

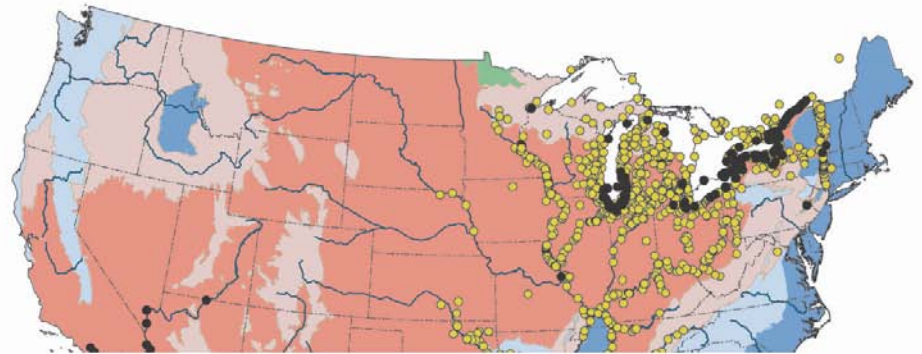
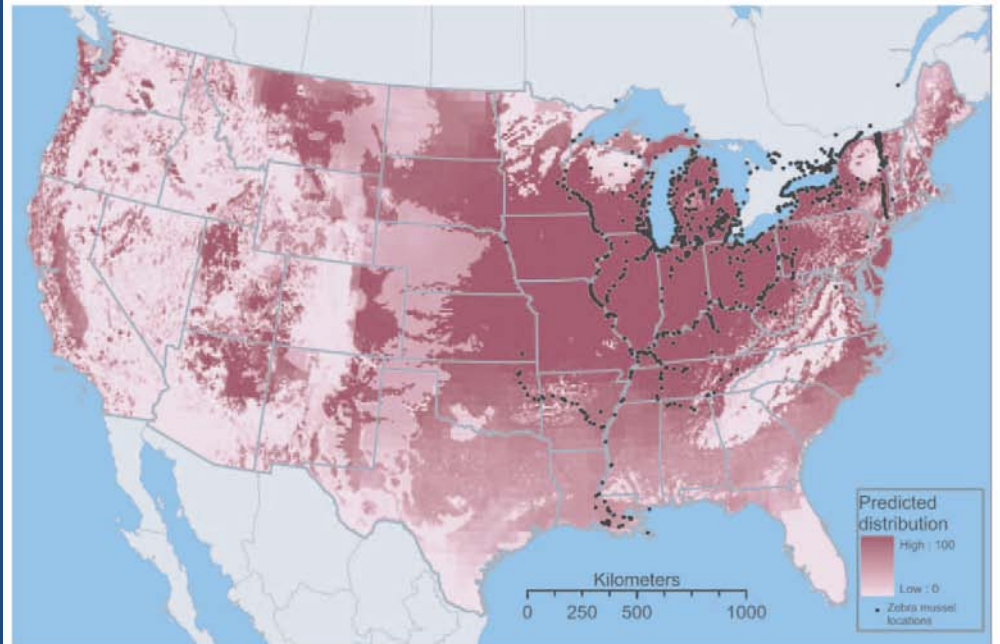
# Outline

- Predictions for Maryland
  - Broad-scale limits on distribution and abundance
  - Local limits on distribution and abundance
  - Ecosystem sensitivity to zebra mussel
- Hudson River case study
- Q+A

# Broad-scale distribution

## Limited by:

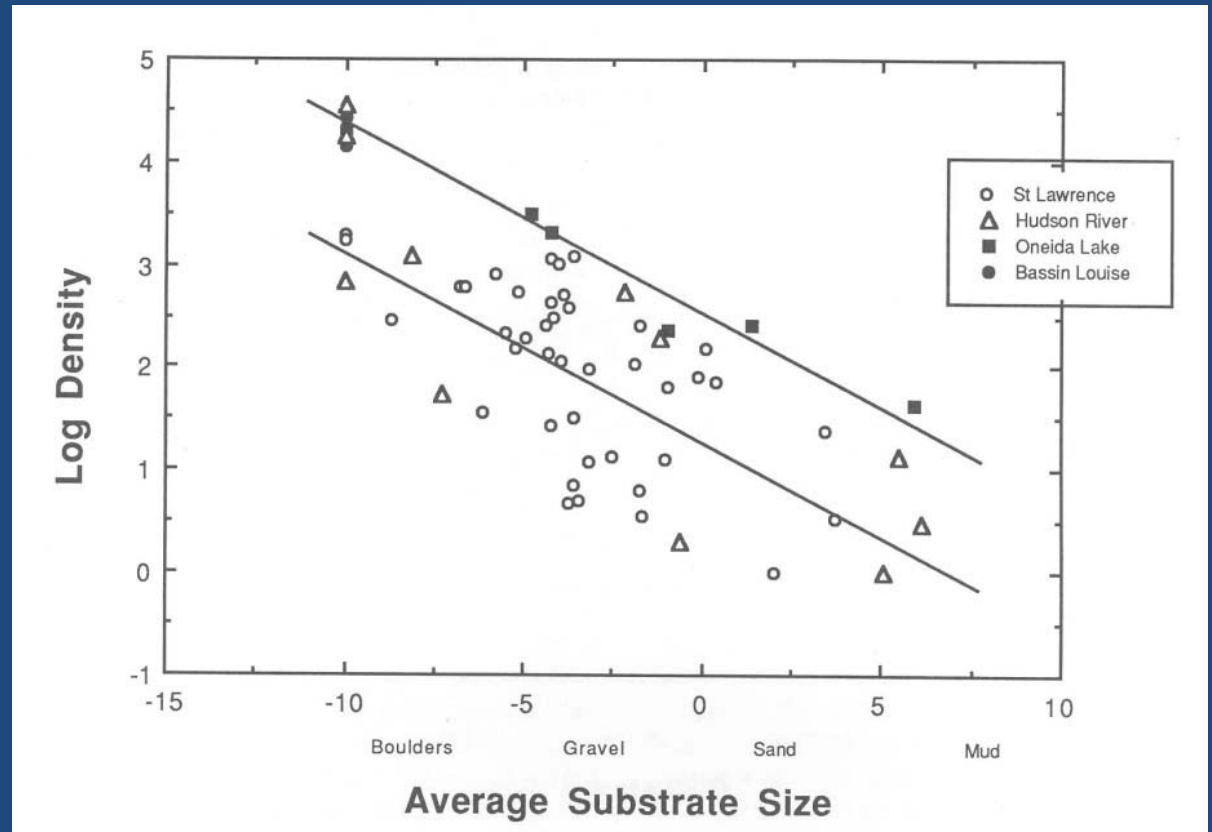
- Dispersal (importance of education and management)
- Calcium (10-15 ppm?)
- Salinity (<3-5 psu)
- Stream size (10-100 m?)
- Reservoirs important?



# Local abundance

Limited by:

- Hard substrate
- Desiccation
- Primary production?



# Ecosystem sensitivity



# Effects of the zebra mussel invasion on aquatic ecosystems: the Hudson River and beyond



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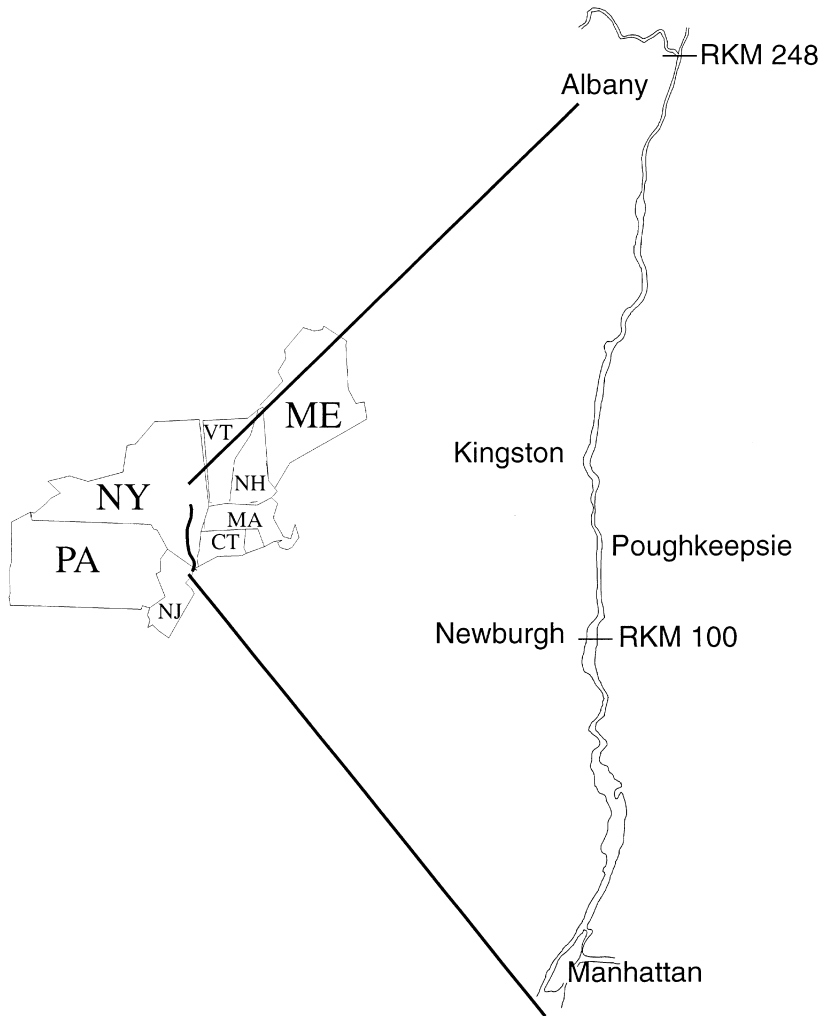


