Talk Outline:

- Introduction
  - Conceptual background
  - Natural history
- Mayfly case study
- Implications

Population Biology:

How many are there?

$$N_{t+1} = N_t + \text{Births} - \text{Deaths} + \text{Immigrants} - \text{Emigrants}$$

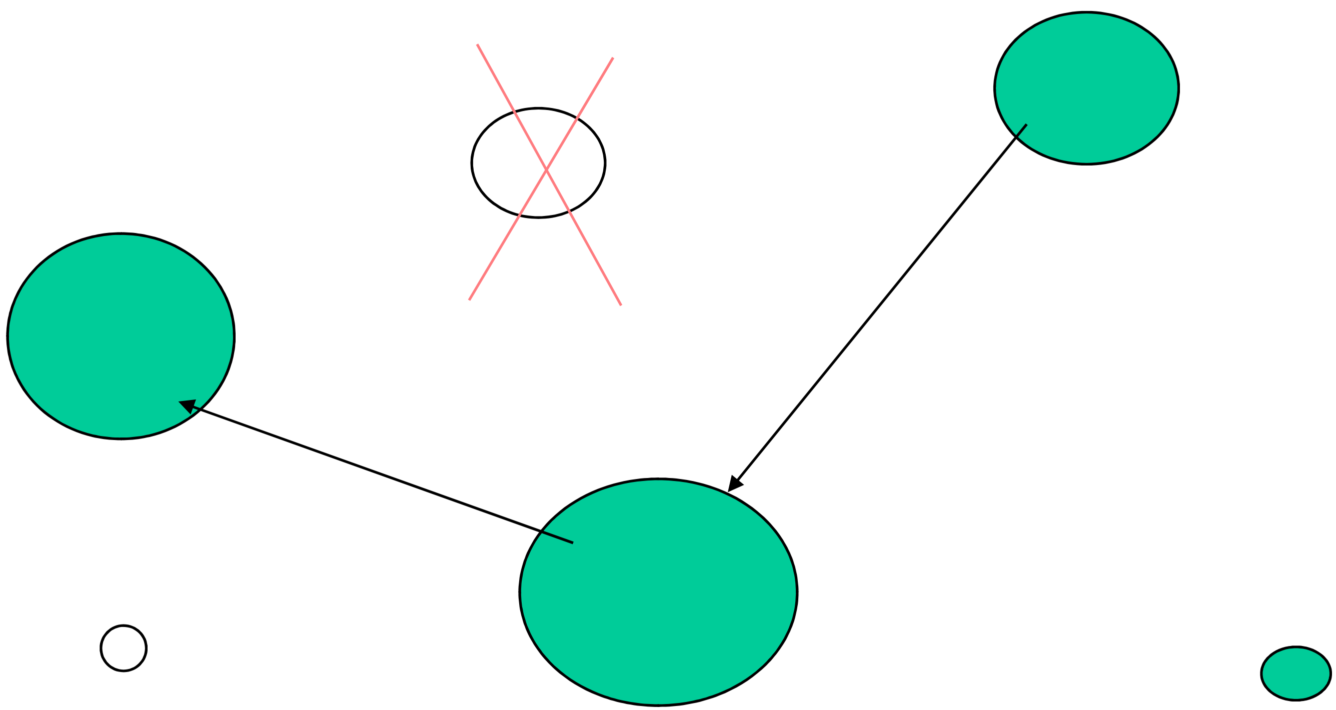
Population Biology:
Historical assumption

$$N_{t+1} = N_t + \text{Births} - \text{Deaths} + \cancel{\text{Immigrants}} - \cancel{\text{Emigrants}}$$

Closed Population
Immigration = Emigration

Metapopulation:
Levins (1969, 1970)

Population of populations, connected by some degree of dispersal



Metapopulation:
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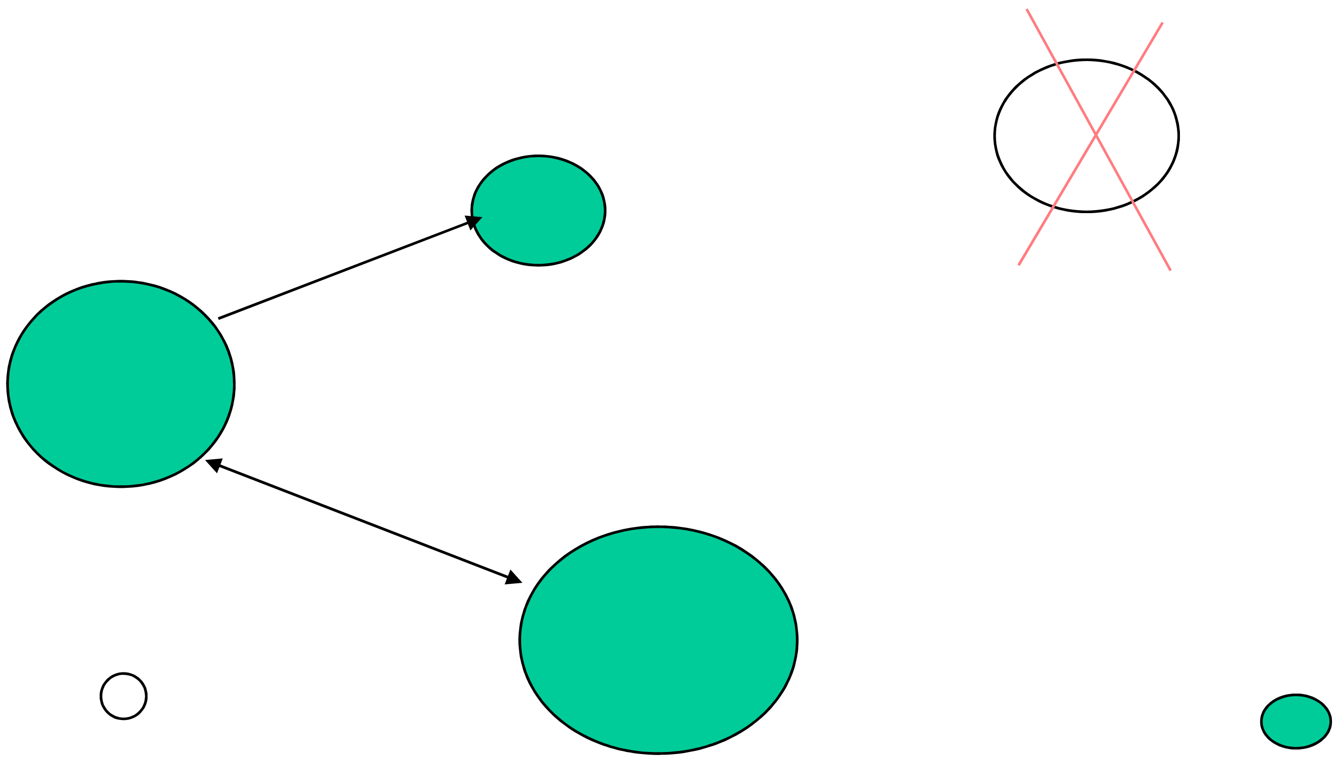
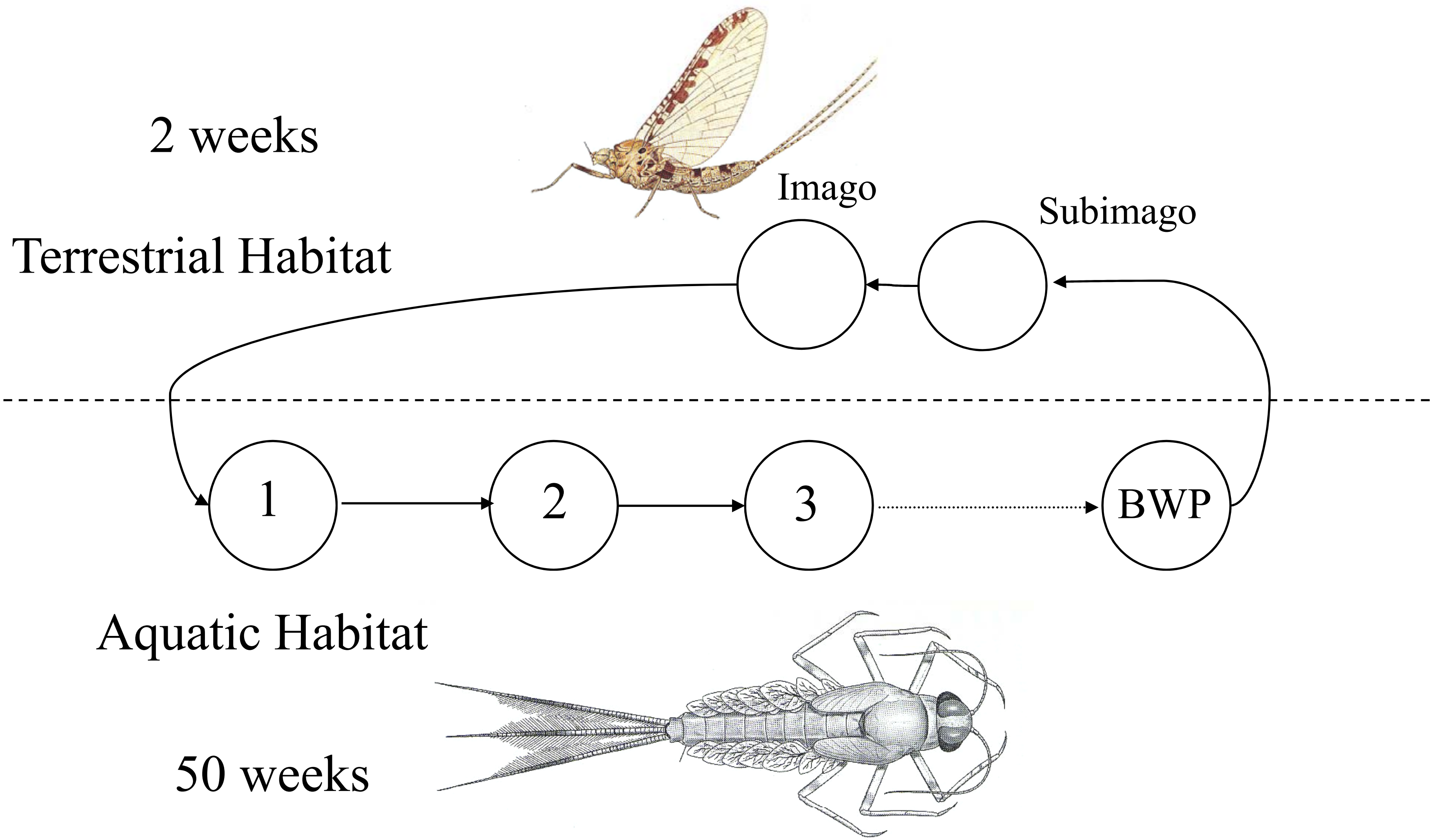


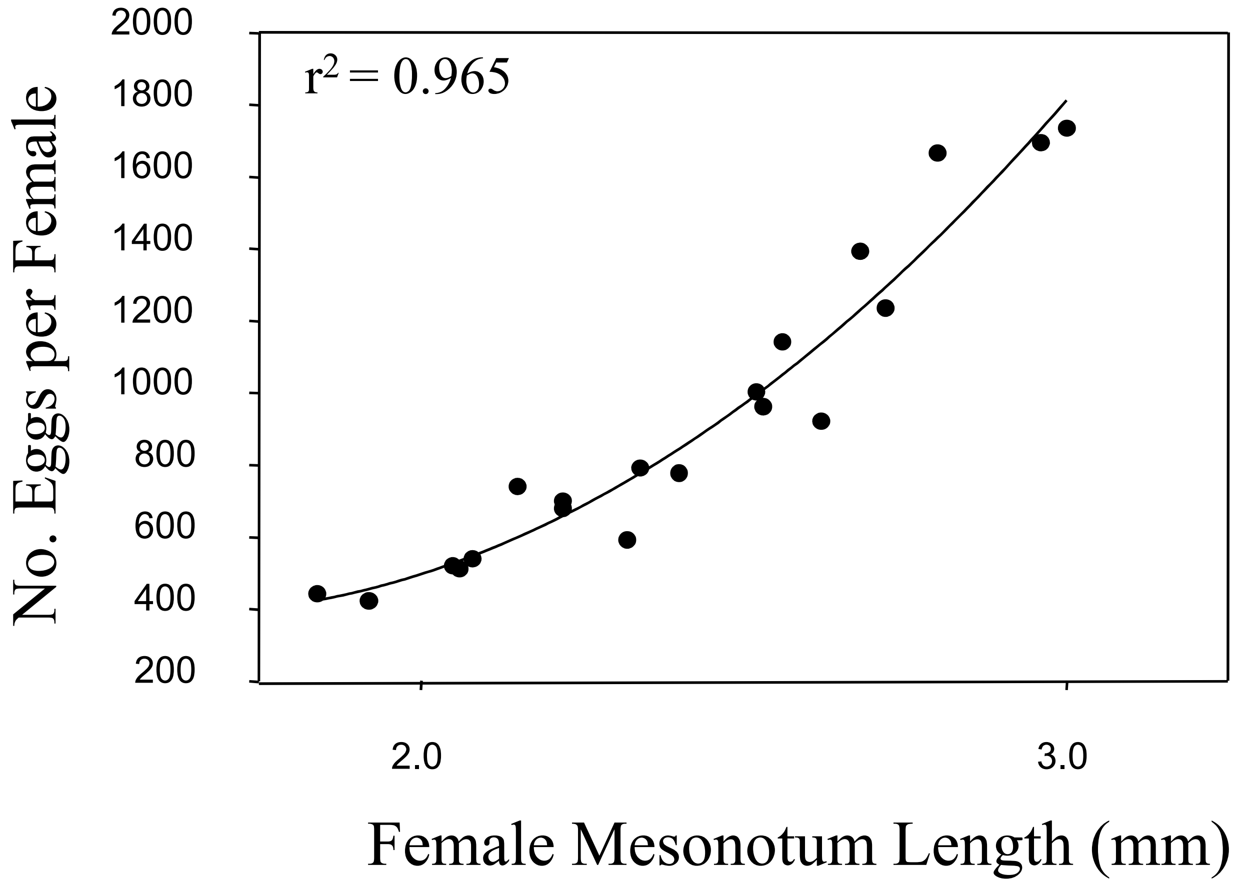
Problem-driven Investigations: Collect data to address hypotheses about a specific species, population. “Applied” science.

