Optimality Models and Game Theory

Principles of Ecology
Biology 472

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Historical Backdrop for Optimality Models

- Late 1950's and early 1960's amongst geneticists
  - Well after the appreciation of the Neo-Darwinian synthesis
  - Neutral Theory of Evolution gaining more acceptance
- Mid 1960's amongst ecologists
  - Rapidly increasing interest in role of ecological strategies
  - Sought ways to analyze strategies
  - Developed an adaptation-oriented perspective

Strategies for Successful Reproduction in Salmon

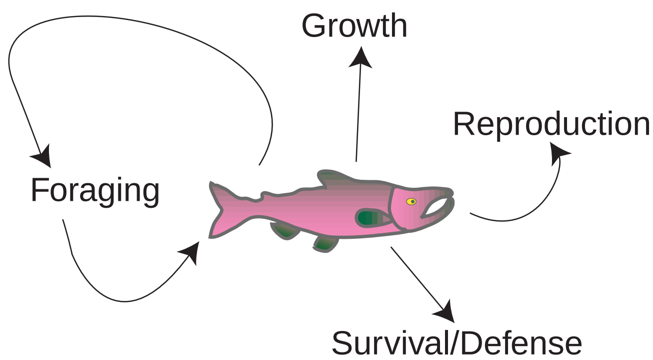
Females establish spawning territory. Males compete with one another for access to females.

- Two distinct strategies for males:
  1. Get big and compete heartily
  2. Mature young and very small and hope larger males won't harass you
- Strategy 1 is adopted by most individuals: much allocation to somatic growth and development of secondary sexual xters (fierce jaws)
- Straregy 2 is adopted by "jacks"—males at least one year younger than most. They allocated much less to somatic growth, and much more energy to the growth and early maturation of their gonads.
  - Sneaking

Evolutionary Ecologists are Interested in the Evolution of Strategies

- Study the fate of different strategies in populations
- Why are some strategies present and some not?
- The classical, genetics-based approach would be to:
  1. Establish strategy heritability
  2. Observe variability in strategies in population
  3. Document fitness differences and hence selection for particular strategies
- Ecologists seldom do this. Instead use Optimality Models or Game Theory

Strategy: a behavior or trait that accounts for energy input into different aspects of life



Assumptions for Optimality Models

The Big Assumptions (that are seldom tested)

1. Strategies are heritable
2. The optimal strategy was available for selection long ago in the population
3. The strategy has been subject to a fairly constant selective regime over some time, so the optimal strategy has had a chance to be selected in the population

Steps for Developing an Optimality Model

1. Choose a currency—Should be a limiting resource
   - food, protein, access to mates, (ENERGY or ENERGY/TIME)
2. Quantify the costs and benefits of different strategies in terms of the chosen currency
3. Find the optimal strategy subject to assumed constraints and trade-offs
4. Test to see if individuals in a population are using the optimal strategy

Constraints and Trade-offs

- Constraint: a restriction not subject to change by evolution
- Trade-off: a relationship between two things which is modifiable by evolution
- There may be many genetic constraints, but these are typically assumed not to exist

Criticisms of Optimality Models

- The strategy investigated may not actually be under selection
- It presents a hypothesis that isn't really falsifiable. Consider the interpretive options if optimal behavior is not observed:
  - We chose the wrong currency
  - We chose the wrong cost-benefit function for the strategies
  - We did our experiment incorrectly
  - These critters truly fail to behave optimally

Optimal Foraging in Fine Grained Environments—Macarthur and Pianka (1966) Optimal Number of Prey Items

- The goal was to predict the optimal diet breadth—i.e. how many prey items should an individual exploit
- This was a cost-benefit analysis—finding a balance between:
  - Time Spent Searching for Food
  - Time Spent Handling Food
- Want to maximize long-term food intake per unit time
- The different strategies are "Different Number of Prey Types in Diet"

Assumptions

- The standard optimality assumptions about evolution
- Environmental structure is repeatable (not patchy)
- "Jack of All Trades Assumption"
  - The animal can't be good at handling all food types
- However, assume that the animal can linearly rank prey items in terms of their Energy/Time (i.e. Benefit/Time)
- In addition to Handling Time for items, some time must be spent searching for items as well. The "Jack of All Trades Assumption" does not apply to searching

The Optimal Strategy Minimizes Time Spent per Unit of Benefit From Food

Let:

- $T(n) =$ total time spent searching and handling for a set a given amount of food *when the diet includes n prey types*
- $T_S(n) =$ amount of time spent searching in order to obtain a given amount of food when the diet includes n prey types
- $T_H(n) =$ amount of time spent in handling prey in order to obtain a given amount of food when the diet includes n prey types
- $T(n) = T_S(n) + T_H(n)$