ASSESSING THE IMPACTS OF REINTRODUCING ALEWIVES: LESSONS FROM ECOLOGICAL THEORY AND EXISTING RESEARCH

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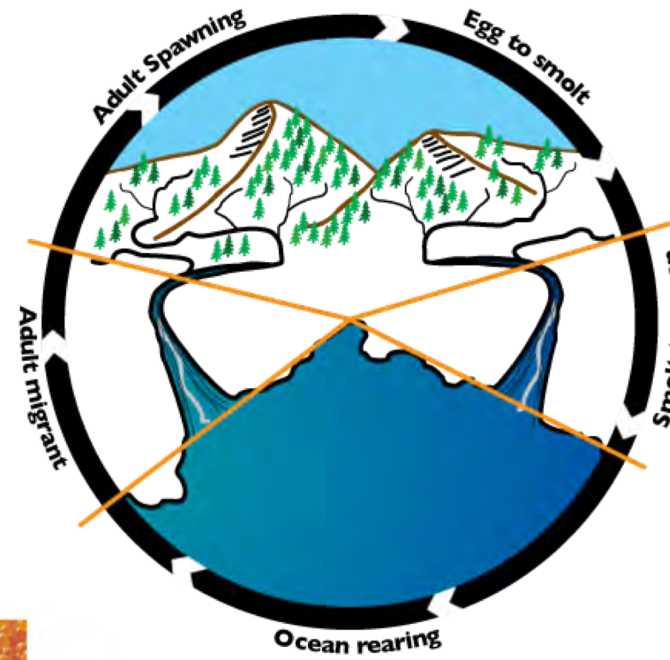
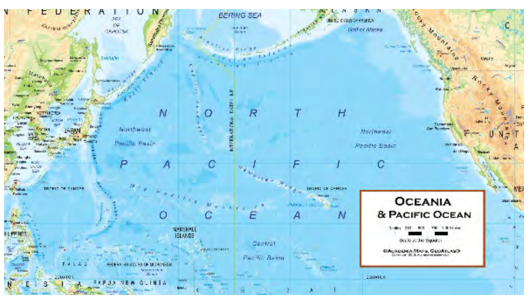
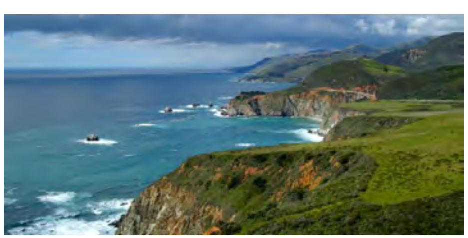
MERRIMACK COLLEGE

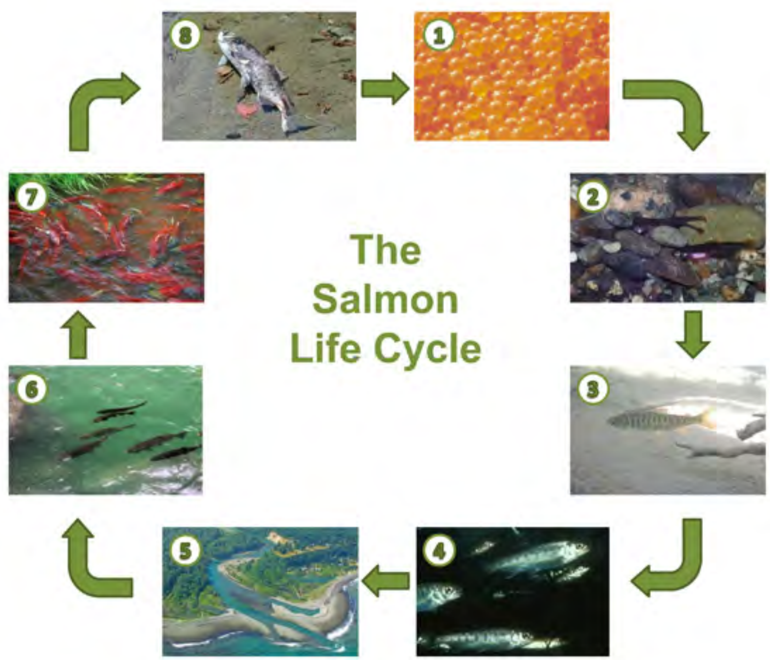
Migratory Fish

- Many fish species include complex life cycles with some
- Anadromous fish live in the ocean as adults, but return to freshwater to reproduce
- Catadromous fish live in freshwater as adults, but reproduce in the ocean







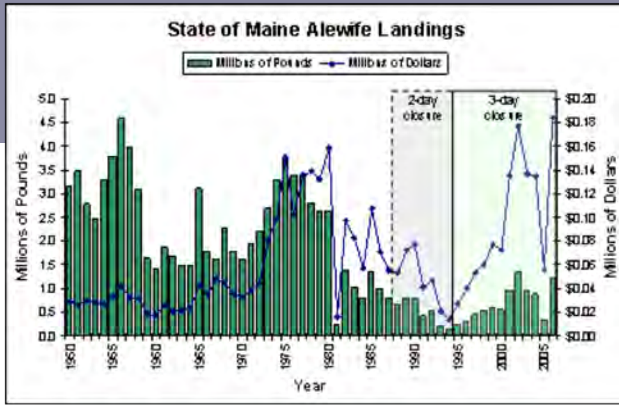


Migratory Fish in Maine

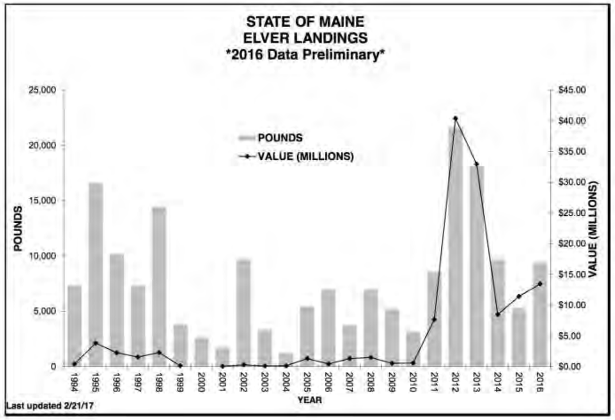
- Many species that are important economically and ecologically are migratory
  - Atlantic Salmon
  - Alewives
  - Striped bass
  - American Eel (catadromous)

