INVESTIGATION

17

Predator-Prey Simulation

Lab

PURPOSE

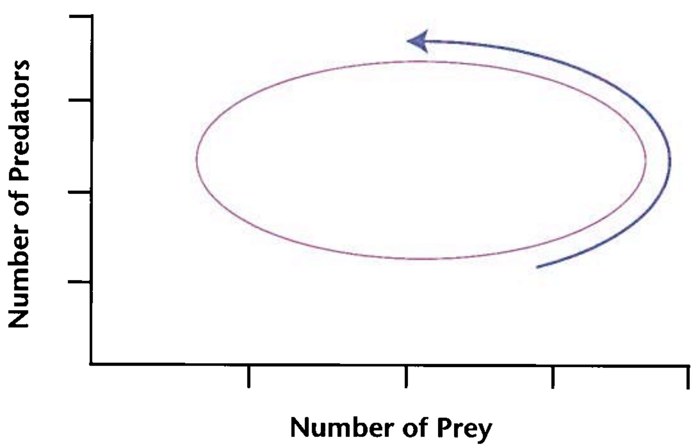
- Simulate and analyze the interactions between a predator population of coyotes and a prey population of mice
- Organize and graph data from the simulation, predicting future populations over several generations
- Compare simulation results to data taken from nature, and apply revised simulation techniques to other population problems

INTRODUCTION

Predator-prey interactions in a population are usually a feedback system. The prey population has a positive effect on the predator numbers, but the predator population has a negative effect on the prey numbers. The predator-prey relationship can be represented as changing cyclically with a phase diagram, as shown in **Fig. 17-1**.

Fig. 17-1

Generalized Scheme of Predator-Prey Relationship in Cyclical Change Through Time



In the lower right quadrant, as the predator population rises, the prey population also rises. But as the predator numbers reach a particular value, the prey population starts to decrease, followed eventually by a decrease in the predator population as well (upper left quadrant). In time the predator population becomes small enough for the prey numbers to rebound and the process continues into another cycle. In nature the cycles are more complex than is indicated in the diagram, as there are many more influences on populations in the wild. In this investigation the factors will be confined simply to predator-prey numerical pressures.

Materials

- masking tape
- graphing paper
- construction paper
- Internet access
- spreadsheet and/or graphing software

Optional:

- computer simulations of predator-prey system

Procedure

Each lab group will need to set its own parameters for the simulation, as follows:

- how many mice are in the field under initial conditions
- the minimum number of mice a coyote needs to eat to survive and reproduce
- OPTIONAL: how many mice a coyote needs to eat *above the minimum* to produce 2 or more pups for the next generation

To generate data for the simulation, you will drop different-sized pieces of paper, representing mice and coyotes, onto a square marked out on the floor in the classroom. These pieces can be cut from sheets of graph paper to ensure size consistency.

Remember, the relationship between predator and prey is usually cyclical, and their corresponding numbers will rise and fall in some pattern. You will probably need at least 15 iterations of the simulation to see if you have a pattern. It may take some trial and error to determine the proper "rules" for your simulation to demonstrate a pattern. It is very possible that your model may produce chaotic variation. If this occurs, revamp your rules and continue.

Step 1 Using masking tape, mark off a "field" on the floor that is 50 cm (about 20 in.) square. If approved by your teacher, some groups should try smaller squares. Larger-sized "fields" will take too many coyotes and mice to be practical in the time allotted for this lab. (*Hint:* If your floor has tiles, use a certain number of them to delineate your field.)

Step 2 Write down all your group parameters and rules, including those for possible larger litters of pups.

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Step 3 Cut out pieces of paper to represent coyotes and mice. You will need many more mice than coyotes, probably about 300 mice to 15 coyotes. The actual number of each may vary based on the parameters you choose.

The pieces of paper should be of two sizes, possibly at a ratio of about 2:1, to simulate the feeding needs of the coyote. They can be squares cut from graph paper for uniformity or, if you are artistically inclined, silhouettes of the animals. Different groups may want to experiment with different size ratios and then compare their results at the end of the simulation.

Step 4 Drop the papers representing the starting number of mice into the square. They should fall randomly inside the borders of the "field." Experimentation will determine from how high the papers need be dropped to give consistent random falls within the square.

Step 5 Once your mice are distributed, drop 1 preying coyote into the field. For the coyote to survive and reproduce, it must fall directly on the number of mice determined by your parameters (see Step 2). Take the "eaten" mice out of the square. Assume that the remaining mice get to reproduce by doubling their number. This ends one generation.

Step 6 The next generation is represented by the new number of mice and they are preyed on by the number of surviving coyotes. If no coyotes survive a generation, start again with one coyote. If all the mice are eaten, start again with the same number as in the first round.

