPL. SIZE = 0.186932E+06

****

EQUILIBRIUM VALUES

****

EFFORT	CATCH/EFFORT	CATCH
0.000000E+00	0.115140E+02	0.000000E+00
0.164832E+04	0.112262E+02	0.185044E+05
0.329664E+04	0.109383E+02	0.360598E+05
0.494496E+04	0.106505E+02	0.526662E+05
0.659327E+04	0.103626E+02	0.683238E+05
0.824159E+04	0.100748E+02	0.830324E+05
0.988991E+04	0.978694E+01	0.967920E+05
0.115382E+05	0.949909E+01	0.109603E+06
0.131865E+05	0.921124E+01	0.121464E+06
0.148349E+05	0.892339E+01	0.132377E+06
0.164832E+05	0.863554E+01	0.142341E+06
0.181315E+05	0.834769E+01	0.151356E+06
0.197798E+05	0.805984E+01	0.159422E+06
0.214281E+05	0.777198E+01	0.166539E+06
0.230765E+05	0.748413E+01	0.172707E+06
0.247248E+05	0.719628E+01	0.177926E+06
0.263731E+05	0.690843E+01	0.182197E+06
0.280214E+05	0.662058E+01	0.185518E+06
0.296697E+05	0.633273E+01	0.187890E+06
0.313181E+05	0.604488E+01	0.189314E+06
0.329664E+05	0.575703E+01	0.189788E+06
0.346147E+05	0.546917E+01	0.189314E+06
0.362630E+05	0.518132E+01	0.187890E+06
0.379113E+05	0.489347E+01	0.185516E+06
0.395597E+05	0.460562E+01	0.182197E+06
0.412080E+05	0.431777E+01	0.177926E+06
0.428563E+05	0.402992E+01	0.172707E+06
0.445046E+05	0.374207E+01	0.166539E+06
0.461529E+05	0.345421E+01	0.159422E+06
0.478013E+05	0.316636E+01	0.151356E+06
0.494496E+05	0.287851E+01	0.142341E+06
0.510979E+05	0.259066E+01	0.132377E+06
0.527462E+05	0.230281E+01	0.121464E+06
0.543945E+05	0.201496E+01	0.109603E+06
0.560429E+05	0.172711E+01	0.967919E+05
0.576912E+05	0.143925E+01	0.830322E+05
0.593395E+05	0.115140E+01	0.683236E+05
0.609878E+05	0.863550E+00	0.526660E+05
0.626361E+05	0.575699E+00	0.360596E+05
0.642845E+05	0.287848E+00	0.185041E+05

```
DO YOU WISH TO RERUN WITH DIFFERENT EFFORT AVERAGES
ENTER 0) OR NEW DATA SET  (ENTER 1) OR TO END RUN (ENTER -1)
-1
FORTRAN STOP
$
```

Example 2. Natural mortality(M) fitted, fishing effort averaged.

```
$RUN FSHA:[712.MASTER.XEQ]PRODFIT
   Generalized Stock Production Model     W.W.Fox,Jr.-S.Clark


INPUT TITLE UP TO 80 CHARACTERS
TEST RUN

NUMBER OF DATA POINTS  + STARTING VALUE FOR M(0.,1.,2.)
34,2.0

IS M TO BE FITTED(ENTER 0) OR FIXED AT STARTING VALUE(ENTER 1)?
0

ARE OBSERVATIONS TO BE UNWEIGHTED(ENTER 0) OR WEIGHTED(ENTER 1)?
1

CATCH VALUES OR CATCH PER EFFORT VALUES AT EQUILIBRIUM
60913,72294,78353,91522,78288,110418,114590,76841
41965,50058,64869,89194,129701,160151,206993,200070
224810,186015,195277,140042,140033,140865,177026,163020
148450,140484,244331,230886,174063,145469,203882,180086
182294,178994
FISHING EFFORT VALUES
5879,6295,6771,8233,6830,10488,10808,9584
5961,5930,6475,9377,13958,20383,24781,23923
31856,18403,34834,36356,26228,17198,27205,26768
31158,28198,35841,41646,42248,33303,42090,43228
40393,33834

ARE EFFORT VALUES TO BE AVERAGED(ENTER 0) OR DO DATA REPRESENT EQUILIBRIUM(ENTER 1)?
0

WILL EFFORT VALUES BE AVERAGED BY A CONSTANT FIGURE THOUGHOUT THE DATA SET(ENTER 0)
OR ARE SEPARATE VALUES USED FOR EACH YEAR(ENTER 1)?
0

CONSTANT FOR AVERAGING EFFORT
3.0
```

RAW DATA

CATCH	EFFORT	NO. YEAR CLASSES
0.609130E+05	0.587900E+04	0.300000E+01
0.722940E+05	0.629500E+04	0.300000E+01
0.783530E+05	0.677100E+04	0.300000E+01
0.915220E+05	0.823300E+04	0.300000E+01
0.782880E+05	0.683000E+04	0.300000E+01
0.110418E+06	0.104880E+05	0.300000E+01
0.114590E+06	0.108080E+05	0.300000E+01
0.768410E+05	0.958400E+04	0.300000E+01
0.419650E+05	0.596100E+04	0.300000E+01
0.500580E+05	0.593000E+04	0.300000E+01
0.648690E+05	0.647500E+04	0.300000E+01
0.891940E+05	0.937700E+04	0.300000E+01
0.129701E+06	0.139580E+05	0.300000E+01
0.160151E+06	0.203830E+05	0.300000E+01
0.206993E+06	0.247810E+05	0.300000E+01
0.200070E+06	0.239230E+05	0.300000E+01
0.224810E+06	0.318560E+05	0.300000E+01
0.186015E+06	0.184030E+05	0.300000E+01
0.195277E+06	0.348340E+05	0.300000E+01
0.140042E+06	0.363560E+05	0.300000E+01
0.140033E+06	0.262280E+05	0.300000E+01
0.140865E+06	0.171980E+05	0.300000E+01
0.177026E+06	0.272050E+05	0.300000E+01
0.163020E+06	0.267680E+05	0.300000E+01
0.148450E+06	0.311580E+05	0.300000E+01
0.140484E+06	0.281980E+05	0.300000E+01
0.244331E+06	0.358410E+05	0.300000E+01
0.230886E+06	0.416460E+05	0.300000E+01
0.174063E+06	0.422480E+05	0.300000E+01
0.145469E+06	0.333030E+05	0.300000E+01
0.203882E+06	0.420900E+05	0.300000E+01
0.180086E+06	0.432280E+05	0.300000E+01
0.182294E+06	0.403930E+05	0.300000E+01
0.178994E+06	0.338340E+05	0.300000E+01

