A Computer Program to Assess Egg Production Per Recruit in a Lobster *(Homarus americanus)* Population

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ABSTRACT

Ennis, G. P., and P. W. Collins. 1983. A computer program to assess egg production per recruit in a lobster (*Homarus americanus*) population. Can. Tech. Rep. Fish. Aquat. Sci. 1198: iv + 15 p.

A computer program which estimates the numbers of eggs produced per female recruit in a lobster population is described. The layout of the input file and an explanation of the parameters, a listing of the program and a sample of the output are provided as appendices. The program is run with various combinations of recruitment length (minimum legal size) and fishing mortality (exploitation rate) thereby providing a basis for assessing the impact of changes in size limit and/or exploitation rate in a lobster fishery on the production of eggs in the population.

Key words: lobster, egg production per recruit, assessment

RÉSUMÉ

Ennis, G. P., and P. W. Collins. 1983. A computer program to assess egg production per recruit in a lobster (*Homarus americanus*) population. Can. Tech. Rep. Fish. Aquat. Sci. 1198: iv + 15 p.

Le présent rapport décrit un programme informatisé pour l'estimation du nombre d'oeufs produits par femelle dans une population de homards. Le topogramme du fichier d'entrée, une explication des paramètres, un listage du programme et un état imprimé type constituent les annexes. Le programme est exécuté avec diverses combinaisons de longueurs au recrutement (taille légale minimum) et de mortalités par pêche (taux d'exploitation), générant ainsi une base pour l'évaluation de l'incidence des changement de la limite de taille ou du taux d'exploitation au cours de la pêche du homard sur la production d'oeufs dans la population.

INTRODUCTION

The basic management tools commonly employed in lobster (genus Homarus) fisheries are a minimum legal landing size (size limit) and effort limitation as a means of controlling exploitation rate. In theory at least, MSY can be realized from a population of lobsters if such regulatory measures are properly applied. However, it appears that the situation in most lobster fisheries can be represented by a point well to the right of MSY on a general production curve (i.e current landings are well below MSY and fishing effort is well in excess of that at MSY).

There are two facets to achieving MSY from a population. One is to maximize yield per recruit, the other is to maximize recruitment. Lobster fisheries are characterized by high exploitation rates and assessments have clearly demonstrated that, with existing size limits, yield per recruit is substantially less than maximum (Anon. 1977, 1979; Anthony and Caddy 1980). In addition, existing size limits are generally below the size at which most females lay eggs for the first time and with the excessively high exploitation rates that prevail in most areas, widespread recruitment overfishing is a distinct possibililty. In fact, recruitment overfishing appears to be the cause of stock collapse in certain areas of Eastern Canada (Robinson 1979).

Stock-recruitment relationships as such are poorly known for the genus Homarus, however, since current levels of landings are well below historical levels in most fisheries, it is reasonable to assume that, within the limits of habitat carrying capacity, increased egg production will result in increased recruitment. While it is clear that increasing the minimum legal size and/or reducing exploitation rates will result in greater numbers of eggs produced, it is only in very recent years that the detailed biological information required to properly assess the impact of changes in these fishery regulatory measures on egg production within a population have become available.

The purpose of this paper is to describe a computer program which has been written in order to carry out egg production per recruit analyses using the kind of information being obtained from studies of lobster population biology in Newfoundland waters.

BIOLOGICAL BASIS OF THE ANALYSIS

The biological concepts on which this egg per recruit program is based are very similar to those developed by Caddy (1979) in his relative population fecundity analysis. In the two analyses, however, there are different approaches to the way mortalities and growth are handled. Also, in the program presented here, there is provision to account for egg loss over and above that due to normal attrition as well as for those females which molt and extrude eggs in the same molting/spawning season.

