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1975/76 PROGRESS REPORT

PROGRAMMING PHASE OF
WATER RESPONSE ECOSYSTEM MODEL:
III. ANIMAL SUBMODEL

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This report describes a portion of the Desert Biome Water Response Ecosystem Model. Five Research Memoranda comprise the full description: Introduction and support programs (RM 76-36); Abiotic submodels (RM 76-37); Animal submodel (RM 76-38); Perennial plant, nitrogen and decomposition submodels (RM 76-39); and Annual plant submodel (RM 76-40). The objectives of the Water Response Model, information on the arrangement of material distributed among the five Research Memoranda and descriptions of program MAIN and support programs F1, F3 and FTAVE are contained in Research Memorandum 76-36, **Programming phase of water response ecosystem model: I. Introduction and support programs**. The relationships between various sections of the model, their interactions and location in the report series are summarized in Table 1 of RM 76-36.

GENERAL DESCRIPTION OF THE ANML SUBMODEL

The animal submodel currently employed in the Water Response Model fulfills the role of a vegetation removal function. It simulates changes in animal numbers and food consumption with time, using data collected on the study site. Two animal organisms are presently represented in the submodel. These are the black-tailed jackrabbit (*Lepus californicus*) and the collective population of herbivorous insects found on the Curlew Valley site.

Jackrabbit population dynamics are modeled after nine years of data compiled by Gross et al. (1974). The population follows a 10-year sine wave with a mean density of 0.62/ha. During the breeding season population dynamics are driven by the birth and death rates characteristic of that period. Death rates during the remainder of the year are determined by the population level relative to a 10-year sine curve. The magnitude of the sine curve is determined from data collected on the site. Control of the population density to that of the reference density (sine wave) is accomplished by a logistic mechanism where the carrying capacity (K) is represented as the sine curve. The control equation used is given by Equation 1:

$$(dN/dt) = N(RC)(CK - N)/CK \quad (1)$$

where

- N = population density
- RC = rate of return to reference
- CK = reference population density (sine curve)

Typical yearly jackrabbit population dynamics are shown in Figure 1.

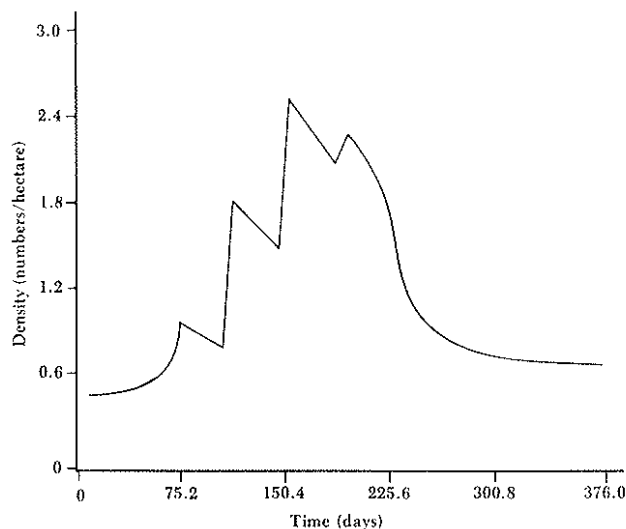


Figure 1. Typical yearly jackrabbit population dynamics.

The calculation of vegetation consumption by jackrabbits is based on data collected by Westoby (1973) and varies both seasonally and with diet preferences. *Sitanion* and *Halogeton* make up a large portion of the diet.

Vegetation consumption by insects is estimated from the number of herbivorous insects observed on the site and the energy requirements for each species. Soil insects are not included in the estimate. Energy requirements are determined using Reichle's equation for vegetation consumption by forest floor insects (Reichle 1967) given in Equation 2:

$$Y = 0.063 X^{.68} \quad (2)$$

where

- Y = milligrams consumed
- X = milligrams dry body weight

Vegetation removal by insects was found to be negligible for the shrubs and is not mechanized in the submodel. An average consumption rate is used in simulating insect removal of annual plant material.

PROGRAM DESCRIPTION

Only the important segments of the code in the program listing are shown and described. Sequence numbers are shown to aid in reference to the full code listing which follows the program description. All comment cards, specification statements and bookkeeping sections have been left out. Almost all initialization has been deleted also. Definitions of variable names may be found in Table 1, which also appears at the beginning of the program listing.