DATA FOR FITTING

CATCH/EFFORT	AVERAGE EFFORT
0.115719E+02	0.646367E+04
0.111165E+02	0.742267E+04
0.114624E+02	0.728783E+04
0.105280E+02	0.889283E+04
0.106023E+02	0.100383E+05
0.801763E+01	0.101427E+05
0.703993E+01	0.797650E+04
0.844148E+01	0.654933E+04
0.100184E+02	0.620767E+04
0.951200E+01	0.783517E+04
0.929223E+01	0.111838E+05
0.785709E+01	0.164070E+05
0.835289E+01	0.215112E+05
0.836308E+01	0.236190E+05
0.705707E+01	0.280325E+05
0.101079E+02	0.238073E+05
0.560593E+01	0.288607E+05
0.385196E+01	0.328565E+05
0.533907E+01	0.310383E+05
0.819078E+01	0.234010E+05
0.650711E+01	0.237065E+05
0.609011E+01	0.253187E+05
0.476443E+01	0.290358E+05
0.498206E+01	0.289463E+05
0.681708E+01	0.325128E+05
0.554401E+01	0.374697E+05
0.412003E+01	0.409795E+05
0.436804E+01	0.376752E+05
0.484395E+01	0.391873E+05
0.416596E+01	0.411945E+05
0.451301E+01	0.416208E+05
0.529036E+01	0.375860E+05

```
ARE VALUES FOR A,B,M AND RESIDUAL SUM OF SQUARES TO BEFITTED WITH THE PROGRAM
ENTER 0) OR ENTERED (ENTER 1)?
0

 STARTING VALUES      A =  0.112336E+02      B = -0.170315E-03      M =  0.200000E+01      RESIDUAL SUM OF SQUARES =  0.100000E+

RE-PARAMETERIZED STARTING VALUES AND LIMITS

            VALUE            LOWER            UPPER


UMAX =    0.112336E+02    0.842523E+01    0.140420E+02
YMAX =    0.185237E+06    0.138928E+06    0.231546E+06
M =   0.200000E+01      UMAX =   0.115336E+02      YMAX =   0.190237E+06      SSQ =   0.764496E+00

UMAX =    0.115336E+02    0.865023E+01    0.144170E+02
YMAX =    0.190237E+06    0.142678E+06    0.237796E+06
M =   0.210000E+01      UMAX =   0.114336E+02      YMAX =   0.190237E+06      SSQ =   0.764589E+00

UMAX =    0.115336E+02    0.865023E+01    0.144170E+02
YMAX =    0.190237E+06    0.142678E+06    0.237796E+06
M =   0.190000E+01      UMAX =   0.116336E+02      YMAX =   0.189237E+06      SSQ =   0.765273E+00

UMAX =    0.115336E+02    0.865023E+01    0.144170E+02
YMAX =    0.190237E+06    0.142678E+06    0.237796E+06
M =   0.201000E+01      UMAX =   0.115047E+02      YMAX =   0.189837E+06      SSQ =   0.764314E+00

UMAX =    0.115047E+02    0.862855E+01    0.143809E+02
YMAX =    0.189837E+06    0.142378E+06    0.237296E+06
M =   0.202000E+01      UMAX =   0.114937E+02      YMAX =   0.189937E+06      SSQ =   0.764292E+00

UMAX =    0.114937E+02    0.862030E+01    0.143672E+02
YMAX =    0.189937E+06    0.142453E+06    0.237421E+06
M =   0.203000E+01      UMAX =   0.114847E+02      YMAX =   0.190017E+06      SSQ =   0.764281E+00

UMAX =    0.114847E+02    0.861355E+01    0.143559E+02
YMAX =    0.190017E+06    0.142513E+06    0.237521E+06
M =   0.204000E+01      UMAX =   0.114757E+02      YMAX =   0.190077E+06      SSQ =   0.764280E+00

UMAX =    0.114757E+02    0.860680E+01    0.143447E+02
YMAX =    0.190077E+06    0.142558E+06    0.237596E+06
M =   0.205000E+01      UMAX =   0.114657E+02      YMAX =   0.190166E+06      SSQ =   0.764289E+00

UMAX =    0.114757E+02    0.860680E+01    0.143447E+02
YMAX =    0.190077E+06    0.142558E+06    0.237596E+06
M =   0.203000E+01      UMAX =   0.114847E+02      YMAX =   0.189997E+06      SSQ =   0.764281E+00

UMAX =    0.114757E+02    0.860680E+01    0.143447E+02
YMAX =    0.190077E+06    0.142558E+06    0.237596E+06
M =   0.204000E+01      UMAX =   0.114757E+02      YMAX =   0.190077E+06      SSQ =   0.764280E+00
*****************************************************************************************************************************
```

*** FINAL ESTIMATES ***

RESIDUAL SUM OF SQUARES MINIMIZED WITHIN PARAMETER PRECISION OF

NO. DECIMAL PLACES FOR M = 2

NO. DIGITS FOR UMAX AND YMAX = 5

WEIGHTED ESTIMATES

A = 0.126524E+02 VAR. INDEX A = 0.503321E+03

B =-0.196202E-03 VAR. INDEX B = 0.183224E-06

M = 0.204000E+01 VAR. INDEX M = 0.566175E+00

RESIDUAL SUM OF SQUARES = 0.764280E+00

DEGREES OF FREEDOM = 0.290000E+02

RESIDUAL VAR. INDEX = 0.263545E-01

DEGREE OF FIT INDEX = 0.776106E+00

VARIABILITY INDEX MATRIX

0.503321E+03	-0.960101E-02	0.168746E+02
-0.960101E-02	0.183224E-06	-0.321759E-03
0.168746E+02	-0.321759E-03	0.566175E+00

AVERAGE EFFORT	CATCH/EFFORT	PRED. C/E	ERROR TERM
0.646367E+04	0.115719E+02	0.103675E+02	0.116164E+00
0.742267E+04	0.111165E+02	0.102027E+02	0.895627E-01
0.728783E+04	0.114624E+02	0.102259E+02	0.120918E+00
0.889283E+04	0.105280E+02	0.994983E+01	0.581120E-01
0.100383E+05	0.106023E+02	0.975262E+01	0.871269E-01
0.101427E+05	0.801763E+01	0.973465E+01	-0.176382E+00
0.797650E+04	0.703993E+01	0.101075E+02	-0.303493E+00
0.654933E+04	0.844148E+01	0.103528E+02	-0.184618E+00
0.620767E+04	0.100184E+02	0.104115E+02	-0.377582E-01
0.783517E+04	0.951200E+01	0.101318E+02	-0.611716E-01
0.111838E+05	0.929223E+01	0.955525E+01	-0.275257E-01
0.164070E+05	0.785709E+01	0.865318E+01	-0.919996E-01
0.215112E+05	0.835289E+01	0.776800E+01	0.752951E-01
0.236190E+05	0.836308E+01	0.740130E+01	0.129948E+00
0.280325E+05	0.705707E+01	0.663107E+01	0.642425E-01
0.238073E+05	0.101079E+02	0.736850E+01	0.371767E+00
0.288607E+05	0.560593E+01	0.648616E+01	-0.135708E+00
0.328565E+05	0.385196E+01	0.578507E+01	-0.334154E+00
0.310383E+05	0.533907E+01	0.610447E+01	-0.125385E+00
0.234010E+05	0.819078E+01	0.743926E+01	0.101021E+00
0.237065E+05	0.650711E+01	0.738606E+01	-0.119001E+00
0.253187E+05	0.609011E+01	0.710508E+01	-0.142852E+00
0.290358E+05	0.476443E+01	0.645549E+01	-0.261957E+00
0.289463E+05	0.498206E+01	0.647116E+01	-0.230114E+00
0.325128E+05	0.681708E+01	0.584549E+01	0.166211E+00
0.374697E+05	0.554401E+01	0.497137E+01	0.115187E+00
0.409795E+05	0.412003E+01	0.434874E+01	-0.525919E-01
0.376752E+05	0.436804E+01	0.493501E+01	-0.114886E+00
0.391873E+05	0.484395E+01	0.466708E+01	0.378981E-01
0.411945E+05	0.416596E+01	0.431049E+01	-0.335296E-01
0.416208E+05	0.451301E+01	0.423459E+01	0.657477E-01
0.375860E+05	0.529036E+01	0.495079E+01	0.685890E-01

****

*** MANAGEMENT IMPLICATIONS OF THE FITTED MODEL ***

	VALUE	VARIABILITY INDEX	ERROR INDEX (PERCENT)
PRE-EXPLOITATION CATCH/EFFORT =	0.114757E+02	0.783386E+00	7.712716
OPTIMUM CATCH/EFFORT =	0.578175E+01	0.288284E+00	9.286482
OPTIMUM FISHING EFFORT =	0.328754E+05	0.617050E+07	7.555957
MAXIMUM SUSTAINABLE YIELD =	0.190077E+06	0.687145E+08	4.361083

