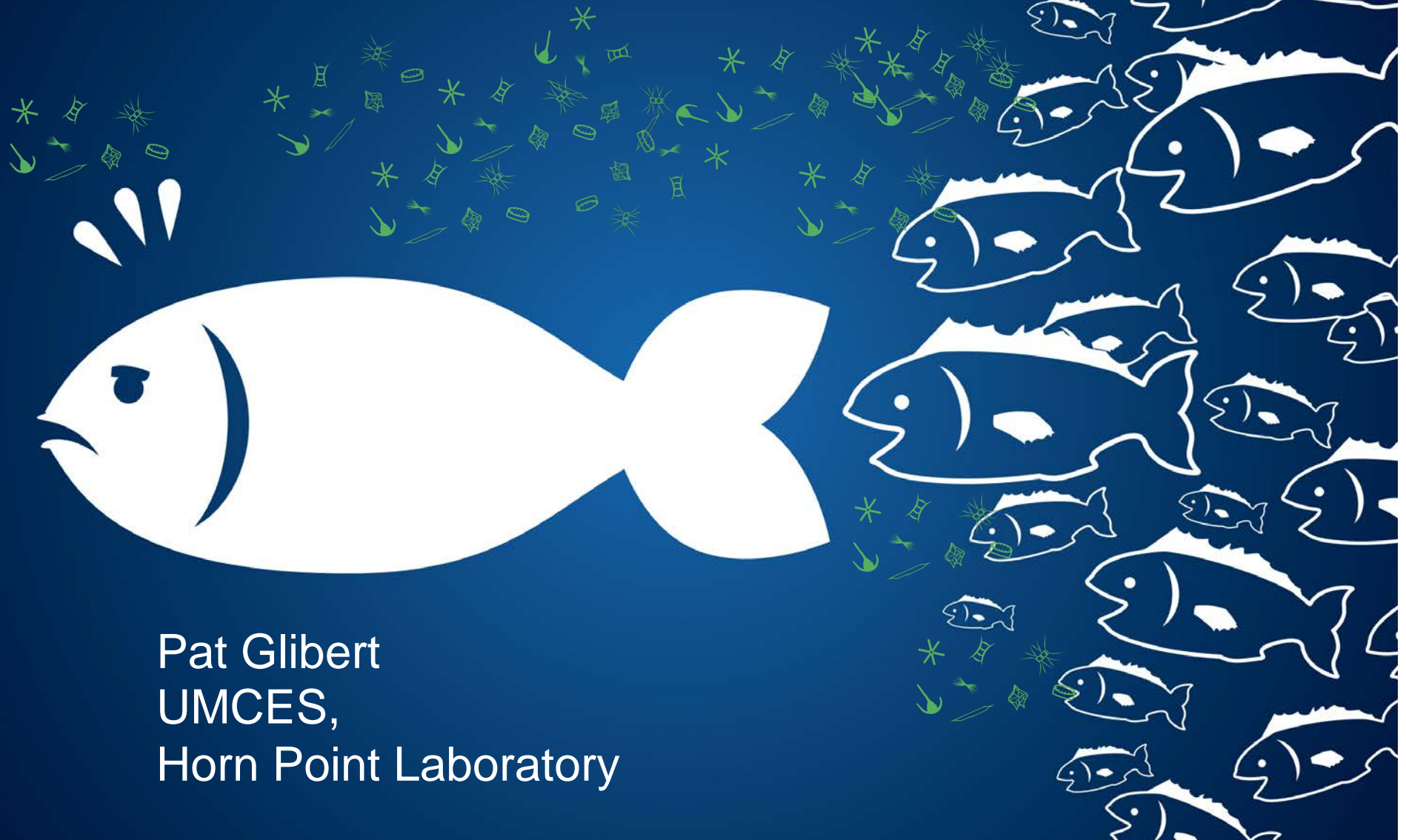
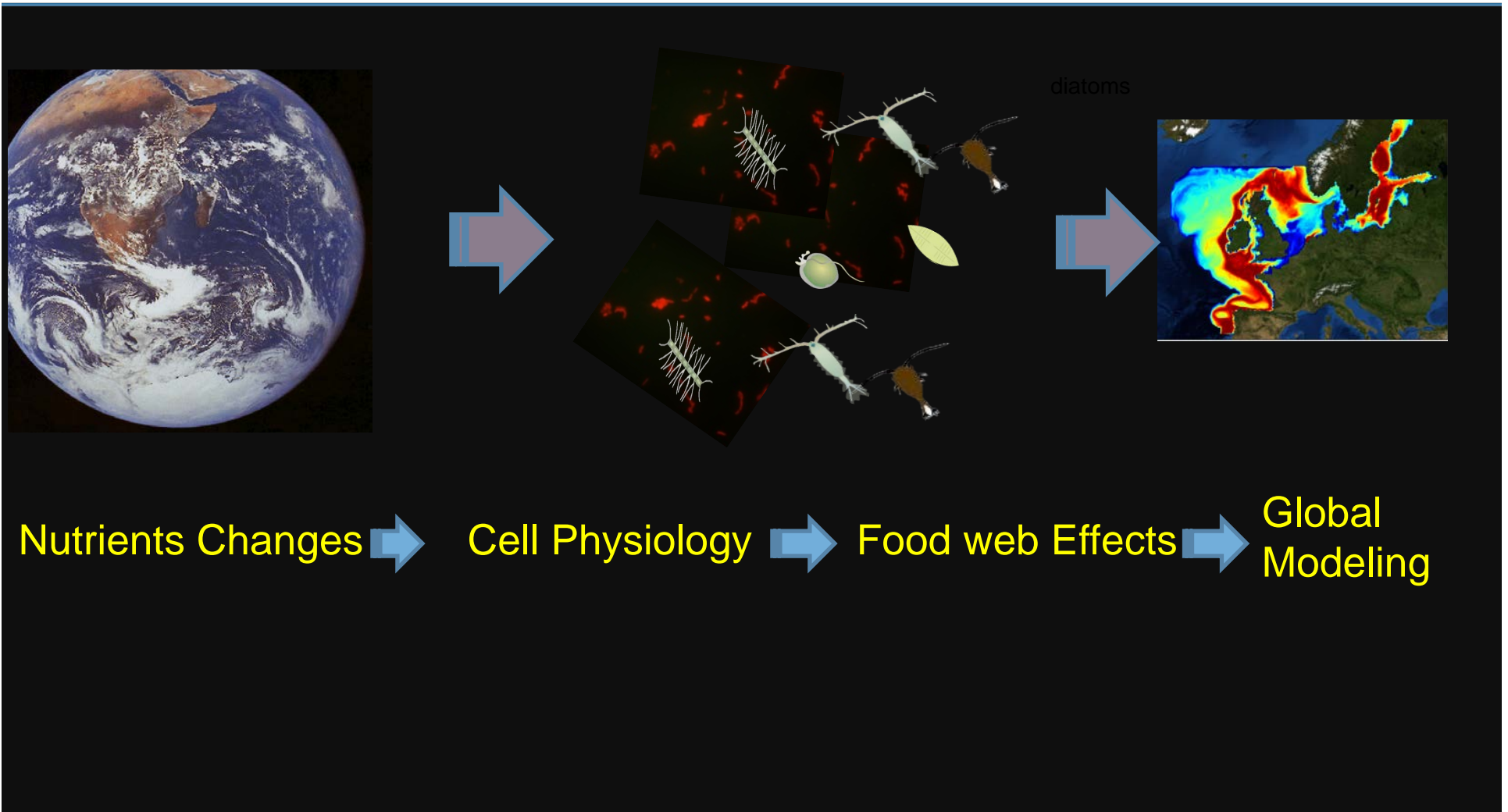


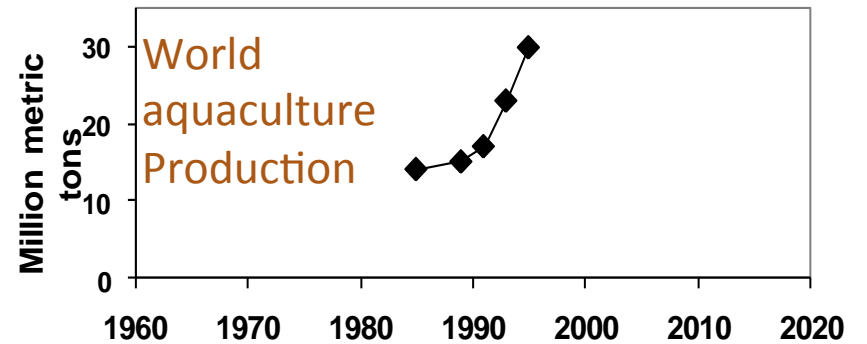
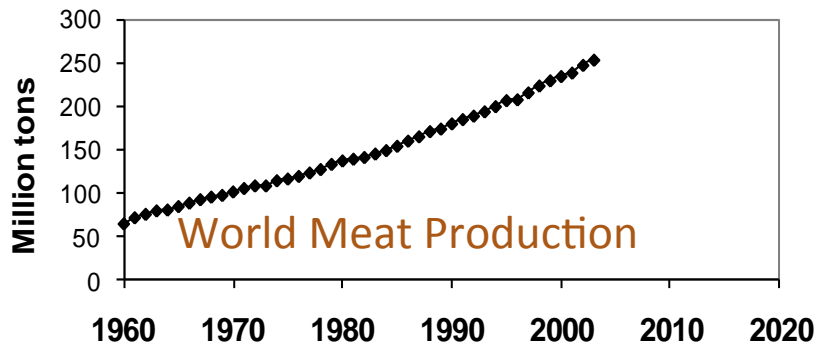
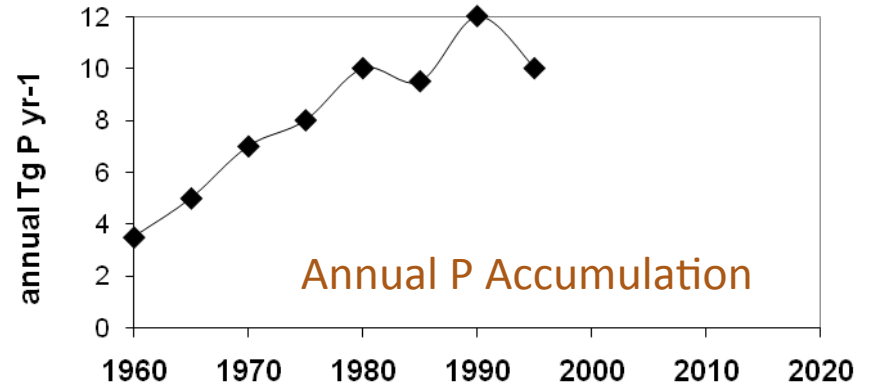
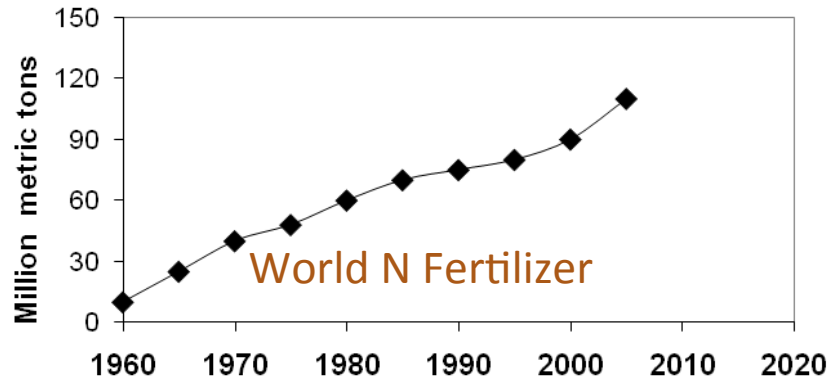
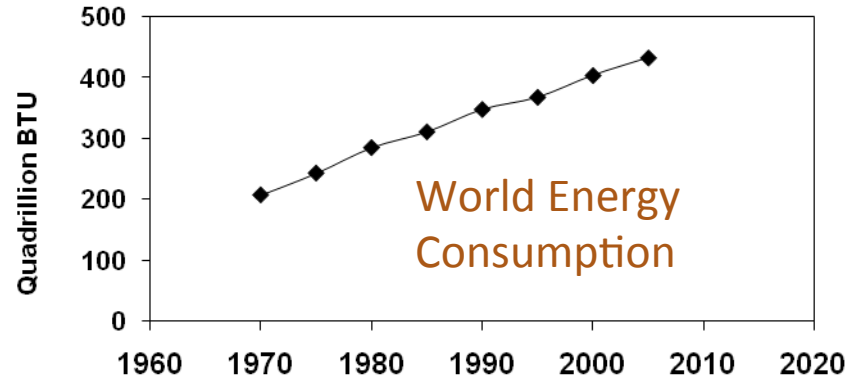
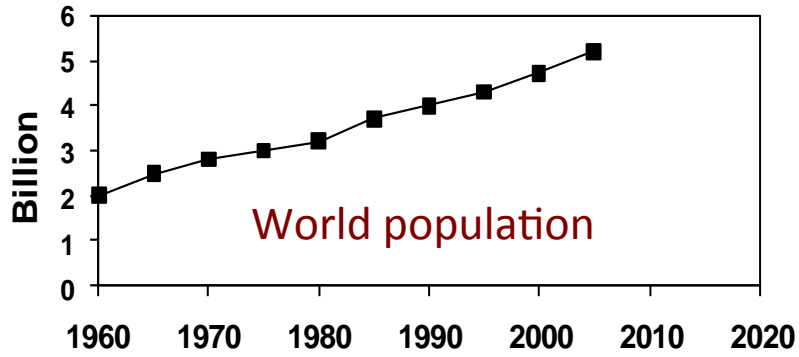
# N and P ratios and their cascade through the food web



