BIOLOGY 1240: BIOLOGY LABORATORY
SPRING SEMESTER

OPTIMAL FORAGING II: THE TEST

Optimal Foraging II: Test

Activities for Today

1. Review math and the predictions
2. Experimental test of fish for optimal foraging
3. Class discussion and energy calculations
4. Experiment report (at end) completed and handed-in next week

Reminder

Recall that the E/T equations for the three foraging strategies were:

$$\frac{E_1}{T_1} = \frac{e_1 n_1}{v + T_{h1} n_1} \tag{1}$$

$$\frac{E_2}{T_2} = \frac{e_2 n_2}{v + T_{h2} n_2} \tag{2}$$

$$\frac{E_{12}}{T_{12}} = \frac{e_1 n_1 + e_2 n_2}{v + T_{h1} n_1 + T_{h2} n_2} \tag{3}$$

where e_i and n_i is the energy content and population density of the i-th prey type respectively. $T_{si} = v/n_i$, and T_{hi} are the search and handling times, respectively, of the i-th prey type.

In order to predict the energy for each strategy for a real system, we must have values for all of the above quantities. The energy content of living organisms is difficult to measure, and we will not attempt to do that in this lab. The quantities are, however, of great interest to ecologists, and we will use published values. Search time, as stated above, is related to v/density, where v is a constant of proportionality. The values for the parameters are shown in table below:

Important values for *Daphnia* and *Artemia*

Prey Name	Caloric Content (Kcal/gm dry wt)	Size (mm)	Dry Wt. μgram	Calories (cal/item)	v (sec × prey density)
Daphnia	5.5	1.0	108	0.59	32.0
		2.0	371	2.04	
Artemia	6.7	6–8	76	1.35	3.26
		>10	488	3.69	

Handling time (T_h) can be measured, as you learned last week. Consequently, we will use your own estimates of handling time from last week and check it again with the fish you use in this week's experiments.

Mini-quiz: In terms of today's experiments, why is it a good idea to re-measure handling time? (Write your answer below.)

Once the parameters are estimated, we can test the prediction.

Mini-quiz: What is our prediction? (Write your answer below.)

Materials

In the lab for all students to use:

1. aquaria with HUNGRY and FED guppies
2. several large aerated tubs of *Artemia* or *Daphnia* (depending on availability of prey)

At the individual lab benches:

1. 1 aquarium with heater and bubbler aerator
2. stop watches
3. event counters
4. 1 small net
5. 2 "replacing" bowls for the prey of the two sizes used to replace consumed prey
6. 1 "mixture" bowl for combining prey sizes together to start an experiment
7. 2 plastic pipettes
8. 1 thermometer
9. data sheets for recording handling times and prey consumed (in this hand-out)

Experimental Design

Our experiment has one **treatment**: densities of two types of prey. We will study the case where the prey densities are equal. We will use three **levels** within this treatment, i.e., three different densities of large and small prey. These are: 1 large and 1 small, 5 large and 5 small, and 10 large and 10 small. Each lab bench group will perform each experiment once, so we will have six **replicates** for the whole class.

Mini-quiz: While we perform this experiment, it is very important to keep the prey numbers constant. **Why?**

Student Activities

Assign duties to your group members as follows.

1. One group member will be the **Timer/Counter** and will (1) time the **2 minute** experiment with the count-down timer or stop watch and (2) will tally the number of large and small prey consumed using the event counter ("clicker").
2. A second group member will be the **Caller** and will call-out which size of prey is eaten ("Large!" or "Small!"). This person will also measure the handling time (T_h) during the low density (1 large, 1 small) experiment. (This is not done at the other densities.)
3. Two group members will be **Prey Replacers** and will replace the prey sizes in the aquarium as they are consumed. (If your group has only three members, one person can do this.)

Experimental Protocol

Before Starting

1. Your instructor will show you the location of fish and containers of prey sorted by size. When replacing fish, **always replace with the same size used previously**. (Estimate the sizes by eye; do not attempt to measure the fish with a ruler.)
2. When selecting prey from the large holding tubs, choose only small and large. If you have trouble distinguishing the prey sizes, get help from the instructor.
3. Always start an experiment with the fish in the aquarium calm and with no prey.
4. The first experiment to do is the lowest density: 1 Large and 1 Small prey.

During Each Experiment

1. Observe carefully the fish in the aquarium on your bench. (If there isn't one present, get one from the tank labeled HUNGRY fish.) Make sure the fish is not agitated. If it does not settle down in 10 minutes, put it in the container marked FED FISH and get a new one.
2. Check the temperature; it should be 25–26°C.
3. Remove the bubbler from the aquarium and set it on the lab bench. (The bubbles distract the fish.)
4. Fill the mixture beaker with a small amount of fresh well water (**not** tap water) and the correct number of large and small prey (i.e., either 1 of each, 5 of each, or 10 of each).
5. Test a single fish for the sizes of prey consumed:

(a) After the fish is quiet in the large compartment of the aquarium, one of the Prey Replacers will **gently** pour the mixture of 2 size classes of prey into the aquarium.

