Nutrient effects on flora & fauna

Tom Frazer
Chuck Jacoby
Ed Phlips

Foci

- Effects of nutrients in context
  - Flora = f(light, substrate, flow , C, O_2, nutrients)
  - Fauna = f(toxicity, habitat, trophic links)
- System effects

Flora = ƒ(light)

- Water clear $\Rightarrow$ ~ no effect
- Flora = ƒ(shading by riparian canopy)
  - empirical evidence consistent
    - production $+\alpha$ light in Silver Springs (Odum 1957a & b)
    - biomass $+\alpha$ light in 31 springs & spring runs (Duarte & Canfield 1990)
    - biomass $-\alpha$ shading in Weeki Wachee (esp. filamentous algae) (Frazer *et al*. 2001)
  - no experimental definition of relationship for FL springs
- Flora = ƒ(shading by epiphytes)
  - evidence sparse & not from FL springs
  - boundary layer effect > shading effect?

Flora = f(substrate)

- FL springs have low topographical gradients
- Flow < 0.6 m sec^{-1} $\therefore$ substrates suit most plants
- Exception = exposed limestone ~~suit~~ rooted plants

Flora = *ƒ*(flow)

- Opposing effects on flora
  - sloughing of epiphytes @ high flow
  - boundary layer limitations on uptake @ low flow
- Sloughing
  - empirical data equivocal
    - epiphytes $\not\alpha$ velocity in 5 spring-fed rivers (Frazer *et al*. 2001)
    - epiphytes $-\alpha$ velocity in Weeki Wachee (Frazer *et al*. 2006)
  - no experimental definition of relationship for FL springs
- Boundary layer; $J = -D \times (\partial\phi/\partial\chi)$
  - $\partial\chi \Rightarrow$ larger layer = problem (opposite of effect in WW)
  - no experimental definition of relationship for FL springs

Flora = f(carbon & oxygen)

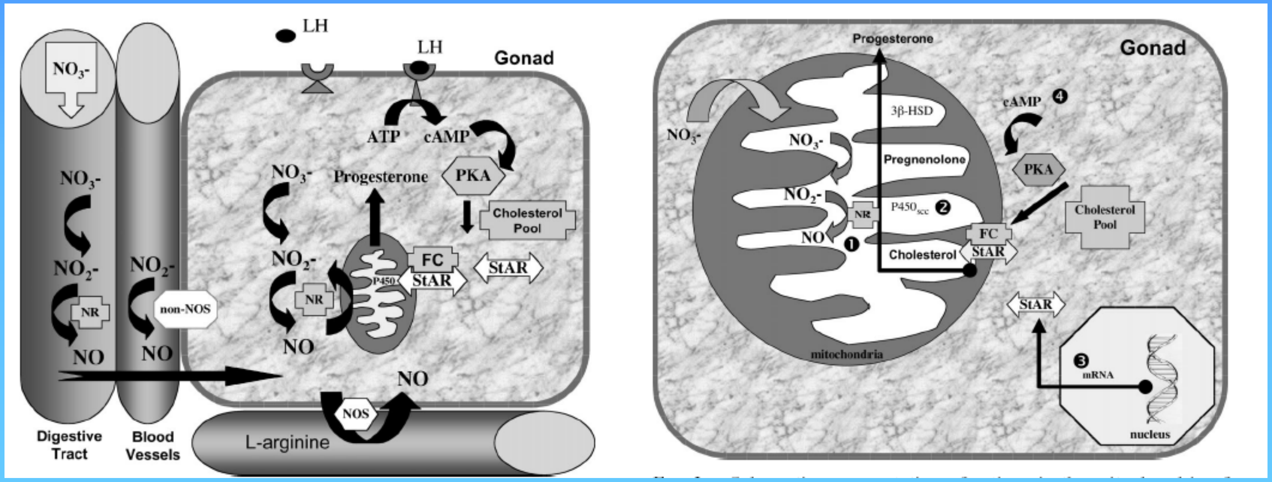
- C
  - DIC in springs high
  - boundary layer $\Rightarrow$ local depletion, e.g. mats
  - no experimental definition of relationship for FL springs
- O_2
  - Δ photosyn $\Rightarrow$ Δ $[O_2]$ $\Rightarrow$ Δ roots $\Rightarrow$ Δ C balance $\Rightarrow$ Δ flora
  - algal cover $-\alpha$ $[O_2]$ in springs (Stevenson *et al*. 2004)
  - $[O_2]$ $\Downarrow$ in FL springs? (Heffernan *et al*. unpublished data)
  - $[O_2]$ $\Downarrow$ enough $\Rightarrow$ Δ fauna $\Rightarrow$ other effects on flora
  - no experimental definition of relationship for FL springs

