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# Effects of phosphorus availability on aquatic food webs and community structure in the Everglades

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Shawn Liston, Joel Trexler, Scot Hagerthey,  
Ryan King & Brian Garrett

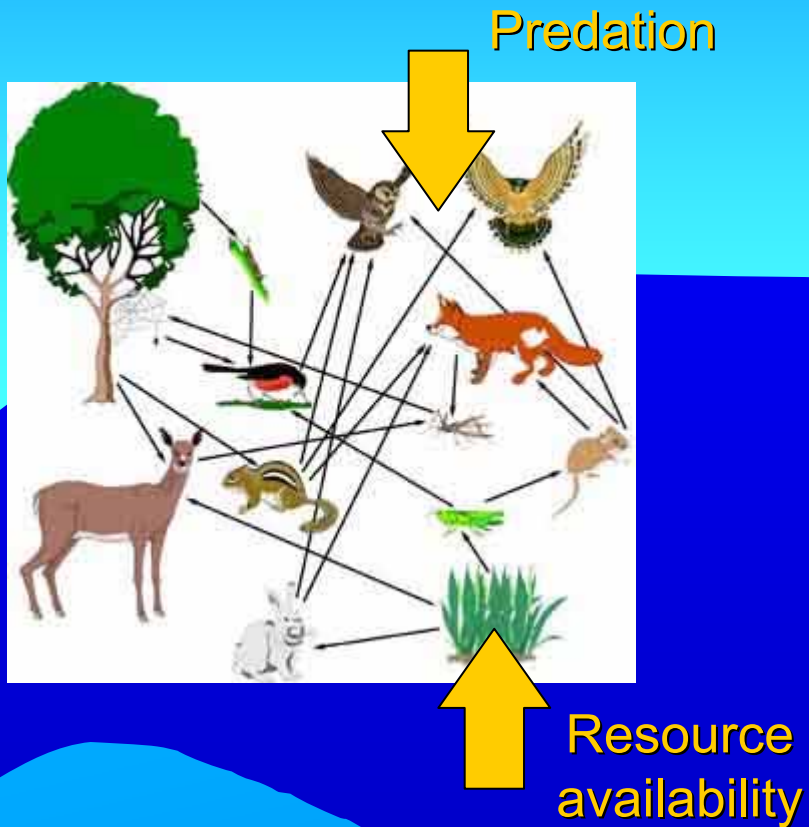


# Outline

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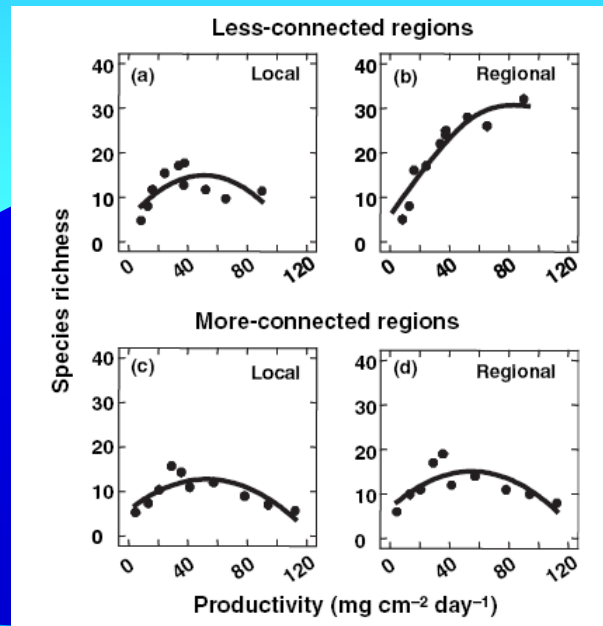
- Food webs
- Our Everglades food web
- Observed effects of P on the food web
- Impact of methodology on interpreting food web data
- Conclusions & future directions

# Food Webs...



- Combined effects of predation (**top-down**) and resource availability (**bottom-up**) control:
  - Distribution of biomass among trophic levels

# Food Webs...



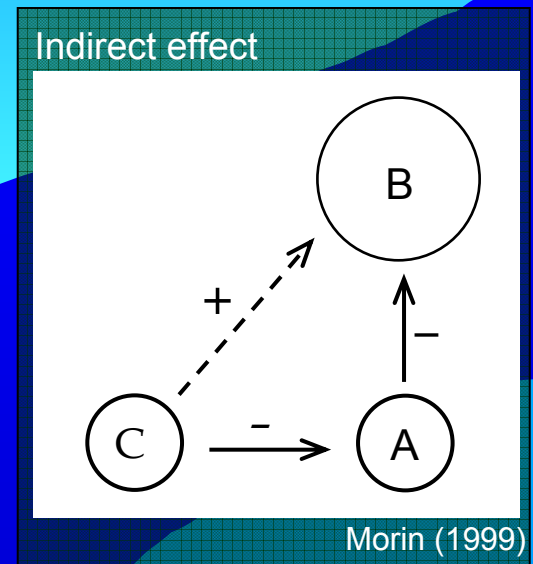
Chase & Ryberg (2004)

- Combined effects of predation (top-down) and resource availability (bottom-up) control:
  - Distribution of biomass among trophic levels
  - Community structure
    - species richness
    - species diversity

# Food Webs...

## Additional factors:

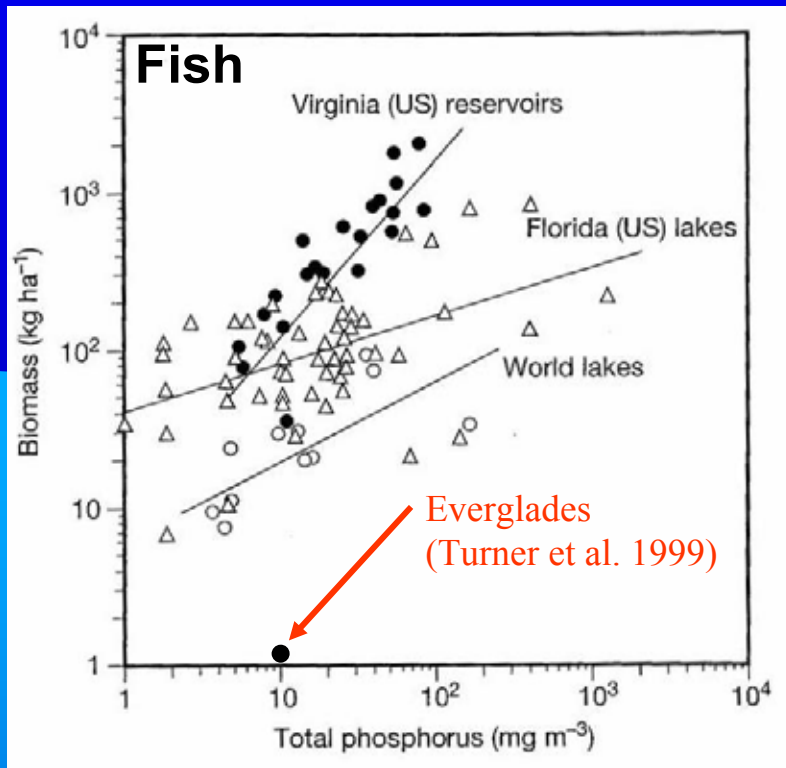
- Food quality
  - Edibility
  - Grazers
- Omnivory
- Habitat complexity
  - Spatial pattern & scale of habitat
  - Connectivity, patches, refuges
  - Interactions with other variables (e.g. hydrology)



