

BIOLOGY 1240: BIOLOGY LABORATORY
SPRING SEMESTER

OPTIMAL FORAGING II: THE TEST
LAB INSTRUCTOR TEACHING GUIDE

White pages are student web pages. Colored pages are the Instructors' Guide.

Introduction

This guide is intended to give help to biology lab instructors in the Optimal Foraging Experiment lab exercises. This exercise is primarily student-based experimental activities. The primary pedagogical challenge is getting students to understand the big picture (i.e., an experimental test of theory) from the details of the feeding trials.

Overall Objectives of the Optimal Foraging Experiment Lab

We want the students to learn:

1. General: that mathematical models produce the predictions that are tested with experiments;
2. General: how to graphically and numerically compare quantitative predictions with experimental results;
3. Specific: to understand and to complete a behavioral ecology experiment using fish;
4. Specific: how to apply parameters estimated with experiments (handling time) to general equations (the optimal foraging E/T equations);
5. Specific: to answer the question: Do the fish in their experiments forage according to the predictions from the equations?

Structure of These Notes

Since this lab is more like a standard biology lab, the comments on colored paper **precede** the major sections of the lab exercise that the students are to perform. This is done to alert you to details that students must perform before they attempt an activity.

Most of the comments are merely suggestions for you to consider in preparing and orchestrating the lab. A few comments are meant to alert you to potential problems or activities that the students must be certain to do.

Activities for Today

Go over this list and emphasize the last item, so that the students will know that they have to hand-in an analysis of today's experiment as a homework assignment due next week.

Reminder

This should be brief; 10 minutes at the most. Do not repeat the derivation of last week; you won't make it through the experiments and write-ups if you try.

The students have the equations they need for today on the hand-out, but you can display them on the overhead projector. Then draw on the board the curves for energy intake from taking only the most profitable prey (E_1/T_1) and from taking both prey (E_{12}/T_{12}). You will need the graph later in the lab, so put it up in a place you won't need to erase.

Here are some questions to ask the class about the equations and curves:

1. What do the two curves mean?
2. What does the intersection (cross-over) point mean?
3. What relative proportion of prey is expected in the diet of an optimal forager if density of prey is below the intersection? What proportion of prey in the diet would you expect if the density of prey is above the intersection? (They are asked to answer this question quantitatively at the end of the lab.)
4. What is the difference between E/T and profitability?

Possible answers to Mini-Quiz 1: Why check the handling time of today's fish?

1. Because there is great inter-individual variation in handling times (and all the foraging parameters). This may be caused by genetics, fish size, previous fish physiological state (temperature, feeding, etc), or handling.

Materials

Check the temperatures of all the aquaria (on benches and at the sides of the room). They should read 25–26°C. Adjust the heaters if the temperature is slightly off. If the temperature is several degrees too warm add some well water from carboys to cool it down. If the temperature is several degrees too cold, turn up the heater, or put in some water from the warmer large aquaria.

The prep TAs will have several spare aquaria to use in case one loses temperature. Check with the TA in charge of this lab for details before your section.

Check that all the listed materials are present in the lab and at the lab benches. To prevent excessive student waiting, divide the *Artemia* into two large containers and position them in different parts of the room. Assign specific benches to these containers and make sure the students know which tubs they should get prey from.

Before your lab, do the following:

1. Sort the prey into large and small size classes and place in large aerated tubs. During the week, we may have to switch to *Daphnia* as prey. Check with a prep TA what the current status of *Artemia* is.
2. Add a fish to each lab aquaria from the HUNGRY fish aquarium. Be careful with the fish at all times. Do not transport fish in nets: before moving them, transfer them to a bowl with water from the aquarium.
3. Remove any prey in the aquaria from previous lab sections. If the students cleaned up properly, the lab aquaria should be empty of all fish and prey. Please make sure this is the case when you leave at the end of your lab.

