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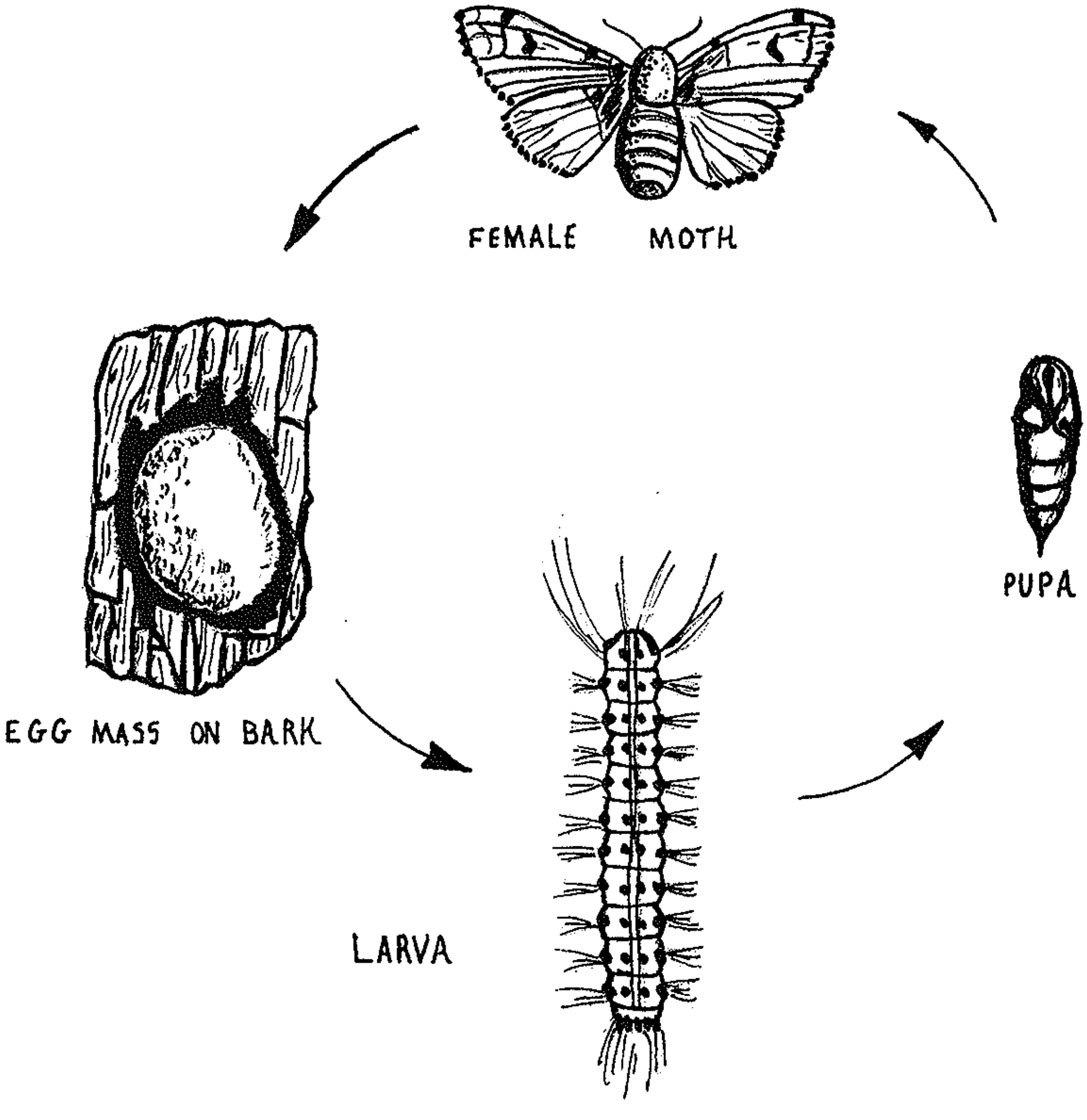
THREE MODELS OF POPULATION GROWTH

POP

STUDENT MANUAL



HUNTINGTON TWO COMPUTER PROJECT

30 March 1973

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POP SERIES

STUDENT MANUAL

We are all interested in what will happen in the future. Can anyone foretell the future? We have all been told that that is impossible. Then how can newspapers make predictions on the population in the year 2000? Are these numbers true or false?

Obviously we will not know how true these projections are for many years, but it is possible to get some idea about their accuracy by examining how such projections are made. All projections are based on models. Just as a model airplane reflects many aspects of a real airplane, population models must take into account those things which influence populations in the real world.