(b) The **Timer/Counter** will start the 2-minute timer. The **Caller** will get ready to measure handling time (1:1 density only).

(c) The other students should immediately begin to observe fish feeding. (**Be alert.** The fish have been starved and may begin to forage immediately.)

What if our fish isn't hungry? If your fish is un-cooperative or not hungry, then place it in the FED FISH aquarium and get a new of the same size. The test that the fish is a "dud" is this:

The fish does not attack a prey item in 2 minutes.

(d) Allow the fish to forage for 2 minutes. Each time the guppy takes a prey, the **Caller** will call-out the size of the prey ("large" or "small").

During the low density experiment only, the **Caller** will also measure the handling time of each attack with a stop watch as was done last week. This will require some concentration, when the fish attacks start the stop watch and stop the timing when the fish has completed the attack. Write the numbers on the handling time data sheet. Do this for both large and small prey.

(e) When the prey has been consumed, the **Timer/Counter** will click the Large or Small event counter.

(f) The **Prey Replacers** will add an individual of the prey type eaten (large or small) from the appropriate bowl of extra prey. Place the new prey item as near to the other prey in the aquarium as possible without disturbing the fish.

6. After the experiment is complete, capture the fish in the net to prevent it from eating more prey. Rest the rim of the net on the edge of the aquarium so that the net and the fish is in the **small** compartment of the aquarium. Put the bubbler in the compartment with the fish.

   The **Prey Replacers** will remove all the prey from the aquarium and then add new prey for the next highest density experiment. Dispose of any dead or injured prey. Re-use any living prey in the next experiment.

   After the low density experiment only, the Caller will go to the front of the room and record the average handling time measured for your fish.

7. Repeat steps 5–6 using the following prey densities

   - 5 large and 5 small prey
   - 10 large and 10 small prey

8. When you have completed all the experiments and the lab instructor asks, go to the front of the room and record your results.

OPTIMAL FORAGING EXPERIMENT DATA SHEETS

YOUR FISH'S HANDLING TIMES

Attack #	T_h Small	T_h Large
1		
2		
3		
4		
5		
6		
7		
mean		

CLASS MEAN HANDLING TIMES

Bench #	T_h Small	T_h Large
1		
2		
3		
4		
5		
6		

YOUR FISH'S DIET (no. eaten per 2 min)

	Density of Prey					
	1 : 1		5 : 5		10 : 10	
	small	large	small	large	small	large
No. Prey in 2 min						

CLASS FISH DIET

	Density of Prey					
	1 : 1		5 : 5		10 : 10	
Bench #	small	large	small	large	small	large
1						
2						
3						
4						
5						
6						
mean						

After the Experiments

Clean Up

- Gently capture your fish, place it in your fish handling bowl, carry the bowl to and gently place the fish in the large FED FISH aquarium.
- Return any healthy prey to the large aerated tubs. Please do not throw them away; we need them for coming lab sections.
- Dispose of dead or unhealthy prey as indicated by your instructor.
- Straighten-up the area around your bench aquarium for the next activities and for the next lab section.

Record Class Results

When instructed to do so, go to the front of the room and record the prey numbers eaten for your three experiments.

Class Discussion and Calculations

1. The instructor will remind you of the purpose of this experiment and the prediction from our mathematical equations.
2. **Each** student will then calculate E_1/T_1 for all 3 densities. This is done now to verify that all students know how to do this. It will be needed for the homework.

   E_1/T_1 for 1:1 =

   E_1/T_1 for 5:5 =

   E_1/T_1 for 10:10 =
3. After calculating, each student will confer with their lab bench group as a whole to compare the individual calculations.
4. The lab instructor will re-convene the class and verify that all benches obtained the correct E_1/T_1.

Experiment Report

As an assignment for next week, **each** student, working with their group members, will write a very short report that summarizes their findings and conclusions. This will be graded and collected during the lab period next week. The correct responses will be discussed next week during lab so that you can be prepared for the final exam.

Here is what the report should include. Use the last two pages to write your report.

1. **Each** student will calculate a fish's E_{12}/T_{12} for all densities of prey using the class data.
2. Using the attached graph paper, graph E_1/T_1 and E_{12}/T_{12} *versus* n_1 as it is predicted by the equations. Use the data from **your** fish, not the class mean.
3. In the space provided, write 2–3 sentences describing what the graph shows.
4. Based on the graph, if the fish foraged optimally, what do you expect will be the **relative** numbers of large and small prey consumed at the 3 densities?
5. Create a **bar chart** (histogram) that shows the results for your fish **and** for the class mean. Think carefully about which variable is the **independent variable** and which variable is the **dependent variable**.
6. In the space provided, write 2–3 sentences stating your *Conclusions*. If the fish did not behave according to your expectations in step 4 above, write 1 sentence giving your best guess as to why this might have occurred.
7. Evolutonary Implications: Suppose you have 2 fish (A and B). When tested in an experiment like you just performed, Fish A foraged optimally but Fish B did not forage optimally. Why would Fish A have higher fitness than Fish B?

All group members may consult with each other in completing the report, but each student must put the answer in their own words. The concepts revealed by the writing the report will appear on the final exam.

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?