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Ant Version I

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DESERT BIOME

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MODELS

ANT

VERSION 1

MODELLING REPORT SERIES NUMBER 4

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DESERT BIOME
UTAH STATE UNIVERSITY
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I N T R O D U C T I O N

Reports in this series are intended for internal use by Desert Biome collaborators. They are not to be quoted or referred to in formal publications. These reports have been produced by the Desert Biome Modelling Group, with the assistance of participants in the Desert Biome and other researchers.

The main function of the models, at this stage of their development, is to provide guidance in the research efforts of the Biome. Therefore, it will be noted that most of the information which they contain is fragmentary evidence, best available estimates, arbitrary assumptions or non-Biome supported research. The collection and incorporation of more accurate data will come after these models have been prepared in this form. Validation of the models will also come later.

Any use of the models must recognize the limitations imposed by their development at this early stage of research.

(1) Biological interpretations must be performed with extreme caution. Output, for example, should be viewed in relation to system behavior (stability, general time relationships, relative magnitude of the variables, general responses to parameter modifications, etc.). These properties should be related to the processes incorporated in the model structure. No particular significance should be attached to the specific numbers given as output.

(2) Data included in these models must not be used without explicit approval of the investigators who have supplied them to us. Please contact the Desert Biome Central Office for details.

(3) The material contained in the models does not constitute publication. It is subject to revision. The modeling group requests that this material not be cited without their expressed permission.

As particular models are revised we will be re-issuing them in new versions. The versions will be numbered according to the general scheme:

Version 1. Models which have been developed by the modeling group in isolation from subject area specialists who have provided the question which has been modeled.

Version 2. Models revised to incorporate subject-areas specialist's criticisms.

