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OAK RIDGE NATIONAL LABORATORY

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# A Users's Guide for the Stock-Recruitment Model Validation Program


S. W. Christensen
B. L. Kirk
C. P. Goodyear



ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1985

Prepared for
Dr. P. Hayes, Project Representative
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
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# A USER'S GUIDE FOR THE STOCK-RECRUITMENT MODEL VALIDATION PROGRAM

S. W. Christensen, B. L. Kirk, and C. P. Goodyear[1]

ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1985

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Task: Methods to Assess Impacts on Hudson River Striped Bass

OAK RIDGE NATIONAL LABORATORY
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operated by
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ABSTRACT

CHRISTENSEN, S. W., B. L. KIRK, and C. P. GOODYEAR. 1982. A user's guide for the stock-recruitment model validation program. ORNL/TM-8216 (NUREG/CR-2562). Oak Ridge National Laboratory, Oak Ridge, Tennessee. 38 pp.

SRVAL is a FORTRAN IV computer code designed to aid in assessing the validity of curve-fits of the linearized Ricker stock-recruitment model, modified to incorporate multiple-age spawners and to include an environmental variable, to variously processed annual catch-per-unit-effort statistics for a fish population. It is sometimes asserted that curve-fits of this kind can be used to determine the sensitivity of fish populations to such man-induced stresses as entrainment and impingement at power plants. The SRVAL code was developed to test such assertions. It was utilized in testimony written in connection with the Hudson River Power Case (U.S. Environmental Protection Agency, Region II). This testimony was recently published as a NUREG report. Here, a user's guide for SRVAL is presented.

SUMMARY

SRVAL is a FORTRAN IV computer simulation model developed to assess the validity of the utilities' curve fits of the Ricker model to striped bass data in the Hudson River Power Case. The mathematical basis for the model and a detailed description of its application are provided in Christensen et al. (1982). Our purpose here is to provide a user's guide for SRVAL.

Section 1 provides an introduction to the purpose of SRVAL and background about the context within which it was used. In Section 2, the input data are described. Section 3 consists of a description of the program's operation. In Section 4, the output is explained. Section 5 provides our conclusions and recommendations. In the Appendix, a listing of SRVAL and its output in a typical application is provided on microfiche.

TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES

# 1. INTRODUCTION AND BACKGROUND

A long-standing controversy about power-plant effects on biota (especially fish) in the Hudson River was settled in December, 1980 (Christensen et al. 1981). The settlement agreement brought to an end a protracted United States Environmental Protection Agency (EPA) hearing in which the United States Nuclear Regulatory Commission (NRC) was a participant.

One of the points of controversy in the EPA hearing was the validity of the utilities' attempts (Exhibits UT-3, -4, and -58) to use the Ricker model to quantify biological compensation for fish populations. A number of pieces of rebutted testimony, sponsored by EPA, were submitted (Bossert 1979, Christensen et al. 1979, Fletcher and Deriso 1979, Golumbek and Christensen 1979, Goodyear 1979, Levin 1979, Robson 1979, and Rohlf 1979). Working from various perspectives, these items of testimony identified problems with the utilities' use of the Ricker model. In particular, Christensen et al. (1979) utilized a FORTRAN IV computer model (SRVAL) to simulate the utilities' curve-fitting exercise for the Hudson River striped bass population. Based on this work, it was concluded that the utilities' projections of long-term impact based on the Ricker model were unreliable and should be disregarded. Our purpose here is to provide a user's guide for SRVAL, the derivation and use of which is explained in Christensen et al. (1979 and 1982). It is important for potential users of the program to realize that it was tailored specifically to the questions arising from the utilities' analysis of Hudson River striped bass. Application to another situation would likely require modification of the program, the extent of which would depend on the degree of similarity between the particular situation and the Hudson River situation.

## 2. PROGRAM INPUT

Portions of the input data for SRVAL are organized in tabular format to facilitate making changes using an interactive computer system. Table 2-1 is a sample input file, to which line numbers have been added. The formats for the variables, and an explanation of some of the variables, are given in Table 2-2. Variables in Table 2-2 that are not explained there are defined in the "Glossary of Terms," contained within the program listing itself (see Appendix).

The input data (Table 2-1) are organized into functional groups. The first 27 cards supply parameter values relating to the dynamics of the population (other than life-table characteristics) and underlying choices relating to the simulation. Cards 28 to 47 constitute basic life-table data for the population. Cards 48 and 49 control the requested graphic output (if any). Cards 50 to 126 supply parameters concerning the utilities' lag appraoch to attempting to derive indices of stock and recruitment from catch-per-unit-effort data; cards 127 to 136 do tne same for the utilities' matrix approach. The remaining cards are specific to the Hudson River and are normally not read; if the user wished to supply data for the full curve-fitting exercise, he or she would substitute his or her data and set LAWFLG equal to one.

