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A Generalized Computer Program for Yield per Recruit Analysis of a Migrating Population with Area Specific Growth and Mortality Rates

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CONTENTS

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A number of yield per recruit computer programs have been developed, but programs for yield per recruit analysis of a stock fished over multiple areas have not been described in the literature. Paulik and Bayliff (1967) described a program for the Ricker model of equilibrium yield per recruit, but the program does not compute estimates of yield for a multi-area fishery and does not take into account possible area specific growth rates.

The need for such a program as MAREA arose while attempting to apply existing yield per recruit models to the Atlantic menhaden, Brevoortia tyrannus, a commercially valuable species found on the Atlantic coast of North America. The population migrates seasonally with an increased northward movement with age (Dryfoos et al. 1973). Nicholson (1972) reported latitudinal differences in the relative density of each age group along the coast and stratification along the coast by size within each age group. Problems were incurred in analyzing such a population because of its migratory nature and apparent area specific growth rates. Similar problems arise when analyzing penaeid shrimp populations and other fisheries in which area specific growth rates exist and where the same stocks migrate into different fisheries as they mature.

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An undescribed program for yield per recruit analysis of multi-gear fisheries (MGEAR) was developed by one of the authors (W. H. Lenarz) and was applied to yellowfin tuna to determine yield per recruit when fishing mortality varies with age and gear type (Lenarz et al. 1974). Lenarz and Zweifel (1978) modified the MGEAR program to estimate egg production over the life of a recruited cohort for Pacific yellowfin tuna. The original MGEAR uses a method of proportioning yield relative to the contribution of the vectors of fishing mortality, of different gears, of different fleets, or of different countries to the total fishing mortality, which has been described by Laurec (1978). The program does not, however, take into consideration area-specific growth rates which the newly modified program, MAREA, does. MAREA is equally applicable to a multiple gear fishery in which size at age of exploited fish is gear specific because of varying size selectivity curves of the gear types. The description and use of MAREA ensues.

The MAREA program uses a modification of the yield equation of Ricker (1975) to estimate yield per recruit. The modification follows the number of survivors across the intervals and biomass within an interval opposed to following biomass throughout. The modification gives the same results as the Ricker model and has no mathematical advantage over that method. For the purposes of this program, however, computer time efficiency was increased using the modification. The Ricker model (Ricker 1975) was chosen over the Beverton and Holt model (Beverton and Holt 1957) because of the former model's greater flexibility over the life span of the fish, allowing instantaneous natural and fishing mortality rates to be varied with age. Also, the Ricker model does not assume that growth of the species during its fishable life span follows a von Bertalanffy growth curve

Yield per recruit per area (Y_j) is calculated as follows:

$$Y = \sum_{i=1}^{NN} Q_{i,j} \, Y_{i,j}$$

where

NN = number of time intervals

$Y_{i,j} = F_i \overline{B}_{i,j}$; yield calculated for entire fishery during ith interval using growth rates of area j

i = ith time interval

j = jth area

$$\overline{B}_{i,j} = B_{i,j} \left(\frac{e^{(G_{i,j}-M_i-F_i)dt}-1}{(G_{i,j}-M_i-F_i)dt} \right);$$ exponential mode

or

$$\overline{B}_{i,j} = B_{i,j} \left(\frac{1+e^{(G_{i,j}-M_i-F_i)dt}}{2} \right);$$ arithmetic mode

$\overline{B}_{i,j}$ = mean biomass for the entire fishery in interval i using growth rates from the jth area

$B_{i,j} = N_i W_{i,j}$; the initial biomass for the entire fishery in the ith interval using the growth rate from the jth area

N_i = number of survivors at beginning of interval i

$dt = t_{i+1} - t_i$

M_i = instantaneous natural mortality rate in ith interval

$$F_i = \sum_{j=1}^{NG} F_{i,j}$$; instantaneous fishing mortality rate in the ith interval

NG = number of areas (or gears, countries, or fleets)

$F_{i,j}$ = instantaneous fishing mortality in ith interval and jth area

$$Q_{i,j} = \frac{F_{i,j}}{F_i}$$; proportion of fishing mortality of an area to that of the entire fishery.

$$G_{i,j} = \ln\left(\frac{W_{i+1,j}}{W_{i,j}}\right);$$ instantaneous growth rate in ith interval and jth area

$W_{i,j}$ = initial weight per fish in ith interval and jth area

The two modes of computing mean biomass can result in important differences in estimates of yield per recruit. Ricker (1975) and Paulik and Bayliff (1967) alluded to the importance of the difference in magnitude between instantaneous growth and total mortality rates ($G_i - Z_i$). They indicated that if the difference was small, arithmetic and exponential calculations approached one another. Ricker suggests using small intervals if the rates are rapidly changing. Based on our findings, the difference between arithmetic and exponential estimates of mean biomass increases rapidly as $G_i - Z_i$ increases in a positive direction, but diverges less rapidly when $G_i - Z_i$ increases in a negative direction. When B_i is arbitrarily taken as unity the relationship is satisfactorily represented by a polynomial regression (Figure 1).

With many fisheries it is only possible to estimate instantaneous fishing mortality (F_i) on an annual basis. Thus, a large interval must be used. The larger the interval, the more likely it is that $G_i - Z_i$ is of a magnitude which would cause significant differences in estimates of $\overline{B}_i$ calculated arithmetically and exponentially. Also, in heavily exploited fisheries there may be a large difference between growth and mortality rates within an interval, especially at older ages.

We employed Ricker's (1975: table 10.3) example of bluegills from Muskellunge Lake to illustrate the difference between the two methods of computing mean biomass. This set was chosen because Ricker's data have been previously used as a historical data set and the data are readily available from his text. Mean biomass was computed arithmetically in the text example and also by Paulik and Bayliff (1967), who used the same data to introduce their computer program. We used the data in MAREA in two separate runs to compute yield per recruit. In one, $\overline{B}$ was computed arithmetically, and in the other it was computed exponentially (Figure 2). There were obvious significant differences. Evaluating various F-multiples and ages of entry when $\overline{B}_i$ was calculated arithmetically, the maximum yield exceeded the maximum biomass of stock (5522.6 g versus 3439.2 g) when F-multiples were large, which is impossible. Maximum biomass of the stock was estimated at F = 0; the time intervals used were four one-eighth of a year intervals followed by one-half year intervals. Despite the small intervals, differences in runs were large, indicating the need to minimize the $G_i - Z_i$ difference regardless of the size of the time intervals. Therefore, in similar circumstances and for the example data set, we recommend that $\overline{B}_i$ be calculated exponentially.