Version 3. Models revised to incorporate finds of biome-sponsored research.

```
1       ANT:    PROC OPTIONS(MAIN);
        /*                                                              */
        /* VERSION 1.                                                   */
        /*                                                              */
        /*                                                              */
        /****************************************************************/
        /*                                                              */
        /* THIS MODEL DEALS WITH THE DYNAMICS FROM YEAR TO YEAR OF      */
        /* THE SEED-CROP PRODUCED BY ANNUALS, THE AMOUNT OF IT CONSUMED AND */
        /* STORED BY HARVESTER ANTS, AND THE SUPPLY OF SEEDS FOR GROWTH IN */
        /* SUBSEQUENT YEARS.                                            */
        /*                                                              */
        /****************************************************************/
        /*                                                              */
2               DCL CURVE ENTRY (FLOAT DEC, (*) FLOAT DEC, (*) FLOAT DEC);
3               DCL
                (GERMINATION,GROWTH_RATE,MEAT_DECOMPOSITION,MEAT_PRODUCTION,
                LARVAL_GROWTH,SOIL_TEMP_EFFECT,TEMP_SUCCESS_FACTOR,
                MEAT_SEARCH_SUCCESS,STARVATION_MORTALITY) FLOAT DEC INIT (0);
4               DCL (MEAT_HARVESTED,LARVAL_DEMAND,LARVAL_FOOD_DEFICIT)
                     FLOAT DEC;
5               DCL (ADULT_ANTS,ANNUAL_BIOMASS,LARVAL_BIOMASS,AVAILABLE_SEED)
                    FLOAT DEC;
6               DCL (LARVAL_METABOLISM,MAX_SUCCESS,MAXIMUM_SEED,
                MEAT_FORAGING_SUCCESS,MORTALITY) FLOAT DEC;
7               DCL AVAILABLE_MEAT FLOAT DEC INIT (0);
        /*                                                              */
        /****************************************************************/
        /*                                                              */
        /* THE VALUES FOR ALL THE BIOLOGICAL VARIABLES ARE IN CALORIES PER */
        /* SQUARE METRE. SINCE NO REAL DATA HAS BEEN USED, IT WAS FELT THAT */
        /* THESE IMPROBABLE UNITS WOULD INTERCONVERT MORE NATURALLY, AND */
        /* COULD MORE READILY BE GUESSED, THAN MOST. I PERSONALLY FIND  */
        /* IT DIFFICULT TO CONTEMPLATE THE NUMBERS OF ANTS UNDER A HECTARE. */
        /*                                                              */
        /****************************************************************/
        /*                                                              */
8               DCL TRUE BIT (1) INIT ('1'B);
9               DCL FALSE BIT (1) INIT ('0'B);
10              DCL HUNGRY BIT(1) INIT ('0'B);
11              DCL LARVAE_STARVED BIT (1) INIT ('0'B);
12              DCL RAINFALL(12) FIXED DEC (5,2);
13              DCL SURTEMP(12) FIXED DEC (3,1);
14              DCL SOILTEMP(12) FIXED DEC (3,1);
15              DCL (X1,X2,X3,X4,X5,X6,X7,X8,X9,Y1,Y2,Y3,Y4,Y5,Y6,Y7,Y8,Y9)
                    (*) DEC FLOAT CTL;
```

```
                /*                                                              */
                /********************************************************************/
                /*                                                              */
                /* THIS STATEMENT ACQUIRES ALL THE DATA AT THE BEGINNING OF THE      */
                /* DATA DECK IN THE FORM OF ASSIGNMENTS, UP TO THE FIRST SEMI-COLON. */
                /*                                                              */
                /********************************************************************/
                /*                                                              */
16                      GET DATA;
                /*                                                              */
                /********************************************************************/
                /*                                                              */
                /* THIS STATEMENT WILL ACQUIRE ANY ASSIGNMENTS BEFORE THE NEXT       */
                /* SEMI-COLON AND COPY THEM; ASSIGNMENTS CAN THEREFORE BE PLACED     */
                /* HERE IF A RECORD IS WANTED OF CHANGES MADE FOR A PARTICULAR       */
                /* RUN. ASSIGNMENTS HERE WILL OVERRIDE THOSE IN THE FIRST GROUP.     */
                /*                                                              */
                /********************************************************************/
                /*                                                              */
17                      GET DATA COPY;
```

```
                /*                                                              */
                /********************************************************************/
                /*                                                              */
                /* THIS GROUP, DOWN TO THE FIRST END STATEMENT, ACQUIRES ONE OF  */
                /* THE DATA GRAPHS TO BE USED IN THE INTERPOLATING PROCEDURE     */
                /* 'CURVE'. THE FIRST STATEMENT READS THE ASSIGNMENT OF THE NUMBER*/
                /* OF POINTS IN THE GRAPH. THE ARRAYS, WHICH WERE DECLARED ABOVE AS*/
                /* OF INDETERMINATE SIZE, THEN ARE DIMENSIONED WITH THIS NUMBER, */
                /* AND THE DATA READ INTO THEM. THE DATA GROUPING LOOKS LIKE:    */
                /*                                                              */
                /* #_OF_POINTS_IN_GRAPH=5;                                      */
                /* 1,1  2,0  4,6  8.1,3  49,6.218                               */
                /*                                                              */
                /* THE LIST IS A SERIES OF PAIRS OF COORDINATES, WITH X VALUES  */
                /* FIRST AND IN ASCENDING ORDER, THE PAIRS SEPARATED BY ANY NUMBER OF*/
                /* BLANKS. THERE SHOULD NOT BE BLANKS INSIDE EACH PAIR.         */
                /*                                                              */
                /********************************************************************/
                /*                                                              */
18                      GET DATA(#_GERMINATION_POINTS);
19                      ALLOCATE X1(#_GERMINATION_POINTS),Y1(#_GERMINATION_POINTS);
20                         DO I=1 TO #_GERMINATION_POINTS;
21                         GET LIST(X1(I),Y1(I));
22                         END;
23                      GET DATA(#_GROWTH_RATE_POINTS);
24                      ALLOCATE X2(#_GROWTH_RATE_POINTS),Y2(#_GROWTH_RATE_POINTS);
25                         DO I=1 TO #_GROWTH_RATE_POINTS;
26                         GET LIST(X2(I),Y2(I));
27                         END;
28                      GET DATA(#_MEAT_DECOMPOSITION_POINTS);
29                      ALLOCATE X3(#_MEAT_DECOMPOSITION_POINTS),
                                 Y3(#_MEAT_DECOMPOSITION_POINTS);
30                         DO I=1 TO #_MEAT_DECOMPOSITION_POINTS;
31                         GET LIST(X3(I),Y3(I));
32                         END;
33                      GET DATA(#_MEAT_PRODUCTION_POINTS);
34                      ALLOCATE X4(#_MEAT_PRODUCTION_POINTS),
                                 Y4(#_MEAT_PRODUCTION_POINTS);