Table 2-1. Sample input data for SRVAL. Line numbers, corresponding to card numbers in Table 2-2, have been added.

```
00001   THIS IS FIRST LINE OF DATA FILE FOR RUN 46, FOR USE WITH SRVAL.
00002   .60093 0.4114
00003   NPAR  IFDBK IRAND NLAG  NSPMT NREP  NSIM  IPLTF IPCH  TLC
00004   ----- ----- ----- ----- ----- ----- ----- ----- ----- -
00005       3     0     1     9     1   120    26     9     1 I
00006                             VARBL      VARBL    VARBL
00007   PARAMETER    MEAN         STDEV      MEAN     CODE
00008                --------  --------   --------    -
00009       ALPHA     1.25                   0.0      B
00010       GAMMA 0.000036                            B
00011        FLOW   15275.      3471.
00012   STK. SURV                 0.0
00013        CRUB               0.357670
00014         R1E 2500000.
00015          R0 2500000.
00016        RQFY   5868.
00017   3890719377
00018   9190327578
00019   SBDAK
00020   PELAG
00021   SPMTX
00022   NOPLT
00023   11
00024     0
00025    46
00026   7
00027     15   50 0.01 0
00028   |AGE||PFCT.FEM||PFCT.MAT||EGS/MIFF||PS TO AG|| FISHING|| WEIGHT ||STK DDFT|
00029     1  0.5        0.0       0.0       0.000005  0.0        0.0228      1.0
00030     2  0.5        0.0       0.0       0.43      0.00646    0.211       1.0
00031     3  0.5        0.04      658000.   0.43      0.164      1.01        1.0
00032     4  0.5        0.07      658000.   0.43      0.128      2.57        1.0
00033     5  0.5        0.19      578000.   0.43      0.291      3.85        1.0
00034     6  0.5        0.43      714000.   0.43      0.240      5.88        1.0
00035     7  0.5        0.86      928000.   0.43      0.0866     8.26        1.0
00036     8  0.5        0.89      1310000.  0.43      0.0220     12.9        1.0
00037     9  0.5        1.00      1570000.  0.43      0.00388    14.4        1.0
00038    10  0.5        1.00      1760000.  0.43      0.0233     16.6        1.0
00039    11  0.5        1.00      1980000.  0.43      0.0233     17.7        1.0
00040    12  0.5        1.00      2090000.  0.43      0.00517    20.6        1.0
00041    13  0.5        1.00      2130000.  0.43      0.00646    22.7        1.0
00042    14  0.5        1.00      2190000.  0.43      0.0        21.3        1.0
00043    15  0.5        1.00      2590000.  0.43      0.0        21.6        1.0
00044   C.... SOURCE OF THE WEIGHT VECTOR IS C.P.GOODYEAR, 5/18/78.  HE USED
00045   C.... FER, TABLE 7.8-1 FOR AGE 1, AND 7.8-2 FOR THE REMAINDER, USING
00046   C.... TI'S CORRECTED FER EQUATION RELATING WEIGHT AND LENGTH.
00047   C.... OTHER DATA FROM SECTION 2-VIII OF EXHIBIT 3.
00048   00000000000000000000000000000000000000000000000000000000000000000000000000000000
00049   00000000000000000000000000000000000000000000000000000000000000000000000000000000
00050    PAR  REC  LAG SIMPLE 4 YEAR LAG          AXX
00051     0    4    4
00052   1
00053    0 1.000
00054   1
00055    4 1.000
00056    PAR  REC  LAG SIMPLE 5 YEAR LAG          BXX
00057     0    5    5
00058   1
00059    0 1.000
00060   1
00061    5 1.000
00062    PAR  REC  LAG AVERAGE OF 5 AND 6 YEARS  CXX
00063     0   5,6  5,6
```

Table 2.1 (continued)

```
 1
  0 1.000
 2
  5 0.500
  6 0.500
  PAR REC  LAG SIMPLE 6 YEAR LAG          DXX
   0    6    6
 1
  0 1.000
 1
  6 1.000
  PAR REC  LAG AVERAGE OF 5,6,7 YEARS     EXX
   0  567  567
 1
  0 1.000
 3
  5 .3334
  6 .3333
  7 .3333
  PAR REC  LAG SIMPLE 7 YEAR LAG          FXX
   0    7    7
 1
  0 1.000
 1
  7 1.000
  PAR REC  EC. EQUATION 15 - EXHIBIT 3    NXX
  0-6 4-10  15
 7
  0 1.000
  1 1.000
  2 1.000
  3 1.000
  4 1.000
  5 1.000
  6 1.000
 7
  4 1.000
  5 1.000
  6 1.000
  7 1.000
  8 1.000
  9 1.000
 10 1.000
  PAR REC MLTI MULTIPLE AGE MODEL-EX.58  PXX
   0  MLTI  AGE
 1
  0 1.000
 5
  5 0.500
  6 0.320
  7 0.100
  8 0.040
  9 0.030
  PAR REC EGGS EGGS ON EGGS MODEL-EX.58  QXX
   0  EONE ON E
 1
  0 1.000
 5
  5 0.169
  6 0.300
  7 0.245
  8 0.142
  9 0.144
```

