Optimal Foraging Theory

# Introduction

The absolute limits of the range of food types eaten by a consumer in a given habitat are defined by morphological constraints, but very few animals actually eat all of the different food types they are capable of consuming. Optimal foraging theory helps biologists understand the factors determining a consumer’s operational range of food types, or diet width. At the one extreme, animals employing a generalist strategy tend to have broad diets; they chase and eat many of the prey/food items with which they come into contact. At the other extreme, those with a specialist strategy have narrow diets and ignore many of the prey items they come across, searching preferentially for a few specific types of food. In general, animals exhibit strategies ranging across a continuum between these two extremes.

# Importance

Foraging is critical to the survival of every animal. More successful foragers are assumed to increase their reproductive fitness, passing their genes on into the next generation.

# Questions

Given that a predator’s diet comprises some number profitable prey items, some of which are more profitable than others, when does it make sense for that predator to broaden its diet and add the next most-profitable item?

# Variables

|  |  |
| --- | --- |
| E | energy content of a prey item (kJ) |
| h | handling time for a prey item |
| i | the "next most-profitable item" |
| s | search time for a given prey item |

# Methods

The profitability of a prey item is the ratio of the item’s energy content (*E*) to the time required for handling the item (*h*). The profitability of the "next most-profitable item" (the *i*th item) can be defined as *Ei/hi*, and the average profitability of items in the current diet (before adding the *i*th item) is defined as . If the predator ignores the *i*th item and continues searching (with the average search time denoted ) for the more profitable items already in its diet, it can expect an overall energy intake of . But if the predator does pursue the *i*th item, then its expected energy intake is equal to the profitability of the *i*th item (*Ei*/*hi*). Therefore, the situation in which pursuing the *i*th item is the optimal foraging strategy (i.e., the strategy that is most profitable) is that in which

|  |  |
| --- | --- |
|  | LaTeX Code: \[ E\_i / h\_i \geq \bar{E} / (\bar{s} + \bar{h}) \] |

Irons *et al*. (1986) studied the foraging behavior of Glaucous-winged Gulls in rocky intertidal habitats on the Aleutian Islands. Prey preference experiments, in which both search and handling times of the different prey items were zero, showed that gulls chose chitons over urchins and mussels. However, under natural conditions, gulls consistently selected sea urchins over chitons, but mussels were still the least preferred despite their high abundance. What would explain these preferences?

Selected data for Chichagof Harbor (Attu Island, Alaska) spring tides are shown below. The Mussel (M), *Alaria* (A) and *Laminaria* (L) zones are intertidal zones ordered from highest to lowest. Gulls were observed foraging across these zones, but most often in the lower two (A and L). Mean densities are given in number per 1/4 m2. Mean search and handling times are given in seconds. Data from Irons *et al*., 1986.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Prey Type | Density (zone M) | Density (zone A) | Density (zone L) | Search Time  (*si*) | Handling Time  (*hi*) | Energy per Prey *Ei* (kJ) | Energy Gain (kJ/hour) |
| urchins | 0.0 | 3.9 | 23.0 | 35.8 | 8.3 | 7.45 | 606.7 |
| chitons | 0.1 | 10.3 | 5.6 | 37.9 | 3.1 | 24.52 | 2153.9 |
| mussels | 852.3 | 1.7 | 0.6 | 18.9 | 2.9 | 1.42 | 243.3 |

In the absence of search and handling time (and presented with prey in equal densities as in the feeding preference experiments), chitons are the obvious choice for maximizing energy intake. However, urchins have higher mean abundance overall than chitons do. For a gull that happens upon an urchin in the more frequently used zones (A and L), the inequality presented above is (7.45 kJ / 8.3 s) > (24.52 kJ / (37.9 s + 3.1 s)), or 3231.3 kJ/h > 2153.9 kJ/h for urchins and chitons, respectively. On the other hand, a gull foraging in the mussel zone, where mussels are by far more ubiquitous but provide a much lower net energy gain, has to decide between eating the mussel it happens upon or continuing to search for a more profitable prey item (a chiton in this zone). In this case, the energy content of the mussel is (1.42 kJ / 2.9 s) versus the energy content of the chiton (24.52 kJ / (37.9 s + 3.1 s), or 1752.8 < 2153.9, so it would make sense for the gull to continue searching for a chiton.

# Interpretation

A predator whose typical prey items require fairly short handling times (i.e., is small) relative to search times will have a diet with a high average profitability (). If the *i*th item has an equally short handling time, then its profitability (the left side of the equation) will be greater than the net profitability of an item that is already in the diet but requires additional search time (the right side of the equation). Optimal foraging theory predicts that these species will be generalists, preying on a wide range of food items with varying profitability. On the other hand, for a species whose handling times (*h*) are long relative to search times (*s* tends to be small), the two sides of the equation are similar. Since the *i*th item is less profitable (*Ei* is smaller) than any items already in the diet, the net profitability will be greater on the right side of the equation, when the predator includes only high-profitability items in its diet. Optimal foraging theory predicts that these species will adopt a specialist strategy, preying only on items with high energy contents.

# Conclusion

The data for the search and handling times of the prey of the Glaucous-winged Gulls show that handling times are quite short relative to search times. The gulls do appear to employ a generalist foraging strategy, as predicted by optimal foraging theory.

Species that employ a generalist strategy sacrifice some profitability, but expend less energy and time searching for prey. Specialists, on the other hand, pursue items with higher profitability, but these items are comparatively rarer, and the specialist must spend more time and energy searching for prey. Different species exhibit a variety of strategies along the continuum from generalist to specialist. The optimal foraging strategy for a species will be that which maximizes net energy intake.

# Additional Questions

1. How do foraging strategies affect competition and coexistence among species in a community?

# Source

Begon, M., J. L. Harper, and C. R. Townsend. 1996. *Ecology: Individuals, Populations, and Communities, 3rd edition*. Blackwell Science Ltd. Cambridge, MA.

Irons, D. B., R. G. Anthony, and J. A. Estes. 1986. Foraging strategies of Glaucous-winged Gulls in a rocky intertidal community. *Ecology 67*:1460-1474.

# About this Resource

This material was originally distributed as part of “Alternative Routes to Quantitative Literacy for the Life Sciences[[1]](#endnote-1)” - National Science Foundation Award DUE-9752339 to the University of Tennessee, Knoxville for August 1, 1998 - July 31, 2000. Principal Investigator: Louis J. Gross. Co-Principal Investigators: Beth C. Mullin and Susan E. Riechert.

This material is now being revised as part of the “Resources for Improving Quantitative Skills in Community College Biology[[2]](#endnote-2)” project. As part of that project is also aligned with the OpenStax Biology Textbook[[3]](#endnote-3).

It is published using the QUBES Open Education Resources publishing platform[[4]](#endnote-4).

1. http://www.tiem.utk.edu/~gross/bioed/ [↑](#endnote-ref-1)
2. https://qubeshub.org/community/groups/quantbioatcc/ [↑](#endnote-ref-2)
3. https://openstax.org/details/books/biology-2e [↑](#endnote-ref-3)
4. https://qubeshub.org/qubesresources/publications/1062/ [↑](#endnote-ref-4)