Economic Value

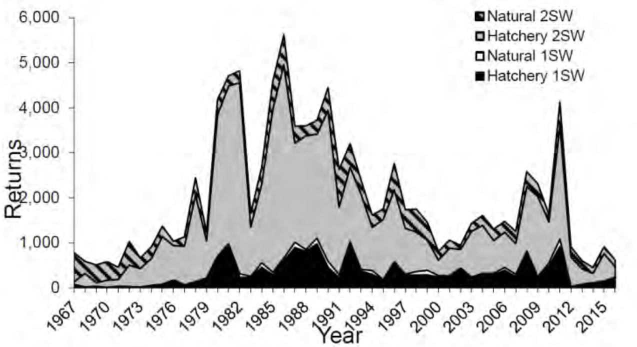
- Alewife fishery
  - Historically used for food
  - Today primarily used for bait (lobster)
  - 1.7 million pounds of alewives landed in 2018
    - 2nd highest total in last 37 years
- Several other important anadromous fish species
  - Atlantic salmon (no longer commercially fished)
  - Elvers (American eel)



Alewife (landings)



Elver (landings)

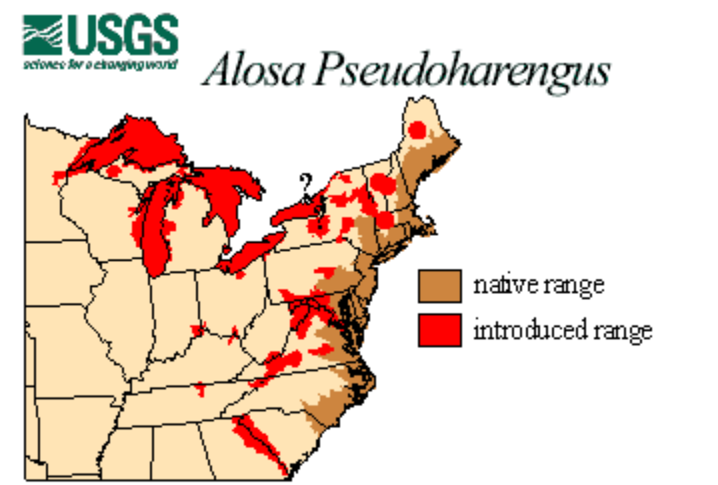


Atlantic salmon (returns)

Alewife Background

- Return to freshwater to spawn at age 3-5 in early spring
- Eggs hatch, and young rear in freshwater until late summer or early fall when juveniles outmigrate
  - Can provide “cover” for outmigrating Atlantic salmon juveniles
- Many Maine populations are increasing, but remain well below historical averages
- How could alewives impact water quality?
  - Bottom up control of productivity
  - Top down control of productivity

Landlocked Alewives

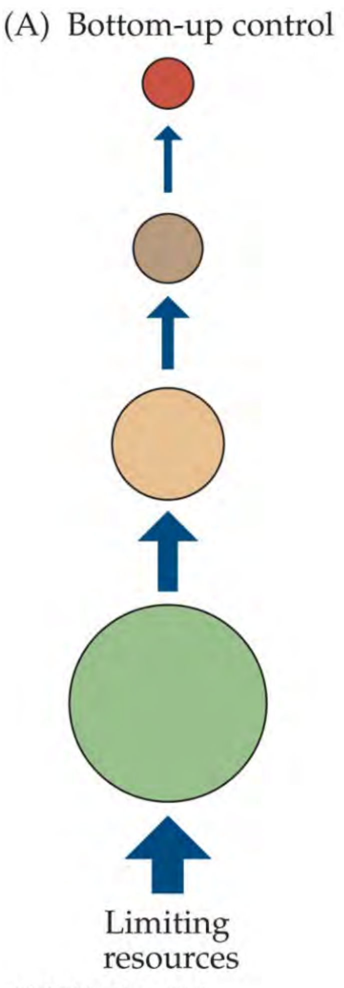


- Invasive species in Great Lakes region
    - Entered via Erie Canal over 100 years ago
- Landlocked, rather than anadromous
- Not a natural part of the ecosystem and foodweb
- Negative impacts on native fish species
- Can experience mass mortality events

What is Bottom Up Control?

- When limiting resource at base of foodweb controls trophic levels above it
  - E.g. light controls plant biomass, which controls herbivore biomass, which controls primary carnivore biomass, etc.

