Chess not checkers: phytoplankton bloom effects and predation

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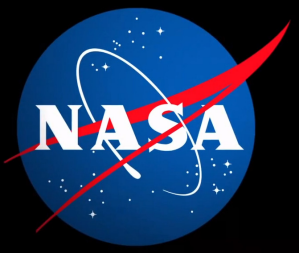
With much appreciated inspiration from Diane Stoecker, Suzanne Strom, Hae Jin Jeong & Karl Banse



Phytoplankton Blooms

- Result from primary production exceeding loss processes
- Vast majority of primary production is lost to herbivores -> grazing

Outline

- Phytoplankton (bloom) effects on predators/predation
- What induces phytoplankton effects on predators/predation
- Challenges

Take home messages

- Blooms are more than Chl a
- Species identities matter (at all trophic levels)
- Individual behaviors and interactions matter
- Predation is a major driver of phytoplankton ecology and evolution

Mechanistic understanding of plankton population dynamics and its biochemical footprint requires understanding of factors that drive grazing rates

This one is important

Phytoplankton bloom effects on predators

1. Trophic transfer
2. Allelochemicals
3. Behaviors and distribution

Trophic transfer

Phytoplankton thought to feed fisheries production. Blooms/ high primary production, thus predicted high fisheries yield

Plankton are without a doubt of great importance for the metabolism of the entire sea - Victor Hensen (1835 - 1924)

Trophic transfer

- Few examples demonstrating fisheries production derived from primary production
  - Atlantic cod (*Gadus morhua* L.) recruitment (Beauregard et al. 2003)
  - good predictor in smaller ecosystems (Mediterranean, Black and Baltic Seas) (Chassot et al. 2007)
  - poor predictor in larger ecosystems (Friedland et al. 2007)
  - estimates of mortality essential for predictions (Kearney et al. 2012)
  - Salmon recruitment tightly linked (Peterson et al.)
- Blooms of some species reduce invertebrate and fish populations, disrupt food webs and alter salmon migration (Livingston 2007)

Trophic transfer

- **Gross** generalization of primary production fate: vast majority is consumed by herbivorous predators
  - heterotrophic protists remove ~75% of daily primary production (e.g. Calbet & Landry 2004, Morison & Menden-Deuer 2015)
  - mesozooplankton consume ~25% (e.g. Campbell et al. 2009).

- Many alternatives:
  - 80 µg Chl L^{-1}! remineralized (Bruussaard et al. 1996)
  - dissipated due to mixing
  - cells dissolved by viral lysis
  - sinking and export

