OPTIMAL FORAGING LABORATORY

Overview

In week one, you will be exposed to optimal foraging theory and challenged to design your own experiment to test predictions of the theory, perhaps by measuring the foraging behavior of your classmates. In week two, you will conduct the experiment, analyze and interpret your data, as well as present your findings. You will work in groups of 3–4 on the research, but each student will write their own concise scientific report.

Objectives

- Learn to derive predictions from theory
- Build skills in experimental design
- Build skills in data analysis and interpretation
- Refine Excel graphing and analysis skills
- Gain an understanding of optimal foraging theory

Introduction

Most plants and animals tend to occur in patches (i.e., they are aggregated and have a clumped dispersion). An important consequence of this patchiness is that predators encounter prey over a range of densities and in a variety of combinations. As a result, patchiness can influence both the prey types eaten (diet breadth) and the foraging rates. For instance, prey types that are consumed under some conditions may be ignored under other circumstances (such as when they are encountered together with more preferred prey types, or when the overall abundance of prey is high). The patch in which a predator or herbivore forages also influences the rate and the quality of food eaten. For example, a forager in a low density patch usually has a lower feeding rates and less pronounced preferences than a forager in a higher density patch.

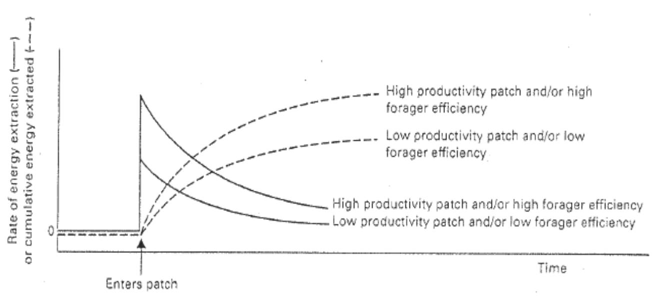
Ecologists hypothesize that natural selection favors individuals that behave in a way that maximizes their fitness. However, fitness is frequently difficult to measure directly. It is sometimes estimated from energy gain, which in turn is a function of feeding rate and food quality. The assumption is that individuals that gain the most energy with the minimum cost will have the greatest fitness. An "optimal forager" is one that forages in a way that maximizes the **net rate of energy gain** (i.e., that maximizes the difference between gross energy gain and the energy invested in foraging).

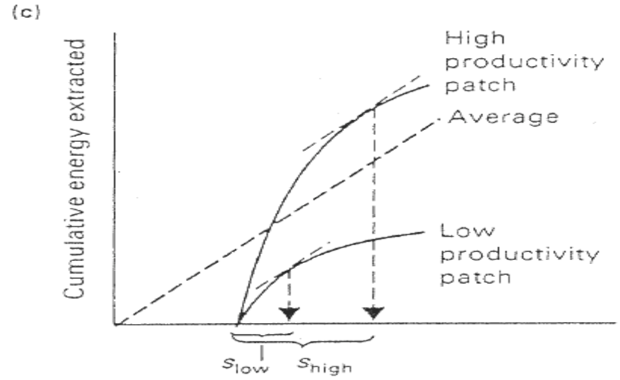
Several optimal foraging models have been developed to quantitatively predict the behavior of foragers under different conditions. In this laboratory we will explore a theoretical model that predicts the behavior of animals foraging in an environment where prey are distributed in discrete (separate) patches. This model was developed by Charnov (1976) and is known as the **marginal value theorem** (MVT). The important features of the model can be understood by examining a graphical representation of foraging behavior (Figure 1).