Table 1. Variable dictionary for ANML

A	MEAN JACKRABBIT POPULATION DENSITY
B	FREQUENCY FACTOR OF POPULATION CYCLE
C	DAY UPON WHICH REPRODUCTIVE SEASON COMMENCES
CAAR(I,J)	BIOMASS OF A GIVEN PLANT PART OF A PARTICULAR FUNCTIONAL GROUP INGESTED BY JACKRABBITS
CADEST(I,J)	BIOMASS OF A GIVEN PLANT PART OF A PARTICULAR FUNCTIONAL GROUP WASTED BY JACKRABBITS
CI(I,J)	BIOMASS OF A GIVEN PLANT PART OF A PARTICULAR FUNCTIONAL GROUP CONSUMED BY INSECTS
CK	REFERENCE POPULATION LEVEL FOR JACKRABBITS
CON(I)	TOTAL CONSUMPTION OF A GIVEN FUNCTIONAL GROUP BY JACKRABBITS
CON(I)	TOTAL CONSUMPTION OF A GIVEN FUNCTIONAL GROUP BY INSECTS
CR(I,J,K)	JACKRABBIT CONSUMPTION RATE/PLANT SPECIES/PLANT PART/SEASON
DR	JACKRABBIT MORTALITY RATE
DT	TIME STEP
D	MAGNITUDE OF JACKRABBIT CYCLIC VARIATION
FF	FRACTION OF JACKRABBIT INTAKE CONVERTED TO FECES
RC	RATE OF RETURN TO EXPECTED JACKRABBIT FLUCTUATION
T	JULIAN DAY
R(K)	JACKRABBIT REPRODUCTIVE RATES
TCN	TOTAL CONSUMPTION BY JACKRABBITS
V	JACKRABBIT CYCLE YEAR AT START
W(I,J,K)	JACKRABBIT WASTAGE/PLANT SPECIES/PLANT PART/SEASON
X	JACKRABBIT POPULATION DENSITY
XAFS(1)	JACKRABBIT FECES
XR	JACKRABBIT POPULATION DENSITY DURING BREEDING SEASON
XVLITR(2,1)	LITTER CATEGORY FOR FECES
XVPLNT(I,J)	PLANT PART FOR A GIVEN FUNCTIONAL GROUP
YB	NUMBER OF YOUNG JACKRABBITS BORN

$$XR = XR - XR * DR * DT$$

ANML 107

Individuals that die during gestation are removed from the population. The number removed is determined by the relative mortality rate (DR) for this period.

$$YB = XR * R(K)$$

ANML 110

The number of young born (YB) to a given litter ($K = 1, 2, 3$ or 4 corresponding to the first, second, third and fourth litter of the breeding season) is determined by multiplying the population density (XR) by the relative birth rate ($R(K)$) for that litter.

$$X = X + YB - YB * DR * DT - X * DR * DT$$

ANML 115

The population is corrected for birth and death using the relative mortality rate (DR).

$$3 \quad CK = A + D * \sin(B * V)$$

ANML 119

This equation generates the reference density to which the population is controlled. The reference density follows a 10-year sine curve with a mean value (A) of $62/\text{km}^2$, a mean to peak amplitude (D) of $68/\text{km}^2$ and a frequency factor (B) of 0.628 . V is the cycle year.

$$X = X * X * DT * RC * (CK - X) / CK$$

ANML 121

Population density is controlled to the reference density during nonbreeding times of the year. This is accomplished using the logistic equation in difference form where

X = population density
 RC = rate of return to the reference density
 CK = reference density

$$CAAR(I, J) = X * .01 * CR(I, J, L1) * DT$$

ANML 135

This equation calculates the biomass of a particular plant part of a given functional group ingested by jackrabbits. This is done by multiplying the population density (X) by the relative ingestion rate for the current season of the year (CR). The factor $.01$ converts kilometers to hectares.

$$CADEST(I, J) = X * .01 * h(I, J, L1) * DT$$

ANML 136

This equation calculates the biomass of a particular plant part of a given functional group wasted by jackrabbits. The equation is the same form as that used for ingestion.

```
CON(I)=CCN(T)+CAAR(I,J)+CADEST(I,J)
```

ANML 137

Here ingestion and wastage are summed over plant parts.

```
13 TCON=TCOA+CAAR(I,J)
```

ANML 138

Total plant material ingested by jackrabbits is obtained by summing ingestion over all plant parts and functional groups.

```
XVLITR(2,1)=XVLITR(2,1)+FF*TCON
```

ANML 140

Feces, calculated by multiplying the fraction of intake converted to feces by the total material ingested, is added to the proper litter category.

```
CONI(I)=CONI(T)+CI(I,J)*XVPLNT(I,J)*DT
```