****

** ESTIMATES OF THE CATCHABILITY COEFFICIENT AND POPULATION SIZE **

** BY THE INTEGRAL METHOD **

TIME	CATCHABILITY COEFFICIENT
(1, 2)	0.426340E-04
(2, 3)	0.111038E-05
(3, 4)	0.604975E-05
(4, 5)	0.479900E-05
(5, 6)	0.158476E-04
(6, 7)	0.131894E-05
(7, 8)	0.168563E-04
(8, 9)	0.867084E-05
(9,10)	0.117205E-04
(10,11)	0.294432E-04
(11,12)	0.318594E-04
(12,13)	0.277175E-04
(13,14)	0.432723E-06
(14,15)	0.222024E-04
(15,16)	0.195420E-06
(16,17)	0.335133E-04
(17,18)	0.790524E-04
(18,19)	0.839579E-05
(19,20)	0.648370E-04
(20,21)	0.420889E-04
(21,22)	0.470069E-04
(22,23)	0.222301E-04
(23,24)	0.237410E-04
(24,25)	0.475334E-04
(25,26)	0.535849E-05
(26,27)	0.115811E-04
(27,28)	0.277542E-04
(28,29)	0.123057E-03
(29,30)	0.155636E-04
(30,31)	0.707085E-04
(31,32)	0.778346E-04
(32,33)	0.895052E-04
(33,34)	0.306831E-04

UNWEIGHTED GEOMETRIC MEAN

Q = 0.162216E-04

COND. VARIANCE Q = 0.183774E-10

VIRGIN POPL. SIZE = 0.707435E+06

OPTIMUM POPL. SIZE = 0.356423E+06

UNWEIGHTED ARITHMETIC MEAN

Q = 0.315546E-04

COND. VARIANCE Q = 0.266928E-10

VIRGIN POPL. SIZE = 0.363679E+06

OPTIMUM POPL. SIZE = 0.183230E+06

****

EQUILIBRIUM VALUES

****

EFFORT	CATCH/EFFORT	CATCH
0.000000E+00	0.114757E+02	0.000000E+00
0.161216E+04	0.111997E+02	0.180558E+05
0.322431E+04	0.109235E+02	0.352207E+05
0.483647E+04	0.106469E+02	0.514936E+05
0.644863E+04	0.103701E+02	0.668729E+05
0.806079E+04	0.100930E+02	0.813573E+05
0.967294E+04	0.981554E+01	0.949451E+05
0.112851E+05	0.953779E+01	0.107635E+06
0.128973E+05	0.925972E+01	0.119425E+06
0.145094E+05	0.898132E+01	0.130314E+06
0.161216E+05	0.870256E+01	0.140299E+06
0.177337E+05	0.842345E+01	0.149379E+06
0.193459E+05	0.814397E+01	0.157552E+06
0.209580E+05	0.786411E+01	0.164816E+06
0.225702E+05	0.758385E+01	0.171169E+06
0.241824E+05	0.730317E+01	0.176608E+06
0.257945E+05	0.702206E+01	0.181131E+06
0.274067E+05	0.674050E+01	0.184735E+06
0.290188E+05	0.645847E+01	0.187417E+06
0.306310E+05	0.617594E+01	0.189175E+06
0.322431E+05	0.589290E+01	0.190005E+06
0.338553E+05	0.560931E+01	0.189905E+06
0.354674E+05	0.532514E+01	0.188869E+06
0.370796E+05	0.504037E+01	0.186895E+06
0.386918E+05	0.475495E+01	0.183977E+06
0.403039E+05	0.446885E+01	0.180112E+06
0.419161E+05	0.418201E+01	0.175293E+06
0.435282E+05	0.389438E+01	0.169515E+06
0.451404E+05	0.360589E+01	0.162771E+06
0.467525E+05	0.331648E+01	0.155054E+06
0.483647E+05	0.302606E+01	0.146354E+06
0.499769E+05	0.273451E+01	0.136662E+06
0.515890E+05	0.244171E+01	0.125966E+06
0.532012E+05	0.214750E+01	0.114250E+06
0.548133E+05	0.185166E+01	0.101496E+06
0.564255E+05	0.155391E+01	0.876801E+05
0.580376E+05	0.125384E+01	0.727701E+05
0.596498E+05	0.950847E+00	0.567178E+05
0.612619E+05	0.643862E+00	0.394443E+05
0.628741E+05	0.330632E+00	0.207882E+05

```
DO YOU WISH TO RERUN WITH DIFFERENT EFFORT AVERAGES
ENTER 0) OR NEW DATA SET  (ENTER 1) OR TO END RUN (ENTER -1)
-1
FORTRAN STOP
$
```