Bias can be introduced into the results of MAREA at extreme multiples of fishing mortality. The area-specific growth rates employed in MAREA represent growth conditions for the data set used in the model, and would require modification to reflect changes in density-dependent growth which might occur under natural conditions with significant changes in stock size. Thus, large F-multiple deviations from conditions used to develop the data base used in the model (F-multiple of 1.0) may be unrealistic and should be used with caution.

MAREA is written in FORTRAN IV for the IBM 360/60, Honeywell 66/80, and Burroughs 7800[4] computers. The program can accommodate up to 5 areas, 30 age intervals, and 10 multipliers of fishing mortality. The number of age intervals, areas and multipliers of fishing mortality can be varied along with the initial number of recruits. Levels of fishing mortality can be varied independently for each area and multiples of fishing mortality can also be varied for all areas in one run. Instantaneous natural mortality (M) can be set to a constant over the age intervals or read as an array of age specific rates. Additionally, if area-specific growth rates are not desired, only one set of weights may be used for input and the program assumes the growth rate to be constant over all areas. Mean biomass can be computed arithmetically or exponentially.

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[4] Use of trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Output options include yield per recruit tables for the entire fishery and if desired, yield per recruit tables for each area when fish below a minimum size are caught and discarded dead, and tables of average weight of the catch for each age of entry determined by:

$$YPR_j/\overline{N}_j, \text{ where } \overline{N}_j = \sum_{i=1}^{NN} (\overline{N}_{i,j} * P_{i,j}),\ P_{i,j} = \frac{N_{i,j}}{N_i},\ \text{and } N_i = \sum_{j=1}^{NG} N_{i,j}.$$

Lastly, tables of yield per effort (YPR_j/X where X is an F-multiple) may be output.

A program listing and documentation, including input and output of a sample run, are given in Appendix I.

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Comments by William W. Fox, Jr. of the Southeast Fisheries Center, Miami, FL., G. Stauffer of the Southwest Fisheries Center, La Jolla, CA; A. McCall of the California Department of Fish and Game, La Jolla, CA; and A. Fonteneau of the Office de al Richerche Scientifique et Technique Outre mer, Abidjan, Ivory Coast, contributed to the development and description of the original MGEAR program.

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FIGURE 1 Difference between arithmetic and exponential calculations of mean biomass when $dt = 1.0$ and $B_i = 1.0$. DELTA $= \overline{B}_{exp.} - \overline{B}_{arith.} = B_i\ (0.0061 + 0.0037\ (G_i - Z_i) - 0.1095\ ((G_i - Z_i)^2 - 0.0491((G_i - Z_i)^3))$, $r = 0.998$.

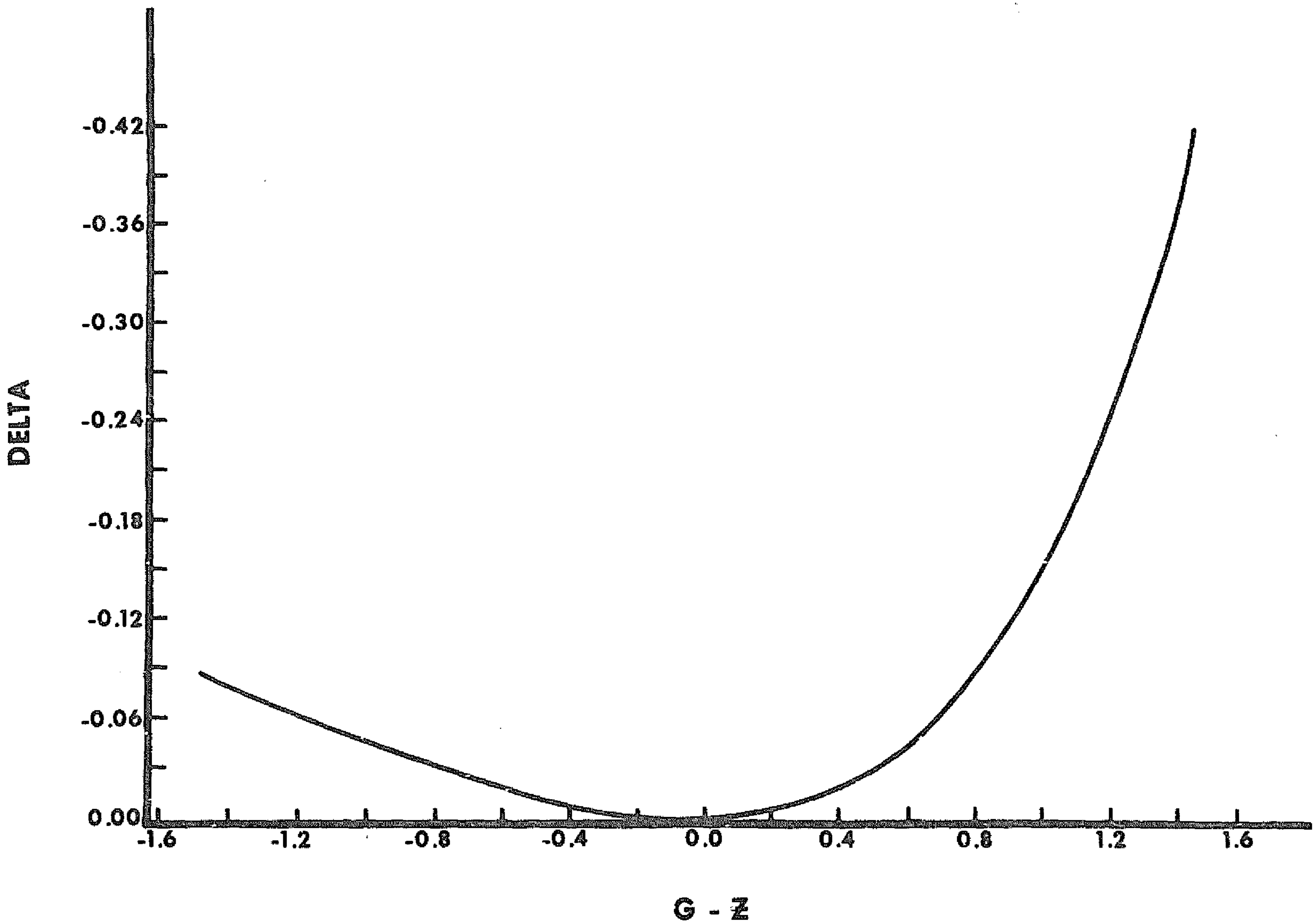

Figure 1

FIGURE 2 Yield per recruit estimates for bluegills of Muskellunge Lake calculating mean biomass a) arithhmetically and b) exponentially (data from Ricker 1975; Table 10.3).