The analysis is carried out as a chronological sequence of annual life history and mortality events which begins subsequent to the annual spring fishing season and just prior to the annual molting/spawning period in summer. Initially, 1000 non-ovigerous females are distributed evenly at 1 mm size intervals over the 71-80 mm carapace length range and the sequence of life history and mortality events is repeated until these have disappeared from the population as a result of fishing or natural mortality. The analysis begins by estimating the number of individuals at each 1 mm CL that will extrude eggs during the molting/spawning period in year one. This estimate is obtained using a proportion derived from a functional size-maturity relationship (logisitc equation relating % mature and CL) which is based on detailed examination of pleopod cement glands done prior to the molting/spawning period as a means of determining whether individual animals will extrude eggs that year (Ennis, in press[1]). This relationship is represented by a sigmoid curve which sometimes does not fit the data very well at the upper and lower ends of the size range. In this analysis 100% maturity is assigned to those sizes at and above which the data indicate this to be the case, instead of assigning a lower percentage derived from the equation.

Some female lobsters molt prior to extruding eggs during the same annual molting/spawning period (Aiken and Waddy 1976, 1980). In annual (since 1975) shell condition sampling done at Arnold's Cove, Newfoundland following the molting period, the number of ovigerous females with new shells has ranged from 6.5 to 38.5% of the total number of ovigerous specimens examined (Ennis 1980). These have generally been smaller animals within the overall size range of ovigerous specimens and it was suggested that those females which molt and extrude eggs in the same year are spawning for the first time. These data have been examined in some detail and it has been found that the incidence of molting and spawning in the same year declines with increasing size. The data were subjected to probit analysis and a good fit obtained ($P > .99$). The resulting equation ($Y = 27.751 - 0.3072X$) is used to determine the number of those females which will extrude eggs in year one that molt before doing so. The number of eggs produced by these females is determined from the size-fecundity relationship using their postmolt length.

Estimates of proportions molting amongst those females which do not extrude eggs in year one are obtained from a relationship derived from molt predictions based on pleopod examination early in the molting/spawning period for non-ovigerous females but excluding those females whose pleopod cement glands indicate egg extrusion to be imminent. A quadratic regression was fitted to such data obtained from sampling at Arnold's Cove during June 9 to July 15, 1983 and the following equation obtained:

$$Y = -330.3593 + 13.5685X - 0.1073X^2 \text{ with } R^2 = .99.$$

The postmolt sizes of lobsters that molt are determined from a premolt-postmolt carapace length relationship obtained from sphyrion tagging (Ennis 1972, 1978).

No reliable estimates of natural mortality in lobsters are available but the general consensus reached by the ICES Working Group on *Homarus* Stocks is that it can be expected to be less than 10% annually for lobsters at sizes around the existing minimum legal sizes (Anon. 1977). One would expect most natural mortality in lobsters to be associated with molting and in this analysis a 10% natural mortality rate is applied only to those lobsters that molt. Lobsters not molting in a particular year are subjected to a 5% rate of natural mortality.

Sphyrion tagging at Arnold's Cove in summer 1981 revealed that around 15% of the females which extrude eggs loose practically all of them over the incubation period (Ennis, in press[2]). Accordingly, the numbers of females which were estimated would extrude eggs were reduced by 15% to account for this egg loss. This percentage was applied uniformly with respect to size. Normal attrition of eggs over the 9-12 month incubation period has been estimated at around 36% (Perkins 1971). This egg loss is accounted for in the analysis by virtue of the fact that the size-fecundity relationship used to estimate the numbers of eggs produced is based on egg counts for ovigerous females taken near the end of the incubation period (Ennis 1981).

In addition to attrition of eggs over the incubation period, some female lobsters molt shortly after extruding thereby loosing the entire clutch of eggs (Ennis, in press[2]). This egg loss is accounted for in the functional size-maturity relationship. In a tag-recapture validation of egg extrusion predictions (based on cement gland staging), the only incorrect predictions recorded were for 2 out of 9 (22%) females with stage 2 cement glands (for which egg extrusion was predicted) which were not egg-bearing (but had molted) when recaptured prior to the following molting/spawning period. It is assumed that these two lobsters extruded eggs as predicted and lost them when they molted soon afterwards. Accordingly, in the data on which the functional size-maturity relationship is based, 22% of the animals with stage 2 cement glands were considered immature (Ennis, in press[1]).