Example 3. Natural mortality(M) fitted, data represent equilibrium.

```
$RUN FSHA:[712.MASTER.XEQ]PRODFIT
   Generalized Stock Production Model     W.W.Fox,Jr.-S.Clark


INPUT TITLE UP TO 80 CHARACTERS
TEST RUN

NUMBER OF DATA POINTS  + STARTING VALUE FOR M(0.,1.,2.)
34,2.0

IS M TO BE FITTED(ENTER 0) OR FIXED AT STARTING VALUE(ENTER 1)?
0

ARE OBSERVATIONS TO BE UNWEIGHTED(ENTER 0) OR WEIGHTED(ENTER 1)?
1

CATCH VALUES OR CATCH PER EFFORT VALUES AT EQUILIBRIUM
10.36,11.48,11.57,11.12,11.46,10.53,10.61,8.02
7.04,8.44,10.02,9.51,9.29,7.86,8.35,8.36
7.06,10.11,5.61,3.85,5.34,8.19,6.51,6.09
4.76,4.98,6.82,5.54,4.12,4.37,4.84,4.17
4.51,5.29
FISHING EFFORT VALUES
5879,6295,6771,8233,6830,10488,10801,9584
5961,5930,6475,9377,13958,20383,24781,23923
31856,18403,34834,36356,26228,17198,27205,26768
31158,28198,35841,41646,42248,33303,42090,43228
40393,33834

ARE EFFORT VALUES TO BE AVERAGED(ENTER 0) OR DO DATA REPRESENT EQUILIBRIUM(ENTER 1)?
1

DATA FOR FITTING

      CATCH/EFFORT          AVERAGE EFFORT

      0.103600E+02           0.587900E+04
      0.114800E+02           0.629500E+04
      0.115700E+02           0.677100E+04
      0.111200E+02           0.823300E+04
      0.114600E+02           0.683000E+04
      0.105300E+02           0.104880E+05
      0.106100E+02           0.108010E+05
      0.802000E+01           0.958400E+04
      0.704000E+01           0.596100E+04
      0.844000E+01           0.593000E+04
      0.100200E+02           0.647500E+04
      0.951000E+01           0.937700E+04
      0.929000E+01           0.139580E+05
      0.786000E+01           0.203830E+05
      0.835000E+01           0.247810E+05
      0.836000E+01           0.239230E+05
      0.706000E+01           0.318560E+05
      0.101100E+02           0.184030E+05
      0.561000E+01           0.348340E+05
      0.385000E+01           0.363560E+05
      0.534000E+01           0.262280E+05
      0.819000E+01           0.171980E+05
      0.651000E+01           0.272050E+05
      0.609000E+01           0.267680E+05
      0.476000E+01           0.311580E+05
      0.498000E+01           0.281980E+05
      0.682000E+01           0.358410E+05
      0.554000E+01           0.416460E+05
      0.412000E+01           0.422480E+05
      0.437000E+01           0.333030E+05
      0.484000E+01           0.420900E+05
      0.417000E+01           0.432280E+05
      0.451000E+01           0.403930E+05
      0.529000E+01           0.338340E+05

ARE VALUES FOR A,B,M AND RESIDUAL SUM OF SQUARES TO BEFITTED WITH THE PROGRAM
ENTER 0) OR ENTERED (ENTER 1)?
0

 STARTING VALUES     A =  0.113057E+02     B = -0.167279E-03     M =  0.200000E+01     RESIDUAL SUM OF SQUARES
```

```
RE-PARAMETERIZED STARTING VALUES AND LIMITS

            VALUE          LOWER          UPPER

UMAX =    0.113057E+02   0.847924E+01   0.141321E+02
YMAX =    0.191025E+06   0.143268E+06   0.238781E+06
M =  0.200000E+01      UMAX =  0.114057E+02      YMAX =  0.198025E+06      SSQ =  0.839081E+00

UMAX =    0.114057E+02   0.855424E+01   0.142571E+02
YMAX =    0.198025E+06   0.148518E+06   0.247531E+06
M =  0.210000E+01      UMAX =  0.113057E+02      YMAX =  0.199025E+06      SSQ =  0.844750E+00

UMAX =    0.114057E+02   0.855424E+01   0.142571E+02
YMAX =    0.198025E+06   0.148518E+06   0.247531E+06
M =  0.190000E+01      UMAX =  0.115057E+02      YMAX =  0.197025E+06      SSQ =  0.834448E+00

UMAX =    0.115057E+02   0.862924E+01   0.143821E+02
YMAX =    0.197025E+06   0.147768E+06   0.246281E+06
M =  0.180000E+01      UMAX =  0.116057E+02      YMAX =  0.196025E+06      SSQ =  0.830912E+00

UMAX =    0.116057E+02   0.870424E+01   0.145071E+02
YMAX =    0.196025E+06   0.147018E+06   0.245031E+06
M =  0.170000E+01      UMAX =  0.117057E+02      YMAX =  0.196025E+06      SSQ =  0.828221E+00

UMAX =    0.117057E+02   0.877924E+01   0.146321E+02
YMAX =    0.196025E+06   0.147018E+06   0.245031E+06
M =  0.160000E+01      UMAX =  0.118057E+02      YMAX =  0.195025E+06      SSQ =  0.826712E+00

UMAX =    0.118057E+02   0.885424E+01   0.147571E+02
YMAX =    0.195025E+06   0.146268E+06   0.243781E+06
M =  0.150000E+01      UMAX =  0.119057E+02      YMAX =  0.195025E+06      SSQ =  0.826049E+00

UMAX =    0.119057E+02   0.892924E+01   0.148821E+02
YMAX =    0.195025E+06   0.146268E+06   0.243781E+06
M =  0.140000E+01      UMAX =  0.120057E+02      YMAX =  0.195025E+06      SSQ =  0.826470E+00

UMAX =    0.119057E+02   0.892924E+01   0.148821E+02
YMAX =    0.195025E+06   0.146268E+06   0.243781E+06
M =  0.151000E+01      UMAX =  0.119067E+02      YMAX =  0.195225E+06      SSQ =  0.826026E+00

UMAX =    0.119067E+02   0.892999E+01   0.148833E+02
YMAX =    0.195225E+06   0.146418E+06   0.244031E+06
M =  0.152000E+01      UMAX =  0.118967E+02      YMAX =  0.195225E+06      SSQ =  0.826050E+00

UMAX =    0.119067E+02   0.892999E+01   0.148833E+02
YMAX =    0.195225E+06   0.146418E+06   0.244031E+06
M =  0.150000E+01      UMAX =  0.119177E+02      YMAX =  0.195235E+06      SSQ =  0.826012E+00

UMAX =    0.119177E+02   0.893824E+01   0.148971E+02
YMAX =    0.195235E+06   0.146426E+06   0.244043E+06
M =  0.149000E+01      UMAX =  0.119287E+02      YMAX =  0.195245E+06      SSQ =  0.826008E+00

UMAX =    0.119287E+02   0.894649E+01   0.149108E+02
YMAX =    0.195245E+06   0.146433E+06   0.244056E+06
M =  0.148000E+01      UMAX =  0.119387E+02      YMAX =  0.195245E+06      SSQ =  0.826015E+00

UMAX =    0.119287E+02   0.894649E+01   0.149108E+02
YMAX =    0.195245E+06   0.146433E+06   0.244056E+06
M =  0.149000E+01      UMAX =  0.119287E+02      YMAX =  0.195245E+06      SSQ =  0.826008E+00
**********************************************************************************************************************
```

RESIDUAL SUM OF SQUARES MINIMIZED WITHIN PARAMETER PRECISION OF

NO. DECIMAL PLACES FOR M = 2

NO. DIGITS FOR UMAX AND YMAX = 5

WEIGHTED ESTIMATES

A = 0.336922E+01 VAR. INDEX A = 0.424325E+02

B =-0.299993E-04 VAR. INDEX B = 0.911632E-08

M = 0.149000E+01 VAR. INDEX M = 0.628711E+00

RESIDUAL SUM OF SQUARES = 0.826008E+00

DEGREES OF FREEDOM = 0.310000E+02

RESIDUAL VAR. INDEX = 0.266454E-01

DEGREE OF FIT INDEX = 0.774675E+00

VARIABILITY INDEX MATRIX

0.424325E+02	-0.621845E-03	0.516465E+01
-0.621845E-03	0.911632E-08	-0.756742E-04
0.516465E+01	-0.756742E-04	0.628711E+00

AVERAGE EFFORT	CATCH/EFFORT	PRED. C/E	ERROR TERM
0.587900E+04	0.103600E+02	0.106890E+02	-0.307815E-01
0.629500E+04	0.114800E+02	0.106039E+02	0.826172E-01
0.677100E+04	0.115700E+02	0.105070E+02	0.101171E+00
0.823300E+04	0.111200E+02	0.102121E+02	0.889051E-01
0.683000E+04	0.114600E+02	0.104950E+02	0.919474E-01
0.104880E+05	0.105300E+02	0.976563E+01	0.782715E-01
0.108010E+05	0.106100E+02	0.970446E+01	0.933113E-01
0.958400E+04	0.802000E+01	0.994339E+01	-0.193434E+00
0.596100E+04	0.704000E+01	0.106722E+02	-0.340344E+00
0.593000E+04	0.844000E+01	0.106786E+02	-0.209632E+00
0.647500E+04	0.100200E+02	0.105672E+02	-0.517847E-01
0.937700E+04	0.951000E+01	0.998432E+01	-0.475067E-01
0.139580E+05	0.929000E+01	0.909848E+01	0.210495E-01
0.203830E+05	0.786000E+01	0.792668E+01	-0.841159E-02
0.247810E+05	0.835000E+01	0.717199E+01	0.164251E+00
0.239230E+05	0.836000E+01	0.731620E+01	0.142669E+00
0.318560E+05	0.706000E+01	0.603861E+01	0.169143E+00
0.184030E+05	0.101100E+02	0.827901E+01	0.221160E+00
0.348340E+05	0.561000E+01	0.559124E+01	0.335610E-02
0.363560E+05	0.385000E+01	0.536937E+01	-0.282969E+00
0.262280E+05	0.534000E+01	0.693210E+01	-0.229671E+00
0.171980E+05	0.819000E+01	0.849727E+01	-0.361607E-01
0.272050E+05	0.651000E+01	0.677249E+01	-0.387580E-01
0.267680E+05	0.609000E+01	0.684365E+01	-0.110124E+00
0.311580E+05	0.476000E+01	0.614601E+01	-0.225514E+00
0.281980E+05	0.498000E+01	0.661220E+01	-0.246847E+00
0.358410E+05	0.682000E+01	0.544393E+01	0.252772E+00
0.416460E+05	0.554000E+01	0.463381E+01	0.195560E+00
0.422480E+05	0.412000E+01	0.455361E+01	-0.952228E-01
0.333030E+05	0.437000E+01	0.581904E+01	-0.249017E+00
0.420900E+05	0.484000E+01	0.457459E+01	0.580108E-01
0.432280E+05	0.417000E+01	0.442456E+01	-0.575344E-01
0.403930E+05	0.451000E+01	0.480305E+01	-0.610124E-01
0.338340E+05	0.529000E+01	0.573951E+01	-0.783178E-01

****

*** MANAGEMENT IMPLICATIONS OF THE FITTED MODEL ***

	VALUE	VARIABILITY INDEX	ERROR INDEX (PERCENT)
PRE-EXPLOITATION CATCH/EFFORT =	0.119287E+02	0.972656E+00	8.267764
OPTIMUM CATCH/EFFORT =	0.528628E+01	0.828857E+00	17.222242
OPTIMUM FISHING EFFORT =	0.369342E+05	0.429650E+08	17.747156
MAXIMUM SUSTAINABLE YIELD =	0.195245E+06	0.673710E+08	4.203952