Flora = ƒ(nutrients)

- Macro & micro important – focus on N & P
- Sparse & equivocal evidence of N or P limitation
  - standing crop $\not\propto$ [TN] or [TP] in 17 streams & 31 springs (Canfield & Hoyer 1988a & b; Duarte & Canfield 1990)
  - standing crop +α [NO_3^-] in 2 of 5 spring-fed rivers (Frazer *et al*. 2001)
  - biomass +α [P], incl. periphyton, in 2 rivers (Frazer *et al*. 2001; Notestein *et al*. 2003)
- Growth & "Competition" = ƒ(nutrients)?
  - no kinetics for flora in springs (e.g. saturation constants)
  - hampers understanding of interactions

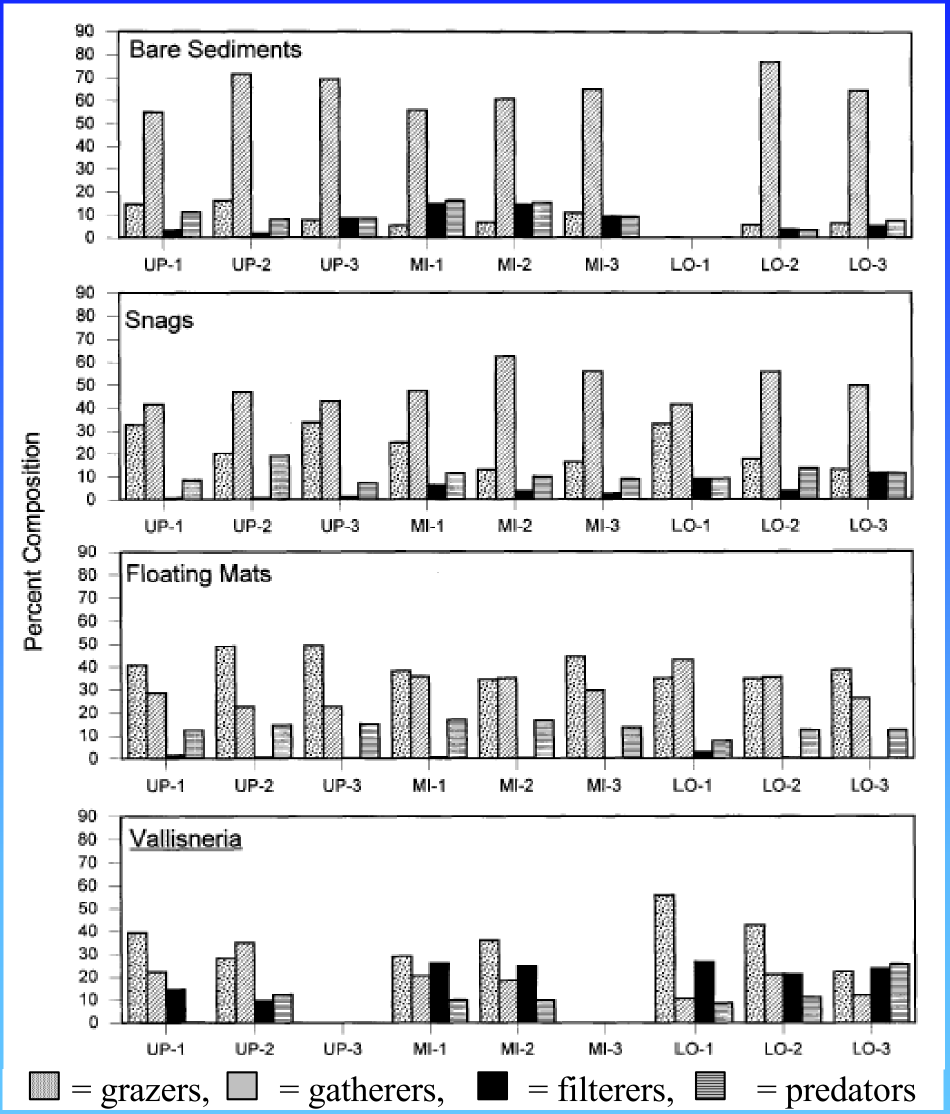
Fauna = f(toxicity)