Step 7 Record the number of surviving mice and coyotes after each round in your Table of Data (**Fig. 17-2**).

Note: To monitor whether the relationship is going as expected, data can be entered directly into a spreadsheet or a graphing program as the simulation proceeds.

- If you enter the data into a spreadsheet such as *Excel*, when you are ready to make a graph, highlight your data and click on the chart icon. On the chart Wizard, select "Custom Types" and then scroll down to "Lines on Two Axes."
- You can also use graphing programs such as *Graphical Analysis* to monitor the data after each generation. It is possible to use graphing calculators as well, but you will need a GraphLink cable to get the data and graph into a computer so that you can write up the lab.

Step 8 It is likely that the initial coyote did not land on the required number of mice needed to survive. If so, again drop a coyote on the square to represent a new animal migrating into the area looking to take advantage of a resource.

Step 9 Record your data for the second generation, based on the number of surviving mice and coyotes. Once more, if the coyote does not land on the required number of mice, start generation 3 with one coyote.

Step 10 Double the surviving mice and repeat. If the coyote lands on the necessary number of mice, it reproduces and yields one or more offspring for the next generation.

Step 11 Repeat this process for at least 15 iterations to see if you have a predictable pattern developing. If your data seem chaotic, rethink your conditions, make parameter adjustments here, and continue.

Step 12 As the coyote numbers increase, remove the mice eaten by each coyote in that generation. (As one coyote eats mice it is harder for the following animals to hunt successfully. In this way the simulation also models the effectiveness of superior hunters and nature's weeding out the less efficient.) Record the total population of each at the end of the generation.

Step 13 When your model seems to be producing a cyclical pattern, complete 25 iterations and graph the data.

Fig. 17-2

Data Table for Predator-Prey Model

Generation Number	Mice (starting number)	Coyotes (starting number)
1		
2		
3		
4		
5		
6		
7		
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10		
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25		

Analysis

On a separate sheet of paper, place the data for both the mice and coyotes on the same graph so that the interrelationship can be easily observed. Use two *y*-axes, one on the left end of the *x*-axis and the other on the right end. The left one is for plotting the mice and the right one is for plotting the coyotes. Label each vertical axis separately. Label the *x*-axis "Time in Generations." Use one color line for the mice and another color for the coyotes.

Problems

1. What do you predict would happen to your results if your system was disturbed by some unforeseen, outside forces? To answer parts **a** and **b**, first draw the last cycle of your experimental graph free-hand. Continue graphing for at least three additional cycles to display your prediction.

   a. Draw on your graph and explain here what would happen if some coyotes died of disease or were driven off by larger predators or hit by cars.

   b. Draw on your graph and explain what would happen to the prey populations in the event of a fire, or of additional predators of another species moving in.

   c. How would it matter at what point in your simulation such disturbances occurred?

2. Search the Internet to find how your simulation compares to data of predator-prey systems taken from nature, such as those of owls and mice, lynx and snowshoe hare in Maine, or the moose-wolf system on Isle Royal in Michigan.

   a. Look for what general pattern exists for the data from nature.

   - How does the predator population vary when the prey numbers change?

   - Are the populations in phase with each other?

   - Are the population curves similar in shape? How do the curves differ from each other?

   b. Describe how your simulation data are similar or different. If your results are very different, explain why.

c. What could you do to adjust your "rules" (model) to better fit the natural patterns?

3. Compare your graphed data to the data of other groups in class.

a. Which parameters generally made the most difference?

b. How could the initial parameters be changed to better simulate a natural system?

c. If adjustments were made to a model in the middle of the simulation, how did the data then compare to the graphs of natural data?

4. How would the graphs look different if the predator were cold-blooded? How could information on such differences be used in examining the fossil record of dinosaurs to determine if a species was warm- or cold-blooded?

5. Design a predator-prey population experiment using a planktonic rotifer, such as *Brachinus calyciflorus*, as the predator and the single-celled green algae, such as *Chlorella vulgaris*, as the prey. Predict what would happen to the populations if:

a. a nutrient like nitrogen were added to the water. Explain why.

b. the nitrogen levels were reduced. Explain why.

Problems

Problems

6. How could this predator-prey method be used to model the spread of a disease, such as measles, SARS, ebola, or the flu, in a large population center?

7. Describe at least three predator adaptations that make hunting easier. Articulate three-adaptations of prey that help them escape predation.

8. Are parasites predators? Explain.

9. In this investigation you examined only the simple relation between changing prey populations and the number of predators. What other variables affect the number of predators and prey in a population? Describe four other possible factors.

10. Describe an example of a predator being used to control a prey population that is considered a pest. Explain scientifically why you believe this is a good idea or not.

Extension

There are several computer simulations of various predator-prey systems. Find one and play it. Describe how the results of your model simulate results from computer models.