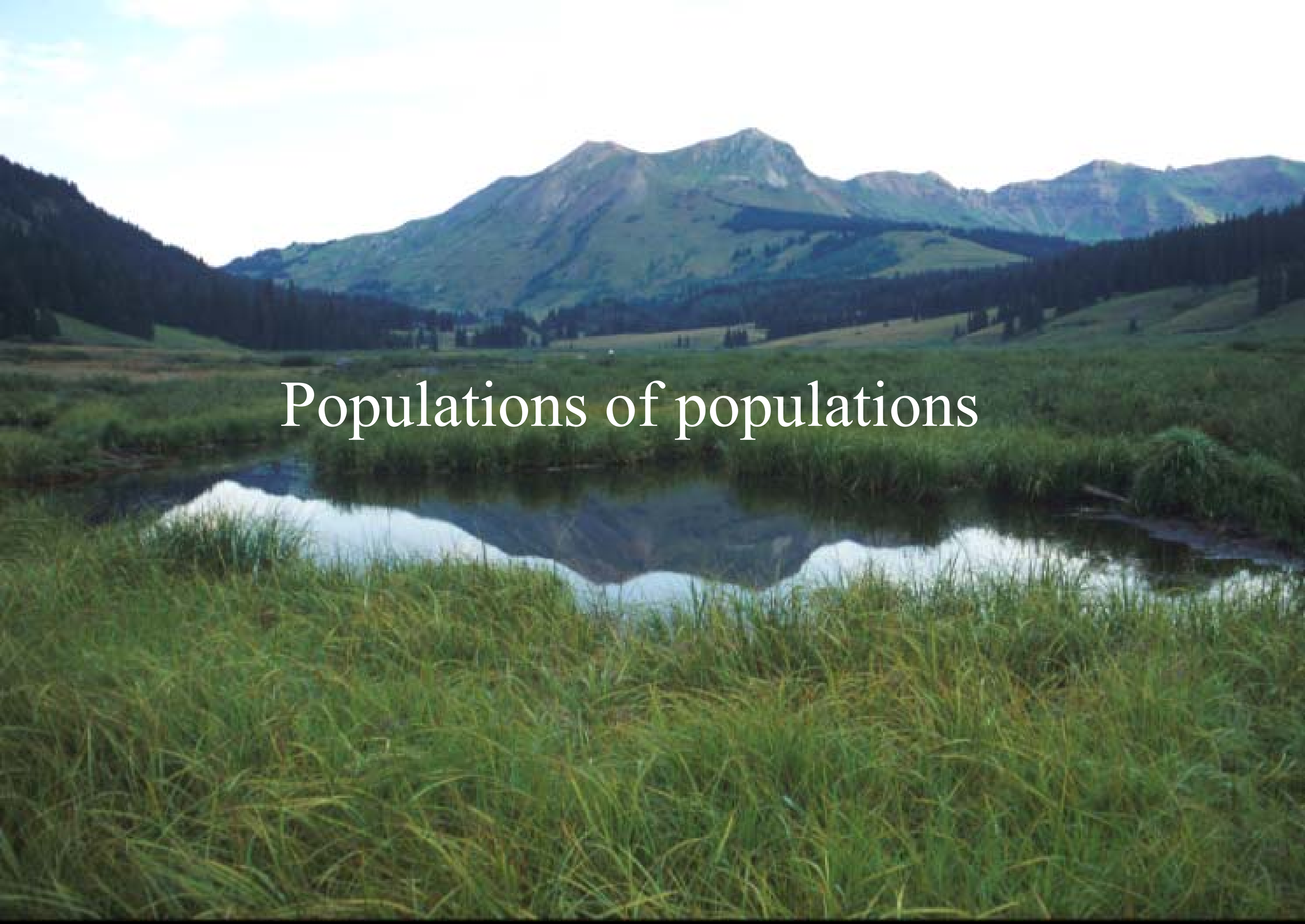
Concept-driven Investigations: Collect data to address general hypotheses. Find a system amenable to question. “Basic” science.

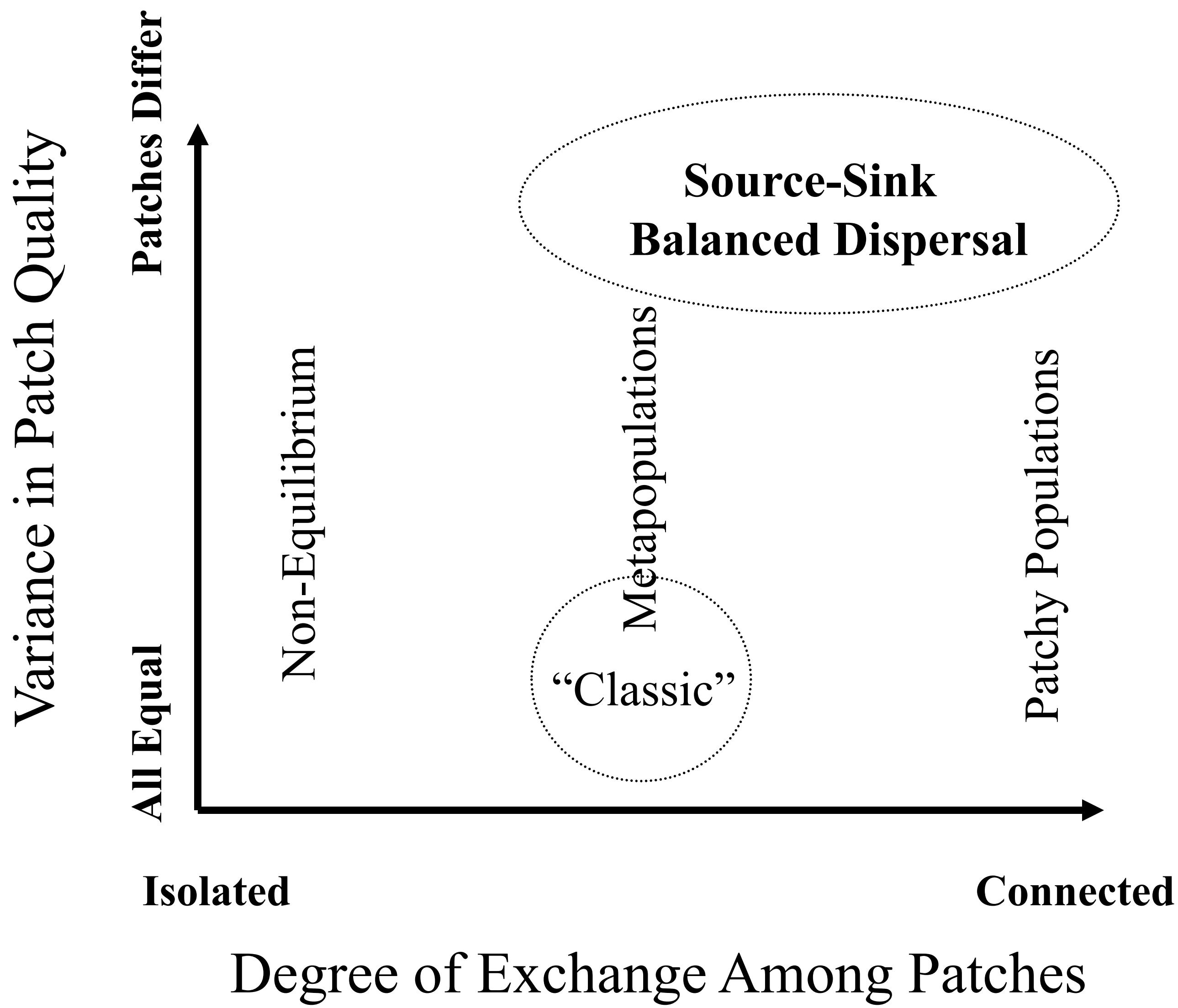
Life Cycle of *Callibaetis ferrugineus hageni:*



Size-Fecundity, *Callibaetis*




Populations of populations



After Harrison and Taylor 1997


U-HAUL
RIGHT EQUIPMENT / LOWEST COST
Venture Across America
WASHINGTON
RARE AMERICAN RAIN FORESTS OF OLYMPIC NATIONAL PARK
Where Will U Go Next?
Gentle-Ride Van
www.uhaul.com
EL 4523 H

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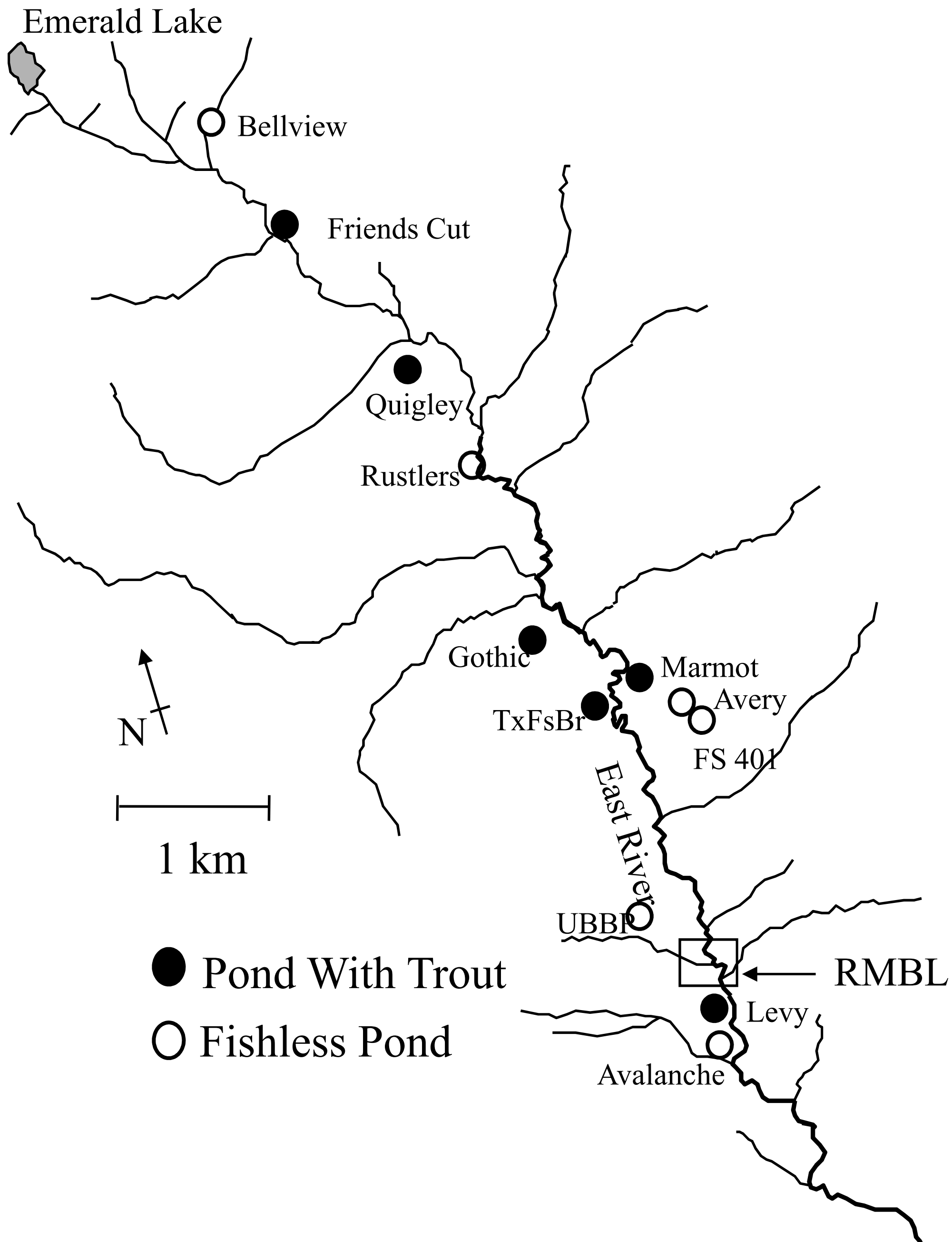
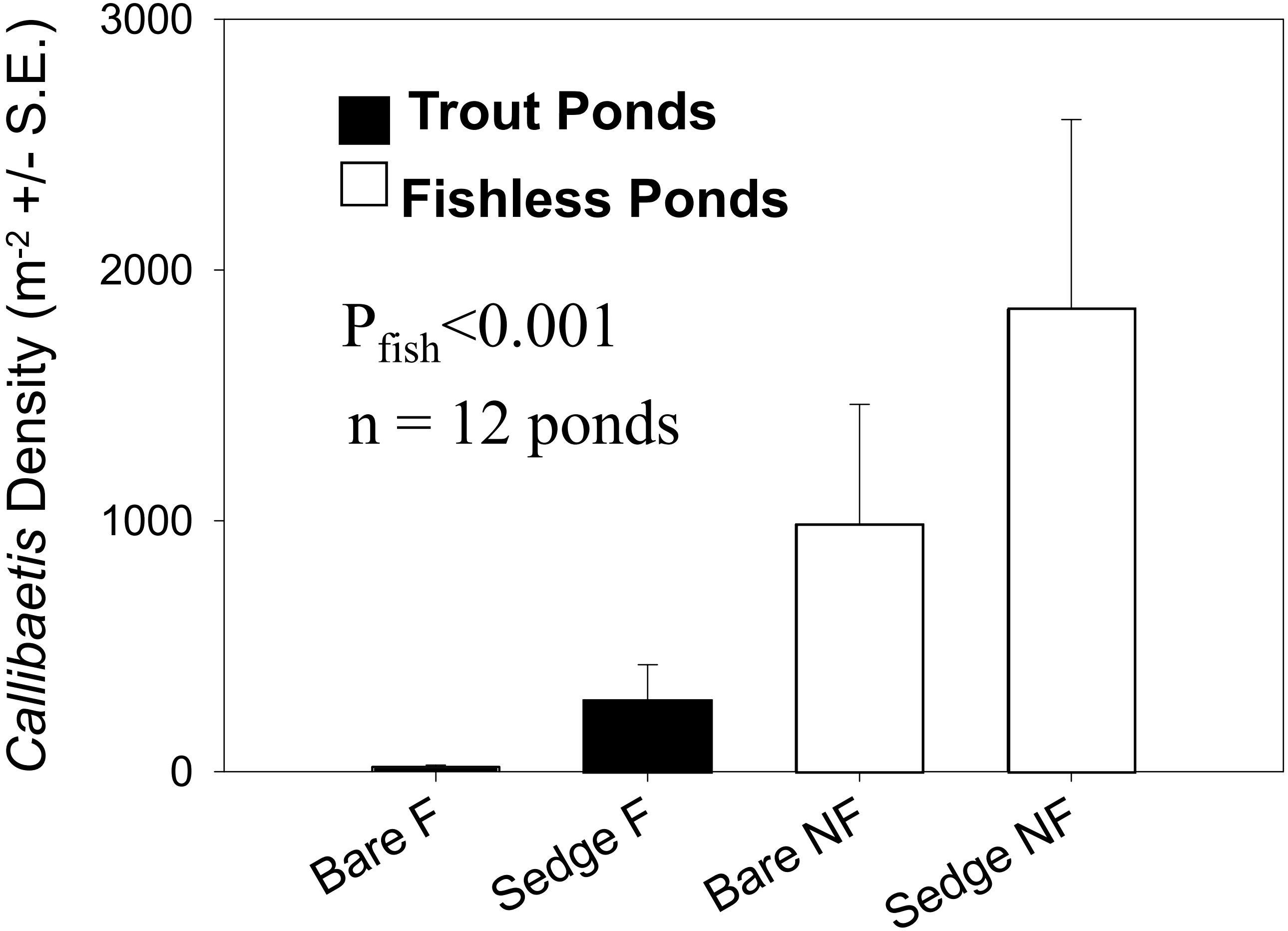
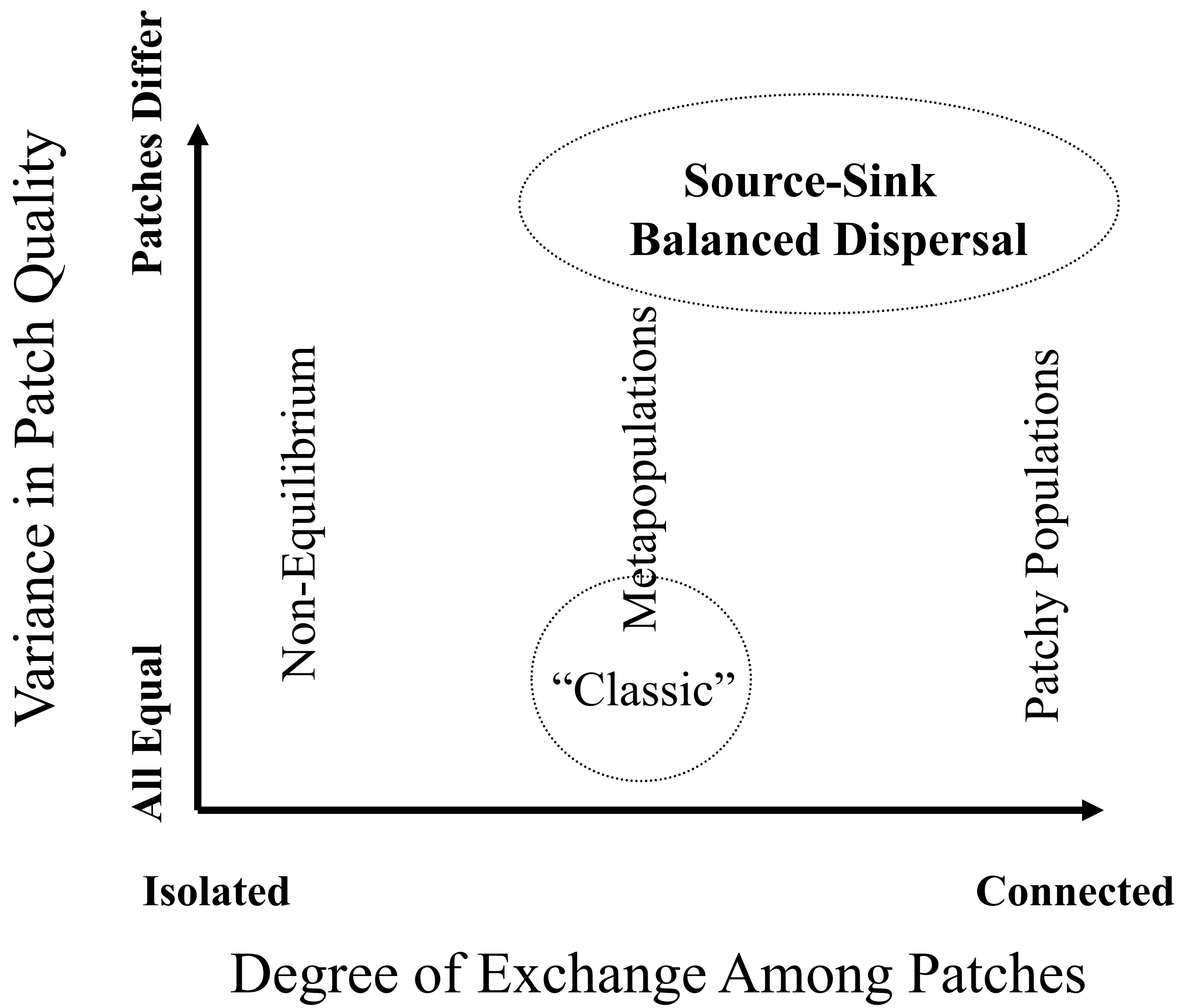
Spatial Patterns of Abundance:

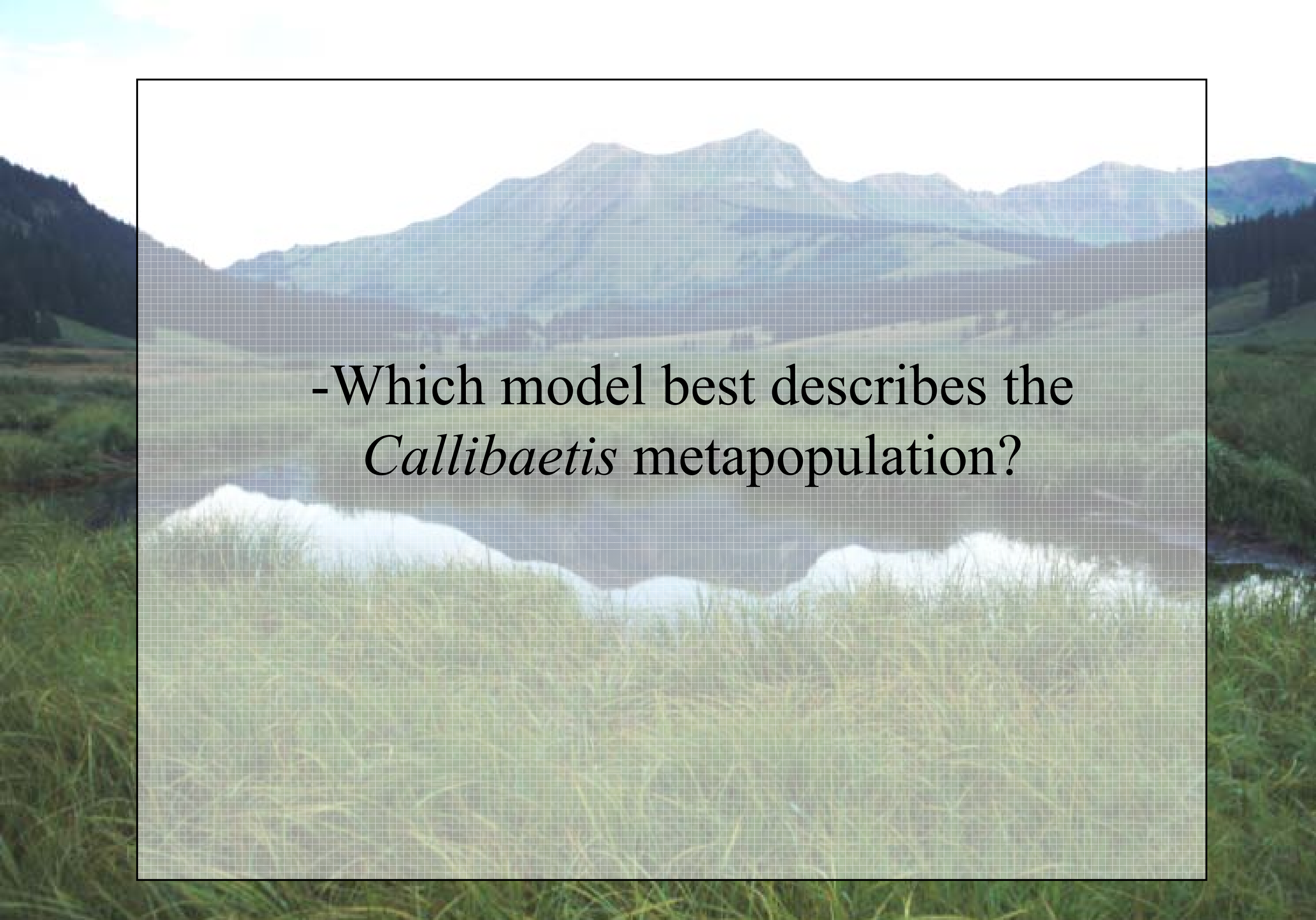




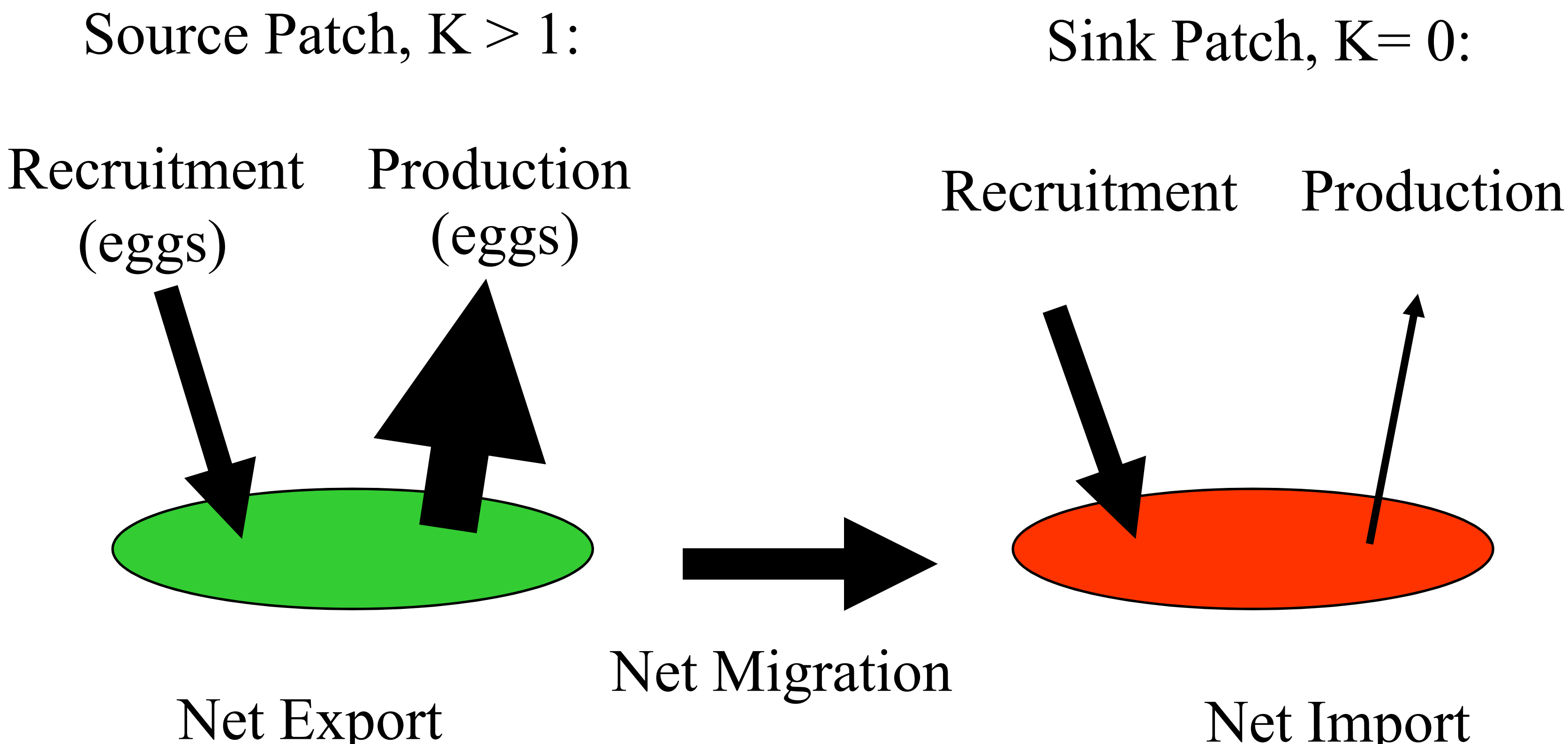
Callibaetis Density (m-2 +/- S.E.)
3000
2000
1000
0
Trout Ponds
Fishless Ponds
Pfish<0.001
n = 12 ponds
Bare F
Sedge F
Bare NF
Sedge NF



After Harrison and Taylor 1997

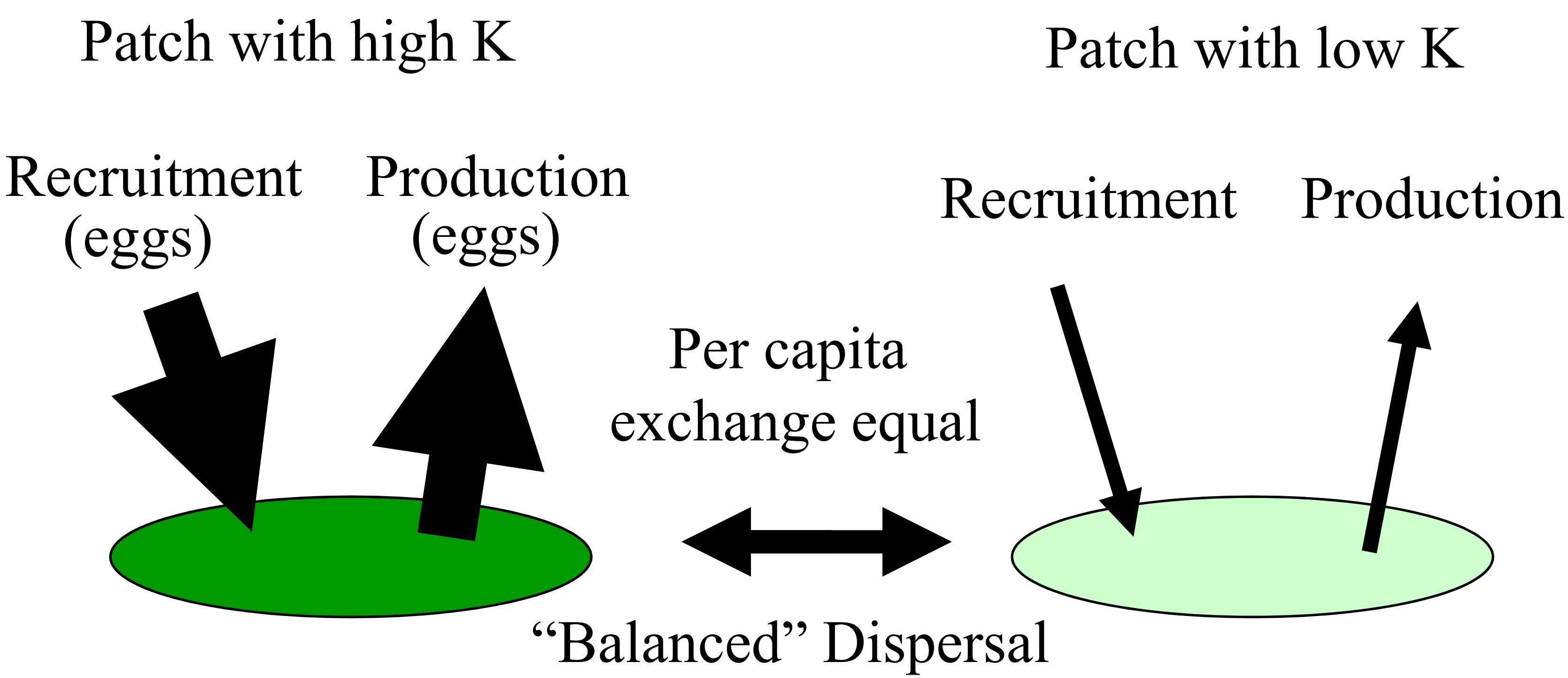

-Which model best describes the
Callibaetis metapopulation?