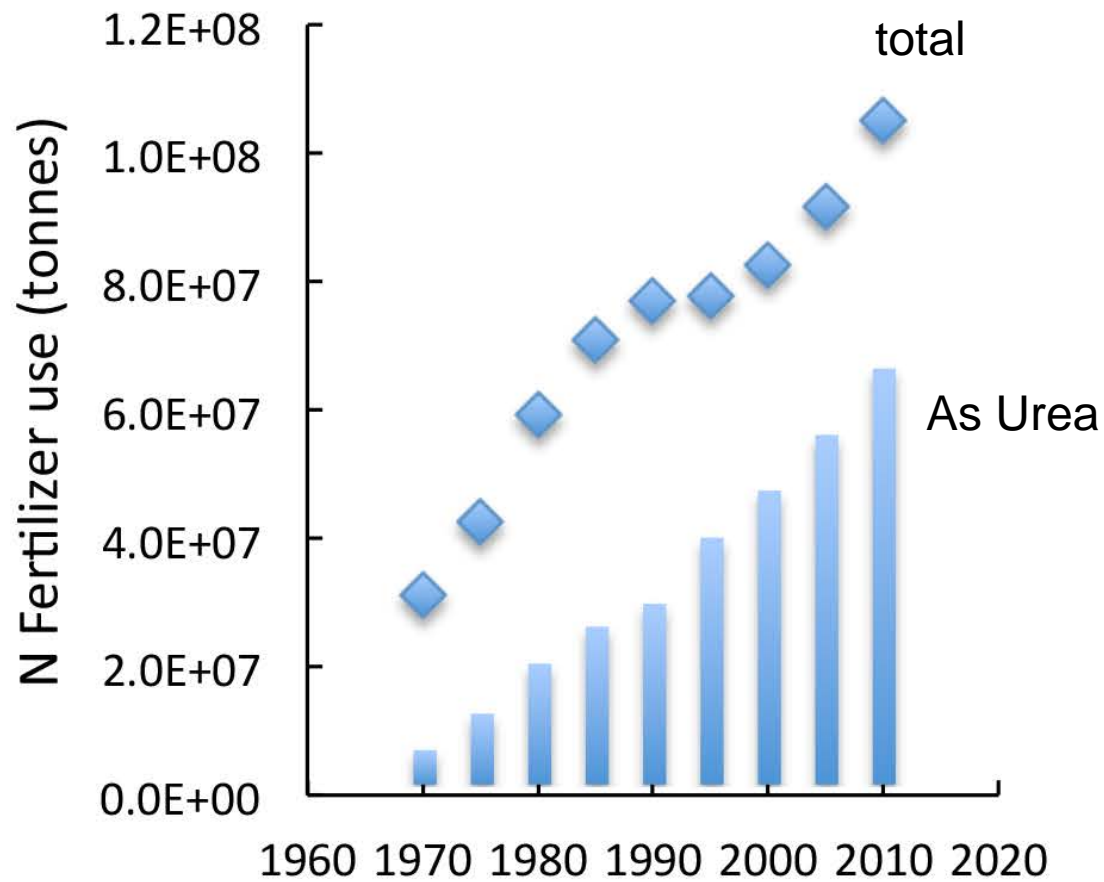
Pat Glibert  
UMCES,  
Horn Point Laboratory

# Changing nutrient loads, forms and ratios: effects on phytoplankton communities and food webs and challenges for modelers and managers

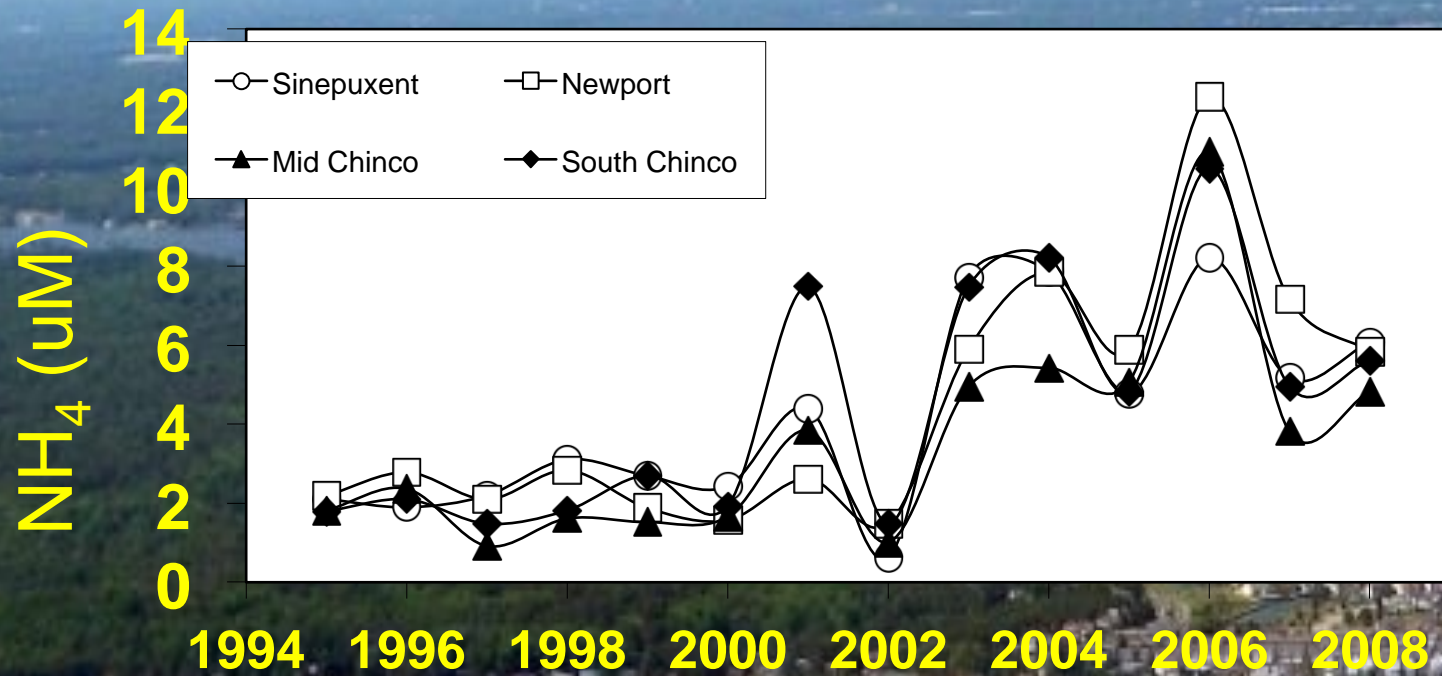




# Nitrogen forms are changing

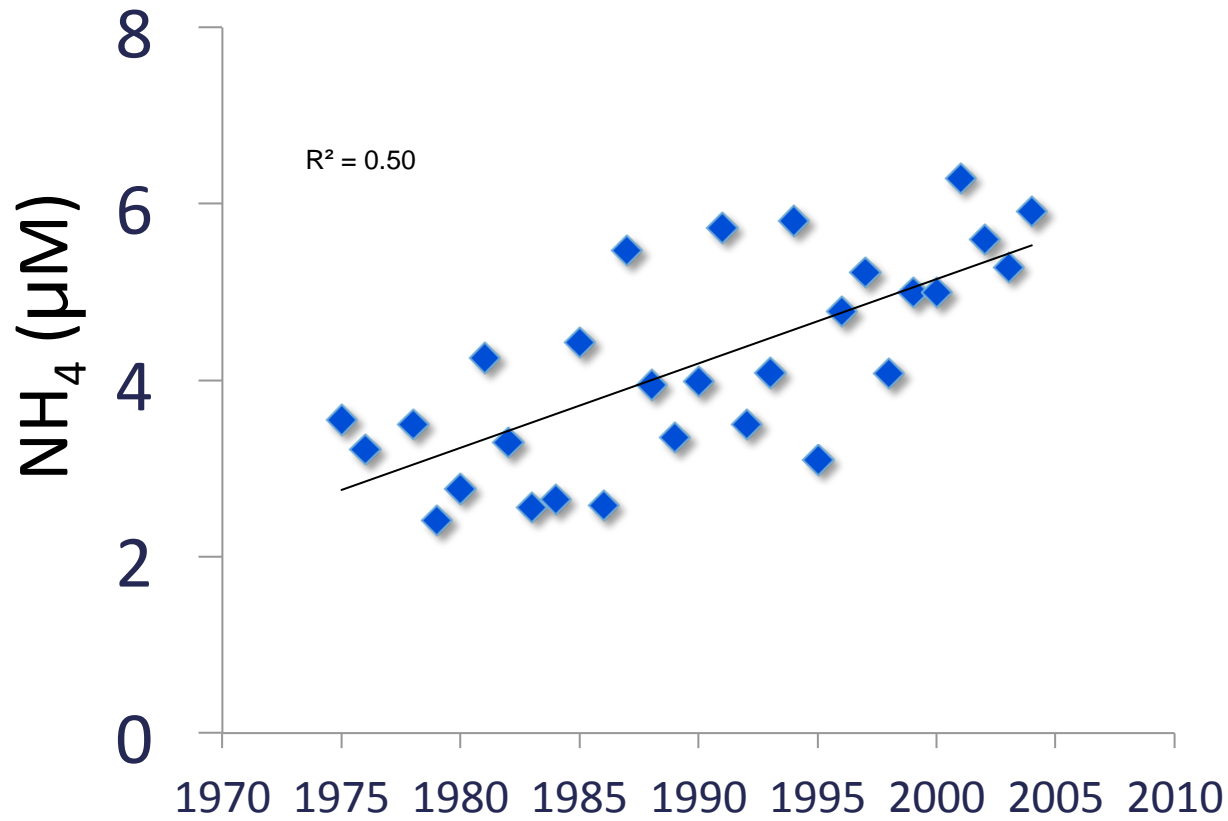


# Increases in Ammonium in the Maryland Coastal Bays



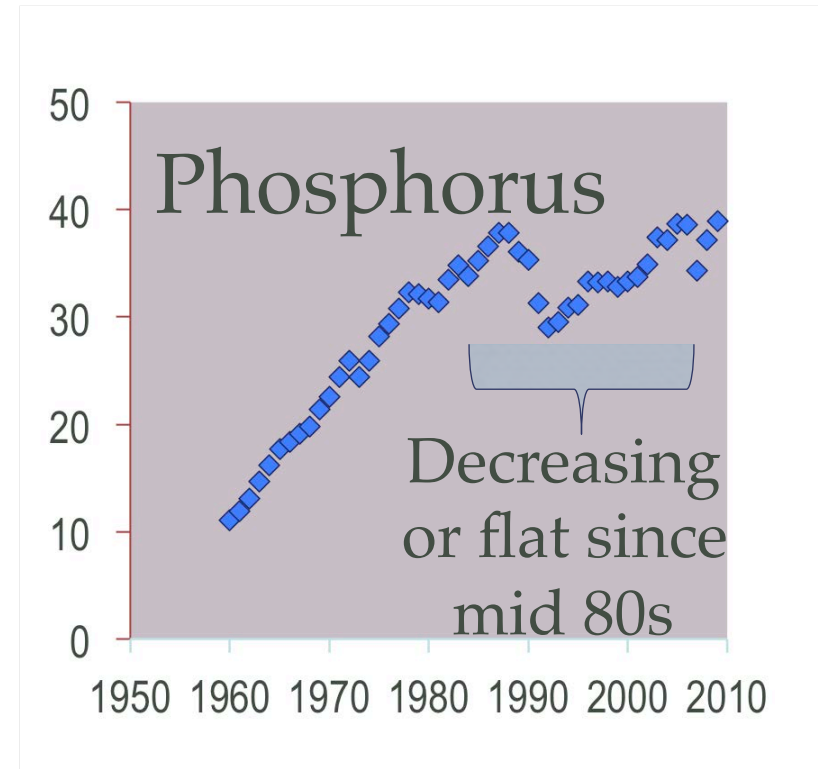
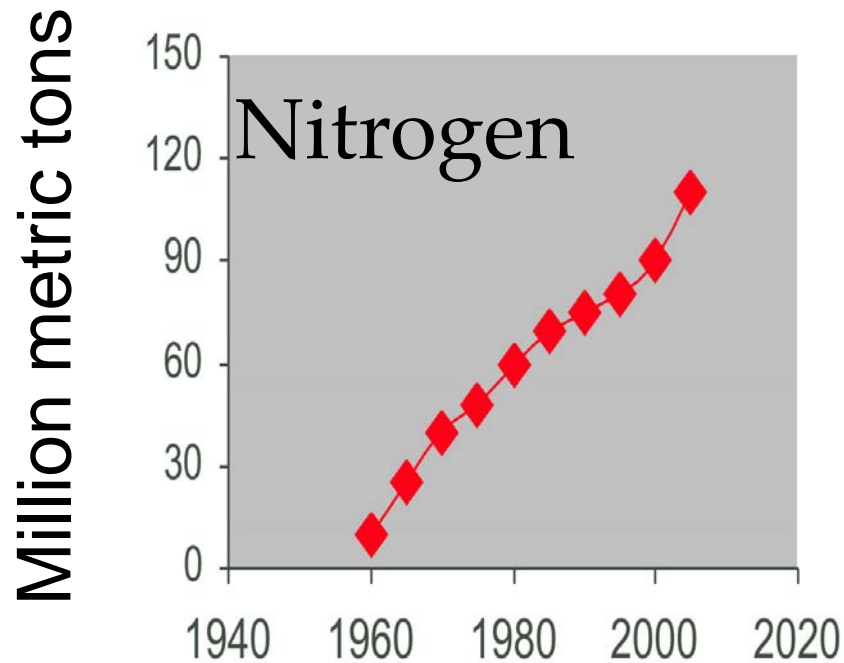
Glibert et al. 2007