So far the analysis has proceeded to the spring of year two and an estimate derived of the number of eggs extruded in year one that remain in the population and from which larvae will hatch during the summer. Except for those at the 71 and 72 mm carapace length intervals, most lobsters that molted in year one would have grown to or beyond the minimum legal size (81 mm CL) and at this stage in the analysis, except for those that laid eggs shortly after molting or were lost as a result of natural mortality, are subjected to fishing mortality. Egg-bearing females are protected from exploitation. In this analysis those females (15%) which loose their eggs over the incubation period are protected from exploitation as well because the presence of even very small numbers of eggs would make them illegal. All of these egg-bearing females (including those that loose their eggs) molt during the molting/spawning period in year two, are subjected to 10% natural mortality, and the survivors are subjected to fishing mortality during the fishing season in year three. For all other females remaining following the fishing season in year two, the initial stage in the analysis (i.e determining numbers that will extrude eggs during the upcoming molting/ spawning season) is now repeated and followed by the subsequent steps in the analysis.

The foregoing sequences are repeated until the 1000 individuals with which the analysis started have been removed from the population. The numbers of eggs produced and carried through the incubation period are then totalled.

DESCRIPTION OF THE PROGRAM

The program is written in Fortran IV and is very similar to the one developed by Ennis and Akenhead (1978) to assess yield per recruit in Newfoundland lobsters. Each component of the annual cycle of life history and mortality events is handled separately and in chronological order. Provision is made for different natural mortality rates for molters and non-molters, for the protection of egg-bearers from fishing mortality, for different growth rates for egg-bearers and non-egg-bearers, and for egg loss over the incubation period in excess of that due to normal attrition. In addition, special treatment is provided for females that molt and lay eggs in the same year.

The organization of the program is shown schematically in Fig. 1. The layout of the input file and an explanation of the parameters are provided in Appendix 1 and Appendix 2 is a listing of the program.

APPLICATION OF THE PROGRAM

The program is run with various combinations of recruitment length (minimum legal size) and fishing mortality (exploitation rate) thereby providing a basis for assessing the impact of changes in size limit and/or exploitation rate in a lobster fishery on the production of eggs in the population. The output (sample provided as Appendix 3) includes an estimate of the number of eggs carried to hatching produced by the 1000 females with which each analysis begins over the period that they remain in the population with a given combination of size limit and exploitation rate. Also included is an estimate of the numbers of eggs produced by these females at sizes smaller than the minimum legal size being considered.