35                         DO I=1 TO #_MEAT_PRODUCTION_POINTS;
36                         GET LIST(X4(I),Y4(I));
37                         END;
```

```
38                      GET DATA(#_LARVAL_GROWTH_POINTS);
39                      ALLOCATE X5(#_LARVAL_GROWTH_POINTS),Y5(#_LARVAL_GROWTH_POINTS);
40                         DO I=1 TO #_LARVAL_GROWTH_POINTS;
41                         GET LIST(X5(I),Y5(I));
42                         END;
43                      GET DATA(#_SOIL_TEMP_EFFECT_POINTS);
44                      ALLOCATE X6(#_SOIL_TEMP_EFFECT_POINTS),
                                 Y6(#_SOIL_TEMP_EFFECT_POINTS);
45                         DO I=1 TO #_SOIL_TEMP_EFFECT_POINTS;
46                         GET LIST(X6(I),Y6(I));
47                         END;
48                      GET DATA(#_TEMP_SUCCESS_FACTOR_POINTS);
49                      ALLOCATE X7(#_TEMP_SUCCESS_FACTOR_POINTS),
                                 Y7(#_TEMP_SUCCESS_FACTOR_POINTS);
50                         DO I=1 TO #_TEMP_SUCCESS_FACTOR_POINTS;
51                         GET LIST(X7(I),Y7(I));
52                         END;
53                      GET DATA(#_MEAT_SEARCH_SUCCESS_POINTS);
54                      ALLOCATE X8(#_MEAT_SEARCH_SUCCESS_POINTS),
                                 Y8(#_MEAT_SEARCH_SUCCESS_POINTS);
55                         DO I=1 TO #_MEAT_SEARCH_SUCCESS_POINTS;
56                         GET LIST(X8(I),Y8(I));
57                         END;
58                      GET DATA(#_STARVATION_MORTALITY_POINTS);
59                      ALLOCATE X9(#_STARVATION_MORTALITY_POINTS),
                                 Y9(#_STARVATION_MORTALITY_POINTS);
60                         DO I=1 TO #_STARVATION_MORTALITY_POINTS;
61                         GET LIST(X9(I),Y9(I));
62                         END;
```

```
                /*                                                              */
                /********************************************************************/
                /*                                                              */
                /* THESE STATEMENTS PRINT THE VALUES OF THE 'CURVE' GRAPHS FOR  */
                /* REFERENCE. BETTER WAYS OF DOING THIS ARE BEING DEVELOPED.    */
                /*                                                              */
                /********************************************************************/
                /*                                                              */
63                      PUT SKIP DATA(X1);
64                      PUT SKIP DATA(Y1);
65                      PUT SKIP DATA(X2);
66                      PUT SKIP DATA(Y2);
67                      PUT SKIP DATA(X3);
68                      PUT SKIP DATA(Y3);
69                      PUT SKIP DATA(X4);
70                      PUT SKIP DATA(Y4);
71                      PUT SKIP DATA(X5);
72                      PUT SKIP DATA(Y5);
73                      PUT SKIP DATA(X6);
74                      PUT SKIP DATA(Y6);
75                      PUT SKIP DATA(X7);
76                      PUT SKIP DATA(Y7);
77                      PUT SKIP DATA(X8);
78                      PUT SKIP DATA(Y8);
79                      PUT SKIP DATA(X9);
80                      PUT SKIP DATA(Y9);
                /*                                                              */
                /********************************************************************/
                /*                                                              */
                /* HEADINGS FOR FIVE COLUMNS OF OUTPUT OF THE MAIN VARIABLES.   */
                /*                                                              */
                /********************************************************************/
                /*                                                              */
81                      PUT PAGE LIST('AVAILABLE_MEAT','AVAILABLE_SEED','SEED_STORE',
                                'ADULT_ANTS','LARVAL_BIOMASS');
```

```
                /*                                                              */
                /* BEGIN YEAR CYCLE.                                            */
                /*                                                              */
82              YEARS:      DO YEAR=1 TO #_OF_YEARS;
83                          PUT SKIP DATA(YEAR);
                /*                                                              */
                /*****************************************************************/
                /*                                                              */
                /* THESE STATEMENTS ACQUIRE THE CLIMATIC CONDITIONS FOR EACH YEAR.  */
                /* THE DATA ARE THREE LISTS IN FREE FORMAT, EACH NUMBER SEPARATED   */
                /* BY COMMAS.                                                   */
                /*                                                              */
                /*****************************************************************/
                /*                                                              */
84                          GET LIST(RAINFALL);
85                          GET LIST(SURTEMP);
86                          GET LIST(SOILTEMP);
87              MONTHS:
                /*                                                              */
                /* CYCLE BY MONTHS.                                             */
                /*                                                              */
                                DO MONTH=1 TO 12;
88                              SURFACE_TEMPERATURE=SURTEMP(MONTH);
89                              SOIL_TEMPERATURE=SOILTEMP(MONTH);
90                              RAIN=RAINFALL(MONTH);
```

```
c1              ANNUALS:
                /*                                                          */
                /************************************************************/
                /*                                                          */
                /* ANNUAL GERMINATION OCCURS IN A GIVEN MONTH.              */
                /*                                                          */
                /************************************************************/
                /*                                                          */
                                IF MONTH=3 THEN
92                                 DO;
93                                 GROWTH=1;
                /*                                                          */
                /************************************************************/
                /*                                                          */
                /* THE NUMBER WHICH GERMINATE DEPENDS ON THE AMOUNT OF SEED AVAILABLE*/
                /* AND ON THE RAINFALL. IT CAN NOT EXCEED A GIVEN MAXIMUM.  */
                /*                                                          */
                /************************************************************/
                /*                                                          */
94                                    IF AVAILABLE_SEED<=MAXIMUM_SEED THEN
95                                    ANNUAL_POP=FACTOR_3*AVAILABLE_SEED;
96                                    ELSE
96                                    ANNUAL_POP=FACTOR_3*MAXIMUM_SEED;