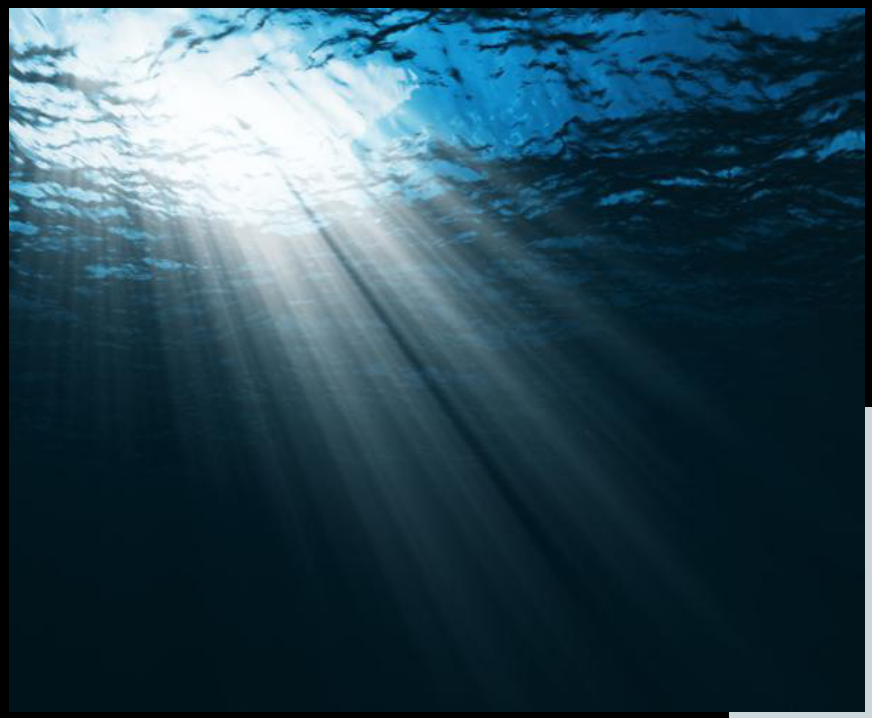
Allelochemicals

- polyunsaturated aldehydes (PUAs) and other inhibitory or stimulatory (!) metabolites
  - reduce or inhibit heterotrophic protist grazing (Stoecker et al. 2015)
  - reduce predator growth rate but species specific (Lavrentyev et al. 2015)
  - can lead to predator cell death
  - can be self inhibitory
  - in lab reduced growth/death of other algae (Hansen & Eilertsen 2006)
  - stimulatory of bacterial remineralization (Edwards et al. 2015) inhibitory at very high concentrations

Phytopl. effects on behaviors & distributions

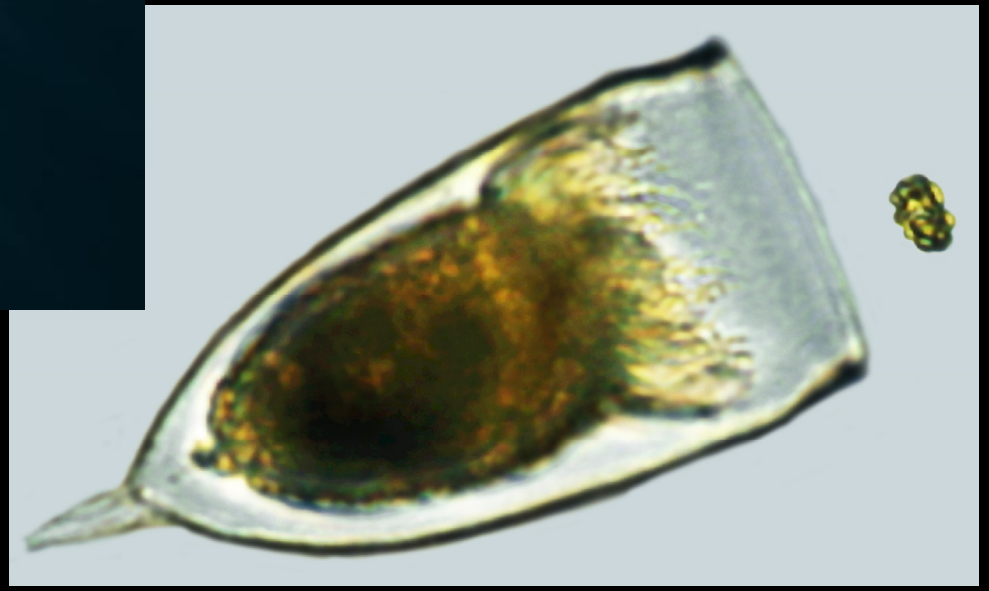
- phytoplankton aggregations induce protistan predator aggregations in the field
  (e.g. Stoecker et al. 1984, Menden-Deuer 2008)
- plankton alter swimming in response to self
  (Harvey et al. in prep., Fong & Menden-Deuer, in prep.)
- algae flee predators
  (Harvey & Menden-Deuer 2012)
- behaviors are consistent over time and across labs
  (Harvey et al. *in review*)
- algal exudates have largely stimulatory/attractive effects on predators (e.g. Menden-Deuer & Grünbaum 2006, Harvey & Menden-Deuer 2011, 2012)

What structures marine ecosystems?



bottom up?

top down?