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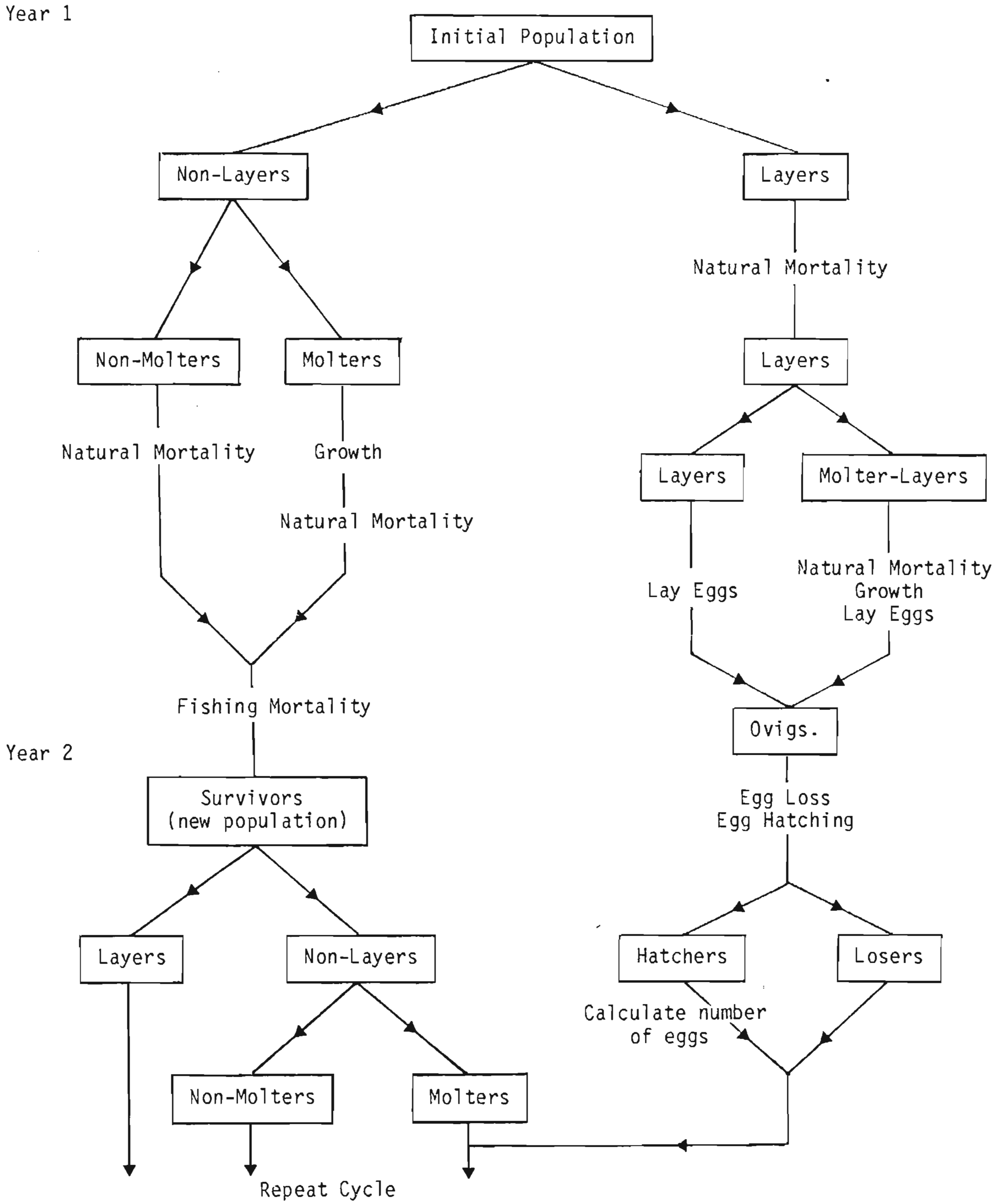

Fig. 1. Diagram showing organization of the program.

APPENDIX 1: INPUT FILE LAYOUT AND EXPLANATION OF PARAMETERS

RECORD LENGTH: 80 columns - card image

Card No.	Parameters	Format
1	LIST (20)	20A4
2	SLEN, FLEN, AMORT, BMORT CMORT, EGLOS, AFEC, BFEC AGR, BGR, IRUN	2F3.0, 4F5.0 4F10.0, I3
3	GDIST (10)	10F8.0
4	FSTRT, FSTOP, FINCR, RECLEN (5)	8F8.0
5-12	PROLAY (80)	10F8.0
13-20	PROMLT (80)	10F8.0
21-28	GROLAY (80)	10F8.0
29-36	PINIT (80)	10F8.0

1) LIST - Header of input file.

2) SLEN - Starting carapace length (mm).
FLEN - Last carapace length (mm).
AMORT - Proportion of molting component surviving natural mortality.
BMORT - Proporiton of laying component surviving natural mortality.
CMORT - Proporiton of old shells (i.e. those which neither molt not lay) surviving natural mortality.
EGLOS - Proportion of successful layers that eventually lose all eggs before hatching.
AFEC - Intercept of length-fecundity regression ($\log_{10}$).
BFEC - Slope of length-fecundity regression ($\log_{10}$).
AGR - Intercept of premolt-postmolt regression (arithmetic).
BGR - Slope of premolt-postmolt regression (arithmetic).
IRUN - Number of years (cycles).

3) GDIST - Distribution of growth scatter around postmolt mean length, derived from deviation around growth regression.

4) FSTRT - Starting exploitation rate.
FSTOP - Final exploitation rate.
FINCR - Increment of change for exploitation rate.
RECLEN - Recruit carapace lengths (mm) (maximum of five for each run).

5-12) PROLAY - Proportion of population laying eggs each length, derived from logistic equation relating % mature and CL based on pleopod cement gland development (see Ennis, In press).