A model airplane cannot be a true copy of the real thing. We wouldn't want a model airplane to be true to size, instrumentation, controls, etc. It would make the model too expensive and very hard to handle. The same is true of our population models. We must leave out many aspects of actual populations if we are to understand and handle the problem of making a prediction of future population size. Will leaving these aspects out seriously affect the accuracy of our prediction?

We have included three different models for you to examine. Each successive model incorporates an additional factor that might affect the population. Do these modifications affect the answer? in what ways?

POPULATION GROWTH MODEL #1 — POP1

POP1 is based on a very simple model of population growth. The name given to this model is the exponential model. The population model includes birth rate (and death rate), number of offspring, and the time necessary for each generation to mature.

While these are all important factors, there are many factors that are not included in this model. Such factors as the amount of food and water, the quality of the environment, the amount of living space, etc., are not considered. For this reason it is said that the exponential model of population growth allows growth without limit.

Using *POP1* - Before we can ask the computer to apply the exponential model and make a prediction as to the future population size of a plant or animal species, it is necessary to supply the computer with certain information on current conditions. When you ask the computer to RUN the program, the computer will ask:

P(Ø) = ? Refers to the population at the current time (time = 0).

REPRO. RATE? Refers to the *average* number of offspring that each individual in the population can be expected to produce for the next generation.

The key word is *average* number. For example, if in Town B each woman will have 4 children, what will be the reproductive rate? The answer is 2, since women make up only half of the population and we must divide the number of offspring by 2 in order to get the reproductive rate (offspring per person).

TIME UNIT PER GENERATION?
Refers to the time necessary for individuals to produce offspring of their own.

NO. OF GENERATIONS?
Refers to the number of generations into the future for which you want the population projected.

OUTPUT DESIRED: 1=CHART, 2=GRAPH, 3=BOTH?
Refers to the format of the output. The chart is more accurate, but the graph is better for understanding patterns of population change.

(NOTE: FOR EASE OF VIEWING, BE SURE TO TURN THE GRAPH SIDEWAYS.)

Here is the necessary information for a few animals that you may wish to investigate with POP1:

ANIMAL	REPRO. RATE	GENERATION TIME
Fruit Fly	about 250	about 12 days
Elephant	about 5	about 10 years
Bacteria	2	about 20 minutes

Your Problem - You may work on the sample problem given below or on another problem assigned by your teacher. After you have completed this task, you might try solving the same problem for some of the animals listed above.

Starting with one male and one female gypsy moth, how many generations will be required to produce 10,000 offspring in a single generation?

To be able to answer this question, you will need the following information:

The female gypsy moth lays about 15 eggs per season that survive to mate in the next generation. The adults generally live only one season, so that the time unit per generation is equal to one year.

Before you go to the computer, you can prepare your inputs using Input Chart #1.

INPUT CHART #1 (USE ONLY WITH POP1)

ANIMAL OR PLANT BEING MODELED ____________________

Computer Input	Meaning	Correct Input
P(Ø)	Population at the beginning of the population study.	________
REPRO. RATE	Number of offspring produced by each female (divide by 2 if half of population is male).	________
TIME UNIT PER GEN.	Number of years (or weeks, or days) necessary for the females to produce offspring.	________
NO. OF GENERATIONS	The number of generations you want the computer to project into the future.	________
OUTPUT DESIRED: 1=CHART 2=GRAPH 3=BOTH	The chart gives more accurate numbers; the graph gives a better idea of patterns.	________

When you have completed this chart and checked it with your teacher (if necessary), you are ready to run the program POP1.

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Some questions about POP1 results:

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?

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.)

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?

4) Explain in your own words how population grows using the exponential growth model.

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?

Population model #1, the exponential growth model, included only the very basic aspects of population control in making its projection. You may have noticed that many factors that are important in determining population size were left out.

POP1 allowed population growth *without limit;* but even in our everyday existence it is clear that limits almost always exist. For example, a population of deer cannot grow without limit. There is only a limited amount of food; there may be a limited amount of shelter or water for them. POP2 uses an exponential model that incorporates the idea of limiting factors. The term *limiting factors* is used to refer to these limits to growth.

In our example of the deer, we noted three possible limiting factors: food supply, shelter and water. These are examples of *density-dependent limiting factors*. When the population is low, the density-dependent limiting factors do not affect the population since there will be plenty of food, etc. But as the population increases, so do the effects of such limiting factors; and fewer and fewer offspring will be able to survive to reproduce in future generations.