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# Acknowledgements

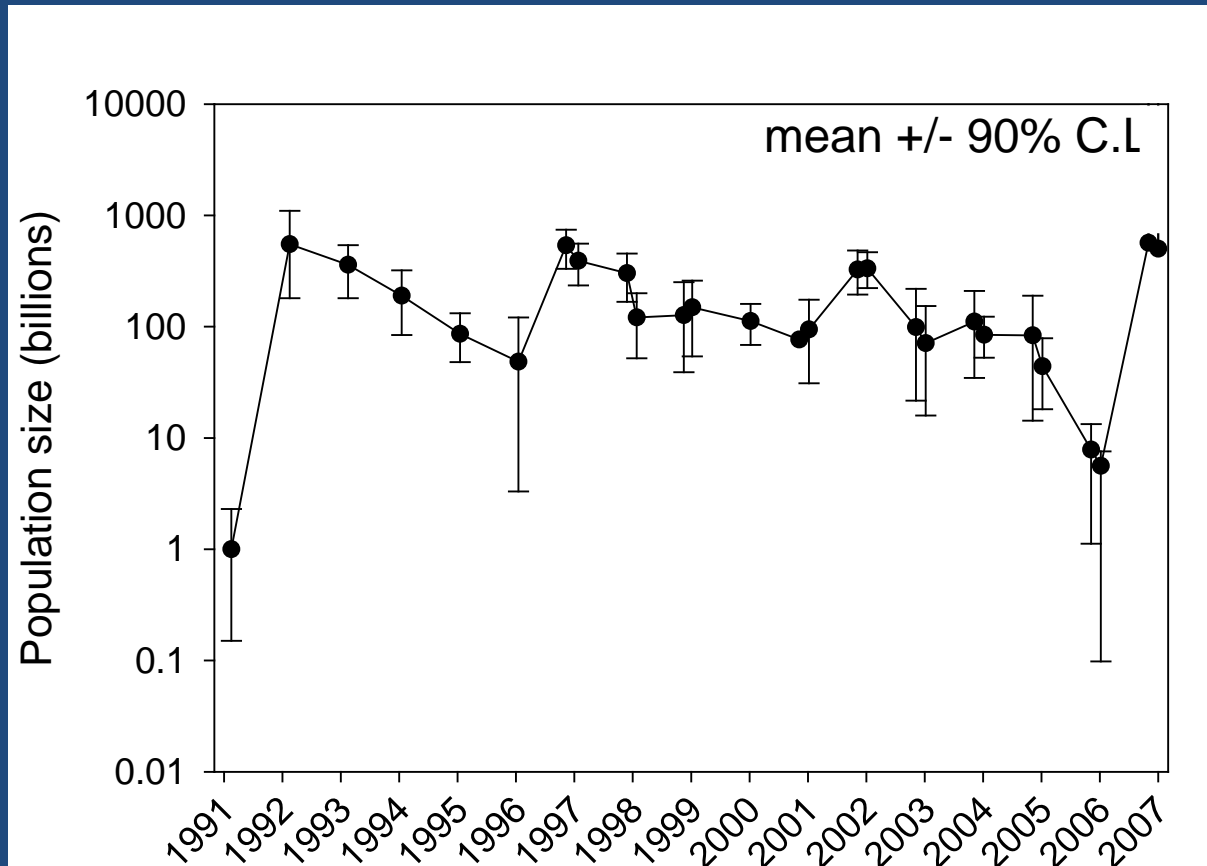
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- Ben Peierls
- Jon Powell
- Peter Raymond
- Hudson Roditi
- Mark Scheuerell
- Lane Smith
- Tom Smith
- Jan Stevenson
- Cathy Wigand
- AND MANY OTHERS!!!

# The Hudson River

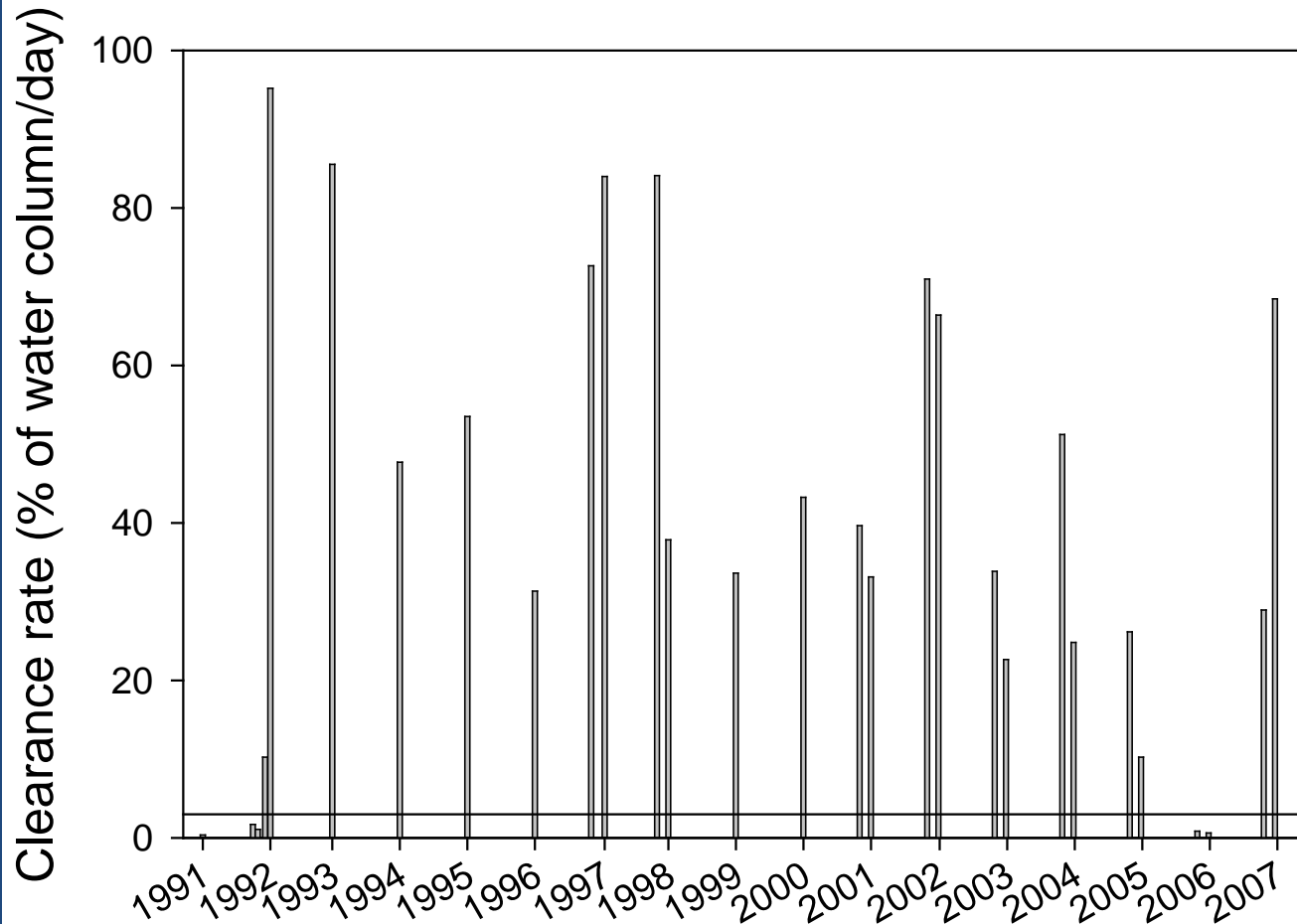


Surface area	140 km <sup>2</sup>
Mean depth	8.3 m
Mean freshwater flow	384 – 533 m <sup>3</sup> /s
Tidal range	0.8 – 1.6 m
pH	7.6
Calcium	27 mg/L
Salinity	<0.5 g/L
Soluble reactive P	20 µg/L
Nitrate-N	0.4 mg/L
% rocky bottom	7%