13-20) PROMLT - Proportion of nonlaying component molting each length, derived from quadratic equation relating % molting amongst non-ovigerous females not going to lay egs and CL.

21-28) GROLAY - Proportion of laying component that also molt in same year each length, derived from probit equation based on incidencce of new-shelled ovigerous females in relation to size from fall sampling.

29-36) PINIT - Initial population numbers each length (start with 100 each length 71-80 mm).

APPENDIX 2: PROGRAM LISTING

FORTRAN IV G LEVEL 21 MAIN

```
      C       ************************************************************
      C       LOBSTER EGG PER RECRUIT PROGRAM
      C       ************************************************************
              INTEGER LIST(20),IGROW(80) NUMLEN,IRUN,ICNTR
              REAL RECLEN(5),POP(80)/80*0.0/,PROLAY(80),PROMLT(80)
              REAL CATCH(80),FEC(80),PINIT(80)/80*0.0/,GDIST(10)/10*0./
              REAL AMORT,BMORT,CMORT,EGLOS,AFEC,BFEC,AGR,BGR
              REAL FSTRT,FSTOP,FINCR,STARTN,NONLAY(80),NEGGS(80),PREG(80)
              REAL HATCHS(80),LOSERS(80),LOST(80),NOMOLT(80),NBOTH(80)
              REAL HOLD(80),MOLTER(80),POPLAY(80)/80*0.0/,GROLAY(80)
              REAL JUSLAY(80)
      C                       ************************
      C
      C       SKIP REINITIALIZATION FIRST TIME THRU
              GO TO 304
      C
      C       REINITIALIZE STORAGE FOR NEXT DATASET
        300      DO 301 I=1,NUMLEN
                    POP(I)=0.
                    PINIT(I)=0.
                    HATCHS(I)=0.
                    POPLAY(I)=0.
                    NBOTH(I)=0.
                    JUSLAY(I)=0.
                    NEGGS(I)=0.
                    PREG(I)=0.
                    NONLAY(I)=0.
                    LOSERS(I)=0.
                    LOST(I)=0.
        301         NOMOLT(I)=0.
                 DO 302 I=1,10
        302         GDIST(I)=0.
                 DO 303 I=1,2
        303         RECLEN(I)=0.
        304   CONTINUE
      C
      C       READ TITLE---'D' IN COLUMN 80 GIVES DETAILED OUTPUT
              READ(5,2,END=305)LIST
              GO TO 306
        305   STOP
        306   CONTINUE
              WRITE(6,2)LIST
      C
      C       READ START LENGTH,LAST LENGTH,MOLTING SURVIVORSHIP,
      C               LAYERS SURVIVORSHIP,OLD SHELL SURVIVORSHIP,
      C               EGG-LOSS MORTALITY,INTERCEPT AND SLOPE OF FECUNDITY
      C               REG.(LOG10),INTERCEPT AND SLOPE OF GROWTH REG.(ARITH),
      C               NUMBER OF YEARS.
```

```
                    C
 0033                     READ(5,1)SLEN,FLEN,AMORT,BMORT,CMORT,EGLOS,AFFC,BFEC,
                        +AGR,BGR,IRUN
 0034                     NUMLEN=FLEN-SLEN
 0035                     NUMLEN=NUMLEN+1
 0036                     LS=SLEN
 0037                     LF=FLEN
 0038                     WRITE(6,13)LS,NUMLEN,AMORT,BMORT,CMORT,EGLOS,
                        +AFEC,BFEC,AGR,BGR,IRUN
 0039                     LS=LS-1
                    C
                    C     READ PROPORTION OF SCATTER AROUND POST-MOLT LENGTH
 0040                     READ(5,5)GDIST
 0041                     WRITE(6,14)GDIST
                    C
                    C     READ VARIABLES OF EXPLOITATION RATE AND RECRUIT LENGTH
 0042                     READ(5,6)FSTRT,FSTOP,FINCR,RECLEN