Table 2.1 (continued)

```
"EQ. "EQ. "EQ.
  8"  13"  14"
MATRIX - EQUATION 8,EX.3  XXX
MATRIX - EQ. 13,EXH. 3    YXX
MATRIX - EQ. 14, EXH. 3   ZXX
    3   10   5
C.... ANNUAL SURVIVAL BEGINNING WITH YEAR 4
 0.43      0.43      0.43      0.43      0.43      0.43      0.43      0.43
C.... FECUNDITY INDEX AS IN FEP, TABLE 10.6-1, ALTERED BY SWC FOR NEW DATA.
 .2632     .460      1.10      3.07      7.98      11.66     15.7      17.6
      1950.     2522.    14092.
      1951.     7663.    18349.
      1952.     9935.    18469.
      1953.     5394.    17927.
      1954.     7623.    17333.
      1955.     4657.    15166.
      1956.     5830.    16899.
      1957.     5357.     9893.
      1958.     4932.    14708.
      1959.     8496.    13373.
      1960.     9250.    17177.
      1961.     4939.    14296.
      1962.     3232.    12444.
      1963.     4548.    12258.
      1964.     3324.    11387.
      1965.     4673.     7912.
      1966.     5879.    12134.
      1967.     8378.    12002.
      1968.     7153.    14444.
      1969.     9994.    16200.
      1970.     4986.    14375.
      1971.     5020.    18191.
      1972.     3399.    24557.
      1973.    10736.    19637.
      1974.     1950.    17061.
      1975.     2698.    16861.
C     YEAR      CPUE     Q7 FLOW
C.... LAWLER'S 1978 CORNWALL REPORT CPUE DATA, TABLE 10.6.3
C.... FLOW DATA ALSO FROM CORNWALL REPORT, TABLE 10.6.5. 1960 CHANGED
C.... TO VALUE FROM EXHIBIT 58, AS PER 1/79 UTILITY LETTER.
```

Table 2.2. Description of the Sample Input File

| Card # | Column(s) | Format | Variable | Comments |
|---|---|---|---|---|
| 1 | 1-80 | None | None | Used to describe input file; is not read. |
| 2 | 1-6 | F6.0 | SIGMA | Standard deviation of random term affecting young-of-the-year (y-o-y) mortality. |
| | 8-13 | F6.0 | COR | Correction Factor. |
| 3-4 | -- | -- | None | Not read. |
| 5 | 1-5 | I5 | NPAR | Either 2 or 3. |
| | 7-11 | I5 | IFDBK | Either 0 or 1. |
| | 13-17 | I5 | IRAND | Either 0 or 1. |
| | 19-23 | I5 | NLAG | Integer from 0 through 9. |
| | 25-29 | I5 | NSPMT | 0, 1, 2, or 3. |
| | 31-35 | I5 | NREP | Positive integer less than 121. |
| | 37-41 | I5 | NSIM | Positive integer less than 27. |
| | 43-47 | I5 | IPLTF | Any integer. |
| | 49-53 | I5 | IPCH | 1 to write main data to another unit as well as to the line printer. |
| | 55 | A1 | TLC | Code transmitted to output. |
| 6-8 | -- | -- | None | Not read. |
| 9 | 11-18 | F8.0 | ALPHA | Typically between 1 and 30. |
| | 31-38 | F8.0 | AMEAN | Zero in all applications. |
| | 43 | A1 | SAC | Identifying code for output. |

Table 2.2 (continued)

| Card # | Column(s) | Format | Variable | Comments |
|---|---|---|---|---|
| 10 | 11-18 | F8.0 | GAMMA | Effect of flow on survival. |
| | 43 | A1 | SGC | Identifying code for output. |
| 11 | 11-18 | F8.0 | FMEAN | Derived from data. |
| | 21-28 | F8.0 | FSTD | Derived from data. |
| 12 | 21-28 | F8.0 | SGMS | Zero in all applications. |
| 13 | 21-28 | F8.0 | SGMC | Typically between 0 and 0.5. |
| 14 | 11-20 | F10.0 | R1E | Arbitrary; Typically millions. |
| 15 | 11-20 | F10.0 | R10 | Arbitrary; Typically millions. |
| 16 | 11-20 | F10.0 | EQFY | Arbitrary; conveniently derived from data. |
| 17 | 1-10 | 10I1 | NSEED1 | Random generator initiator. Each of the first eight digits of NSEED1 should be a non-negative integer. These digits should not all equal the corresponding first eight digits of NSEED2 (see card 18). |
| 18 | 1-10 | 10I1 | NSEED2 | Random generator initiator. |
| 19-22 | -- | -- | None | Not read. |
| 23 | 1 | I1 | IFPR | Use 1. |
| | 2 | I1 | IRNO | Use 1. |
| 24 | 1-3 | I3 | NPR | Number of prior executions if any, of this Run. Use 0. |
| 25 | 1-3 | I3 | IDR | Run number (for identification). |