# Ammonium in San Francisco Bay Delta



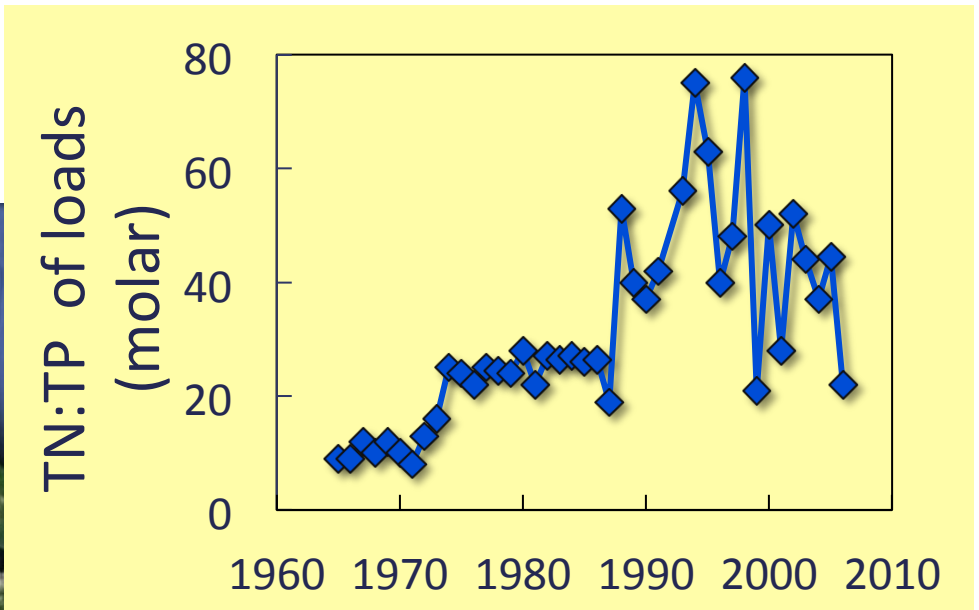
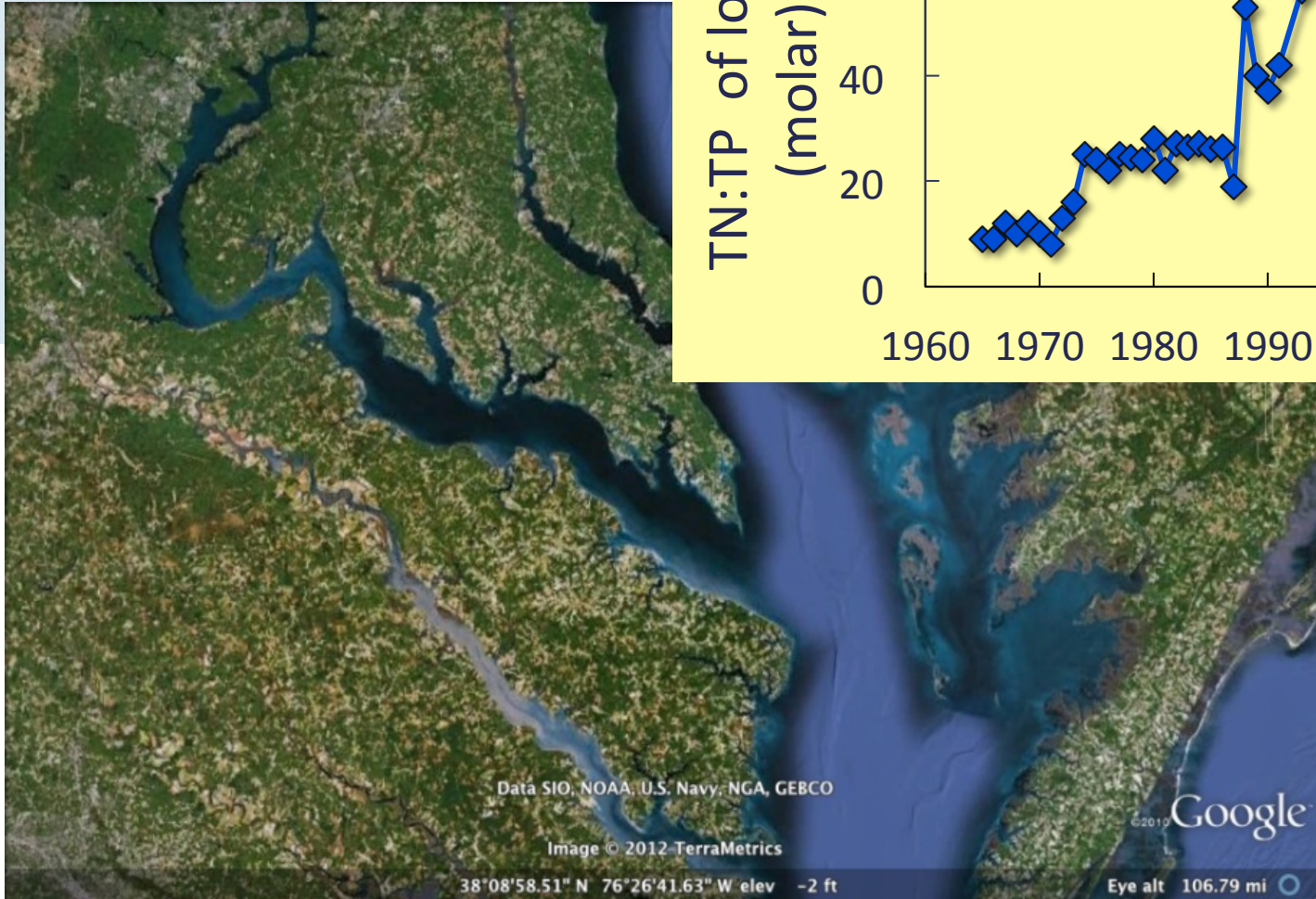


## Global trends in phosphorus and nitrogen fertilizer use differ



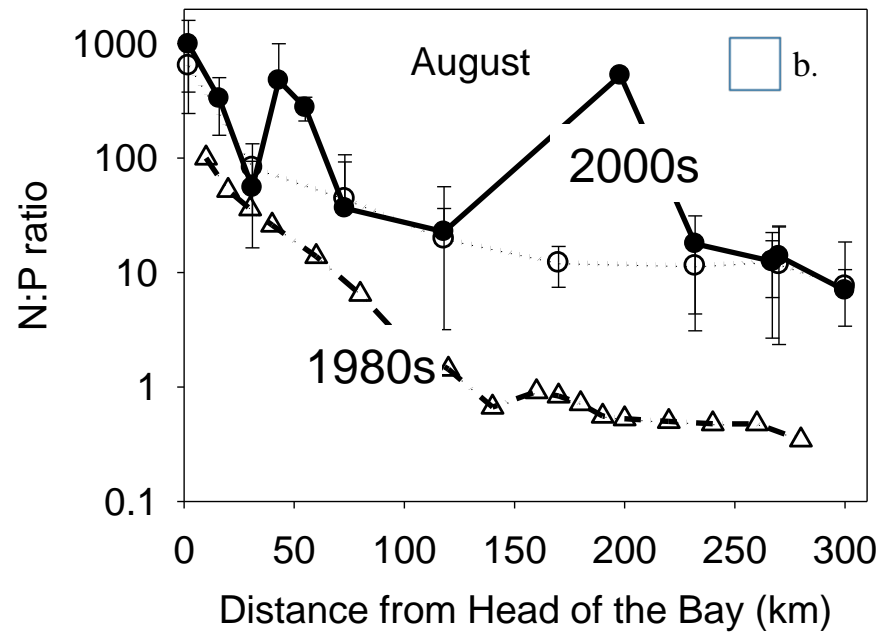
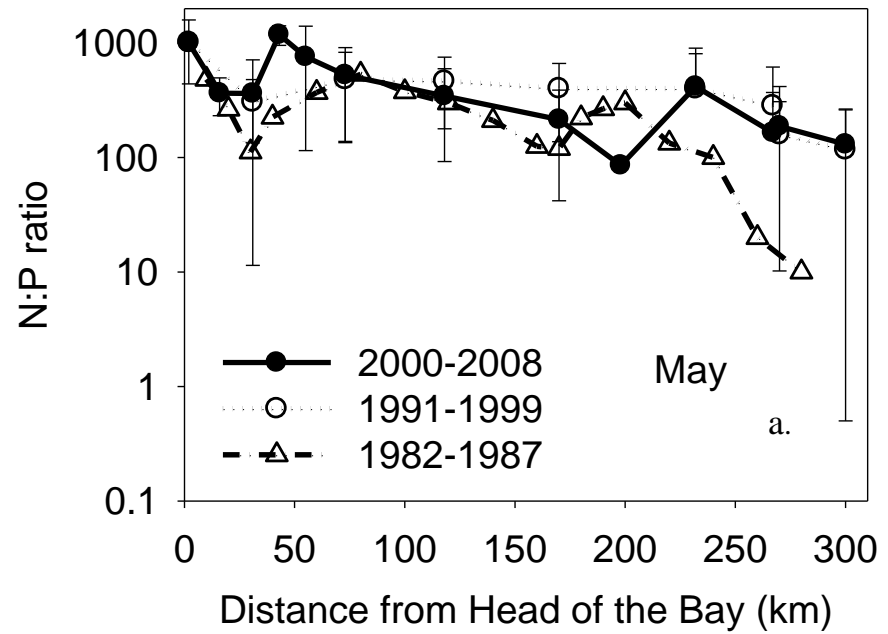
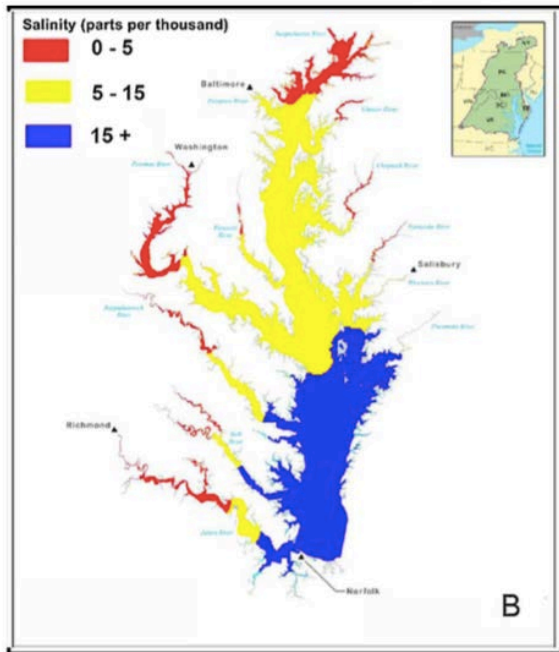
Glibert et al. 2013, J Mar. Systems

