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LIFE 48: A BASIC COMPUTER PROGRAM TO CALCULATE LIFE TABLE PARAMETERS FOR AN INSECT OR MITE SPECIES

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ABSTRACT

A computer program in BASIC was developed following methods used by Birch (1948) to calculate life table parameters for an arthropod from experimental data. Actual data were presented as an example and data previously used by Birch (1948) were included in this paper for verification. This program was written to run on VAX minicomputer or IBM microcomputer compatibles.

RESUMEN

Se desarrolló un programa de computadoras en BASIC siguiendo los métodos usados por Birch (1948) usando datos experimentales para calcular los parámetros de un cuadro sobre la vida de un artrópodo. Se presentó datos actuales como ejemplo y se incluyó datos usados por Birch (1948) como verificación. Este programa se escribió para ser usado en microcomputadoras VAX o con microcomputadoras compatibles con IBM.

Birch (1948) identified the life table parameters to be used in calculating insect population development by adapting human demography values. The primary population parameter was the intrinsic rate of natural increase (r_m) which fits the following approximation for an insect species under a definite condition:

$$\sum_{0}^{max} e^{-r_m X} (L_x)(M_x) \simeq 1 \quad (1)$$

where: e = the base of the natural logarithm, r_m = the intrinsic rate of natural increase, X = the female age, L_x = the fraction of females alive at age X, and M_x = the expected number of daughters produced per female alive at age X.

Birch (1948) provided both approximate and precise methods for calculating the value of r_m. The approximate method calculated the mean generation time (T), using equation (2), then estimated the value of r_m using equation (3).

$$T = \Sigma ((X)(L_x)(M_x)) / R_o \quad (2)$$

$$r_m = \ln (R_o) / T \quad (3)$$

where: R_o = the net reproductive rate [$\Sigma ((L_x)(M_x))$].

Birch (1948) tried different values until the appropriate precise value of r_m was reached.

The technique used by Birch (1948) was used in this program. The program first calculates X, M_x, L_x, $(M_x)(L_x)$, and $(X)(L_x)(M_x)$ for each interval using the input data. Applying equations (2) and (3) the approximate r_m value is calculated. For each interval, the product of $(M_x)(L_x)$ is then divided by the value of e raised to the power of $[(r_m)(X)]$ to get the value of $[e^{-(r_m)(X)} (M_x)(L_x)]$ as RML for each interval. The sum of RML over all the intervals is compared to the range of 0.9995 to 1.0005. If the sum of RML is not in that range, then the program reduces or increases the value of r_m by 0.0001 and executes the calculation again in a loop until the sum of RML reaches the indicated range. The last trial r_m value is considered the precise value.

The output of this program will be stored in a file (to be named by the operator). This file includes the following information for each interval of adult female age: total progeny per interval (M), number of females alive at age X (L_x), mean female age at each interval mid-point (X), female progeny per female (M_x), rate of survival (L_x), the product of $[(M_x)(L_x)]$ as (M_xL_x), and the final values of RML to meet the original formula (equation 1). Finally, the program prints the precise life table parameters of that study as the sum of RML, the net reproductive rate (R_o), the generation time (T), the intrinsic rate of natural increase (r_m) and the finite rate of increase (e^{r_m}).

An example of this program is presented (Fig. 1) using data of *Euseius mesembrinus* (Dean) (Acari: Phytoseiidae) reared on ice plant, *Malephora crocea* (Jacq.) at 30°C (Abou-Setta and Childers, unpublished data). To evaluate the accuracy of this program, previously calculated (X), (M_x) and (L_x) values from published data by Birch (1948) for *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae), were used. The obtained results of this program gave a calculated r_m value of 0.761957 vs. the estimated r_m value of 0.76

