Chapter 8

Predator-Prey Simulation Exercises for the Classroom

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Dr. Waddell is currently Assistant Professor of botany and zoology at the University of Maine at Orono. A native of Scotland he earned a B.Sc. in zoology at Glasgow University in 1968. While working on his Doctorate in biology at the University of Pennsylvania he began his involvement in laboratory education as Laboratory Coordinator for one of the core courses in the undergraduate curriculum. Dr. Waddell came to Maine in 1977 after having taught at the University of Pennsylvania, Drexel University, Cabrini College and Cornell University. Having revised the laboratory component of the introductory zoology course he is now in charge of the basic biology course taken by over 1000 biology majors and non-majors alike. His interests are in improving instruction at the introductory level by using auto-tutorial and traditional methods.

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Introduction

In teaching a general biology course, some of the most difficult concepts to demonstrate in the classroom are those in ecology. Some excellent demonstrations of ecological principles using live material are possible but they require either large numbers of organisms, long periods of time, many repeated observations or all of the above. For example, ecological succession can be shown in a gallon jar of pond water, but this takes time and some taxonomic ability that beginning students may not possess. Flour beetles (*Tribolium*) can be used to demonstrate competition and niche utilization but this experiment requires a lot of sifting through flour.

We in the Zoology Department of the University of Maine at Orono have devised a series of laboratory exercises for our introductory students that have several advantages.

1. They can be done in one class period.
2. They require very simple equipment (pegboard, wooden partitions, wooden dowels, and beans).
3. Students require no taxonomic ability, and
4. Students enjoy the exercises, which adds considerable reinforcement.

Student Materials

Equipment

Best results are obtained when students work in teams of 4. Each team requires the following:

1 sheet of pegboard (1 × 1 m) laid horizontally on a table
6 wooden partitions (2.0 × 2.5 × 25 cm)
6 wooden partitions (2.0 × 2.5 × 50 cm)
2 dozen 2.5 cm long wooden dowels to fit the holes in the pegboard
(These are used to hold the partitions in place)
110 g dry navy beans or similar-sized objects
2 blindfolds

Procedure

The demonstration is divided into five separate exercises. The first establishes baseline data with a very simple system. The other four involve the alteration of one or more variables to test their effect on the system.

Exercise 1. Baseline data.

One student is blindfolded while the other members of the team arrange 50 beans randomly on the pegboard. The students then assume the following roles:

1. Predator. The blindfolded student moves a hand over the entire board, just above it, lightly tapping it continuously with one finger only. The aim is to locate by touch as many beans as possible.
2. Predator's assistant. As soon as a bean has been touched by the predator it is deemed to be caught and is removed from the board by the predator's assistant.
3. Timekeeper. A student calls out "start" and "stop" to the predator, allowing one minute to "catch the prey".
4. "Ecologist". This person records the number of prey consumed by the predator, and any other information as required.

The beans are then replaced on the board and the students exchange roles and repeat the procedure until each has had at least one turn at being predator. The number of prey taken per minute by each predator is then averaged to obtain the baseline data. This establishes the efficiency of a predator in a very simple environment. See Figure 8.1.

Figure 8.1. Students participating in the predator-prey simulation (see text for description).

Exercise 2. Effect of different prey distributions.

In this exercise, while the predator is blindfolded, the team arranges the beans on the board in one of three ways:

A. Random. As before. (See Figure 8.2a)
B. Even. The beans are distributed in a regular manner as in Figure 8.2b. The holes in the pegboard assist in creating a regular array of prey.
C. Clumped. (See Figure 8.2c) The 50 beans are arranged in 5 groups of 10 beans each. Within each group the beans should be 2.0 to 2.5 cm apart.