Experimental Design

The students will need help in understanding the relation of the experiment to the model. Try the following:

1. Announce to the class what experiment they will be performing by stating the contents of the section *Experimental Design* in their hand-out.
2. Check that the students understand why we are doing this experiment by asking of randomly chosen students:
 - (a) “What does *treatment*, *levels*, and *replicates* mean?”
 - (b) “Why do we need replicates?”

[We won’t be asking students to do statistics in this lab, but they should have the concept of the effects of random sampling from a population. In this case, each experiment performed at each bench is a random sample from a population of all possible realizations of this same experimental design.

One question to ask is: “If you performed the same experiment tomorrow, would you get the same results? If not, why not?”]

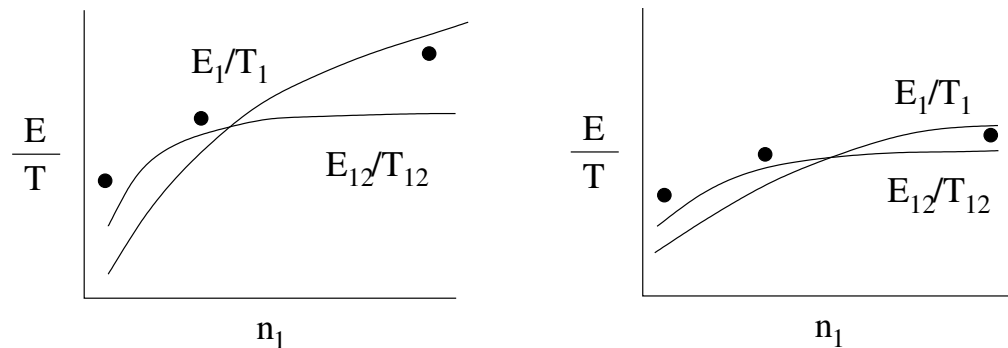
- (c) “The hand-out says the experiment will be three levels of prey density. What is the

independent and dependent variable? Why did we choose this independent variable?”

We haven't told the students what the dependent variable is at this point, so you will get different answers. You should take a few minutes soliciting suggestions and dealing with them.

Two possibilities (there may be more) are:

- i. **Total Rate of Energy Consumed:** This is a reasonable suggestion since that is what we used for the disc simulations. However, if we did measure this and plotted the values against n_1 with the theoretical curves, would we be able to ascertain clearly that the predator changed its behavior? We might if the curves were greatly separated at the densities, but not if the curves were close and there was statistical variation. See sketch:



- ii. **Numbers of Prey Eaten:** This would show a behavioral shift. (Ask the students what shift they would predict.) The shift is may be qualitative (to all of one type of prey) and therefore might be easier to detect.

- (d) “What are the answers to mini-quiz 2? (Why keep prey numbers constant?)”

[Since we predict that predator behavior will change with prey density, we don't want the prey density to change during the experiment. We're controlling this variable to see if the predator will maximize energy intake rate by shifting its diet. We need to hold prey density constant in order to estimate the rate (we can't measure it instantaneously).]

Before turning the students loose, show them which size of fish to use. Also show them the two prey sizes. It would be a good idea to have several beakers with the two sizes together to pass around to the students while they are sitting at their benches. Tell them to use only *Artemia* that are not mating (attached to each other).

The tubs of prey will probably have more than two sizes, so you will have to know how to separate them. Learn how to do this well in advance of your lab (e.g., during the TA lab meeting).

Notify the students that they should always use fish of the same size if they have to change fish.

Student Activities

Self-explanatory: tell them to divide up.

Experimental Protocol

The students will have had the opportunity to have read this before class, but most won't have, so go over the basics anyway. Some items to note:

- Demonstrate setting up an experiment by pipetting equal numbers of the 2 size classes of *Artemia* into a bowl with a small amount of freshwater, then pouring it into a large beaker to simulate their aquaria.
- The criterion for a “dud” fish: no interest in feeding in 2 minutes.
- When replacing prey, try to put the replacement prey near to the remaining prey, so that the fish will have a clear choice and not just take the closest prey.
- The fish must be calm and the students should not move quickly near their aquaria. The students may have to tape paper to the sides of the aquaria to reduce visual disturbance.
- After a feeding trial, remove the fish from the large compartment immediately and hold it in the net in the small compartment. Leave it in the net. Demonstrate this for the students.
- Handling time. Emphasize that this is done only for the low density experiment. If less than 3 of the benches in your lab fail to get good handling times on either prey size, stop the experiment and have the students do just the handling timing on the prey size which has not been timed. This is especially important for the large prey size, which has a long handling time. The small prey will have a time of about 0.5–1.5 seconds. The handling time of large *Artemia* will be about 5–6 seconds. (The theoretical prediction (and the success of the lab exercise) is very sensitive to this.)