 0043                     WRITE(6,15)FSTRT,FSTOP,FINCR,RECLEN
                    C
                    C     READ PROPORTION LAYERS EACH LENGTH
 0044                     READ(5,5)  (PROLAY(I),I=1,NUMLEN)
                    C
                    C     READ PROPORTION MOLTING EACH LENGTH
 0045                     READ(5,5)  (PROMLT(I),I=1,NUMLEN)
                    C
                    C     READ PROPORTION MOLTING AND LAYING SAME YEAR EACH LENGTH
 0046                     READ(5,5)  (GROLAY(I),I=1,NUMLEN)
                    C
                    C     READ INITIAL POPULATION DISTRIBUTION
 0047                     READ(5,5)  (PINIT(I),I=1,NUMLEN)
 0048                20   CONTINUE
                    C
                    C     CALCULATE VECTOR OF FECUNDITY FOR LENGTHS
                    C     PRINT HEADER FOR INPUT DATA
 0049                     WRITE(6,4)
 0050                       AFEC=10.**AFEC
 0051                       STARTN=0.
 0052                     DO 11 I=1,NUMLEN
 0053                      FEC(I)=AFEC*FLOAT(LS+I)**BFEC
 0054                         IGROW(I)=AGR+BGR*FLOAT(LS+I)
 0055                         IL=LS+I
 0056                         WRITE(6,3)IL,PINIT(I),PROMLT(I),PROLAY(I),GROLAY(I),
                        +IGROW(I),FEC(I)
 0057                         STARTN=STARTN+PINIT(I)
 0058                11   CONTINUE
                    C
                    C     ALL DATA NOW INPUT
                    C     SET UP FISHING RATE LOOP AND CHECK FOR MORE VALUES
```

```
                C       IF NONE RETURN FOR NEW DATASET AND REINITIALIZE
 0059                   ICNTR=0
 0060             198   CONTINUE
 0061                   ICNTR=ICNTR+1
 0062                     IF(ICNTR.GT.5)  GOTO 300
 0063                     IF(RECLEN(ICNTR).EQ.0.)GOTO 300
 0064                     LR=IFIX(RECLEN(ICNTR))
 0065                     FMORT=FSTRT-FINCR
 0066             200     FMORT=FMORT+FINCR
 0067                     IF(FMORT.GT.FSTOP)GOTO 198
                C
                C       SET UP FOR LOOP THRU YEARS
 0068                     TEGGS=1.E-10
 0069                     TNUM=0.
 0070                     TCAT=0.
 0071                     TPREG=1.E-10
 0072                     THAT=0.
 0073                       DO 22 I=1,NUMLEN
 0074                          HATCHS(I)=0.
 0075                          POPLAY(I)=0.
 0076                          JUSLAY(I)=0.
 0077                          NBOTH(I)=0.
 0078                          NEGGS(I)=0.
 0079                          PREG(I)=0.
 0080                          NONLAY(I)=0.
 0081                          LOSERS(I)=0.
 0082                          LOST(I)=0.
 0083                          MOLTER(I)=0.
 0084                          NOMOLT(I)=0.
 0085             22           POP(I)=PINIT(I)
 0086                     WRITE(6,16)FMORT,LR
 0087                     IF(LIST(20).NE.    0)GOTO 23
 0088                     WRITE(6,18)
 0089             23      CONTINUE
                C
                C       LOOP THRU IRUN NUMBER OF YEARS
 0090                   DO 100 IY=1,IRUN
                C
                C           SET UP FOR LOOP THRU LENGTHS
 0091                       SEGGS=0.
 0092                       SUMN=0.
 0093                       CSUM=0.
 0094                       SPREG=0.