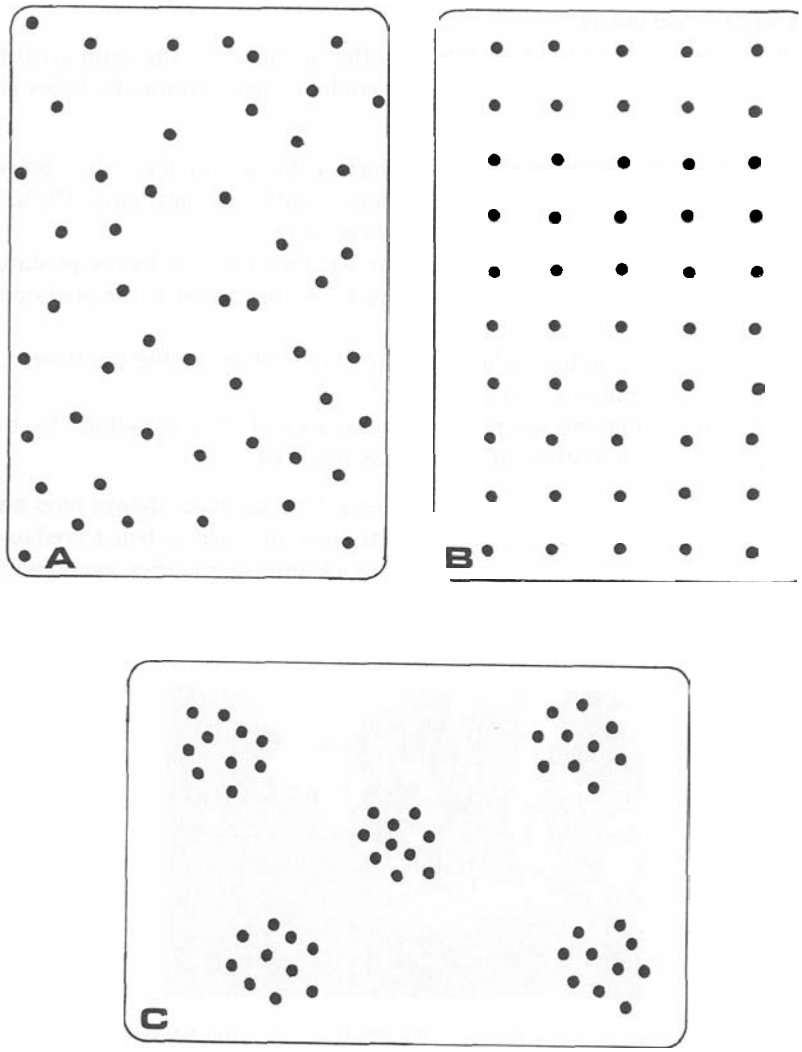

Figure 8.2. Examples of prey distribution: (a) random, (b) even, (c) clumped.

The predator should not be aware of the type of distribution. The predator is then allowed to "hunt", in the same manner as in exercise 1, for one minute. Roles are then switched until all of the students have preyed on each type of distribution at least once. The sequence of distributions should be randomized so that the predator cannot predict how the prey will be arranged.

Although the predator should not know the distribution pattern of the prey at the start of a trial, he should be encouraged to try to guess the pattern from his contacts with prey and perhaps alter his hunting strategy accordingly.

This exercise tries to determine which prey strategy is best for the survival of the prey species. It should be pointed out that in nature, the distribution of animals and plants is determined not by predation alone, but that many other factors are involved. For example, territoriality tends to produce an even distribution but the main reason may be to ensure an adequate feeding range for the individual. Clumping in some species may be mainly to ensure ease of mate selection whereas in others, such as schooling in fish, it may be to confuse a visual predator as it tries to attack the group.

Exercise 3. Effect of structural complexity of the environment.

For this exercise the baseline data may be used as a measure of predator efficiency in a structurally simple environment. Next the environment should be made moderately complex. To do this the team should place half of the wooden partitions (3 long and 3 short) on the board. These represent barriers like streams, boulders, mountains, deserts according to the imagination of the ecologist. The predator should be blindfolded during the preparation of the environment. The partitions should be placed only at right angles to each other but no closed boxes should be constructed. The wooden dowels are used to hold the partitions in place. Fifty prey are then added randomly. During each one minute trial the predator must not jump over any of the partitions, he must go around the ends in search of prey. The method of hunting is as before and again all members of the team should take a turn at being predator and an average number of prey captured per minute calculated. The partitions may be altered between predators but this will probably not affect the results.

The next step is to repeat the procedure using all of the partitions (6 long and 6 short) to represent a complex environment. Again run a trial with each team member being predator and calculate an average.

Exercise 4. Effect of the prey's reproductive rate.