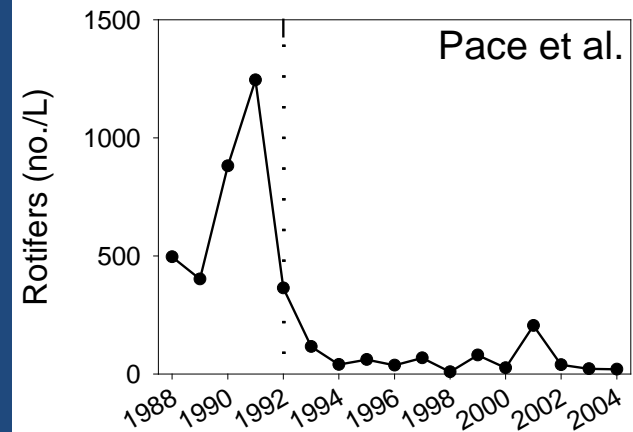
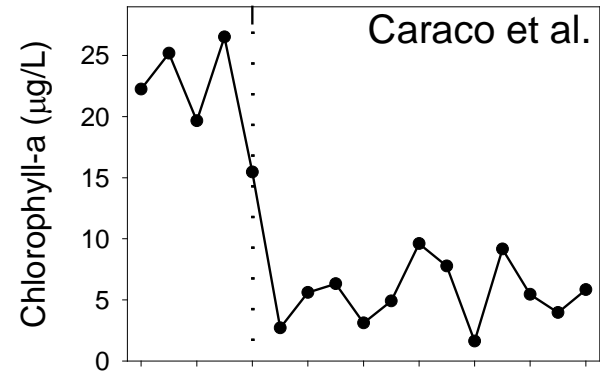
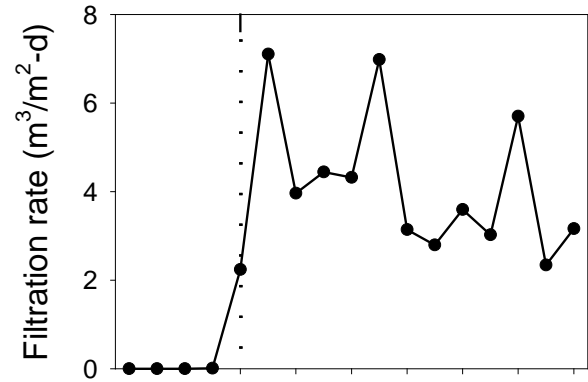
# Population dynamics in Hudson



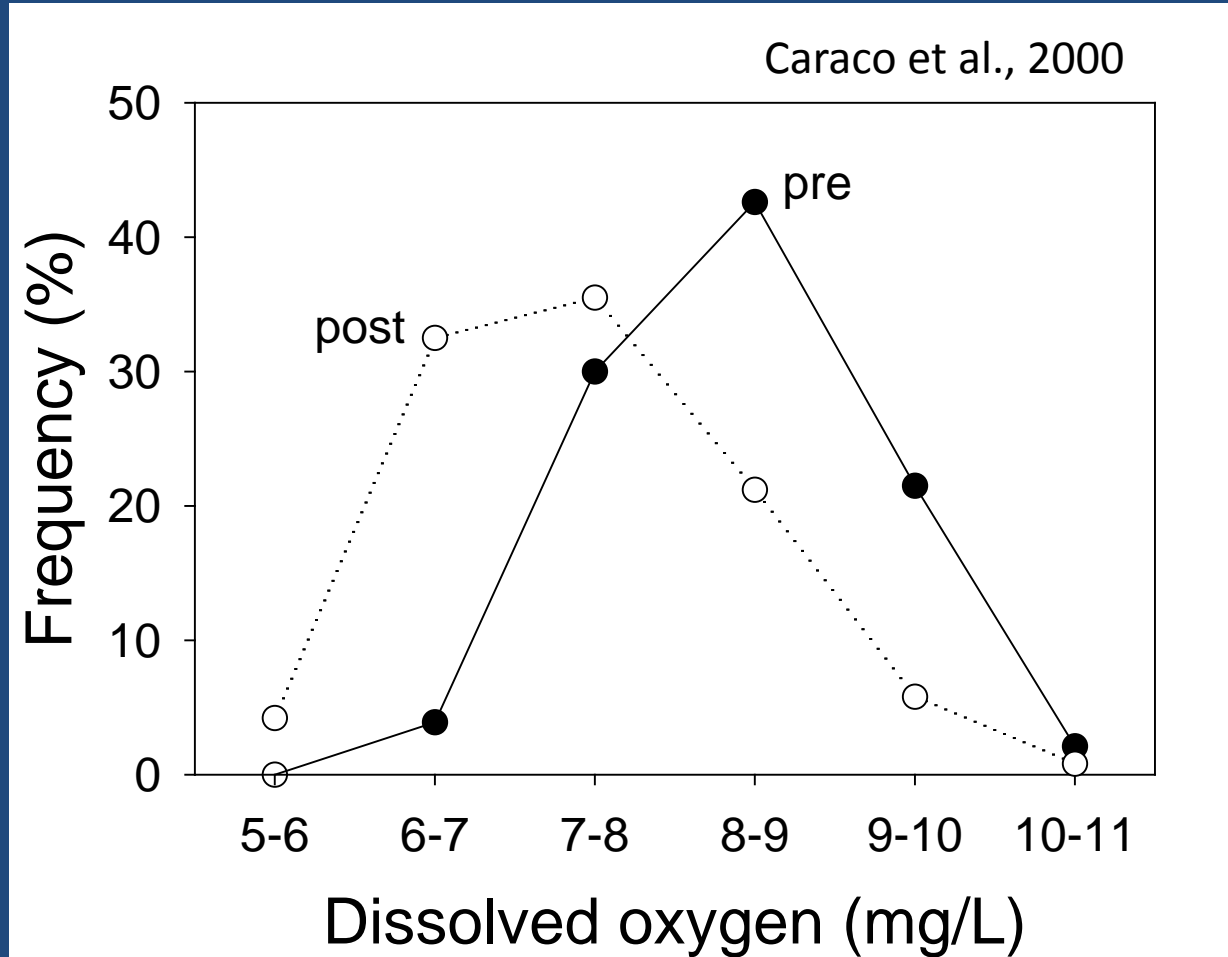
# Filtration rate in Hudson



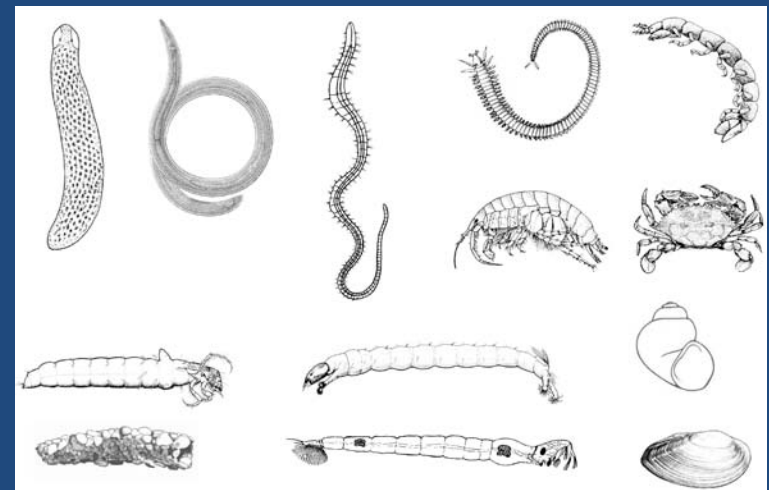
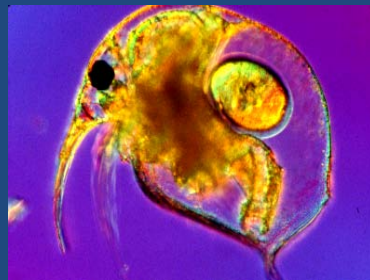
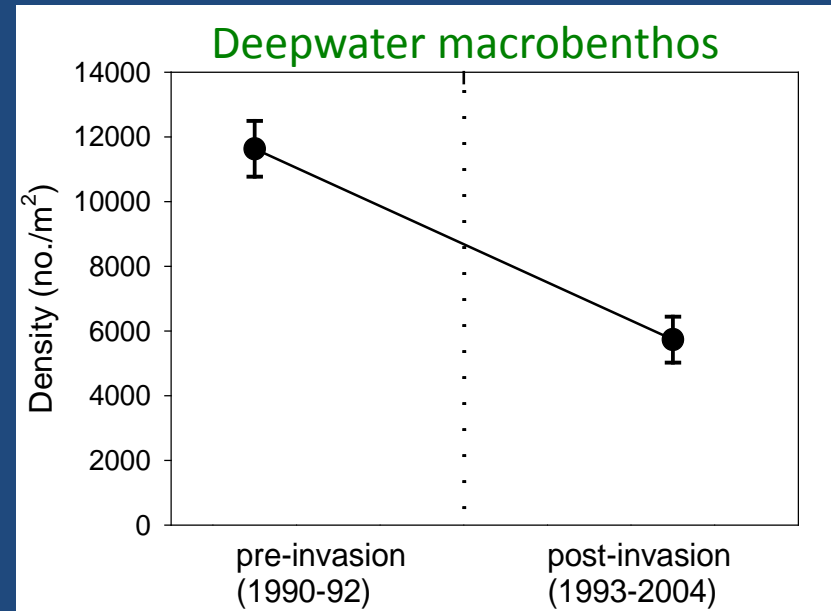
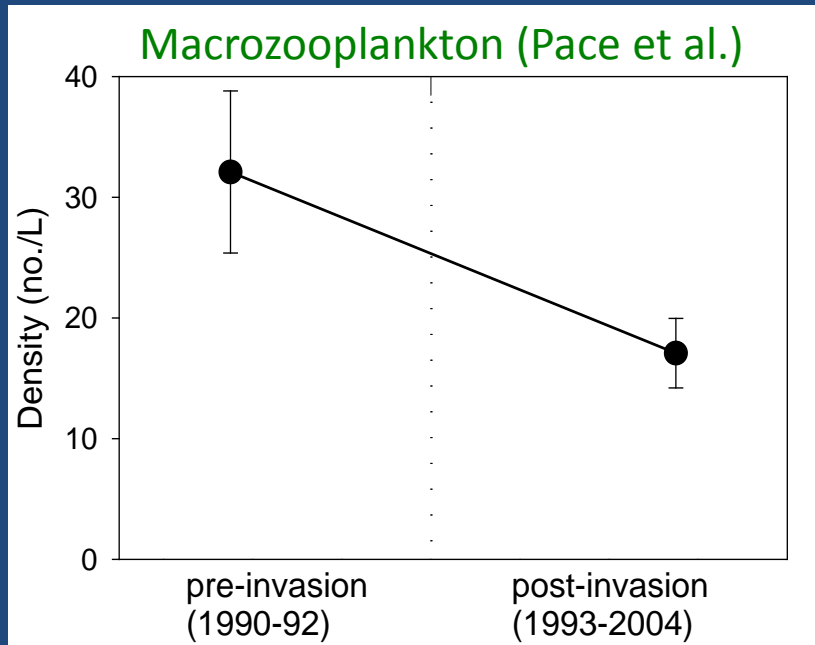
# 1. Zebra mussels consumed resources (food)