- Nutrient additions are a common driver of bottom up control



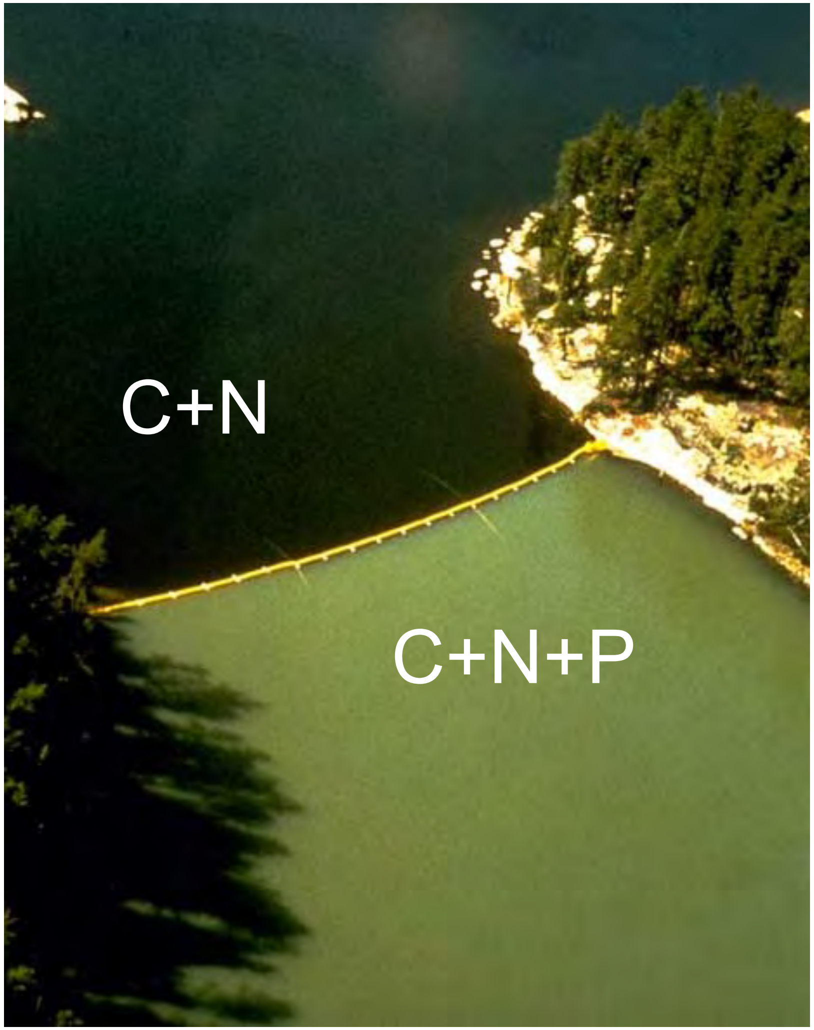
Bottom Up Control

Eutrophication

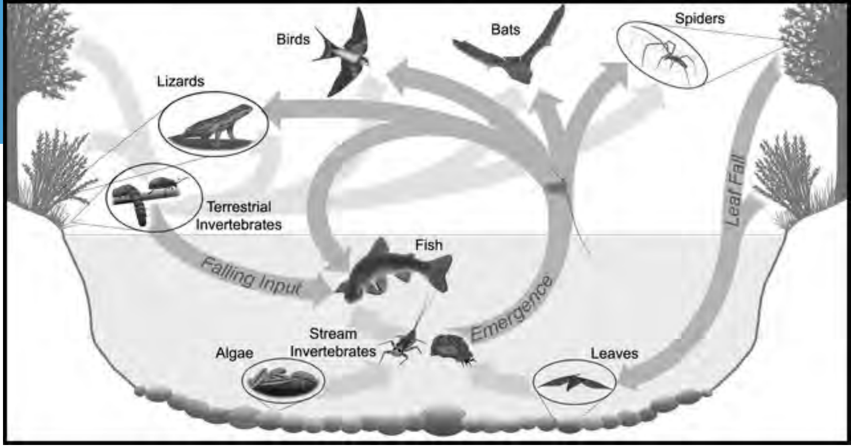
- Nutrient pollution major threat to aquatic ecosystems
- In US (per EPA national assessment):
  - ~15% of stream miles impaired
  - ~25% of lake acres impaired
  - ~21% of bay/estuaries impaired (mi^2)
- Trophic state measured by combined metrics of nutrient concentrations, transparency, and chlorophyll a concentrations

Phosphorus in Lakes

- Phosphorus in particular is important in freshwater systems
  - Most are phosphorus limited – nitrogen is abundant, but additions of phosphorus will lead to large algal blooms
- Clearly demonstrated with manipulative experiments with experimental lakes in Canada
  - Single lake divided in half
  - One side had carbon and nitrogen added
  - One side had carbon, nitrogen, and phosphorus added
  - Massive algal bloom on C+N+P side