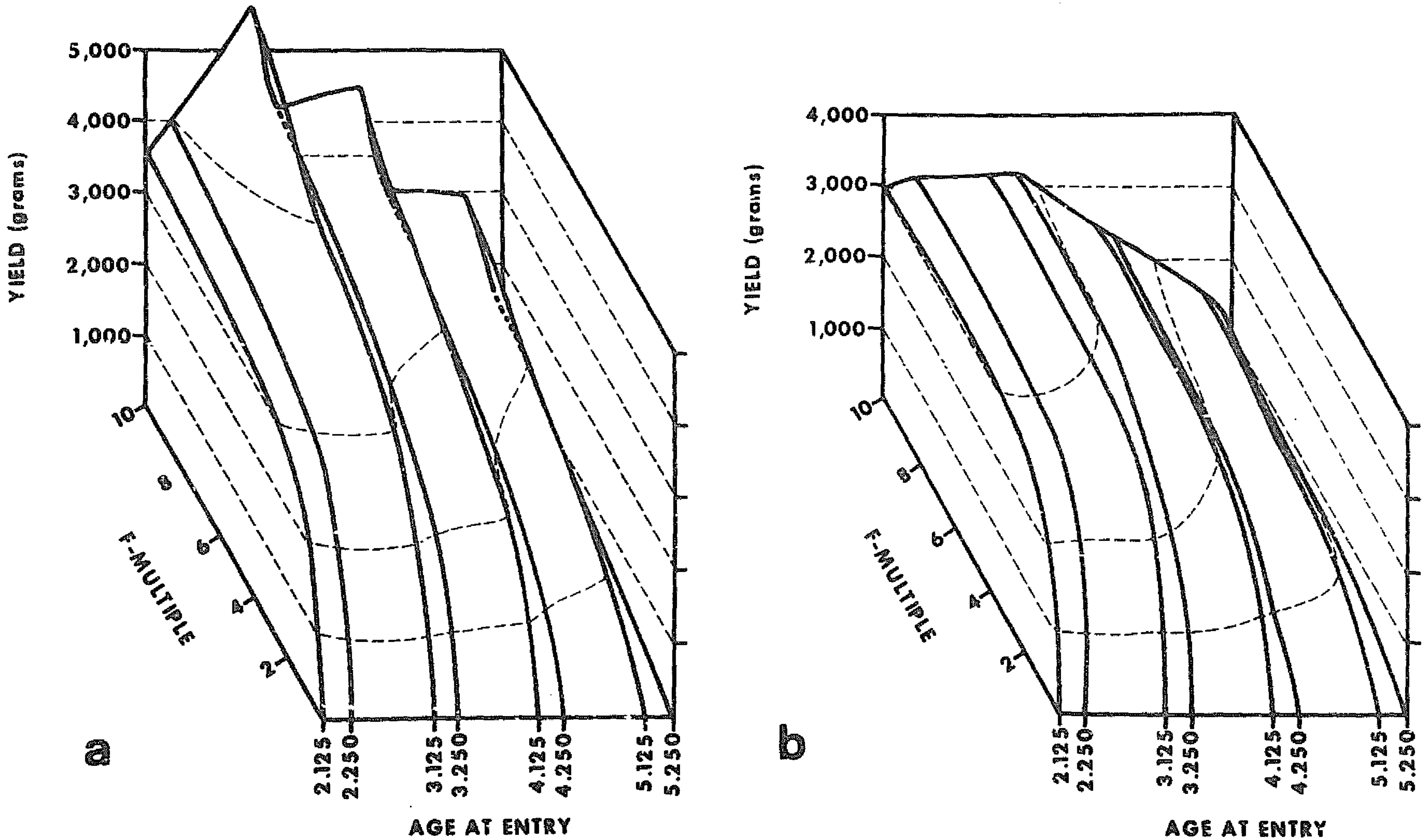
5,000
4,000
3,000
2,000
1,000
YIELD (grams)
10
8
6
4
2
F-MULTIPLE
a
2.125
2.250
3.125
3.250
4.125
4.250
5.125
5.250
AGE AT ENTRY
4,000
3,000
2,000
1,000
YIELD (grams)
10
8
6
4
2
F-MULTIPLE
b
2.125
2.250
3.125
3.250
4.125
4.250
5.125
5.250
AGE AT ENTRY

Figure 2

APPENDIX I

DOCUMENTATION FOR MAREA

INPUT FORMATS

SET 1 -- PARAMETER LIST

LINE TYPE 1 OF SET 1

Input	Format	Columns	Explanation
M(1)	F4.1	1-4	Value of coefficient of instantaneous natural mortality under the assumption that M is constant. Enter 0.0 if M is age specific and an array of M(I) is to be input. Note: This format may be overridden as long as the field size remains the same.
X(1)	F4.1	5-8	First multiplier of vector of coefficients of age specific instantaneous fishing mortality (F(I)). Yield estimates are output as functions of the multiplier and minimum size.
X(2)	F4.1	9-12	Second multiplier
.	.	.	. . . . .
.	.	.	. . . . .
.	.	.	. . . . .
X(10)	F4.1	41-44	Tenth multiplier
NN	I2	45-46	Number of age intervals (Maximum number = 30)
NG	I1	47	Number of areas (Maximum number = 5)
SCALE	F5.0	48-52	SCALE is used to convert coefficients of instantaneous fishing mortality to annual rates. (Example: quarterly values are multiplied by 4.0 to convert to annual values). Note: If time intervals are not equal in length, enter 1.0 and enter only annual instantaneous fishing mortality rates.
MODE	I1	53	Enter 0 when biomass is to be computed arithmetically. Enter 1 when biomass is to be computed exponentially.
CK	I1	54	Enter 1 when growth of stock is not area specific. Enter 0 when growth of stock is area specific.

LINE TYPE 1 OF SET 1

Input	Format	Columns	Explanation
N(1)	F10.2	55-64	Initial number of recruits (If yield per recruit estimates are desired, enter 1.0 in columns 62-64)
NF	I2	65-66	Number of multipliers of fishing mortality (Maximum number = 10).
ITO	I1	67	The following tables can be printed: (A) Yield-per-N(1) number of recruits (B) Yield when fish below a minimum size are caught and discarded dead (C) Average weight of the catch (D) Yield per effort Enter 0 if all tables are desired. Enter 1 if only Table A, B, and C are desired. Enter 2 if only Table A and B are desired. Enter 3 if only Table A is desired.
IGO	I1	68	Enter 0 when tables for each area and the entire fishery are desired. Enter 1 when only tables for the entire fishery are desired or when NG = 1.

