TEACHER'S GUIDE $.30

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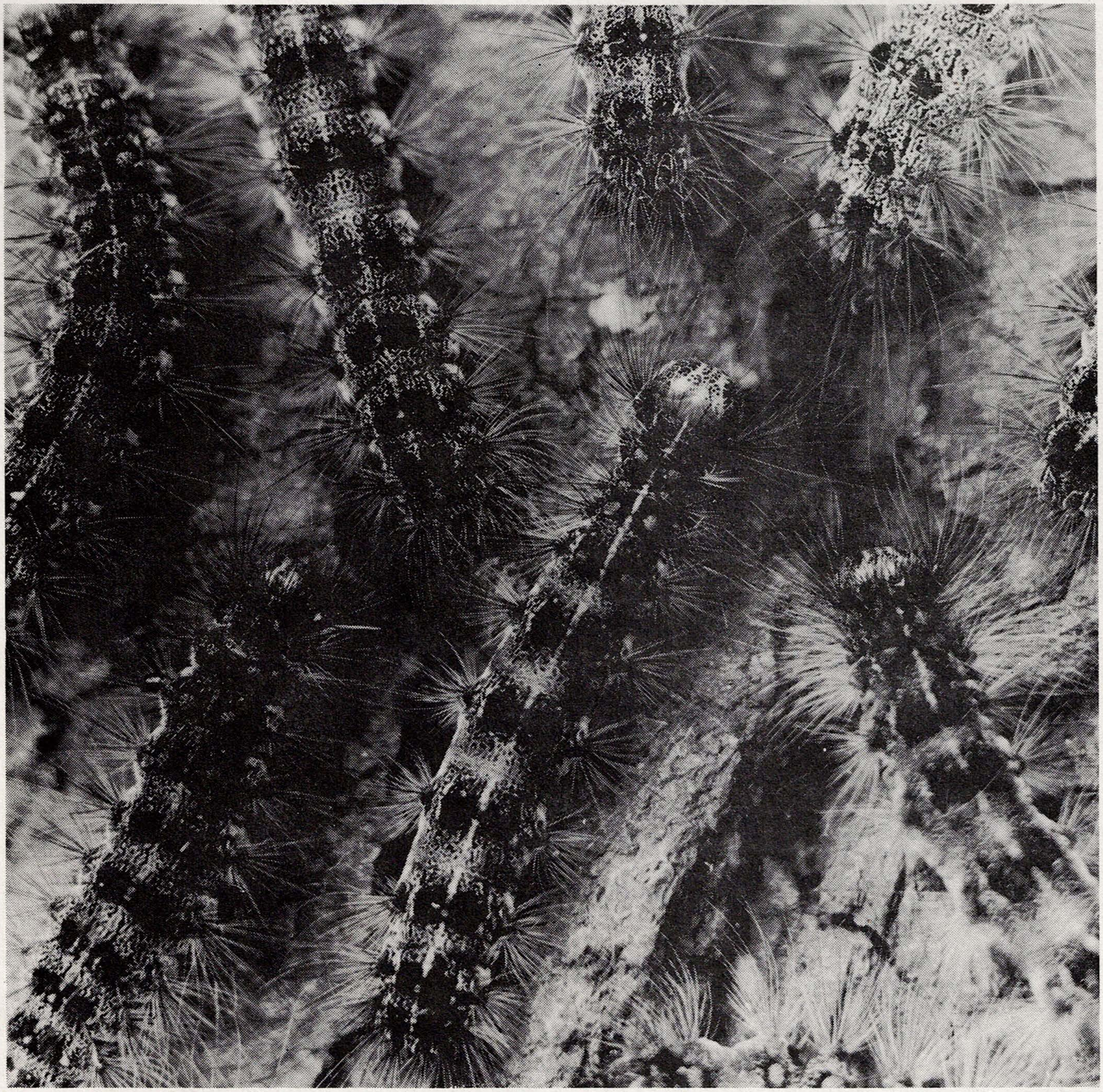

