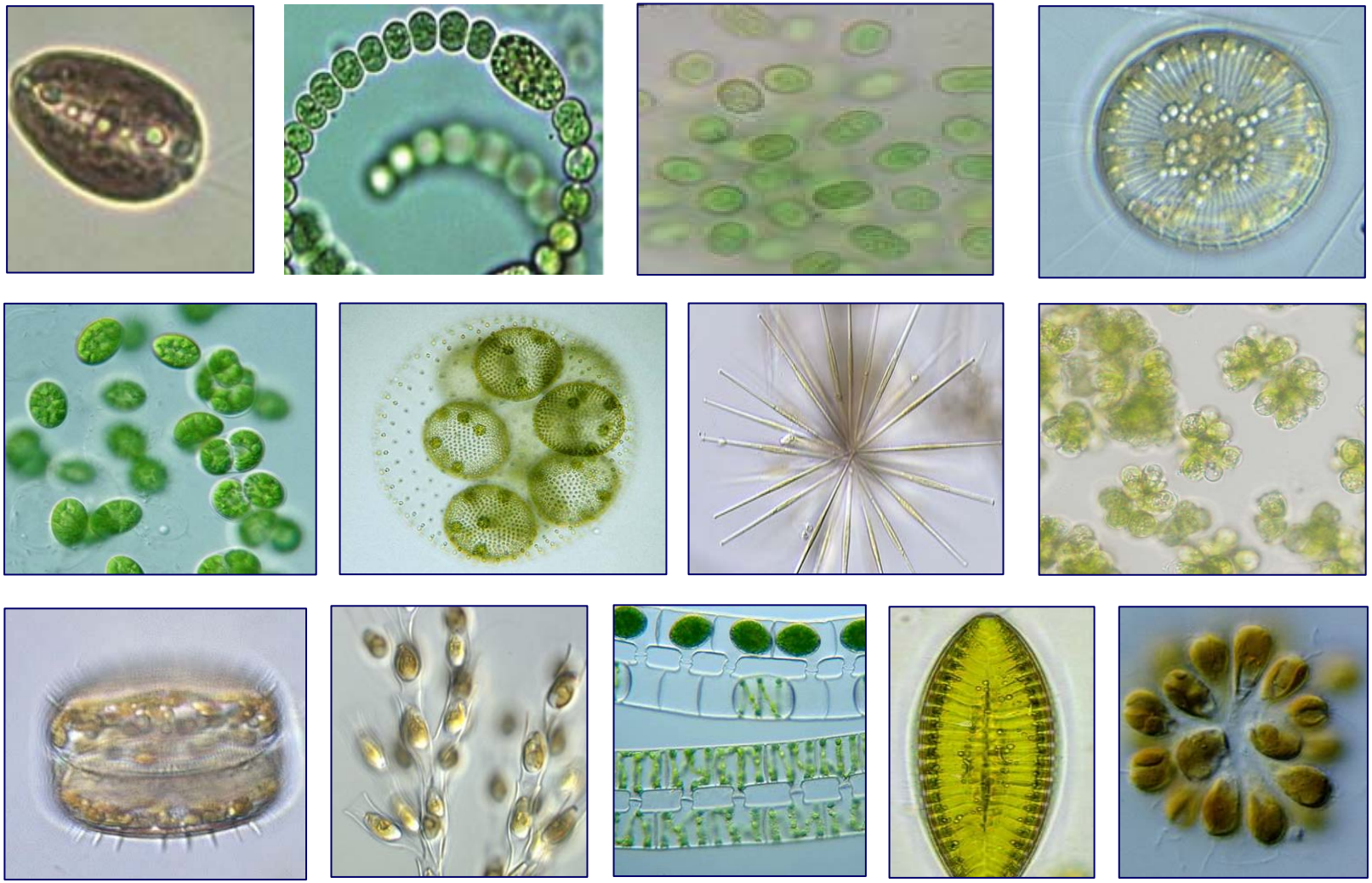
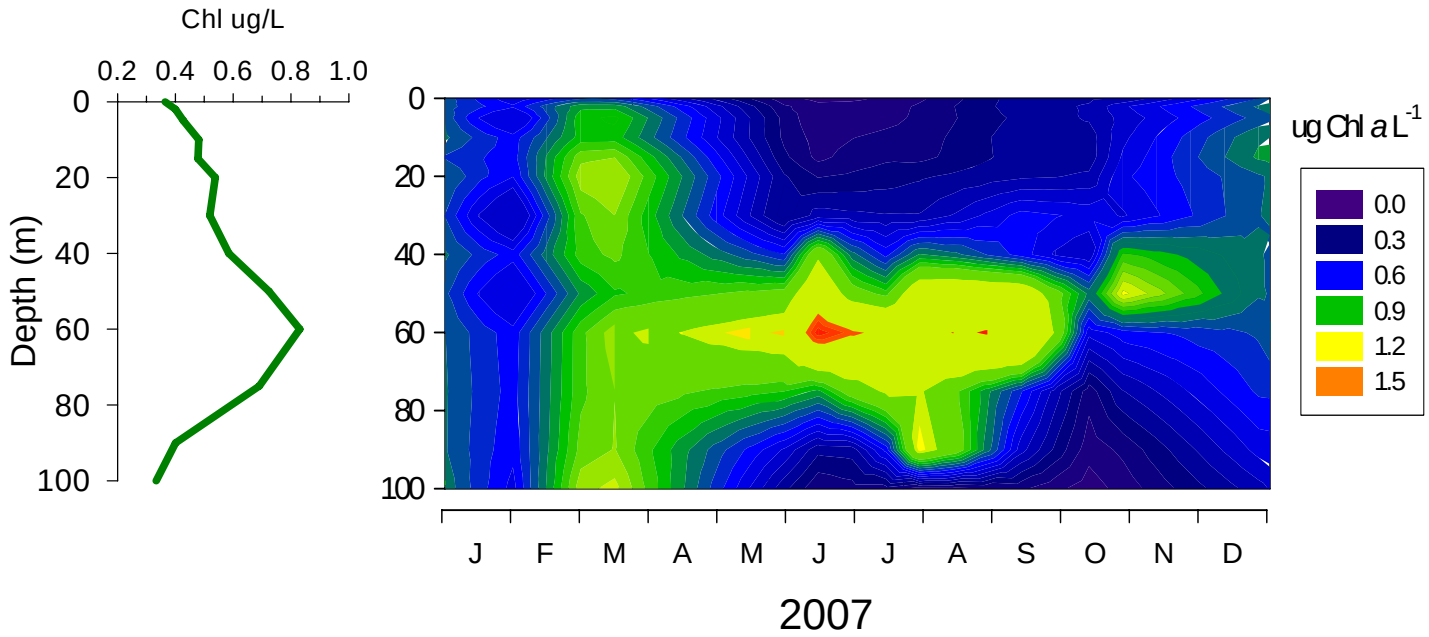
Visible impacts to Lake Tahoe's invisible biota in response to climate change