SET 2 -- GENERAL TITLE

LINE TYPE 1 OF SET 2 IT

Input	Format	Columns	Explanation
IT	20A4	1-80	General title for yield analysis

SET 3 -- LENGTHS USED FOR LABELING TABLES

LINE TYPE 1 OF SET 3   AD(I,J)

Input	Format	Columns	Explanation
AD(1,1)	F5.1	1-5	Length at beginning of first interval for first area
AD(2,1)	F5.1	6-10	Length at beginning of second interval for first area
.	.	.	. . . .
.	.	.	. . . .
.	.	.	. . . .
AD(14,1)	F5.1	66-70	Length at beginning of fourteenth interval for first area
			Second line is needed if NN is greater than 14.
			*** If OK = 0 repeat the above for each area and for the entire fishery. If OK = 1 do the above only for the entire fishery. ***

SET 4 -- DATA AND TABLE LABELS

LINE TYPE 1 OF SET 4   M (I)

Input	Format	Columns	Explanation
			*** Delete if M(1) is not equal to 0.0***
M(1)	F5.2	1-5	Coefficient of instantaneous natural mortality for the first age interval
M(2)	F5.2	6-10	Coefficient of instantaneous natural mortality for second age interval
.	.	.	. . . .
.	.	.	. . . .
.	.	.	. . . .
M(14)	F5.2	66-70	Coefficient of instantaneous natural mortality for fourteenth age interval
			*** Continue on second line if NN is greater than 14. ***

LINE TYPE 2 OF SET 4 IG(J)

Input	Format	Columns	Explanation
IG(1)	5A4	1-20	Label for first area
IG(2)	5A4	1-20	Label for second area
.	.	.	. . . .
.	.	.	. . . .
.	.	.	. . . .
IG(NG+1)	5A4	1-20	Label for entire fishery
			*** Repeat for each area and entire fishery. If IGO = 1, enter blank data lines for NG areas and enter only label for entire fishery. ***

LINE TYPE 3 OF SET 4 FI(I,J)

Input	Format	Columns	Explanation
FI(1,1)	F5.2	1-5	Coefficient of instantaneous fishing mortality for the first age and first area (Interval estimate)
FI(2,1)	F5.2	6-10	Coefficient of instantaneous fishing mortality for the second age and first area (Interval estimate)
.	.	.	. . . .
.	.	.	. . . .
.	.	.	. . . .
FI(14,1)	F5.2	66-70	Coefficient of instantaneous fishing mortality for the fourteenth age and first area (Interval estimate)
			*** Continue on second line if NN is greater than 14. ***
			*** Repeat for each area. Do not enter values for the entire fishery. Values are summed over areas at each age interval for entire fishery estimates. ***

LINE TYPE 4 OF SET 4 A(I)

Input	Format	Columns	Explanation
A(1)	F5.2	1-5	Age at beginning of first time interval
A(2)	F5.2	6-10	Age at beginning of second time interval
.	.	.	. . . .
.	.	.	. . . .
.	.	.	. . . .
A(14)	F5.2	66-70	Age at beginning of fourteenth time interval
			*** Continue on second line (if necessary) until the age at the beginning of the last interval is entered. Then, enter the age at the end of the last time interval (A(NN + 1)). ***

LINE TYPE 5 OF SET 4   W(I,J)

Input	Format	Columns	Explanation
W(1,1)	F5.1	1-5	Weight of a fish at beginning of first time interval in the first area
W(2,1)	F5.1	6-10	Weight of a fish at beginning of second time interval in the first area
.	.	.	. . . .
.	.	.	. . . .
.	.	.	. . . .
W(14,1)	F5.1	6-80	Weight of a fish at beginning of fourteenth time interval in the first area
			*** Continue on second line if necessary until the weight at the beginning of the last interval in the first area is entered. Then, enter the weight at the end of the last time interval (W(NN + 1),1) in the first area. ***
			*** Repeat for each area and entire fishery. ***

SET 5 -- MULTIPLE RUNS (OPTIONAL)

*** If run is to be terminated or if another run is desired on different data sets which follow, then enter 9999.99 in columns 4-10. If fishing effort is to be varied independently for each area enter values of AM(J). The program will use the data from the previous run but will alter all F(I,J) in an area by the factors (AM(J)). ***

Input	Format	Columns	Explanation
AM(1)	F10.2	1-10	Factor for all FI(I,1) in area 1
AM(2)	F10.2	11-20	Factor for all FI(I,2) in area 2
.	.	.	. . . .
.	.	.	. . . .
.	.	.	. . . .
AM(J)	F10.2		Factor for all FI(I,NG) in area NG