- NH_3 & NO_3^- = 2 toxic species
- NH_3 covered by USEPA criteria = formulae
  - maximums for short-term & long-term exposures
  - protection for all species = ? (esp. stygobiota & endemics)
- NO_3^- multiple effects
  - blue baby ⇒ criterion
  - Δ growth, reproduction, … ⇒ potential for ecological effects (Guillette & Edwards)
  - bottom line = most springs OK, [NO_3^-] worth watching



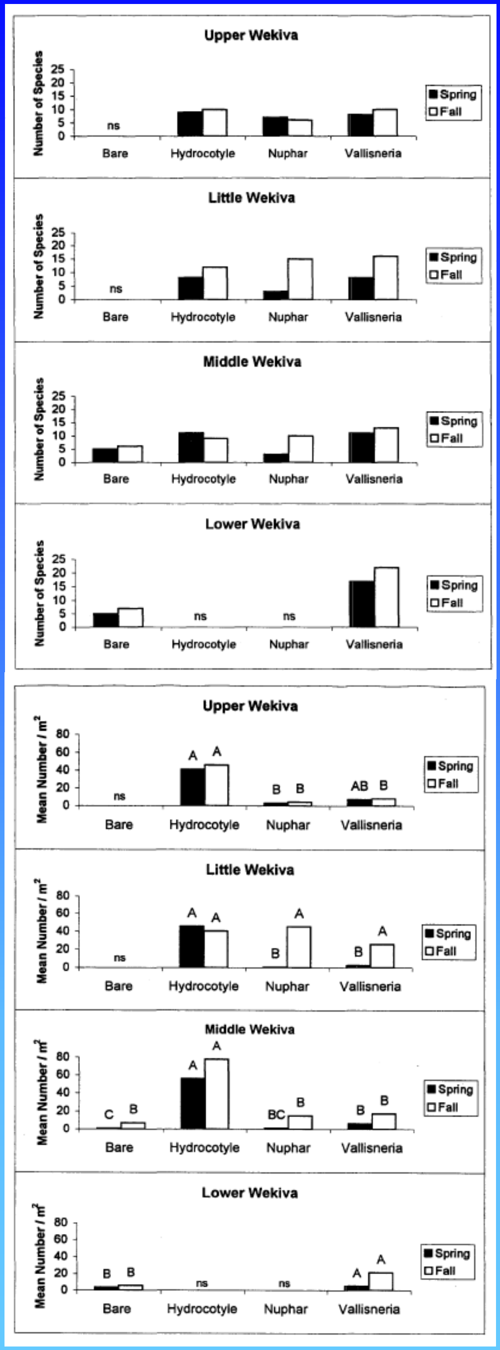
Fauna = ƒ(habitat)

- Inverts = ƒ(habitat) (Warren *et al.* 2000)
  - Wekiva River
  - 4 habitats = bare, snag, pennywort, *Vallisneria*
  - numbers = (20,000–34,000 m^{-2})
  - assemblage varied
  - no definition of relationship