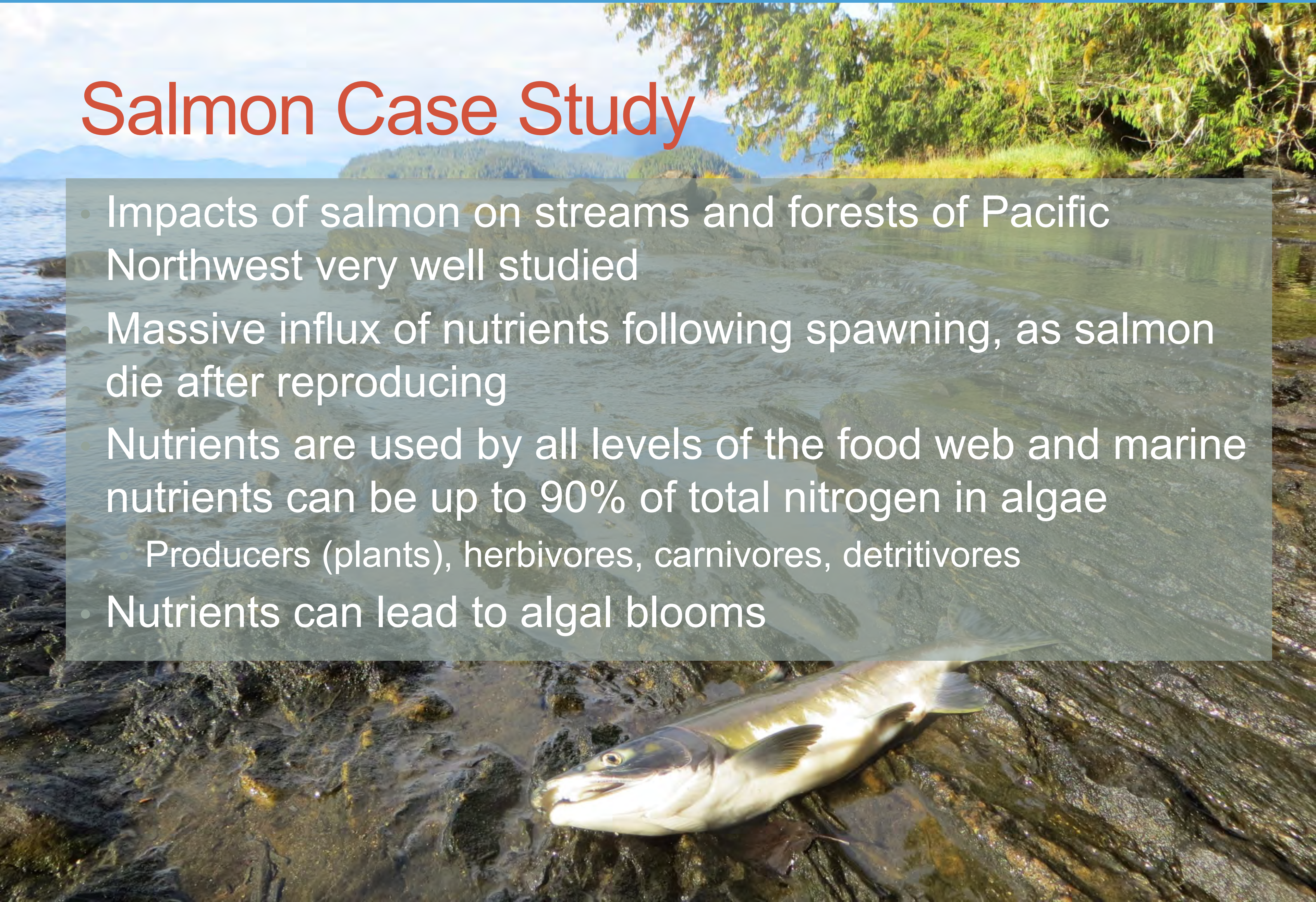
Bottom Up Control



Ecosystem Subsidies

- Ecosystem subsidy = movement of energy and nutrients from one ecosystem to another, often through organisms
- By returning as adults to spawn, alewives could bring marine derived nutrients back to freshwaters
- Release nutrients via:
  - Excretion
  - Mortality
- Shown in small systems in Connecticut and Rhode Island
  - Bride Brook, CT: 1050 g N, 120 g P
  - Pausocaco Pond, RI: 2700 g N, 430 g P

Bottom Up Control



Salmon Case Study

- Impacts of salmon on streams and forests of Pacific Northwest very well studied
- Massive influx of nutrients following spawning, as salmon die after reproducing
- Nutrients are used by all levels of the food web and marine nutrients can be up to 90% of total nitrogen in algae
  - Producers (plants), herbivores, carnivores, detritivores
- Nutrients can lead to algal blooms

Bottom Up Control

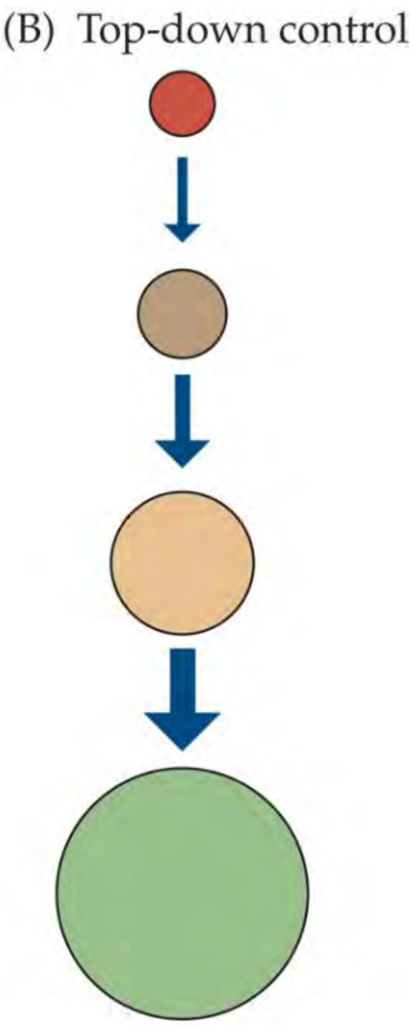
Salmon vs Alewives

- Major differences between the two species, however
- Salmon are much larger as adults, therefore contain many more nutrients
  - But, juveniles are similar size when they outmigrate
- Salmon are semelparous (except for steelhead), meaning they only reproduce once and then die, unlike alewives
- Key Question: Are alewives a net importer or exporter of nutrients?
  - How does the amount they bring back from marine ecosystems compare to the amount that they
- Key Question: How does the reintroduction of alewives impact water quality?