# Potomac River

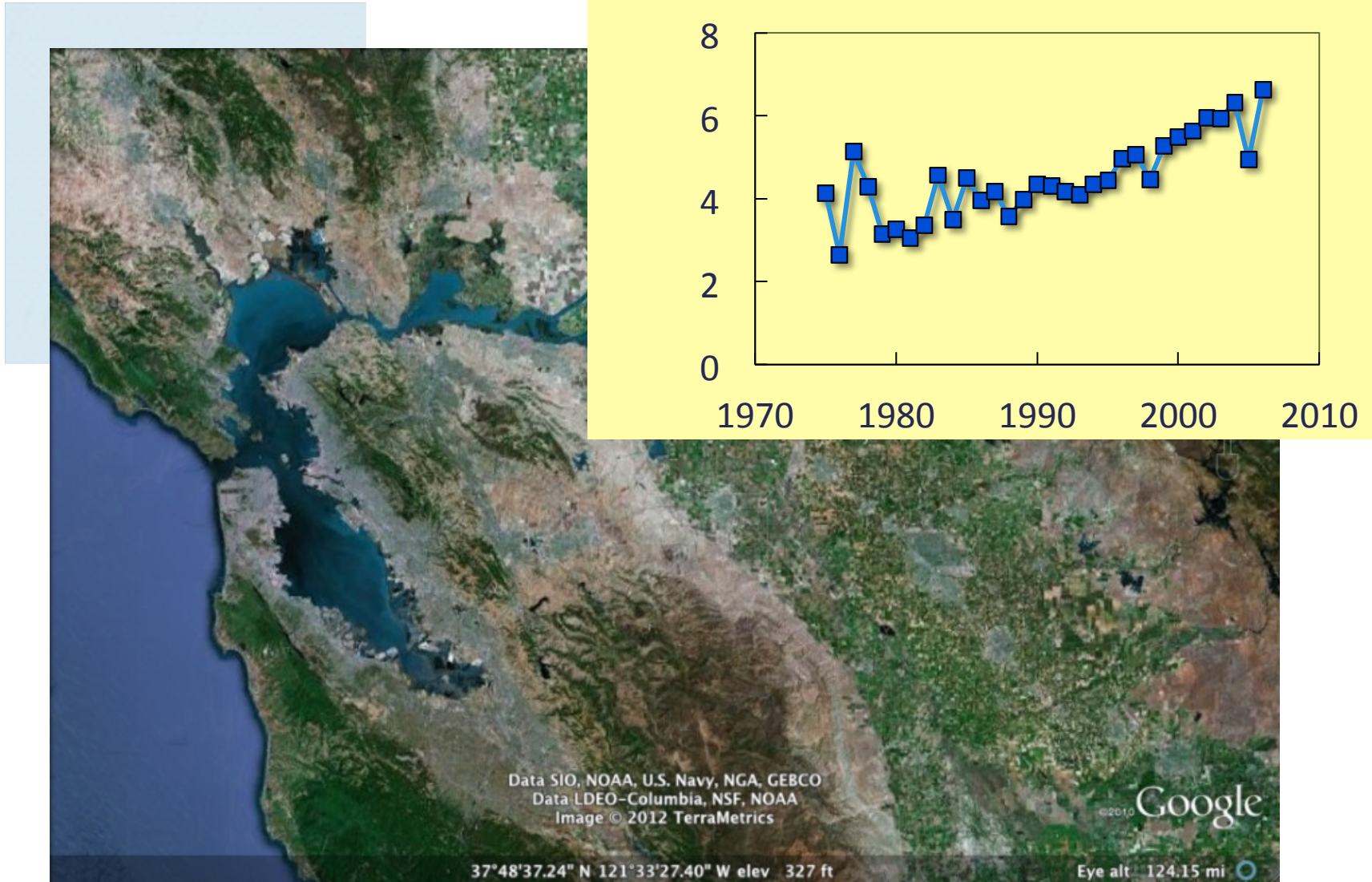


Replotted from Jawarski et al.  
2007

# Chesapeake Bay

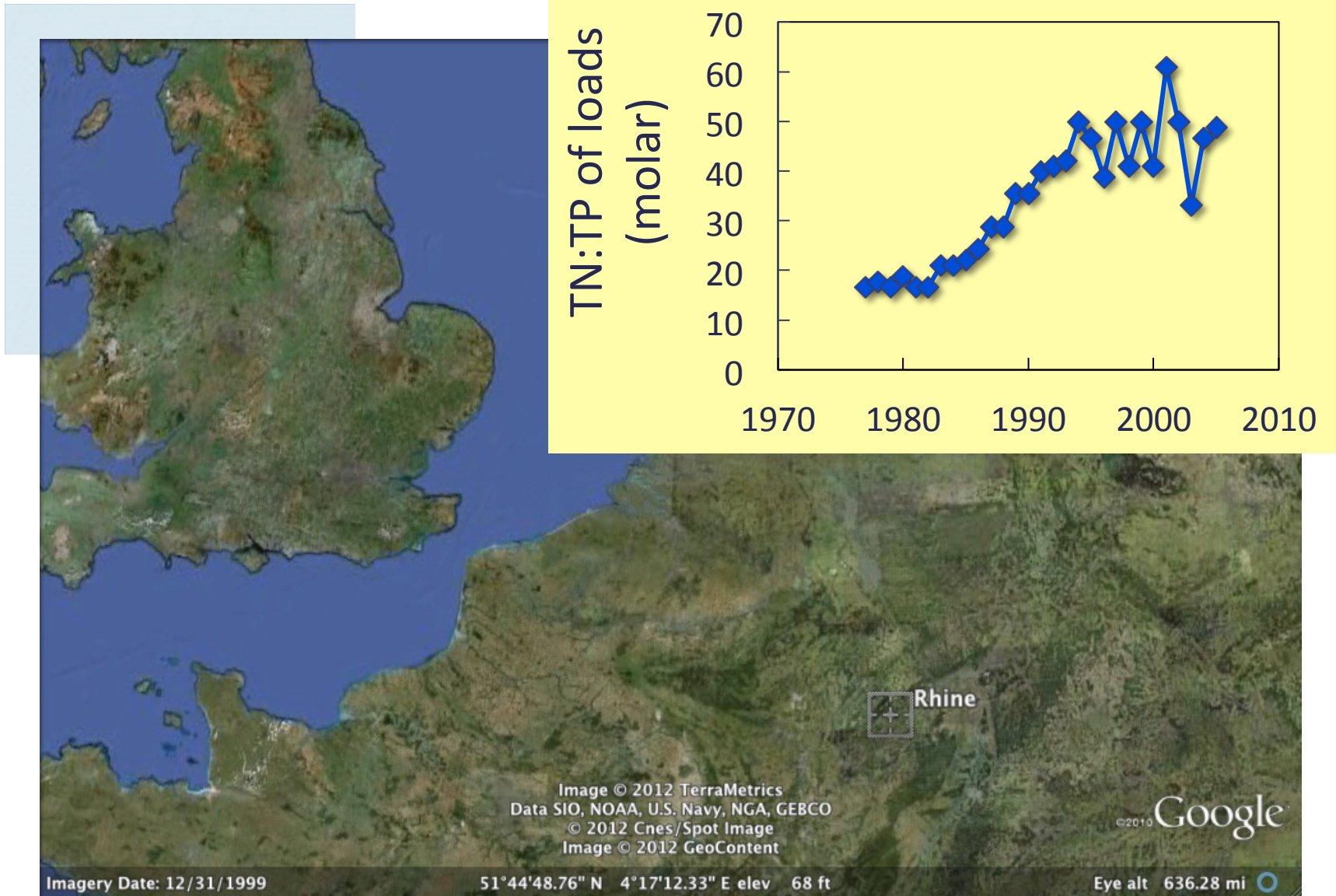


# San Francisco Bay Delta



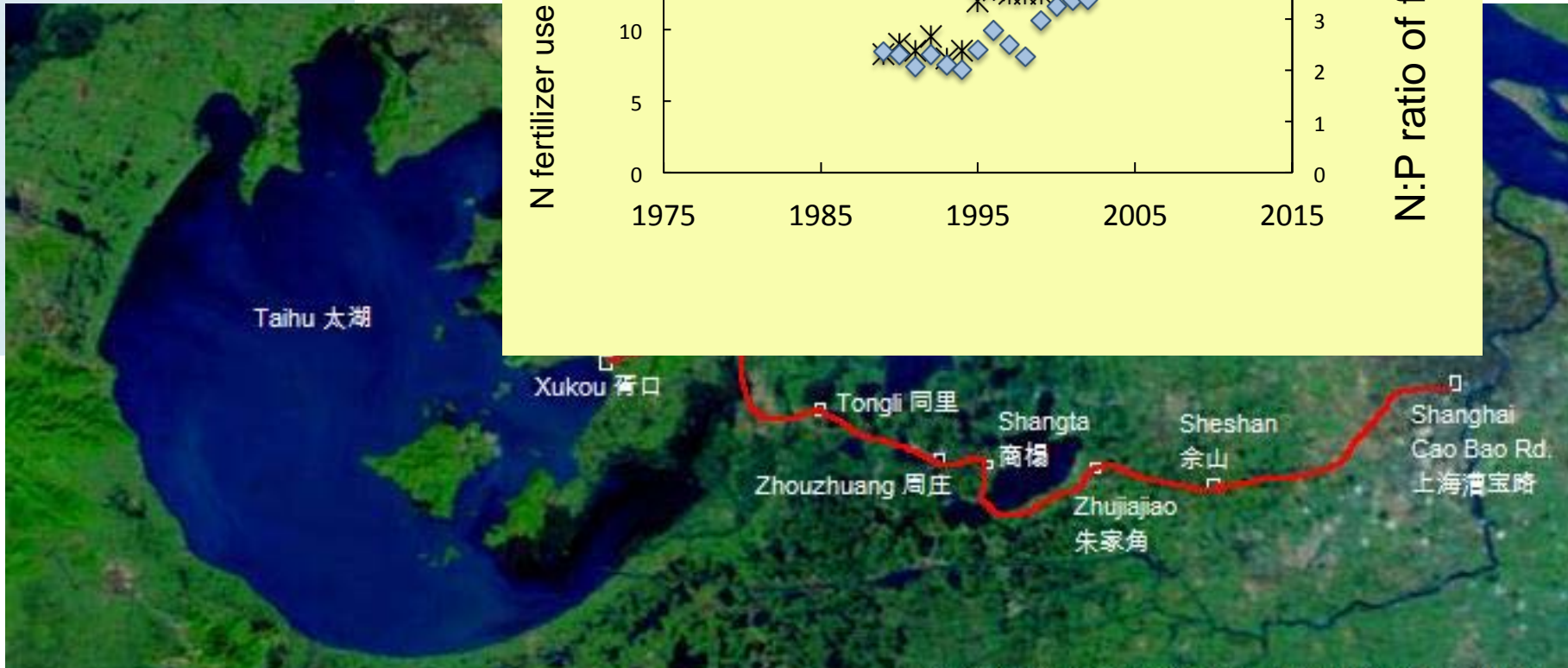
Glibert et al. 2011, Rev Fish Sci

# Rhine River



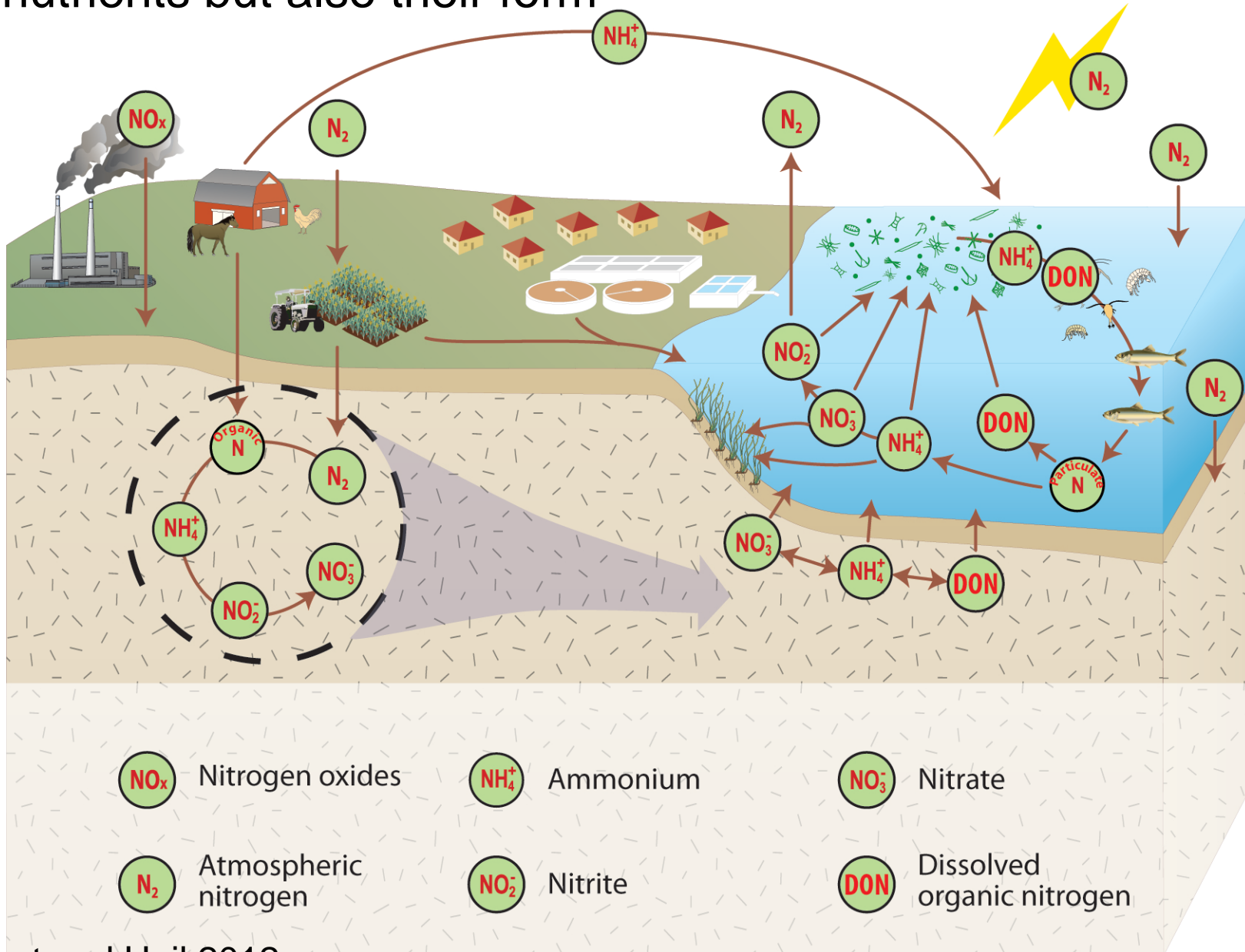
Replotted from Van Nieuwenhuyse 2007

# Lake Taihu



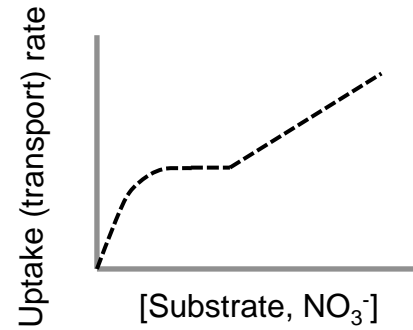
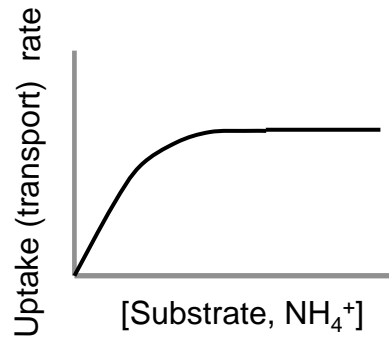
Replotted from Glibert et al. 2014

# Phytoplankton respond not only to the total amount of nutrients but also their form

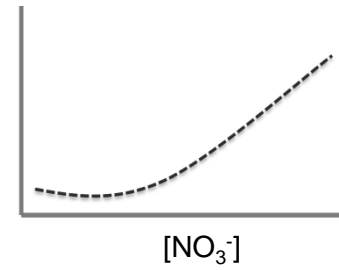
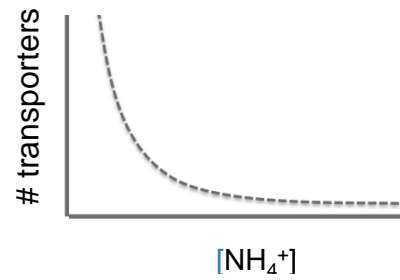




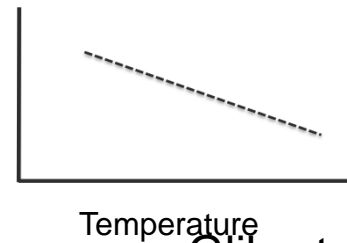
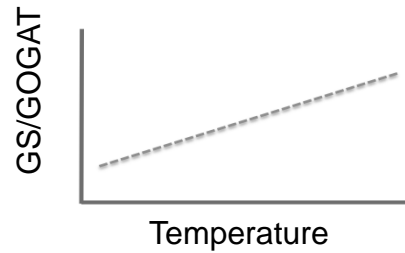
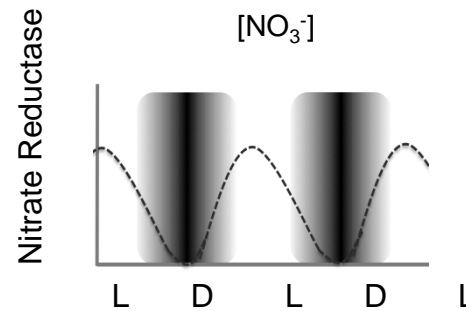
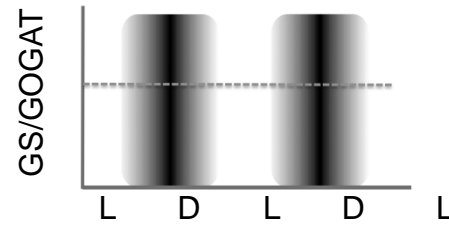
Uptake rate

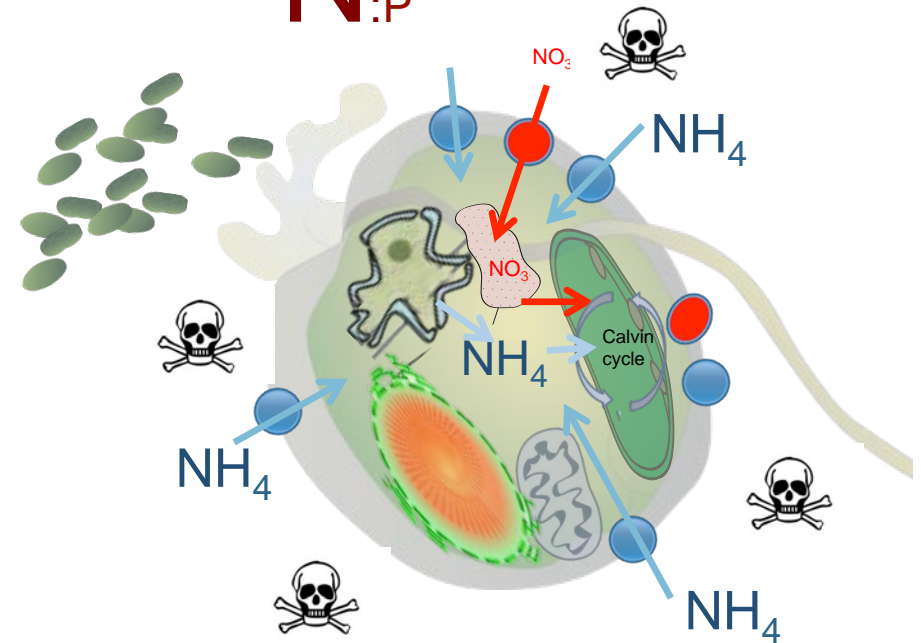
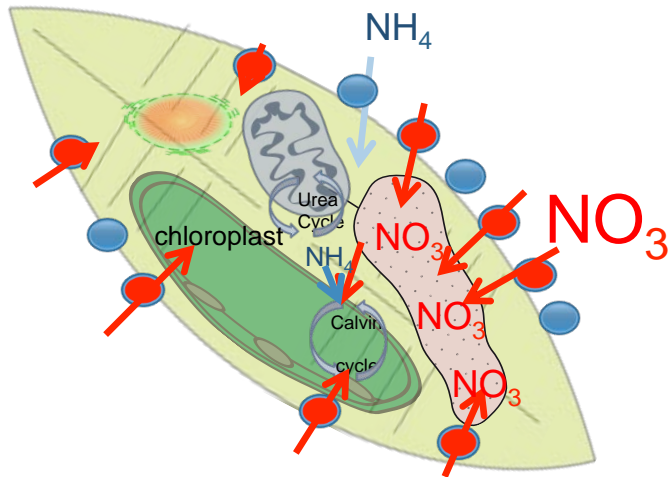
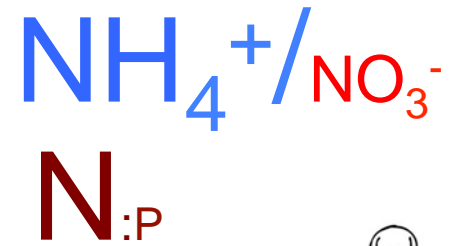
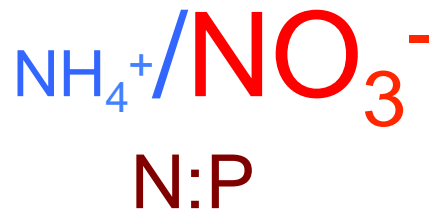