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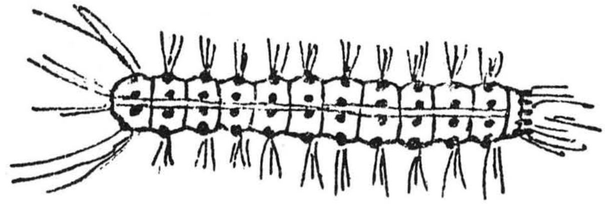

THREE MODELS OF POPULATION GROWTH

# POP

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T E A C H E R

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Developed by:

L. Braun, State University of New York,
Stony Brook, New York
J. Friedland, D. MacArthur High School
Levittown, New York

Programmed by:

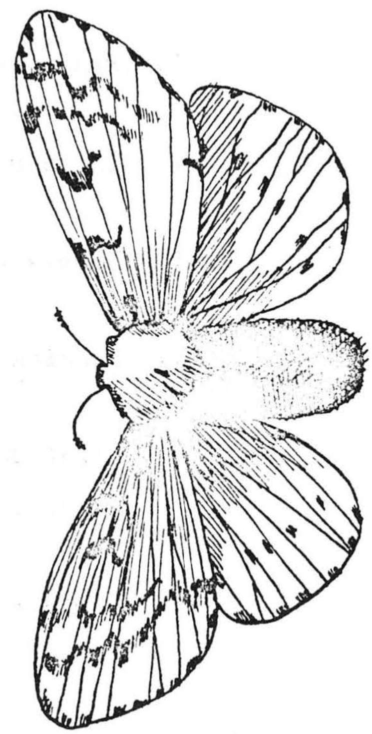
L. Braun
J. Friedland
S. Hollander, State University of New York

Support Material by:

J. Friedland
K. Moy, State University of New York

Illustrations by:

M. Youla, State University of New York



HUNTINGTON TWO COMPUTER PROJECT

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30 March 1973

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*POP SERIES*

TEACHER MANUAL

Table of Contents

# *POP SERIES*

## TEACHER MANUAL

## I. BASIC INFORMATION ABOUT THE UNIT

Subject Area: Biology

Specific Topic: Population Growth Modeling

Grade Level: 10 - 12

Coordinated Computer Programs: POP 1, POP 2, POP 3

Computer Language: BASIC

Abstract: The *POP SERIES* programs are designed to allow a student with little mathematical background to explore various simple mathematical models of population growth. Student exercises revolve about studies of the growth of a gypsy-moth population. The gypsy moth was chosen as the primary animal for investigation because of its current ecological interest as an important species with few natural enemies and because its population meets the assumptions of the models presented in the *POP SERIES*.

The following models are explored in the *POP SERIES*.

*POP1* - simple exponential growth (population explosion)

*POP2* - logistic model (environmental limiting factor)

*POP3* - logistic model with a low-density modification

Each of these programs is general enough so that it can be used to model other plant and animal populations. The necessary information for using the *POP SERIES* programs with a number of other organisms can be found in the *RESOURCE MANUAL*.

## II. INTRODUCTION TO TEACHER MANUAL

The materials in this section were written under the assumption that you will be using the *STUDENT MANUAL* as the first part of the documentation for the programs. For other applications of the POP Series programs, please skip first to the *RESOURCE MANUAL*.

All students are concerned with the future world in which they will have to live. Often they read or hear predictions of the vast populations that will be present by the year 2000:

> "Today there are some three billion human beings on the planet. About 270,000 infants are born daily, or a population increase every month equivalent to that of Chicago...this sort of population cannot continue much longer...by the year 2000 the world's population would double today's."*

How are such figures arrived at? The POP Series attempts to acquaint students with the strengths, as well as the weaknesses, of population projection by examining how three different population-growth models give vastly different projections for a sample population's growth. At the same time the student is introduced to the concept of successive refinement of a model, since each successive POP Series model is a refinement of the previous model.

While the whole POP Series used together provides an introduction to population modeling, the POP programs can also be used separately. For example, a teacher currently presenting the Malthusian Theory might elect for his students to study only POP1, since the POP1 model gives the geometrical increase that Reverend Malthus predicted for population growth. More information on these single applications appears in the *RESOURCE MANUAL*.