ANML 156

Insect consumption for each plant is determined by summing consumption of each plant part. Plant part consumption is calculated by multiplying plant part biomass by the insect consumption rate (*CI*). Here *CI* represents a fraction of the biomass removed during each time-step.

```
16 CAAR(T,J)=CI(I,J)*XVPLNT(I,J)*DT+CAAR(I,J)
```

ANML 159

Here insect consumption is added to jackrabbit ingestion to determine the total plant material removed through animal ingestion.

```
ENTRY AINIT
```

ANML 166

ANML INITIALIZATION SECTION

Initial data are read in and written here.

```
READ(5,850)RCHECK
WRITE(6,851)RCHECK
WRITE(6,852)
```

ANML 186

ANML 187

ANML 188

These statements are used to read and write comments (the variable RCHECK is used only to read and write comments). These particular statements read and write the comment BEGIN ANML INITIALIZATION.

```
READ(5,850)RCHECK
WRITE(6,851)RCHECK
READ(5,/)X
WRITE(6,/)X
WRITE(6,852)
```

```
ANML 191
ANML 192
ANML 193
ANML 194
ANML 195
```

These statements read and write the comments NUMBER OF JACKRABBITS/SQUARE KM followed by reading and writing the values of the variable.

A similar procedure is utilized for reading and writing R, DR, A, B, V, C, D, RC, FF, CR, W AND CI.

```
READ(5,850)RCHECK
WRITE(6,851)RCHECK
WRITE(6,852)
```

```
ANML 282
ANML 283
ANML 284
```

These statements read and write the comment END ANML INITIALIZATION.

COMPLETE PROGRAM LISTING

```

$ RESET FREE ANML 001
$SET OWN ANML 002
$ SET SEPARATE ANML 003
C ANML 004
C ANML 005
C ANML 006
C SUBROUTINE ANML ANML 007
C ANML 008
C VEGETATION REMOVAL FUNCTION OF DESERT BIOME WATER RESPONSE MODEL ANML 008
C ANML 009
C MARCH 1976. WRITTEN BY: JOHN E. HEASLEY ANML 010
C WILDLIFE SCIENCE,UMC 52 ANML 011
C UTAH STATE UNIVERSITY ANML 012
C LOGAN,UTAH 84322 ANML 013
C ANML 014
C ANML 015
C ANML 016
C ANML 017
C ANML 018
C VARIABLE DICTIONARY FOR ANML ANML 019
C ANML 020
C ANML 021
C A MEAN JACKRABBIT POPULATION DENSITY ANML 022
C ANML 023
C B FREQUENCY FACTOR OF POPULATION CYCLE ANML 024
C ANML 025
C C DAY UPON WHICH REPRODUCTIVE SEASON COMMENSES ANML 026
C ANML 027
C CAAR(I,J) BIOMASS OF A GIVEN PLANT PART OF A PARTICULAR ANML 028
C FUNCTIONAL GROUP INGESTED BY JACKRABBITS ANML 029
C ANML 030
C CADEST(I,J) BIOMASS OF A GIVEN PLANT PART OF A PARTICULAR ANML 031
C FUNCTIONAL GROUP WASTED BY JACKRABBITS ANML 032
C ANML 033
C CI(I,J) BIOMASS OF A GIVEN PLANT PART OF A PARTICULAR ANML 034
C FUNCTIONAL GROUP CONSUMED BY INSECTS ANML 035
C ANML 036
C CK REFERENCE POPULATION LEVEL FOR JACKRABBITS ANML 037
C ANML 038
C CONCI TOTAL CONSUMPTION OF A GIVEN FUNCTIONAL GROUP BY ANML 039
C JACKRABBITS ANML 040
C ANML 041
C CONI(I) TOTAL CONSUMPTION OF A GIVEN FUNCTIONAL GROUP BY ANML 042
C INSECTS ANML 043
C ANML 044
C CR(I,J,K) JACKRABBIT CONSUMPTION RATE/PLANT SPECIES/PLANT PART/ANML 045
C SEASON ANML 046
C ANML 047
C ANML 048
C DR JACKRABBIT MORTALITY RATE ANML 049
C ANML 050
C DT TIME STEP ANML 051
C ANML 052
C D MAGNITUDE OF JACKRABBIT CYCLIC VARIATION ANML 052