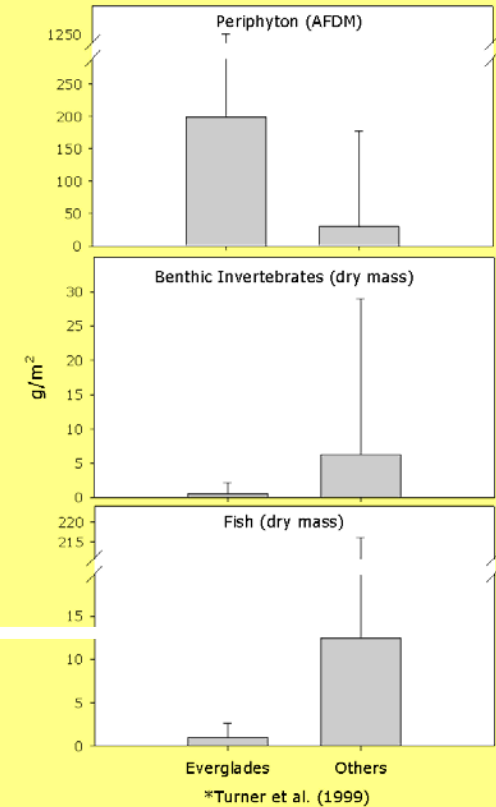


# Everglades Food Web

- Unique distribution of biomass
  - High algal biomass + Low consumer biomass

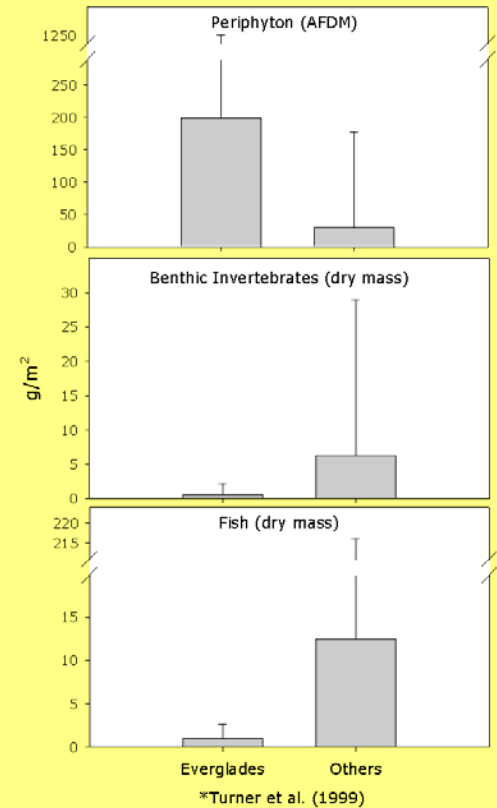
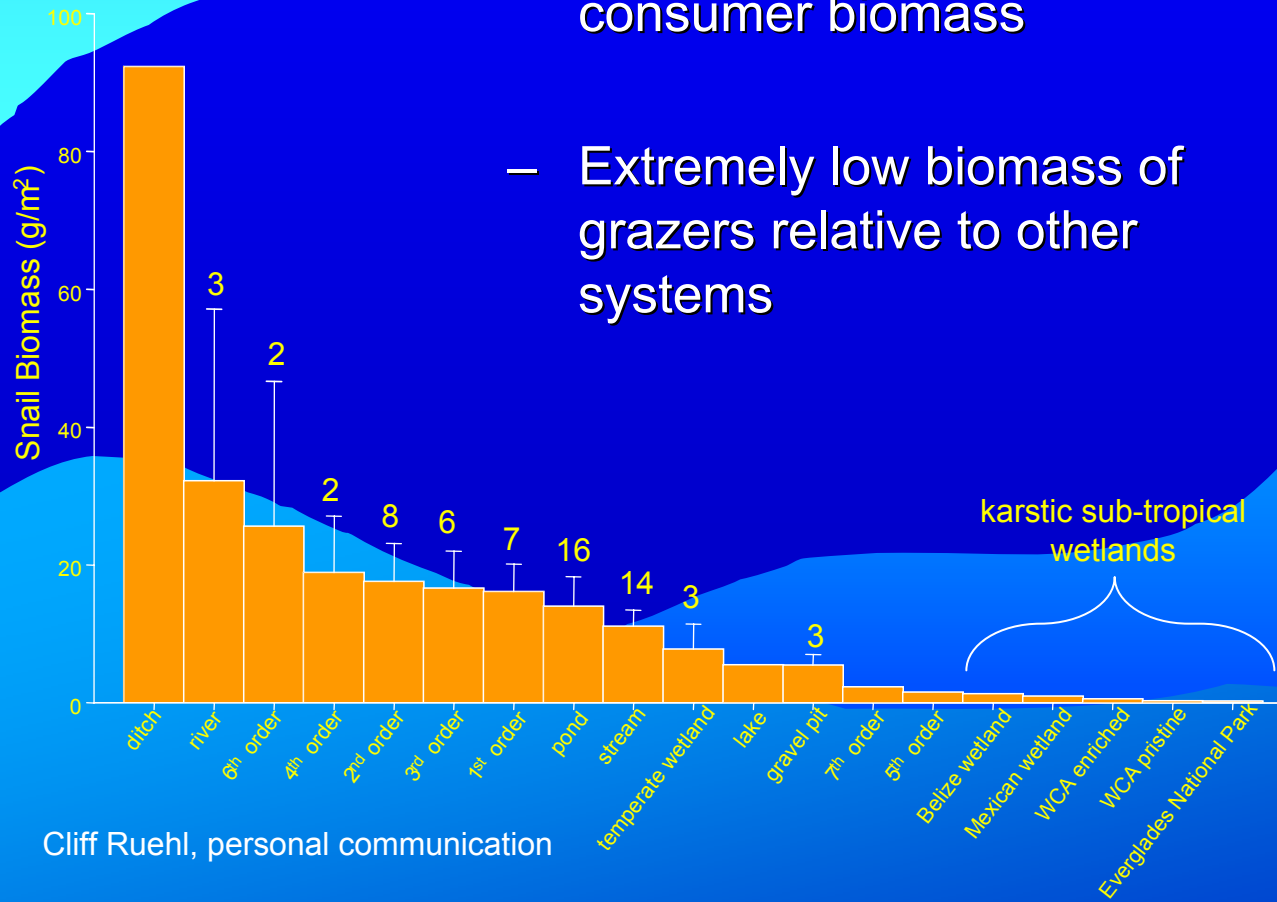


Kalf (2002)



# Everglades Food Web

- Unique distribution of biomass
  - High algal biomass + Low consumer biomass
  - Extremely low biomass of grazers relative to other systems



Cliff Ruehl, personal communication



# Everglades Food Web



3°  
Consumer

Nutrient excretion  
(local @ colonies)



2°  
Consumer

Macrophytes  
(habitat structure)

Periphyton, epiphyton  
(refuge)

(habitat)