Monika Winder
University of California, Davis

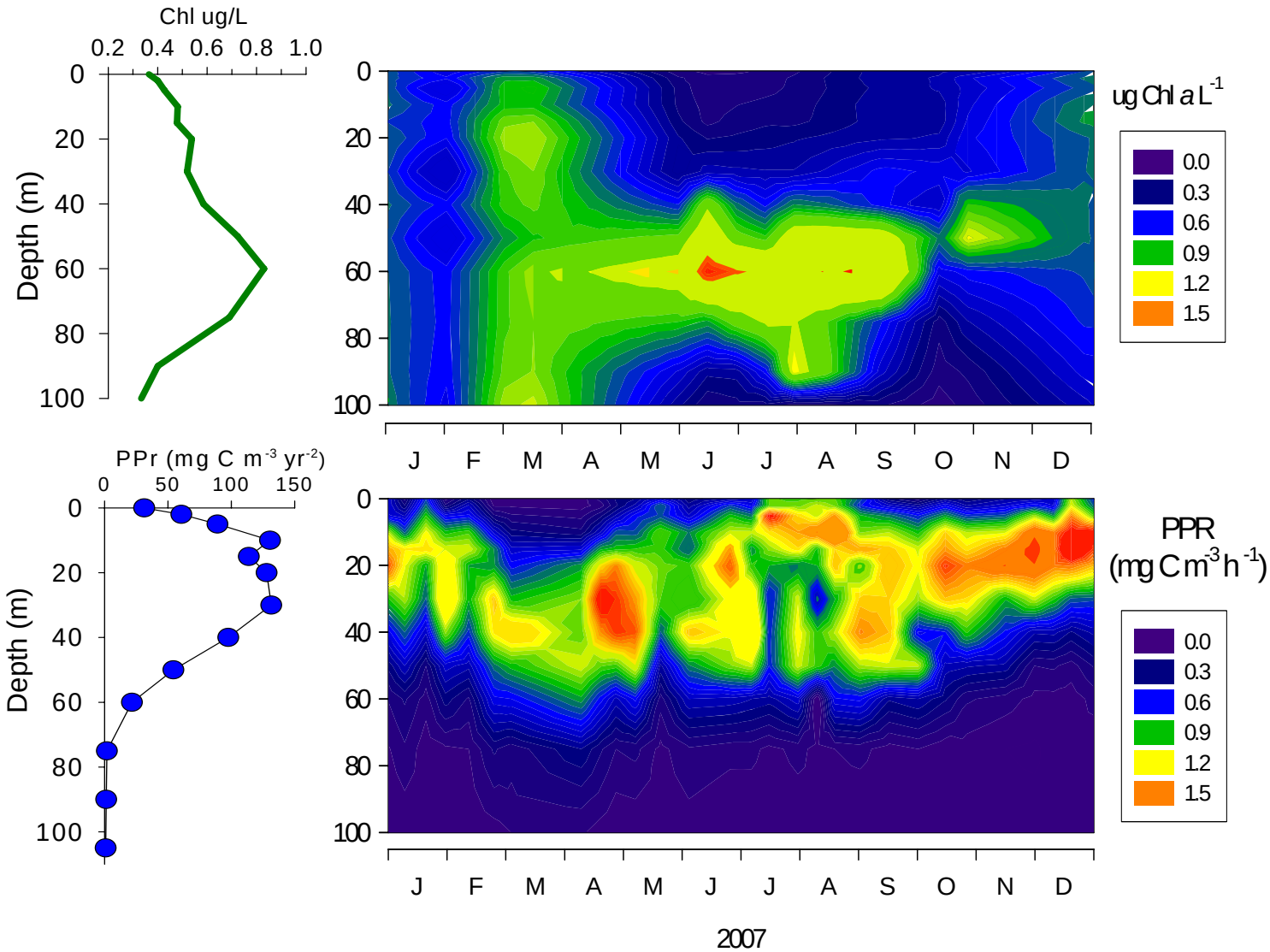
Phytoplankton - microscopic plants



Deep-chlorophyll maximum

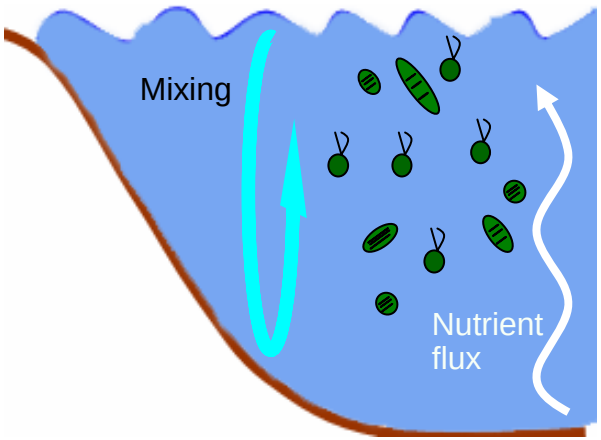


Primary production dominates between 10 – 50 m

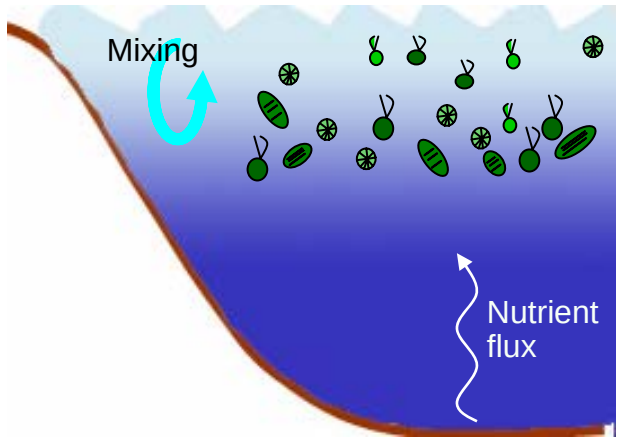


Seasonal patterns of mixing and stratification