Table 2.2 (continued)

| Card # | Column(s) | Format | Variable | Comments |
|---|---|---|---|---|
| 26 | 1 | I1 | IPUNCH | Unit to which main data are written. These data are also written to the line printer. |
| 27 | 1-5 | I5 | NAGE | Number of post-y-o-y ages. |
| | 6-10 | I5 | NYR | Years prior to simulation. |
| | 11-15 | F5.0 | SCALE | Not used, recalculated by code. |
| | 17 | I1 | LAWFLG | 1 can be used to analyze real data as the first replicate. As validation program, do not use 1. |
| 28 | -- | -- | None | Not read. |
| 29 | 1-5 | -- | None | Not read. |
| | 6-15 | F10.0 | FF | Data for one-year-olds. See Glossary in program for explanation of FF, FM, EMF, PS, FSHG, W, and SDDP. |
| | 16-25 | F10.0 | FM | |
| | 26-35 | F10.0 | EMF | |
| | 36-45 | F10.0 | PS | |
| | 46-55 | F10.0 | FSHG | |
| | 56-65 | F10.0 | W | |
| | 66-75 | F10.0 | SDDP | |
| 30-43 | -- | -- | None | Like card 29, but for fish aged 2-15, respectively. |
| 44-47 | -- | -- | None | Not read. Available for use as comments. |
| 48-49 | 1-80 | 80I1 | IFPLOT | Use value other than 1 to suppress plots. Number of values (and cards) needed depends on IDIM, which is set equal to NREP. |

Table 2.2 (continued)

| Card # | Column(s) | Format | Variable | Comments |
|---|---|---|---|---|
| 50 | 1-4 | A4 | JTL(1,1,I) | I = 1. Label to identify output for first lag method. |
| | 6-9 | A4 | JTL(1,2,I) | See above. |
| | 11-14 | A4 | ITL(1,I) | See above. |
| | 16-40 | 6A4, A1 | KTL(K,I) | I = 1. K = 1 to 7. Label to identify output. |
| | 42 | A1 | PTC(I) | Code to identify method of processing CPUE data. I = 1. |
| 51 | 1-4 | A4 | JTL(2,1,I) | I = 1. Label to identify output. |
| | 6-9 | A4 | JTL(2,2,I) | See above. |
| | 11-14 | A4 | ITL(2,I) | See above. |
| 52 | 1 | I1 | NYRLGP(I) | I = 1. Number of years over which parent index is to be averaged. |
| 53 | 1-2 | I2 | LGP(II,I) | Lag for parent index II. I = 1. Value of II will vary (and more than one card will be needed) if NYRLGP(I) is not 1. |
| | 4-8 | F5.0 | WTP(II,I) | Weighting factor for parent index II. See above or index values. |
| 54-55 | -- | -- | -- | Same as 52-53, but using arrays NYRLGR, LGR, and WTR for recruits rather than parents. |
| 56-61 | -- | -- | -- | Like 50-55, but I = 2. This group contains data for the second lag method. |

Table 2.2 (continued)

| Card # | Column(s) | Format | Variable | Comments |
|---|---|---|---|---|
| 62-68 | -- | -- | -- | Like 56-61, but I = 3. Not the "extra" card (58), needed because NYRLGR(3) is 2 rather than 1. |
| 69-74 | -- | -- | -- | Like 50-55, but I = 4. |
| 75-82 | -- | -- | -- | Like 56-61, but I = 5, and two "extra" cards are needed because NYRLGR(5) = 3. |
| 83-88 | -- | -- | -- | Like 50-55, but I = 6. |
| 89-106 | -- | -- | -- | Like 56-61, but I = 7, and many "extra" cards are needed because both NYRLGP(7) and NYRLGR(7) are equal to 7. |
| 107-116 | -- | -- | -- | Like 56-61, but I = 8. |
| 117-126 | -- | -- | -- | Like 56-61, but I = 9. |
| 127 | 1-4 | A4 | ITL(1,1) | Label to identify matrix output. |
| | 6-9 | A4 | ITL(1,2) | See above. |
| | 11-14 | A4 | ITL(1,3) | See above. |
| 128 | -- | -- | -- | Like card 127, but for ITL(2,J), with J = 1 to 3. |
| 129 | 1-25 | 6A4,A1 | KTL(K,J) | J = 10. K = 1 to 7. Label to identify output. |
| | 27 | A1 | PTC(J) | Code to identify method of processing CPUE data. J = 10. |
| 130-131 | -- | -- | -- | Like 129, but J = 11 and 12, respectively. Labels for second and third matrix processing methods. |

