Evolutionary Aspects of Population Ecology

- Why do populations have the characteristics and rates they do?
- How can knowledge of these rates help predict the response of populations to changing conditions?
Evolutionary Aspects

- Evolution occurs over long time scales
- Management action occurs over much shorter ("ecological") time scales
- Often need to make decisions with little specific data. Knowledge of a species life history can help bound possibilities
Life history traits and demographic rates are product evolutionary history

- Iteroparity (one-time reproduction) vs. semelparity (repeat breeder)
- Metamorphosis; niche shifts
- Fecundity
- Age at first reproduction
- Parental care
- Migration/Anadromy

Diagram:
- Terrestrial Habitat
- Aquatic Habitat
Life history traits

• May differ between closely related species
  – Semelparity vs. iteroparity in salmonids
• Among populations of the same species
  – Anadromy in *O. mykiss*:
    • Rainbow trout (resident freshwater)
    • Steelhead (sea-run rainbow trout)
• or even among individuals in the same population
  • Anadromy: residual steelhead
  • Age at 1st reproduction: early return by “jacks”
Evolutionary strategies
Evolutionary strategies

• Robert Mac Arthur and Ed Wilson (1967) suggested in their pioneering work on Island Biogeography that:
  – On arrival to an island “in an environment with no crowding (r selection) genotypes which harvest the most food will be most fit…” whereas
  – “in a crowded area (K selection), genotypes which can at least replace themselves with a small family at the lowest food level will win.”
Evolutionary strategies

• Pianka (1970) expanded on these ideas and suggested species fall on a **continuum** with two endpoints:

  • **r selected**
    - Rapid development
    - Early reproduction
    - small body size
    - semelparity (annual)

  • **K selected**
    - slow development
    - late reproduction
    - large body size
    - iteroparity (perennial)
Life history “decisions”

- At the beginning of any given breeding season, an individual must make several “decisions” with the goal of maximizing:

\[ \lambda = S f \]

where \( S = \) survival rate
and \( f = \) fecundity
Life history “decisions”

• First decision: Breed?
  – Age at first reproduction
    • Size and fecundity
    • Grow and become more fecund, but risk death & no fitness?
      – pre-reproductive mortality stronger selective force than post-breeding mortality
    • May differ by species, sex, population
    • May differ through time
Life history “decisions”

– If breeding, how much effort?
– Reproductive effort:
  • RE is the resources consumed during reproduction
    – propagules
    – migration
    – parental care
  • RE = total weight of propagules / Total biomass at maturity
    = gonadosomatic index (GSI)
– High RE reduces parental survival (Roff 1992: 116)
– Expend all (semelparity) or only some (iteroparity)?
Life history “decisions”

• Reproductive effort divided among
  – Offspring number and offspring size
    • Many small eggs vs. a few big eggs
  – Parental care: Yes?, No?, if so, How much?
    • Pre-breeding: redd building by salmon, egg size, content in fishes
    • Post-breeding: feeding of nestlings
  – Number of broods per season
Three example life history decisions

• Under what circumstances will fitness be maximized by the devotion of so much effort during first reproductive event that death ensues (semelparity)?

• Factors affecting clutch size in birds

• Evolution of diadromy in fishes
Semelparity vs. Iteroparity

• Annual vs. perennial plants
• Varies among species and populations of fishes:
  – Salmonids
  – American shad of east coast U.S. (Glebe and Leggett 1981)
  – coastal vs. interior populations of steelhead
• What happens when we alter the costs of reproduction and RE?
Semelparity vs. Iteroparity

• Cole (1954) asked the question: what effect does repeated reproduction have on r?
• Life table analysis
Semelparity vs. Iteroparity

• Cole (1954) concluded that the maximum gain for switching to iteroparity is equivalent to adding one individual to the average brood size for the semelparous case.

• In other words, annual with single brood of 101 has equal fitness as perennial with multiple broods of 100!

• Why? Even in best case (perfect survival after reproduction), older perennial individuals are contributing not much more than offspring of annual.
Semelparity vs. Iteroparity

• But most species are iteroparous! Why?
Semelparity vs. Iteroparity

• But most species are iteroparous! Why?
• Unrealistic assumptions:
  – Constant conditions
Semelparity vs. Iteroparity

• But most species are iteroparous! Why?
• Unrealistic assumptions:
  – Constant conditions
  – No cost to reproduction—survival was not linked to fecundity
  – Nonetheless, very useful model for understanding how fitness changes with reproduction schedule:
    – Reproductive value \( V_x \) = How much is an individual of a given age worth in terms of future offspring.
      • When is \( V_x \) highest?
Semelparity vs. Iteroparity

• Semelparity is favored
  – when reproductive success increases only when RE is high (*Pacific salmon?*) or
  – when mortality in reproductive stages is high compared to juvenile stages (American shad, mayflies)
Semelparity vs. Iteroparity

• Semelparity is favored
  – when reproductive success increases only when RE is high (Pacific salmon?) or
  – when mortality in reproductive stages is high compared to juvenile stages (American shad, mayflies)

• Iteroparity is favored when
  – reproductive success is relatively high at low RE or
  – when survival rates in juveniles are poor and/or unpredictable compared to adult stages
American shad

• Leggett and Carscadden (1978) and Glebe and Leggett (1981) compared life history traits of populations of American shad along east coast of North America.