During this exercise the prey is allowed to reproduce. The first step is to start with a simple environment and 50 random prey. After one trial the prey remaining are counted. Sixty percent of this figure are then added to the prey already on the board and the new total noted. Recording the number of prey consumed by the predator is optional. The same or a different predator then preys on the new number of beans, using the usual preying technique, for one minute. Again 60% are added and the new total noted. If 6 to 8 trials are run a trend in the number of prey remaining (and those caught by the predator) should be detectable.

This experiment can be repeated with a 30% growth rate of the prey to represent what might happen with a population of more slowly reproducing prey.

The data from these exercises should be plotted on a graph to make the trends more obvious.

Exercise 5. Effect of both predator and prey reproduction in a complex environment.

This exercise most closely approximates the real world. All of the partitions are used to make a complex environment. The prey population starts at 50 and increases at the rate of 100% of the remaining prey per minute. That is, at the end of each trial the number of prey left on the board is doubled. In this exercise a successful predator also reproduces. Success is defined as eating 15 or more prey in one turn. If the predator catches this many prey or more, another predator (team member) is added. However if any predator fails to catch 15 prey he must drop out (the predator either reproduces or dies in this simple system). A solitary predator cannot die, regardless of the number of prey he catches. This ensures that there will always be at least one predator on the board.

Since many more hands are required in this exercise to hunt for and remove prey, two teams should be combined to produce an eight-student group.

At the end of each trial, after both predator (if successful) and prey have reproduced, the number of prey on the board and the number of active predators should be noted. At least six trials are required to produce any observable trend, more may be needed on some occasions. Both the number of predators and prey remaining should be graphed for ease of interpretation.

Results

The results of each trial should be recorded immediately after the trial. Tables 8.1 through 8.5 are provided to record the results of exercises 1 through 5. Figures 8.3 through 8.5 are provided so that you may graph the results of exercises 3 through 5. Trends are usually more easily observed when the data is presented in graph form rather than as numbers in a table.

The following tables and figures show the results of one session with the game. Your class results will probably be different. Note that the abscissae of all graphs provided are not numbered. This is to prevent any prejudice on the part of the class as to what numbers to expect.

Table 8.1. Sample results of exercise 1. Baseline data.

Trial Number	1	2	3	4	5	6	Total	Average
Prey Taken/min	32	23	40	33	34	33	195	32.5

Table 8.2. Sample results of exercise 2. Effects of different prey distributions.

Trial Number	Prey Taken		
	Random	Even	Clumped
1	32	25	43
2	23	23	34
3	40	26	37
4	33	22	41
5	34	23	40
6	33	24	37
Total	195	143	232
Average	32.5	23.8	38.7

Table 8.3. Sample results of exercise 3. Effects of differing structural complexity of the environment.

Trial Number	Prey Taken		
	Simple	Moderate	Complex
1	32	25	10
2	23	20	15
3	40	23	14
4	33	28	18
5	34	19	12
6	33	22	17
Total	195	137	86
Average	32.5	22.8	14.3

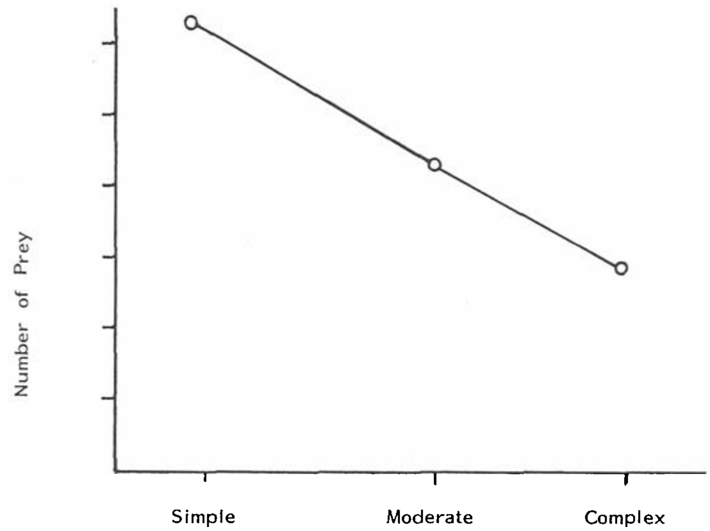

Figure 8.3. Sample results of exercise 3. Effects of differing structural complexity of the environment.