LIFE TABLE DATA SHEET LIFE48.LIS

THE MITE OR INSECT NAME : EUSEIUS MESEMBRINUS (DEAN)
THE TEMPERATURE USED WAS : 30 C

M	L	X	Mx	Lx	MxLx	RML
4	20	4.90	0.12	1.00	0.122	.036599
46	20	5.90	1.40	1.00	1.403	.329197
34	20	6.90	1.04	1.00	1.037	.190311
33	20	7.90	1.01	1.00	1.007	.144473
26	20	8.90	0.79	1.00	0.793	.089030
27	20	9.90	0.82	1.00	0.824	.072312
23	20	10.90	0.70	1.00	0.701	.048180
16	20	11.90	0.49	1.00	0.488	.026215
15	20	12.90	0.46	1.00	0.458	.019222
15	19	13.90	0.48	0.95	0.458	.015035
16	18	14.90	0.54	0.90	0.488	.012543
7	18	15.90	0.24	0.90	0.213	.004292
9	16	16.90	0.34	0.80	0.275	.004316
11	16	17.90	0.42	0.80	0.336	.004126
9	15	18.90	0.37	0.75	0.275	.002640
5	15	19.90	0.20	0.75	0.153	.001147
2	13	20.90	0.09	0.65	0.061	.000359
2	13	21.90	0.09	0.65	0.061	.000281

THE OBSERVATION (OBS.) INTERVAL USED WAS 1 DAY
THE DEVELOPMENTAL TIME WAS CONSIDERED AS 4.4 INTERVALS
THE SEX RATIO WAS (FEMALES/TOTAL): .61
THE FRACTION OF EGGS REACHING MATURITY : 1

THE SUM OF RML = 1.00028
THE NET REPRODUCTIVE RATE (Ro) = 9.15
THE GENERATION TIME (T) IN OBS. INTERVALS = 9.00947
THE INTRINSIC RATE OF NATURAL INCREASE (rm) = .245714
THE FINITE RATE OF INCREASE = 1.27853

COLUMN DEFINITIONS

M - Total progeny at each interval for all females
L - Number of females alive
X - Actual female age (time from egg stage)
Mx - Female progeny per female
Lx - Proportion surviving at age X
MxLx- Female progeny per female times rate of survival
RML - MxLx times (e raised to the power of (-rm times x))
(COLUMNS M & L CONTAIN THE INPUT DATA)

Fig. 1. Life 48 BASIC program output model.

by Birch (1948) (Fig. 2). This program substantially reduces the time and effort required for calculating precise life table parameters.

This BASIC computer program (Fig. 3) uses either original life history data or precalculated M_x and L_x values. The program accepts the insect or mite name, temperature used, number of intervals, type of interval used, and asks for the data type. If the operator selects (1), the program will ask for the initial number of females, developmental time of female immatures, percentage that reach maturity from the original progeny, sex ratio (assuming that it is stable during the progeny time), total fecundity

```
                    LIFE TABLE DATA SHEET        LIFE48.LIS

THE MITE OR INSECT NAME : CALANDRA ORYZAE
THE TEMPERATURE USED WAS : 29 C

  X       Mx      Lx      MxLx       RML

 4.50   20.00    0.87    17.400    .564206
 5.50   23.00    0.83    19.090    .288922
 6.50   15.00    0.81    12.150    .085830
 7.50   12.50    0.80    10.000    .032972
 8.50   12.50    0.79     9.875    .015197
 9.50   14.00    0.77    10.780    .007744
10.50   12.50    0.74     9.250    .003101
11.50   14.50    0.66     9.570    .001498
12.50   11.00    0.59     6.490    .000474
13.50    9.50    0.52     4.940    .000168
14.50    2.50    0.45     1.125    .000018
15.50    2.50    0.36     0.900    .000007
16.50    2.50    0.29     0.725    .000003
17.50    4.00    0.25     1.000    .000002
18.50    1.00    0.19     0.190    .000000

    THE OBSERVATION (OBS.) INTERVAL USED WAS 1 WEEK
    THE DEVELOPMENTAL TIME WAS CONSIDERED AS  4   INTERVALS

    THE SUM OF RML                                 =  1.00014
    THE NET REPRODUCTIVE RATE    (Ro)              =  113.485
    THE GENERATION TIME (T) IN OBS. INTERVALS      =  6.20989
    THE INTRINSIC RATE OF NATURAL INCREASE (rm)    =  .761957
    THE FINITE RATE OF INCREASE                    =  2.14246

        COLUMN DEFINITIONS

    X    - Actual female age (time from egg stage)
    Mx   - Female progeny per female
    Lx   - Proportion surviving at age X
    MxLx- Female progeny per female times rate of survival
    RML  - MxLx times (e raised to the power of (-rm times x)
   (COLUMNS Mx & Lx CONTAIN THE INPUT DATA)
```