Organizing principle

Avoiding pitfalls

No suggestion that grazing is most important or only process but a shaping driver

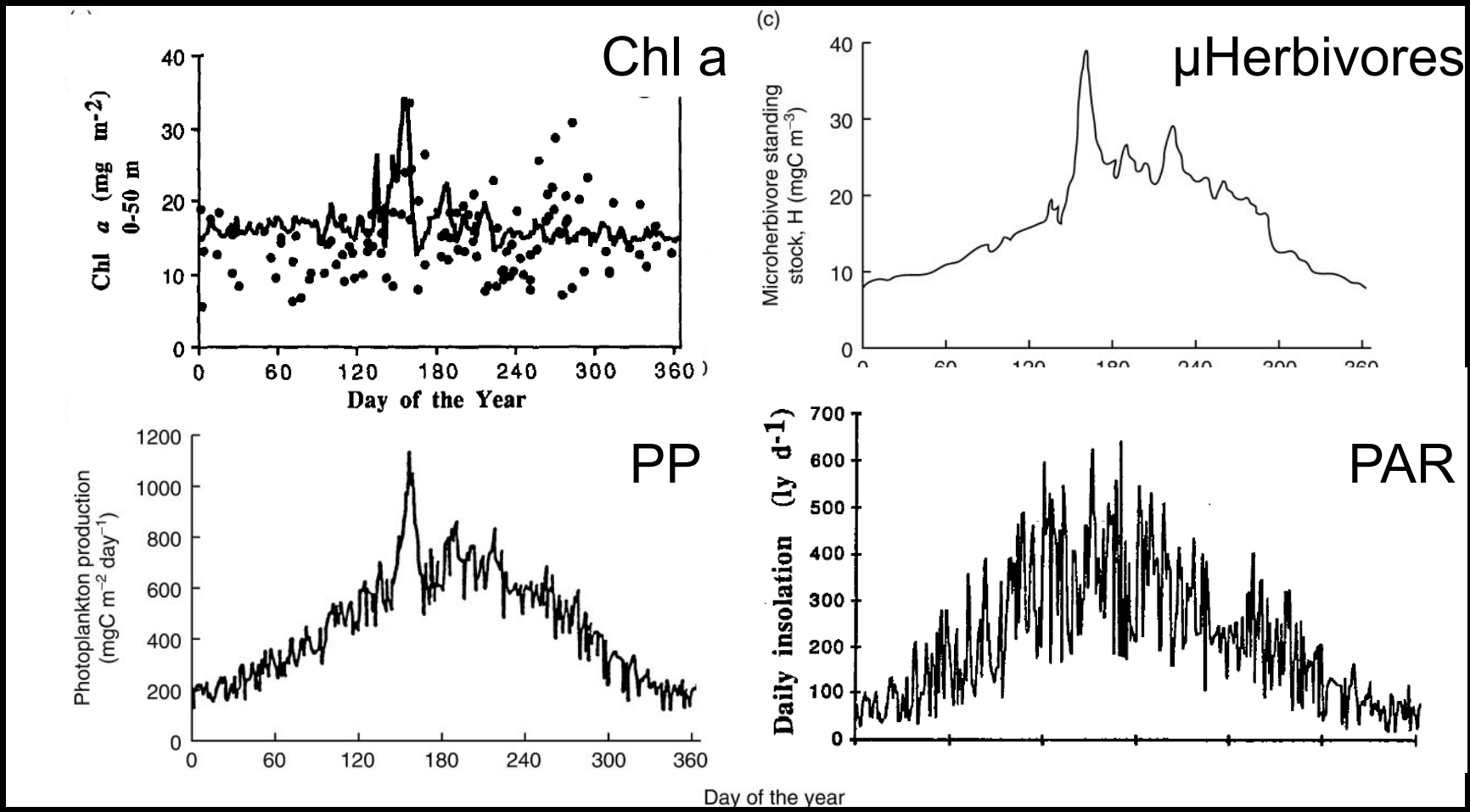
Predation effects on phytoplankton

Why is predation so important?