When the limiting factor that is in shortest supply is being fully used by the population, no extra organisms can be added without serious consequences to the group as a whole. The population size at which the limiting factor is being consumed at the same rate that it is being produced is called the *carrying capacity*.

The POP2 model is called the *logistic model*. The logistic model behaves quite differently with different populations. If you wish to understand this model fully, it is important that you try several different organisms. But first you may want to continue with the gypsy-moth problem.

As you saw in POP1, the gypsy-moth population grows explosively when there is no limiting factor. What happens to such a population when it nears the carrying capacity?

Your Problem - Again starting with two gypsy moths, one male and one female, how will population size vary over ten generations, if the 10-square-mile forest in which the moths live can support only 500,000 moths?

Remember that each female moth produces about 15 eggs which survive to reproduce, and that the life span is only one year.

Before you try this model you may want to enter your inputs on Input Chart #2.

INPUT CHART #2 (USE ONLY WITH POP2)

ANIMAL OR PLANT BEING MODELED ______________________________

Computer Input	Meaning	Correct Input
P(Ø)	Population at the beginning of the population study.	________
REPRO. RATE	Number of offspring produced by each female (divide by 2 if the population is half male and half female).	________
TIME UNIT PER GEN.	Number of years (or weeks, or days) necessary for the females to produce offspring.	________
CARRYING CAPACITY	The size of the population that uses up the limiting factor as fast as it becomes available. *(BE SURE TO USE NO COMMAS IN INPUTTING THIS FIGURE.)*	________
NO. OF GENERATIONS	The number of generations you want the computer to project into the future.	________
OUTPUT DESIRED: 1=CHART 2=GRAPH 3=BOTH		________

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Some questions about POP2 results:

1) Does the POP2 model give a more realistic prediction of population change than POP1? What is still unrealistic about the model?

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.)

3) In reality, are the limiting factors the same all year round for an animal such as the gypsy moth? How would they change?

4) Are all limiting factors in the environment density-dependent?

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?

As we said at the beginning of this manual, each new model would include a new feature that might be important in producing a more accurate prediction of population change. POP1 examined how a population would grow without limiting factors. POP2 examined the effect of a limiting factor in the environment on population growth. POP3 adds another consideration: low-density problems -- i.e., problems associated with populations that are too small.

Let's return to our gypsy-moth problem. In each case, we started with only two moths (one male and one female) in a whole forest. If the male and the female were released in distant locations, what is the chance that the male would find the female in time to mate? Even though the moths are equipped with a very good system for mate location (as your teacher may have told you), it would seem that the chances of mating would not be good. This is a problem of low mating density. When there are many in the population, the density is said to be high and mates are easy to find; when there are few in the population and the density is low, mate location can be very difficult. In addition to mating problems, what other problems arise for populations at low densities?

When you run POP3, the computer will ask for the following additional piece of information, so that it may figure out the low mating-density effect:

AT WHAT POPULATION ARE LOW-DENSITY EFFECTS FIRST NOTED?

This means that the computer is asking for the minimum number of moths that are required for mating to occur easily.

Your Problem - What is the lowest number of moths that will result in a growing population, in the first five years?

To answer this question, you need the following information:

In our particular 10-square-mile forest, it is estimated that 100 moths are required for easy mate location. Under ideal conditions, each female lays about 15 eggs that will hatch for the next generation. Each generation takes one year. There is enough food to support 500,000 moths.

Before using the computer, you can map out your inputs for POP3 on Chart #3.

INPUT CHART #3 (USE ONLY WITH POP3)

ANIMAL OR PLANT BEING MODELED ______________________________

Computer Input	Meaning	Correct Input
P(Ø)	Population at the beginning of your problem.	________
REPRO. RATE	Number of offspring produced by each female (divide by 2 if the population is half male and half female).	________
TIME UNIT PER GEN.	Number of years (or weeks, or days) necessary for females to produce the next generation of offspring.	________
CARRYING CAPACITY	The size of the population that just uses up the limiting factor.	________
AT WHAT POPULATION ARE LOW-DENSITY EFFECTS FIRST NOTED	What is the size of the population necessary for easy mate location?	________
NO. OF GENERATIONS	The number of generations you want the computer to project into the future.	________
OUTPUT DESIRED: 1=CHART 2=GRAPH 3=BOTH		________

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Some questions about POP3 results:

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?

2) What other problems besides mating might animals (or plants) have at low densities?

3) How do many wild populations, such as deer or buffalo, avoid the problems of low mating densities?

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?