PROGRAM LISTING, BURROUGHS 7800 VERSION[4]

```
FILE  5(KIND=DISK,FILETYPE=7);
FILE  6(KIND=PRINTER,MAXRECSIZE=132);
C-    PROGRAM MAREA
      DIMENSION TF(30),IT(20),F(30,6),W(31,6),Y(30,10,6),D(30,10,6),S(30
     *,6),X(10),A(31),M(30),N(31),AW(30,10,6),AB(6),AY(6),AD(30,6),
     *IG(5,6),AM(6),FI(30,6),GR(31,6),WS(30,6),G(6)
      COMMON NG,IG,X,NF,NN,AD,W,NM,IT,NG1,IGO
      REAL M,N
      INTEGER CK
 1000 READ(5,1,END=1001)M(1),X,NN,NG,SCALE,MODE,CK,N(1),NF,ITO,IGO
      WRITE(6,107)
      WRITE(6,906) M(1),NN,NG,SCALE,MODE,CK,NF,ITO,IGO,N(1)
 906  FORMAT(1H0,"PARAMETER LIST/",1X,"M(1)=",F4.2,2X,"NN=",I3,2X,"NG=",
     *I2,2X,"SCALE=",F10.4,2X,"MODE=",I2,2X,"CK=",I2,2X,"NF=",I3,2X,"ITO
     *="I2,2X,"IGO=",I2,2X,"N(1)=",F10.2)
      IF(NN.LE.30.AND.NG.LE.5.AND.NF.LE.10)GO TO 105
      WRITE(6,106) M(1),X,NN,NG,SCALE,NF,ITO,IGO
      STOP
 105  NG1=NG+1
      READ(5,103)IT
      IF(CK .EQ. 1) GO TO 450
      DO 130 J=1,NG1
      READ(5,5) (AD(I,J),I=1,NN)
 130  CONTINUE
      GO TO 440
  450 READ(5,5)(AD(I,NG1),I=1,NN)
      DO 470 J=1,NG
      DO 480 I=1,NN
      AD(I,J)=AD(I,NG1)
  480 CONTINUE
  470 CONTINUE
  440 IF(M(1) .EQ. 0.) GO TO 1200
      DO 42 I=1,NN
      M(I)=M(1)
 42   CONTINUE
      GO TO 1201
 1200 READ(5,30) (M(I),I=1,NN)
 1201 DO 102 I=1,NG1
      READ(5,101) (IG(J,I),J=1,5)
 102  CONTINUE
      DO 4 J=1,NG
      READ(5,30) (FI(I,J),I=1,NN)
      DO 100 I=1,NN
      FI(I,J)=FI(I,J)*SCALE
 100  F(I,J)=FI(I,J)
    4 WRITE(6,31) J,(F(I,J),I=1,NN)
      NNP1 = NN + 1
      READ(5,3)(A(I),I=1,NNP1)
      IF(CK .EQ. 1) GO TO 520
      DO 131 J=1,NG1
      READ(5,5) (W(I,J),I=1,NNP1)
```

```
131   CONTINUE
      GO TO 111
 52Ø  READ(5,5)(W(I,NG1),I=1,NNP1)
      DO 54Ø J=1,NG1
      DO 55Ø I=1,NNP1
      W(I,J)=W(I,NG1)
 55Ø  CONTINUE
 54Ø  CONTINUE
 111  DO 6 I=1,NN
      IF(I.EQ.1)GO TO 66
      N(I)=N(I-1)*EXP(-M(I-1)*(A(I)-A(I-1)))
 66   TF(I)=Ø.
      DO 14 J=1,NG
      TF(I)=TF(I)+F(I,J)
  14  CONTINUE
   6  CONTINUE
      DO 61 I=1,NN
      IF (TF (I) .EQ. Ø.)  GO TO 61
      DO 6Ø J=1,NG
      F(I,J)=F(I,J)/TF(I)
 6Ø   CONTINUE
  61  CONTINUE
      DO 12 K=1,NG1
      DO 12 J=1,NF
      DO 12 I=1,NN
 12   D(I,J,K)=Ø.
      DO 7 I=1,NF
      DO 7 J=1,NN
      DO 9 K=1,NG1
      DO 21 IK=1,NN
      S(IK,K)=Ø
 21   WS(IK,K)=Ø
      AB(K)=Ø
  9   AY(K)=Ø
      NM=NN+1
      AL1=N(J)
      JP1 = J + 1
      DO 11 L=JP1,NM
      LL=L-1
      B=A(L)-A(LL)
      C=X(I)*TF(LL)
      CB=C*B
      ZB=(M(LL)+C)*B
      AL=AL1*EXP(-ZB)
      IF(TF(LL) .EQ. Ø.) GO TO 11
      IF(MODE .NE. 1) S(LL,NG1)=CB*(AL1+AL)/2
      IF(MODE .EQ. 1) S(LL,NG1)=CB*AL1*(1-EXP(-ZB))/ZB
      DO 8ØØ K=1,NG1
      IF(W(LL,K) .EQ. Ø.) GO TO 21Ø
      IF(W(L,K) .LE. Ø.)GO TO 21Ø
209   GR(LL,K)=ALOG(W(L,K)/W(LL,K))
      IF(MODE .EQ. 1)WS(LL,K)=CB*AL1*W(LL,K)*(EXP(GR(LL,K)-ZB)-1)/
     *(GR(LL,K)-ZB)
      IF(MODE .NE. 1)WS(LL,K)=CB*.5*((W(LL,K)*AL1)+(W(L,K)*AL))
```

```
      GO TO 211
 210  IF(W(LL,K) .EQ. Ø.) WS(LL,K)=Ø.
 211  G(K)=WS(LL,K)
 8ØØ  CONTINUE
      B=S(LL,NG1)
      DO 8 K=1,NG1
      Q=1.
      IF(K.NE.NG1)Q=F(LL,K)
      C=G(K)*Q
      AY(K)=AY(K)+C
      AB(K)=AB(K)+B*Q
      IF(J.NE.1)GO TO 8
      DO 1Ø JJ=1,LL
  1Ø  D(JJ,I,K)=D(JJ,I,K)+C
 8    CONTINUE
 11   AL1=AL
      DO 8Ø K=1,NG1
      IF (AB (K) .EQ. Ø.)  GO TO 8Ø
      AW(J,I,K)=AY(K)/AB(K)
 8Ø   Y(J,I,K)=AY(K)
 7    CONTINUE
      CALL OUT (1,Y)
      IF(ITO.GT.2)GO TO 1ØØ2
      CALL OUT(2,D)
      IF(ITO.GT.1)GO TO 1ØØ2
      CALL OUT(3,AW)
      IF(ITO.GT.Ø)GO TO 1ØØ2
      DO 22 I=1,NG1
      DO 22 J=1,NF
      DO 22 K=1,NN
 22   Y(K,J,I)=Y(K,J,I)/X(J)
      CALL OUT(4,Y)
1ØØ2  CONTINUE
      READ(5,1Ø8,END=1ØØ1) AM
      IF(AM(1).EQ.9999.99)GO TO 1ØØØ
      WRITE(6,1Ø9) (I,AM(I),I=1,NG)
      DO 11Ø I=1,NN
      DO 11Ø J=1,NG
 11Ø  F(I,J)=FI(I,J)*AM(J)
      GO TO 111
1     FORMAT(11F4.1,I2,I1,F5.Ø,2I1,F1Ø.2,I2,2I1)
 3    FORMAT(14F5.2)
  5   FORMAT(14F5.1)
 19   FORMAT(1H A3,1ØF1Ø.3)
3Ø    FORMAT(14F5.2)
31    FORMAT(22HØVALUES OF F FOR AREA I5/16(1XF7.5)/16(1XF7.5))
1Ø1   FORMAT(5A4)
1Ø3   FORMAT(2ØA4)
1Ø6   FORMAT(32H PARAMETER EXCEEDS ALLOWED VALUE/1X11F5.Ø,I3,I2,F2Ø.1Ø,2
     *ØX,I2,2I1)
 1Ø7  FORMAT("PROGRAM MAREA--WILLIAM H LENARZ--MODIFIED BY S P EPPERLY
     *AND L L MASSEY")
1Ø8   FORMAT(6F1Ø.2)
1Ø9   FORMAT(17H1AREA MULTIPLIERS/ (5H AREAI5,F1Ø.2))
```

```
2000 FORMAT(11F6.2,I2,I2,F15.2,2F10.4,I3,3I2)
5000 FORMAT(16F7.3)
1001 STOP
     END
     SUBROUTINE OUT(KK,A)
     DIMENSION A(30,10,6),X(10),IG(5,6),AD(30,6),W(31,6),IT(20)
     COMMON NG,IG,X,NF,NN,AD,W,NM,IT,NG1,IGO
     NGO=1
     IF(IGO.EQ.1)NGO=NG1
     DO 16 I=NGO,NG1
     IF(I.NE.NGO)GO TO 41
     GO TO (1,2,3,4),KK
 1   WRITE(6,42) IT,(IG(L,NGO),L=1,5)
     GO TO 43
 2   WRITE(6,46) IT,(IG(L,NGO),L=1,5)
     GO TO 43
 3   WRITE(6,52) IT,(IG(L,NGO),L=1,5)
     GO TO 43
 4   WRITE(6,49) IT,(IG(L,NGO),L=1,5)
     GO TO 43
  41 WRITE(6,44) (IG(L,I),L=1,5)
 43  CONTINUE
     WRITE(6,17) (X(JJ),JJ=1,NF)
     DO 14 JJ=1,NN
     J=NM-JJ
     WRITE(6,15) AD(J,I),W(J,I),(A(J,K,I),K=1,NF)
 14  CONTINUE
  16 CONTINUE
     RETURN
15   FORMAT(1H 2F6.1,10F10.2)
17   FORMAT(13H MINIMUM SIZE29X20HMULTIPLIER OF EFFORT//3X2HMM4X2HGM2X1
    *0F10.2/)
42   FORMAT(46H1TABLE  . ESTIMATES OF YIELD PER RECRUIT (GM)./1H 20A4//
    *40X5A4/)
44   FORMAT(19H1TABLE  . CONTINUED//40X5A4/)
46   FORMAT(103H1TABLE  . LANDINGS PER RECRUIT (GM) WHEN FISH LESS THAN
    * THE MINIMUM SIZE ARE CAUGHT AND DISCARDED DEAD./1H 20A4//40X5A4/)
49   FORMAT(57H1TABLE  . ESTIMATES OF YIELD PER RECRUIT PER EFFORT (GM)
    *./1H 20A4//40X5A4/)
52   FORMAT(52H1TABLE  . ESTIMATES OF AVERAGE WEIGHT OF CATCH (GM)./1H
    *20A4//40X5A4/)
     END
```