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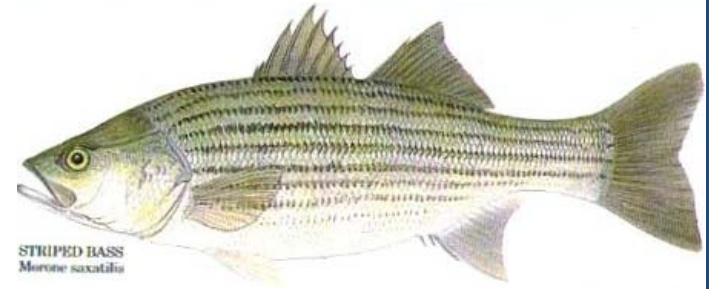
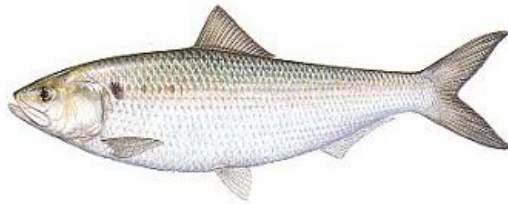
## 2. Planktivores suffered



# Source of wonderful fish data

- **Hudson River electric utilities:** (1) Ichthyoplankton survey (post-yolk-sac larvae), stratified random design, weekly for 26 years (19 pre-invasion, 7 post-invasion), numbers and body lengths of 7 species; (2) Beach-seine surveys (young-of-year), stratified random design, every 2 weeks in late summer for 26 years, numbers of 15 species, body lengths of 6 species
- **New York State Department of Environmental Conservation:** Beach-seine surveys (young-of-year), selected index sites, every 2 weeks in late summer for 15 years (8 pre-invasion, 7 post-invasion), body lengths of 5 species

Fish that live in the open water and whose young feed on zooplankton for a long time will become less abundant, grow slower, and/or shift downriver.