Transporters



Enzyme relationships

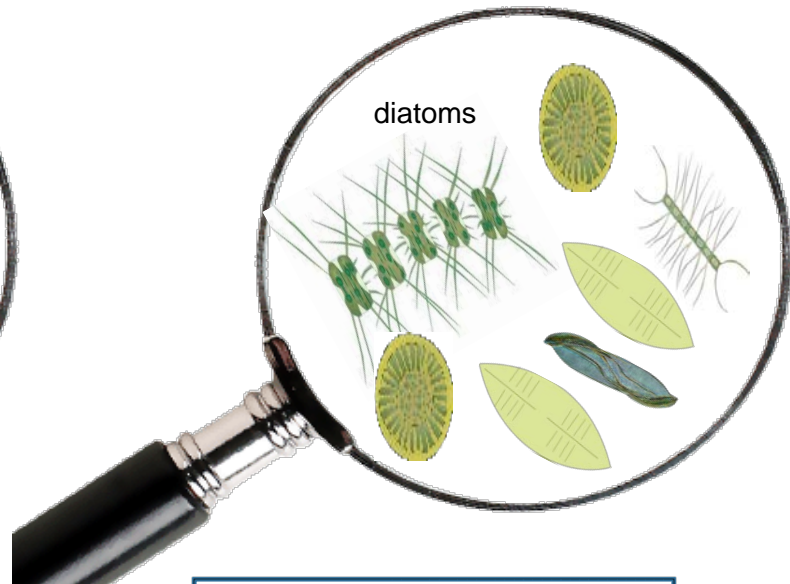
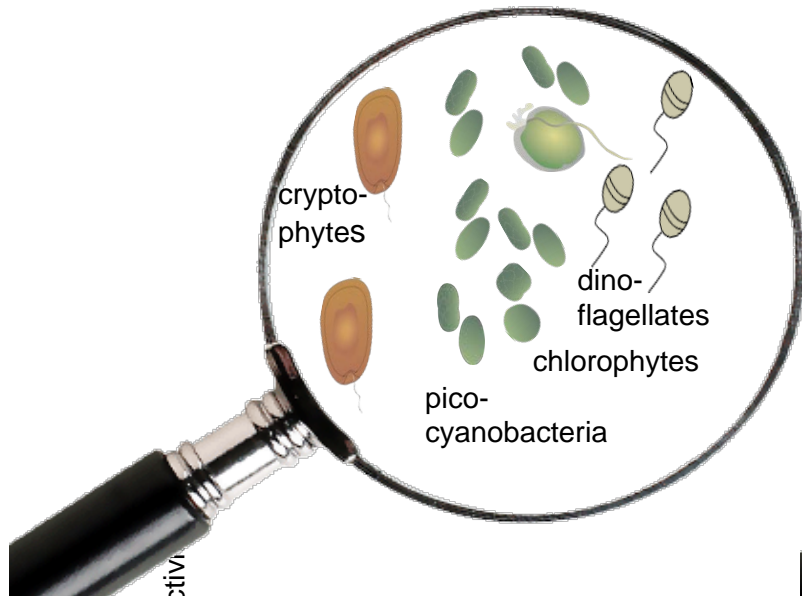
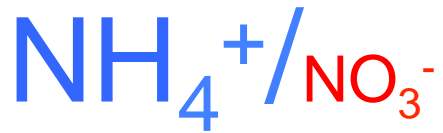




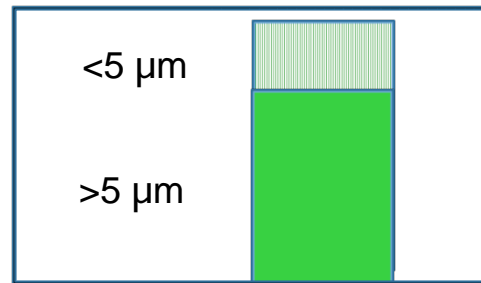
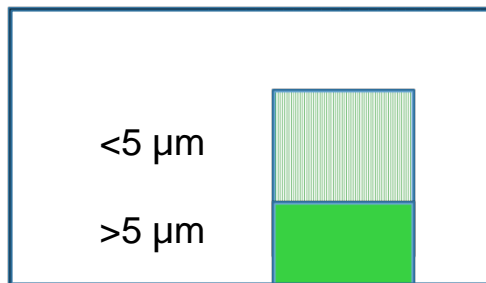
- high growth rate (high P demand)
- high capacity for  $\text{NO}_3^-$  uptake and assimilation

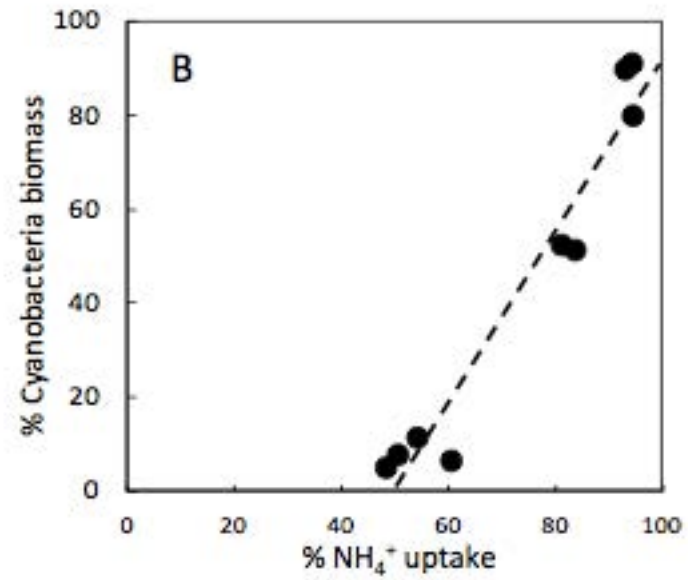
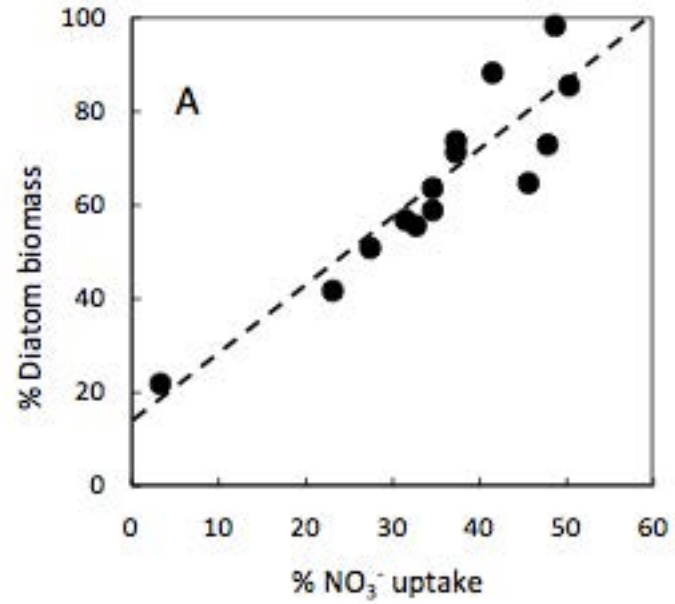
- slower growth rate (decreased cell demand for P)
- increased dependence on  $\text{NH}_4^+$  and mixotrophy
- increased toxin production