SAMPLE INPUT

The sample input is from the Ricker (1975) example of Table 10.3 using bluegills of Muskellunge Lake.

```
            1         2         3         4         5         6         7
   1234567890123456789012345678901234567890123456789012345678901234567890

 1  0.0 0.5 1.0 1.5 2.5 3.5 5.0 6.0 7.0 8.010.0301  8.001       1.01001
 2 BLUEGILLS
 3  95.0109.0122.0135.0145.0145.0145.0145.0145.0153.0160.0165.0170.0170.0
 4 170.0170.0170.0175.0178.0182.0185.0185.0185.0185.0185.0188.0191.0193.0
 5 195.0195.0

 6   0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
 7   0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6 0.84 1.12  1.6
 8   2.4  2.4
 9
10 ENTIRE FISHERY

11   0.0 0.04 0.14  0.0  0.0  0.0  0.0  0.0  0.0 0.33 0.17  0.0  0.0  0.0
12   0.0  0.0  0.0 0.33 0.17  0.0  0.0  0.0  0.0  0.0  0.0 0.33 0.17  0.0
13   0.0  0.0
14   2.02.125 2.252.375  2.52.625 2.752.875  3.03.125 3.253.375  3.53.625
15  3.753.875  4.04.125 4.254.375  4.54.625 4.754.875  5.05.125 5.255.375

16   5.55.625 5.75
17  13.0 29.0 44.0 58.0 69.0 69.0 69.0 69.0 69.0 80.0 91.0101.0110.0110.0
18 110.0110.0110.0118.0131.0131.0137.0137.0137.0137.0137.0143.0148.0153.0
19 158.0158.0158.0
20    9999.99

   1234567890123456789012345678901234567890123456789012345678901234567890
            1         2         3         4         5         6         7
```

SAMPLE OUTPUT

PROGRAM MAREA--WILLIAM H LENARZ--MODIFIED BY S P EPPERLY AND L L MASSEY

PARAMETER LIST/ M(1)=0.00 NN= 30 NG= 1 SCALE= 8.0000 MODE= 0 CK= 1 NF= 10 ITO= 0 IGO= 1 N(1)= 1.00

VALUES OF F FOR AREA 1
0.00000 0.32000 1.12000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 2.64000 1.36000 0.00000 0.00000 0.00000 0.00000 0.00000
0.00000 2.64000 1.36000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 2.64000 1.36000 0.00000 0.00000 0.00000
TABLE 1. ESTIMATES OF YIELD PER RECRUIT (GM).
BLUEGILLS