• All adults share the same ocean habitat (Gulf Stream)

• Observed strong differences in life history:
  – Connecticut River, CT
  – York River, VA
  – St. John’s River, FL
American shad

• At the time of river entry, gonadosomatic index (GSI) was higher in Connecticut River than St. John’s River, but eggs/mass higher for St. John’s females.
  – In CT population, all ova were mature at river entry
  – ~25% of somatic energy reserves transferred to eggs in FL population during upstream migration
  – Total energy / egg was similar
  – Timing of development and energy allocation differed between populations
American shad

• Latitudinal pattern:

<table>
<thead>
<tr>
<th>Population</th>
<th>% Repeat Spawn</th>
<th>% Energy Consumed</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Brunswick</td>
<td>70%</td>
<td>--</td>
</tr>
<tr>
<td>Connecticut</td>
<td>35%</td>
<td>40-60%</td>
</tr>
<tr>
<td>York River, VA</td>
<td>25%</td>
<td>30%</td>
</tr>
<tr>
<td>St. John’s R., FL</td>
<td>0%</td>
<td>70-80%</td>
</tr>
</tbody>
</table>

Glebe and Leggett 1981
American shad

• What factors explain the latitudinal gradient?
• **Proximate:** Energetics during migration and reproduction:
  – **Northern** populations: 40% upstream migration, + 0% egg development + 15% outmigration = 55%
  – **Southern** populations: 50% upstream migration + 0% outmigration (died) + 30% gonad growth = 80%
American shad

- What factors explain the latitudinal gradient?
- Ultimate?:
- Temperature—warmer in FL = higher metabolic rates? Simply a population at edge of range?
American shad

• What factors explain the latitudinal gradient?
• **Ultimate?:**
• Temperature—warmer in FL = higher metabolic rates and costs of migration
• Predictability in spring warming, run-off, and food supply higher in Florida than New England ~ safer to put all the eggs in one basket...
General rule for fishes?

• Glebe and Leggett (1981) suggested that when adults expend more than a threshold value (~70%) of their energetic reserves during migration and spawning, the population is semelparous (Figure 13 of Glebe and Leggett 1981)
Lack 1966, 1968

• Reproductive rate depends on:
  – Number of eggs laid / clutch
  – Number of clutches laid / year
  – Age at first reproduction

• Clutch size
  – Increases during high food conditions (Cody 1966)
  – Increases with latitude
• Many species have a characteristic clutch size:
  – Petrel = 1
  – Pigeon = 2
  – Gull = 3
  – Duck = 7-12
  – Partridge = 10-20

• Why have a specific clutch size?
  – Why not a larger clutch size?
1) Mechanical / physiological constraints

• Only so many eggs can be produced inside the body the cavity or with available resources

• Does the observed clutch size reflect mechanical/physiological constraints?
  – How could we test?
1) Mechanical / physiological constraints

• Only so many eggs can be produced inside body the cavity or with available resources

• Does the observed clutch size reflect mechanical/physiological constraints?
  – How could we test (for indeterminate layers)?
    • Remove eggs—does female lay more eggs?
2) Incubation

- Clutch size is limited by number of eggs the sitting bird can cover
3) Mortality

- Past mortality during rearing (natural selection) has adjusted the clutch size to maximize the number of offspring—clutches that were too large were selected against
In most birds, clutch-size has evolved through natural selection to correspond with the largest number of young for which the parents can, on the average, find food.
Food to nestlings

- **House Wrens**

<table>
<thead>
<tr>
<th>Brood size</th>
<th>Trips</th>
<th>Trips/Nestling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>2</td>
<td>156</td>
<td>78</td>
</tr>
<tr>
<td>3</td>
<td>198</td>
<td>66</td>
</tr>
<tr>
<td>4</td>
<td>236</td>
<td>59</td>
</tr>
<tr>
<td>5</td>
<td>270</td>
<td>54</td>
</tr>
<tr>
<td>6</td>
<td>300</td>
<td>50</td>
</tr>
</tbody>
</table>
The Lack value

- The Lack value (the clutch size that produces the largest number of offspring) is probably incorrect for at least two reasons:
The Lack value

• The Lack value (the clutch size that produces the largest number of offspring) is probably incorrect for at least two reasons:
  – Effects of large clutch size on parent survival or future fecundity
The Lack value

• The Lack value (the clutch size that produces the largest number of offspring) is probably incorrect for at least two reasons:
  – Effects of large clutch size on parent survival or future fecundity
  – Environmental variability
Evolution of diadromous migration in fishes

- Diadromy—use of ocean and freshwater
- Anadromy—freshwater reproduction, ocean feeding
- Catadromy—ocean reproduction, freshwater feeding
- Remember: $\lambda = S f$
Evolution of diadromous migration in fishes

- Diadromy-use of ocean and freshwater
- Anadromy-freshwater reproduction, ocean feeding
- Catadromy-ocean reproduction, freshwater feeding
- Remember: \( \lambda = S f \)
  \[ = (S_{FW} S_{ocean})(f_{FW} + f_{ocean}) \]
Evolution of diadromous migration in fishes

- Remember: $\lambda = S \cdot f$
  
  $= (S_{FW} S_{ocean}) (f_{FW} + f_{ocean})$
  
  assume $f \sim$ growth

$S_{FW} / S_{ocean}$ in early life history stages determines where to spawn

$f_{FW} / f_{ocean}$ determines where to feed
Evolution of diadromous migration in fishes

$S_{FW} / S_{ocean}$ in early life history stages determines where to spawn

$f_{FW} / f_{ocean}$ determines where to feed

Predictions? Salmon

Eels

What data could we collect to test?
Gross et al. (1988)
Gross et al. (1988)

![Graph showing the number of fish species against latitude intervals. The graph compares Anadromy and Catadromy species distributions.](image-url)
Gross et al. (1988)
Summary

• Evolution (and ecology) shape the life histories of species, populations, and individuals
• Life history theory can help clarify which selective forces may have been important in the past and
• Which selective forces could have the greatest effect in the future
Summary

• Can use life history theory to understand potential future conditions
  – Increased energetic costs during migration?
  – Increased food supply during nesting period?