N Inputs

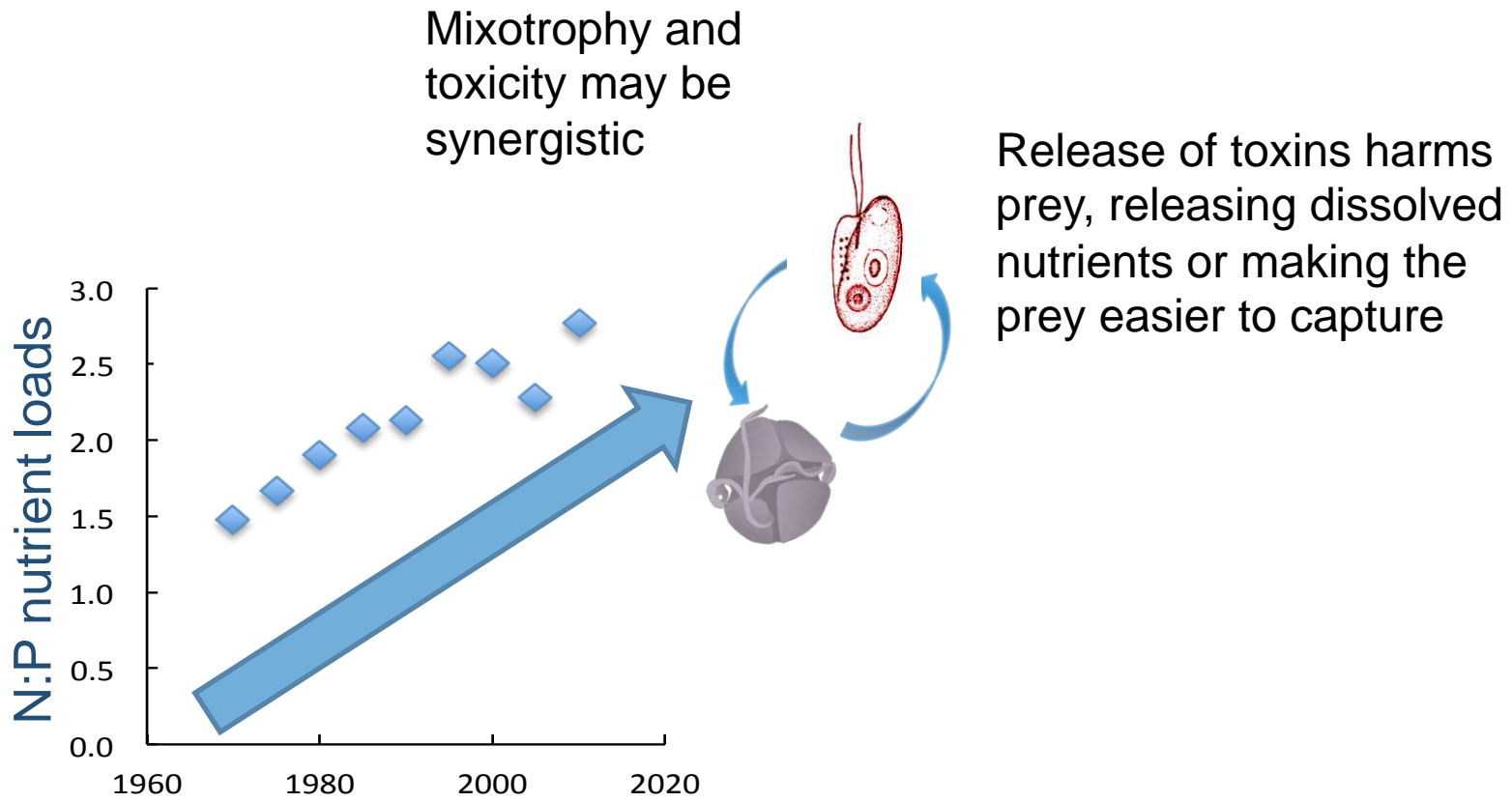


Rate of production



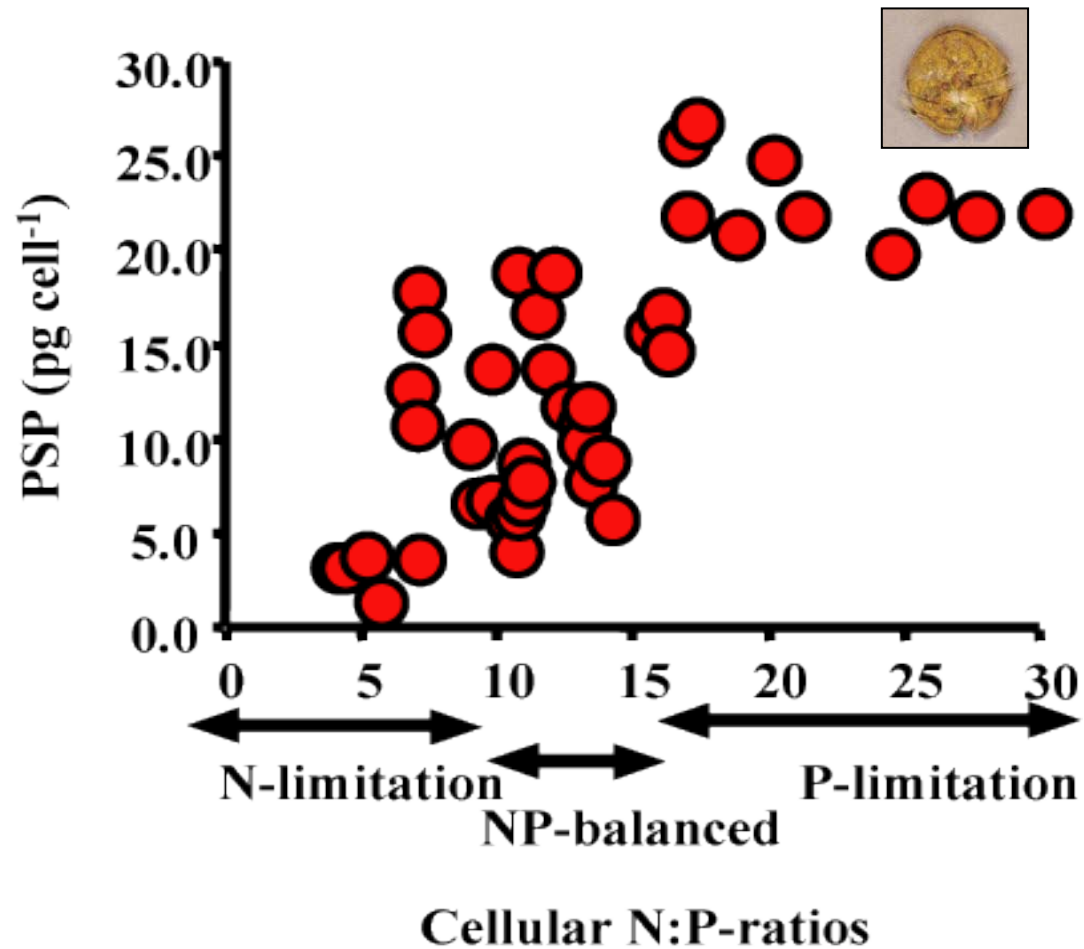


Glibert and Berg 2009

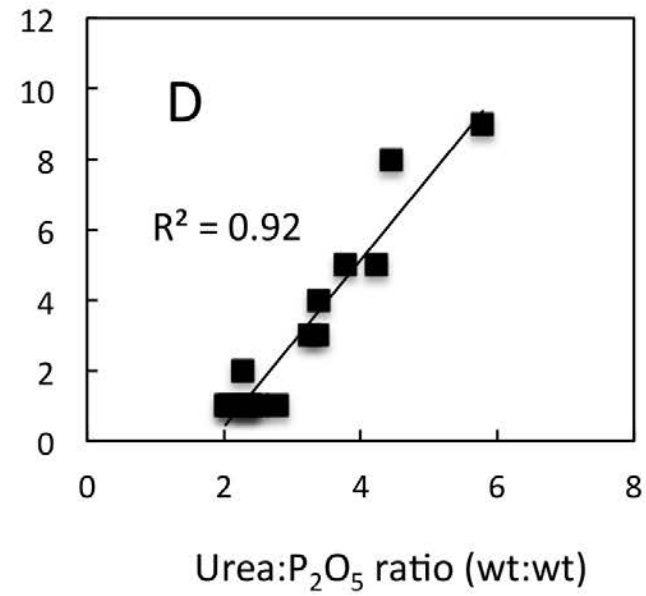
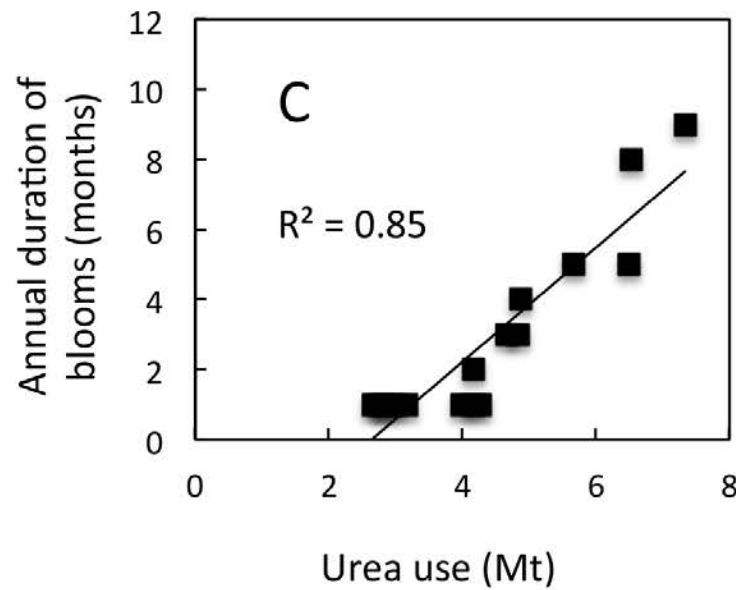
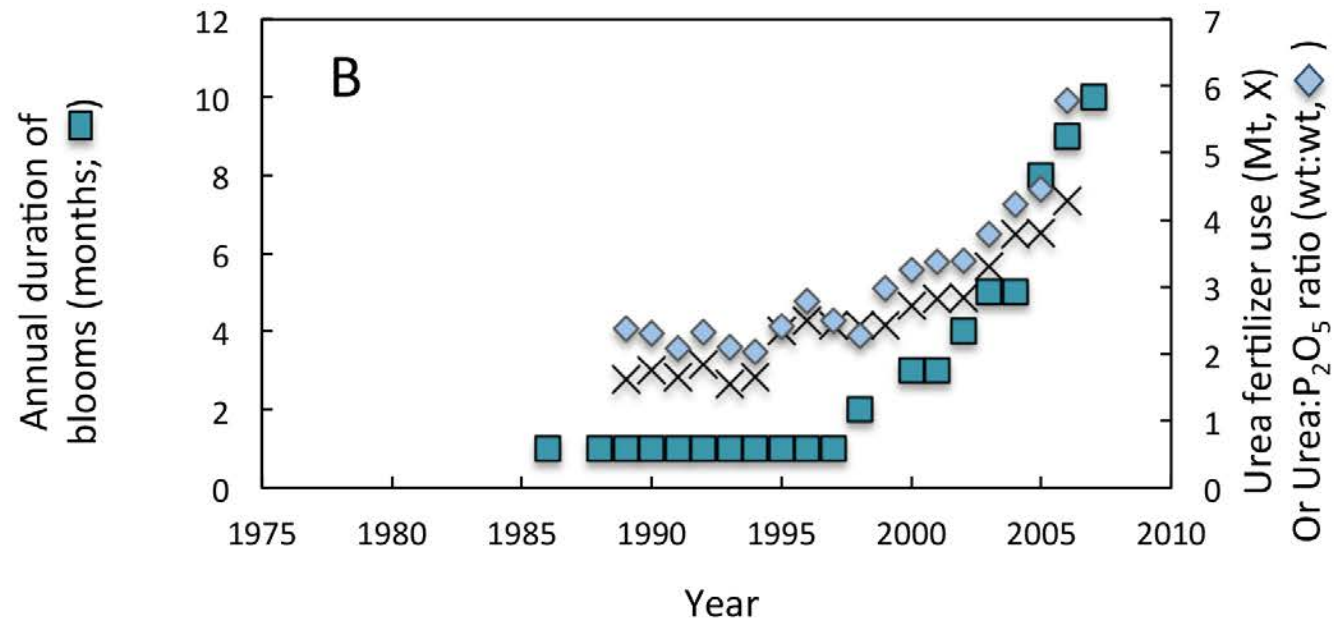


Collectively, these strategies may promote more HABs under conditions of imbalanced elemental loads

More paralytic shellfish toxin is produced at high N:P ratios



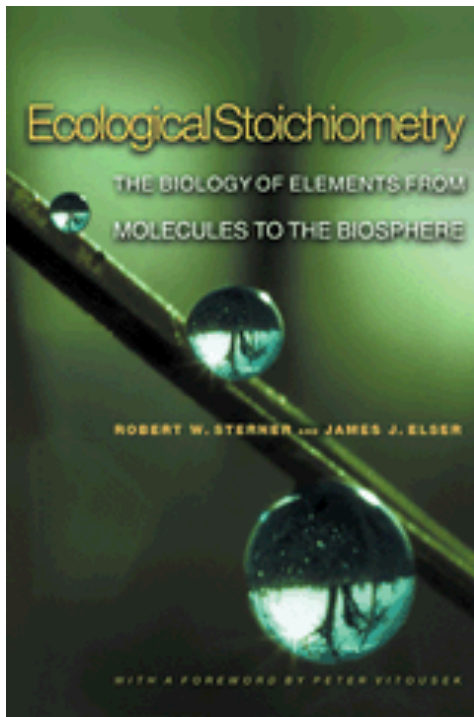
# Lake Taihu, China



## The 'guacamole thick' bloom of Florida, 2016

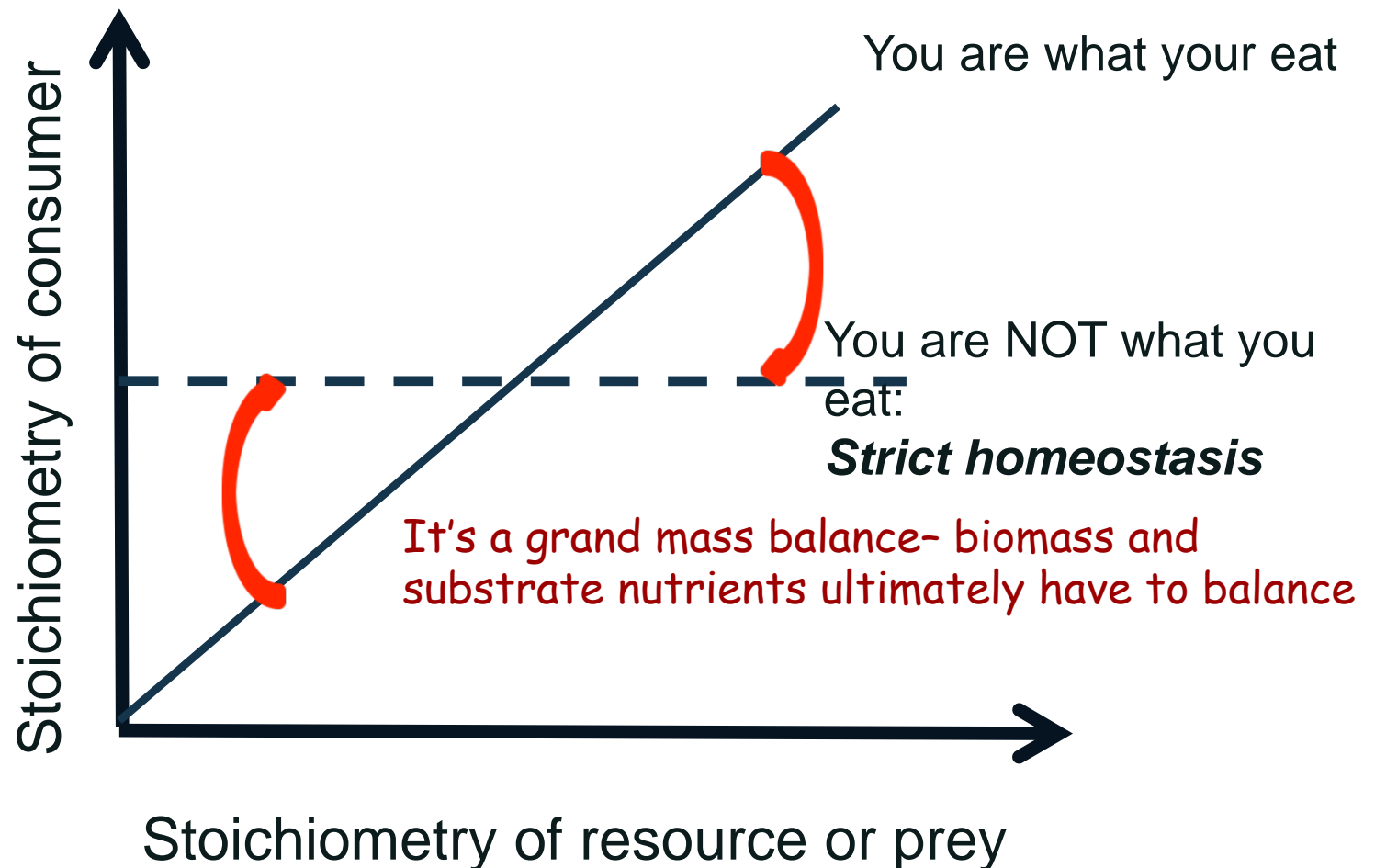


# This concept formalized as **Ecological Stoichiometry**



Nutrients affect food quality , in turn altering food webs

Ecological stoichiometry theory suggests that grazers follow a "You are **NOT** what you eat" strategy, more or less