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*From *ECOLOGY*, Peter Farb and editors of Time-Life Books. Time-Life Books, New York, 1969, p.167.

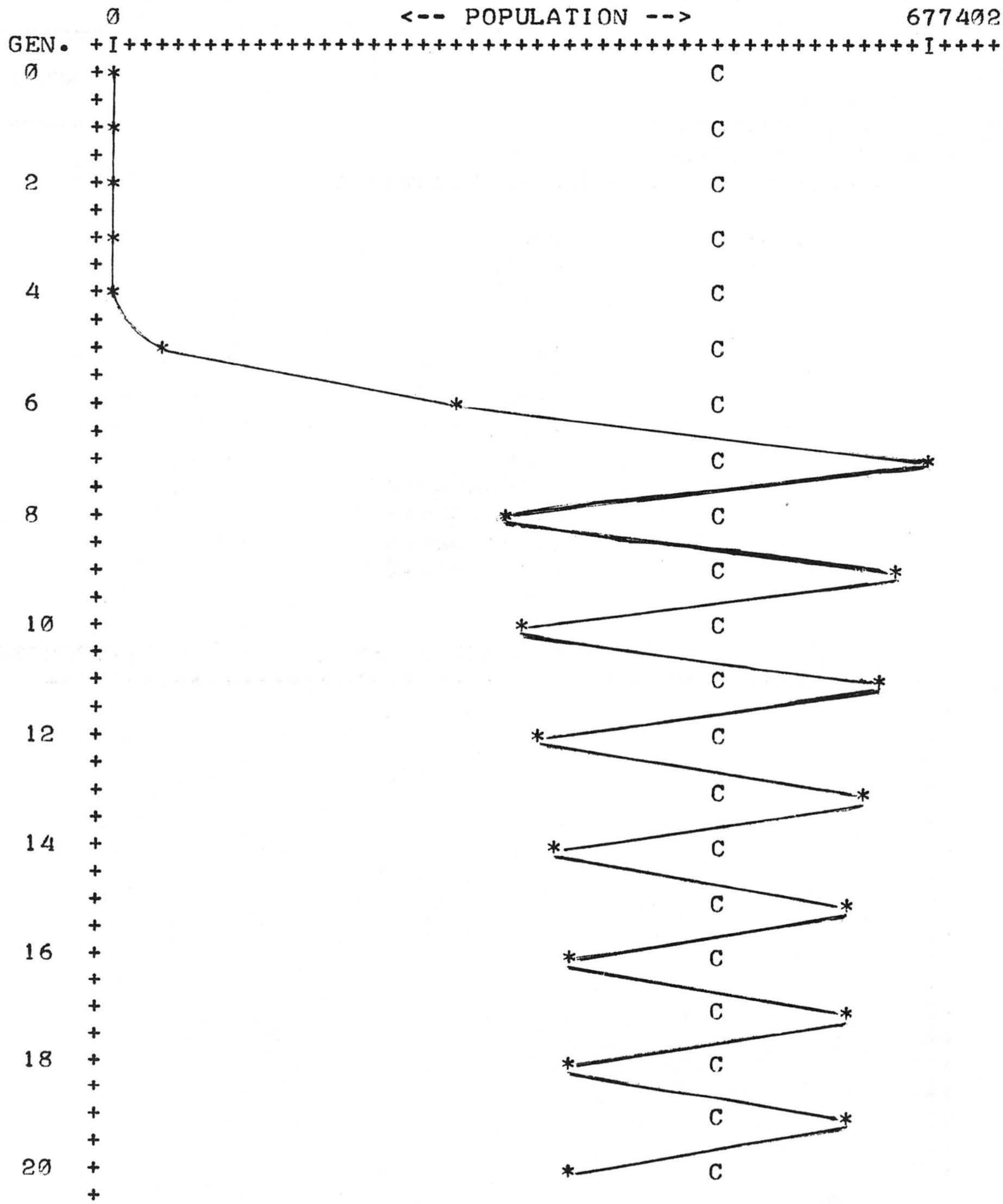
*NOTE: THE FOLLOWING ARE ANSWER RUNS TO THE 3 PROBLEMS POSED IN THE STUDENT MANUAL. THE INDIVIDUAL POINTS ON EACH GRAPH HAVE BEEN CONNECTED FOR EASY VIEWING.*