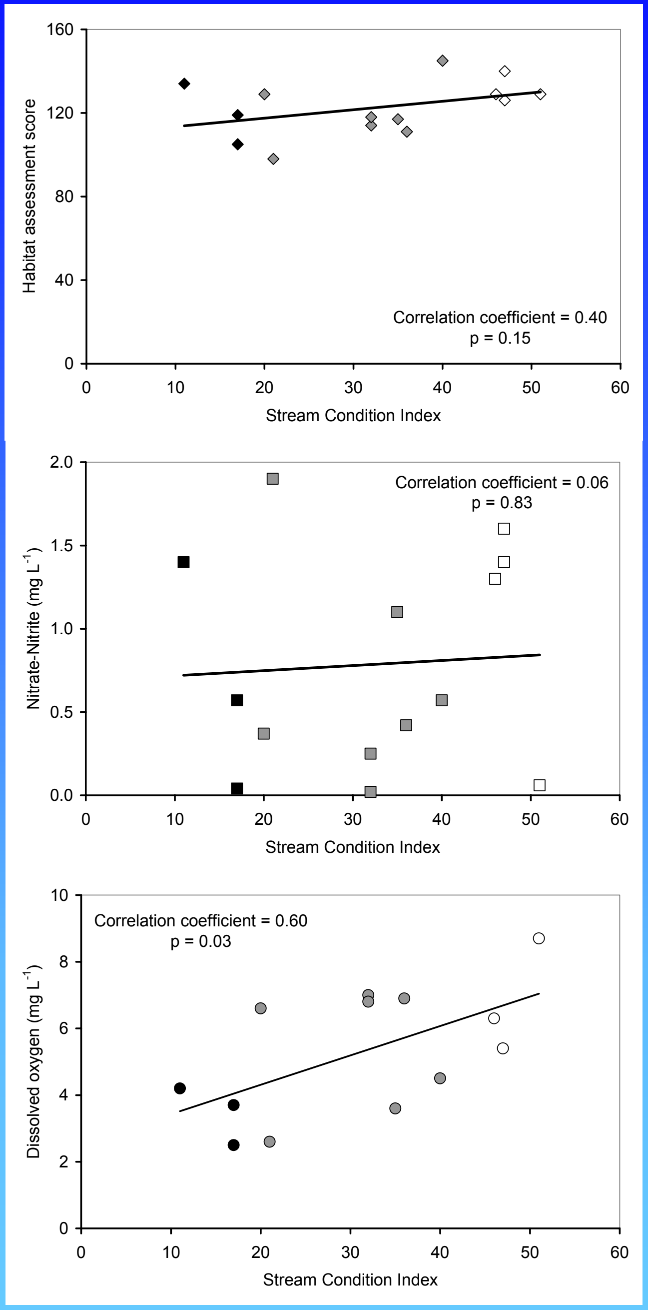
Fauna = ƒ(habitat)

- Fish = ƒ(habitat) (Warren *et al.* 2000)
  - Wekiva River
  - 4 habitats = bare, pennywort, spatterdock, *Vallisneria*
  - vegetated ⇒ > species richness & > densities
  - no definition of relationship



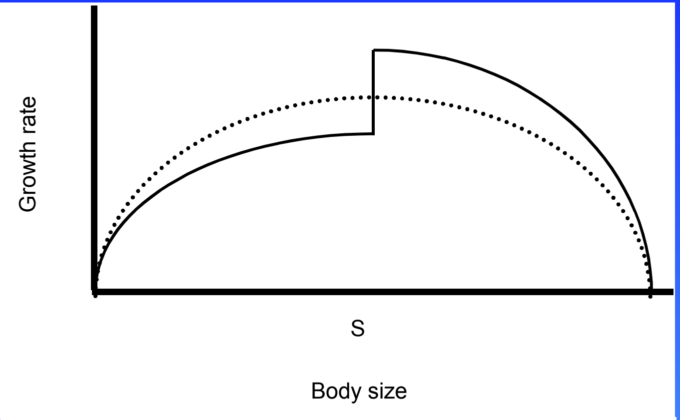
Fauna = ƒ(nutrients)