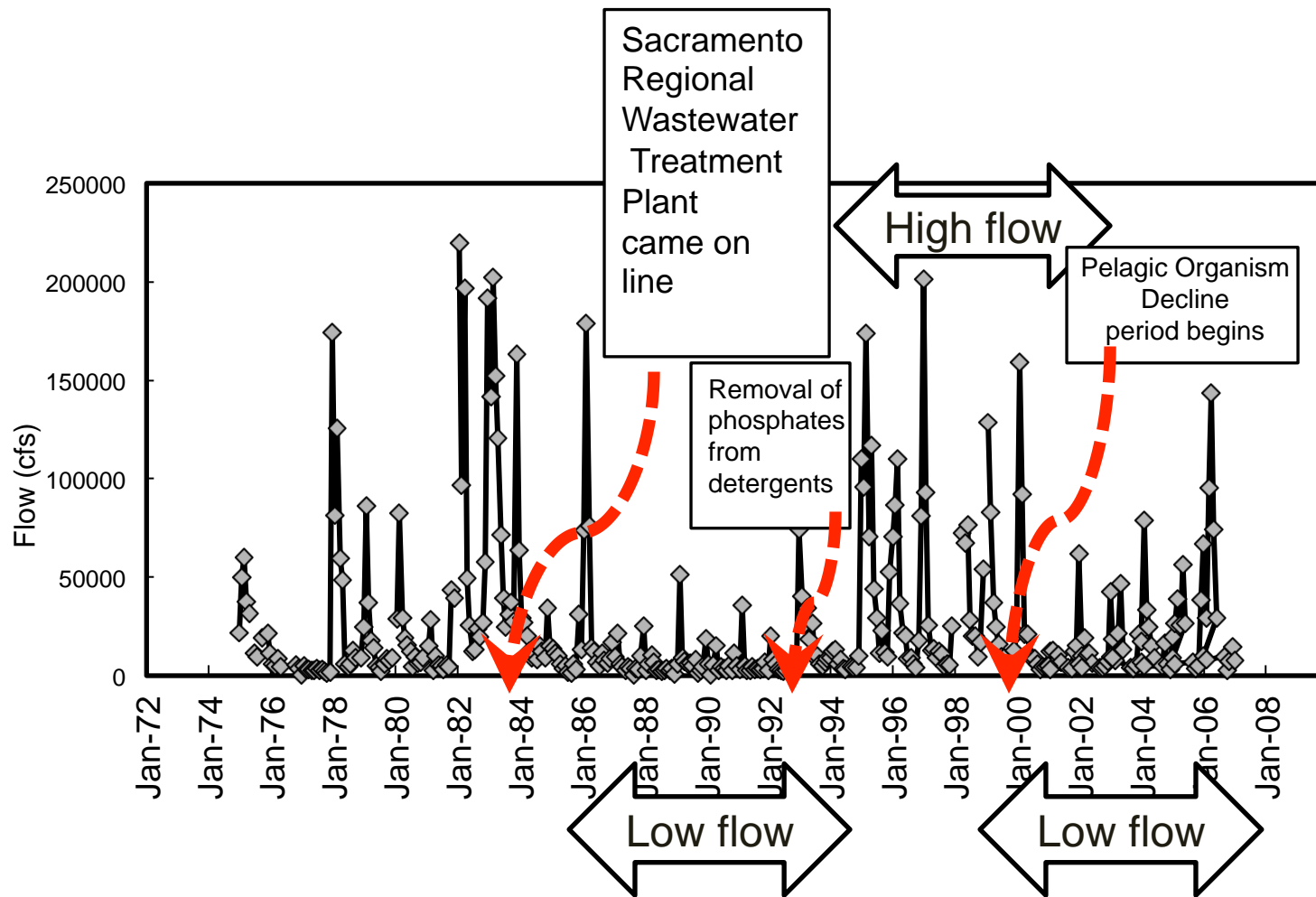


Glibert et al., 2011

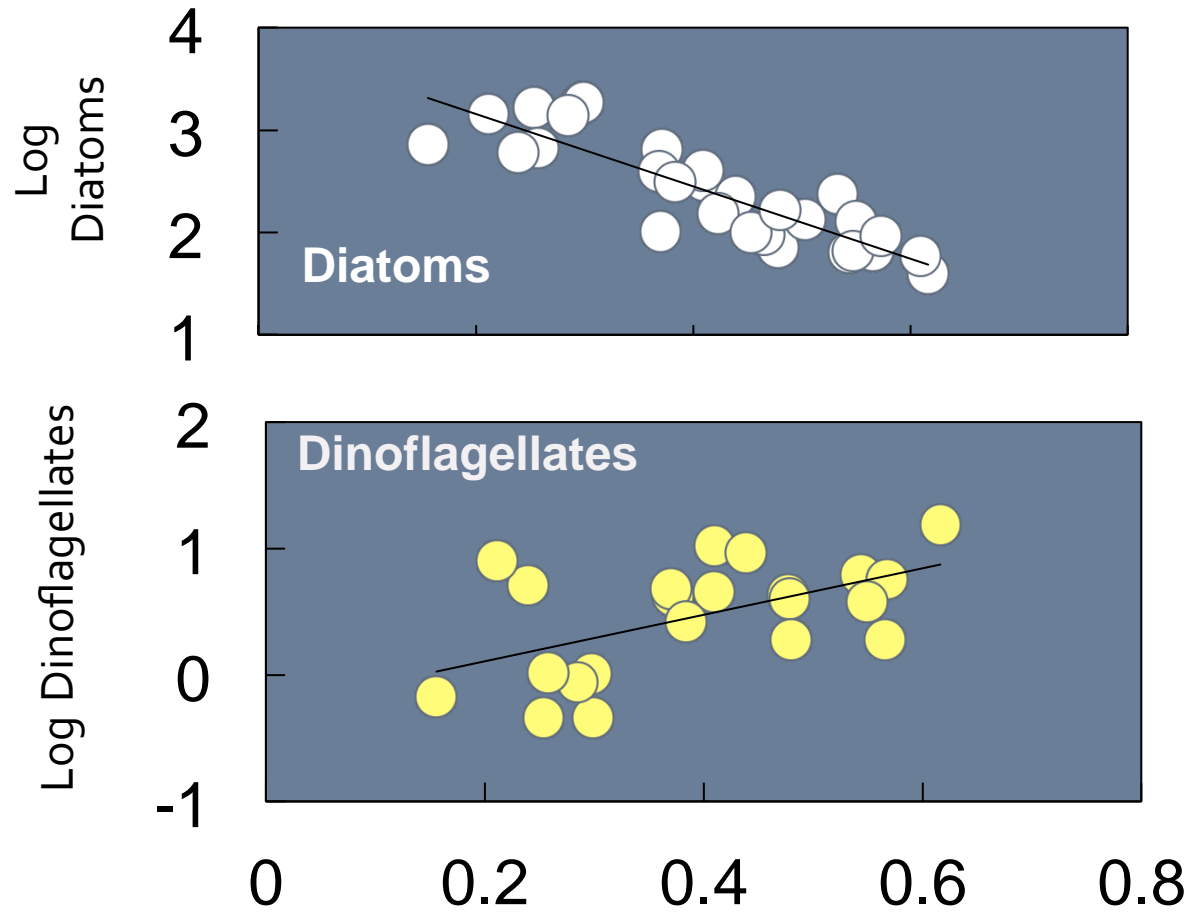
Modified from Sterner and Elser 2002

# San Francisco Bay Delta

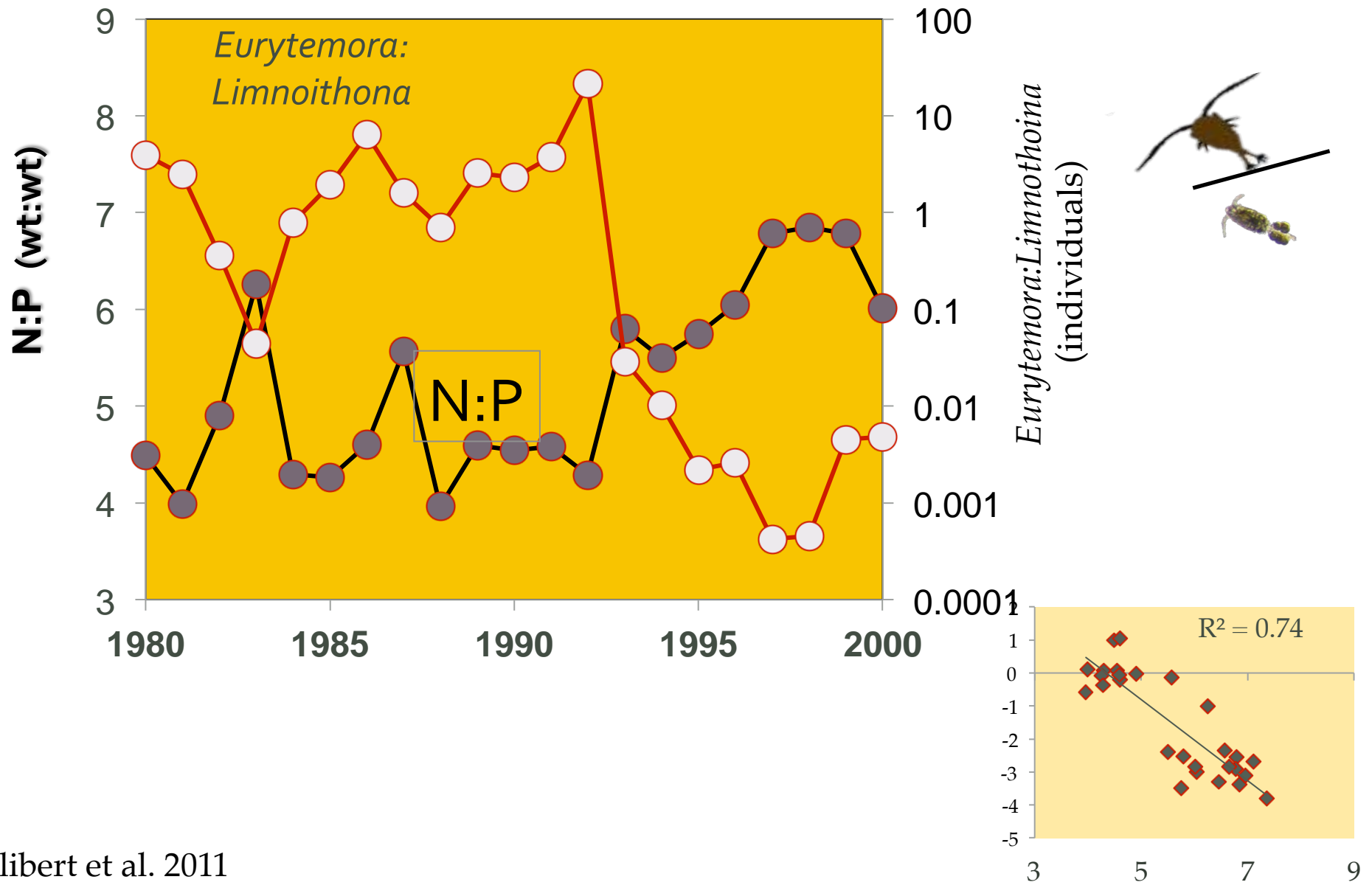




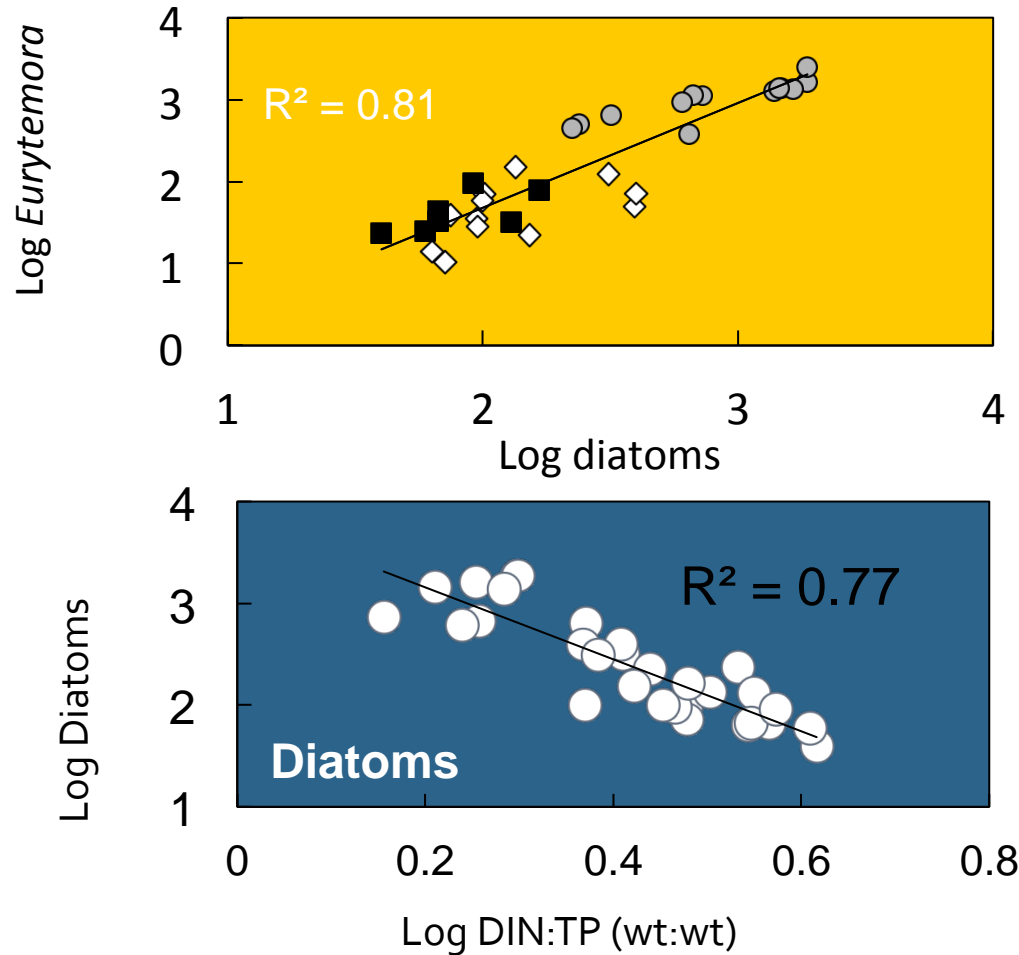
# Algal community composition has changed



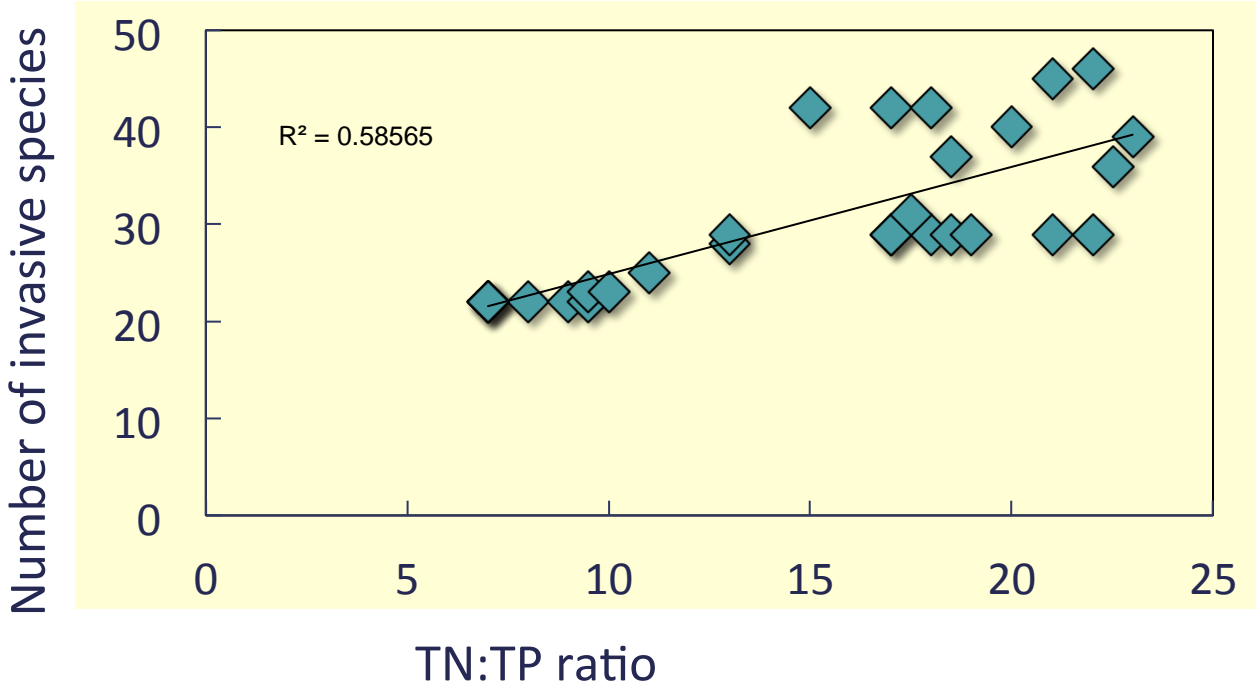
# The correlation of the change in species with N:P