STRIPED BASS  
*Morone saxatilis*

Ron Pittard

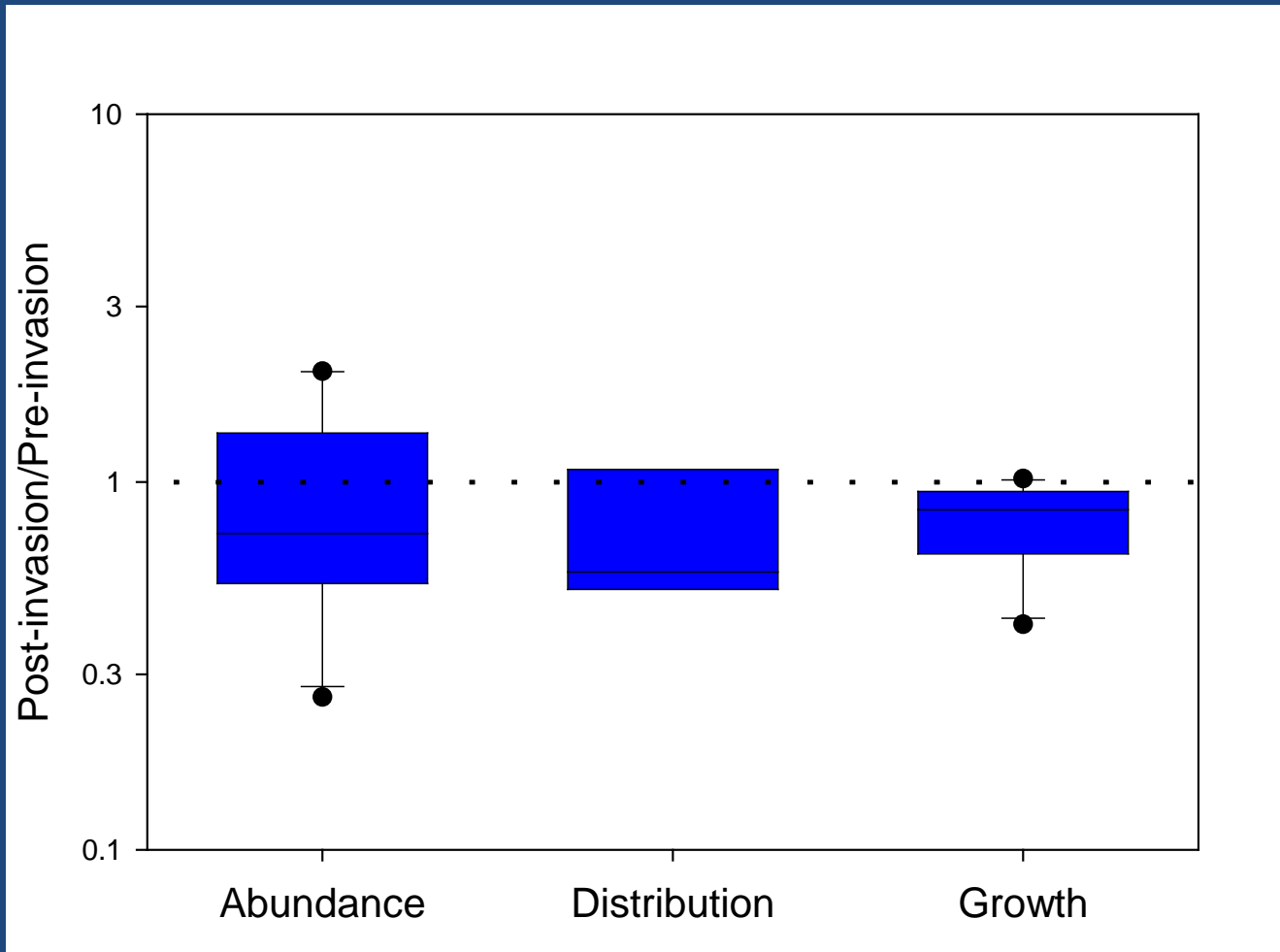


Blackback herring - *Alosa aestivalis*  
averages 10-14 inches

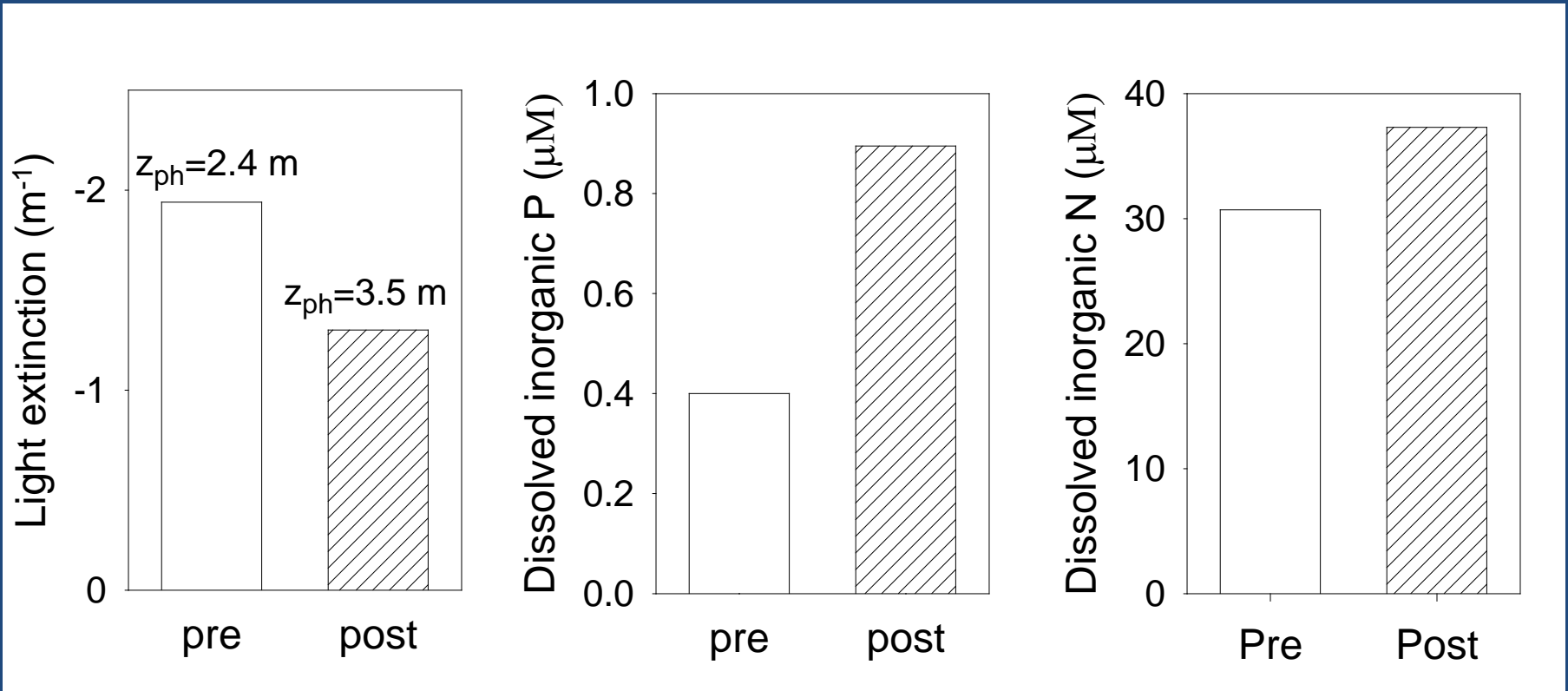


- “Abundance” is mean riverwide number of fish over standard period of time
- “Distribution” is ratio of number of fish above RKM 100 (Newburgh) and number of fish below RKM 100 for each species
- “Growth” is apparent growth, based on field measurements of length
- Covariates include year (time-trends), freshwater flow, water temperature
- Technique is multiple regression, using model-averaging

## 2. Planktivores suffered



### 3. Resources formerly used by phytoplankton increased

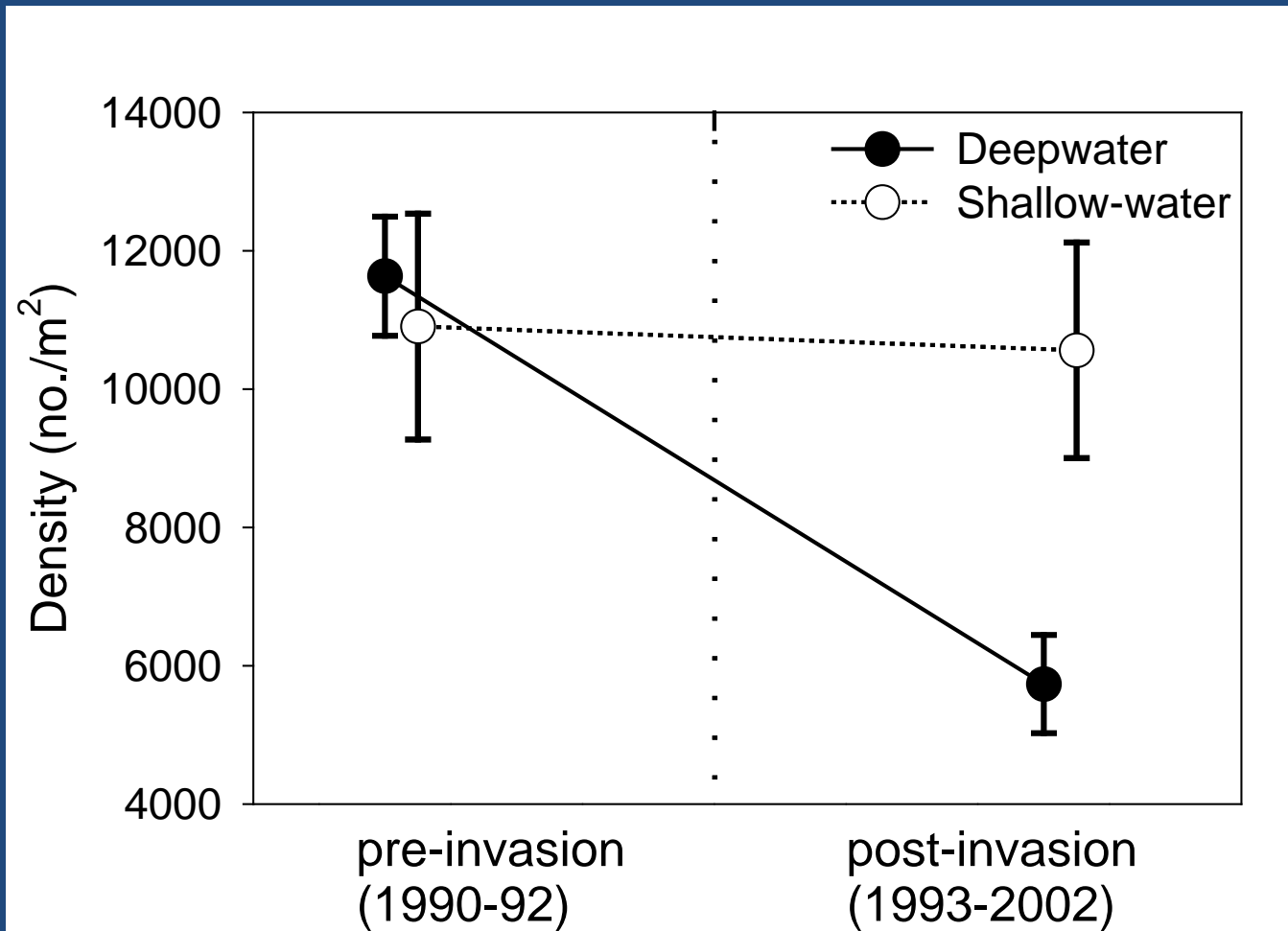


Caraco et al.

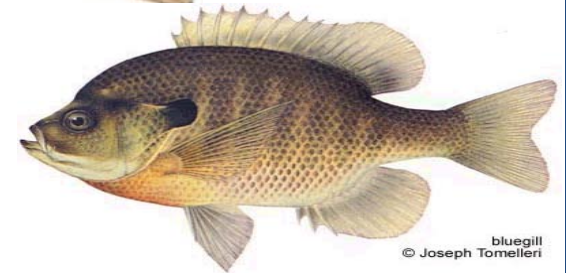
# 4. The littoral food web flourished



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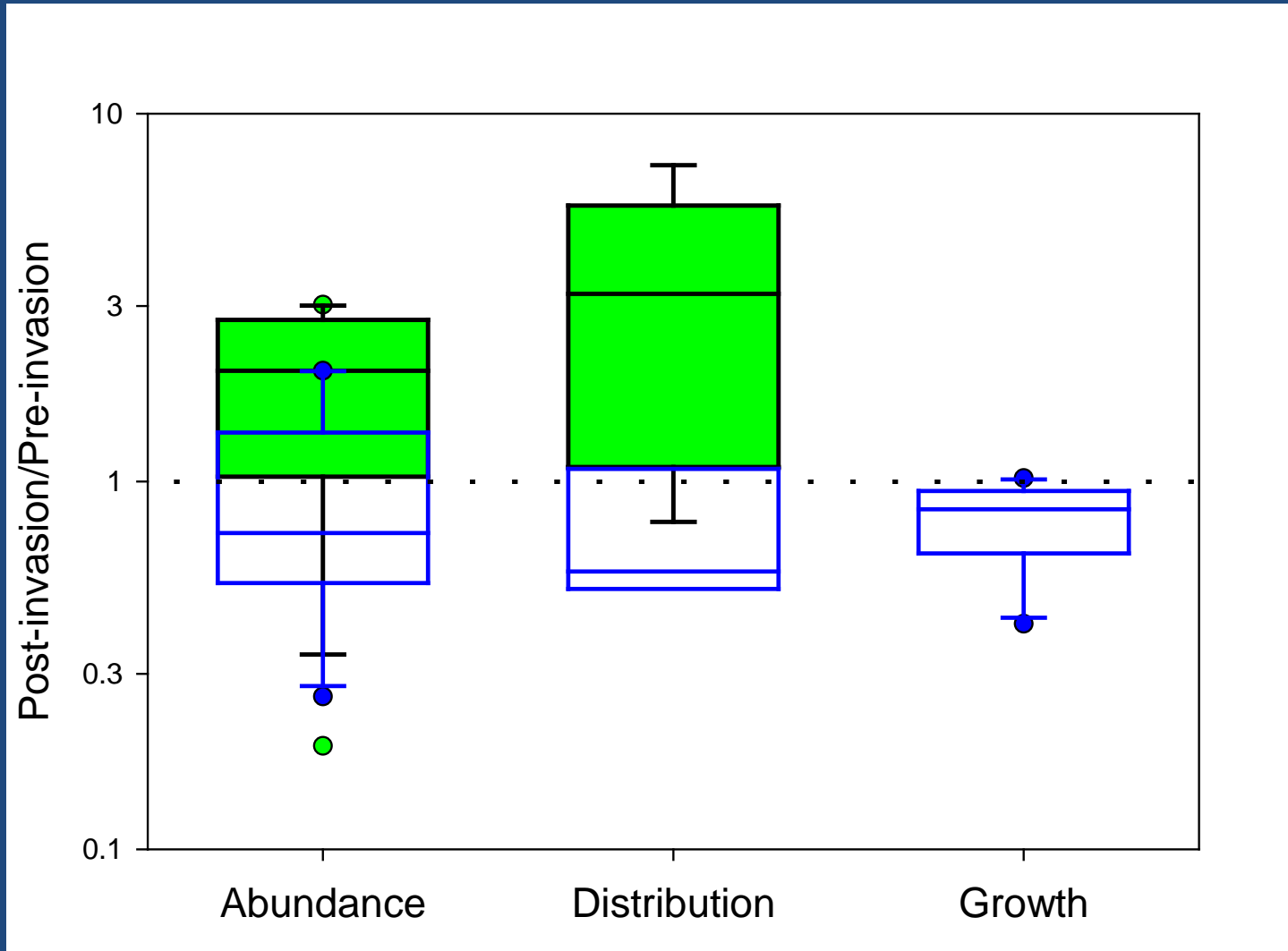