****

EQUILIBRIUM VALUES

****

EFFORT	CATCH/EFFORT	CATCH
0.000000E+00	0.119287E+02	0.000000E+00
0.184671E+04	0.115318E+02	0.212959E+05
0.369342E+04	0.111418E+02	0.411512E+05
0.554013E+04	0.107586E+02	0.596040E+05
0.738684E+04	0.103823E+02	0.766920E+05
0.923355E+04	0.100127E+02	0.924531E+05
0.110803E+05	0.965006E+01	0.106925E+06
0.129270E+05	0.929419E+01	0.120146E+06
0.147737E+05	0.894515E+01	0.132153E+06
0.166204E+05	0.860291E+01	0.142984E+06
0.184671E+05	0.826749E+01	0.152676E+06
0.203138E+05	0.793886E+01	0.161268E+06
0.221605E+05	0.761702E+01	0.168797E+06
0.240072E+05	0.730198E+01	0.175300E+06
0.258539E+05	0.699372E+01	0.180815E+06
0.277006E+05	0.669224E+01	0.185379E+06
0.295473E+05	0.639753E+01	0.189030E+06
0.313941E+05	0.610958E+01	0.191805E+06
0.332408E+05	0.582840E+01	0.193740E+06
0.350875E+05	0.555397E+01	0.194875E+06
0.369342E+05	0.528628E+01	0.195245E+06
0.387809E+05	0.502534E+01	0.194887E+06
0.406276E+05	0.477112E+01	0.193839E+06
0.424743E+05	0.452364E+01	0.192138E+06
0.443210E+05	0.428287E+01	0.189821E+06
0.461677E+05	0.404881E+01	0.186925E+06
0.480145E+05	0.382146E+01	0.183486E+06
0.498612E+05	0.360081E+01	0.179541E+06
0.517079E+05	0.338684E+01	0.175126E+06
0.535546E+05	0.317956E+01	0.170280E+06
0.554013E+05	0.297894E+01	0.165037E+06
0.572480E+05	0.278499E+01	0.159435E+06
0.590947E+05	0.259769E+01	0.153510E+06
0.609414E+05	0.241704E+01	0.147298E+06
0.627881E+05	0.224303E+01	0.140835E+06
0.646349E+05	0.207563E+01	0.134158E+06
0.664816E+05	0.191486E+01	0.127303E+06
0.683283E+05	0.176069E+01	0.120305E+06
0.701750E+05	0.161311E+01	0.113200E+06
0.720217E+05	0.147211E+01	0.106024E+06

```
DO YOU WISH TO RERUN WITH DIFFERENT EFFORT AVERAGES
ENTER 0) OR NEW DATA SET  (ENTER 1) OR TO END RUN (ENTER -1)
-1
FORTRAN STOP
$
```

PROGRAM NAME: von Bertalanffy growth in length program

PROGRAM TYPE: Main

DATE CREATED: May 1 1964

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]BGCII.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]BGCII.EXE

AUTHOR: N.J. Abramson

DOCUMENTED BY: R.K. Mayo

REVISIONS (Date/Reviser - Description)

Jun 16 1983 /R.K. Mayo -
Revised to conform with VAX 11/780 compatable FORTRAN 77.
Nov 14 1983 /R.K. Mayo -
Documented to conform with NERFIS Standards.

STATUS: Operational

CLASSIFICATION: Analytical Curve Fitting

PURPOSE OF PROGRAM:

This program fits the von Bertalanffy growth curve by least squares with weights proportional to sample size at each age group. A constant time interval between ages is required, but the number of lengths in the age groups may be unequal.

DESCRIPTION:

The program reads individual length at age observations according to a specific format supplied by the user as a control record. The length at age data are fit by least squares to the von-Bertalanffy growth curve vis:

$$L(t) = L(inf) * (1-EXP(-K(t-t(o)))$$

The following parameters of the equation are estimated:

L(inf) = asymptotic length.
K = instantaneous rate of growth
t(o) = hypothetical age of zero length.

The program also computes standard errors of the above estimated parameters, sample mean lengths, fitted lengths and their standard errors, and the variance-covariance matrix.

DATA USED: User supplied individual length at age observations.

INSTRUCTIONS FOR RUNNING:

The user must supply a header record, control information, the number of fish at each age, and the length at age data as follows:

Record Number	Record Description
1	Header record with alphanumeric labels (20A4)
2	Variable format specifying configuration of length at age data, left parentesis placed in column 1 of record. (20A4)
3	Number of ages, age of the youngest age group, and time interval between ages (constant). Left justify last two items with three decimal places understood. (I2,2F4.3)
4(+n)	Number of lengths in each age group, beginning with the first. (20I4) If more than 20 age groups are represented, numbers continue on subsequent record(s).
5(+n)	Length at age data entered according to the variable format specified by the user on control record number 2 above. Age groups must be arranged in ascending order, and each new age group begins on a new record.

To run the program online, type:

```
$RUN FSHA:[712.MASTER.XEQ]BGCII
```

and you will be prompted for input. Users may also place all control records and data in a single file which is read on device FOR005. In this case, you must assign the file to the input device as follows:

```
$ASSIGN filename.DAT FOR005
```

before entering the $RUN command from your terminal.

RESTRICTIONS:

Number of age groups LE 30; lengths per age group LE 600.

REFERENCES:

Tomlinson, P.K. and N.J. Abramson. 1961. Fitting the von-Bertalanffy growth curve by least squares. Calif. Dept. Fish. and Game, Fish. Bull. 116, 69 pp.

```
$ ASSIGN BGCII.DAT FOR005
$ RUN FSHA:[712.MASTER.XEQ]BGCII

  VON-BERTALANFY GROWTH PROGRAM --BGC II
  Written by N.J. Abramson, Cal. F+G, May 1964
  VAX 11/780 Ver. 1.0  14 Nov 1983  R.K. Mayo
```

VON BERTALANFFY GROWTH IN LENGTH CURVE

BGCII SAMPLE PROBLEM TEST DECK

ESTIMATED PARAMETERS AND STANDARD ERRORS

	L INFINITY	K	T SUB-ZERO
ESTIMATES	1102.17	0.190181	-2.3232
STANDARD ERRORS	90.84	0.049441	0.574846

FITTED LENGTHS AND SAMPLE LENGTHS

AGE	FITTED LENGTH	SAMPLE MEAN LENGTH	S.E. OF SAMPLE MEAN	SAMPLE SIZE
0.0	393.62	NO SAMPLE DATA FOR THIS AGE		
1.0	516.34	512.00	17.302	9
2.0	617.80	631.27	15.737	11
3.0	701.69	671.83	18.582	6
4.0	771.04	770.56	9.982	9
5.0	828.39	848.75	11.747	8
6.0	875.81	869.43	13.571	7
7.0	915.01	893.80	17.028	5
8.0	947.43	978.50	14.500	2

SAMPLE DATA BEYOND AGE 8.0 NOT AVAILABLE

VARIANCE-COVARIANCE MATRIX

	L INFINITY	K	T SUB-ZERO
L INFINITY	0.82519908E+04	-0.44147839E+01	-0.47356251E+02
K	-0.44147839E+01	0.24443913E-02	0.27419950E-01
T SUB-ZERO	-0.47356251E+02	0.27419950E-01	0.33044823E+00

STANDARD ERROR OF ESTIMATE-- 43.7393

PROGRAMMED BY - BIOMETRICAL ANALYSIS UNIT
MRO, CALIF. FISH AND GAME
MAY 1964 - BGC II

$
$

```
$ T BGCII.DAT


  BGCII SAMPLE PROBLEM TEST DECK
(11F4.0)
0810001000
000900110006000900080007000500 02
048005480503048505950497058304420475
06360688069906520662055405590668064505590622
065906450666066206370762
07350837077707480772079007490764 0763
08870843085808940841078708460834
08340844093408820892083908 61
08550915094009050854
09930964
$
```

PROGRAM NAME: von Bertalanffy Growth Curve Fitting

PROGRAM TYPE: Main

DATE CREATED: May 1 1964

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]BGCIII.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]BGCIII.EXE

AUTHOR: P.K. Tomlinson

DOCUMENTED BY: R.K. Mayo

REVISIONS (Date/Reviser - Description)

May 01 1983. /R.K. Mayo. -
Revised to conform with VAX 11/780 compatible FORTRAN 77.
Jan 16 1984. /R.K. Mayo. -
Documented to conform with NERFIS Standards.