Freshly caught coho (~10 kg) and Chinook (~25 kg) salmon vs alewife (~0.5 kg)

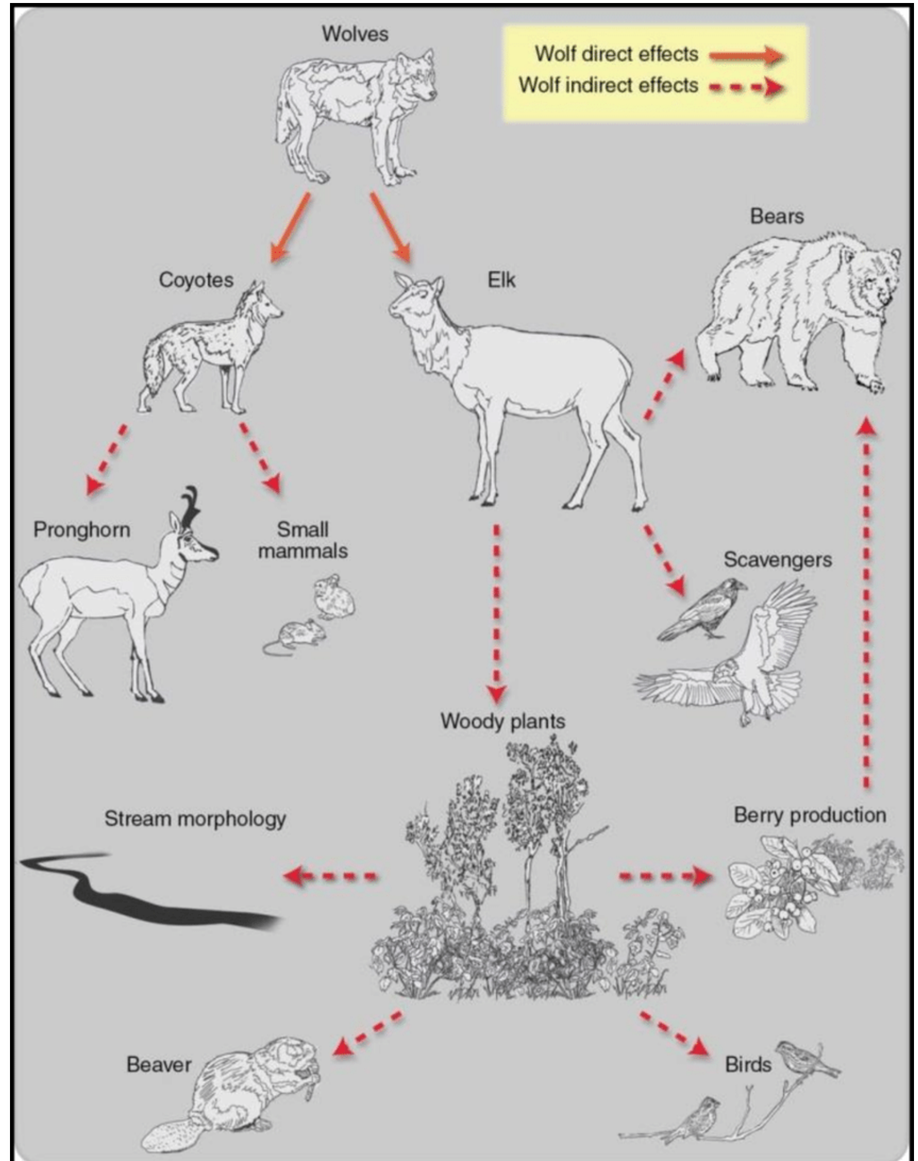
What is Top Down Control?

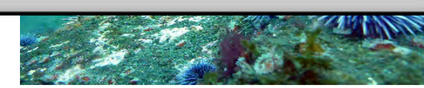
- "World is green" hypothesis (Hairston, Smith, and Slobodkin 1960)
  - Lots of plant biomass everywhere
  - Therefore, cannot be limiting resource
- If plant biomass does not control foodwebs, higher trophic levels must
  - Top predator controls biomass of level below it
  - Each successive level controls level below it



Trophic Cascades

- When change at top of food web cascades down through lower trophic levels
- Sea otters control sea urchin populations
  - Maintain kelp forests
- Reintroduction of wolves into Yellowstone National Park





Piscivore

Food Web Experiments

- Observed that nutrient inputs could only explain about 50% of phytoplankton biomass
- Food web structure could help explain this discrepancy
- More planktivores (relative to piscivores), more primary production (algae)