"The observed near-perfect balance between rates of cell division and mortality at time scales of >~24 hours is astonishing"

Banse 2012

Standing stock does not reflect dynamics



Predation

from Miller, after Frost 1993

Predation effects on phytoplankton

Why is predation so important:

"The observed near-perfect balance between rates of cell division and mortality at time scales of >24 hours is astonishing" Banse 2012

1. predation pressure is constant
   - e.g. seasonal average grazing for coastal estuary was 94% (Lawrence & Menden-Deuer 2012)
   - heterotrophic protists remove ~75% of daily primary production (e.g. Calbet & Landry 2004, Morison & Menden-Deuer 2015)
   - mesozooplankton consume ~25% (e.g. Campbell et al. 2009).

Predation effects on phytoplankton

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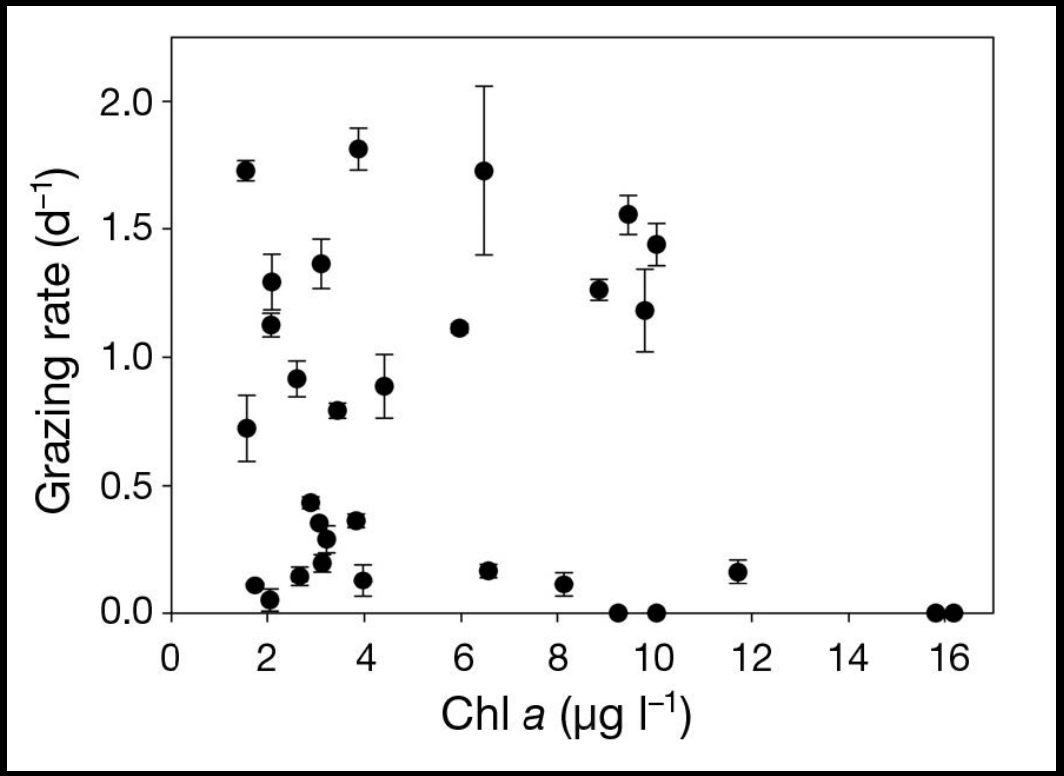
1. predation pressure is constant