Fish that live in the vegetated shallows and whose young feed chiefly on benthos will become more abundant, grow faster, and/or shift upriver.



bluegill  
© Joseph Tomelleri

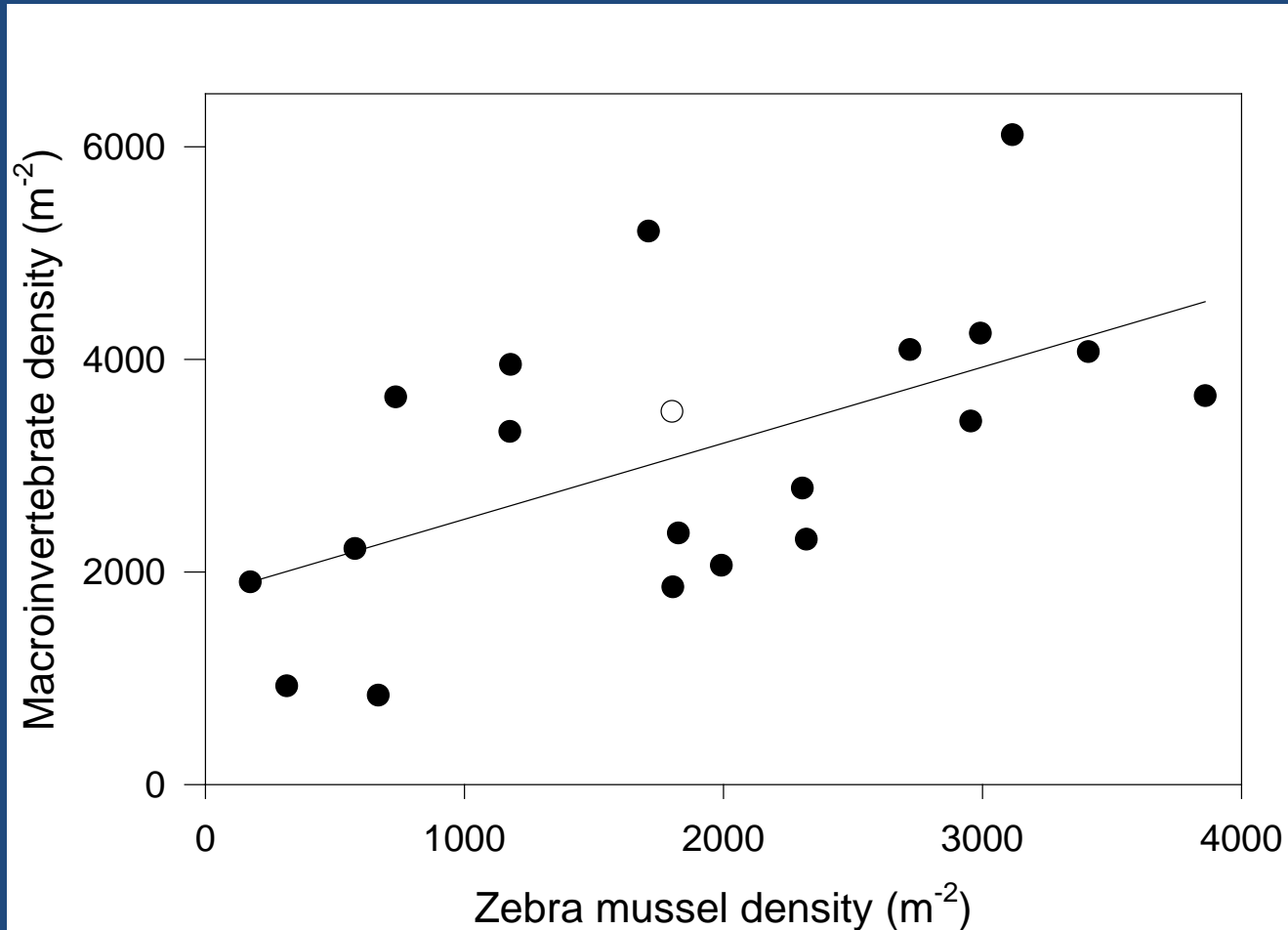
# 4. The littoral food web flourished



## 5. Resources increased in zebra mussel beds

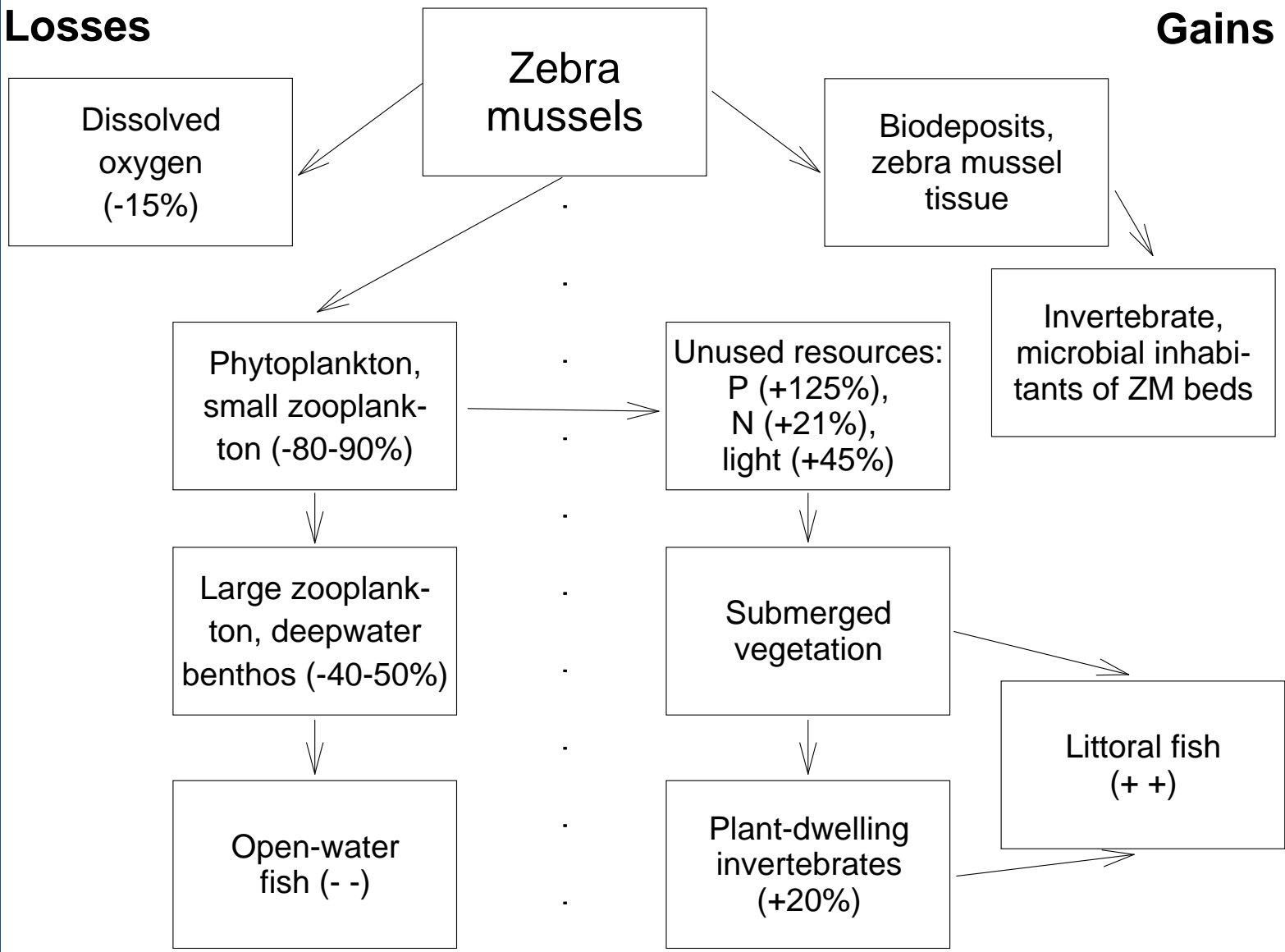