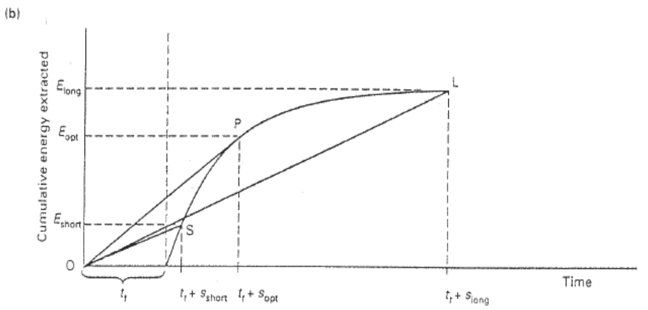
Imagine an animal that travels to a patch and then begins feeding in the patch. Consider its average feeding rate (including travel time) from the start of the travel period to any instant during the feeding bout. Initially, the feeding rate is zero because the animal is merely traveling to the patch. After reaching the patch, the feeding rate increases sharply then decreases as the forager depletes the prey in the patch (Figure 1, middle). Consequently, the time between captures (the intercapture interval) increases, cumulative energy gain tends to plateau (Figure 1, upper), and the average feeding rate eventually declines.

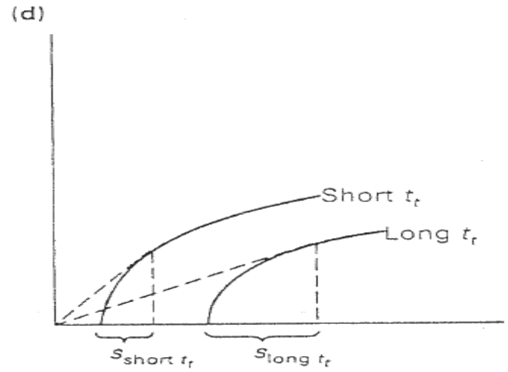
The average rate of energy gain (feeding rate) is represented by the **slopes** of the diagonal lines in the lower panel of Fig. 1. [Recall that the slope of a line is the change in Y divided by the change in X, which in this case is the amount of energy gained (change in Y) per unit time (change in X), hence, the feeding rate]. The average feeding rate for a foraging bout tends to be maximized with an intermediate stay within the patch ($t_t + S_{opt}$ in Fig. 1). Foragers that remain shorter or longer are predicted to have lower average feeding rates.

The model can be extended to yield predictions about how an optimal foraging organism should behave in different environments. For example, consider: (1) an animal foraging in an environment with patches of low productivity vs. an environment with patches of high productivity, (2) an animal foraging in an environment where the traveling time (t_t) between patches is short vs. long, or (3) patches of variable prey density. When should an optimal forager leave one patch to forage in another? Envision other complications that foragers may encounter (e.g. different prey types, predators, etc…) and see if you can extend Charnov's framework to predict an optimal foraging strategy. (Hint: try to express your predictions in terms of the graphical models in Figure 1 and compare these predictions to your intuition as a forager. "If *I* were foraging in such an environment, what would *I* do?")









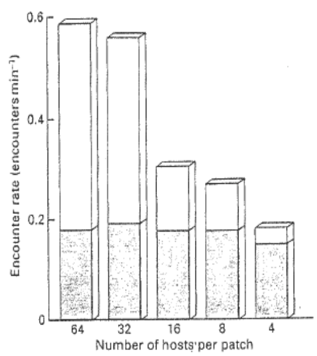
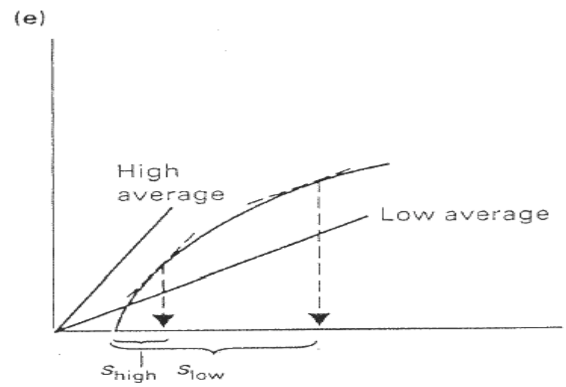


Figure 9.18 The estimated terminal encounter rates of *Venturia canescens* with its host in patches of different host density (shaded areas) compared with the initial rates in these patches (open areas). (After Hubbard & Cook, 1978.)



Experimental Design

Work in groups of 3 to design an experiment, to be conducted during the next two lab periods, which will test some *prediction* of optimal foraging theory. (Remember that you need to form groups ONLY with others who will be in lab with you on your next scheduled lab day!!) You may assume that your classmates will be willing to function as experimental subjects if you can design a protocol that will require no more than 5–10 minutes of each student's time. In scheduling your own time during the lab, be sure to allow for participating as subjects in 5–8 other studies.