2. predators discriminate amongst species

Predators eat algae not Chl *a*

- Chl a is a lousy predictor of grazing rate



Lawrence and Menden-Deuer 2012

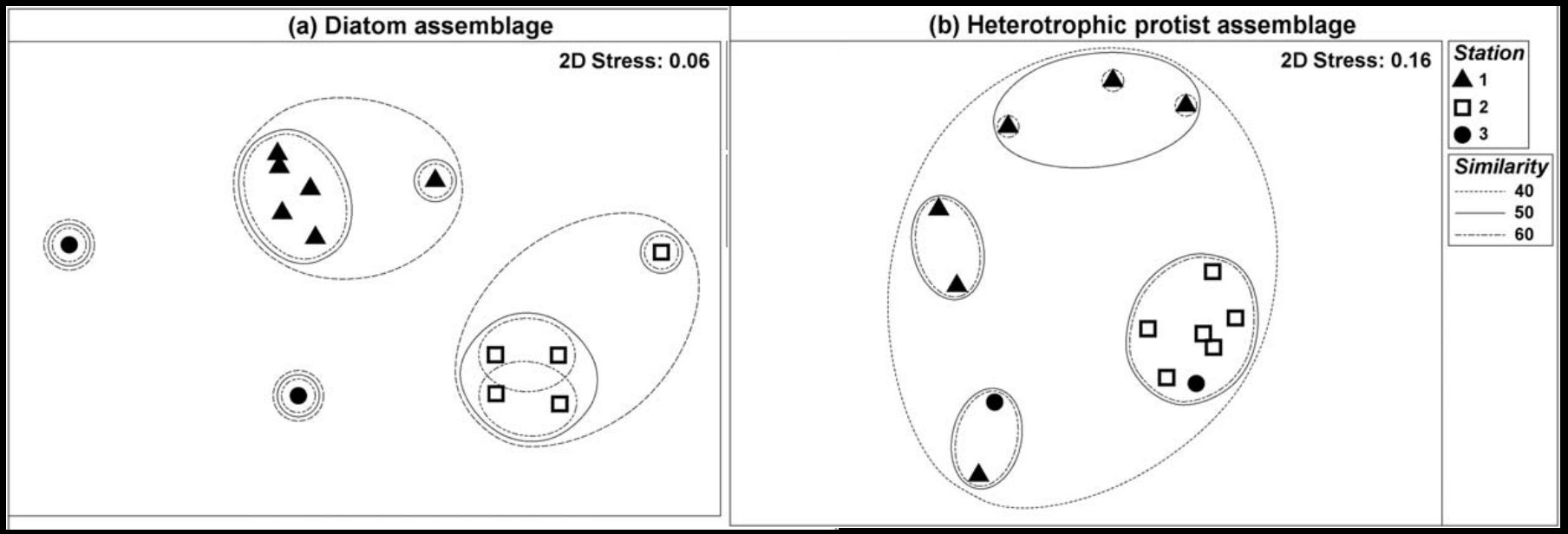
Strom et al. 2001
Olson and Strom 2002
Verity et al. 2002
Sherr et al. 2009
Menden-Deuer & Fredrickson 2010
Menden-Deuer et al. *in review*

Algal community composition matters

- Algal and predator assemblages differed at 2stations
  - Station 1 varying assemblages of both predator and prey species
  - Station 2 consistent assemblages of well matched predator and prey species