Table 2.2 (continued)

| Card # | Column(s) | Format | Variable | Comments |
|---|---|---|---|---|
| 132 | 1-5 | I5 | NMIN | See glossary in subroutine SPMTSC for explanation of variables on this card. |
| | 6-10 | I5 | NMAX | |
| | 11-15 | I5 | NAGC | |
| 133 | -- | -- | None | Not read-available for comments. |
| 134 | 1-80 | 8F10.0 | SVR(I) | I = 4 to 10. |
| 135 | -- | -- | -- | Like 133. |
| 136 | 1-80 | 8F10.0 | FI(I) | I = 3 to 10. |
| 137 | 1-10 | F10.0 | YEAR(I) | I = 1. Not read in this example. |
| | 11-20 | F10.0 | FY(I) | I = 1. Not read. |
| | 21-30 | F10.0 | FL(I) | I = 1. Not read. |
| 138-162 | 1-30 | -- | -- | Like 137, but I = 2 to 26. These data are not read in this example. If LAWFLG were set to 1 (Card 27), these data would be read. |
| 163-166 | -- | -- | None | Not read. Available for making comments. |

# 3. PROGRAM OPERATION

SRVAL consists of a main program and a large number of subroutines. Figure 3-1 is a flowchart of the main program; the Appendix contains a complete listing of the program and all subroutines. The program is written in FORTRAN IV, and it has run on IBM 360 and 3033 machines as well as (using reduced dimensions for some arrays) on a DEC-10.

## 3.1. Operation of the Main Program

In this section the operation of the main program is described. In Section 3.2, the subroutines are identified and their functions are described.

Program operation comprises several steps. First, the input data are read in and values are initialized; this process takes place entirely within the main program. Next, a number of values germane to the population simulation are calculated. In this step, as in the remaining steps, subroutines are utilized. Third, the random numbers called for in the input file are generated. Fourth, the population is simulated for the required number of years (3170 for the sample data). Some output is then printed. The program next enters a loop, within which simulated indices are subjected, one replicate at a time, to the curve-fitting and "prior estimation of beta" procedures (Christensen et al. 1982). The resulting estimates of alpha, beta, gamma, and $r^2$ from each replicate are stored prior to processing of the next replicate. When processing of the replicates is complete, the remainder of the output, including tables of the stored values and a condensed file suitable for subsequent statistical analysis (if desired), is written.