97                                 GERMINATION=CURVE(RAIN,X1,Y1);
98                                 ANNUAL_POPULATION=ANNUAL_POP*GERMINATION;
99                                 END;
```

```
                /*                                                              */
                /******************************************************************/
                /*                                                              */
                /* ANNUALS MAY GROW UP TO A DEFINED MONTH.                      */
                /*                                                              */
                /******************************************************************/
                /*                                                              */
100                     IF MONTH>=3&MONTH<=6 THEN
101                        DO;
102                           IF MONTH=3 THEN
103                              DO;
                /*                                                              */
                /******************************************************************/
                /*                                                              */
                /* FIRST A GIVEN BIOMASS IS PRODUCED FROM EACH SEED GERMINATING.  */
                /* THIS IS INDEPENDENT OF RAINFALL.                             */
                /*                                                              */
                /******************************************************************/
                /*                                                              */
104                                 ANNUAL_BIOMASS=GROWTH_FROM_SEED*
                                                   ANNUAL_POPULATION;
105                                 AVAILABLE_SEED=0;
106                                 END;
```

```
                /*                                                              */
                /******************************************************************/
                /*                                                              */
                /* SUBSEQUENT GROWTH IS AT A RATE DEPENDING ON RAINFALL.        */
                /*                                                              */
                /******************************************************************/
                /*                                                              */
107                         ELSE
107                            DO;
108                               IF GROWTH=1 THEN
109                                  DO;
110                                  GROWTH_RATE=CURVE(RAIN,X2,Y2);
111                                  ANNUAL_BIOMASS=ANNUAL_BIOMASS*
                                                    (1+GROWTH_RATE);
112                                  END;
113                            END;
                /*                                                              */
                /******************************************************************/
                /*                                                              */
                /* WHEN A CERTAIN BIOMASS PER INDIVIDUAL IS REACHED, GROWTH STOPS */
                /* AND SEEDING OCCURS; THE SEED PRODUCED IS A LINEAR FUNCTION   */
                /* OF THE GROWTH THAT WOULD OTHERWISE HAVE BENN PRODUCED IN THAT */
                /* MONTH.                                                       */
                /*                                                              */
                /******************************************************************/
                /*                                                              */
114                         IF ANNUAL_POPULATION=0 THEN
115                         GO TO BELOW;
116                         IF(ANNUAL_BIOMASS/ANNUAL_POPULATION>=
                               SEEDING_BIOMASS) THEN
117                            DO;
118                               IF GROWTH=1 THEN
119                                  DO;
120                                  SEED_CROP=CONSTANT*ANNUAL_BIOMASS*
                                                   GROWTH_RATE;
121                                  SEEDING_MONTH=MONTH;
122                                  GROWTH=0;
123                                  END;
124                            END;
```

```
                  /*                                                                  */
                  /**********************************************************************/
                  /*                                                                  */
                  /* IN THE MONTH AFTER SEEDING, THE SEED CROP IS ADDED TO THE        */
                  /* STORE OF SEED OPEN TO HARVESTING, AND THE VEGETATIVE BODY        */
                  /* OF THE ANNUALS DISAPPEARS.                                       */
                  /*                                                                  */
                  /**********************************************************************/
                  /*                                                                  */
125                           IF MONTH=SEEDING_MONTH+1 THEN
126                              DO;
127                              AVAILABLE_SEED=AVAILABLE_SEED+SEED_CROP;
128                              ANNUAL_BIOMASS=0;
129                              END;
130                        END;
131               BELOW:   IF MONTH=7 THEN
132                        ANNUAL_BIOMASS=0;
```

```
                /*                                                              */
                /******************************************************************/
                /*                                                              */
                /* THE OTHER MATERIALS AVAILABLE TO THE HARVESTER ANTS ARE THE  */
                /* BODIES AND BODY PARTS OF INSECT SPECIES. THESE ARE PRODUCED  */
                /* AT A RATE WHICH IS TIME BASED, PLUS A PROPORTION OF THE BIOMASS */
                /* OF ANNUALS, IN EACH MONTH.                                   */
                /*                                                              */
                /******************************************************************/
                /*                                                              */
133             INSECT:
                        G=MONTH;
134                     MEAT_PRODUCTION=CURVE(G,X4,Y4)+FACTOR_1*ANNUAL_BIOMASS;
                /*                                                              */
                /******************************************************************/
                /*                                                              */
                /* THE ANTS FORAGE WHENEVER THE TEMPERATURE OF THE GROUND       */
                /* SURFACE IS ABOVE A GIVEN VALUE. THE NUMBER FORAGING IS ALWAYS */
                /* 10% OF THE TOTAL NUMBER OF ADULTS IN THE NEST.               */
                /*                                                              */
                /******************************************************************/
                /*                                                              */
135             FORAGE:         IF SURFACE_TEMPERATURE>=FORAGING_TEMPERATURE THEN