STATUS: Operational

CLASSIFICATION: Analytical Curve Fitting

PURPOSE OF PROGRAM:

This program fits the von Bertalanffy growth in length curve to unequally spaced age groups with unequal sample sizes for separate ages. It fits the equation:

$$\text{Length at age } t = D(t) = A + B*R^{t} \quad ; \; 0 < R < 1 \qquad (1)$$

by least squares when data of the form (length, age) are given in pairs (L(t), t).

DESCRIPTION:

The program minimizes the function:

$$Q = \sum^{n} (L(t) - A - B*R^{t})^{2}$$

by use of the partial derivatives evaluated near zero. Output is in the von Bertalanffy form, where:

$$A = L(inf)$$
$$R = EXP(-K) \qquad \text{or} \qquad K = -LOG(R)$$
$$B = -L(inf)*L^{K*t(o)} \qquad \text{or} \qquad t(o) = [LOG(-B) - LOG(A)] / K$$

The output gives values of the calculated length at age using equation (1) evaluated at ages selected by the user. The user enters an initial age (t(i)) and a DELTA t. The values t(i+1) = t(i) + DELTA t are displayed on the output device. The user must also enter the number of ages to be displayed.

Fitted value of L(inf), K, and t(o) are also given, where:

L(inf) = asymptotic length.
K = instantaneous rate of growth, and
t(o) = hypothetical age of zero length.

ERROR MESSAGES.

1. TOO MANY ITERATIONS - Implies that the program is not providing for : ¶(R(i)-R(i+1))¶ less than 0.0001.
2. DATA DO NOT FIT - Implies that the program failed to get by step 6 and the data cannot be fitted by equation (1).

METHODS

Given n pairs (L(t), t) and equation (1), the program minimizes the function:

$$Q = \sum^{n} (L(t) - A - B*R^{t})^{2}$$

by use of the partial derivatives evaluated near zero. Since $0 < R < 1$, the program uses the following sequence:

1. Set R = 0.0001
2. Solve for A and B using $\partial Q/\partial A$ and $\partial Q/\partial B$.
3. Using the values of A, B, and R from steps 1 and 2, evaluate $\partial Q/\partial R$.
4. Set R = 0.9999 and Repeat steps 2 and 3.
5. Check the sign of $\partial Q/\partial R$ (0.0001) against the sign of $\partial Q/\partial R$ (0.99999).
6. If step 5 does not produce different signs, the program tries R = 0.01 vs. R = 0.99, and R = 0.1 vs. R = 0.9. If the signs at step 5 are still not different, the data are considered to be unsuitable for equation (1).
7. If the signs at step 5 (or 6) are different, then the sign of $\partial Q/\partial R$ (0.5) is compared to the sign of $\partial Q/\partial R$ (0.0001). If the signs differ, then R is between 0.0001 and 0.5; otherwise R is between 0.5 and 0.9999. As long as the signs differ, the best estimate of R is between the two values of R producing the signs. The interval is then divided by 2 and the process continued until ¶(R(i)-R(i+1))¶ < 0.0001.
8. The program now considers the partials to be sufficiently close to zero and it solves for L(inf), K, and t(o).

SUBROUTINE EST - solves for A and B where R is given and evaluates $\partial Q/\partial R$ at the given R.

DATA USED: The program reads user supplied data in two forms.

INSTRUCTIONS FOR RUNNING:

The pairs (L(t), t) may be read by the program in two different forms. The first form assumes that no type of ordering or sorting has occurred, and each (L(t), t) pair represents a single fish. The second method allows for frequency distributions, and the user provides a triple (L(t), t, m) where m is the number of times (or some weighting factor) the pair (L(t), t) occurs.

INPUT.

The user must supply a header record, control information, and the length-age pairs or triples as specified below. The records used are grouped as sets.

Set No.		Record Description
1	Any no. recs.	FORMAT(12A6,I8)
-	Col 1.	Blank for each record
	Cols 2-72.	Any title information desired. Use as many records as needed.
	Cols 73-80.	Blank for each record
2	1 record	FORMAT(12A6,I8)
-	Cols 1-79.	Blank
	Col. 80.	Enter numeral 1.
3	1 record	FORMAT(2F10.0,2I4)
-	Cols 1-10.	Youngest age for which you wish to compute length for output. Left justify with decimal.
	Cols 11-20.	Increment between ages for which you wish to compute length for output. Left justify with decimal.
	Cols 21-24.	Number of ages for which you wish to compute length for output. Right justify with no decimal.
	Cols 25-28.	Leave blank if data in form of set no. 4. Enter numeral 1 in col 28 if data in form of set no. 5.
4	1 <recs< 1250	FORMAT(8F10.0)
-		** See set no. 3, Cols 25-28.
	Cols 1-80.	Each record has 8 fields of 10 columns each. Data are entered as pairs of (length, age) with 4 pairs per record. Each value is entered left justified with decimal. If the number of pairs is an

exact multiple of 4, then the last record in this set must be blank.

5	1 <recs< 5000	FORMAT(2F10.0,I4)
-		** See set no. 3, Cols 25-28.
	Cols 1-10.	Enter length left justified with decimal.
	Cols 11-20.	Enter age left justified with decimal.
	Cols 21-24.	Enter number of times (frequency or weighting factor) this length-age pair is to be used. Enter one triple per record until all lengths are represented. Last record is blank.

** Repeat all sets of records for additional analyses.

6	1 record	FORMAT(A72,I8)
-	Cols 1-79.	Blank
	Col. 80.	Enter numeral 9 in column 80 of last record in job stream to terminate analysis.

To run the program online, type:

```
$RUN FSHA:[712.MASTER.XEQ]BGCIII
```

and you will be prompted for input. Users may also place all control records and data in a single file which is read on device FOR005. In this case, you must assign the file to the input device as follows:

```
$ASSIGN filename.DAT FOR005
```

before entering the $RUN command from your terminal.

```
$ ASSIGN FSHA:[712.MASTER.DATA]BGCIII.DAT FOR005
$ RUN FSHA:[712.MASTER.XEQ]BGCIII

  VON-BERTALANFY GROWTH PROGRAM -- BGCIII
  Written by P.K. TOMLINSON, May 1964
  VAX 11/780 Ver. 1.0  16 JAN 1984  R.K. Mayo



NORTHERN SHRIMP GROWTH DATA (MEANS) SPRING-SUMMER 78-80

***********************************************************************

L(INF)= 35.5149   K=0.3553   T(NAUGHT)=  0.0483   NO. FISH AGED=   7

***********************************************************************

       AGE              LENGTH
     0.500               5.267
     1.000              10.190
     1.500              14.312
     2.000              17.764
     2.500              20.653
     3.000              23.072
     3.500              25.097
     4.000              26.793
     4.500              28.213
     5.000              29.401
***********************************************************************



$ T FSHA:[712.MASTER.DATA]BGCIII.DAT

 NORTHERN SHRIMP GROWTH DATA (MEANS) SPRING-SUMMER 78-80
                                                                    1

0.5        0.5          10    1
12.6       1.3        001
15.3       1.6        001
19.3       2.3        001
21.5       2.6        001
23.9       3.3        001
25.7       3.6        001
27.7       4.3        001

                                                                    9

$
```

PROGRAM NAME: von Bertalanffy Growth Curve Fitting

PROGRAM TYPE: Main

DATE CREATED: 1971

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]BGCIV.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]BGCIV.EXE

AUTHOR: P.K. Tomlinson

DOCUMENTED BY: J.B. O'Gorman

REVISIONS (Date/Reviser - Description)

Feb 22 1984 / J.B. O'Gorman
Revised to execute with DOUBLE PRECISION(REAL*16) data type under DEC VAX-11/780 FORTRAN 77. Allows data triples to have explicit decimal places.