Nonselective Dispersal:
Source-Sink Dynamic

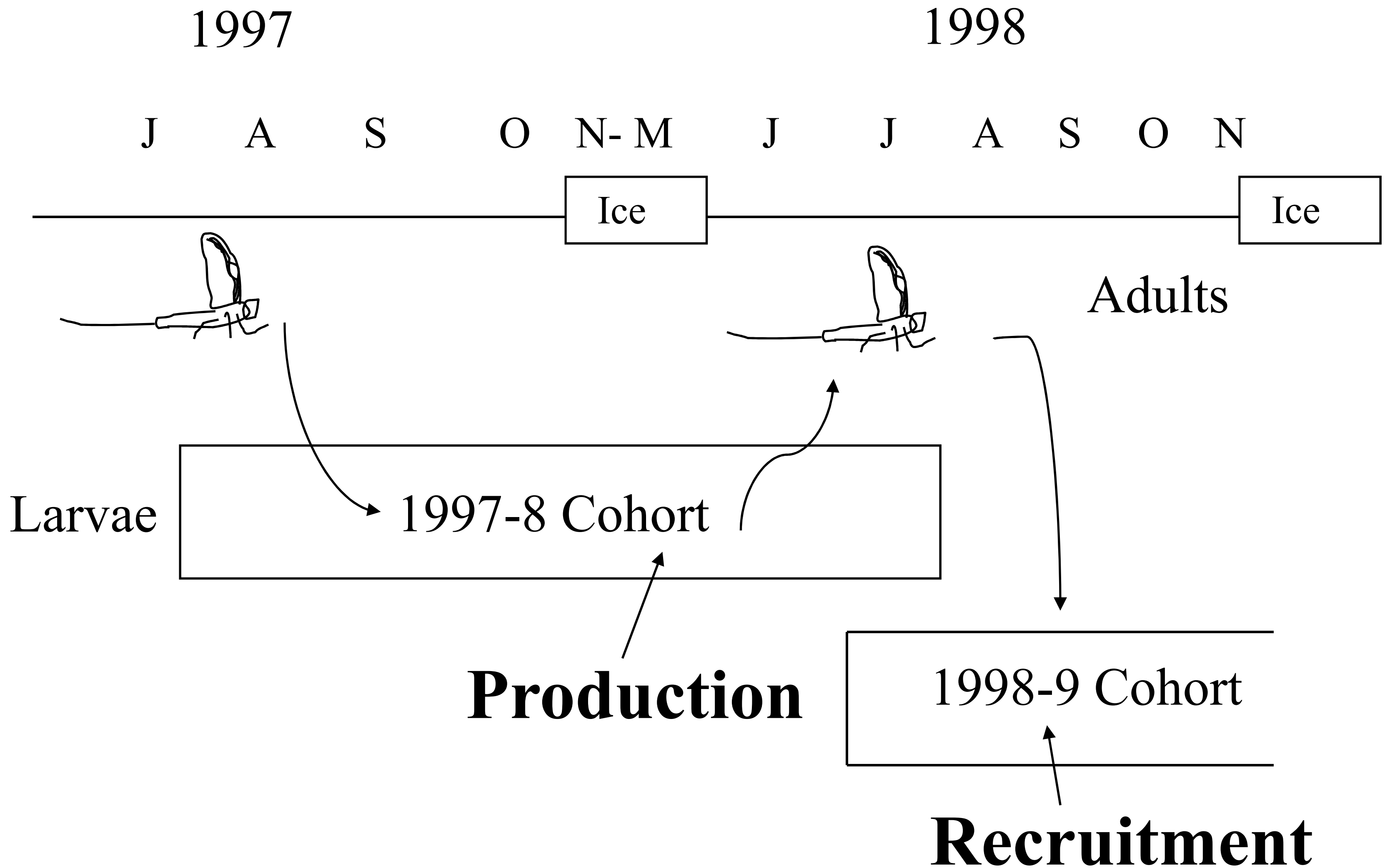


Selective Dispersal

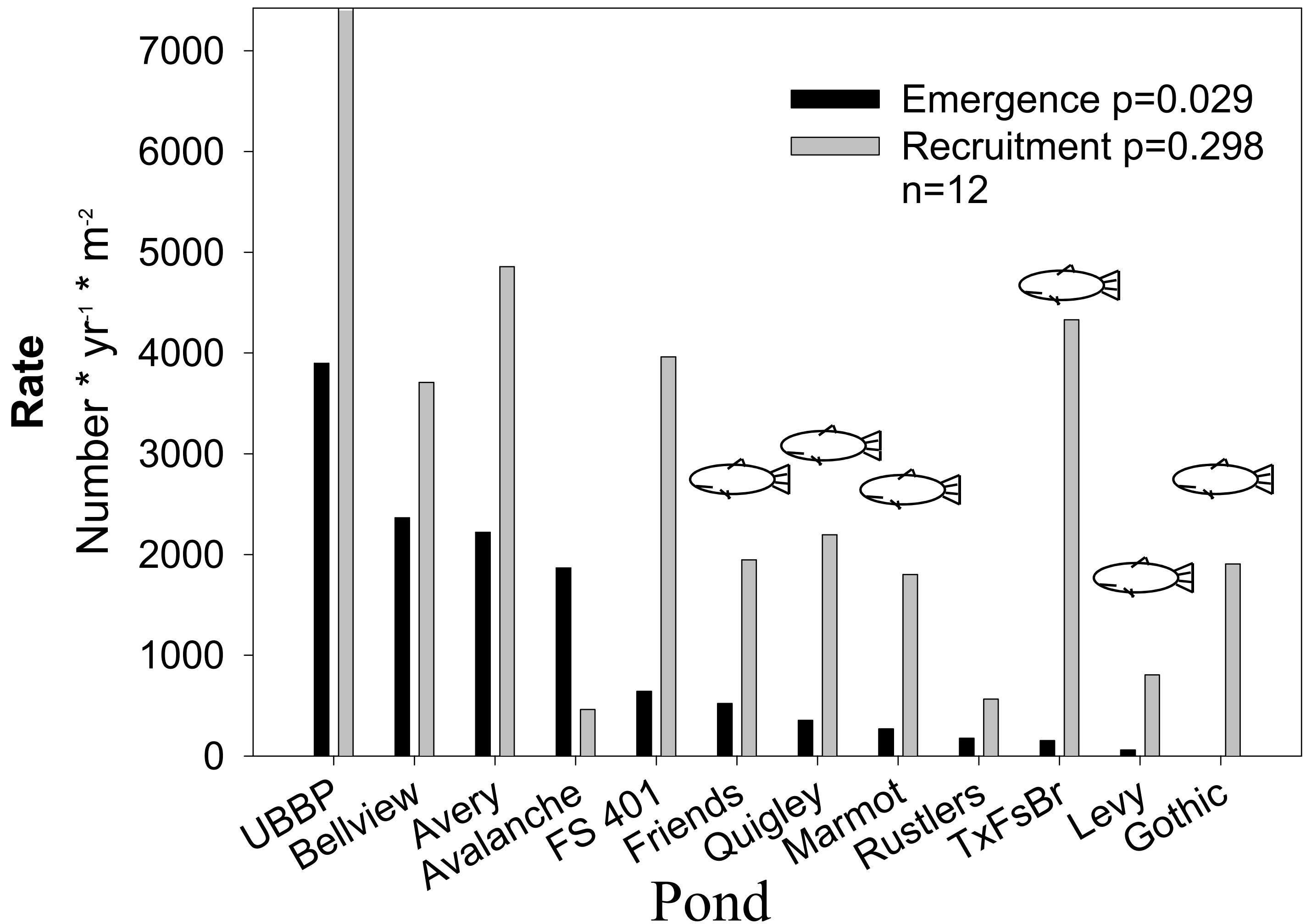
Balanced Dispersal Dynamic



No net import or export of eggs


1997
1998
J
A
S
O
N- M
J
J
A
S
O
N
Ice
Ice
Adults
Larvae
1997-8 Cohort
1998-9 Cohort
Production
Recruitment

Microhabitat Scale: Adult Emergence Rate from the Sedge Microhabitat



Emigration Index (EI):
Closed Populations

$$EI_i = Recruitment_{expected} / Recruitment_{observed}$$

where

$$Recruitment_{expected} = N_i * Fecundity_i * Mortality_{adult}$$

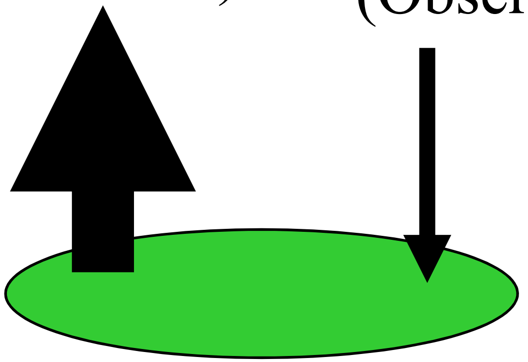
Emigration Index (EI):

Source Sink Dynamic:

Source = Net Exporter:

Production
(Expected
Recruitment)

Recruitment
(Observed)

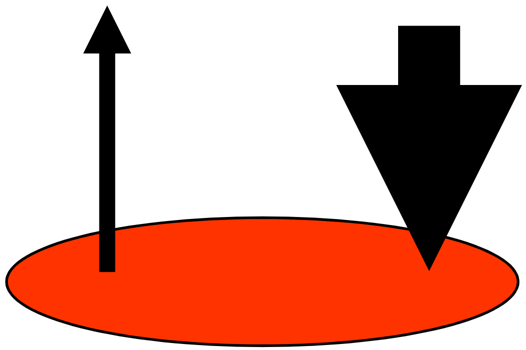


EI > 1

Sink = Net Importer:

Production

Recruitment



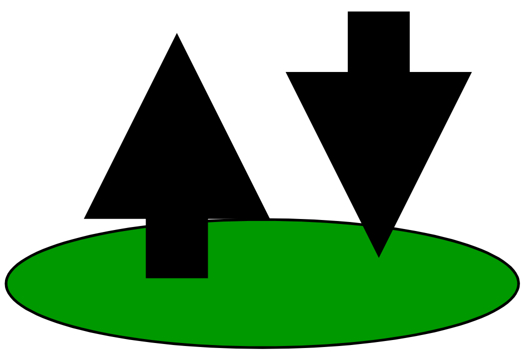
EI < 1

Emigration Index (EI):

Balanced Dispersal:

High K:

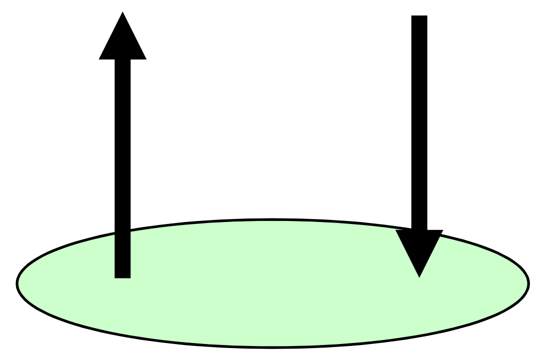
Production Recruitment



EI = 1

Low K:

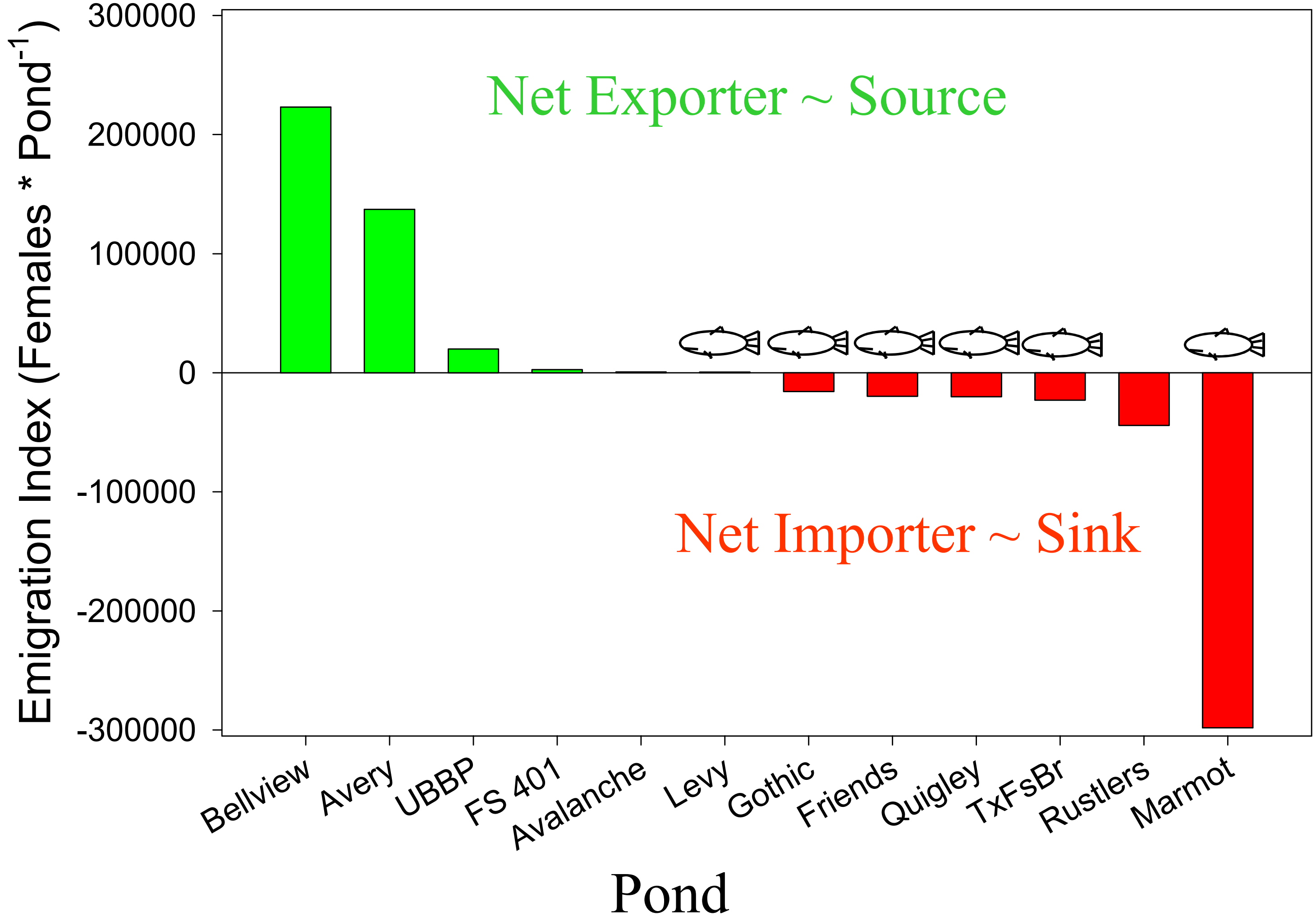
Production Recruitment



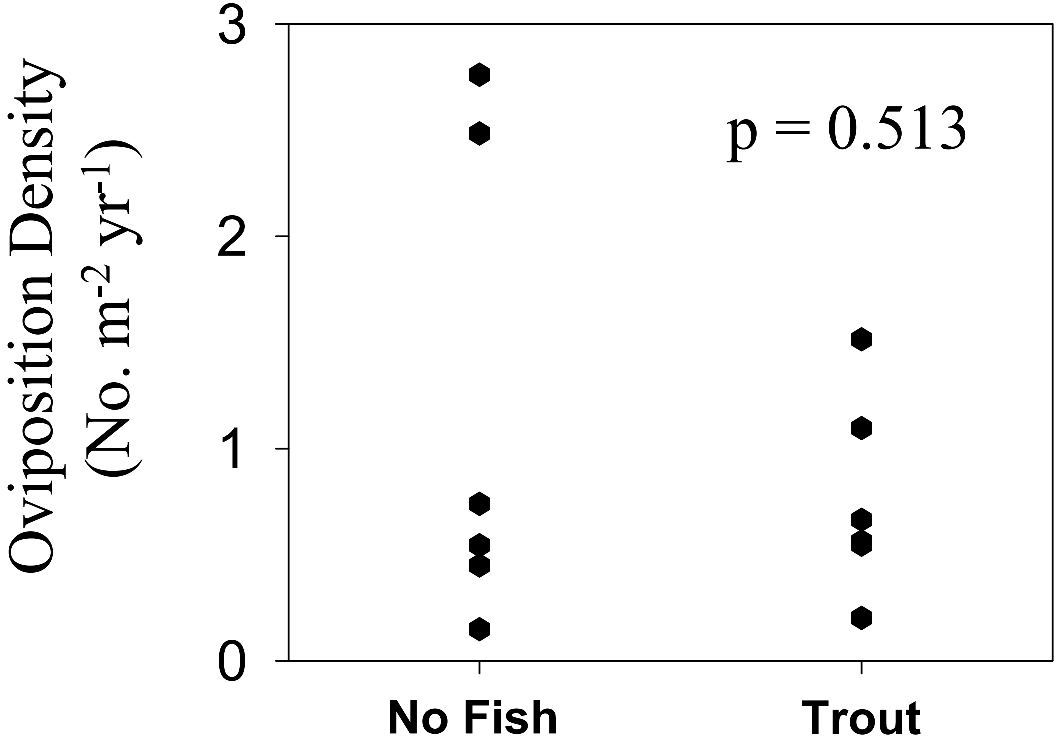
EI = 1

Emigration Index

w/ Observed Adult Mortality Rate

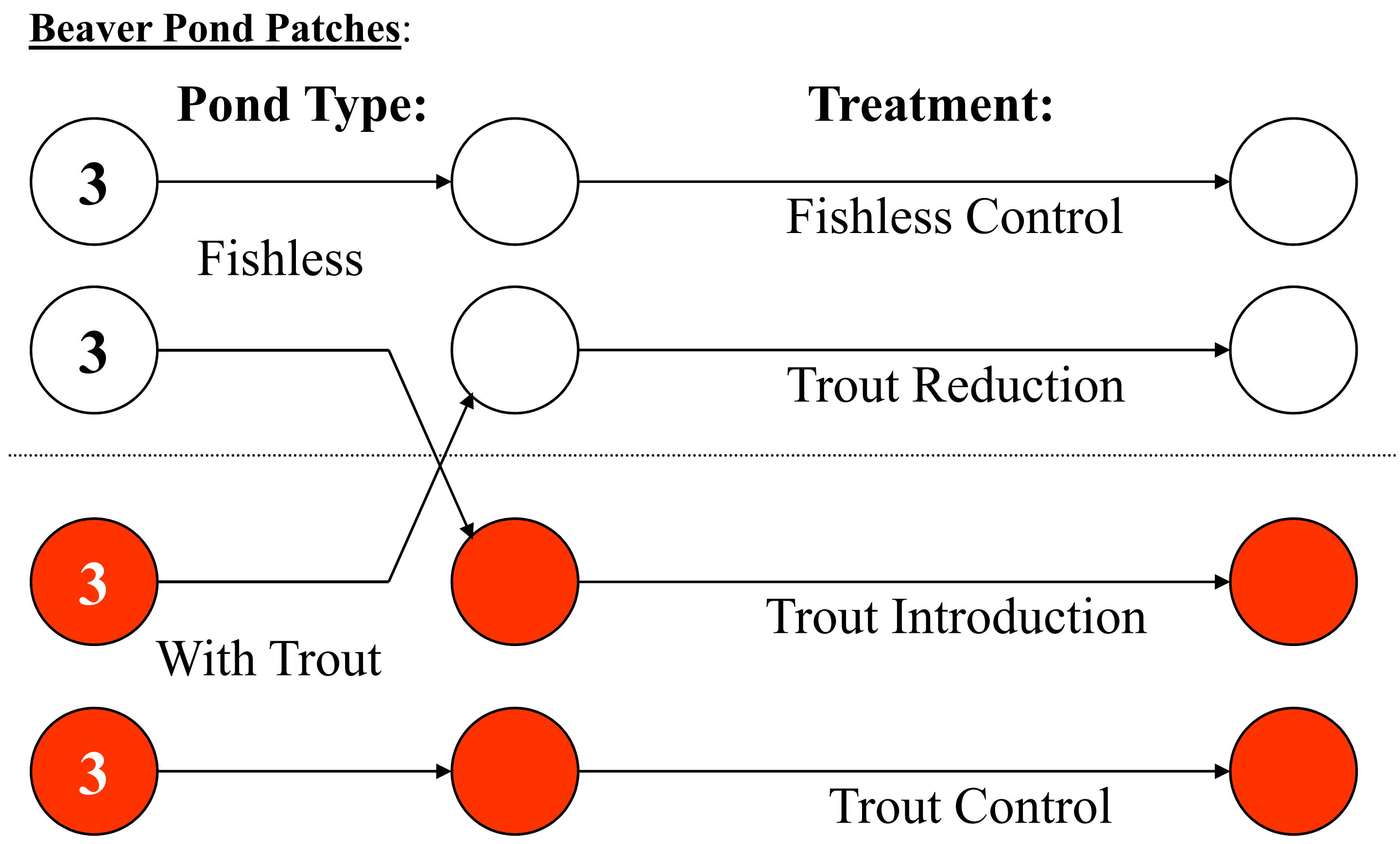


Patch Selection Behavior:



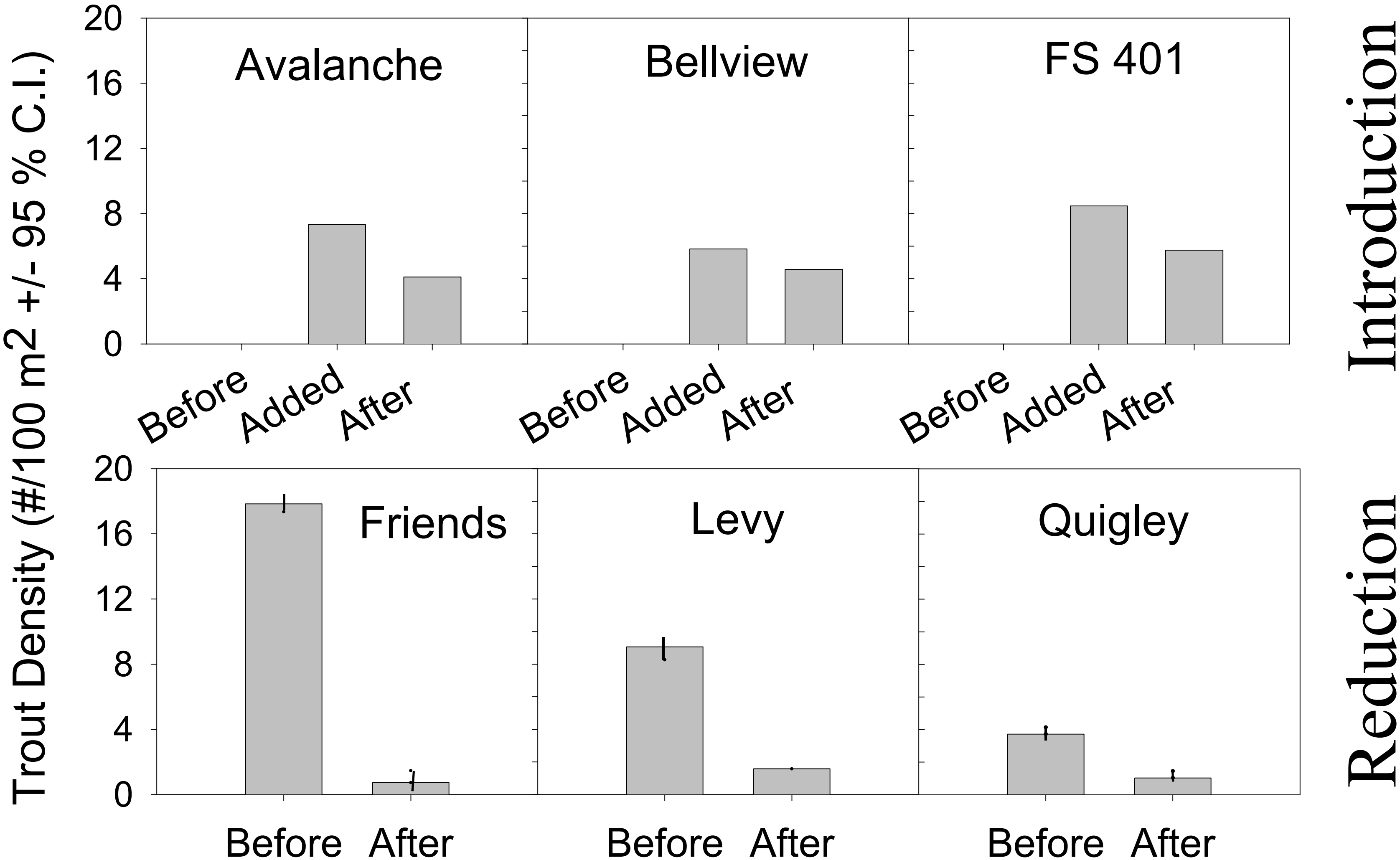
- Conclusions: Patterns of Abundance:
  - **Source-Sink** Metapopulation:
    - Large Differences in Emergence Rate
    - Local Production ≠ Local Recruitment
    - Emigration Index: Net Migration
    - Non-Selective Oviposition
- Mayfly as model system

- Objectives:
  - Spatial Patterns
  - Patch Quality (Fish)
  - Dispersal
  - Larval Plasticity

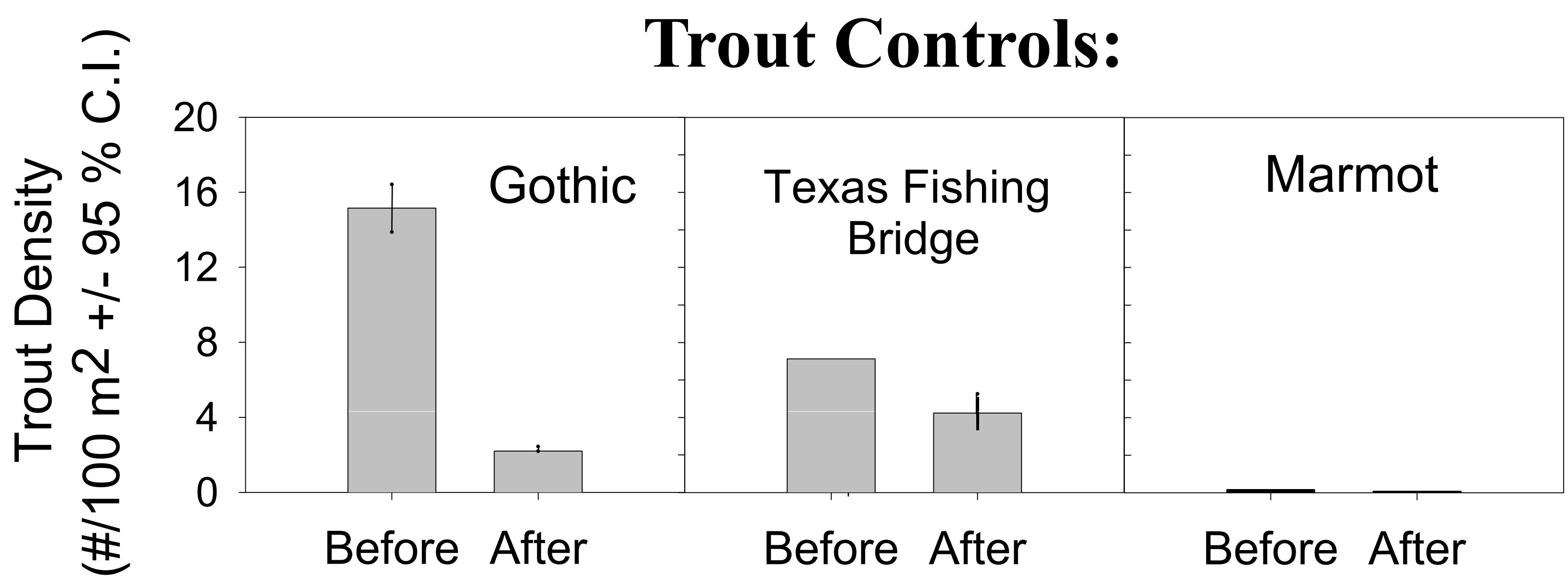


Beaver Pond Patches:
Pond Type:
Treatment:
3
Fishless
3
Fishless Control
Trout Reduction
3
With Trout
3
Trout Introduction
Trout Control

Trout Density by Treatment



Trout Density by Treatment

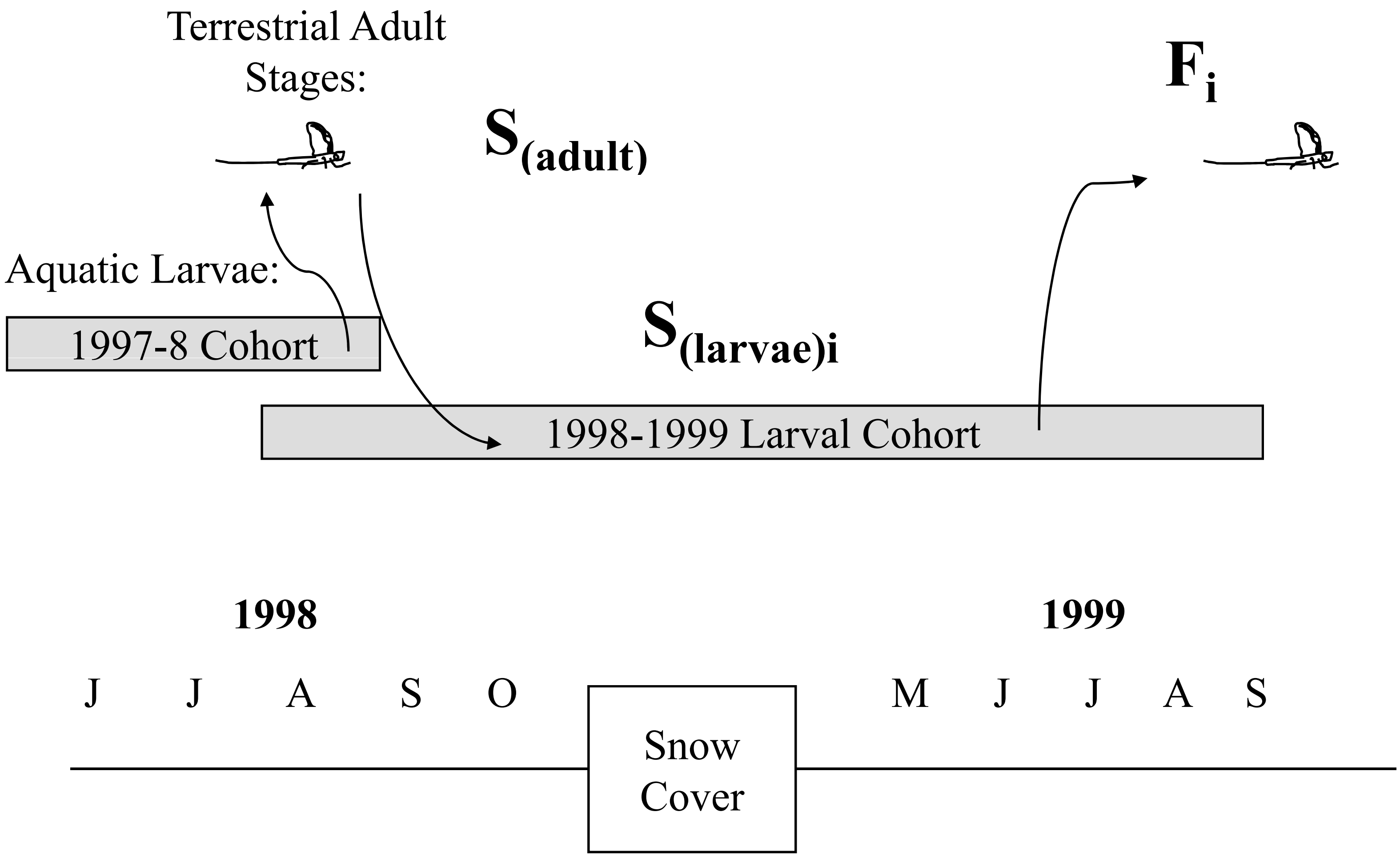


Local Population Growth Rate:

$$\lambda = S_{(larvae)i} * S_{(adults)} * F_i$$

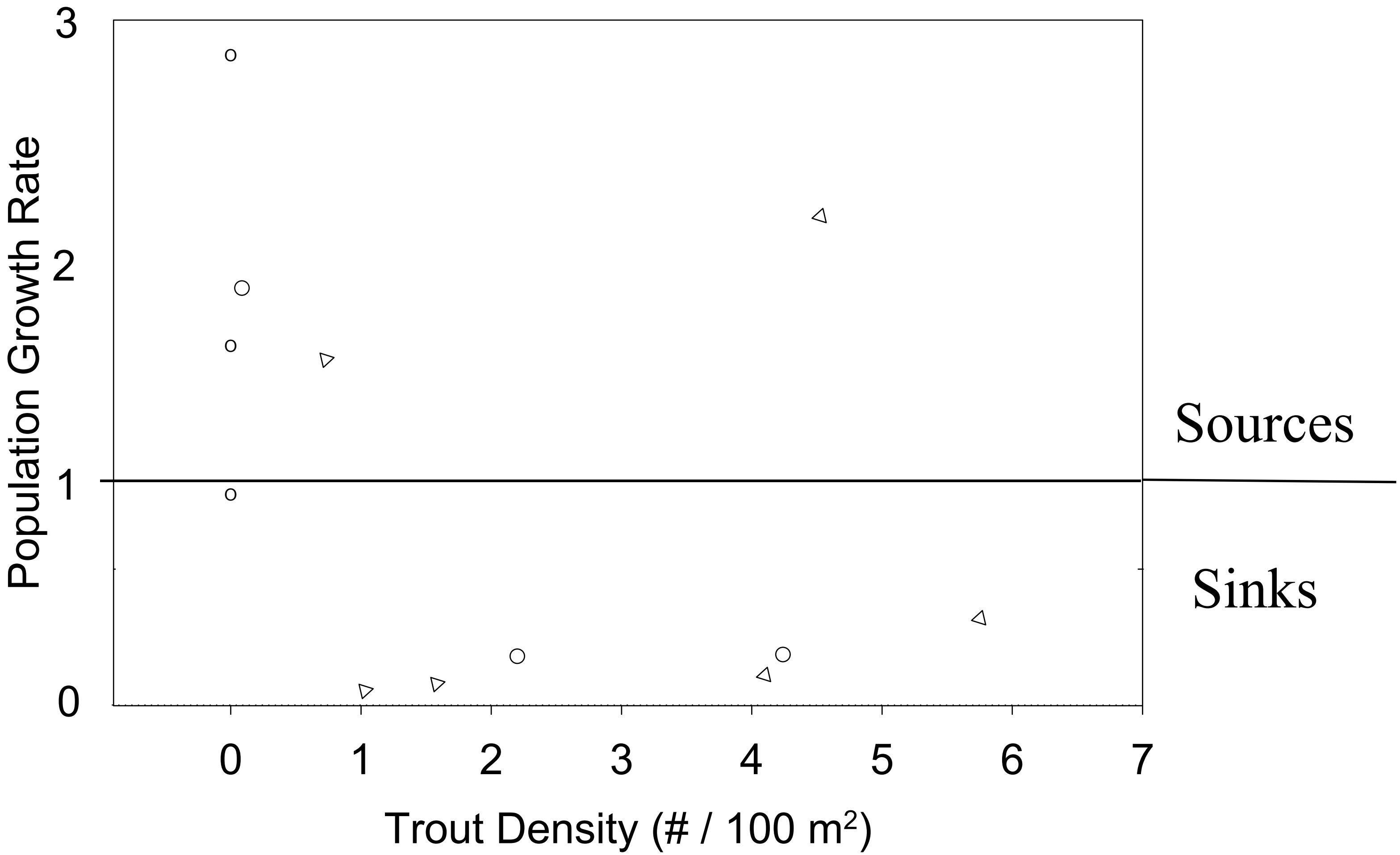
$$\lambda > 1 = \text{Source}$$

$$\lambda < 1 = \text{Sink}$$



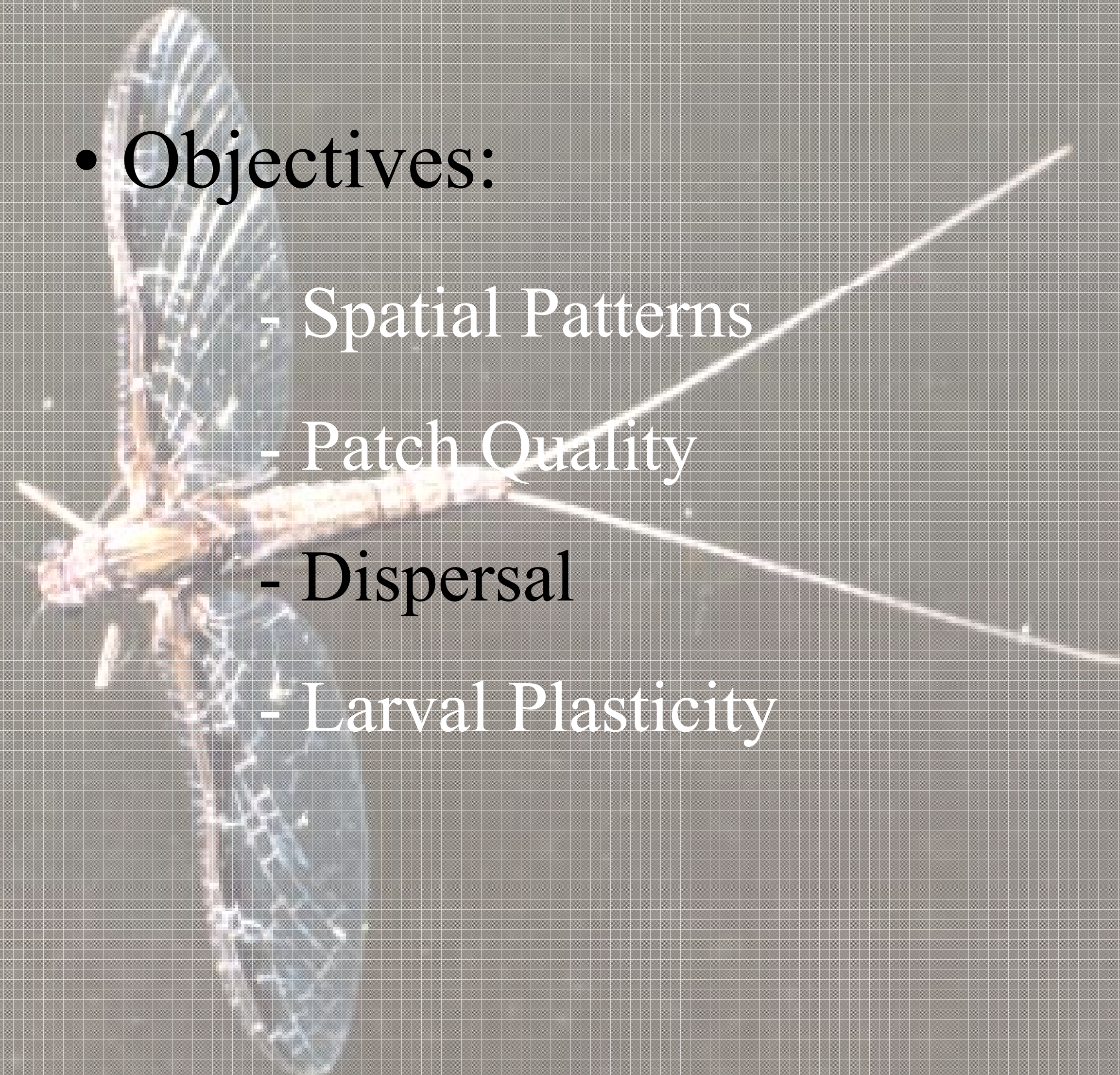
Terrestrial Adult Stages:
$S_{(adult)}$
F_i
Aquatic Larvae:
1997-8 Cohort
$S_{(larvae)i}$
1998-1999 Larval Cohort
1998
1999
J J A S O
Snow Cover
M J J A S

Do Trout Reduce Patch Quality?
Callibaetis Population Growth Rate (λ):



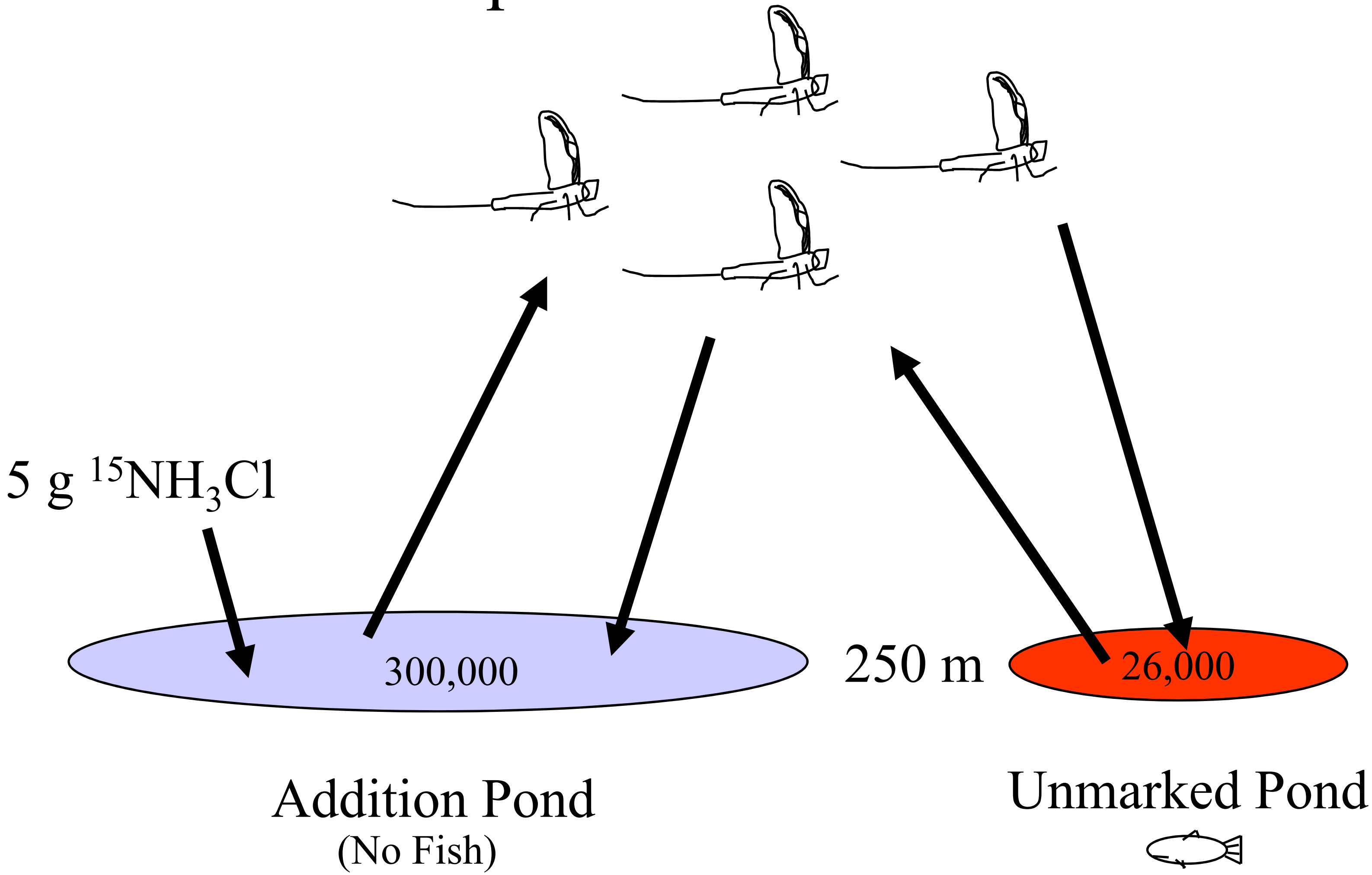
Conclusions:

- Patch Quality
  - Trout reduce λ
  - > 1 Trout 100 m^{-2} = Sink
  - < 1 Trout 100 m^{-2} ~ Source

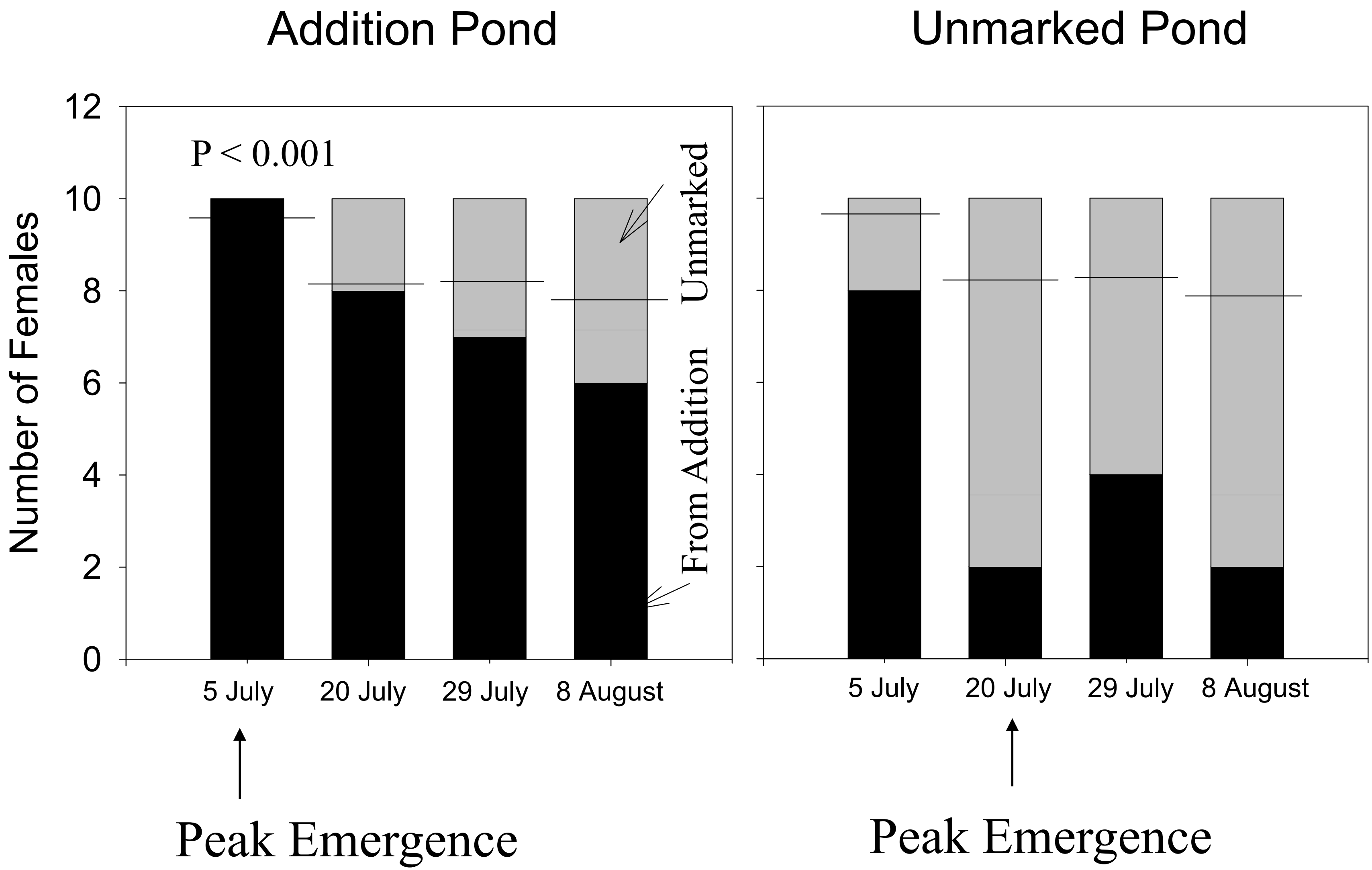


- Objectives:
    - Spatial Patterns
    - Patch Quality
    - Dispersal
    - Larval Plasticity

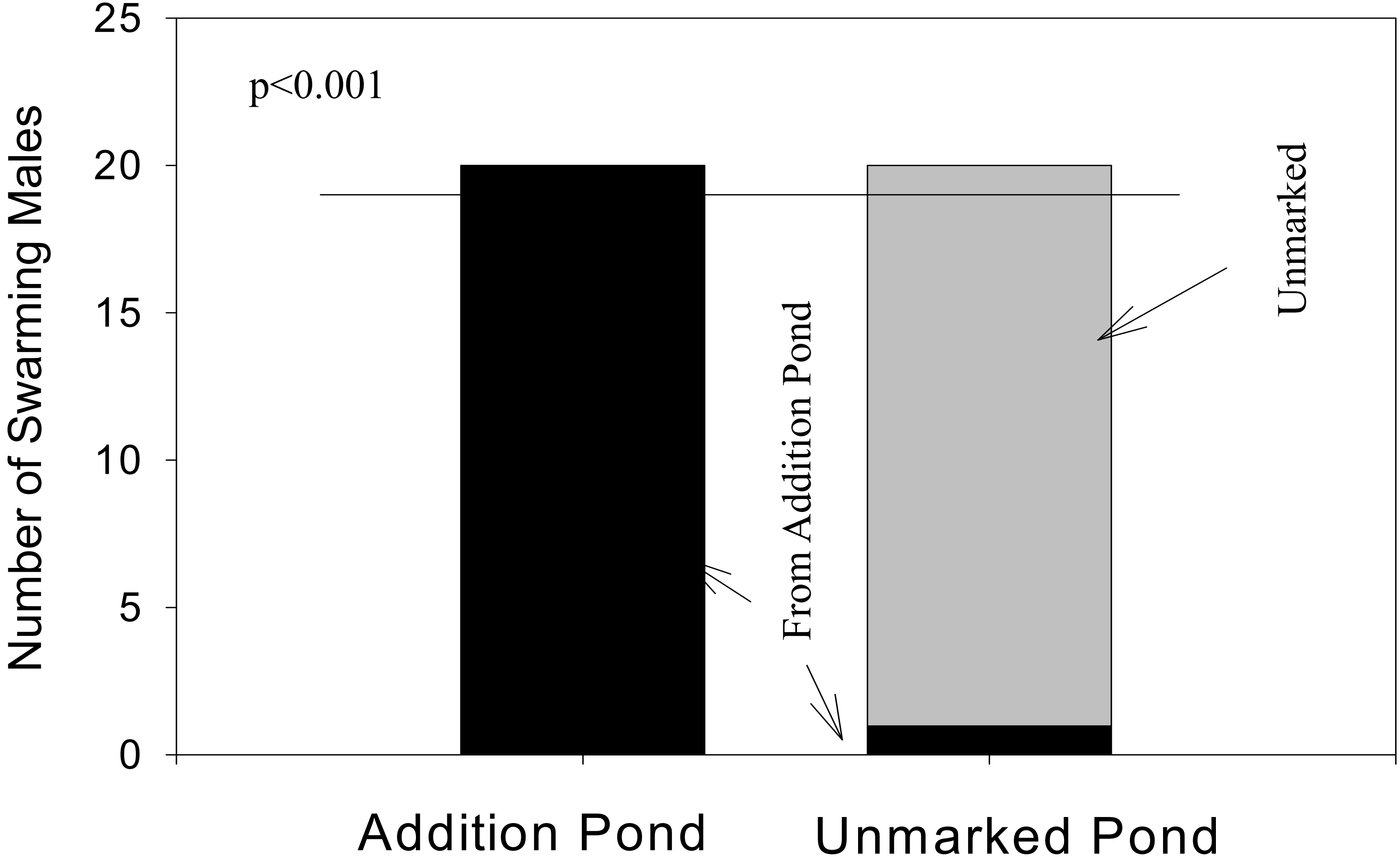
15N Stable Isotope Mark-Recapture Experiment: 2 Patches