## 3.2. Functions of the Subroutines

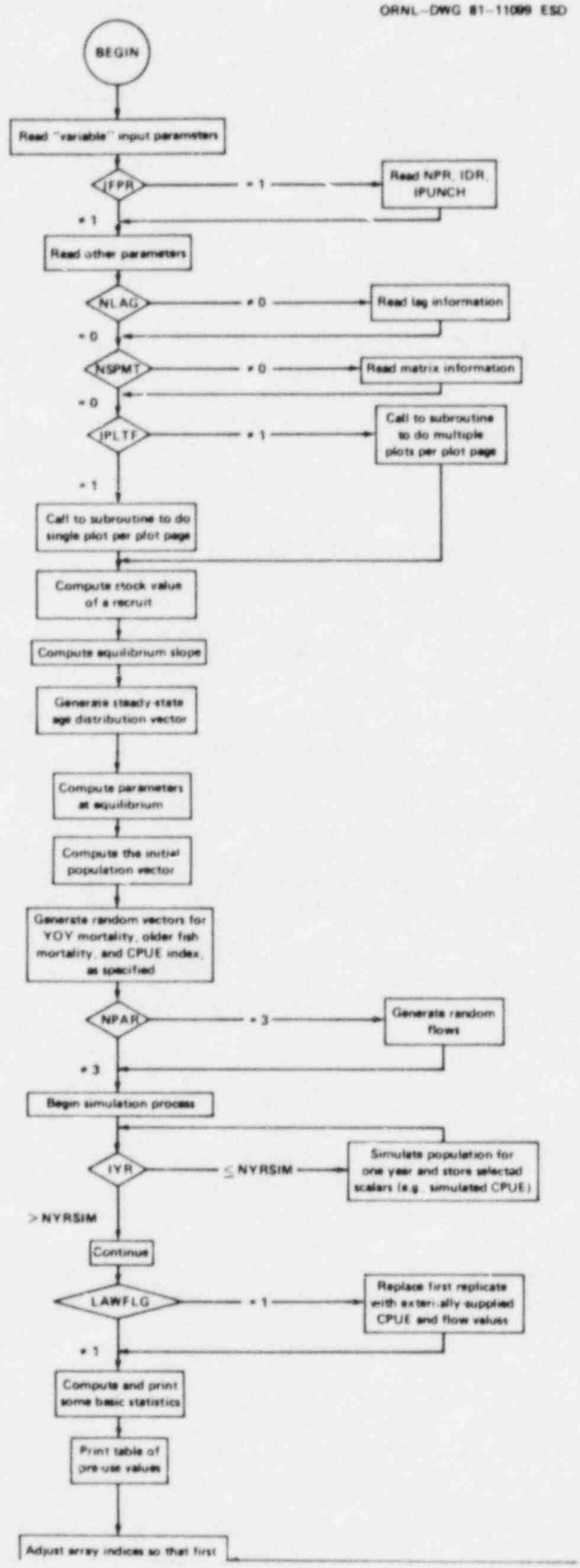
### 3.2.1. VECCOM

This subroutine computes the initial age vector of the simulated population. This is accomplished by utilizing the first-year survival value $S_1$ from Equation (7) in Christensen et al. (1982), with no random variation, together with other specified population parameters to establish a steady-state age structure which would yield a specified catch-per-unit-effort value.

### 3.2.2. GGNOR1

This subroutine returns normally distributed pseudo-random variables using the "direct method" of Abramowitz and Stegun (1965).

ORNL-DWG 81-11099 ESD



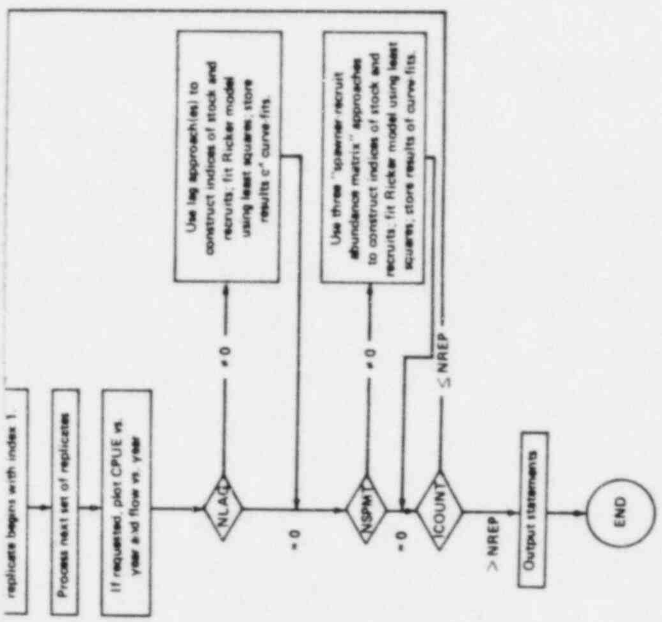



Figure 3-1. Flow chart for the main program of SRVAL.



3.2.3. GGU11

This driver subroutine calls RAND1 and returns pseudo-random variables with uniform distribution.

3.2.4. RAND1

This subroutine, used by both GGNOR1 and GGU11, generates pseudo-random numbers with uniform distribution, based on techniques described by Allard et al. (1963).

3.2.5. BLSQ

This subroutine performs linear least-squares regression.

3.2.6. STAT

This subroutine is used to calculate means, standard deviations, and coefficients of variation. Refer to Section 3.2.22 (subroutine BLITZ) for guidance about values for the five variables SM, BG, SF, TF, and BF.

3.2.7. TABLE

This subroutine prints out the major summary tables of results.

3.2.8. DOPLT

This is a graphics subroutine, used with the proprietary software package DISSPLA. For installations not having DISSPLA, many subroutines called by DOPLT and other graphics subroutines will not exist. This problem is easily circumvented by adding "dummy" subroutines, as explained in Section 3.3. Subroutine DOPLT is the main graphics routine; if enabled, it draws on other graphics routines within SRVAL and in DISSPLA to produce large plots (i.e., one plot per page).

3.2.9. GPHBGN

This graphics subroutine sets up a new plot page.

3.2.10. GPHEND

This graphics subroutine draws and ends an individual plot.

3.2.11. FINDMX

This subroutine, which is used with graphics subroutines, returns the maximum value contained in an array. It is used in determining scaling for plots.

3.2.12. MXMIN

This subroutine, which is used with graphics subroutines, returns the maximum and the minimum values contained in an array. It is used in determining scaling for plots.