```



```

C          FF          FRACTION OF JACKRABBIT INTAKE CONVERTED TO FECES          ANML 053
C          RC          RATE OF RETURN TO EXPECTED JACKRABBIT FLUCTUATION        ANML 054
C          RC          RATE OF RETURN TO EXPECTED JACKRABBIT FLUCTUATION        ANML 055
C          RC          RATE OF RETURN TO EXPECTED JACKRABBIT FLUCTUATION        ANML 056
C          T           JULIAN DAY                                               ANML 057
C          T           JULIAN DAY                                               ANML 058
C          T           JULIAN DAY                                               ANML 059
C          R(K)        JACKRABBIT REPRODUCTIVE RATES                           ANML 060
C          TCON        TOTAL CONSUMPTION BY JACKRABBITS                          ANML 061
C          TCON        TOTAL CONSUMPTION BY JACKRABBITS                          ANML 062
C          V           JACKRABBIT CYCLE YEAR AT START                           ANML 063
C          V           JACKRABBIT CYCLE YEAR AT START                           ANML 064
C          W(I,J,K)    JACKRABBIT WASTAGE/PLANT SPECIES/PLANT PART/SEASON      ANML 065
C          W(I,J,K)    JACKRABBIT WASTAGE/PLANT SPECIES/PLANT PART/SEASON      ANML 066
C          X           JACKRABBIT POPULATION DENSITY                            ANML 067
C          X           JACKRABBIT POPULATION DENSITY                            ANML 068
C          X*FTS(1)    JACKRABBIT FECES                                         ANML 069
C          X*FTS(1)    JACKRABBIT FECES                                         ANML 070
C          X*FTS(1)    JACKRABBIT FECES                                         ANML 071
C          XR          JACKRABBIT POPULATION DENSITY DURING BREEDING SEASON    ANML 072
C          XR          JACKRABBIT POPULATION DENSITY DURING BREEDING SEASON    ANML 073
C          XVLITR(2,1) LITTER CATEGORY FOR FECES                               ANML 074
C          XVLITR(2,1) LITTER CATEGORY FOR FECES                               ANML 075
C          XVPLNT(I,J) PLANT PART FOR A GIVEN FUNCTIONAL GROUP                 ANML 076
C          XVPLNT(I,J) PLANT PART FOR A GIVEN FUNCTIONAL GROUP                 ANML 077
C          YB          NUMBER OF YOUNG JACKRABBITS BORN                          ANML 078
C          YB          NUMBER OF YOUNG JACKRABBITS BORN                          ANML 079
C          YB          NUMBER OF YOUNG JACKRABBITS BORN                          ANML 080
C          YB          NUMBER OF YOUNG JACKRABBITS BORN                          ANML 081
C          YB          NUMBER OF YOUNG JACKRABBITS BORN                          ANML 082
C          YB          NUMBER OF YOUNG JACKRABBITS BORN                          ANML 083
C          YB          NUMBER OF YOUNG JACKRABBITS BORN                          ANML 084
C          YB          NUMBER OF YOUNG JACKRABBITS BORN                          ANML 085
C          T=PMJDAT
C SET BOOKKEEPING CONSTANTS EQUAL TO THE NUMBER OF TIME CONSTANTS IN THE ANML 086
C BREEDING SEASON (YL) AND THE NUMBER OF TIME CONSTANTS DURING GESTATION ANML 087
C (JL)
      M=DT
      IL=160/M
      JL=40/M
      IF(T.LE.365)GO TO 7
C INCREMENT THE JACKRABBIT POPULATION CYCLE
      V=V+1
      7 IF(T-C)3,2,2
C STATEMENTS 2 TO 3 INCLUDE CALCULATIONS FOR POPULATION CHANGE DURING ANML 096
C THE BREEDING SEASON
      2 IB=IB+1
      JB=JB+1
      IF(IB.GT.IL)GO TO 3
      IF(IB.EQ.1)XR=X
      IF(IB.EQ.1)JB=0
      IF(JB.EQ.JL)JB=0
C K EQUALS THE LITTER NUMBER OF THE BREEDING SEASON
      IF(JB.EQ.0)K=K+1
C INDIVIDUALS THAT DIED DURING GESTATION ARE REMOVED FROM THE POPULATION ANML 106
      XR=XR-XR*DR*DT
      IF(JB.GT.0)GO TO 5
C THE NUMBER OF YOUNG BORN ARE CALCULATED NEXT
      YB=XR*R(K)
      GO TO 8
      5 YB=0.
      8 CONTINUE
C THE POPULATION IS NOW CORRECTED FOR BIRTH AND DEATH
      X=X+YB-YB*DR*DT-X*CR*DT
      GO TO 9
C CALCULATE THE REFERENCE POPULATION DENSITY CHARACTERISTIC TO THE ANML 117
C SPECIES
      3 CR=A+D*SIN(B*V)
C ADJUST POPULATION DENSITY TOWARD THE REFERENCE VALUE
      X=X+X*DT*RC*(CR-X)/CR
      IF(T.LT.C)IB=0
      IF(T.LT.C)JB=0
      IF(T.LT.C)K=0
      9 CONTINUE
C THE FOLLOWING "IF" STATEMENTS SET THE CONSUMPTION RATES CORRESPONDING ANML 126
C TO THE CURRENT SEASON
      IF(T.GE.0.AND.T.LT.32.OR.T.GE.305.AND.T.LE.365)LI=1
      IF(T.GE.32.AND.T.LE.120)LI=2
      IF(T.GE.121.AND.T.LE.211)LI=3
      IF(T.GE.212.AND.T.LE.304)LI=4
C CALCULATE JACKRABBIT INGESTION AND WASTAGE
      DO 13 I=1,6
      DO 13 J=1,6
      CAAR(I,J)=X*.01*CR(I,J,LI)*DT
      CADEST(I,J)=X*.01*W(I,J,LI)*DT
      COR(I)=COR(T)+CAAR(I,J)+CADEST(I,J)
      13 TCON=TCON+COR(I,J)
C ADD FECES TO LITTER
      XVLITR(2,1)=XVLITR(2,1)+FF*TCON
      X*FTS(1)=FF*TCON
      TCON=0.
  