diatoms

heterotrophic protists



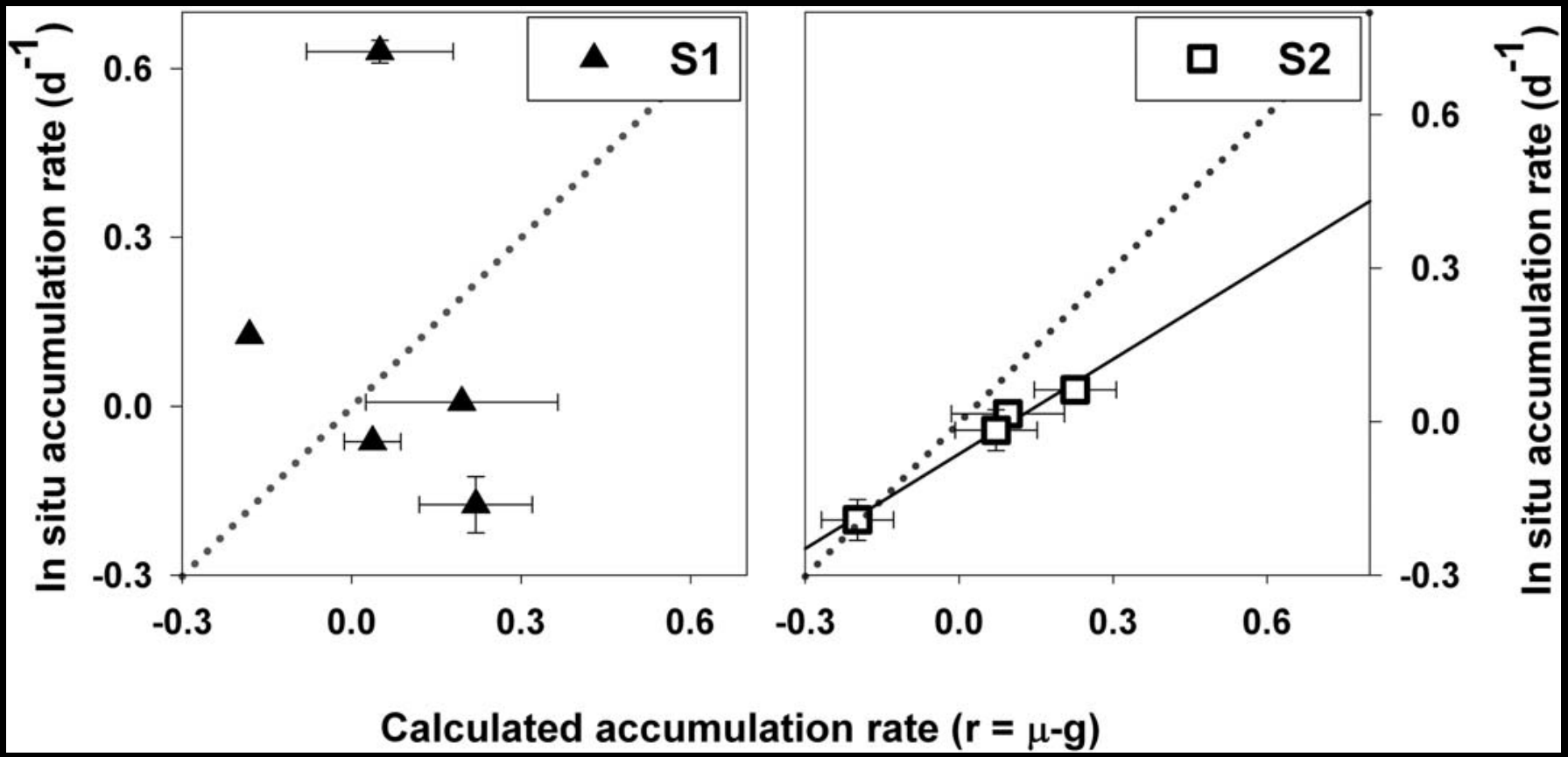
Morison and Menden-Deuer 2015

Algal community composition matters

- and affects resulting grazing pressure

variable species

persistent species



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Predation effects on phytoplankton

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- predation pressure is constant
- predators discriminate among species
- predation may not be entirely antagonistic
  - herbivores recycle nutrients and maintain them in euphotic zone

Predation effects as driver of bloom effects?