Fig. 2. Validation of Life 48 program using data presented by Birch (1948).

per interval, and the number of females alive at each interval. If the operator selects (2), the program will ask for the precalculated M_x and L_x values for each interval instead of M and L. The program was developed to run on DEC VAX minicomputers or IBM PC compatible microcomputers. A computer program in Turbo Pascal is planned.

Acknowledgment

Thanks to the AMIDEAST Peace Fellowship Program for supporting the first author during this study. This publication was in partial fulfillment of his requirements for the Ph.D. degree.

Florida Agricultural Experiment Stations Journal Series No. 7396.

```
100  REM  PROGRAM LIFE48                               JULY 1985
110  REM  M. M. ABOU-SETTA, R. W. SORRELL, AND C. C. CHILDERS
120  REM    THIS PROGRAM CAN RUN ON BOTH A DEC VAX MINICOMPUTER
130  REM       AND ON THE IBM PC MICROCOMPUTER AND COMPATIBLES IF
140  REM       APPROPRIATE CHANGES ARE MADE AS DESCRIBED ON LINES
150  REM       1061 THROUGH 1064
160  REM  DEFINE OUTPUT FILE
170  REM  INPUT INITIAL PARAMETERS
180  ON ERROR GOTO 1580
190   INPUT "   ENTER MITE OR INSECT NAME  ";TITLE$
200   INPUT "   ENTER THE TEMPERATURE USED (C) ";TEMP$
210   INPUT "   ENTER THE NUMBER OF OBSERVATIONS  ";N
220   PRINT "   ENTER THE TIME INTERVAL BETWEEN OBSERVATIONS ";
225   INPUT    TIMINT$
230   PRINT "   ENTER THE DEVELOPMENT TIME FROM EGG TO ADULT "
240   PRINT "   FEMALE AS THE NUMBER OF OBSERVATION INTERVALS ";
245   INPUT  DT
250  PRINT
260  PRINT "   CALCULATE LIFE TABLE PARAMETERS USING "
270  PRINT "     (1) LIFE HISTORY DATA ( M and L )"
275  PRINT "     (2) PRECALCULATED  Mx AND Lx DATA"
280  PRINT
290  PRINT "   PLEASE ENTER YOUR DATA TYPE AS 1 OR 2 ",
300  INPUT DATYPE
305  PRINT
310  IF DATYPE <> 1 AND DATYPE <> 2 THEN 260
320  DIM X(N), M(N), M1(N), MX(N), L(N), LX(N), MXLX(N), XML(N)
325  DIM RML(N)
330  IF DATYPE = 2 THEN 640
340   INPUT "   ENTER THE INITIAL NUMBER OF FEMALES ";NF
350   PRINT "   ENTER THE FRACTION OF EGGS LAID REACHING";
355   INPUT " MATURITY ";PERM
360   INPUT "   ENTER THE SEX RATIO AS FEMALES PER TOTAL ";SR
370  PRINT
380  PRINT "   FOR EACH OF ";N;" INTERVALS"
390  PRINT "   ENTER THE NUMBER OF EGGS LAID (M) AND ";
391  PRINT "THE NO. OF SURVIVING FEMALES (L) "
400  PRINT
410   FOR C = 1 TO N
420    PRINT "  M FOR INTERVAL ";C;"    ";
430    INPUT M(C)
490    PRINT "  L FOR INTERVAL ";C;"    ";
500    INPUT L(C)
510    IF L(C) > 0 AND L(C) <= NF THEN 535
520    PRINT "  ERROR - NUMBER MUST BE GREATER THAN 0 AND LESS";
525    PRINT " THAN ";NF
530    GOTO 490
535    PRINT
540   NEXT C
550  PRINT
560  REM  CALCULATING THE DAILY AND LIFE TABLE VALUES
570  FOR C = 1 TO N
580   X(C) = C + DT - .5
590   M1(C)= M(C) / L(C)
600   LX(C) = L(C) / NF
610   MX(C) = M1(C) * SR * PERM
620  NEXT C
630  GO TO 740
```