3.2.13. GENLAG

This subroutine constructs indices of stock and recruits from a single time series of catch data by pairing weighted averages of lagged catch values. These indices then constitute a part of the data used in the curve-fitting exercise.

3.2.14. ASIGN

This subroutine stores results from least-squares curve fits in arrays. These arrays are later utilized by subroutine TABLE to print out summary tables of results and by subroutine PUNCH to provide the summary data in a format suitable for offline data storage.

3.2.15. LSTSQ

This subroutine controls the process of fitting the Ricker model to a particular set of data. It calls LSTSQ1 for two- and three-parameter fits, as appropriate, and determines the significance level of the results.

3.2.16. LSTSQ1

This subroutine computes values for the transformed (linearized) Ricker model, calls BLSQ to perform the fit, and computes useful statistics associated with the fit. If plots are requested, it also calls the appropriate entry in subroutine DOPLT or DOPLT1 to draw the plot.

3.2.17. OVWRTE

If called, this subroutine reads year, CPUE, and flow data from the input file and replaces the analogous data in the first replicate (see Christensen et al. 1982) with these data. This enables the entire curve-fitting exercise to be conducted on real-world data by simply running the program with LAWFLG set equal to 1. Of course, any such execution should not be used for normal model-validation purposes because the results from the first replicate are no longer model-generated but are for real data.

### 3.2.18. TEST

This subroutine substitutes a repeating series of numbers for the random numbers normally used. It was used in checking the operation of this program against a different program written by Dr. C. P. Goodyear and might be of some use to other users.

### 3.2.19. DOPLT1

This subroutine is the driver for a group of subroutines which use DISSPLA to generate multiple plots per page. The typical user, who will likely not want to use this feature, should note the commentary in Section 3.2.8.

### 3.2.20. GPHSET

This subroutine produces the individual subplots in a multiple-plot-per-page context.

### 3.2.21. SPMTSC

This subroutine computes indices of stock and recruits from a single time series of catch data using the utilities' "matrix" approach. These indices, which are analogous to those generated by subroutine GENLAG, constitute a part of the data used in the curve-fitting exercise.

### 3.2.22. BLITZ

This subroutine utilizes the utilities' "prior estimation of beta" technique (McFadden et al. 1978, see Christensen et al. 1982 for an explanation) to estimate alpha. This technique is an alternative to the two-parameter curve-fitting exercise. The technique is capable of causing overflow or underflow conditions (e.g., the technique can call for division by zero). Five variables (SM, BG, SF, TF, and BF) are used to test for and correct conditions that could cause overflow or underflow (as well as to set appropriate warning flags). These variables are assigned values near the beginning of BLITZ. The values given SM and BG should be at least several orders of magnitude larger or smaller, respectively, than the smallest or largest single-precision constant permitted by the computer being used. SF, TF, and BF should be about six orders of magnitude further from the respective limits than SM and BG.

### 3.2.23. MED

This subroutine calculates the median of values contained in the array passed to it. It is used in preparing printed output summaries of some of the results.

### 3.2.24. PUNCH

This subroutine writes the essential output information in abbreviated, 80-column format to the regular output device (e.g., the line printer) and also to some other device (e.g., a card punch or magnetic tape), the unit number of which is passed to the subroutine as IPUNCH. This enables the user to perform statistical analysis of the results, if desired.

## 3.3. Use of Dummy Subroutines

For installations where DISSPLA is not available, it will be necesary to include "dummy" subroutines (as is done in the program listing in Appendix A.) Each "dummy" subroutine consists of three FORTRAN statements: a SUBROUTINE statement, giving the name, a RETURN statement, and an END statement. The names of the needed subroutines are: CALCMP, TKTRN, GRID, FRAME, CURVE, ENDGR, TITLE, BGNPL, XAXANG, PHYSOR, XNONUM, YNONUM, MESSAG, INTNO, COMPRS, DASH, XTICKS, SCLPIC, YAXANG, LINPLT, YTICKS, HLDPLT, PAGE, DONEPL, HEIGHT, GRAF, OREL, and ENDPL.

# 4. PROGRAM OUTPUT

Program output consists of output to a line printer and, if IPCH is 1, output of summary information to a device specified as a unit number by the variable IPUNCH. The summary information is also written to the line printer. It is convenient to think of the line printer output as consisting of sections, as follows:

(1) The first section provides a record of the main input variable values. A life table of adult parameters is printed, followed by groups of lines providing the parameters used by the lag and matrix processing methods. The next twenty lines provide a record of key stock-recruitment parameters and some statistics derived from the population trajectory.

(2) Output data from the pre-fit simulation are provided, with one line per year. At the end of these data, the mean, standard deviation, and coefficient of variation of the simulated catch-per-unit-effort (CPUE) are given.