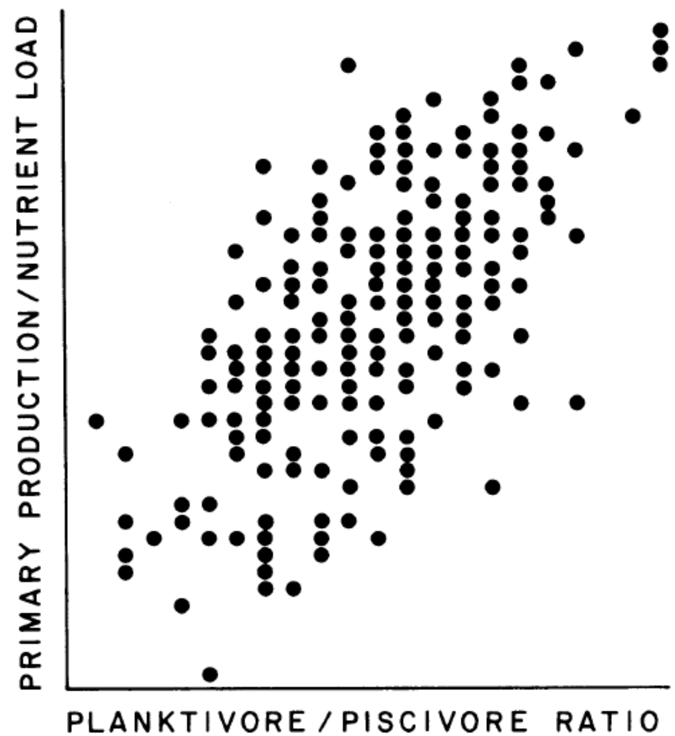
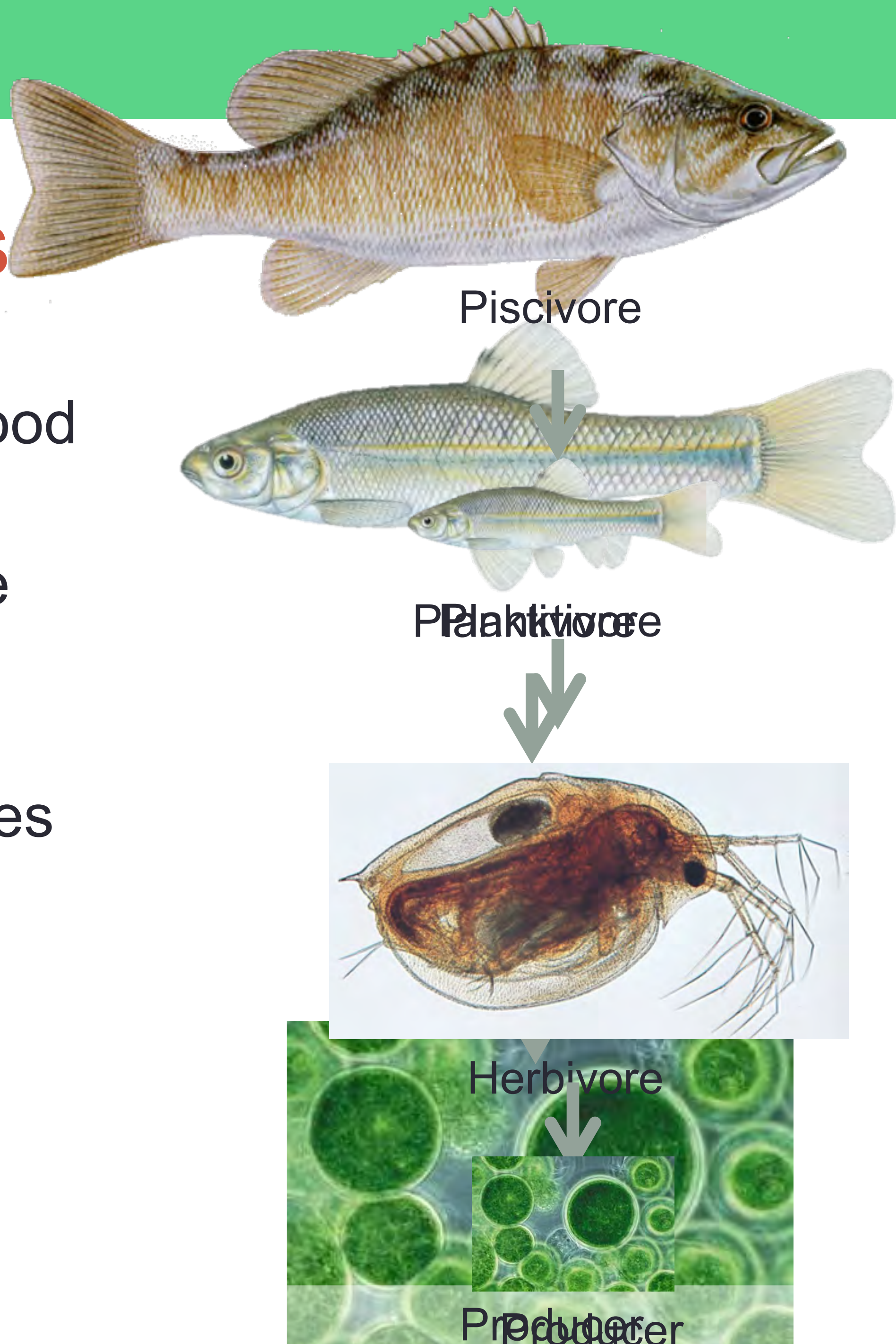


Figure 1. Relationship between the planktivore/piscivore ratio and lake primary productivity at constant nutrient supply. Each point represents the annual mean for a lake.