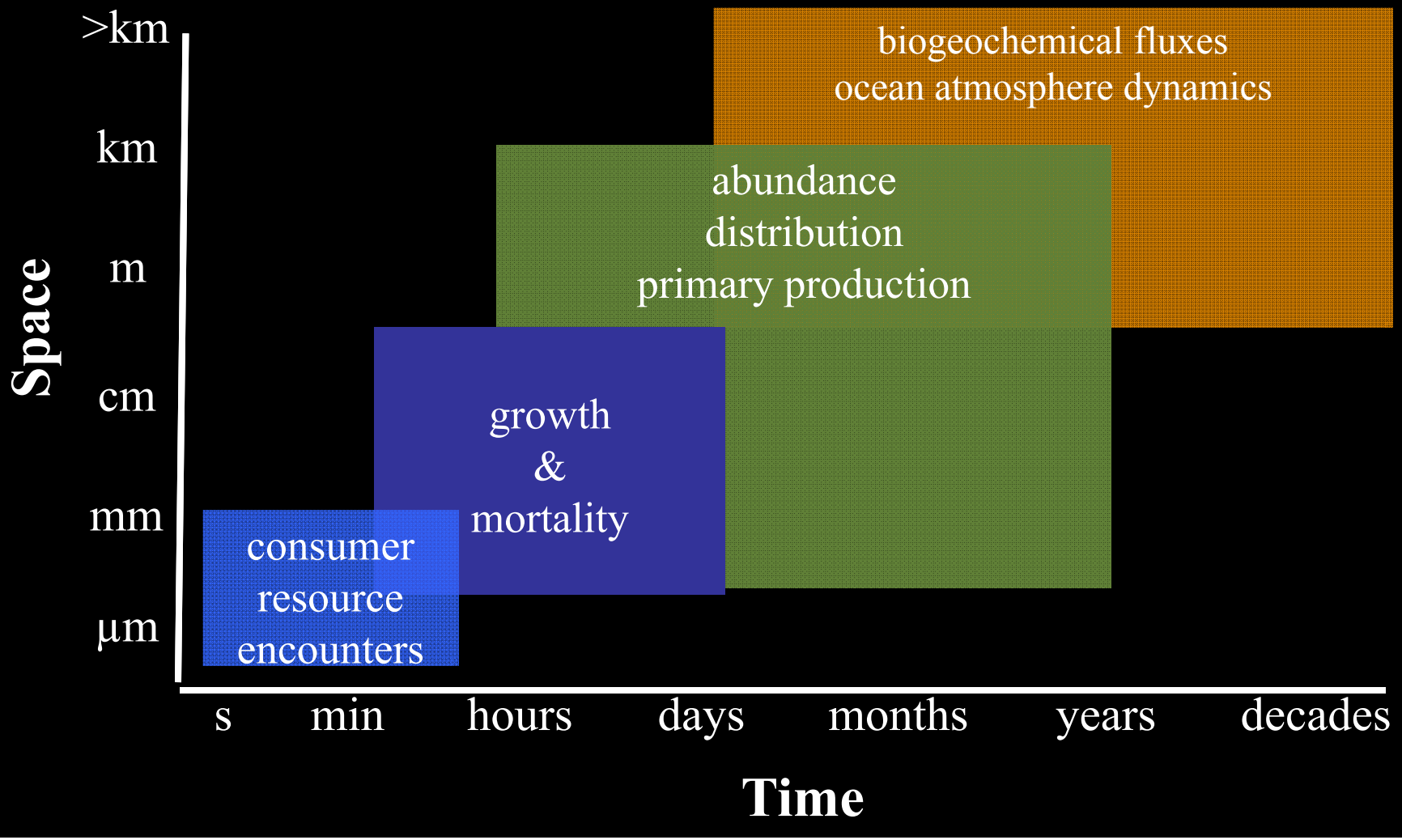
- Algal physiology embedded in a perfect reproduction of abiotic environment can not predict plankton population dynamics (sensu Banse 2012)

- Predation is the single most important driver of phytoplankton ecology and evolution (e.g. watery arms race Smetacek 1999)

Suggestion: bloom 'effects' of inducing behaviors and secondary metabolite production are responses to constant predation pressure

Challenge

- linking ecologically relevant to biogeochemically relevant rates (i.e. individuals to ecosystems)