ENTIRE FISHERY

MINIMUM SIZE		MULTIPLIER OF EFFORT									
MM	GM	0.50	1.00	1.50	2.50	3.50	5.00	6.00	7.00	8.00	10.00
195.0	158.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
195.0	158.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
193.0	153.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
191.0	148.0	1.59	3.05	4.42	6.89	9.09	12.02	13.80	15.48	17.10	20.22
188.0	143.0	4.58	8.24	11.20	15.76	19.25	23.64	26.41	29.21	32.09	38.17
185.0	137.0	4.58	8.24	11.20	15.76	19.25	23.64	26.41	29.21	32.09	38.17
185.0	137.0	4.58	8.24	11.20	15.76	19.25	23.64	26.41	29.21	32.09	38.17
185.0	137.0	4.58	8.24	11.20	15.76	19.25	23.64	26.41	29.21	32.09	38.17
185.0	137.0	4.58	8.24	11.20	15.76	19.25	23.64	26.41	29.21	32.09	38.17
185.0	137.0	4.58	8.24	11.20	15.76	19.25	23.64	26.41	29.21	32.09	38.17
182.0	131.0	4.58	8.24	11.20	15.76	19.25	23.64	26.41	29.21	32.09	38.17
178.0	125.0	6.82	11.96	15.93	21.57	25.43	29.60	31.84	33.87	35.77	39.41
175.0	118.0	10.77	17.89	22.76	28.91	32.95	38.02	41.47	45.16	49.13	57.83
170.0	110.0	10.77	17.89	22.76	28.91	32.95	38.02	41.47	45.16	49.13	57.83
170.0	110.0	10.77	17.89	22.76	28.91	32.95	38.02	41.47	45.16	49.13	57.83
170.0	110.0	10.77	17.89	22.76	28.91	32.95	38.02	41.47	45.16	49.13	57.83
170.0	110.0	10.77	17.89	22.76	28.91	32.95	38.02	41.47	45.16	49.13	57.83
170.0	110.0	10.77	17.89	22.76	28.91	32.95	38.02	41.47	45.16	49.13	57.83
165.0	101.0	10.77	17.89	22.76	28.91	32.95	38.02	41.47	45.16	49.13	57.83
160.0	91.0	13.44	21.92	27.49	34.18	38.22	42.56	45.02	47.33	49.56	53.98
153.0	80.0	17.77	27.58	33.32	39.55	43.39	48.59	52.42	56.67	61.35	71.82
145.0	69.0	17.77	27.58	33.32	39.55	43.39	48.59	52.42	56.67	61.35	71.82
145.0	69.0	17.77	27.58	33.32	39.55	43.39	48.59	52.42	56.67	61.35	71.82
145.0	69.0	17.77	27.58	33.32	39.55	43.39	48.59	52.42	56.67	61.35	71.82
145.0	69.0	17.77	27.58	33.32	39.55	43.39	48.59	52.42	56.67	61.35	71.82
145.0	69.0	17.77	27.58	33.32	39.55	43.39	48.59	52.42	56.67	61.35	71.82
135.0	58.0	17.77	27.58	33.32	39.55	43.39	48.59	52.42	56.67	61.35	71.82
122.0	44.0	19.40	29.44	34.93	40.21	42.81	45.43	46.93	48.34	49.69	52.21
109.0	29.0	19.66	29.55	34.77	39.44	41.41	42.99	43.72	44.31	44.79	45.46
95.0	13.0	19.66	29.55	34.77	39.44	41.41	42.99	43.72	44.31	44.79	45.46

TABLE 2. LANDINGS PER RECRUIT (GM) WHEN FISH LESS THAN THE MINIMUM SIZE ARE CAUGHT AND DISCARDED DEAD.
BLUEGILLS

ENTIRE FISHERY

MINIMUM SIZE		MULTIPLIER OF EFFORT									
MM	GM	0.50	1.00	1.50	2.50	3.50	5.00	6.00	7.00	8.00	10.00
195.0	158.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
195.0	158.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
193.0	153.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
191.0	148.0	0.75	0.67	0.46	0.16	0.05	0.01	0.00	0.00	0.00	0.00
188.0	143.0	2.54	2.53	1.91	0.82	0.31	0.06	0.02	0.01	0.00	0.00
185.0	137.0	2.54	2.53	1.91	0.82	0.31	0.06	0.02	0.01	0.00	0.00
185.0	137.0	2.54	2.53	1.91	0.82	0.31	0.06	0.02	0.01	0.00	0.00
185.0	137.0	2.54	2.53	1.91	0.82	0.31	0.06	0.02	0.01	0.00	0.00
185.0	137.0	2.54	2.53	1.91	0.62	0.31	0.06	0.02	0.01	0.00	0.00
185.0	137.0	2.54	2.53	1.91	0.82	0.31	0.06	0.02	0.01	0.00	0.00
182.0	131.0	2.54	2.53	1.91	0.82	0.31	0.06	0.02	0.01	0.00	0.00
178.0	125.0	4.11	4.36	3.50	1.73	0.74	0.19	0.07	0.03	0.01	0.00
175.0	118.0	7.66	9.06	8.21	5.28	3.05	1.27	0.70	0.39	0.21	0.06
170.0	110.0	7.66	9.06	8.21	5.28	3.05	1.27	0.70	0.39	0.21	0.06
170.0	110.0	7.66	9.06	8.21	5.28	3.05	1.27	0.70	0.39	0.21	0.06
170.0	110.0	7.66	9.06	8.21	5.28	3.05	1.27	0.70	0.39	0.21	0.06
170.0	110.0	7.66	9.06	8.21	5.28	3.05	1.27	0.70	0.39	0.21	0.06
170.0	110.0	7.66	9.06	8.21	5.28	3.05	1.27	0.70	0.39	0.21	0.06
165.0	101.0	7.66	9.06	8.21	5.28	3.05	1.27	0.70	0.39	0.21	0.06
160.0	91.0	10.42	13.16	12.79	9.55	6.41	3.32	2.11	1.33	0.84	0.33
153.0	80.0	16.24	23.03	25.44	25.22	23.11	19.75	17.80	16.08	14.54	11.87
145.0	69.0	16.24	23.03	25.44	25.22	23.11	19.75	17.80	16.08	14.54	11.87
145.0	69.0	16.24	23.03	25.44	25.22	23.11	19.75	17.80	16.08	14.54	11.87
145.0	69.0	16.24	23.03	25.44	25.22	23.11	19.75	17.80	16.08	14.54	11.87
145.0	69.0	16.24	23.03	25.44	25.22	23.11	19.75	17.80	16.03	14.54	11.87
145.0	69.0	16.24	23.03	25.44	25.22	23.11	19.75	17.80	16.08	14.54	11.87
135.0	58.0	16.24	23.03	25.44	25.22	23.11	19.75	17.80	16.09	14.54	11.87
122.0	44.0	19.02	28.29	32.90	36.39	37.22	37.20	36.92	36.54	36.08	35.00
109.0	29.0	19.66	29.55	34.77	39.44	41.41	42.99	43.72	44.31	44.79	45.46
95.0	13.0	19.66	29.55	34.77	39.44	41.41	42.99	43.72	44.31	44.79	45.46