Ovipositing Females



Swarming Males



Conclusions:

- Dispersal:
  - Strongly Sex-Biased
    - Consistent w/ mating system
  - High Patch Exchange Rate

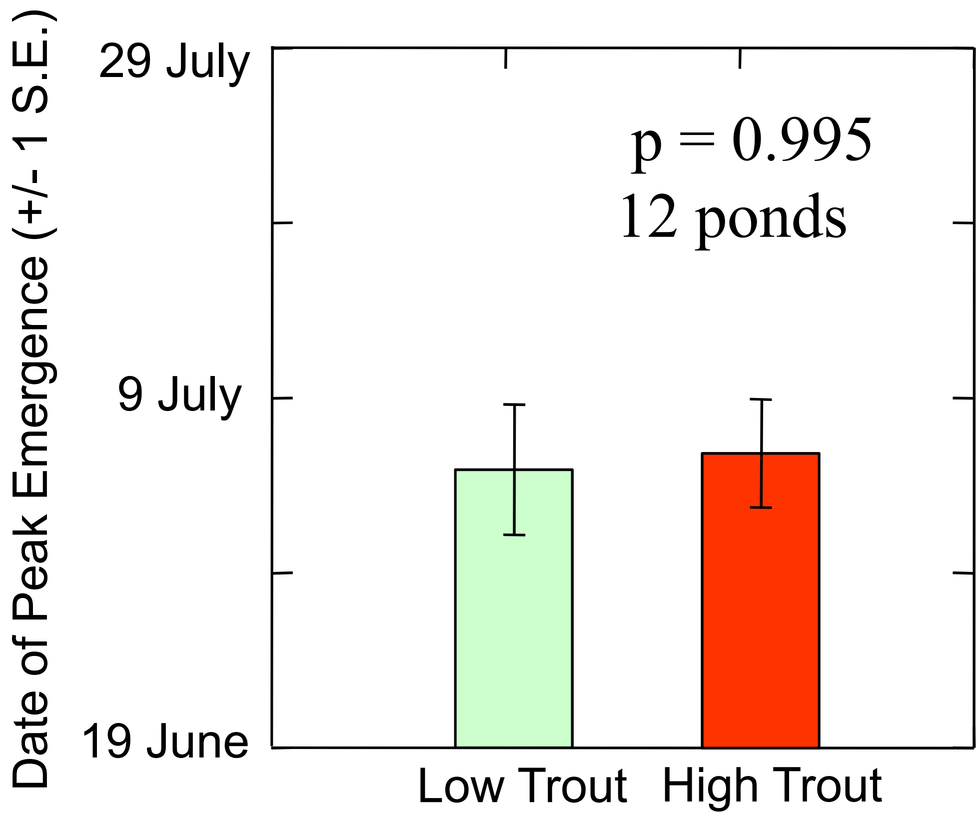
- Objectives:
  - Spatial Patterns
  - Patch Quality
  - Dispersal
  - Larval Responses

“Appropriate” Antipredator Traits:

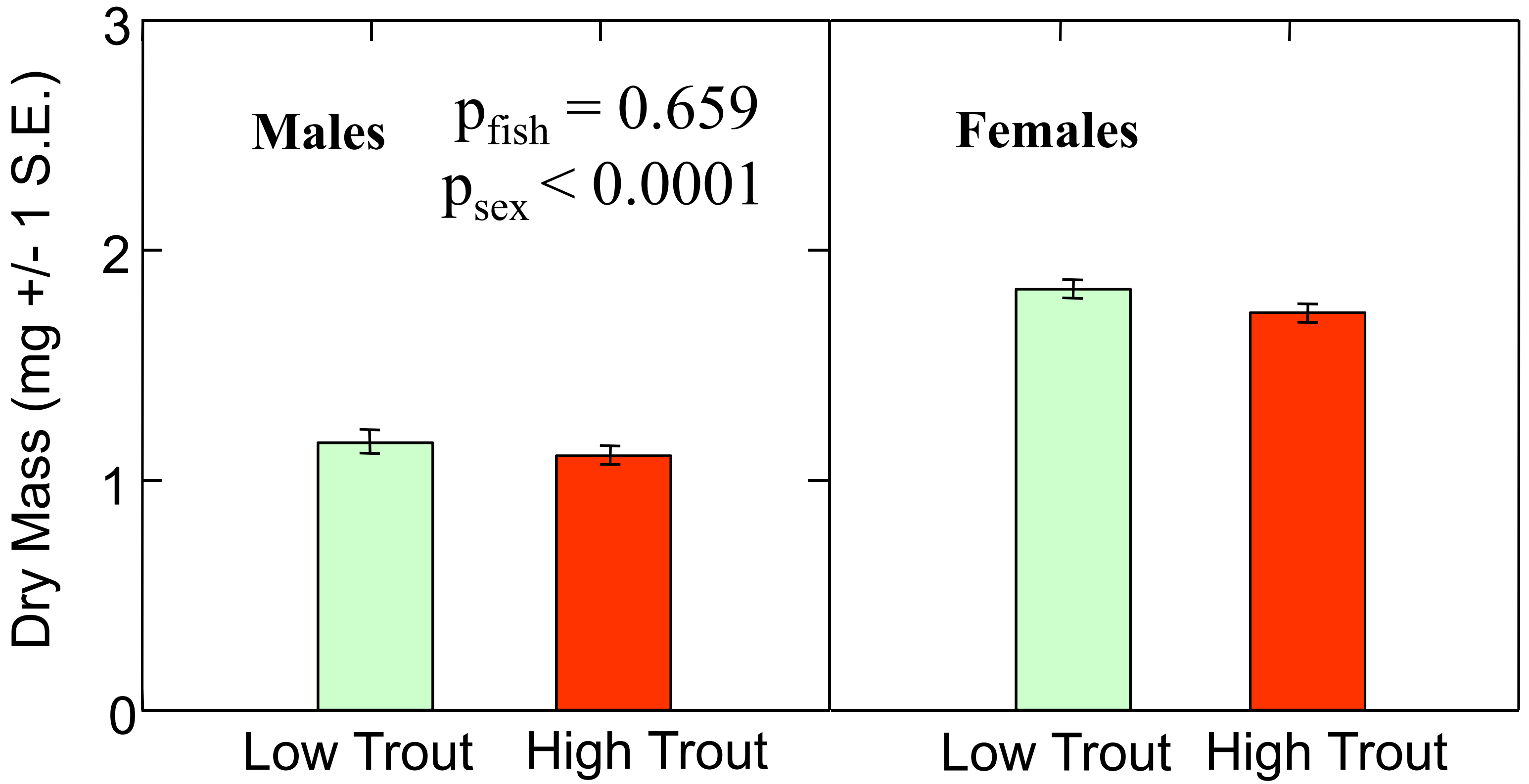
- Behavior:
  - Reduced Activity
  - Increased Crypsis
- Life History:
  - Reduced Growth Rate
  - Accelerated Development
  - Altered Size at Maturity

- Field Populations:
  - Timing of Emergence
  - Size at Emergence
- Tank Experiment:
  - Timing of Emergence
  - Size at Emergence
  - Behavior

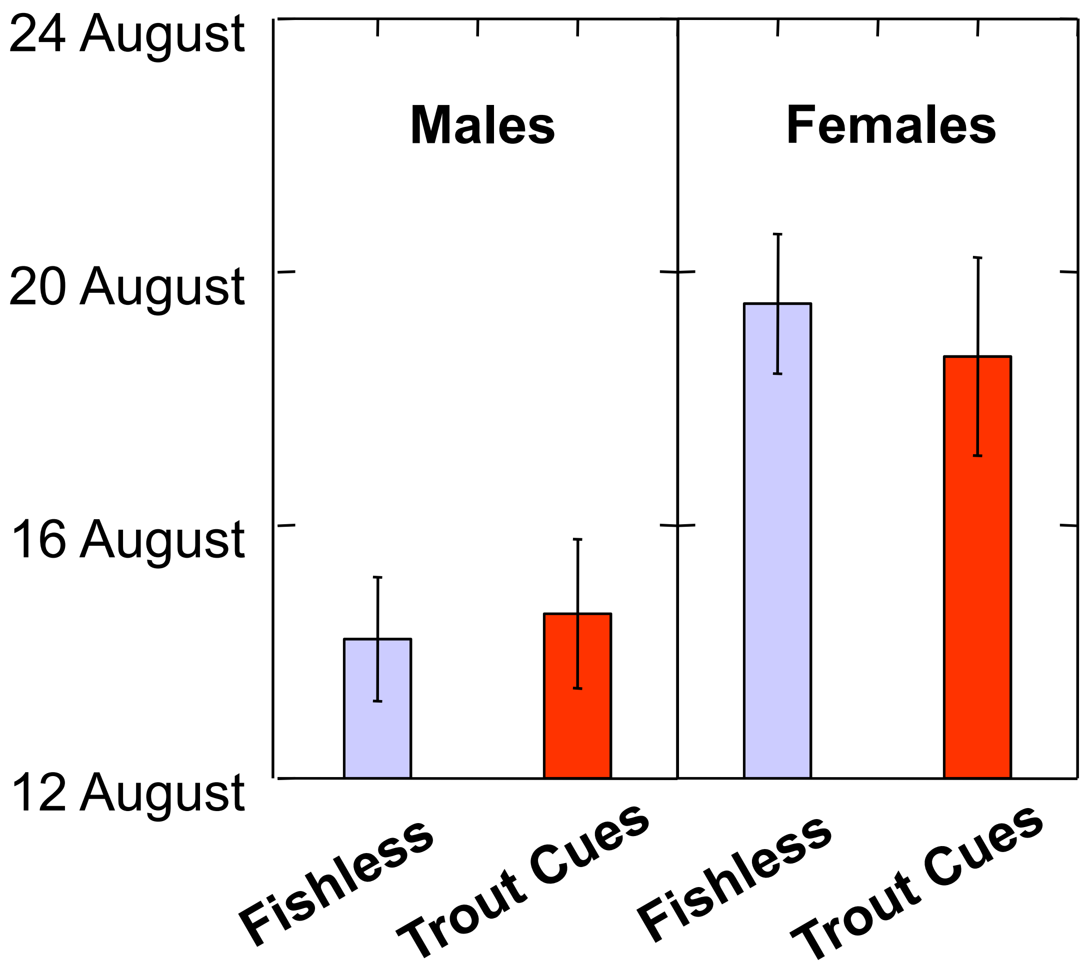
Date of Emergence from Field Populations