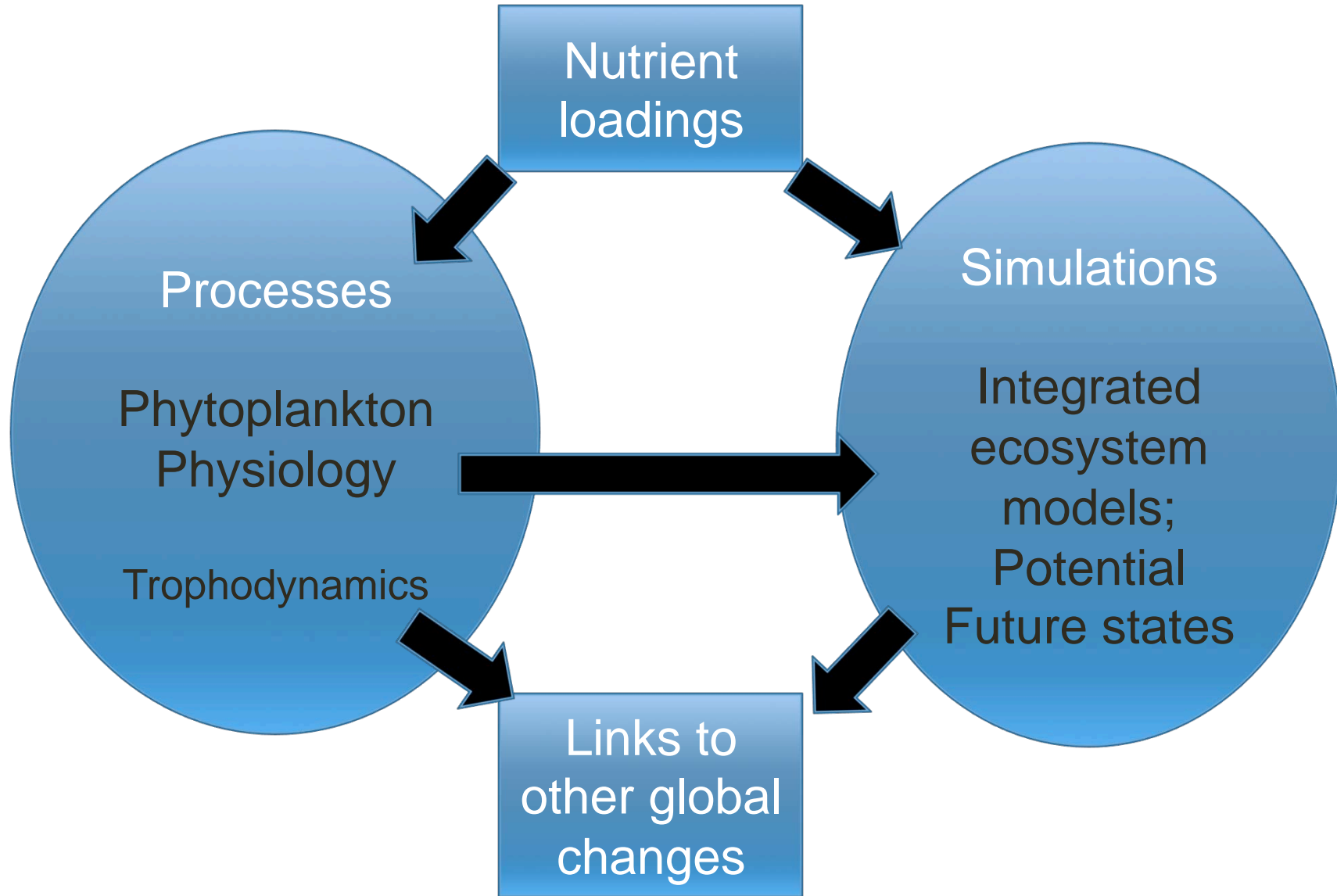
Ultimately species composition changes- even when nutrients are not in classically defined "limiting" conditions



# Rhine River



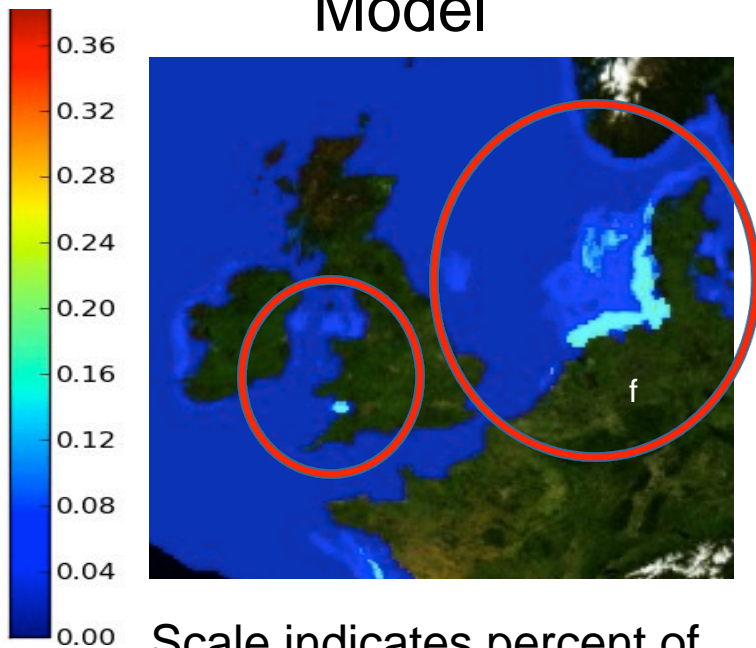
# Linked suite of models



# Comparing Present Condition with data N European coast

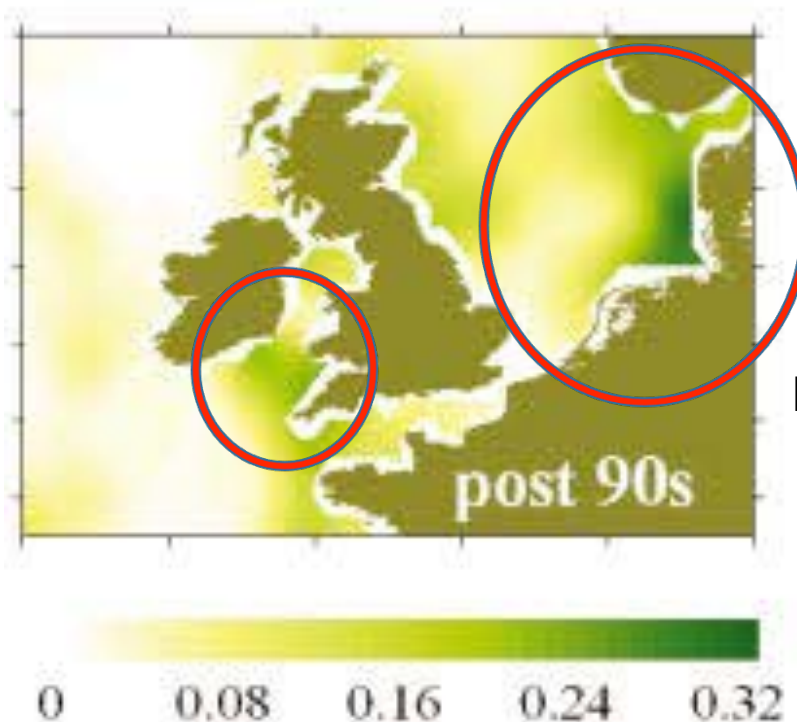
*Prorocentrum spp*

“Present Day”  
Model



Scale indicates percent of pixels in model with suitable habitat conditions

Cell Counts (log (x+1))



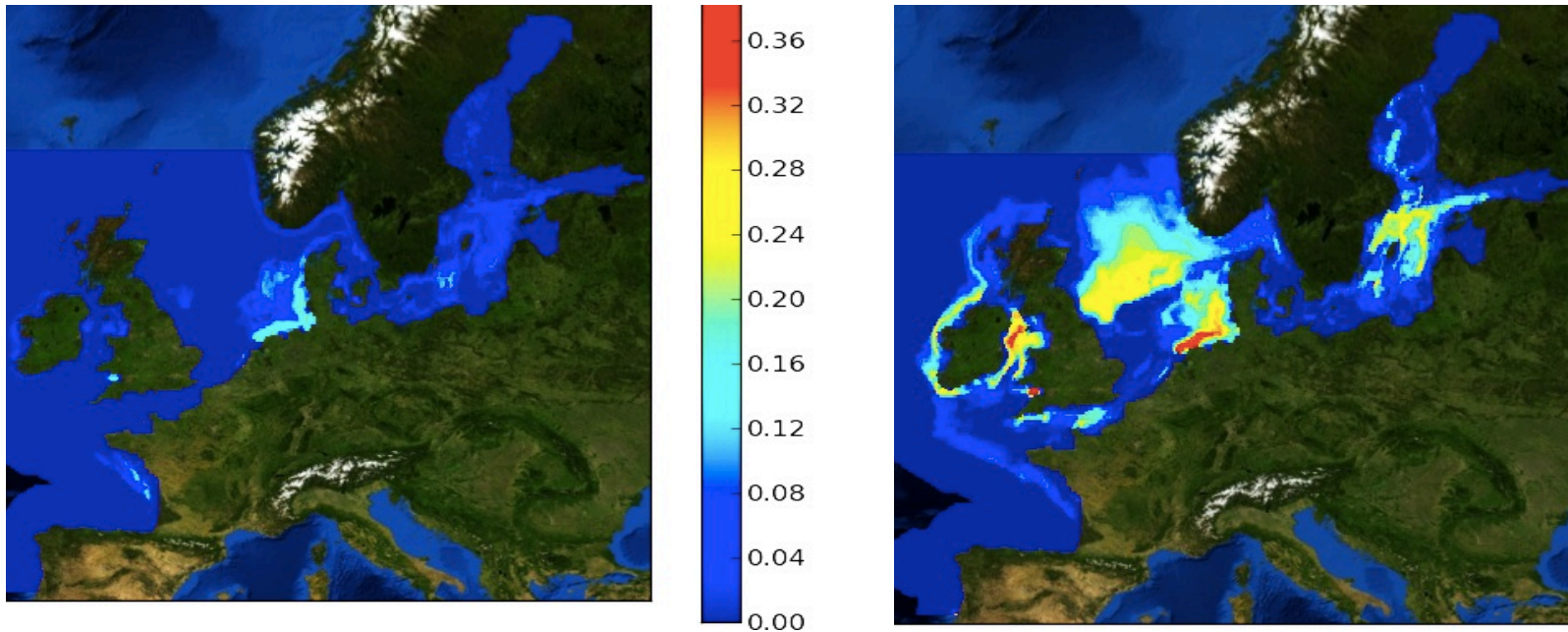
Edwards  
et al. 2006

# Comparing Present Condition with Future Projection: N European coast

## *Prorocentrum* spp

Present Day

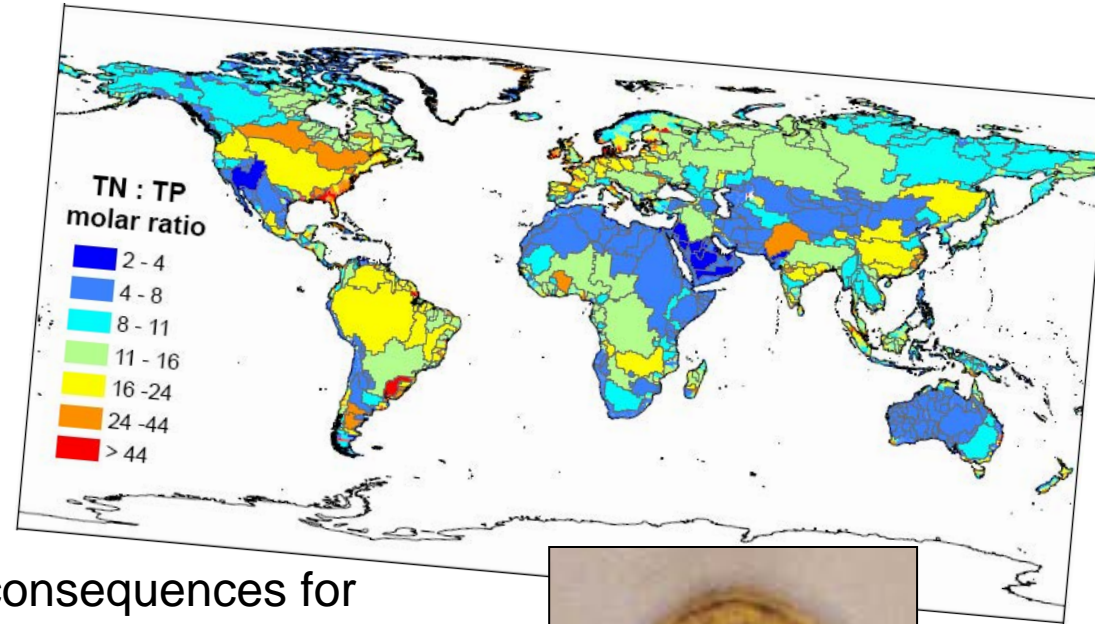
Future Projection (2100)



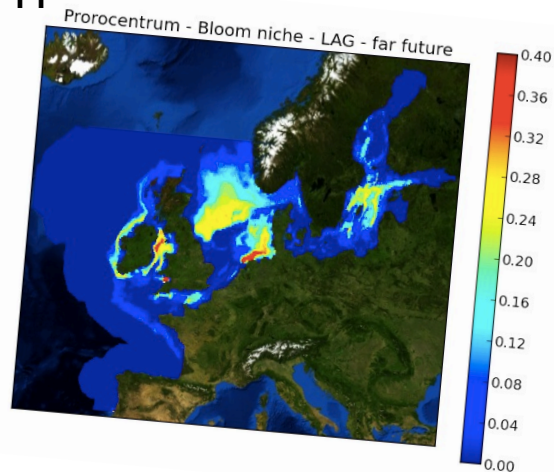
Scale indicates percent of pixels in model with suitable habitat conditions

## Large expansion in potential habitat

Anthropogenic changes in nutrients are driving systems into stoichiometric imbalance and this can amplify the positive feedbacks that result in HABs



Changes in nutrient form have consequences for ecosystem productivity and species composition; this has implications for nutrient management and nutrient criteria which are largely defined in terms of TN and TP



**There is much to be learned about organismal and ecosystem responses to nutrient saturated and super-saturated and stoichiometrically imbalanced nutrient levels**

# Summary & conclusions

1.

Nutrient loads are changing throughout the world in form and composition;

2.

Phytoplankton have different nutrient preferences/requirements; nutrient form and stoichiometry affect algal community composition;

3.

Changes in nutrient stoichiometry and form ultimately have effects through the entire food web;

4.

Similar trajectories of change are occurring in comparative ecosystems throughout the world; future changes projected to be large;

5.

More 'reduced' N and higher N:P lead to more HABs.  
Ratios matter.

## Acknowledgements:

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Delta Science Program