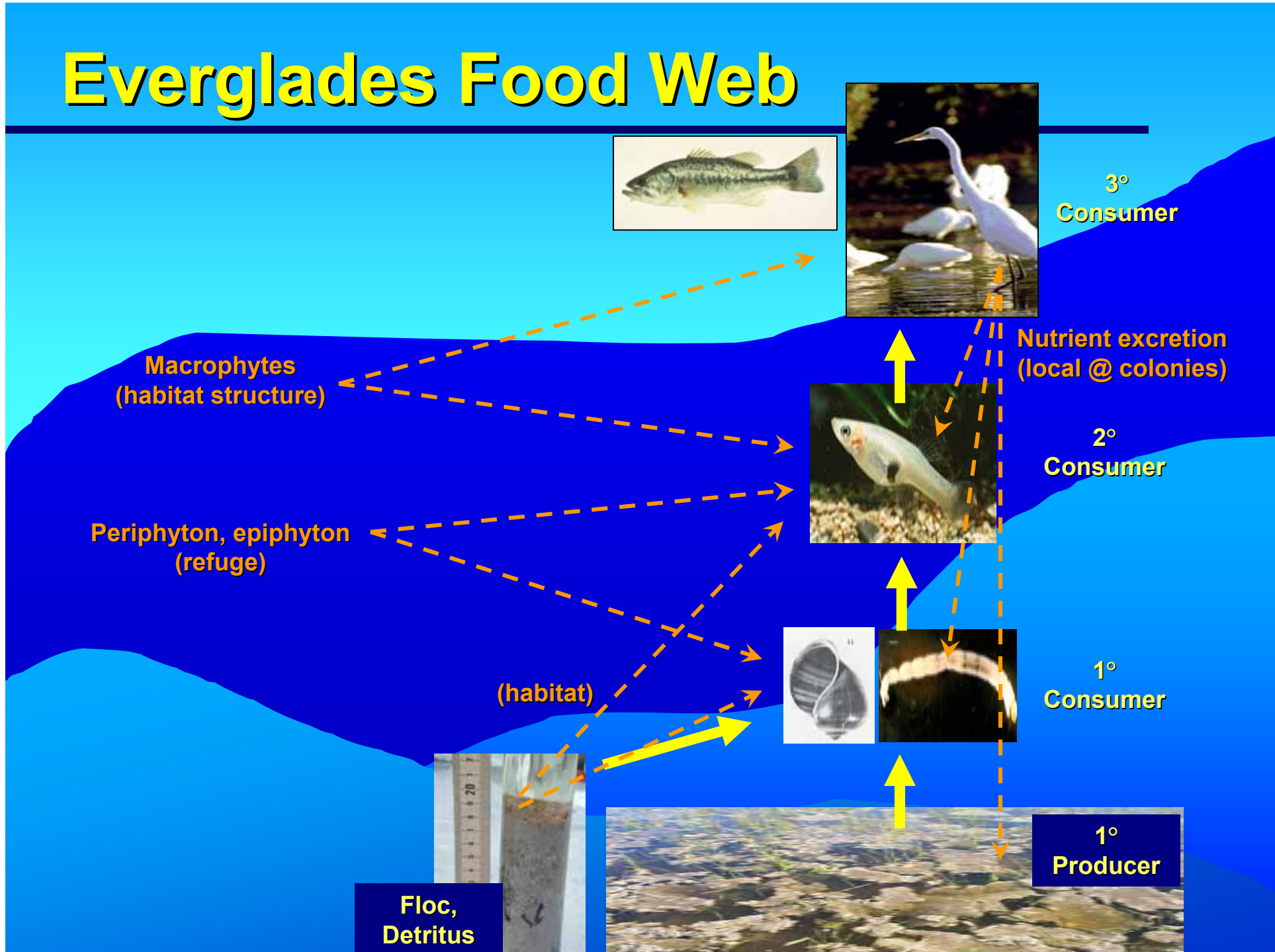
1°  
Consumer



Floc,  
Detritus



1°  
Producer

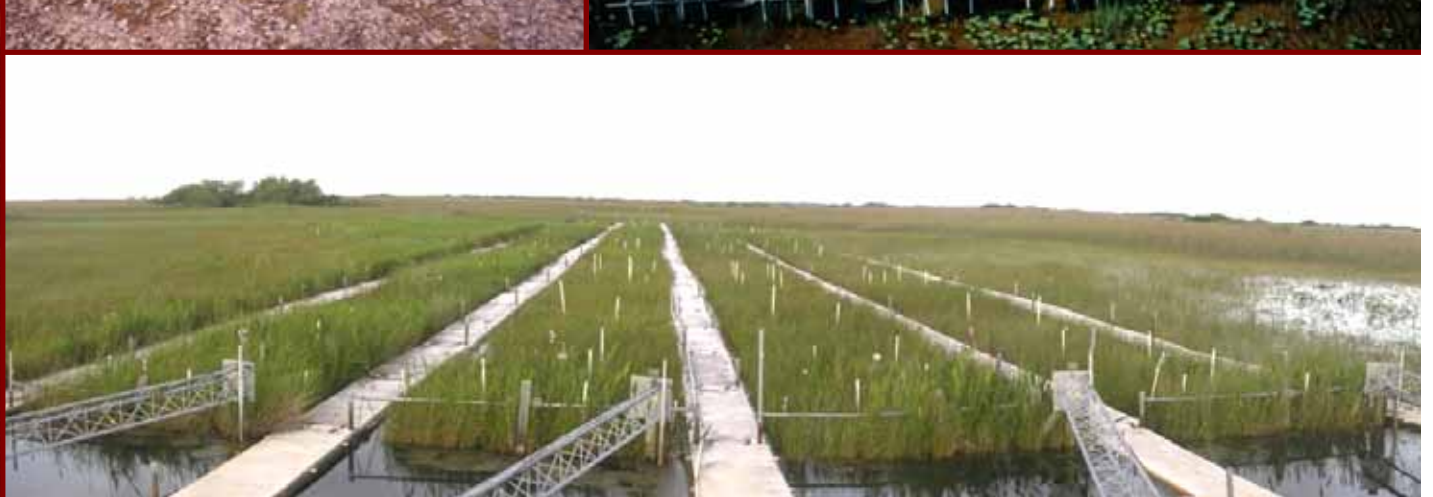


# Everglades Food Web

## ROLE OF CALCIUM CARBONATE

- Physiological Limitations (Direct)
  - maintain osmotic balance, construct shells, skeletons, etc.
  - mat-forming periphyton
- Cascading Trophic Effects (Indirect)
  - $\text{CaCO}_3$  in periphyton mats affects consumers
    - algae edibility, palatability
    - critical for detritus production
    - important consumer habitat
- $\text{CaCO}_3$  is responsible for this low nutrient, P-limited system





# Effects of P on food webs

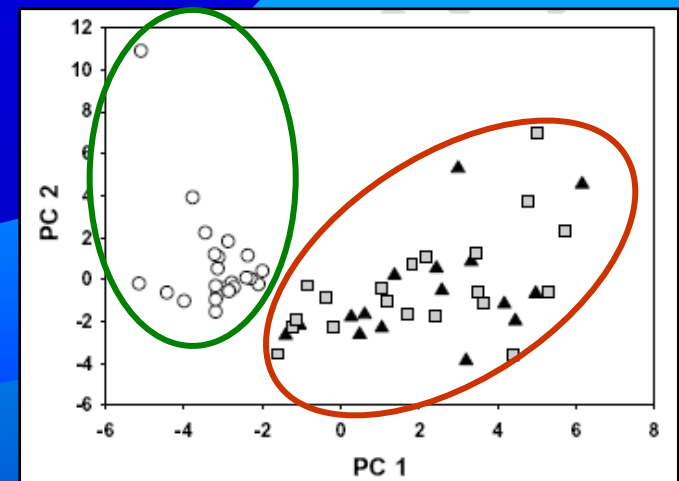
## Effects on Community Structure:

### FISH

- Data suggest more herbivores

### MACROINVERTEBRATES

- Shift in community structure with P enrichment
  - Apparent at low levels of enrichment
  - More oligochaetes, more predators
  - Indicator species (esp. Chironomidae)

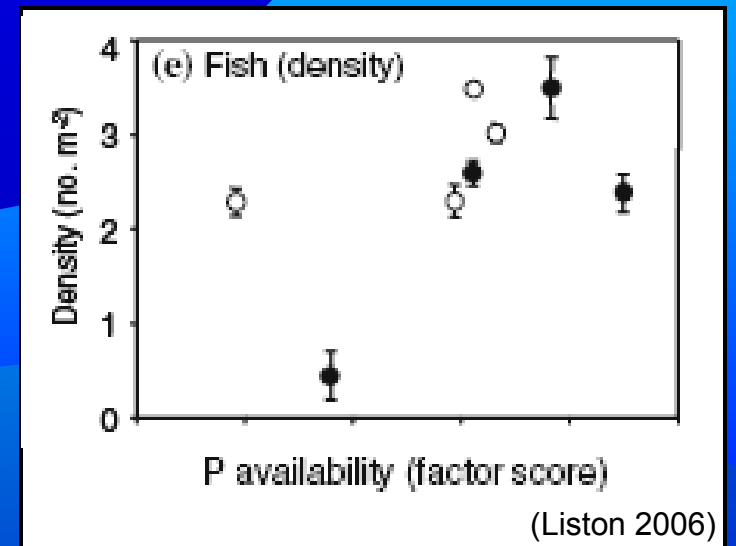
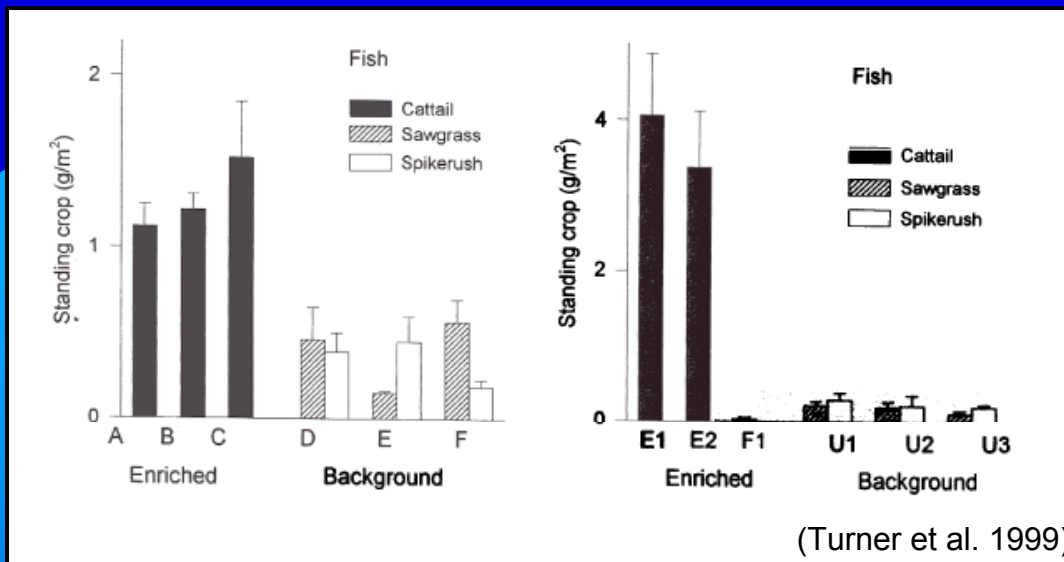
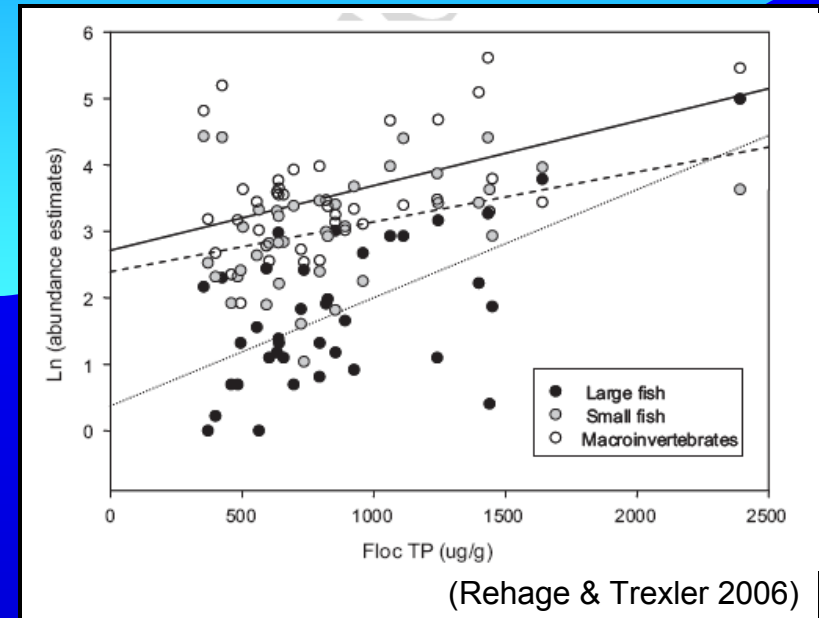


(McCormick et al. 2004)

# Effects of P on food webs

## FISH

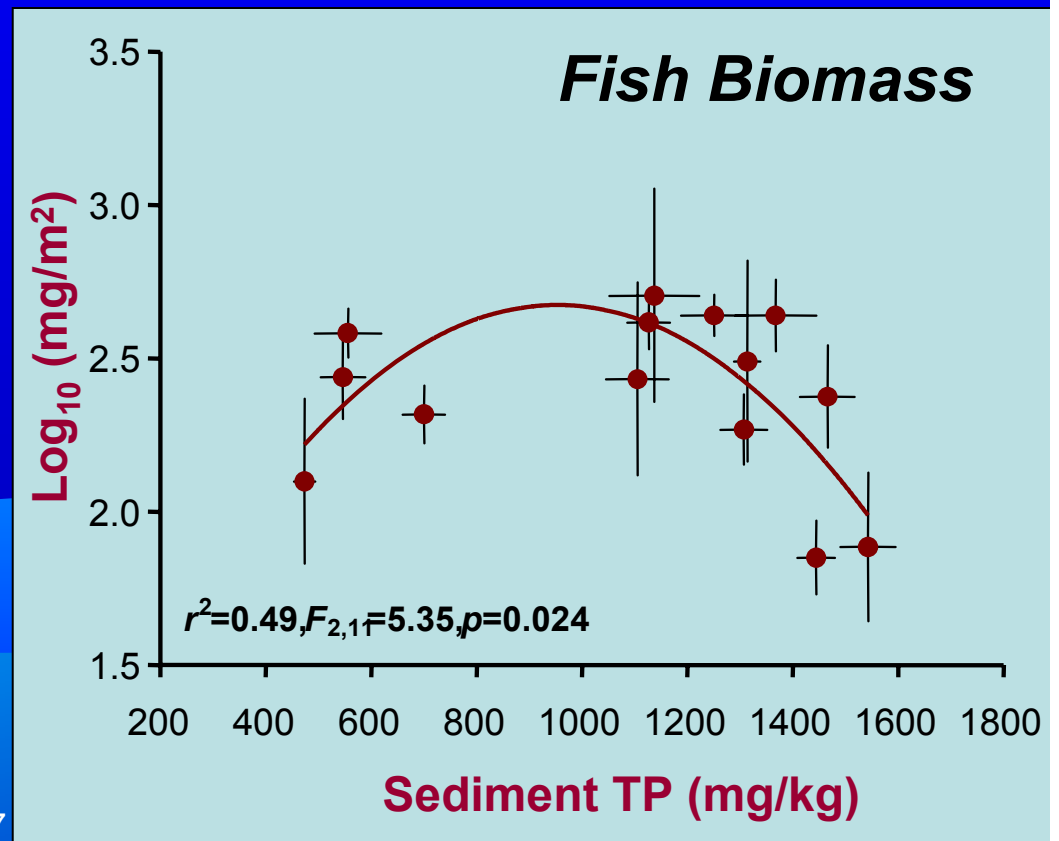
- Generally, INCREASE in fish (large & small) density and biomass with enrichment