 0095                       SHOLD=0.
 0096                       SHAT=0.
                C
                C           LOOP THRU LENGTHS
 0097                       DO 30 IK=1,NUMLEN
```

```
0098                   I=(NUMLEN-IK)+1
               C
               C       CALCULATE LAYERS,MOLTERS AND NON-MOLTERS
0099                   POPLAY(I)=POP(I)*PROLAY(I)
0100                   NONLAY(I)=POP(I)-POPLAY(I)
0101                   MOLTER(I)=NONLAY(I)*PROMLT(I)
0102                   NOMOLT(I)=NONLAY(I)-MOLTER(I)
               C
               C       CALCULATE NATURAL MORTALITY OF LAYERS,NON-MOLTERS
0103                   POPLAY(I)=POPLAY(I)*BMORT
0104                   NOMOLT(I)=NOMOLT(I)*CMORT
               C
               C       SEPARATE LAYING COMPONENT INTO LAYERS AND MOLTER/LAYERS
0105                   IF(GROLAY(I).EQ.0)GO TO 27
0106                   NBOTH(I)=POPLAY(I)*GROLAY(I)
0107                   JUSLAY(I)=POPLAY(I)-NBOTH(I)
0108                   NBOTH(I)=NBOTH(I)*AMORT
0109                   POPLAY(I)=0
               C
               C       DISTRIBUTE MOLTER/LAYERS AROUND PREDICTED POST MOLT
               C       MEAN LENGTH
0110                   JZ=(IGROW(I)-LS)-6
0111                      DO 26 K=1,10
0112                      JX=JZ+K
               C
               C          CHECK IF LEGAL SIZE TO GROW INTO
0113                      IF(JX.LT.1)JX=1
0114                      IF(JX.GT.NUMLEN)JX=NUMLEN
0115                      POPLAY(JX)=POPLAY(JX)+GDIST(K)*NBOTH(I)
0116              26      CONTINUE
0117                   POPLAY(I)=POPLAY(I)+JUSLAY(I)
0118              27   CONTINUE
               C
               C       CALCULATE NATURAL MORTALITY OF MOLTERS
               C       (I.E.  SURV. EGG-LOSERS+LAST YEARS LAYERS
               C       (THIS YEARS HATCHERS)+THIS YEARS MOLTERS
0119                   MOLTER(I)=MOLTER(I)+LOST(I)+HATCHS(I)
0120                   MOLTER(I)=MOLTER(I)*AMORT
               C
0121                   POP(I)=0.
               C
               C       DISTRIBUTE GROWERS AROUND PREDICTED POSTMOLT MEAN LENGTH
0122                   IZ=(IGROW(I)-LS)-6
0123                      DO 32 K=1,10
0124                         IX=IZ+K
               C
               C             CHECK THAT THIS IS A LEGAL SIZE TO GROW INTO
0125                         IF(IX.LT.1)IX=1
```

```
                      IF(IX.GT.NUMLEN)IX=NUMLEN
                      POP(IX)=POP(IX)+GDIST(K)*MOLTER(I)
       32          CONTINUE
                PoP(I)=POP(I)+NOMOLT(I)
       30       CONTINUE
      C
      C         CALCULATE TOTAL FECUNDITY AND CATCH
                   DO 50 IJ=1,NUMLEN
                      I=(NUMLEN-IJ)+1
                      LOSERS(I)=HATCHS(I)*EGLOS
                      HATCHS(I)=HATCHS(I)-LOSERS(I)
                      NEGGS(I)=HATCHS(I)*FEC(I)
                      HOLD(I)=HATCHS(I)
                      PREG(I)=NEGGS(I)
                      IF(LS+I.GE.LR)PREG(I)=0.
                      CATCH(I)=POP(I)*FMORT
                      IF(LS+I.LT.LR)CATCH(I)=0.
                      HATCHS(I)=POPLAY(I)
                      LOST(I)=LOSERS(I)
                      POP(I)=POP(I)-CATCH(I)
       50          CONTINUE
      C
      C         CALCULATE YEARLY SUMMATIONS
                DO 31 I=1,NUMLEN
                   SEGGS=SEGGS+NEGGS(I)