RUN 1

```
RUN

                 POPULATION GROWTH SIMULATION

WHICH POPULATION MODEL? (1, 2, OR 3). TYPE IN NUMBER? 1


P(Ø)=? 2
REPRO.RATE=? 7.5
TIME UNIT PER GENERATION? 1
NO. OF GENERATIONS? 1Ø
OUTPUT DESIRED: 1=TABLE, 2=GRAPH, 3=BOTH? 3

GEN.            TIME            POP.
------          ------          ------
 Ø               Ø               2
 1               1               15
 2               2               113
 3               3               844
 4               4               6328
 5               5               47461
 6               6               355957
 7               7               2.669678E+6
 8               8               2.002258E+7
 9               9               1.501694E+8
 1Ø              1Ø              1.126270E+9

     Ø                  <-- POPULATION -->                 1.12627ØE+9
GEN. +I+++++++++++++++++++++++++++++++++++++++++++++++++I++++
 Ø   +*
     +
     +*
     +
 2   +*
     +
     +*
     +
 4   +*
     +
     +*
     +
 6   +*
     +
     +*
     +
 8   +*
     +
     +      *
     +
 1Ø  +                                                  *
     +

ANOTHER RUN? (YES=1, NO=Ø)? 1
```

```
WHICH POPULATION MODEL? (1, 2, OR 3). TYPE IN NUMBER? 2

P(Ø)=? 2
REPRO. RATE=? 7.5
TIME UNIT PER GENERATION? 1
CARRYING CAPACITY? 5ØØØØØ
NO. OF GENERATIONS? 2Ø
OUTPUT DESIRED: 1=TABLE, 2=GRAPH, 3=BOTH? 2
```

RUN 2




```
ANOTHER RUN? (YES=1, NO=Ø)? 1
```

RUN 3(a)

```
WHICH POPULATION MODEL? (1, 2, OR 3). TYPE IN NUMBER? 3

P(Ø)=? 2
REPRO. RATE=? 7.5
TIME UNIT PER GENERATION? 1
CARRYING CAPACITY? 5ØØØØØ
AT WHAT POP. ARE LOW DENSITY EFFECTS FIRST NOTED?  1ØØ
NO. OF GENERATIONS? 1Ø
OUTPUT DESIRED: 1=TABLE, 2=GRAPH, 3=BOTH? 3

GEN.          TIME          POP.
------        ------        ------
 Ø             Ø             2
 1             1             1
 2             2             Ø             POPULATION DIED OUT

      Ø                <-- POPULATION -->                 2
GEN. +I++++++++++++++++++++++++++++++++++++++++++++++++++I++++
 Ø   +                                                    *
     +
     +                         *
     +
     +*     POPULATION DIED OUT

ANOTHER RUN? (YES=1, NO=Ø)? 1
```

RUN 3(b)

```
WHICH POPULATION MODEL? (1, 2, OR 3). TYPE IN NUMBER? 3


P(Ø)=? 5
REPRO. RATE=? 7.5
TIME UNIT PER GENERATION? 1
CARRYING CAPACITY? 5ØØØØØ
AT WHAT POP. ARE LOW DENSITY EFFECTS FIRST NOTED?  1ØØ
NO. OF GENERATIONS? 1Ø
OUTPUT DESIRED: 1=TABLE, 2=GRAPH, 3=BOTH? 1

GEN.          TIME          POP.
------        ------        ------
 Ø             Ø             5
 1             1             5
 2             2             5
 3             3             5
 4             4             5
 5             5             5
 6             6             5
 7             7             5
 8             8             5
 9             9             5
 1Ø            1Ø            5

ANOTHER RUN? (YES=1, NO=Ø)? 1
```