# Effects of P on food webs

## FISH

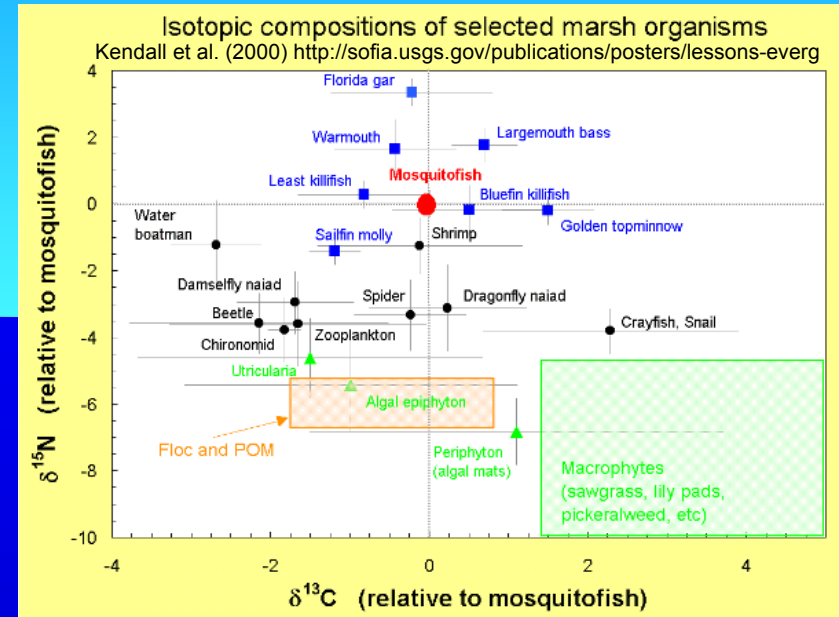
- Generally, INCREASE in fish (large & small) density and biomass with enrichment
- May decrease at high P levels (subsidy-stress)



# Effects of P on food webs

## MACROINVERTEBRATES

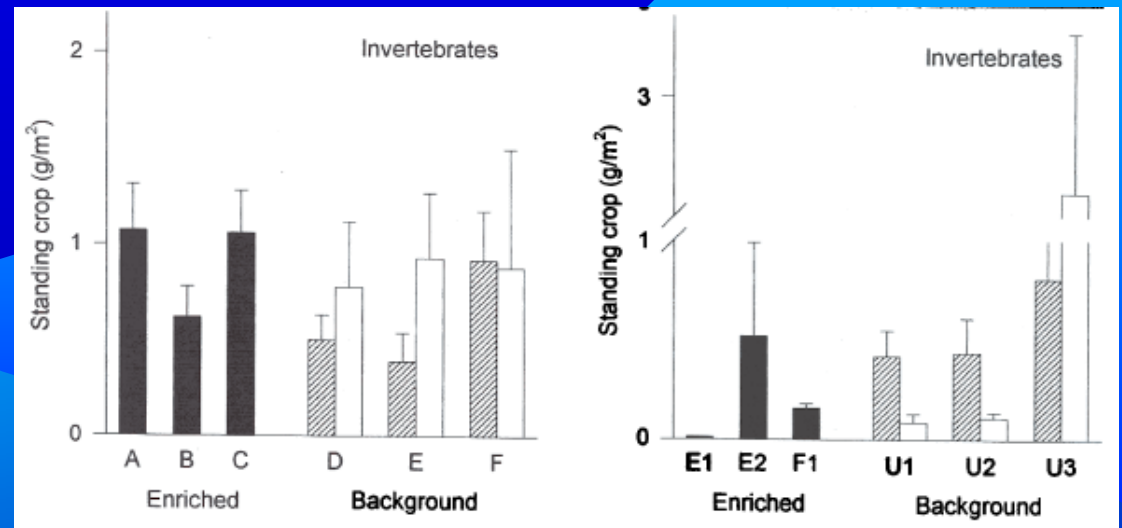
- Macroinvertebrate density & biomass responses to P enrichment are complex...



# Effects of P on food webs

## MACROINVERTEBRATES

- Macroinvertebrate density & biomass responses to P enrichment are complex...
- Driving factors
  - Higher trophic levels (cascade)



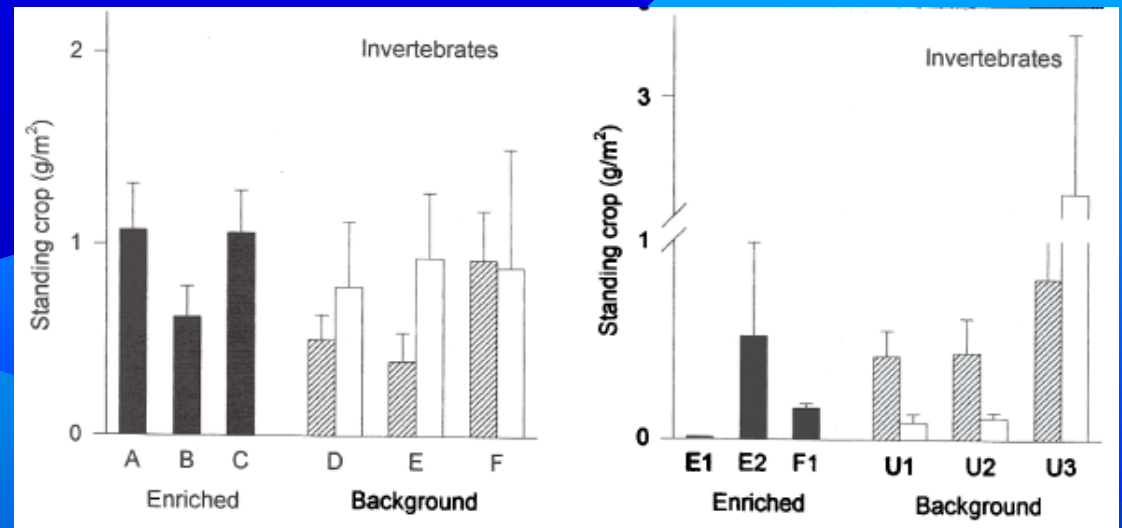
(Turner et al. 1999)