Fig. 3. Listing of Life 48 program for life table calculations.

```
640  PRINT "   ENTER THE Mx AND Lx DATA FOR EACH INTERVAL";
645  PRINT " OF ADULT AGE"
646  PRINT "     FOR  ";N;" INTERVALS"
647  PRINT
650  FOR C = 1 TO N
660   X(C) = C + DT - .5
670   PRINT "   Mx FOR INTERVAL NO. ";C;"  : ";
680   INPUT MX(C)
690   PRINT "   Lx FOR INTERVAL NO. ";C;"  : ";
700   INPUT LX(C)
710   IF LX(C) > 1 THEN 690
720      PRINT
730  NEXT C
735  PRINT "  WORKING  "
740  FOR C = 1 TO C
750   MXLX(C)= MX(C)  * LX(C)
760   XML(C)= MXLX(C) * X(C)
770   EXML =  EXML + XML(C)
780   RO  = RO + MXLX(C)
790  NEXT C
800  REM  CALCULATING THE APPROXIMATE VALUE OF RM
810   RM = LOG( RO ) / (EXML / RO)
820   FOR C = 1 TO N
830    RML(C) = MXLX(C) / EXP( X(C) * RM )
840    ERML = ERML + RML(C)
850   NEXT C
860 REM  FINDING THE ACCURATE (RM) USING THE APPROXIMATE
865 REM  VALUE AS A GUIDE
870 IF ERML <= 1.0005 AND ERML => .9995 THEN 1030
880 IF ERML <.9995 THEN 960
890   ERML = 0
895   PRINT "*";
900   RM = RM + .0001
910  FOR C = 1 TO N
920   RML(C) = MXLX(C) / EXP( X(C) * RM )
930   ERML = ERML + RML(C)
940  NEXT C
950  IF ERML > 1.0005 THEN 890 ELSE 1030
960   ERML = 0
965   PRINT "*";
970   RM = RM - .0001
980  FOR C = 1 TO N
990   RML(C) = MXLX(C) / EXP( RM * X(C) )
1000   ERML = ERML + RML(C)
1010  NEXT C
1020  IF ERML < .9995 THEN 960
1030   T = LOG( RO ) / RM
1040  PRINT " ENTER NAME OF FILE IN WHICH RESULTS WILL BE ";
1050  INPUT "PLACED ";FILE$
1060  OPEN FILE$ FOR OUTPUT AS #1
1061  REM FOR VAX COMPATIBILITY, A COMMA MUST NOT BE PLACED
1062  REM     AFTER THE #1 IN LINES 1260,1270,1560 ( PRINT #1 USING )
1063  REM FOR IBM COMPATIBILITY, A COMMA MUST BE PRESENT
1064  REM (       PRINT #1, USING          CLOSE #1,     )
1070  PRINT #1," "
1080  PRINT #1,"                         LIFE TABLE DATA SHEET";
1090  PRINT #1,"        ";FILE$
```

```
1100  PRINT #1," "
1110  PRINT #1,"    THE MITE OR INSECT NAME : ";TITLE$
1120  PRINT #1,"    THE TEMPERATURE USED WAS : ";TEMP$;" C"
1130  PRINT #1," "
1140  IF DATYPE = 2 THEN 1160
1150  PRINT #1,"     M       L ";
1160  PRINT #1,"      X       Mx      Lx      MxLx        RML"
1170  PRINT #1," "
1180  F1$ =     "    ###    ###"
1190  F2$ =     "    ##.##   ##.##    #.##    ##.###     .######"
1200  FOR C = 1 TO N
1250  IF DATYPE = 2 THEN 1270
1260   PRINT #1, USING F1$; M(C); L(C);
1270   PRINT #1, USING F2$; X(C); MX(C); LX(C); MXLX(C); RML(C)
1280  NEXT C
1290  PRINT #1," "
1300  PRINT #1,"  THE OBSERVATION (OBS.) INTERVAL USED WAS ";
1305  PRINT #1, TIMINT$
1310  PRINT #1,"  THE DEVELOPMENTAL TIME WAS CONSIDERED AS ";
1315  PRINT #1,DT;"  INTERVALS"
1320 IF DATYPE = 2 THEN 1350
1330  PRINT #1,"  THE SEX RATIO WAS (FEMALES/TOTAL): ";SR
1340  print #1,"  THE FRACTION OF EGGS REACHING MATURITY :  ";