WHICH POPULATION MODEL? (1, 2, OR 3). TYPE IN NUMBER? 3

RUN 3(c)

P(Ø)=? 6
REPRO.RATE=? 7.5
TIME UNIT PER GENERATION? 1
CARRYING CAPACITY? 500000
AT WHAT POP. ARE LOW DENSITY EFFECTS FIRST NOTED? 100
NO. OF GENERATIONS? 10
OUTPUT DESIRED: 1=TABLE, 2=GRAPH, 3=BOTH? 1

| GEN. | TIME | POP. |
|---|---|---|
| Ø | Ø | 6 |
| 1 | 1 | 7 |
| 2 | 2 | 1Ø |
| 3 | 3 | 19 |
| 4 | 4 | 62 |
| 5 | 5 | 393 |
| 6 | 6 | 2943 |
| 7 | 7 | 21812 |
| 8 | 8 | 149825 |
| 9 | 9 | 614375 |
| 1Ø | 1Ø | 387492 |

ANOTHER RUN? (YES=1, NO=Ø)? Ø

## IV. RUNNING POP SERIES PROGRAMS

The POP series programs are supplied on a single paper tape; however, each program functions independently of the others and can be used separately.

POP1 is a simple exponential (Malthusian) model.

POP2 is a logistic model, with a density-dependent limiting factor.

POP3 is a modified logistic model with a low-density correction that limits reproduction of the population at very low population densities.

Since instructions within the body of the computer program are minimal, it is essential that the materials in the *STUDENT MANUAL* be used along with the program. This holds true even if some plant or animal population other than the gypsy moth is used. In addition to instructions the *STUDENT MANUAL* includes background information, input sheets, and follow-up questions for each program.

Each program will begin by asking a certain number of questions. Explanations of these questions are found in the *STUDENT MANUAL*. Once these questions have been answered, the computer program carries out all the necessary mathematical operations and outputs the population information either as a chart, a graph or both. The chart is more accurate, but the graph displays dramatically the explosive nature of the gypsy moth's population growth.

To aid in the input of correct answers to the computer question, student input sheets have been designed. These are found in the appropriate sections of the *STUDENT MANUAL*.

## V. USING THE POP SERIES PROGRAMS IN THE CLASSROOM

### A. Necessary Background for Students

1. Concept of a biological population

2. Concept of a generation

   generation time - the time necessary for a generation to produce its own offspring (the next generation).

3. Concept of birthrate

   a) When the birthrate exactly equals the deathrate, population size should stabilize. (This is only true in simple populations such as the gypsy moth; in man's case the situation is not this simple.)

b) The POP series use of *birthrate* refers to the average number of offspring each individual will contribute to the next generation:

i) If the population is half male, the average number of offspring per female will have to be divided in half.

*Example:* If in Town A, every female dog has about 14 puppies in her lifetime, the average birthrate is 15/2 or 7.5 puppies per dog per generation.

ii) If the birthrate equals one, each individual is just being replaced in the next generation. This means population size will be constant.

4. Concept of exponential growth

(Optional - your students may be allowed to develop their own ideas during investigation of the POP model.)

B. Classroom Use

The *POP SERIES* programs were designed with three possible approaches in mind: 1) as a classroom tool; 2) as a laboratory; and 3) for individual or small group usage, perhaps as extra work. While we agree that we have not been totally successful in all these areas, we think that you will find at least one of the above approaches satisfactory with your students.

1. As a classroom tool - The POP Series programs have been made as general as possible. While the objective of the entire series is to have students develop a critical sense about population projection, any single part of the series may provide the teacher with a valuable demonstration tool within the classroom. A possible example of this might revolve about the Malthusian concept of geometrical growth in population. While a teacher may attempt to give an example of this type of growth, the students generally will pose "What if..." types of questions. If the teacher has POP1 available to him in the classroom, many of these "what if" questions can be answered. (Data for possible animals that a teacher may wish to use with POP1 are given on pages 15-16 of the *RESOURCE MANUAL*.)