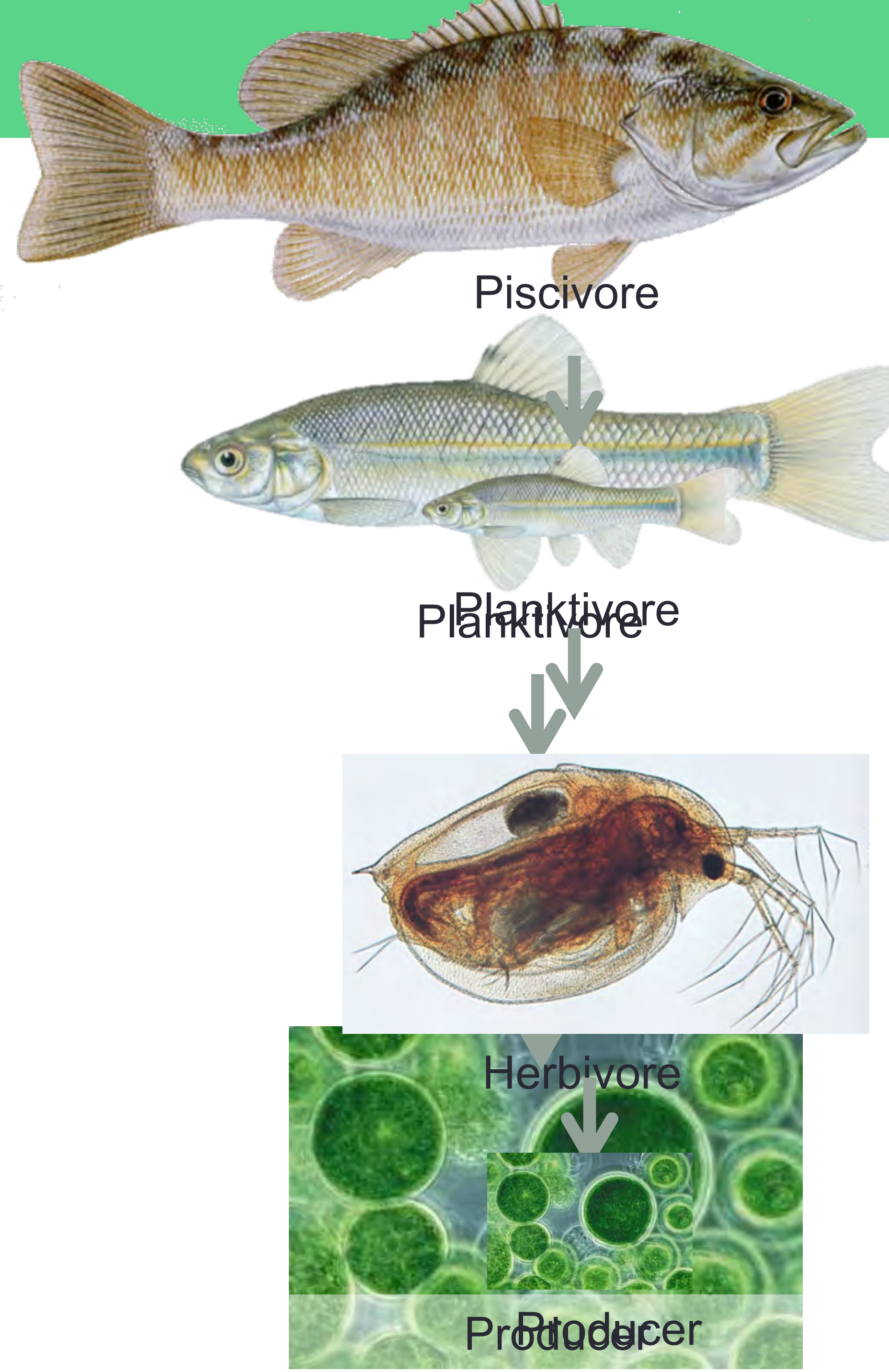
Food Web Experiments



- Experimentally manipulated food webs
- Added bass (piscivore) to lake that did not have them previously
- Large reductions in planktivores and producers, increase in herbivores

Food Web Experiments

- Experimentally manipulated food webs
- Removed bass (piscivore) from another lake where they were abundant
- Large increases in planktivores and producers, decreases in herbivores