1345  PRINT #1,PERM
1350  PRINT #1," "
1360  PRINT #1,"  THE SUM OF RML                              ";
1365  PRINT #1," = ";ERML
1370  PRINT #1,"  THE NET REPRODUCTIVE RATE   (Ro)           ";
1375  PRINT #1," = ";RO
1380  PRINT #1,"  THE GENERATION TIME (T) IN OBS. INTERVALS  ";
1385  PRINT #1," = ";T
1390  PRINT #1,"  THE INTRINSIC RATE OF NATURAL INCREASE (rm)";
1395  PRINT #1," = ";RM
1400  PRINT #1,"  THE FINITE RATE OF INCREASE                 ";
1405  PRINT #1," = ";EXP(RM)
1410  PRINT #1," "
1420  PRINT #1,"              COLUMN DEFINITIONS"
1430  PRINT #1," "
1440  IF DATYPE = 2 THEN 1470
1450  PRINT #1,"  M    - Total progeny at each interval for all";
1455  PRINT #1," females"
1460  PRINT #1,"  L    - Number of females alive  "
1470  PRINT #1,"  X    - Actual female age (time from egg stage)"
1480  PRINT #1,"  Mx   - Female progeny per female"
1490  PRINT #1,"  Lx   - Proportion surviving at age X"
1500  PRINT #1,"  MxLx- Female progeny per female times rate";
1505  PRINT #1," of survival"
1510  PRINT #1,"  RML - MxLx times (e raised to the power of";
1515  PRINT #1," (-rm times x))"
1520  IF DATYPE = 2 THEN 1550
1530  PRINT #1,"          (COLUMNS M & L CONTAIN THE INPUT DATA)"
1540  GOTO 1560
1550  PRINT #1,"        (COLUMNS Mx & Lx CONTAIN THE INPUT DATA)"
1560  CLOSE #1,
1570  GOTO 1700
1580 REM ERROR HANDLING ROUTINE
1590  IF ERL > 740 THEN 1640
1600   PRINT " DATA ERROR - PLEASE CHECK DATA AND RE-ENTER"
1610   IF ERL = 430 THEN RESUME 420
1620   IF ERL = 500 THEN RESUME 490
```

```
1621   IF ERL = 680 THEN RESUME 670
1622   IF ERL = 700 THEN RESUME 690
1640  IF ERL <> 1060 THEN 1670
1650   PRINT " ERROR OPENING OUTPUT FILE - TRY AGAIN"
1660   RESUME 1040
1670  PRINT " ERROR IN PROGRAM"
1680   PRINT " ERROR #";ERR;" OCCURRED AT LINE ";ERL
1690   RESUME 1700
1700 END
```

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DELTA CAMPANIFORME RENDALLI (BINGHAM) AND *ZETA ARGILLACEUM* (LINNAEUS) ESTABLISHED IN SOUTHERN FLORIDA, AND COMMENTS ON GENERIC DISCRETION IN *EUMENES s. l.* (HYMENOPTERA: VESPIDAE: EUMENINAE)

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Abstract

Delta campaniforme rendalli (Bingham), an African wasp, and *Zeta argillaceum* (Linnaeus), a South American wasp, are established in southern Florida. These insects add two more genera to the North American fauna. The existing key to the North American genera is modified to include *Delta* and *Zeta*.

Resumen

La avispa africana *Delta campaniforme rendalli*, y la avispa sudamericana *Zeta argillaceum* (Linnaeus) están establecidas en el sur de la Florida. Estas añaden dos géneros a más de insectos a la fauna de Norteamérica. Se modificó la clave de los géneros de Norteamérica para incluir a *Delta* y a *Zeta*.