Winter mixing



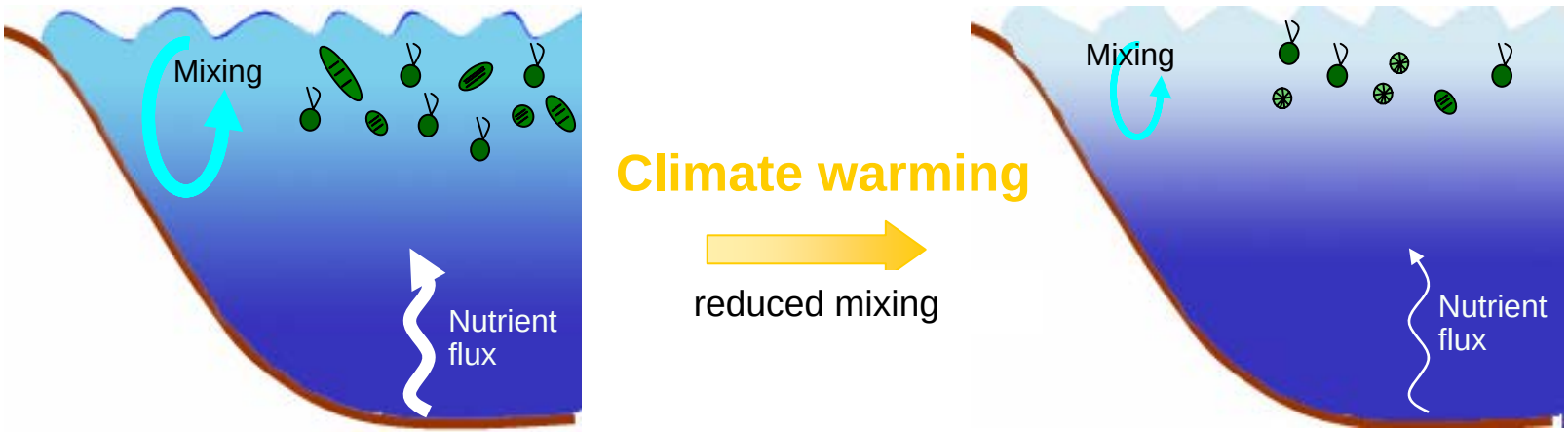
Summer stratification



Climate warming affects intensity of mixing and stratification

Climate-phytoplankton links

i) water-column mixing

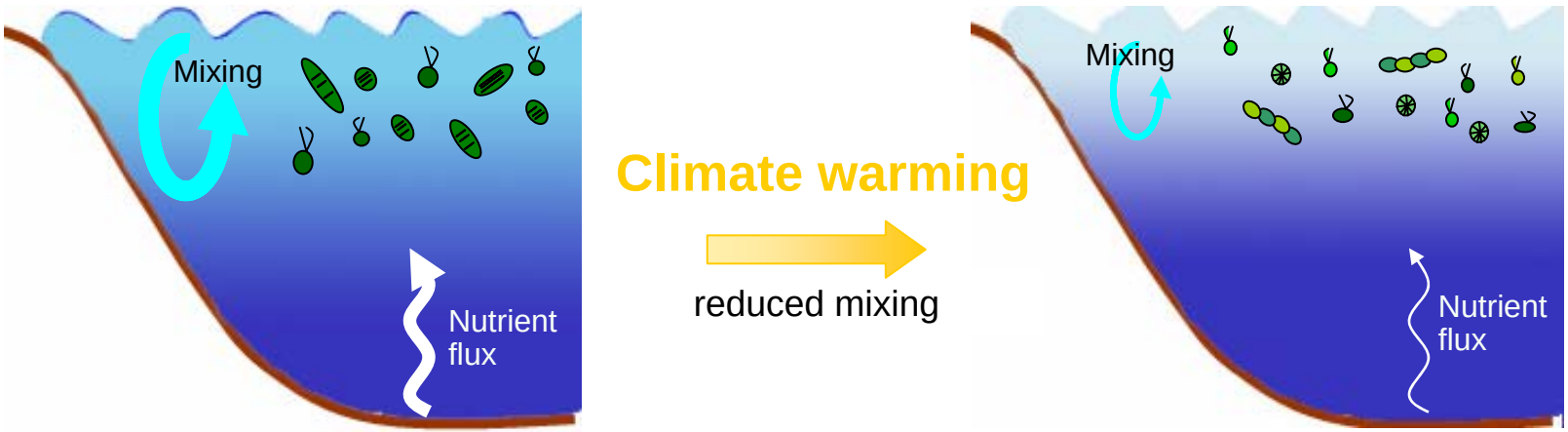


- suppress nutrient exchange through vertical mixing