2. As a laboratory - There are several approaches that have proved useful for different teachers. Some teachers will find it easiest to use a POP Series program in conjunction with another laboratory, rotating the class through each set of exercises over several laboratory periods. Other teachers will prefer to have their entire class use a single POP Series program within a laboratory session. POP Series materials were designed in such a way that either approach could be attempted.

   a) Rotation with another experiment - It should be possible for you to devote a majority of your time to the bulk of the class carrying out the regular laboratory, especially if your students have used a computer simulation previously. Those students doing the POP Series laboratory should be issued the *STUDENT MANUAL* at least one day before the lab period. In that time they should design their inputs on the computer input sheets (see *STUDENT MANUAL*) so that they will be prepared to start when they enter the lab. After using the computer, they can answer the follow-up questions and submit the package as a laboratory report to you.

   b) Laboratory for the entire class - Instead of attempting the entire POP Series, it is suggested that you attempt one program at a time. (It is best to start with POP1.)

      Divide the class into small groups, and issue to the students the portion of the *STUDENT MANUAL* to be covered in lab; this should be done at least one day before the lab session. If the students design their inputs on the computer input sheets before class, each student should be able to receive and interpret his results during a single laboratory session. In addition to the laboratory report, you might have your students ask for a tabular output in each case in addition to the computer graph. This will allow students to regraph the results in a more conventional form and yield more accurate graphs at the same time. (This activity will also give groups that have had first access to the computer something useful to do in the meantime.)

      If you feel it important that each group have a different problem, you may be interested in alternative model animals listed in the *STUDENT MANUAL* and on pages 15-16 of the *RESOURCE MANUAL*.

3. With individual students or small groups of students on their own - The *STUDENT MANUAL* should be sufficient for the student with average ability to function on his own, if he has had any experience with other simulations. For students of average ability, investigations using the POP Series programs with other animals may prove interesting and enlightening. Suggestions for other animal populations to model can be found on pp. 15-16 of the *RESOURCE MANUAL*.

## VI. OUTCOME FOR THE POP SERIES

A. Correct Inputs for POP1 (If using gypsy-moth problem)

*QUESTION:* Starting with one male and one female gypsy moth, how many generations will be required to produce 10,000 offspring in a single generation? Assume that the female moth lays 15 eggs that hatch and that these young live one year.

| Computer Question | Correct Input | |
|---|---|---|
| P(Ø)? | 2 | |
| REPRO. RATE? | 7.5 | (*NOTE:* answer equals 15/2 since one half of the population is male.) |
| TIME UNIT PER GENERATION? | 1 | (Year is understood) |
| NO. OF GENERATIONS? | | Any number greater than 4 and less than 20 |
| OUTPUT DESIRED: 1=CHART, 2=GRAPH, 3=BOTH? | 1, 2, or 3 | |

*ANSWER FOR POP1 STUDENT QUESTION*

The 5th generation of offspring will be greater than 10,000. The actual number in the 5th generation will be over 47,000. (See Sample Run 1 (p.3) for the actual output for the above.)

Suggested answers to POP1 questions: (It is important to note that these are only *examples* of correct responses.)

1) *AS WE SAID BEFORE, EVERY MODEL MUST LEAVE CERTAIN ASPECTS OF A PROBLEM OUT. SOMETIMES THE ASPECTS LEFT OUT ARE SO IMPORTANT THAT THE ANSWER THE MODEL GIVES IS NOT REALISTIC. DOES THE ANSWER TO THE POPULATION PROBLEM GIVEN BY POP1 SEEM REALISTIC? WHY OR WHY NOT?*

After the 6th generation, there are over a million gypsy moths in the 10-square-mile forest. This would lead to severe food shortages and the population growth would have to slow.

2) *IF YOU FELT THE SOLUTION OFFERED BY POP1 WAS UNREALISTIC, WHAT ASPECTS OF POPULATION CONTROL SHOULD BE ADDED TO THE MODEL TO MAKE IT GIVE A REALISTIC ANSWER? (YOU MAY WISH TO REREAD THE INTRODUCTION TO POP1.)*

(Answer for this question depends on the responses above.) A necessary corrective factor could limit high populations in some way. (This is actually done by limiting the reproductive capacity at high population densities.)