Trial Number	Prey Remaining	
	60% Reproduction	30% Reproduction
1	27	36
2	15	22
3	10	9
4	6	4
5	3	2
6	0	0

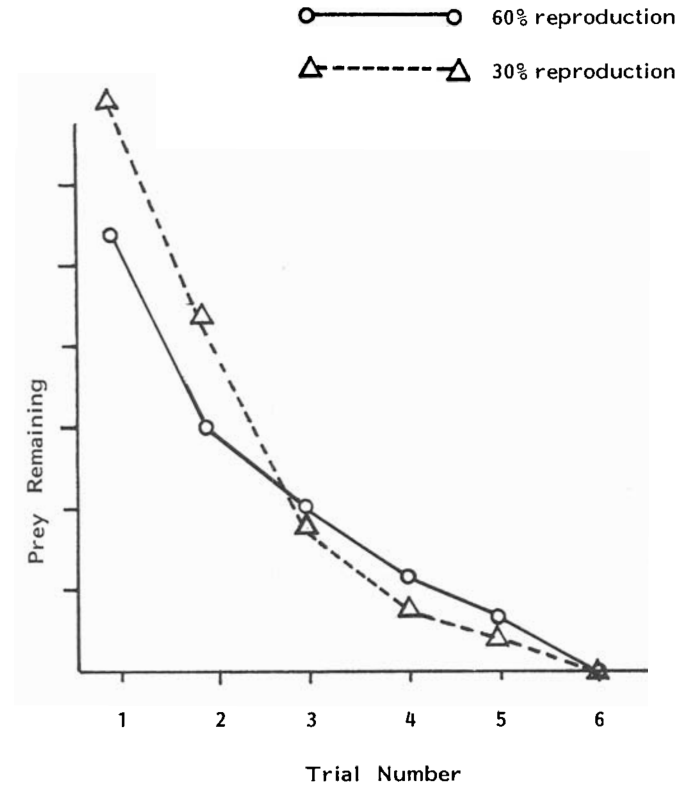

Figure 8.4. Sample results of exercise 4. Effects of different rates of prey reproduction.

Trial Number	1	2	3	4	5	6		
Prey Remaining	66	82	104	108	128	144		
Number of Predators	2	2	3	4	4	2		

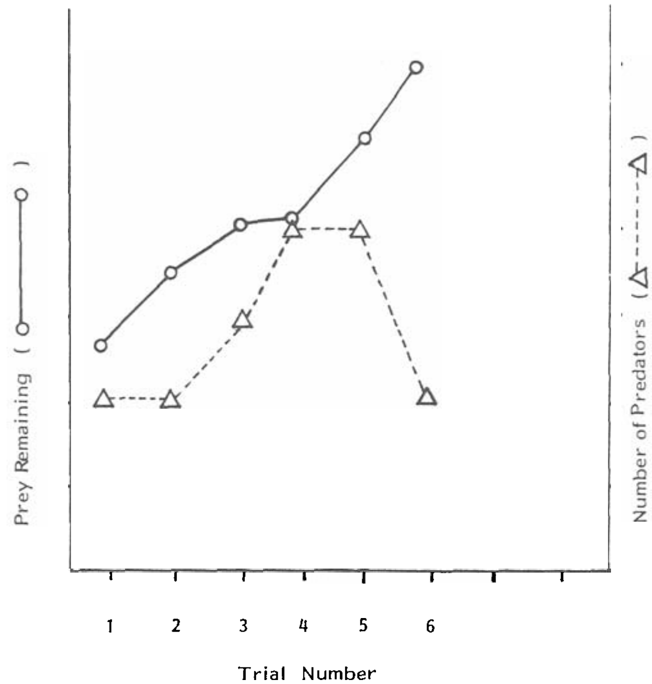

Figure 8.5. Sample results of exercise 5. Effects of both predator and prey reproduction in a structurally complex environment.