Challenge

Predation is hard to measure

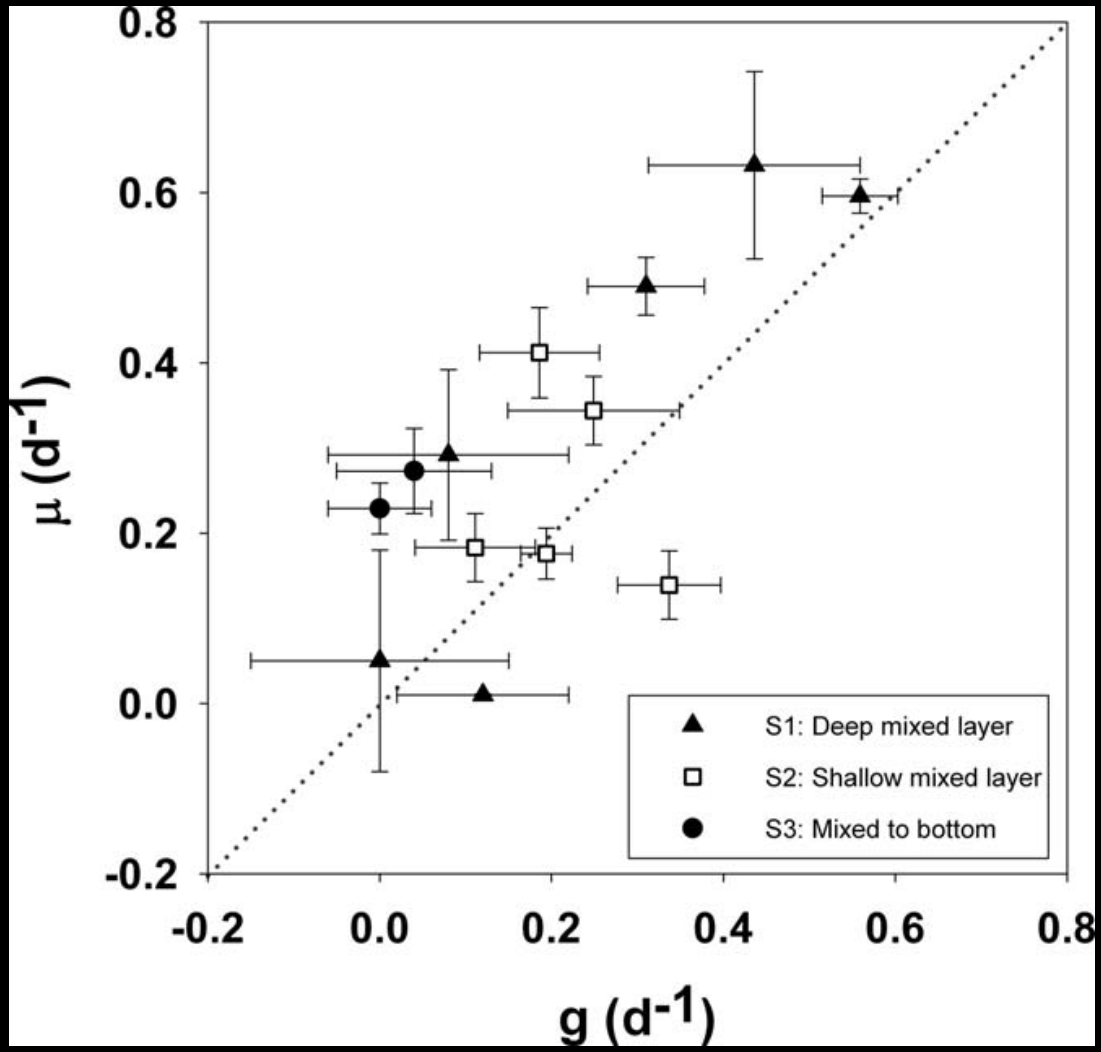
- seasonal fluctuation in predation pressure can match fluctuations in primary production
- significant fluctuations in environmental conditions are not reflected in changes in Chl a concentration (e.g. oligotrophic gyres Church et al. 2013, Frost 1993)

Problem I: underlying highly dynamic system appears stable - fluctuating rates are disguised by relative stability of Chl *a* signal

Problem II: tight coupling of production and consumption rates implies a miniscule signal to noise ratio

Predation - a proportion of production

- but there is some good news… consumption appears to be a fraction of phytoplankton growth
- North Atlantic, early bloom protistan grazing ~ 64% of algal growth



Morison & Menden-Deuer 2015

Are phytoplankton blooms important?

images from www