STATUS: Operational

CLASSIFICATION: Analytical curve fitting

PURPOSE OF PROGRAM:

The program fits the parameters K and L(infinity) to the von Bertalanffy growth in length equation. The program is useful when lengths of an individual fish at points in time are known, but the absolute age of the fish may not. It lends itself well to fitting the equation to mark and recapture data. The program produces a list of final lengths given a user supplied initial length, time elapsed, and number of time increments. Derivation of the method may be found in Fabens (1965). Typical uses and applications are found in Conan and Gunderson (1979) and Sundberg and Klein (1982).

DESCRIPTION:

The program fits the following equation by least squares when data is in the form of triples (initial length, final length, time elapsed):

$$L(r) = L(m)*R**t + A*(1 - R**t) \; ; \; 0 < R < 1$$

where:

L(r) = final length (eg. at recapture),
L(m) = initial length (eg. at marking),
t = the time elapsed,
A = asymptotic length, L(infinity),

R = a constant , exp(-K) or K=-ln(R).

Output includes the fitted values of L(infinity), K, and final lengths after the elapsed time given an initial length.

Method:

A function proportional to the residual sum of squares is minimized by evaluating the partial derivatives of the function with respect to A and R. The function is considered minimized when the absolute value of the difference of two successive estimates of R is less than 0.0001.

Two possible error messages are:

1. TOO MANY ITERATIONS - Implies that the program is not providing for the absolute value of the difference in two successive approximations of R or exp(-K) to be less than 0.0001.
2. DATA DOES NOT FIT - Means that the partial derivatives of the function with respect to R or exp(-K) do not agree in sign when R is set to 0.1 and 0.9.

SUBROUTINE EST - solves for L infinity when exp(-K) is given and evaluates the partial derivitive of exp(-K).

DATA USED: User supplied lengths at intervals and the time interval
---

INSTRUCTIONS FOR RUNNING:

Data records, defined as sets, are as follows:

Set No.		Record Description
1	Any no. recs.	FORMAT(9A8,I8)
	Col 1	Blank for each record.
	Cols 2-72	Any title information desired. Use as many records as neccessary.
	Cols 73-80	Blank for each record.
2	1 Record	FORMAT(9A8,I8)
	Cols 1-79	Blank
	Col 80	Enter numeral one (1).
3	1 Record	FORMAT(2F10.0,I4)
	Cols 1-10	Shortest length to be used in computing expected lengths. Left-justify with decimal.
	Cols 11-20	Time increment between initial length and final length for computing expected values. Left-justify with decimal.
	Cols 21-24	Number of times you wish to add the time increment. (Also, number of expected

values in output.) Right-justify with no decimal.

4	1 - 5000 records Cols 1-30	FORMAT(3F11.1,I4) Data are entered as triples (initial length, final length, time elapsed), one triple per record. Initial length is entered left-justified with decimal in cols 1-10. Final length is entered left-justified with decimal in cols 11-20. Time elapsed is entered left-justified with decimal point in cols 21-30.
5	Blank	End of data indicator.

** Repeat all records for additional runs.
** Last record - 9 in column 80 to end run.

To execute the program enter:

```
$RUN FSHA:[712.MASTER.XEQ]BGCIV
```

You will not be prompted for data. Data may also be placed in a file and the program run by entering:

```
$ASSIGN [directory]filename.DAT FOR005
```

before entering the RUN command.

REFERENCES:

Conan, G.Y and K.R. Gunderson. 1979. Growth curve of tagged lobsters (Homarus gammarus) in Norwegian waters as inferred from the relative increase in size at moulting and frequency of moult. Rapp. P.-v. Reun. Cons. int. Explor. Mer. 175:155-166.

Fabens, A.G. 1965. Properties of fitting the von Bertalanffy growth curve. Growth 29:265-289.

Sundberg, P. and W. Klein. 1982. Goodness of fit for the von Bertalanffy growth curves, as estimated from data at unequal time intervals. J. Cons. int. Explor. Mer. 40:304-305.

```
$ASSIGN [712.MASTER.DATA]BGCIV.DAT  FOR005
$ASSIGN BGCIV.OUT                   FOR006
$RUN [712.MASTER.XEQ]BGCIV

$ T BGCIV.OUT


    von Bertalanffy Growth Program -- BGCIV
        written by P.K. Tomlinson, 1971
VAX 11/780 Ver. 1.0  22 Feb 1984  J.B. O'Gorman



BANANA PRAWN
PENAEUS MERGUIENSIS DE MAN
DATA FROM SUNDBERG AND KLEIN J CONS INT EXPLOR MER 40:304-305
LENGTHS IN MM AND TIME IN DAYS
*****************************************************************************************************

L(INFINITY)=     29.9818          K=  0.0167          NO. FISH MEASURED=  79

*****************************************************************************************************
```

INITIAL LENGTH	TIME ELAPSED	FINAL LENGTH
0.0000	25.0000	10.2493
10.2493	25.0000	16.9949
16.9949	25.0000	21.4345
21.4345	25.0000	24.3564
24.3564	25.0000	26.2794
26.2794	25.0000	27.5451
27.5451	25.0000	28.3781
28.3781	25.0000	28.9263
28.9263	25.0000	29.2871
29.2871	25.0000	29.5246

```
$ t [712.MASTER.DATA]BGCIV.DAT

 BANANA PRAWN
 PENAEUS MERGUIENSIS DE MAN
 DATA FROM SUNDBERG AND KLEIN J CONS INT EXPLOR MER 40:304-305
 LENGTHS IN MM AND TIME IN DAYS
                                                                    1
00000000.000000025.00010
000000021.0000000024.5000000024.0
000000023.2000000026.5000000031.0
000000027.1000000027.4000000022.0
000000015.0000000024.1000000032.0
000000024.4000000024.1000000007.0
000000025.1000000025.0000000013.0
000000022.3000000025.0000000014.0
    .          .          .
    .          .          .
    .          .          .
    .          .          .
000000021.7000000025.5000000030.0
000000027.0000000029.8000000149.0
000000016.8000000024.1000000062.0
000000017.9000000024.7000000051.0
000000016.0000000025.1000000041.0
000000019.5000000025.0000000048.0
000000019.4000000027.5000000050.0
000000016.6000000022.7000000049.0

                                                                    9
$
```

PROGRAM NAME: Normal Distribution Separator

PROGRAM TYPE: Main

DATE CREATED: 1966

SOURCE FILE NAME: FSHA:[712.MASTER.SOURCE]NORMSEP.FOR

EXECUTE FILE NAME: FSHA:[712.MASTER.XEQ]NORMSEP.EXE

AUTHOR: V. Hasselblad

DOCUMENTED BY: A.M.T. Lange

REVISIONS (Date/Reviser - Description)

Oct 1979 /A.M.T. Lange
Modified to run interactively
Sept 1983 /F.P. Almeida
Converted to FORTRAN77 to run on VAX 11/780

STATUS: Operational

CLASSIFICATION: Statistical Analysis

PURPOSE OF PROGRAM:

The program separates length frequency sampling distributions into component normal distributions. It is used to estimate relative abundance of age groups in length samples when age data are not available.

DESCRIPTION:

Under the assumption that the lengths of fish within age groups are normally distributed and that an unbiased sample of the length distribution can be obtained, this program separates the mixture of normal length distributions into their components. The method is statistically superior to graphical procedures.