                   SHOLD=SHOLD+HOLD(I)
                   SUMN=SUMN+POP(I)
                   CSUM=CSUM+CATCH(I)
                   SPREG=SPREG+PREG(I)
                   SHAT=SHAT+HATCHS(I)
       31       CONTINUE
      C         IF DETAILED OPTION PRINT YEARLY SUMMATIONS
                IF(LIST(20).NE.   0)GOTO 51
                WRITE(6,19)SUMN,CSUM,SHAT,SHOLD,SEGGS
       51       CONTINUE
      C
      C         CALCULATE FINAL SUMMATIONS
                TEGGS=TEGGS+SEGGS
                TNUM=TNUM+SUMN
                TCAT=TCAT+CSUM
                TPREG=TPREG+SPREG
                THAT=THAT+SHOLD
      C
      C         CHECK IF ANOTHER YEAR WILL CHANGE VALUES
                IF(SUMN.LT.STARTN*.001)GOTO 101
      100    CONTINUE
             WRITE(6,17)
      101    CONTINUE
```

```
      C
      C       CALCULATE YIELD VALUES
              YN=TEGGS/STARTN
              PP=TPREG/TEGGS
              PR=1.-PP
              WRITE(6,8)TNUM,TCAT,THAT,TEGGS,TPREG,YN,PR,PP
      C
      C       RETURN FOR NEW VALUES OF EXPLOITATION RATE AND RECRUIT LENGTH
      C
              GO TO 200
      C       ****************************************************************
      C       ******************FORMAT STATEMENTS******************************
            1 FORMAT(2F3.0,4F5.0,4F10.0,I3)
            2 FORMAT(20A4)
            3 FORMAT(4X,I4,5X,F10.0,F12.4,5X,F12.4,5X,F12.4,8X,I10,8X,F9.0)
            4 FORMAT('0LENGTH(MM)     INIT POP.     PROP MOLTING     PROP LAYING
             +    PROP MOLT/LAY   POSTMOLT LENGTH     FECUNDITY')
            5 FORMAT(10F8.0)
            6 FORMAT(8F8.0)
            8 FORMAT(//' POPULATION NUMBERS:',F10.2/
             +' TOTAL CATCH:',5X,F10.2/
             +' TOTAL OVIGS:',5X,F10.2/
             +' TOTAL EGGS:',5X,F10.0/
             +' PRERECRUIT EGGS:',3X,F10.0/
             +' EGG YIELD/RECRUIT:',F10.0/
             +' PROP. RECRUIT EGGS:',F10.4/
             +' PROP. PRERECRUIT EGGS:',F10.4)
           13 FORMAT('0START LENGTH:',I5/'0NO. OF LENGTHS:',
             +I5/'0MOLTING SURVIVORSHIP:',F8.3/'0EGG-LAYING SURVIVORSHIP:',
             +F8.3/'0NON-MOLTING/LAYING SURVIVORSHIP:',F8.3/
             +'0EGG-LOSS MORTALITY:',F8.3/'0A AND B OF LOG10(FEC)=',
             +'A+B*LOG10(LENGTH):',2F10.5/'0A AND B OF POSTMOLT=',
             +'A+B*PREMOLT LENGTH:',2F10.5/'0NO. OF YEARS:',I5)
           14 FORMAT('0PROP. OF GROWERS AROUND PREDICTED LENGTH:',
             +/10X,10F8.4)
           15 FORMAT('0VARIABLE VALUES FOR EXPLOITATION RATE AND RECRUIT',
             +'LENGTH:'/10X,'FISH. MORT.: START   STOP   INCREMENT:',3F10.2/
             +' RECRUIT LENGTHS:',5F8.0)
           16 FORMAT(//' EXPLOITATION RATE:',F6.2,5X,'RECRUIT LENGTH:',I5/)
           17 FORMAT(' ***PROGRAM WENT BEYOND ALLOTED NUMBER OF YEARS*** ')
           18 FORMAT('0POPULATION        CATCH         OVIGS       HATCHED',
             +'       NO. OF EGGS')
           19 FORMAT(' ',3X,F6.2,8X,F6.2,7X,F6.2,6X,F6.2,4X,F10.0)
      C       ****************************************************************
              END
```

APPENDIX 3: SAMPLE OF PROGRAM OUTPUT

Exploitation rate: 0.80 Recruit length: 81

Population numbers:	509.79
Total catch:	893.07
Total ovigs:	434.71
Total eggs:	5076735.
Prerecruit eggs:	2463943.
Egg yield/recruit:	5077.
Prop. recruit eggs:	0.5147
Prop. prerecruit eggs:	0.4853