# Local increases in invertebrates (and microbes?)



# Losses

# Gains

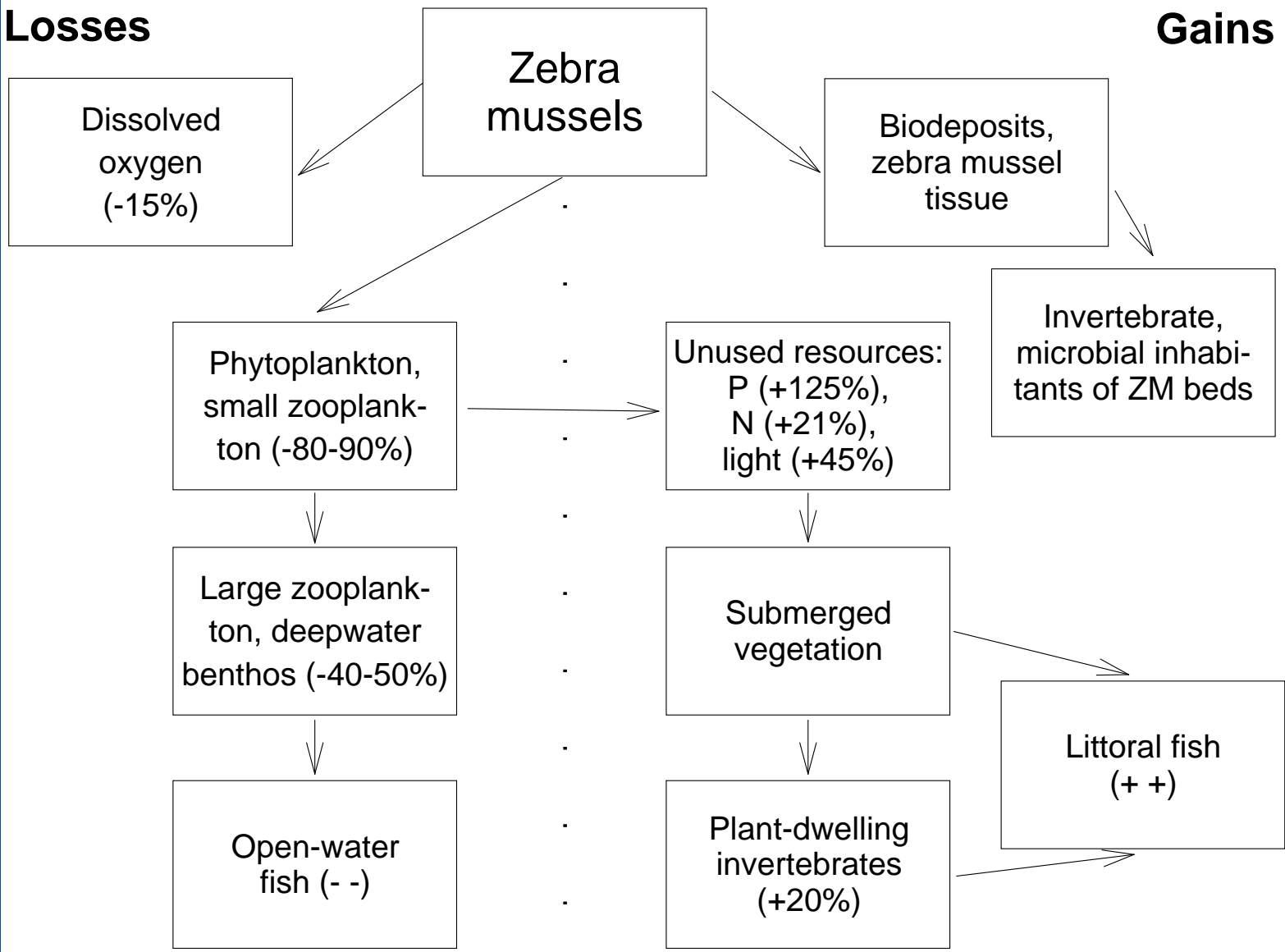


# How do the effects of an alien species vary across ecosystems?

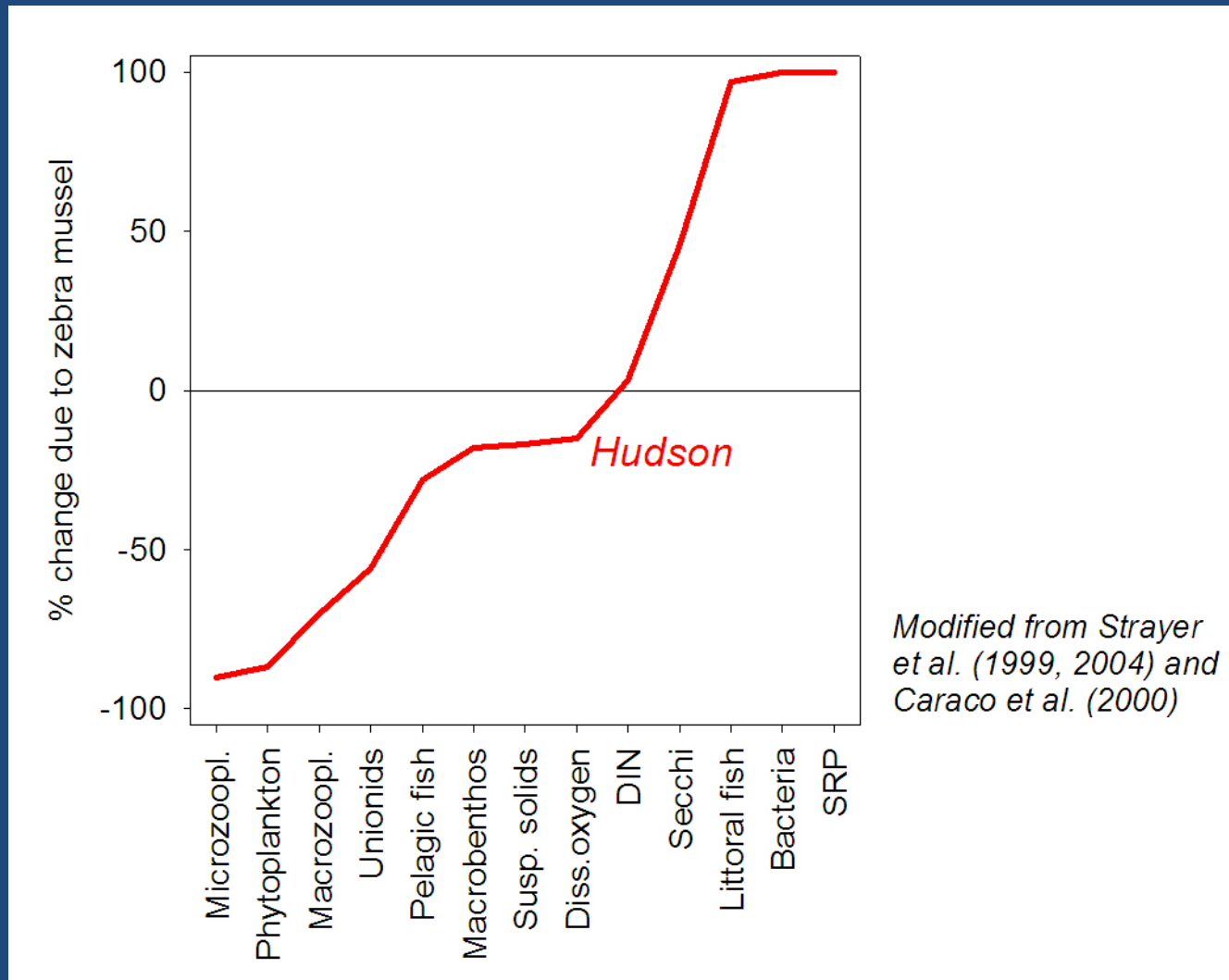


# Losses

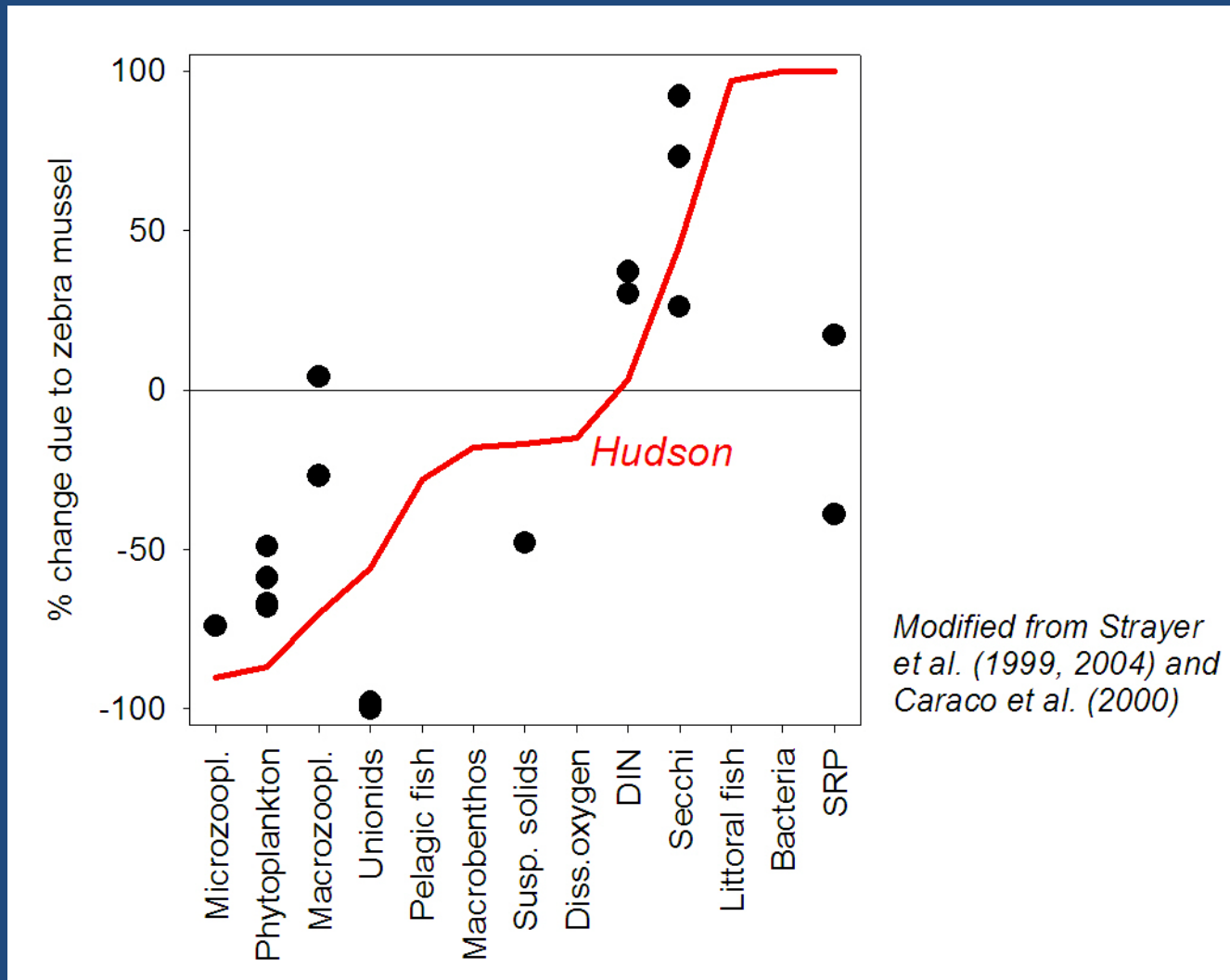
# Gains



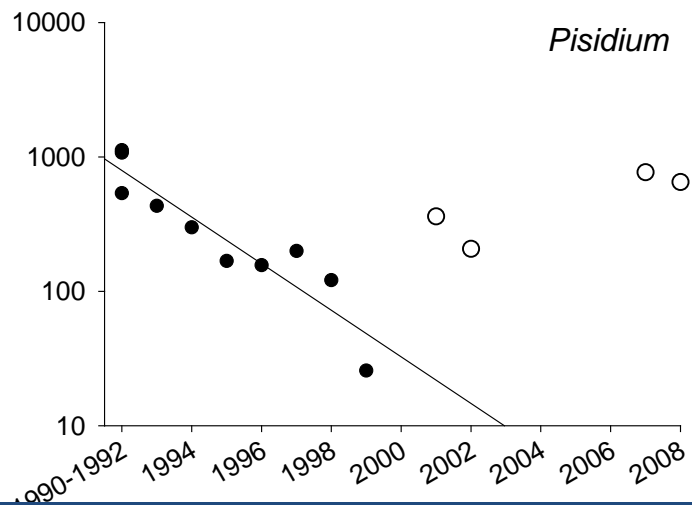
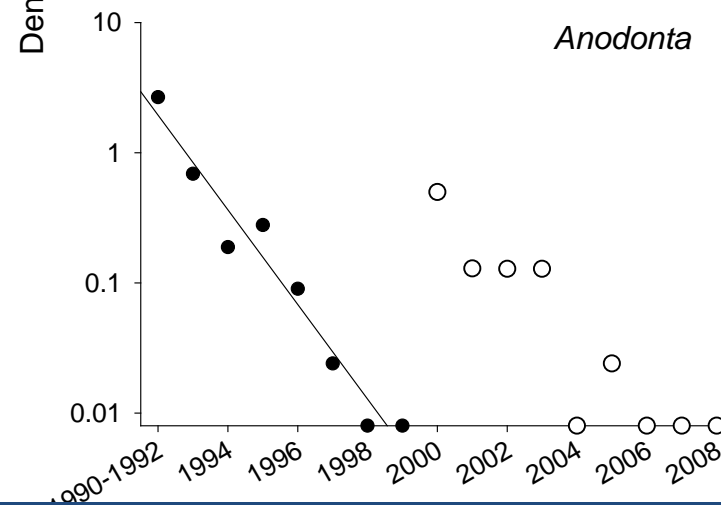
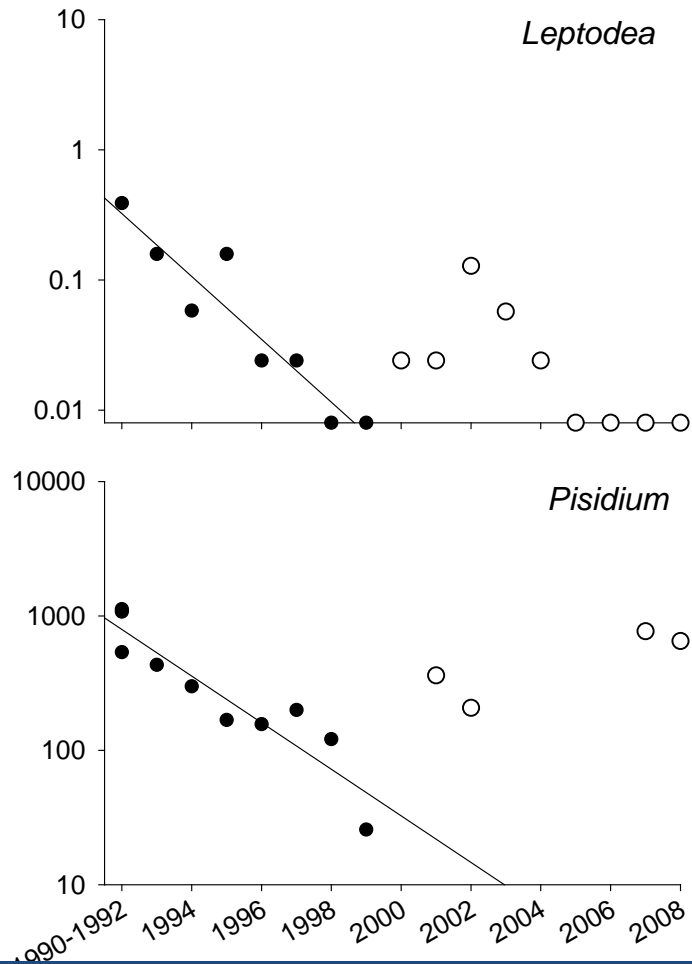
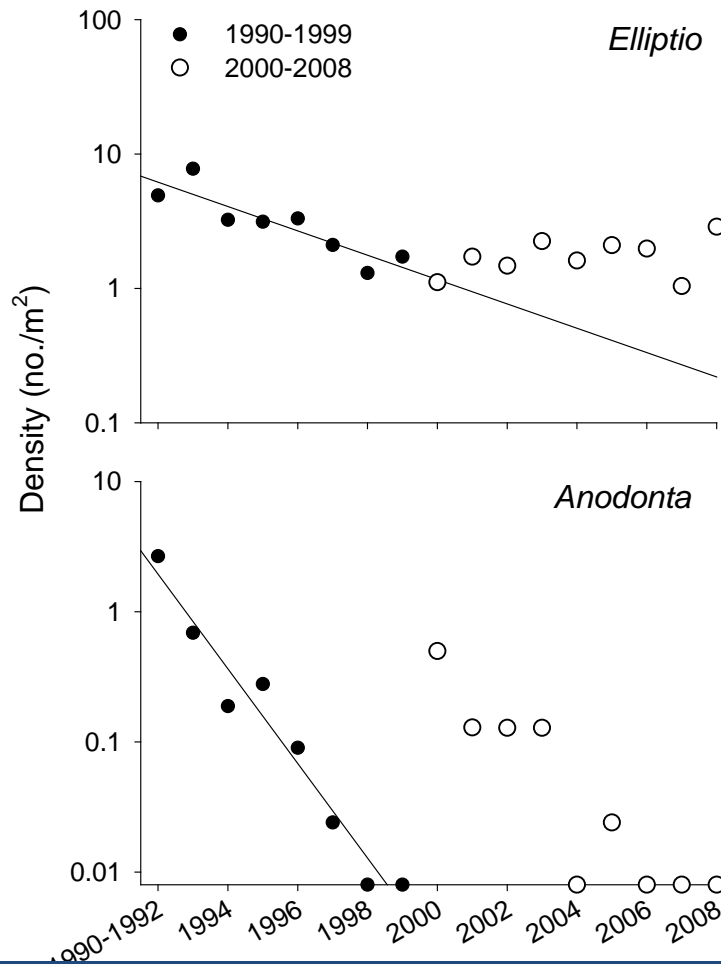
# Effects of zebra mussels vary across ecosystems



# Effects of zebra mussels vary across ecosystems



# Interesting long-term dynamics?



# Conclusions

- Zebra mussels consumed resources (food, oxygen)
- Planktivores suffered
- Resources formerly used by phytoplankton increased
- The littoral food web flourished
- Resources increased in zebra mussel beds
- Effects will vary across ecosystems and through time