# Effects of P on food webs

## MACROINVERTEBRATES

- Macroinvertebrate density & biomass responses to P enrichment are complex...
- Driving factors
  - Higher trophic levels (cascade)
  - Habitat structure

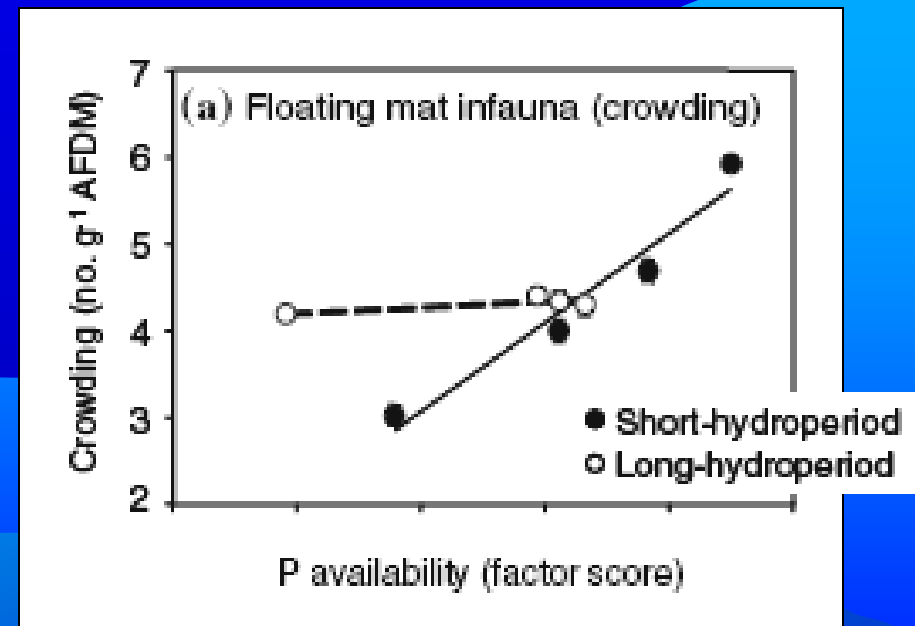


(Turner et al. 1999)

# Effects of P on food webs

## MACROINVERTEBRATES

- Macroinvertebrate density & biomass responses to P enrichment are complex...
- Driving factors
  - Higher trophic levels (cascade)
  - Habitat structure
  - Hydroperiod

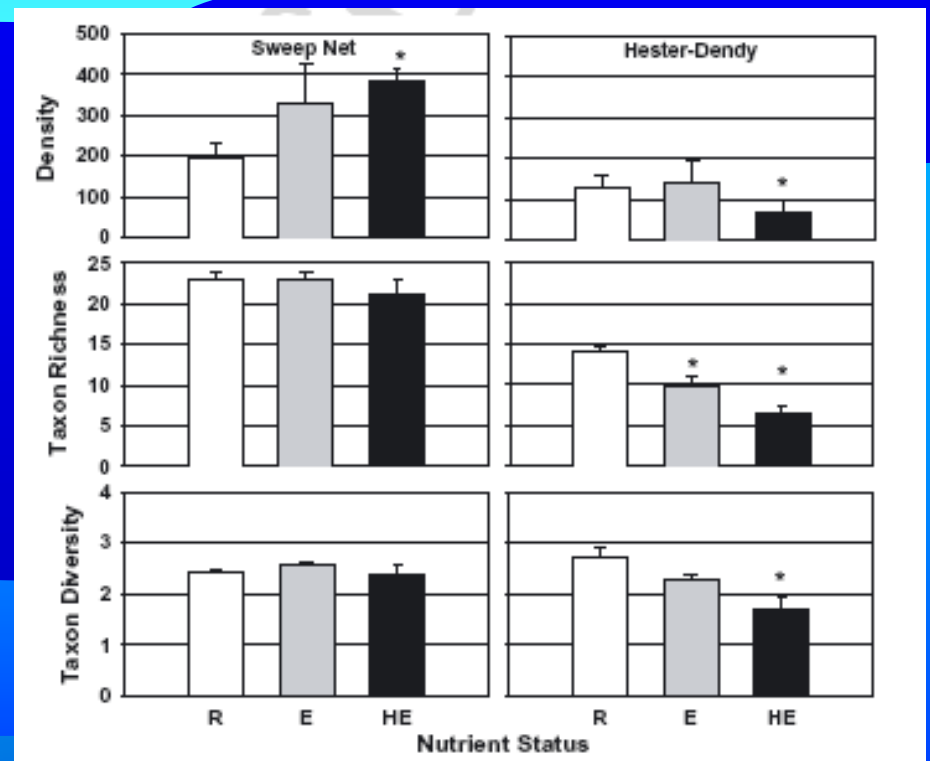


(Liston 2006)

# Effects of P on food webs

## MACROINVERTEBRATES

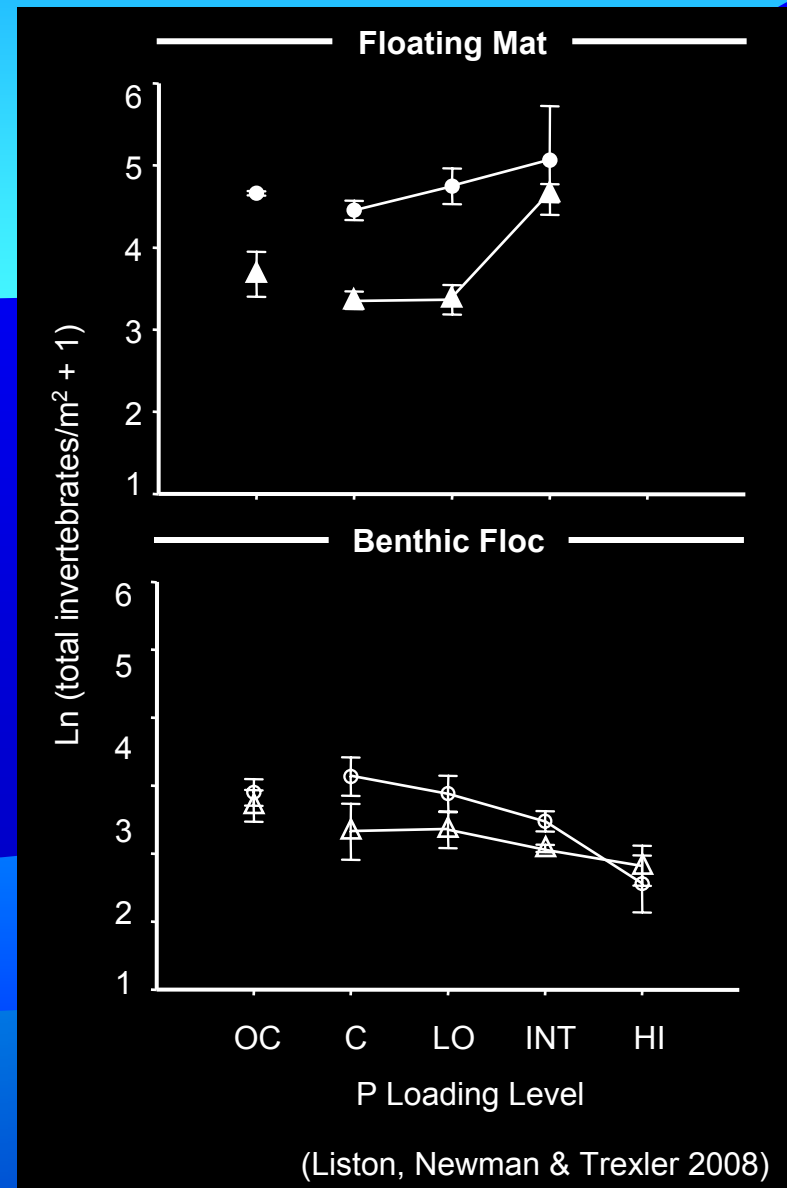
- Macroinvertebrate density & biomass responses to P enrichment are complex...
- Driving factors
  - Higher trophic levels (cascade)
  - Habitat structure
  - Hydroperiod
  - Sample method vs. microhabitat variation