136                                DO;
```

```
                /*                                                              */
                /******************************************************************/
                /*                                                              */
                /* THE SUCCESS OF THE ANTS IN OBTAINING SEEDS (RATE/UNIT ANT    */
                /* BIOMASS) IS A FUNCTION OF THE TEMPERATURE AT THE GROUND SURFACE */
                /* AND OF THE DENSITY OF THE SUPPLY.                            */
                /*                                                              */
                /******************************************************************/
                /*                                                              */
137                         TEMP_SUCCESS_FACTOR=CURVE(SURFACE_TEMPERATURE,X7,Y7
                );
138                         SEED_SEARCH_FACTOR=CURVE(AVAILABLE_SEED,X8,Y8);
139                         SEED_FORAGING_SUCCESS=MAX_SUCCESS*
                                                 TEMP_SUCCESS_FACTOR*
                                                 SEED_SEARCH_FACTOR;
140                         SEED_HARVESTED=MAX(0,ADULT_ANTS*
                                               SEED_FORAGING_SUCCESS);
141                         SEED_HARVESTED=MIN(AVAILABLE_SEED,SEED_HARVESTED);
                /*                                                              */
                /******************************************************************/
                /*                                                              */
                /* THE INSECT HARVEST IS FOUND IN THE SAME WAY.                 */
                /*                                                              */
                /******************************************************************/
                /*                                                              */
142                         MEAT_SEARCH_SUCCESS=CURVE(AVAILABLE_MEAT,X8,Y8);
143                         MEAT_FORAGING_SUCCESS=MAX_SUCCESS*
                                                 TEMP_SUCCESS_FACTOR*
                                                 MEAT_SEARCH_SUCCESS;
144                         MEAT_HARVESTED=ADULT_ANTS*MEAT_FORAGING_SUCCESS;
145                         MEAT_HARVESTED=MIN(AVAILABLE_MEAT,MEAT_HARVESTED);
146                         END;
147                       ELSE
```

```
147                     MEAT_HARVESTED,SEED_HARVESTED,SEED_FORAGING_SUCCESS=0;
                  /*                                                        */
                  /************************************************************/
                  /*                                                        */
                  /* THE METABOLIC DEMAND OF THE TWO BIOMASS TYPES IS TAKEN TO  */
                  /* BE A Q10 TYPE (DOUBLING) FUNCTION OF TEMPERATURE. ALL LARVAE AND */
                  /* 90% OF THE ADULTS ARE SUBJECTED TO SOIL TEMPERATURES, AND 10% */
                  /* OF THE ADULTS TO SURFACE TEMPERATURES, AT ALL TIMES.       */
                  /*                                                        */
                  /************************************************************/
                  /*                                                        */
148               DEMAND:       SOIL_TEMP_EFFECT=CURVE(SOIL_TEMPERATURE,X6,Y6);
149                             AIR_TEMP_EFFECT=CURVE(SURFACE_TEMPERATURE,X6,Y6);
150                             LARVAL_DEMAND=LARVAL_BIOMASS*LARVAL_METABOLISM*
                                              SOIL_TEMP_EFFECT;
151                             ADULT_DEMAND=ADULT_ANTS*ADULT_METABOLISM*
                                             (.9*SOIL_TEMP_EFFECT+.1*AIR_TEMP_EFFECT);
152                             TOTAL_DEMAND=LARVAL_DEMAND+ADULT_DEMAND;
```

```
                /*                                                          */
                /************************************************************/
                /*                                                          */
                /* IN THIS SECTION THE HARVEST IS DISTRIBUTED AMONG ADULT ANTS,     */
                /* LARVAE, AND THE SEED STORE OF THE ANT COLONY. MEAT IS CONSUMED   */
                /* FIRST, THEN SEED; STORED SEED IS USED AFTER THAT HARVESTED.      */
                /* ONLY SEED CAN BE STORED. THE DEMAND OF ADULT ANTS IS SATISFIED   */
                /* FIRST, THEN THAT OF LARVAE. IF THAT OF ADULTS IS NOT SATISFIED,  */
                /* A DEFICIT  BETWEEN 0 AND 1 IS FOUND, AND ALSO THE DEFICIT FOR    */
                /* LARVAE IS 1. IF ADULT FOOD DEFICIT IS 0, A DEFICIT FOR LARVAE    */
                /* IS FOUND. IF BOTH DEFICITS ARE 0, ANY SURPLUS SEED IS ADDED      */
                /* TO THE SEED STORE.                                       */
                /*                                                          */
                /************************************************************/
                /*                                                          */
153                         IF TOTAL_DEMAND<=MEAT_HARVESTED THEN
154                            DO;
155                            ADULT_FOOD_DEFICIT,LARVAL_FOOD_DEFICIT=0;
156                            SEED_STORE=SEED_STORE+SEED_HARVESTED;
157                            END;
158                         ELSE
158                            DO;
159                               IF SEED_HARVESTED+MEAT_HARVESTED<TOTAL_DEMAND
                                  THEN
160                               GO TO STORES;
161                            STORE_INCREMENT=SEED_HARVESTED-
                                           (TOTAL_DEMAND-MEAT_HARVESTED);
162                            SEED_STORE=SEED_STORE+STORE_INCREMENT;
163                            ADULT_FOOD_DEFICIT,LARVAL_FOOD_DEFICIT=0;
164                            GO TO ANTS;
165                STORES:     SEED_STORE=SEED_STORE+SEED_HARVESTED;
166                            SEEDS_NEEDED=TOTAL_DEMAND-MEAT_HARVESTED;
167                               IF SEEDS_NEEDED>SEED_STORE THEN
168                                  DO;
169                                  SEED_STORE=0;
170                                  HUNGRY=TRUE;
171                                  END;
```

```
172                                  ELSE
172                                     DO;
173                                     SEED_STORE=SEED_STORE-SEEDS_NEEDED;
174                                     ADULT_FOOD_DEFICIT,LARVAL_FOOD_DEFICIT=0;
175                                     HUNGRY=FALSE;
176                                     END;
177                                  IF HUNGRY THEN
178                                     DO;
179                                     AVAILABLE_FOOD=MEAT_HARVESTED+SEED_STORE;
180                                        IF ADULT_DEMAND=0 THEN
181                                        GO TO HOP;
182                                     ADULT_FOOD_DEFICIT=1-(AVAILABLE_FOOD/
                                                             ADULT_DEMAND);
183                  HOP:                  IF ADULT_FOOD_DEFICIT<=0 THEN
184                                           DO;
185                                           ADULT_FOOD_DEFICIT=0;