TABLE 3. ESTIMATES OF AVERAGE WEIGHT OF CATCH (GM).
BLUEGILLS

ENTIRE FISHERY

MINIMUM SIZE		MULTIPLIER OF EFFORT									
MM	GM	0.50	1.00	1.50	2.50	3.50	5.00	6.00	7.00	8.00	10.00
195.0	158.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
195.0	158.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
193.0	153.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
191.0	148.0	150.22	150.12	150.01	149.81	149.62	149.35	149.19	149.05	148.91	148.69
188.0	143.0	146.61	146.30	146.00	145.42	144.90	144.27	143.95	143.70	143.51	143.26
185.0	137.0	146.61	146.30	146.00	145.42	144.90	144.27	143.95	143.70	143.51	143.26
185.0	137.0	146.61	146.30	146.00	145.42	144.90	144.27	143.95	143.70	143.51	143.26
185.0	137.0	146.61	146.30	146.00	145.42	144.90	144.27	143.95	143.70	143.51	143.26
185.0	137.0	146.61	146.30	146.00	145.42	144.90	144.27	143.95	143.70	143.51	143.26
185.0	137.0	146.61	146.30	146.00	145.42	144.90	144.27	143.95	143.70	143.51	143.26
182.0	131.0	146.61	146.30	146.00	145.42	144.90	144.27	143.95	143.70	143.51	143.26
178.0	125.0	138.78	137.85	136.96	135.34	133.93	132.20	131.26	130.46	129.77	128.63
175.0	118.0	129.98	128.44	127.03	124.63	122.78	120.85	120.00	119.40	118.97	118.47
170.0	110.0	129.98	128.44	127.03	124.63	122.78	120.85	120.00	119.40	118.97	118.47
170.0	110.0	129.98	128.44	127.03	124.63	122.78	120.85	120.00	119.40	118.97	118.47
170.0	110.0	129.98	128.44	127.03	124.63	122.78	120.85	120.00	119.40	118.97	118.47
170.0	110.0	129.98	128.44	127.03	124.63	122.78	120.85	120.00	119.40	118.97	118.47
170.0	110.0	129.98	128.44	127.03	124.63	122.78	120.85	120.00	119.40	118.97	118.47
165.0	101.0	129.98	128.44	127.03	124.63	122.78	120.85	120.00	119.40	118.97	118.47
160.0	91.0	118.69	115.93	113.43	109.25	106.05	102.60	100.91	99.54	98.40	96.60
153.0	80.0	103.85	99.93	96.59	91.44	87.91	84.57	83.17	82.20	81.53	80.74
145.0	69.0	103.85	99.93	96.59	91.44	87.91	84.57	83.17	82.20	81.53	80.74
145.0	69.0	103.85	99.93	96.59	91.44	87.91	84.57	83.17	82.20	81.53	80.74
145.0	69.0	103.85	99.93	96.59	91.44	87.91	84.57	83.17	82.20	81.53	80.74
145.0	69.0	103.85	99.93	96.59	91.44	87.91	84.57	83.17	82.20	81.53	80.74
145.0	69.0	103.85	99.93	96.59	91.44	87.91	84.57	83.17	82.20	81.53	80.74
135.0	58.0	103.85	99.93	96.59	91.44	87.91	84.57	83.17	82.20	81.53	80.74
122.0	44.0	89.95	84.42	79.75	72.60	67.62	62.64	60.30	58.43	56.89	54.41
109.0	29.0	85.79	79.84	74.84	67.25	62.01	56.78	54.32	52.36	50.74	48.14
95.0	13.0	85.79	79.84	74.84	67.25	62.01	56.78	54.32	52.36	50.74	48.14

TABLE 4. ESTIMATES OF YIELD PER RECRUIT PER EFFORT (GM).
BLUEGILLS

ENTIRE FISHERY

MINIMUM SIZE		MULTIPLIER OF EFFORT									
MM	GM	0.50	1.00	1.50	2.50	3.50	5.00	6.00	7.00	8.00	10.00
195.0	158.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
195.0	158.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
193.0	153.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
191.0	148.0	3.17	3.05	2.95	2.76	2.60	2.40	2.30	2.21	2.14	2.02
188.0	143.0	9.17	8.24	7.47	6.30	5.50	4.73	4.40	4.17	4.01	3.82
185.0	137.0	9.17	8.24	7.47	6.30	5.50	4.73	4.40	4.17	4.01	3.82
185.0	137.0	9.17	8.24	7.47	6.30	5.50	4.73	4.40	4.17	4.01	3.82
185.0	137.0	9.17	8.24	7.47	6.30	5.50	4.73	4.40	4.17	4.01	3.82
185.0	137.0	9.17	8.24	7.47	6.30	5.50	4.73	4.40	4.17	4.01	3.82
185.0	137.0	9.17	8.24	7.47	6.30	5.50	4.73	4.40	4.17	4.01	3.82
182.0	131.0	9.17	8.24	7.47	6.30	5.50	4.73	4.40	4.17	4.01	3.82
178.0	125.0	13.63	11.96	10.62	8.63	7.26	5.92	5.31	4.84	4.47	3.94
175.0	118.0	21.53	17.89	15.17	11.56	9.41	7.60	6.91	6.45	6.14	5.78
170.0	110.0	21.53	17.89	15.17	11.56	9.41	7.60	6.91	6.45	6.14	5.78
170.0	110.0	21.53	17.89	15.17	11.56	9.41	7.60	6.91	6.45	6.14	5.78
170.0	110.0	21.53	17.89	15.17	11.56	9.41	7.60	6.91	6.45	6.14	5.78
170.0	110.0	21.53	17.89	15.17	11.56	9.41	7.60	6.91	6.45	6.14	5.78
170.0	110.0	21.53	17.89	15.17	11.56	9.41	7.60	6.91	6.45	6.14	5.78
165.0	101.0	21.53	17.89	15.17	11.56	9.41	7.60	6.91	6.45	6.14	5.78
160.0	91.0	26.89	21.92	18.33	13.67	10.92	8.51	7.50	6.76	6.20	5.40
153.0	80.0	35.53	27.58	22.22	15.82	12.40	9.72	8.74	8.10	7.67	7.18
145.0	69.0	35.53	27.58	22.22	15.82	12.40	9.72	8.74	8.10	7.67	7.18
145.0	69.0	35.53	27.58	22.22	15.82	12.40	9.72	8.74	8.10	7.67	7.18
145.0	69.0	35.53	27.58	22.22	15.82	12.40	9.72	8.74	8.10	7.67	7.18
145.0	69.0	35.53	27.58	22.22	15.82	12.40	9.72	8.74	8.10	7.67	7.18
145.0	69.0	35.53	27.58	22.22	15.82	12.40	9.72	8.74	8.10	7.67	7.18
135.0	58.0	35.53	27.58	22.22	15.82	12.40	9.72	8.74	8.10	7.67	7.18
122.0	44.0	38.80	29.44	23.29	16.08	12.23	9.09	7.82	6.91	6.21	5.22
109.0	29.0	39.32	29.55	23.18	15.78	11.83	8.60	7.29	6.33	5.60	4.55
95.0	13.0	39.32	29.55	23.18	15.78	11.83	8.60	7.29	6.33	5.60	4.55