# Effects of P on food webs

## MACROINVERTEBRATES

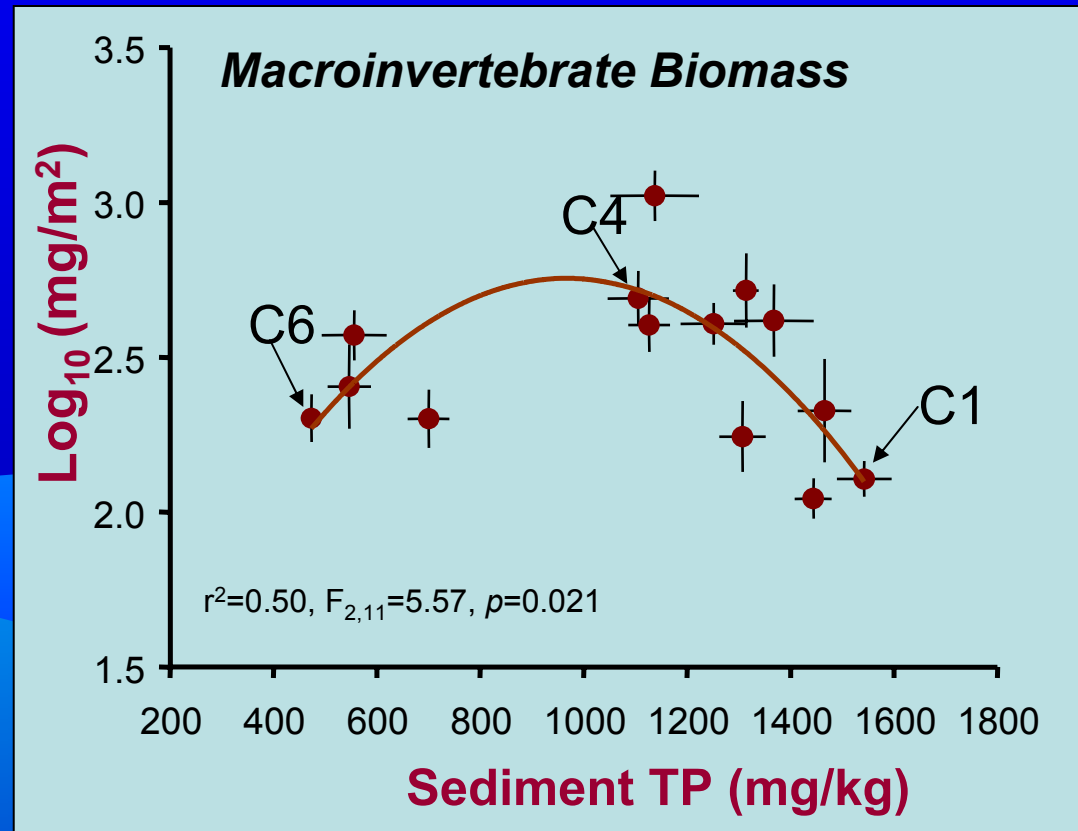
- Macroinvertebrate density & biomass responses to P enrichment are complex...
- Driving factors
  - Higher trophic levels (cascade)
  - Habitat structure
  - Hydroperiod
  - Sample method vs. microhabitat variation



# Effects of P on food webs

## MACROINVERTEBRATES

- Macroinvertebrate density & biomass responses to P enrichment are complex...
- Driving factors
  - Higher trophic levels (cascade)
  - Habitat structure
  - Hydroperiod
  - Sample method vs. microhabitat variation
  - P range



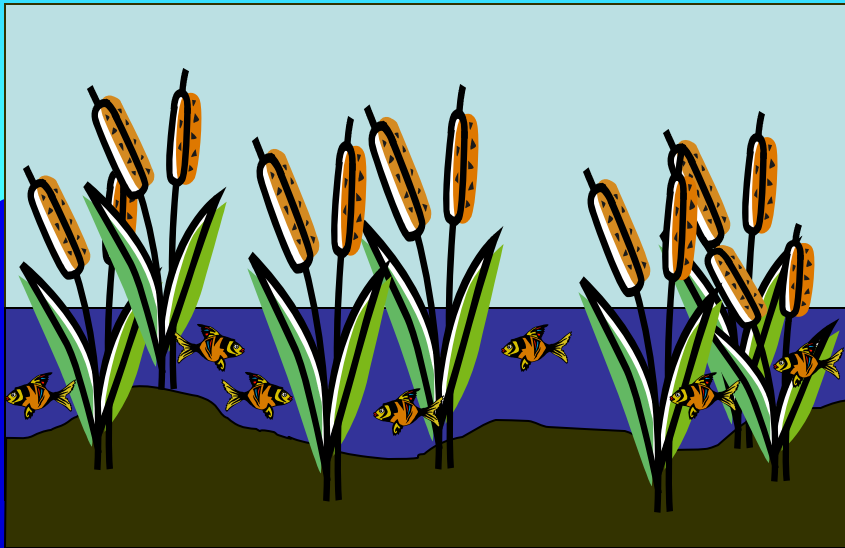
# Wading Bird Response to P

- Greater overall abundance of wading birds at moderately enriched sites (WHIB, GREG, WOST, GBH)
- Preference for foraging in more openly-vegetated slough-like habitats (most typical of unenriched locations)
- Annual hydrologic conditions may greatly affect foraging locations:
  - Wet years may increase foraging by wading birds in enriched areas
  - Dry years may increase foraging by wading birds in unenriched areas



# Wading Bird Response to P

## Eutrophic Conditions



Increased prey abundance

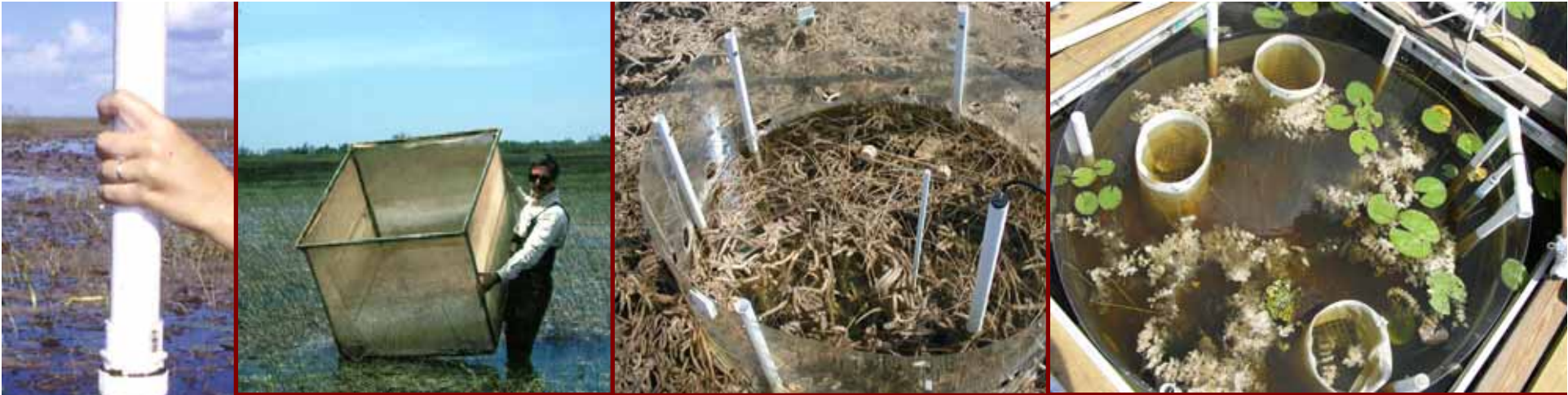
Increased habitat structure  
reduces prey availability