If N fish were measured for length and it is assumed that these fish were taken from a mixture of K normally distributed age groups then the program will estimate a mean length for each age group, a standard deviation for each age group, and an expected value for each observed frequency. The program will produce estimates of the percent and number of fish in each age group. The program allows up to 10 age groups.

The user is allowed to enter upper and lower bounds of the means and standard deviations of each age group to aid in the iteration process.

DATA USED: User supplied

INSTRUCTIONS FOR RUNNING:

The program may be run completely interactively or the user may place length frequency data in a file. The program should be run separately for each length frequency distribution. Input to the program is free-formatted, described as follows:

Record Number	Record Description
1	Number of length intervals (number of frequencies), number of expected modes/age groups (K<10), and number of sets of cut-off points (number of times the same set of modes should be analysed based on user supplied bounds).
2	Initial length (smallest length represented in the frequency data) and interval (size interval between each frequency).
3	Logical device containing frequency data (5- if entered interactively, or as assigned).
4 a..n	(Entered interactively or supplied on file): Frequency data, 10 frequencies per record, 5 columns each, (right-justified).
5	Y-axis title (Vertical title, if histogram is to be displayed).
6	X-axis title (Horizontal title, if histogram is to be displayed).
7	Plot histogram option (0- no plot, 1-plot).

The following set of 5 cards establishes limits to reduce the iteration process used in determining mean lengths and standard deviations for each mode/age class.

8	Cut-off points (estimated cut-off length between each age group. (K-1 values).
9	Lower bounds of means (expected lower limit of mean length for each age group).
10	Upper bounds of means (expected upper limit of mean length for each age group).
11	Lower bounds of standard deviation (expected lower limit of the standard deviation for each age group).
12	Upper bounds of standard deviations (expected upper limit of the standard deviation for the mean of each age group).

After the program displays estimated mean lengths, standard deviations and 'age' composition of distribution, and a summary of the input parameters and goodness of fit statistics, the user has the option of viewing the fitted to observed data, rerunning with another set of limits (8-12 above), or displaying the length-age composition.

To run the program interactively, type:

```
$RUN FSHA:[712.MASTER.XEQ]NORMSEP
```

and you will be prompted for all values, or create a data file with the frequency data (4 a..n) and use:

```
$ASSIGN datafile.DAT FOR___
$RUN FSHA:[712.MASTER.XEQ]NORMSEP
```

(___ represents the logical device number your data file will be assigned in the program.)

REFERENCES:

Tomlinson, P.K. 1971. Program name - NORMSEP. Programmed by V. Hasselblad. In N.J. Abramson (compiler). Computer programs for fish stock assessment. 10p. FAO, Fish. Tech. Pap. 101.

Hasselblad, V. 1966. Estimation of parameters for a mixture of mixed normal distributions. Technometrics 8(3):431-444.

```
$ T FSHA:[712.MASTER.DATA]NORMSEP.DAT

     1     2     4     9    15    12     8     6     8    12
    15    21    13     7     2


$ ASSIGN FSHA:[712.MASTER.DATA]NORMSEP.DAT  FOR001
$ RUN FSHA:[712.MASTER.XEQ]NORMSEP


          Normal Distribution Separator
         Version 1.0  1966 V. Hasselblad
  VAX 11/780 Version 1.0  Feb 1984 A.M.T. Lange

ENTER NUMBER OF FREQUENCIES
      NUMBER OF AGE GROUPS, AND
      NUMBER OF SETS OF CUTOFFS
15,2,1
ENTER INITIAL LENGTH, AND INTERVAL
8,1
LENGTH FREQUENCIES ARE ON WHAT DCB?
1
 Y-AXIS TITLE (IF PLOTTING, RETURN IF NOT)
FREQUENCY
 X-AXIS TITLE
LENGTH
DO YOU WISH TO PLOT THE DATA (ENTER 1) OR NOT (0)?
1
```

PLOT OF DATA

```
F  100.................
R     .    .    .    .
E     .    .    .    .
Q     .    .    .    .
U     .    .    .    .
E   90.................
N     .    .    .    .
C     .    .    .    .
Y     .    .    .    .
      .    .    .    .
    80.................
      .    .    .    .
      .    .    .    .
      .    .    .    .
      .    .    .    .
    70.................
      .    .    .    .
      .    .    .    .
      .    .    .    .
      .    .    .    .
    60.................
      .    .    .    .
      .    .    .    .
      .    .    .    .
      .    .    .    .
    50.................
      .    .    .    .
      .    .    .    .
      .    .    .    .
      .    .    .    .
    40.................
      .    .    .    .
      .    .    .    .
      .    .    .    .
      .    .    .    .
    30.................
      .    .    .    .
      .    .    .    .
      .    .    .    .
      .    .    . X  .
    20............X...
      .    .    . X  .
      .    X    .XX  .
      .    X    .XXX .
      .    XX   XXXX .
    10....XXX...XXXX..
      .   XXXX XXXXXX.
      .   XXXXXXXXXXX.
      .  XXXXXXXXXXXX.
      .XXXXXXXXXXXXXX
      ................
           5   10   15
```

```
VALUE OF LEFT-HAND LIMIT =   8.00000

     LENGTH OF INTERVALS =   1.00000
ENTER GROUP CUTOFF POINTS
15,22
ENTER LOWER BOUNDS OF MEANS FOR EACH GROUP
11,18
ENTER UPPER BOUNDS OF GROUP MEANS
13,20
ENTER LOWER BOUNDS OF GROUP STANDARD DEVIATION
.1,.1
ENTER UPPER BOUNDS OF GROUP STANDARD DEVIATION
2.,2.
RESULTS USING STEEPEST DESCENT METHOD
VALUES AFTER   29 ITERATIONS
GROUP      MEAN         ST. DEV.      PERCENT    SIZE

  1      12.92605      1.754952       42.75      57.7

  2      19.10436      1.583688       57.25      77.3
TOTAL SAMPLE SIZE =    135
 DO YOU WANT ACTUAL VS. PREDICTED (1 IF YES)
1

                    ACTUAL VS. PREDICTED FREQUENCIES

       1.0       2.0       4.0       9.0      15.0      12.0       8.0       6.0
       8.0      12.0
       0.5       2.0       5.0       9.4      12.7      12.5       9.1       5.9
       6.7      12.1

      15.0      21.0      13.0       7.0       2.0
      18.2      18.9      13.2       6.2       2.0


CUT-OFF POINTS                        15.0   23.0
LOWER BOUNDS FOR MEANS                11.0   18.0
UPPER BOUNDS FOR MEANS                13.0   20.0
LOWER BOUNDS FOR ST. DEV.              0.1    0.1
UPPER BOUNDS FOR ST. DEV.              2.0    2.0

LOWER COLLAPSING POINT =  3           UPPER COLLAPSING POINT = 14
DEGREES OF FREEDOM =  6
CHI SQUARE VALUE =   1.747           PROB. =.94144
LOG OF LIKELIHOOD = -0.14768233E+03

 ENTER 0 IF CHI SQUARE IS ADEQUATE

0
```

CALCULATED FREQUENCIES, NUMBER AT LENGTH PER AGE

X	NUMBERS			
8.5	0.5	0.0	0.5	1.0
9.5	2.0	0.0	2.0	2.0
10.5	5.0	0.0	5.0	4.0
11.5	9.4	0.0	9.4	9.0
12.5	12.7	0.0	12.7	15.0
13.5	12.4	0.0	12.5	12.0
14.5	8.8	0.3	9.1	8.0
15.5	4.5	1.5	5.9	6.0
16.5	1.6	5.0	6.7	8.0
17.5	0.4	11.7	12.1	12.0
18.5	0.1	18.1	18.2	15.0
19.5	0.0	18.9	18.9	21.0
20.5	0.0	13.2	13.2	13.0
21.5	0.0	6.2	6.2	7.0
22.5	0.0	2.0	2.0	2.0

```
WANT TO RUN WITH NEW DATA SET (ENTER 1) OR QUIT (0)?
0
FORTRAN STOP
$
```