Size at Emergence from Field Populations

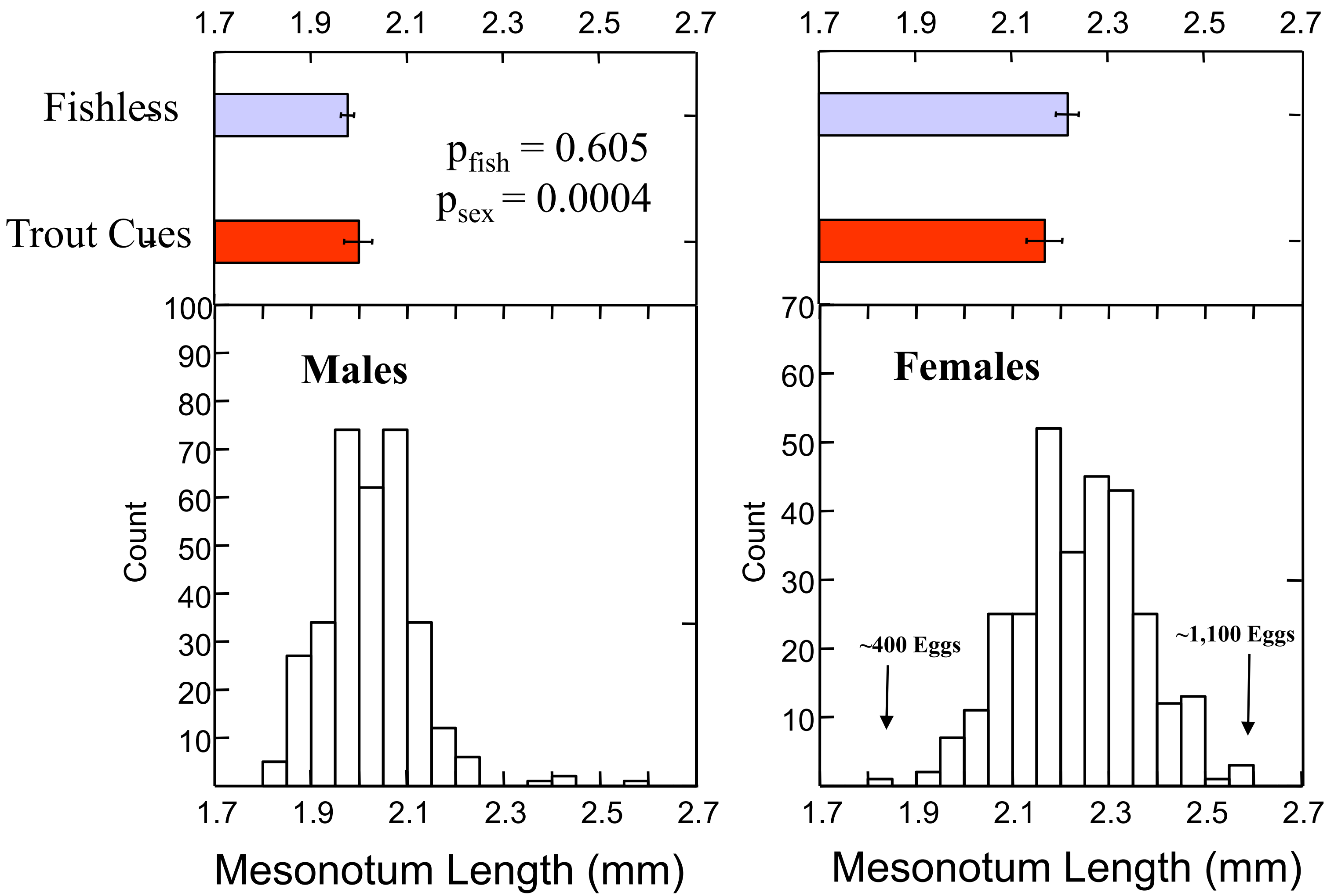


Development Rate in Tanks

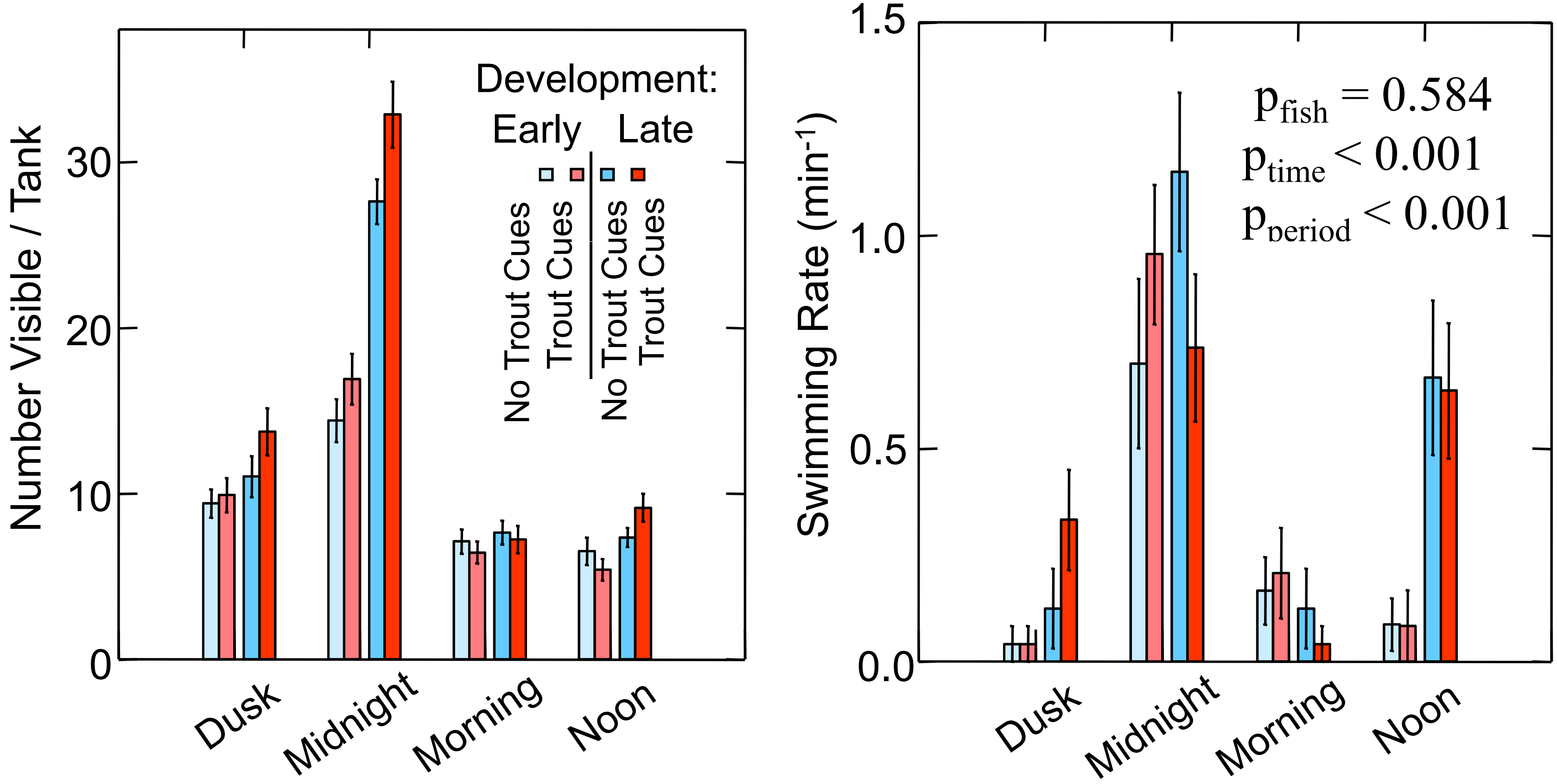


$p_{fish} = 0.885$
$p_{sex} < 0.0001$
12 tanks

Size at Emergence from Tanks



Larval Mayfly Behavior in Tanks:



Conclusions:

- Larval Responses (Not!):
  - No Life History Shift
  - No Effect of Trout on Size
  - No Anti-predator Behavior
    - Increased Activity Late in Development

Speculation:

- Why Not?
  - Introduced Predator? Do non-native trout create “ecological traps”?
    - Vulnerable to Native Trout
    - Strong Response in *Baetis*
  - *Need to test*

Speculation:

- Why Not?
  - Introduced Predator?
  - Lack of Trade-off?
  - Phylogenetic Inertia
    - Ephemeral Larval Habitat
    - Appropriate Anti-Invertebrate Behavior

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- Why Not?
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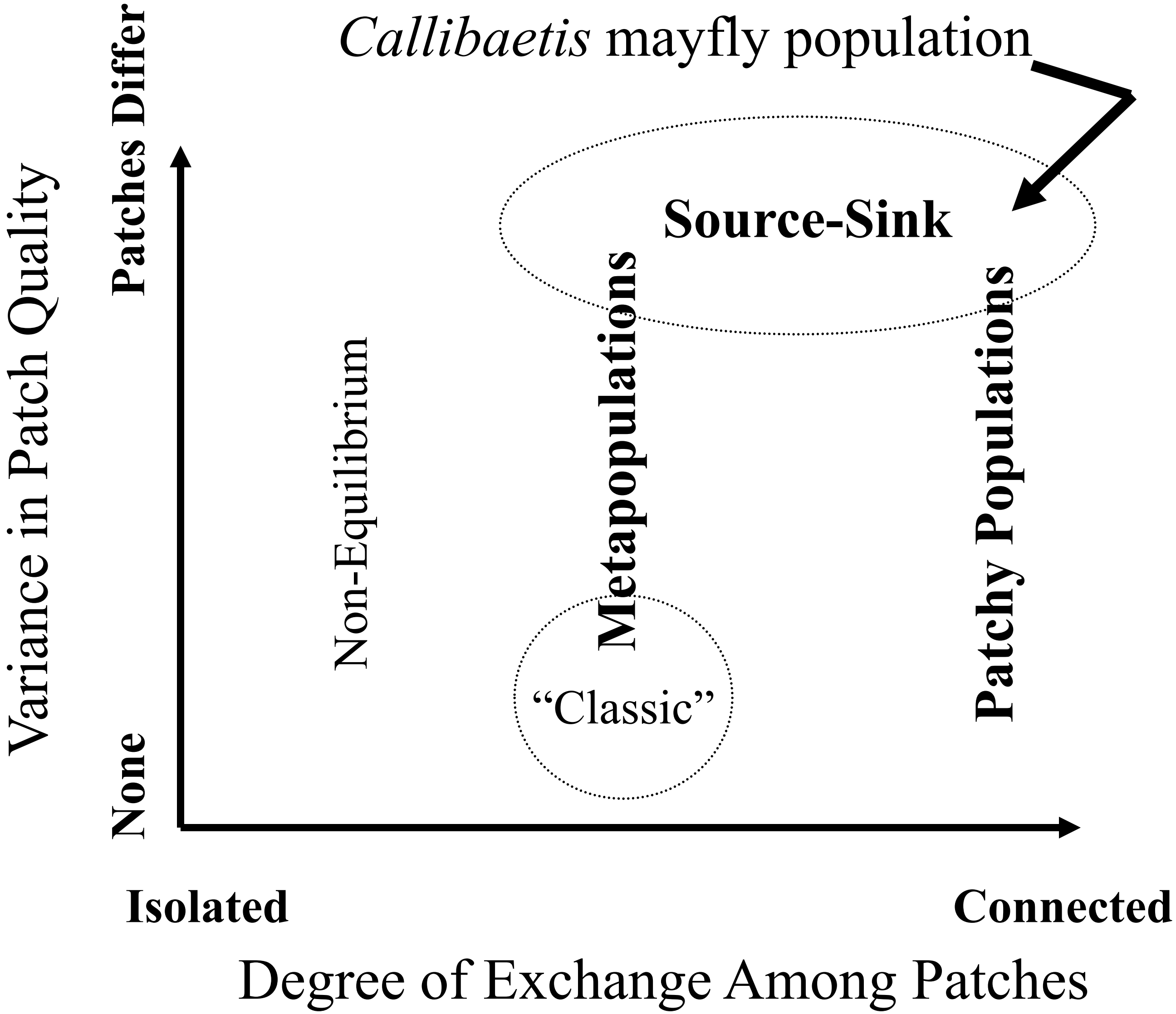
    - Ephemeral Larval Habitat
    - Appropriate Anti-Invertebrate Behavior
    - Dispersal from Sources to Sinks

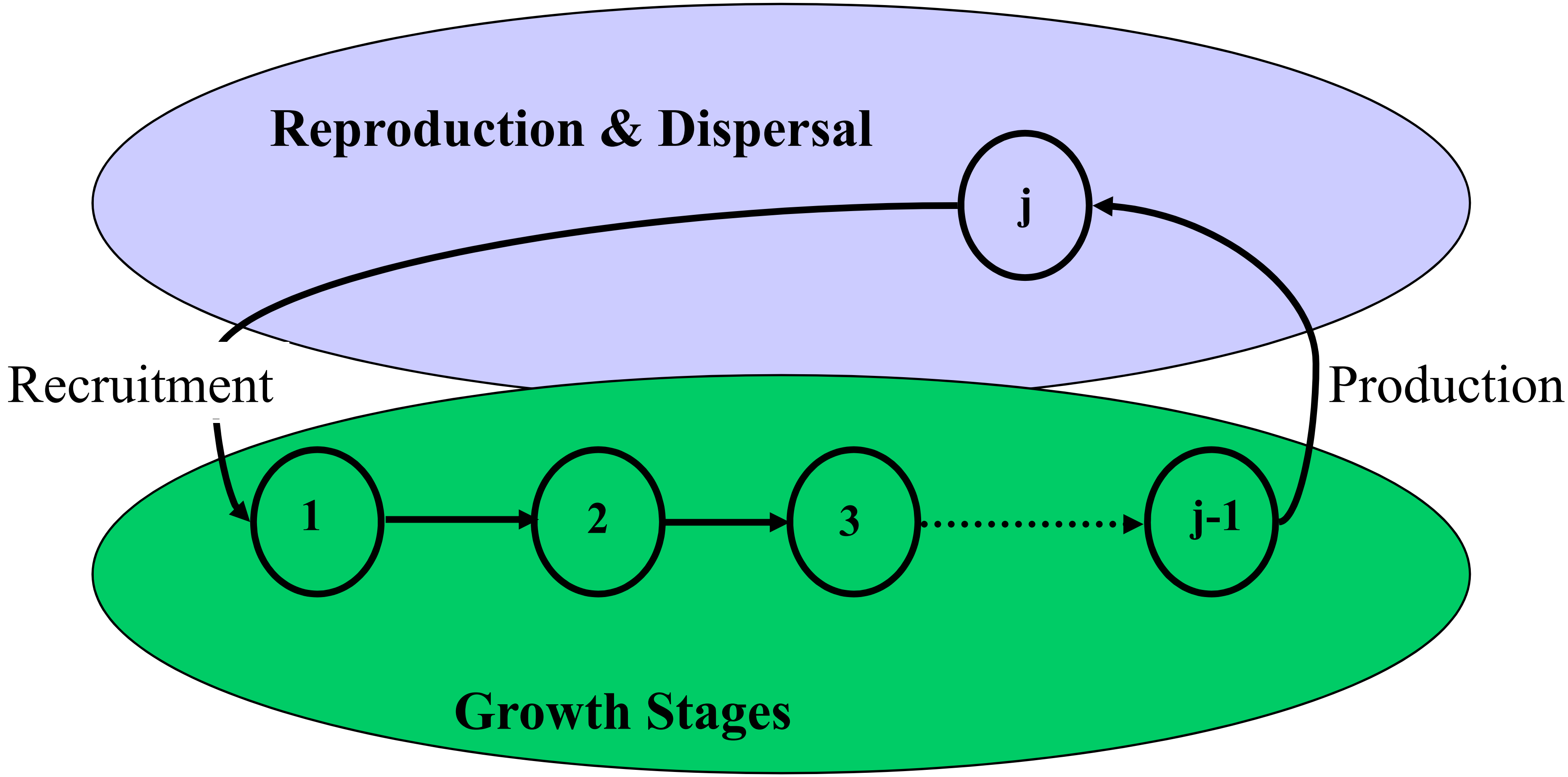
Summary

- Source-Sink Metapopulation:
  - Life History
  - Dispersal / Habitat Selection Behavior
  - Larval Behavior
  - Predator Distribution



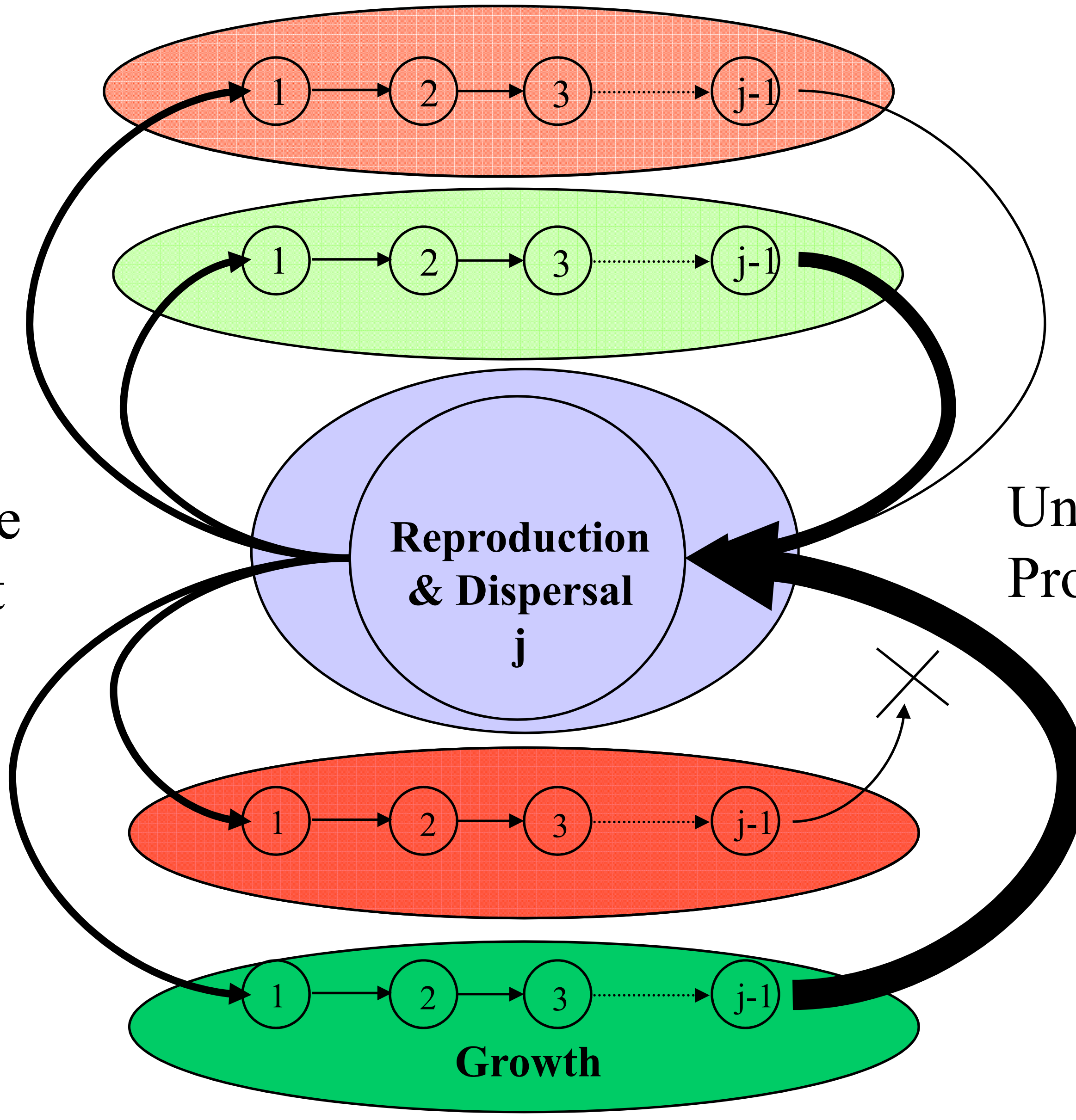
After Harrison and Taylor 1997

Traditional View of Complex Life Cycles:
(Most plants, invertebrates, amphibians, and fishes)



Complex life cycles in spatially complex habitats:

Nonselective Recruitment



Unequal Production

Source-sink dynamics may be common in groups with “constrained” dispersal:

- Social (Territorial):
  - **Birds**
  - **Mammals**
  - some fishes

Source-sink dynamics may be common in groups with “constrained” dispersal:

- Social (Territorial):
  - **Birds**
  - **Mammals**
  - some fishes
- “Passive” dispersal:
  - Plankton
  - **Marine invertebrates**
  - **Pathogens**
  - **Plants**
  - **Agricultural Pests**
  - Algae
  - **Marine & FW Fishes**
  - Aquatic insects

Bold = Commercially Important

Management Implications

- Behavior and habitat quality interact to determine regional population dynamic
- Imperative to identify sources
  - Conservation Targets
  - Pests / Pathogens / Invasive species (e.g, Eurasian Water Milfoil)
- Management of “Patch Quality”
  - Trout stocking programs
  - “Ecological Traps”