186                                           AVAILABLE_FOOD=AVAILABLE_FOOD-
                                                             ADULT_DEMAND;
187                                              IF LARVAL_DEMAND=0 THEN
188                                              GO TO JUMP;
189                                           LARVAL_FOOD_DEFICIT=1-AVAILABLE_FOOD/
                                                                 LARVAL_DEMAND;
190                  JUMP:                    LARVAL_FOOD_DEFICIT=0;
191                                           END;
192                                        ELSE
192                                        LARVAL_FOOD_DEFICIT=1;
193                                     END;
194                               END;
```

```
                /*                                                              */
                /*****************************************************************/
                /*                                                              */
                /* IN THE TENTH MONTH ALL LARVAL BIOMASS IS TRANSFERRED TO      */
                /* ADULTS. MORTALITY OF THE ADULT BIOMASS IS MADE UP OF A LINEAR */
                /* FUNCTION OF THE SUCCESS IN FINDING SEED, PLUS A FUNCTION OF  */
                /* THE ADULT FOOD DEFICIT. (THE SUCCESS IN FINDING SEED IS AMONG */
                /* OTHER THINGS AN INDEX OF THE TIME SPENT EXPOSED TO VARIOUS   */
                /* RISKS.)                                                      */
                /*                                                              */
                /*****************************************************************/
                /*                                                              */
195             ANTS:
                        IF MONTH=10 THEN
196                     ADULT_ANTS=ADULT_ANTS+LARVAL_BIOMASS;
197                   STEADY_MORTALITY=FACTOR_2*SEED_FORAGING_SUCCESS;
198                   STARVATION_MORTALITY=CURVE(ADULT_FOOD_DEFICIT,X9,Y9);
199                   MORTALITY=MIN(1,STEADY_MORTALITY+STARVATION_MORTALITY);
200                   ADULT_ANTS=ADULT_ANTS*(1-MORTALITY);
                /*                                                              */
                /*****************************************************************/
                /*                                                              */
                /* LARVAL BIOMASS IS INITIATED IN THE FOURTH MONTH. ITS RATE OF */
                /* INCREASE HAS A MAXIMUM, AND OTHERWISE IS A FUNCTION OF THE FOOD */
                /* DEFICIT BEING SUFFERED, GOING NEGATIVE AT DEFICITS ABOVE     */
                /* CERTAIN VALUES. AT THE TENTH MONTH ALL LARVAL BIOMASS IS     */
                /* TRANSFERRED TO ADULTS.                                       */
                /*                                                              */
                /*****************************************************************/
                /*                                                              */
201             LARVAL:
                      IF MONTH>=4&MONTH<=9 THEN
202                     DO;
203                     LARVAL_GROWTH=CURVE(LARVAL_FOOD_DEFICIT,X5,Y5);
204                     LARVAL_BIOMASS=MAX(0,LARVAL_BIOMASS+LARVAL_GROWTH);
205                     END;
206                   IF MONTH=10 THEN
207                   LARVAL_BIOMASS=0;
```

```
                /*                                                              */
                /****************************************************************/
                /*                                                              */
                /* IT IS ASSUMED THAT THERE IS NO LOSS OF SEED ON THE GROUND OTHER  */
                /* THAN BY ANT HARVEST, AND A COMPLETE LOSS AT THE TIME OF      */
                /* GERMINATION.                                                 */
                /*                                                              */
                /****************************************************************/
                /*                                                              */
208             SEED:       AVAILABLE_SEED=MAX(0,AVAILABLE_SEED-SEED_HARVESTED);
                /*                                                              */
                /****************************************************************/
                /*                                                              */
                /* THE INSECT BODIES ARE ASSUMED TO DECOMPOSE AT A RELATIVE RATE    */
                /* DEPENDENT ON THE TIME OF YEAR.                               */
                /*                                                              */
                /****************************************************************/
                /*                                                              */
209             MEAT:       MEAT_DECOMPOSITION=CURVE(G,X3,Y3);
210                         AVAILABLE_MEAT=AVAILABLE_MEAT*(1-MEAT_DECOMPOSITION)
                                    -MEAT_HARVESTED+MEAT_PRODUCTION;
211                         AVAILABLE_MEAT=MAX(0,AVAILABLE_MEAT);
212                         PUT SKIP LIST(AVAILABLE_MEAT,AVAILABLE_SEED,SEED_STORE,
                                    ADULT_ANTS,LARVAL_BIOMASS);
213                     END MONTHS;
214                 END YEARS;
```

```
215             CURVE:     PROCEDURE(X,XVAL,YVAL)RETURNS(FLOAT DECIMAL);
                /*                                                          */
                /************************************************************/
                /*                                                          */
                /* THE PROCEDURE CURVE INTERPOLATES LINEARLY BETWEEN THE TWO */
                /* NEAREST POINTS ON A GIVEN GRAPH. IF AN X COORDINATE IS GIVEN */
                /* OUTSIDE THE RANGE OF THE XS DEFINED BY THE DATA, THE Y VALUE */
                /* WILL BE RETURNED AS THAT CORRESPONDING TO THE HIGHEST OR  */
                /* LOWEST X VALUE.                                          */
                /*                                                          */
                /************************************************************/
                /*                                                          */
216                        DCL X FLOAT DEC;
217                        DCL XVAL(*), YVAL(*);
218                        NDIM=DIM(XVAL,1);
219                           IF X<XVAL(1)|X>XVAL(NDIM)THEN
220                              DO;
221                                 IF X<XVAL(1)THEN
222                                 X=XVAL(1);
223                                 ELSE
223                                 X=(XVAL(NDIM)-XVAL(NDIM-1))*0.98+XVAL(NDIM-1);
224                              END;
225                           DO I=1 TO NDIM;
226                              IF XVAL(I)>X THEN
227                                 DO;
228                                 AM=(YVAL(I)-YVAL(I-1))/(XVAL(I)-XVAL(I-1));
229                                 C=YVAL(I)-AM*XVAL(I);
230                                 RETURN(AM*X+C);
231                                 END;
232                           END;
233                        END CURVE;
234                     END ANT;
```