3) *THE MODEL THAT POP1 IS BASED ON IS CALLED THE EXPONENTIAL MODEL OF POPULATION GROWTH. DOES POPULATION GROW AT AN EVEN RATE USING THIS MODEL?*

No, the rate of population growth, while constant, causes the population to grow at an ever-increasing number per unit time.

4) *EXPLAIN IN YOUR OWN WORDS HOW POPULATION GROWS USING THE EXPONENTIAL GROWTH MODEL.*

Any answer that indicates that population grows slowly at first and then more rapidly as time goes on should be acceptable.

5) *DO YOU THINK THAT IT WOULD BE FAIR TO USE THE EXPONENTIAL MODEL TO FORECAST MAN'S POPULATION 100 YEARS FROM NOW? WHY OR WHY NOT?*

This is a matter of opinion among demographers; it is included to stimulate discussion.

B. Correct Inputs for POP2 (If using gypsy-moth problem)

*QUESTION:* Starting again with two gypsy moths, one male and one female, how will the population vary over twenty generations, if the forest in which they live has enough food to support only 500,000 moths? The female moth produces about 15 eggs that survive the winter to hatch and reproduce the next year. The life span is only one year.

| Computer Question | Correct Input |
|---|---|
| P(O)? | 2 |
| REPRO. RATE? | 7.5 (See POP1) |
| TIME UNIT PER GENERATION? | 1 |
| CARRYING CAPACITY? | 500000 (Make sure no commas are used) |
| NO. OF GENERATIONS | 20 |
| OUTPUT DESIRED: 1=CHART, 2=GRAPH, 3=BOTH? | 1, 2, or 3 |

*SAMPLE ANSWER FOR POP2 QUESTION*

Every time the population exceeds the carrying capacity, the population for the next year drops below the carrying capacity. At this point the cycle repeats itself. (See Sample Run 2.)

*Suggestion:* Have the students select either the graph output or the graph and table (output selection #3), since this question is involved with a pattern of growth. Once they have the output, suggest to them that they connect the points on the graph. (This makes the pattern much clearer.)

It may be necessary to explain that with computer graphs, points are only approximate; that is, if a point is on the zero line the number may be near zero, but not necessarily equal to zero. The point marked by "C" on the graph is the carrying capacity.

Suggested answers to POP2 questions

1) *DOES THE POP2 MODEL GIVE A MORE REALISTIC PREDICTION OF POPULATION CHANGE THAN POP1? WHAT IS STILL UNREALISTIC ABOUT THE MODEL?*

POP2 gives a more realistic answer than POP1, but the answer is still unrealistic. For instance, the overpopulation of moths should reduce the carrying capacity of the forest as trees will be destroyed.

2) *IN OUR PROBLEM, THE LIMITING FACTOR WAS FOOD SUPPLY. DO GYPSY MOTHS, WHO LIVE BY EATING THE LEAVES FROM TREES, EVER REACH THIS LIMITING FACTOR? (SOME READING IN THE LIBRARY MAY BE NECESSARY. IF THERE ARE NO GYPSY MOTHS IN YOUR AREA.)*

Yes, many areas of New England and certain areas in the Mid-Atlantic and Midwestern States have been defoliated by the gypsy moth. (See bibliography for references in periodical literature.)

3) *IN REALITY, ARE THE LIMITING FACTORS THE SAME ALL YEAR ROUND FOR AN ANIMAL SUCH AS THE GYPSY MOTH? HOW WOULD THEY CHANGE?*

No, not always. For example, in certain seasons such as spring, food might be more available than in the summer or the fall. This would mean a lower carrying capacity in the summer or the fall.

4) *ARE ALL LIMITING FACTORS IN THE ENVIRONMENT DENSITY-DEPENDENT?*

No. An example of a density-independent limiting factor would be one that would affect populations of any size in the same manner. An example of this might be the temperature.