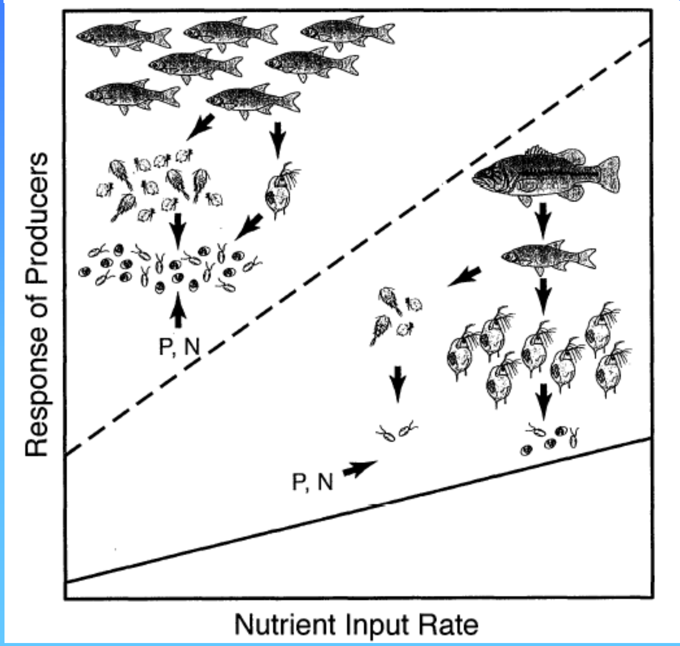
- Inverts = ƒ(nutrients)
  - Suwannee River (Hornsby *et al.* 2004)
    - abundance $+\alpha$ [NO_3^-]
    - biodiversity $-\alpha$ [NO_3^-]
  - Stream Condition Index
    - $+\alpha$ [habitat score]
    - $\not\alpha$ [NO_3^-]
    - $+\alpha$ [O_2]
- Fish = ƒ(nutrients)
  - biomass $+\alpha$ [TP] w/ > $+\alpha$ @ lower [TP] (Hoyer & Canfield 1991)
- Fauna = ƒ(habitat) = ƒ(flora) = ƒ(nutrients)?



Fauna = ƒ(trophic links)

- Complex & non-linear
  - fish growth v habitat use w/ predator (Diehl & Kornijów 1998)
    - slow growth where safe
    - size refuge ⇒ shift & > growth
  - trophic cascades (Carpenter *et al.* 2001)
    - piscivores ⇒ < planktivores
    - < planktivores ⇒ > zooplankton
    - > zooplankton ⇒ < phytoplankton
    - cascade ⇒ stable control over years & across N & P inputs
- No definitions of relationships for FL springs





Fauna = f(trophic links)

- Probably important in FL springs
  - prevent grazing by caddisflies $\Rightarrow$ more periphyton (Lamberti & Resh 1983)
  - grazing on periphyton $\Rightarrow \Downarrow$ biomass (70% of expts) & altered assemblages (81% of expts) (Feminella & Hawkins 1995)
  - invertebrate abundance $+\alpha$ $[NO_3^-]$ (Hornsby *et al*. 2004)
  - biomass of fish $+\alpha$ [TP] w/ > $+\alpha$ @ lower [TP] (Hoyer & Canfield 1991)

System effects

- Nutrients $\Rightarrow$ complex & non-linear effects
  - Eutrophication progression scheme (Duarte 1995)
  - characteristics of plants drive interactions (e.g.s)

Characteristic	**Relationship**
Need for nutrients in water	Vascular < Algae
[Nutrient]/unit plant or growth	Vascular < Algae
Other sources (sediment, stores, recycling)	Vascular > Algae
Need for light	Vascular > Algae
Compensation points (photosynthesis or growth)	Vascular > Algae
Light harvest	Vascular < Algae
Resistance to grazing (*Lyngbya* toxicity?)	Vascular > Algae

System effects

- Indirect effects & feedbacks (e.g.s) ⇒
  - thresholds
  - decoupling from inputs
  - alternative stable states

1	> nutrients ⇒	> algae ⇒	< light ⇒	< vascular ⇒	> nutrients		
2	> nutrients ⇒	> algae ⇒	> respn ⇒	< [DO] ⇒	> reducing ⇒	> nutrients	
3	> nutrients ⇒	> algae ⇒	> respn ⇒	< sed [O_2] ⇒	< N uptake ⇒	< vascular ⇒	> nutrients
4	> nutrients ⇒	> algae ⇒	> respn ⇒	< [DO] ⇒	< grazing ⇒	> algae ⇒	1, 2 or 3

Implications

- Data for FL springs sparse ∴ draw from elsewhere
- Direct toxicity probably OK if indirect effects OK
- Interactions & indirect effects poorly known
- Experiments ⇒ cause–effect links @ fine-scale
- Management ⇒ cause–effect links @ large-scale
- Adaptive management ⇒ learning & improvement