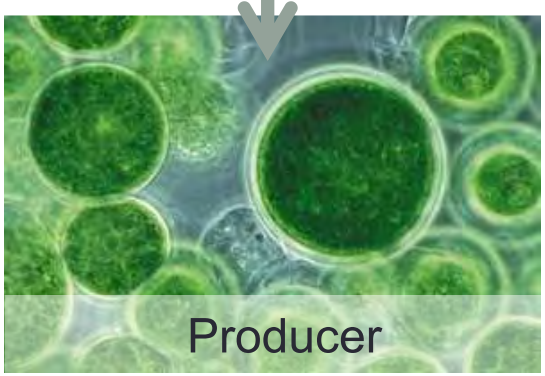


Top Down Control

Food Web Experiments

Planktivore

Herbivore

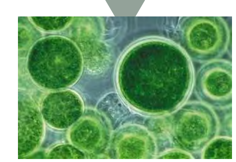


- Trophic structure can determine productivity and biomass

Piscivore

Planktivore

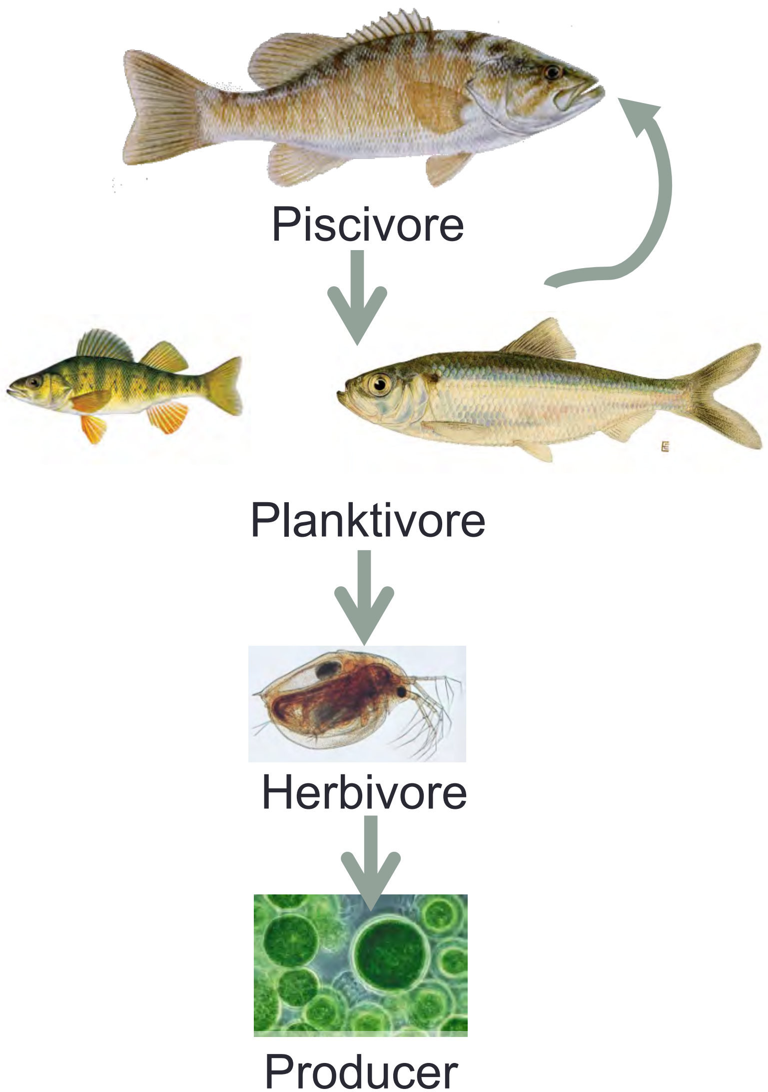
Herbivore



Producer

Top Down Control

Alewives within foodwebs

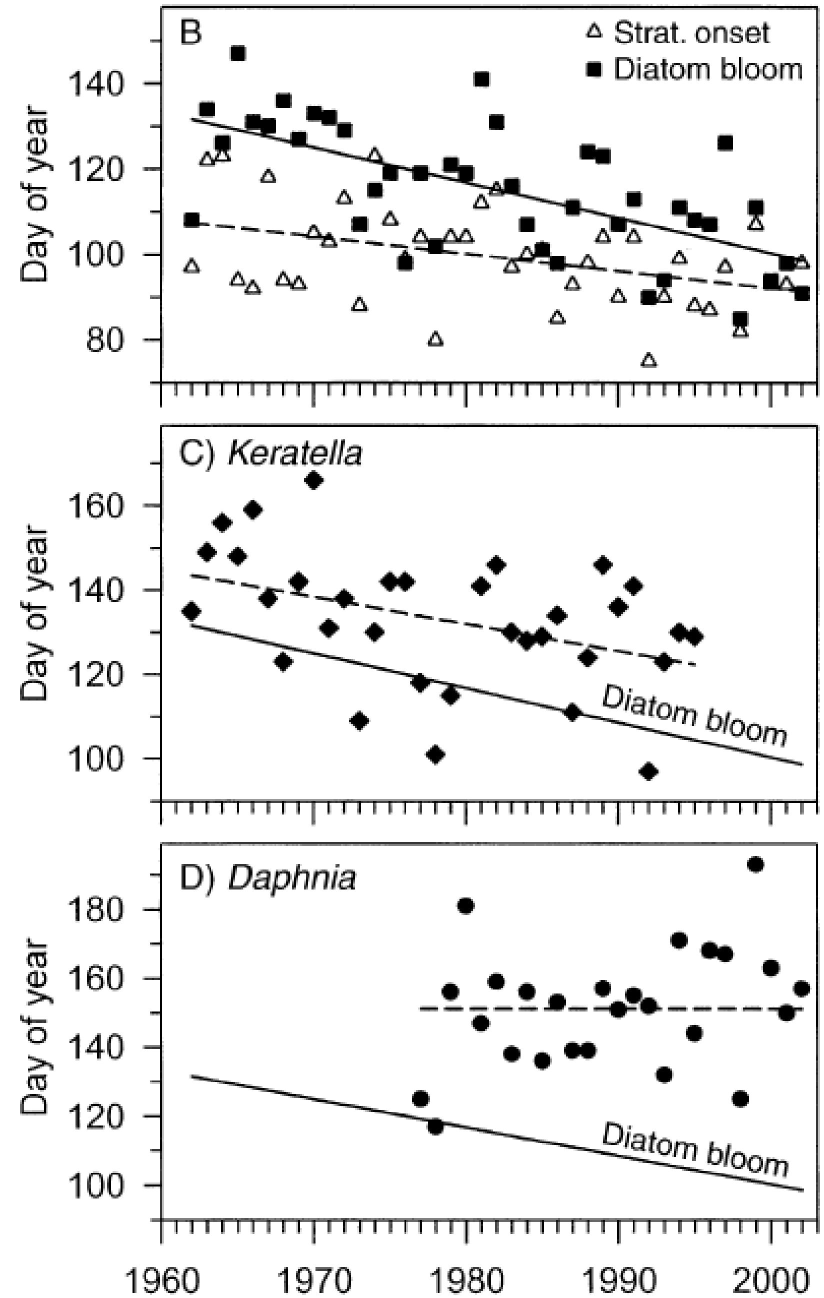


- Alewives are planktivores
- Could lead to decrease in herbivore abundance, increase in producers
  - Therefore an increase in eutrophication
  - Though no additional nutrients, algal biomass
- Key question: Do alewives control trophic levels below them? Do they create trophic cascades? Do they impact levels above them?
  - Real food webs much more complicated than simple models presented

Future Considerations

Climate Change

- Can alter phenology – timing of important events
  - E.g. when alewives arrive, when ice melts and growing season begins for algae
  - Can lead to decoupling of events
- Can alter importance of both top down and bottom up effects
  - What we understand now about these systems may change in the future



Future Considerations