ATTRIBUTE AND CROSS-REFERENCE TABLE

DCL NO.	IDENTIFIER	ATTRIBUTES AND REFERENCES
5	ADULT_ANTS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 140,144,151,196,196,200,200,212
	ADULT_DEMAND	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 151,152,180,182,186
	ADULT_FOOD_DEFICIT	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 155,163,174,182,183,185,198
	ADULT_METABOLISM	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 151
	AIR_TEMP_EFFECT	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 149,151
	AM	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 228,229,230
5	ANNUAL_BIOMASS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 104,111,111,116,120,128,132,134
	ANNUAL_POP	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 95,96,98
	ANNUAL_POPULATION	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 98,104,114,116
91	ANNUALS	STATEMENT LABEL CONSTANT
1	ANT	ENTRY,DECIMAL,FLOAT(SINGLE)
195	ANTS	STATEMENT LABEL CONSTANT 164
	AVAILABLE_FOOD	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 179,182,186,186,189
7	AVAILABLE_MEAT	AUTOMATIC,ALIGNED,INITIAL,DECIMAL,FLOAT(SINGLE) 142,145,210,210,211,211,212
5	AVAILABLE_SEED	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 94,95,105,127,127,138,141,208,208,212
131	BELOW	STATEMENT LABEL CONSTANT 115
	C	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 229,230

DCL NO.	IDENTIFIER	ATTRIBUTES AND REFERENCES
	CONSTANT	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 120
215	CURVE	ENTRY,DECIMAL,FLOAT(SINGLE) 97,110,134,137,138,142,148,149,198,203,209
148	DEMAND	STATEMENT LABEL CONSTANT
	DIM	GENERIC,BUILT-IN FUNCTION 218
	FACTOR_1	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 134
	FACTOR_2	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 197
	FACTOR_3	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 95,96
9	FALSE	AUTOMATIC,UNALIGNED,INITIAL,STRING(1),BIT 175
135	FORAGE	STATEMENT LABEL CONSTANT
	FORAGING_TEMPERATURE	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 135
	G	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 133,134,209
3	GERMINATION	AUTOMATIC,ALIGNED,INITIAL,DECIMAL,FLOAT(SINGLE) 97,98
	GROWTH	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 93,108,118,122
	GROWTH_FROM_SEED	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 104
3	GROWTH_RATE	AUTOMATIC,ALIGNED,INITIAL,DECIMAL,FLOAT(SINGLE) 110,111,120
183	HOP	STATEMENT LABEL CONSTANT 181
10	HUNGRY	AUTOMATIC,UNALIGNED,INITIAL,STRING(1),BIT 170,175,177
*********	I	AUTOMATIC,ALIGNED,BINARY,FIXED(15,0) 20,21,21,25,26,26,30,31,31,35,36,36,40,41,41,45,46,46,50,51,51,55,56 56,60,61,61,225,226,228,228,228,228,229,229

DCL NO.	IDENTIFIER	ATTRIBUTES AND REFERENCES
133	INSECT	STATEMENT LABEL CONSTANT
	#_GERMINATION_POINTS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 18,19,19,20
	#_GROWTH_RATE_POINTS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 23,24,24,25
	#_LARVAL_GROWTH_POINTS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 38,39,39,40
	#_MEAT_DECOMPOSITION_POINTS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 28,29,29,30
	#_MEAT_PRODUCTION_POINTS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 33,34,34,35
	#_MEAT_SEARCH_SUCCESS_POINTS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 53,54,54,55
	#_OF_YEARS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 82
	#_SOIL_TEMP_EFFECT_POINTS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 43,44,44,45
	#_STARVATION_MORTALITY_POINTS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 58,59,59,60
	#_TEMP_SUCCESS_FACTOR_POINTS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 48,49,49,50
190	JUMP	STATEMENT LABEL CONSTANT 188
11	LARVAE_STARVED	AUTOMATIC,UNALIGNED,INITIAL,STRING(1),BIT
201	LARVAL	STATEMENT LABEL CONSTANT
5	LARVAL_BIOMASS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 150,196,204,204,207,212
4	LARVAL_DEMAND	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 150,152,187,189
4	LARVAL_FOOD_DEFICIT	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 155,163,174,189,190,192,203
3	LARVAL_GROWTH	AUTOMATIC,ALIGNED,INITIAL,DECIMAL,FLOAT(SINGLE) 203,204

