Individuals: Foraging, Group Behavior

1 Foraging Decisions: Context

1.1 Importance: consequences for survival, reproduction

1.2 Foraging decisions:
abundance vs. quality
pursue vs. ignore
exposure to predation risk

1.3 Economic reasoning: maximize gain or minimize cost of some currency

1.4 Simple rules: simple organisms need not make complex decisions

1.5 3 kinds of foraging behavior:
(i) active search (ii) sit and wait (iii) mixed strategies

2 Example 1: Maximizing Energy Gained

E = total energy gained
T = total foraging time
a_1 = energy from 1
t_1 = handling time for 1

2.1 Simple case: 2 prey types, 1 & 2

2.2 3 possible strategies

2.3 Equations for E_1 & E_{12}

$$E_1 = \frac{Ta_1}{t_1} \qquad E_{12} = \frac{T(a_1 + a_2)}{t_1 + t_2}$$

2.4 Apply to demonstration:
T = 5 sec $a_1 = 10$ $a_2 = 1$ suppose $t_1 = 3$ $t_2 = 1$

$$E_1 = \frac{5*10}{3} = 16.67 \qquad E_{12} = \frac{5(10+1)}{3+1} = 55/4 = 13.75 \qquad (E_2 = 5)$$

Conc: eat type 1 only; ignore 2

2.5 Best strategy: ignore 2 if $a_1/a_2 > t_1/t_2$

3 Example 2: Minimizing Foraging Time (what to eat when in a hurry)

3.1 Intuition: when prey rare, eat all prey types
when prey abundant, selective

3.2 Simple case: 2 prey types

3.3 3 possible strategies

3.4 Compare strategies: Equations for T_1 vs. $T_{1\&2}$:

T = mean search & handling time
a = abundance
t = handling time

$$T_1 = \frac{1}{a_1} + t_1 \qquad T_{1\&2} = \frac{1}{a_1 + a_2} + \frac{a_1 t_1}{a_1 + a_2} + \frac{a_2 t_2}{a_1 + a_2}$$

3.5 Best strategy: ignore prey type 2 if $a_1 > \frac{1}{t_2 - t_1}$

3.6 <u>Conclusion</u>: foragers should be more selective when overall prey abundance high
foragers should be less selective when overall prey abundance low

4 Diet Breadth

4.1 If increase variety in diet: a) decrease search time (T_s) (more prey available)
b) increase handling time (T_h) (include difficult prey)

4.2 Optimal diet breadth = $\min(T_s + T_h)$

4.3 Increase environmental productivity —> decrease T_s —> increase specialization

(continued)

5 Optimal Foraging Theory

- 5.1 Theory to predict behavior of efficient forager
- 5.2 <u>Basic argument</u>: optimality results from natural selection for efficient organisms
  - 5.2.1 survival & reproduction require energy (food)
  - 5.2.2 food resources are limited
  - 5.2.3 efficient foragers have more energy for survival & reproduction
    $\Rightarrow$ have more offspring $\Rightarrow$ higher fitness
  - 5.2.4 optimal forging evolves because natural selection favors efficient foragers
- 5.3 Approach
  - 5.3.1 Identify currency that forager should optimize.
    2 primary currencies: time (minimize foraging time)
    energy (maximize energy gained)
  - 5.3.2 Develop models of foraging strategies in terms of currency
  - 5.3.3 Determine strategy that optimizes currency; predict animals will use it
- 5.4 Other Currencies
  - 5.4.1 Maximize rate of energy gain
  - 5.4.2 Maximize efficiency (max gain / min time)
  - 5.4.3 Minimize starvation risk
  - 5.4.4 Maximize survival
- 5.5 Critique of Optimal Foraging Theory
  - 5.5.1 Assumptions often violated in the field
  - 5.5.2 Often contradicted by observations & difficult to test
  - 5.5.3 “Adaptationist Programme” (cf, S.J. Gould)

6 Limitations of Optimal Foraging Theory

- 6.1 Nutritional considerations ignored
- 6.2 Predation risk may affect foraging
- 6.3 Ignores learning
- 6.4 Ignores efficiency of experience (search images)

7 Marginal Value Theorem

- 7.1 Decision: when to change foraging area
- 7.2 Assumptions: knowledge of environment
  - 7.2.1 know rate of food capture in current patch
  - 7.2.2 know projected rate of food capture in other patches
  - 7.2.3 know travel time to other patches
- 7.3 Marginal Value Theorem:
  Leave current patch when food capture rate = average yield of entire habitat.
  Equivalently, “leave when can do better elsewhere.”

Derivation:

$F(t)$ = amount food obtained in a patch during time t; assume $F(0) = 0$.

$R(t)$ = rate of food gathering, including travel time between patches, τ:

$$R(t) = \frac{\text{food/visit}}{\text{time/visit}} = \frac{F(t)}{t+\tau}$$

Determine t^*, time to leave patch that maximizes R.

$R'(t^*) = 0$ and $R''(t^*) < 0$, for some time $t^*>0$

=> $F'(t^*) = R(t^*)$

Example: $F(t) = bt - at^2$; $F'(t) = b - 2at$

$$b - 2at^* = \frac{bt^* - at^{*2}}{t^* + \tau}$$

$$at^{*2} + 2a\tau t^* - b\tau = 0$$

Apply quadratic formula:

$$t^* = -\tau \pm \sqrt{\tau(\tau + b/a)}$$

7.4 Prediction: optimal Giving Up Time (GUT) decreases as travel time betw/ patches decreases

7.5 Implications for various taxa

7.6 Few tests of Marginal Value Theorem

8 Learning and Foraging Behavior

9 Foraging Theory: different philosophical approach to science

– primacy of individual agenda vs. primacy of mechanism

10 Behavior in Groups

Complex group behavior emerges from simple individual rules.

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