```


C READ IN DAY UPON WHICH REPRODUCTIVE SEASON COMMENCES	ANML 232
RFAD(5,850)RCHECK	ANML 233
WRITE(6,851)RCHECK	ANML 234
RFAD(5,/)C	ANML 235
WRITE(6,/)C	ANML 236
WRITE(6,852)	ANML 237
C	ANML 238
C READ IN MAGNITUDE OF CYCLIC VARIATION	ANML 239
READ(5,850)RCHECK	ANML 240
WRITE(6,851)RCHECK	ANML 241
READ(5,/)D	ANML 242
WRITE(6,/)D	ANML 243
WRITE(6,852)	ANML 244
C	ANML 245
C READ IN RATE OF RETURN TO EXPECTED JACKRABBIT FLUCTUATION	ANML 246
READ(5,850)RCHECK	ANML 247
WRITE(6,851)RCHECK	ANML 248
RFAD(5,/)RC	ANML 249
WRITE(6,/)RC	ANML 250
WRITE(6,852)	ANML 251
C	ANML 252
C READ IN FRACTION OF JACKRABBIT INTAKE CONVERTED TO FECES	ANML 253
RFAD(5,850)RCHECK	ANML 254
WRITE(6,851)RCHECK	ANML 255
RFAD(5,/)FF	ANML 256
WRITE(6,/)FF	ANML 257
WRITE(6,852)	ANML 258
C	ANML 259
C READ IN JACKRABBIT INGESTION RATES	ANML 260
READ(5,850)RCHECK	ANML 261
WRITE(6,851)RCHECK	ANML 262
RFAD(5,/)(((CR(I,J,K),K=1,4),J=1,6),I=1,6)	ANML 263
WRITE(6,/)(((CR(I,J,K),K=1,4),J=1,6),I=1,6)	ANML 264
WRITE(6,852)	ANML 265
C	ANML 266
C READ IN JACKRABBIT WASTAGE RATES	ANML 267
READ(5,850)RCHECK	ANML 268
WRITE(6,851)RCHECK	ANML 269
RFAD(5,/)(((W(I,J,K),K=1,4),J=1,6),I=1,6)	ANML 270
WRITE(6,/)(((W(I,J,K),K=1,4),J=1,6),I=1,6)	ANML 271
WRITE(6,852)	ANML 272
C	ANML 273
C READ IN INSECT CONSUMPTION RATES	ANML 274
READ(5,850)RCHECK	ANML 275
WRITE(6,851)RCHECK	ANML 276
READ(5,/)(((CI(I,J),J=1,6),I=1,6)	ANML 277
WRITE(6,/)(((CI(I,J),J=1,6),I=1,6)	ANML 278
WRITE(6,852)	ANML 279
C	ANML 280
C READ IN INITIALIZATION COMPLETE	ANML 281
RFAD(5,850)RCHECK	ANML 282
WRITE(6,851)RCHECK	ANML 283
WRITE(6,852)	ANML 284
RETURN	ANML 285
END	ANML 286

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