DCL NO.	IDENTIFIER	ATTRIBUTES AND REFERENCES
6	LARVAL_METABOLISM	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 150
	MAX	GENERIC,BUILT-IN FUNCTION 140,204,208,211
6	MAX_SUCCESS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 139,143
6	MAXIMUM_SEED	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 94,96
209	MEAT	STATEMENT LABEL CONSTANT
3	MEAT_DECOMPOSITION	AUTOMATIC,ALIGNED,INITIAL,DECIMAL,FLOAT(SINGLE) 209,210
6	MEAT_FORAGING_SUCCESS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 143,144
4	MEAT_HARVESTED	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 144,145,145,147,153,159,161,166,179,210
3	MEAT_PRODUCTION	AUTOMATIC,ALIGNED,INITIAL,DECIMAL,FLOAT(SINGLE) 134,210
3	MEAT_SEARCH_SUCCESS	AUTOMATIC,ALIGNED,INITIAL,DECIMAL,FLOAT(SINGLE) 142,143
	MIN	GENERIC,BUILT-IN FUNCTION 141,145,199
*********	MONTH	AUTOMATIC,ALIGNED,BINARY,FIXED(15,0) 87,88,89,90,91,100,100,102,121,125,131,133,195,201,201,206
87	MONTHS	STATEMENT LABEL CONSTANT
6	MORTALITY	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 199,200
*********	NDIM	AUTOMATIC,ALIGNED,BINARY,FIXED(15,0) 218,219,223,223,223,225
	RAIN	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 90,97,110
12	RAINFALL	(12)AUTOMATIC,ALIGNED,DECIMAL,FIXED(5,2) 84,90
208	SEED	STATEMENT LABEL CONSTANT
	SEED_CROP	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE)

DCL NO.	IDENTIFIER	ATTRIBUTES AND REFERENCES
		120,127
	SEED_FORAGING_SUCCESS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 139,140,147,197
	SEED_HARVESTED	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 140,141,141,147,156,159,161,165,208
	SEED_SEARCH_FACTOR	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 138,139
	SEED_STORE	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 156,156,162,162,165,165,167,169,173,173,179,212
	SEEDING_BIOMASS	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 116
	SEEDING_MONTH	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 121,125
	SEEDS_NEEDED	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 166,167,173
3	SOIL_TEMP_EFFECT	AUTOMATIC,ALIGNED,INITIAL,DECIMAL,FLOAT(SINGLE) 148,150,151
	SOIL_TEMPERATURE	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 89,148
14	SOILTEMP	(12)AUTOMATIC,ALIGNED,DECIMAL,FIXED(3,1) 86,89
3	STARVATION_MORTALITY	AUTOMATIC,ALIGNED,INITIAL,DECIMAL,FLOAT(SINGLE) 198,199
	STEADY_MORTALITY	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 197,199
	STORE_INCREMENT	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 161,162
165	STORES	STATEMENT LABEL CONSTANT 160
	SURFACE_TEMPERATURE	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 88,135,137,149
13	SURTEMP	(12)AUTOMATIC,ALIGNED,DECIMAL,FIXED(3,1) 85,88
	SYSIN	FILE,EXTERNAL 16,17,18,21,23,26,28,31,33,36,38,41,43,46,48,51,53,56,58,61,84,85,86

DCL NO.	IDENTIFIER	ATTRIBUTES AND REFERENCES
	SYSPRINT	FILE,EXTERNAL 63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,83,212
3	TEMP_SUCCESS_FACTOR	AUTOMATIC,ALIGNED,INITIAL,DECIMAL,FLOAT(SINGLE) 137,139,143
	TOTAL_DEMAND	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE). 152,153,159,161,166
8	TRUE	AUTOMATIC,UNALIGNED,INITIAL,STRING(1),BIT 170
216	X	PARAMETER,ALIGNED,DECIMAL,FLOAT(SINGLE) 215,219,219,221,222,223,226,230
15	X1	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 19,21,63,97
15	X2	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 24,26,65,110
15	X3	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 29,31,67,209
15	X4	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 34,36,69,134
15	X5	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 39,41,71,203
15	X6	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 44,46,73,148,149
15	X7	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 49,51,75,137
15	X8	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 54,56,77,138,142
15	X9	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 59,61,79,198
217	XVAL	(*)PARAMETER,ALIGNED,DECIMAL,FLOAT(SINGLE) 215,218,219,219,221,222,223,223,223,226,228,228,229
15	Y1	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 19,21,64,97
15	Y2	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 24,26,66,110

DCL NO.	IDENTIFIER	ATTRIBUTES AND REFERENCES
15	Y3	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 29,31,68,209
15	Y4	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 34,36,70,134
15	Y5	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 39,41,72,203
15	Y6	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 44,46,74,148,149
15	Y7	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 49,51,76,137
15	Y8	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 54,56,78,138,142
15	Y9	(*)CONTROLLED,ALIGNED,DECIMAL,FLOAT(SINGLE) 59,61,80,198
	YEAR	AUTOMATIC,ALIGNED,DECIMAL,FLOAT(SINGLE) 82,83
82	YEARS	STATEMENT LABEL CONSTANT
217	YVAL	(*)PARAMETER,ALIGNED,DECIMAL,FLOAT(SINGLE)