(3) Data in format similar to (2) are provided for the first replicate. A list of estimates of beta from the lagged CPUE values using subroutine BLITZ is provided, with lines printed out indicating the PTC values associated with negative estimates. Next, a table showing statistics for the lagged CPUE values is printed, followed by a table of the matrix statistics. Finally, a group of lines gives beta estimates obtained by applying subroutine BLITZ to the matrix-processed CPUE values, with appropriate lines indicating PTC values associated with negative estimates.

(4) A section like (3) but for replicate 2 is printed. Similar sections for replicates 3 to 120 are suppressed to save paper; the "explanation of coded comment flags" section near the beginning of the program provides a means of locating the places where this suppression is achieved if it is not wanted. The suppression does not extend to the printing of beta estimates from subroutine BLITZ; approximately 13 pages of such estimates and messages about negative estimates are printed.

(5) A table of alpha estimates obtained by two-parameter curve-fitting is provided, with summary statistics at the head. Asterisks indicate a statistically significant ($P < 0.05$) fit, as judged by a test on beta; a dollar sign indicates that the associated estimate of beta is negative.

(6) A table of the $r^2$ values corresponding to the fits in (5) is printed.

(7) A section of 22 lines provides more information about a few input data and some statistics obtained from the simulation.

(8) A table of beta estimates corresponding to the fits in (5) is printed.

(9) A table of estimates of alpha obtained from subroutine BLITZ is printed.

(10) A table similar to (5), but based on three-parameter curve-fits (i.e., with simulated river flow included in the fit), is printed.

(11) A line giving the input value of gamma is printed, followed by a table of gamma estimates (gamma here estimates the effect of river flow on survival of young-of-the-year fish).

(12) A table of the $r^2$ values for the three-parameter curve fits is printed.

(13) A table of the beta values for the three-parameter curve fits is printed.

(14) The remaining output is produced by subroutine PUNCH. Each line begins with a letter code identifying the source value of alpha (1.25 in this example, denoted by a B) in the first field, followed by a three-digit field giving the replicate number. The first 1800 lines provide, in repeating sequence, values of CPUE, number of young-of-the-year, and egg production (identified respectively by W, a V, or a U in column 5) for each year of the simulation. The next 1440 lines give, in condensed format, the main results of the fits, as indicated in Table 4-1.

(15) A line is printed to indicate that card images of the preceding 3240 lines have been "punched" (i.e., have been output to some other device besides the line printer).

(16) The four final lines indicate the cumulative number of replicates, the run identification, and the final values of the seeds returned by the random number generators.

Table 4.1. Key to main summary output table.

| Column(s) | Variable | Format | Comments |
|---|---|---|---|
| 1 | SAC | A1 | Source alpha code. |
| 2-4 | I | I3 | Replicate number. |
| 5 | PTC | A1 | Type of processing used on CPUE data. |
| 6-8 | IDR | I3 | Identification number for the computer execution. |
| 9 | SGC | A1 | Source gamma code. |
| 10-14 | CV | F5.2 | Coefficient of variation (expressed as proportion) for the CPUE values in the replicate. |
| 15 | TLC | A1 | Code available for user's use. |
| 16-25 | ALF2 | E10.4 | Two-parameter alpha estimate. |
| 26-29 | RSQ2 | F4.2 | Two-parameter $r^2$. |
| 30-37 | BET2 | E8.2 | Two-parameter beta estimate. |
| 38 | SGN2 | A1 | "*" denotes significance at $P < .05$. |
| 39-48 | ALF3 | E10.4 | Three-parameter alpha estimate. |
| 49-52 | RSQ3 | F4.2 | Three-parameter $r^2$. |
| 53-60 | BET3 | E8.2 | Three-parameter beta estimate. |
| 61-68 | GAM3 | E8.2 | Estimate of gamma. |
| 69 | SGN3 | A1 | "*" denotes "significant" improvement of fit with third parameter at $P < 0.1$. |
| 70-79 | BLZ | E10.4 | Alpha estimated using the "prior estimation of beta" technique as proposed by the utilities. |
| 80 | IWARN | A1 | A code to warn of numerical problems which frequently arise in using the "prior estimation of beta" technique. |

## 5. CONCLUSIONS AND RECOMMENDATIONS

Based on this work, we offer the following conclusion:

> Application of SRVAL to other populations than the Hudson River striped bass would likely require modification of the program.

We also have the following recommendation:

> Use, and particularly modification, of the program should be attempted only by persons who have read and understood Christensen et al. (1982).

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# APPENDIX

## LISTING OF THE COMPUTER PROGRAM "SRVAL" WITH OUTPUT

This Appendix consists of a listing of the computer program SRVAL with output generated from the input data in Table 2-1. The listings are on microfiche to save paper and printing costs (inside back cover).

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