Your experimental design should include the components listed below.

1. An explanation of the prediction.
2. A description and/or schematic of the experimental design.
3. Two graphs showing two possible results of the experiment, one in which the prediction is supported (Fig. 1), and one in which the prediction is falsified (Fig. 2). Be sure the axes are fully labeled.
4. A brief statement of your interpretations for the cases where (1) the prediction is supported, and (2) the prediction is falsified.
5. A sample data sheet such as you will use to collect data (modified from the datasheet provided, or, if your design requires it a novel datasheet).
6. A list of materials and supplies that will be needed.
7. An estimate of the measurement time required per replicate.

Independent Variables (Treatments)

- Energy value of resources
- Amount of resources
- Capture efficiency
- Distance between patches
- Productivity of environment

Dependent Variables (Measurements)

- Stay-time
- Number of resources consumed
- Foraging rate
- Giving-Up-Time
- Inter-Capture Interval (Time between finding each bean)

Optimal Foraging Scientific Report

The evaluation of your work in the optimal foraging lab will incorporate the quality of your experiment and your ability to perform appropriate data analysis and communicate your results in an individual scientific report. The report should be a concise report, in scientific format, detailing your experimental results in relation to the predictions of the Marginal Value Theorem (Charnov, 1976) of optimal foraging.

This report should be an elegant, compact summary of your work written in scientific format (introduction, methods, results, discussion). The Charnov (1976) paper is an excellent example of the concise writing style you should employ. Aim for around 5 pages, including appropriately sized figures into your text. Length, however, is not a component of your grade, rather, you should aim to cover all of the important information in your report while cutting out all unnecessary or superfluous language. External references are **not** required to produce an excellent report of this data.

Along with evaluating your ability to conduct and report your work, this lab is an excellent chance to hone your skills with Microsoft Excel, a fundamental tool for anyone entering a scientific field. Data will be collected as a group, and we expect that preliminary data entry and analysis will be done as a group. Your conclusions, however, should be your own. Using the graphical and analytical tools at your disposal within Excel look at the data from multiple perspectives to reach your conclusion. Use the power of averaging among experimental replicates both to improve the power of your results, and to provide concise graphical representations of your results. Your report should provide a compelling logical argument, based on the trends and relationships within your data, to support or reject the predictions of the Marginal Value Theorem.

The primary emphasis will be on the quality of your experiment. Do not be distressed if your conclusions are less conclusive than you had hoped. This is always a possibility even in the most elaborate and carefully planned experiments. Describe what happened and discuss what conclusions can and cannot be drawn. If you are unsatisfied with your conclusions, it is appropriate to suggest what could be done to learn more. The TA's will be available to answer your questions in regard to data analysis or the use of MS Excel.

Evaluation Criteria

A. Quality of the experiment

- Did the experiment clearly address the hypothesis and prediction?
- Was it at least possible (within the time constraints of the project) to obtain results that would falsify or support the hypothesis?
- Was the experiment carefully conducted?
- Were the results carefully analyzed?
- Are the conclusions appropriate for the data?

B. Quality of the Scientific Report

How successful is the writing at efficiently describing the research project? Specifically, we will evaluate:

- Are the title, background, hypothesis, prediction, methods, results, interpretations, and conclusions clearly stated?
- Do the tables and/or figures clearly show the patterns in the data (including appropriate labeling of figures, tables, and graph axes)
- Organization
- Clarity
- Conciseness

Selected references

Begon, M., J.L. Harper, & C.R. Townsend. 1996. Ecology: individuals, populations, and communities. Sinauer, Sunderland, Massachusetts. Pages 359-364.

Charnov, E.L. 1976. Optimal foraging: the marginal value theorem. *Theoretical Population Biology* 9:129-136.

Grier, J. W. and T. Burk. 1992. (2nd edition) Biology of Animal Behavior. Mosby Year Book, St. Louis. Pages 249-267.