Instructor's Materials

With students working in teams of 4, the following materials would be sufficient for a class of 20:

5 sheets of pegboard (1 × 1 m) laid horizontally on tables
30 wooden partitions (2.0 × 2.5 × 25 cm)
30 wooden partitions (2.0 × 2.5 × 50 cm)
10 dozen 2.5 cm long wooden dowels to fit the holes in the pegboard
(These are used to hold the partitions in place)
454 g dry navy beans or similar-sized objects
10 blindfolds

Class discussion

Class discussion after these exercises is most valuable. Assuming that the students have read the appropriate sections of their textbook (see bibliography for some examples) discussion is virtually endless. Some suggestions for starting points for discussion pertaining to the various segments follow.

Exercise 1. Baseline data.

Even in this exercise the concept of biological variability can be introduced. Different predators/students have differing strategies and amounts of enthusiasm, leading to differing efficiencies.

Exercise 2. Prey distribution.

These results can often be used to point out that animals are seldom distributed completely randomly in nature. It can also be mentioned that although a clumped distribution in this artificial set-up seems to be the poorest for the prey species, other factors such as mate selection and the confusing effect that a large concentration of prey can have on a visual predator may come into play in the real world.

Exercise 3. Structural complexity.

This exercise usually points out that the prey fares better if it has some place to hide from a predator.

Exercise 4. Prey reproduction.

The most probable outcome of this exercise shows that a greater reproductive rate in a prey species may allow it to maintain a higher population, all other factors being equal.

Exercise 5. Multiple factors.

Above all, this exercise shows that the real world cannot be adequately modeled in the laboratory. If the "game" continues long enough it may show that:

a. This particular prey species cannot reproduce fast enough to keep pace with predation (unlikely).
b. This prey species reproduces so fast that predation alone cannot account for its population density. Other factors like intra-specific competition for resources must be used to explain the number of organisms in the environment.
c. Wildly oscillating predator—prey cycles may occur in such a simple system.

General

It is important during the discussion to point out the simplicity of the systems used in these simulations compared to the complexity of the real world. For example even in the most complex of the exercises (Exercise 5) there is still only one "species" of predator preying on only one "species" of prey. In a natural ecosystem (or even in an unnatural one like farmland or a managed forest) each prey species may be preyed on by several species of predator. For example, mice are eaten by owls, hawks, raccoons, and even cats and dogs. Also, a typical predator, like an owl, may eat not only mice but also shrews, voles, squirrels, snakes and many species of small birds as well. The greater diversity found in nature is likely to result in a system that is much more stable and much less sensitive to a change in one factor than the simulated system.

Another important difference between simulation and reality is that in the real world populations are not controlled by predators alone. Natural populations are limited by many density dependent and density independent factors. Density dependent factors include predation, disease and intra-specific competition, while density independent factors may include the proverbial earthquake, wind and fire.

Finally, human predators differ to a greater or lesser extent from other predators in their ability to learn from their previous hunting experience. Whereas higher mammalian predators frequently refine their hunting technique from past experience, the behavior of simple invertebrate predators like some predatory worms or the more instinctively oriented insects may not be capable of great change.

References

The following list indicates where to find appropriate background reading in a few of the more widely used introductory biology texts. Keeton's text is used in the course for which these exercises were developed; therefore, a closer relationship is likely to exist between the concepts presented in Keeton and simulated in the exercises than with the other texts. However, most introductory texts that cover ecology provide enough background to allow the students to gain some appreciation of predator-prey relationships from the exercises. Students should be strongly encouraged to read the text assignment before doing the laboratory exercises.

Arms, Karen; Camp, P. S. *Biology*. New York. Holt, Rinehart and Winston. 1979. (See pages 734 to 779.)

Hickman, Cleveland P. Sr.; Hickman, C. P. Jr.; Hickman, F. M.; Roberts, L. S. *Integrated Principles of Zoology*. C. V. Mosby Company. 1979. (See pages 945 to 963.)

Keeton, William T. *Biological Science*. New York. W. W. Norton and Company. 1980. (See pages 822 to 849.)

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Villee, Claude A.; Walker, W. F. Jr.; Barnes, R. D. *Introduction to Animal Biology*. Philadelphia. W. B. Saunders Company. 1979. (See pages 584 to 597.)

Wilson, Edward O.; et al. *Life on Earth*. Sunderland, MA. Sinauer Associates Inc. 1978. (See pages 712 to 733.)