While the lab benches are getting set-up for the 5 and 5 density, have the “Caller” student go to the board and record the means of their handling times for the two prey sizes.

NB: Later in the lab, you will need to check the calculations for E_1/T_1 and E_{12}/T_{12} using these data, so you might want to start computing them at the front desk as soon as the numbers are recorded.

As the numbers come in, you might want to quickly graph *for each lab bench separately* the 2 E/T curves to see where the cross-over point is.

Alternatively, you can compute the cross-over point using the equation for the cross-over point (n^*) obtained by setting the equation for E_1/T_1 equal to the equation for E_{12}/T_{12} :

$$n^* = \frac{e_2 v}{e_1 T_{h2} - e_2 T_{h1}}$$

assuming $n_1 = n_2$.

After the Experiments

1. Have the students clean up before the discussion. This will ensure that it gets done and remove distractions.
2. Remind them of the purpose of the experiment. You might want to refer to the curves for the 2 equations again. Engage them in the following discussion:
 - (a) “How does our experiment differ from the real world, i.e., in a natural, field setting?”
[Possible answers: In real world (1) densities not constant; (2) predators eat more than 2 prey types; (3) prey choices not always visible simultaneously (predator has uncertainties about possibilities); (4) other distractions from feeding (predation on the predator); (5) complex habitats interfere with feeding.]
 - (b) “Given unrealism of the experiment, is it still valid and useful to do these simple experiments?”
[Yes. To understand the mechanisms of behavior, we must isolate key variables and processes. This is analogous to experiments in physics or chemistry where we control temperature, friction, etc.]
3. Have each student at their own seats calculate the value of E_1/T_1 for each density (1, 5, and 10). They will then confer among their group and agree on their calculations. After this, solicit a value from one bench and make sure there are not dissenters. Make sure every one agrees.
4. Read the list of items needed in the Experiment Report and ask for questions. The report is due next week; groups may work together, but each student is to turn in their own work. They should prove this by giving written answers in their own words. You have, included here, some possible answers. An important learning objective is that the students will have to present the correct data to plot and compare with the predictions. They won't learn this objective if you tell them what to plot.

However, emphasize that they must plot carefully in Step 1 of their Report templates in order to obtain an accurate estimate of the cross-over density.

5. The Experiment Report asks the students to compare both their own fish to the theoretical expectations as well as the class mean for the number of prey eaten at different densities. Use this to ask the question: “Why not use as the handling time, the mean of all the individual handling times of all fish used in the class?”

[Answer: Our hypothesis is that fish individually forage optimally. So our sample unit is individual fish. If we wish to test that the entire sample forages optimally, then we should compare the mean proportion of prey sizes predated at each density by individual fish. We should not test the proportion of prey sizes predated by an “average fish” (i.e., a hypothetical fish with the average handling time).]

EXPERIMENT REPORT ON OPTIMAL FORAGING EXPERIMENT

Names of Group Members:

TA: _____

Lab Section: _____

1. Theoretical graph E/T

2. Description of Graph

3. Expected **Relative** Numbers of Large and Small Prey Consumed at 3 Densities
 - 1 Large and 1 Small:
 - 5 Large and 5 Small:
 - 10 Large and 10 Small:
4. Bar Chart of Numbers of Prey Sizes Consumed at 3 Densities. (Your group's fish and the class mean.)

5. Conclusions

6. Evolutionary Implications (see lab handout explanation): Why is the fitness of Fish A greater than Fish B?