5) *IF YOU INVESTIGATED THE POP2 MODEL FURTHER, WHAT DIFFERENCES DID YOU FIND BETWEEN SPECIES WITH LOW RATES OF REPRODUCTION AND SPECIES WITH HIGH RATES, SUCH AS THE GYPSY MOTH?*

Answer would depend on which animals were investigated.

C. Correct Inputs for POP3 (If using gypsy-moth problem)

*NOTE:* POP3 requires student investigation. To arrive at a correct solution to the following question, several trial runs will be required; thus this program may not be appropriate for a class laboratory.

*QUESTION:* What's the smallest number of moths that will result in a growing population during the first 5 years?

To answer this question you need the following information. In our particular forest it has been estimated that 100 moths are required for easy mate location. Each female moth lays about 15 eggs that hatch to form the next generation. Each generation takes one year. There is enough food to support 500,000 moths.

*NOTE: THIS QUESTION HAS BEEN INCLUDED TO ALLOW CONTINUITY OF SUBJECT FOR THE ENTIRE POP SERIES. A FIGURE FOR THE REQUIRED MINIMUM DENSITY IN THE CASE OF THE GYPSY MOTH IS NOT AVAILABLE. IF ACCURACY IS MORE IMPORTANT THAN CONTINUITY, SEE P.17 IN THE RESOURCE MANUAL FOR ALTERNATE ORGANISMS FOR POP3 MODELING.*

| Computer Question | Correct Input | |
|---|---|---|
| P(Ø)? | ____ | (Any number that the student feels might be an answer to the question.) |
| REPRO. RATE? | 7.5 | |
| TIME UNIT PER GENERATION? | 1 | (Year) |
| CARRYING CAPACITY? | 500000 | (Make sure no commas are used ) |
| AT WHAT POPULATION ARE LOW-DENSITY EFFECTS FIRST NOTED? | 100 | (No commas) |
| NO. OF GENERATIONS? | ____ | (5 or more; any number acceptable) |
| OUTPUT DESIRED: 1=CHART, 2=GRAPH, 3=BOTH? | 1 or 3 | desirable (any response allowable) |

*SAMPLE ANSWER FOR POP3 QUESTION*

Any population of less than 5 dies out. A population of 5 organisms remains at that number. A population of 6 organisms results in growth. (See Sample Runs 3a, b, and c.)

Suggested answers to the POP3 questions

1) *IF THE POP3 MODEL IS ACCURATE IN ITS PREDICTION OF POPULATION CHANGE, IS IT NECESSARY TO KILL ALL THE ANIMALS IN A POPULATION IN ORDER TO KILL THE POPULATION OFF? WHY?*

According to POP3, it is not necessary to kill every animal to cause the population to die off. If the population is reduced to very low levels, low-density effects may cause the extinction of the population without any additional slaughter.

2) *WHAT OTHER PROBLEMS BESIDES MATING MIGHT ANIMALS (OR PLANTS) HAVE AT LOW DENSITIES?*

Animals that use large numbers for protection would have problems at low densities. Also animals with complex social organizations, such as man or the bee, would have low-density problems if there were too few individuals to fill the necessary roles in the society.

3) *HOW DO MANY WILD POPULATIONS, SUCH AS DEER OR BUFFALO, AVOID THE PROBLEMS OF LOW MATING DENSITIES?*

Deer and buffalo keep their densities high, either by herding or by congregating in certain locations at mating seasons. (Many other species exhibit such grouping activities; have students investigate to see if the reasons for these activities might be to avoid low-density problems.)

4) *WHAT OTHER REFINEMENTS DO YOU THINK WOULD BE NECESSARY BEFORE POP3 COULD BE USED TO ACCURATELY PREDICT THE POPULATION OF MAN IN THE YEAR 2000?*

Man does not live for just one generation; neither are all the children produced in a single year. Other modifications which could be made include the following:

a) A life span factor

b) A changing limiting factor

c) A factor for the number of people not having families

d) A factor for the time after birth that marriage takes place.

*Many other modifications should be suggested by the students. The objective of this question is to demonstrate that modeling human populations is a vastly difficult enterprise even with the help of computers.*