## Oligotrophic Conditions

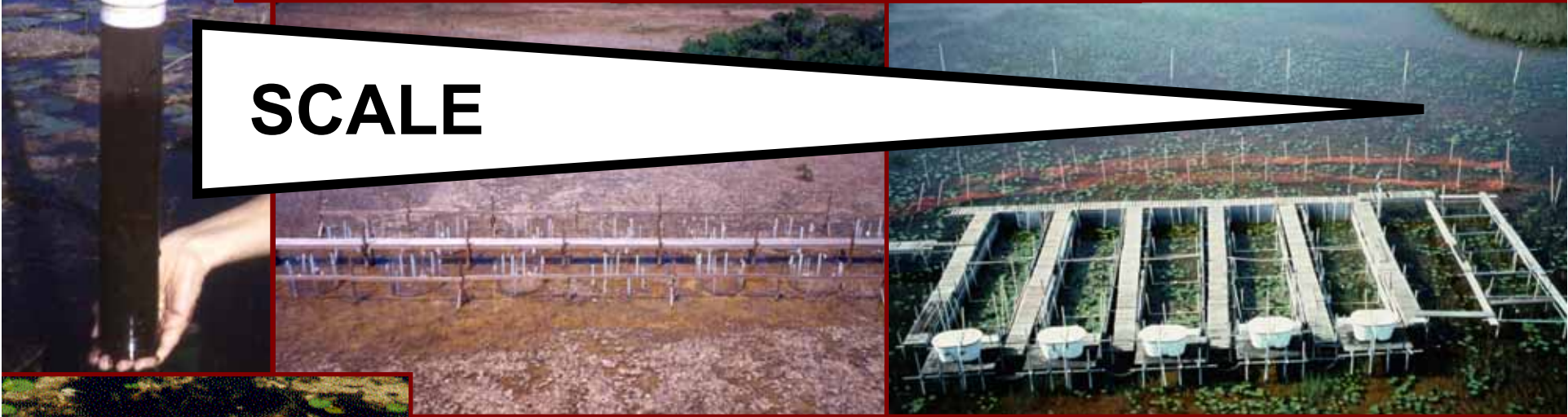


Limited prey abundance

Less habitat structure  
increases prey availability



**SCALE**





# Assessing these effects is tricky...

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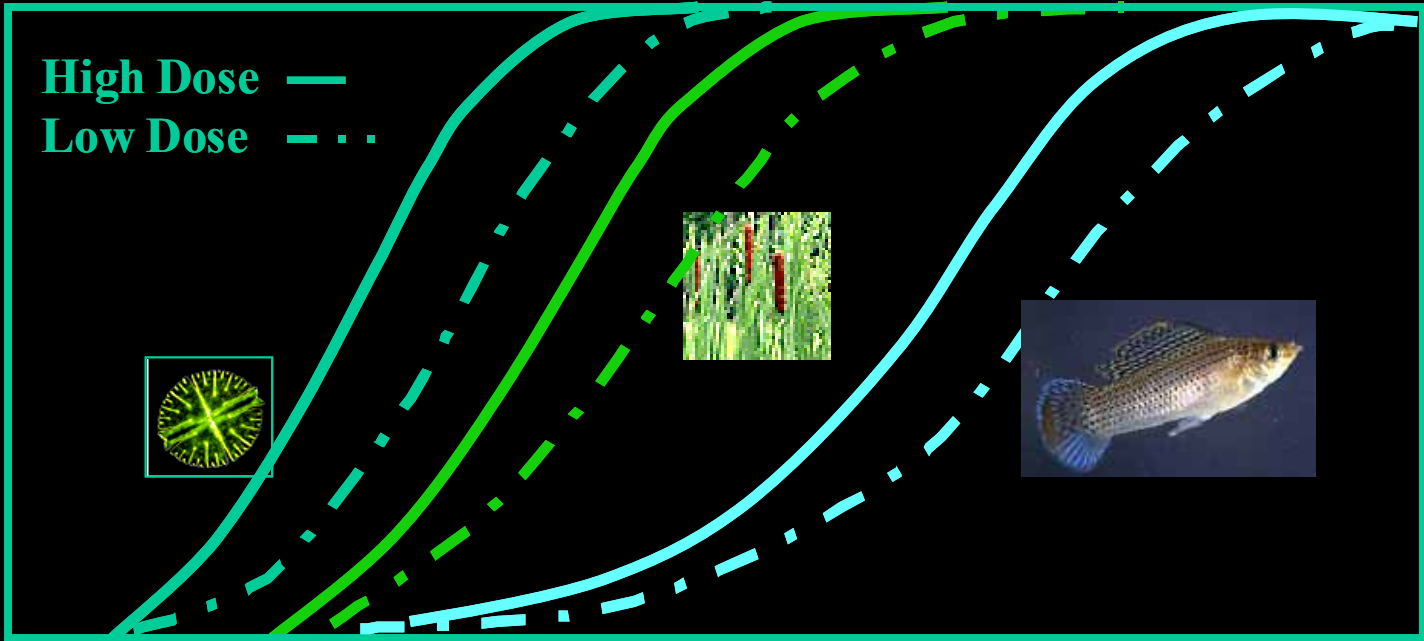
- SPATIAL SCALE

- Patchiness
- Landscape-level vs. mesocosms
- Open vs. closed systems (oasis of enrichment)

- TEMPORAL SCALE

- Short-term vs. long-term dynamics
- Are we studying a system that is at equilibrium?

Difference from Natural State



Time



# Conclusions

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- Everglades aquatic consumers are P-limited and this limitation relaxes with P enrichment
- The Everglades food web is typical of karstic tropical ecosystems; P enrichment alters the unique distribution of biomass characteristic of these systems
- Increased P influences Everglades aquatic consumer communities through a combination of direct and indirect factors
  - Disappearance of periphyton mats results in habitat loss for many macroinvertebrates; prior to mat collapse, change in relative abundance of algae in mats may make edible algae more available to grazers
  - Increased macrophyte density with enrichment provides increased habitat for aquatic consumers (increased density of fish), but makes prey less available to wading birds

# Conclusions

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- Scale (spatial & temporal) is a critical consideration when designing experiments and interpreting data on food web effects of P enrichment
- Future research is needed to understand the interaction of hydroperiod and P enrichment on Everglades food webs

# Special thanks to...

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- Numerous funding sources for supporting our research
- Ramesh Reddy & Ronnie Best for inviting us to participate in this symposium