- favors species with lower nutrient requirements

Climate-phytoplankton links

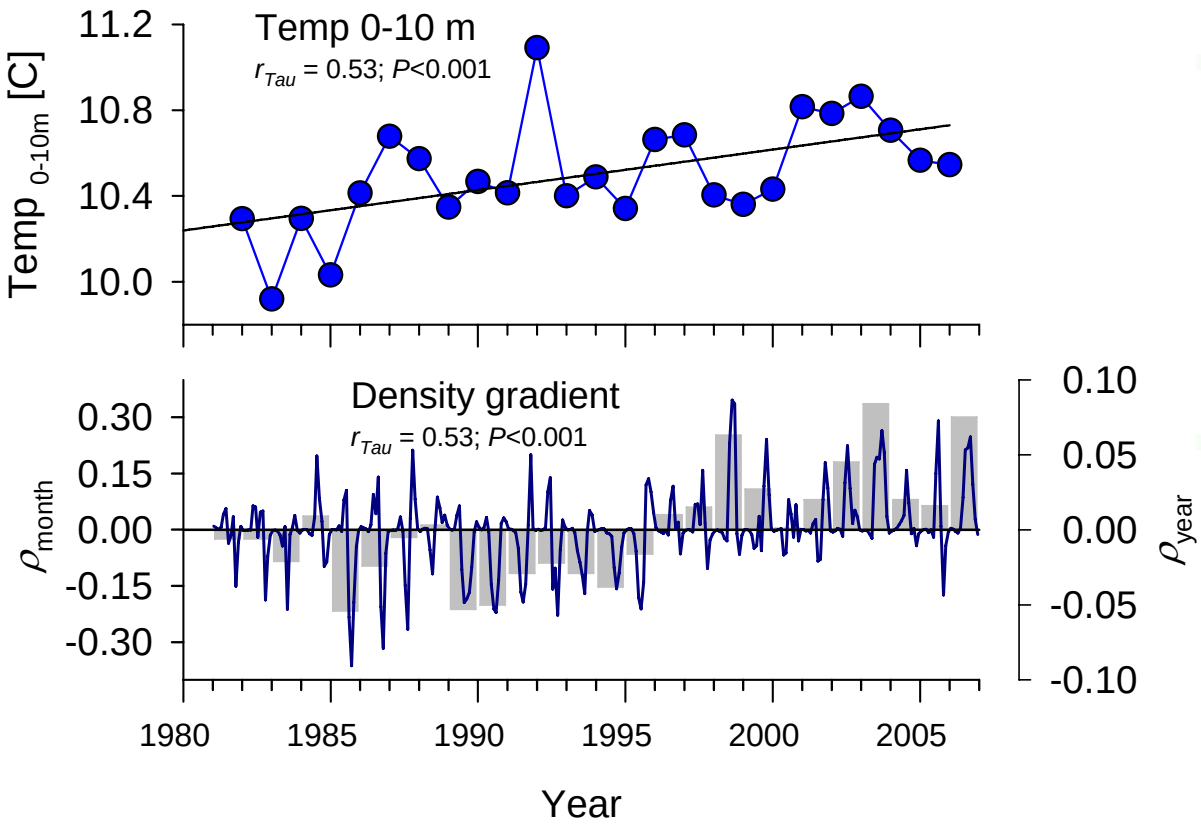
i) water-column mixing

ii) cell sinking velocities



- floristic shift in phytoplankton
- expansion of small-sized species / that are able to regulate buoyancy

Lake Tahoe: long-term trends

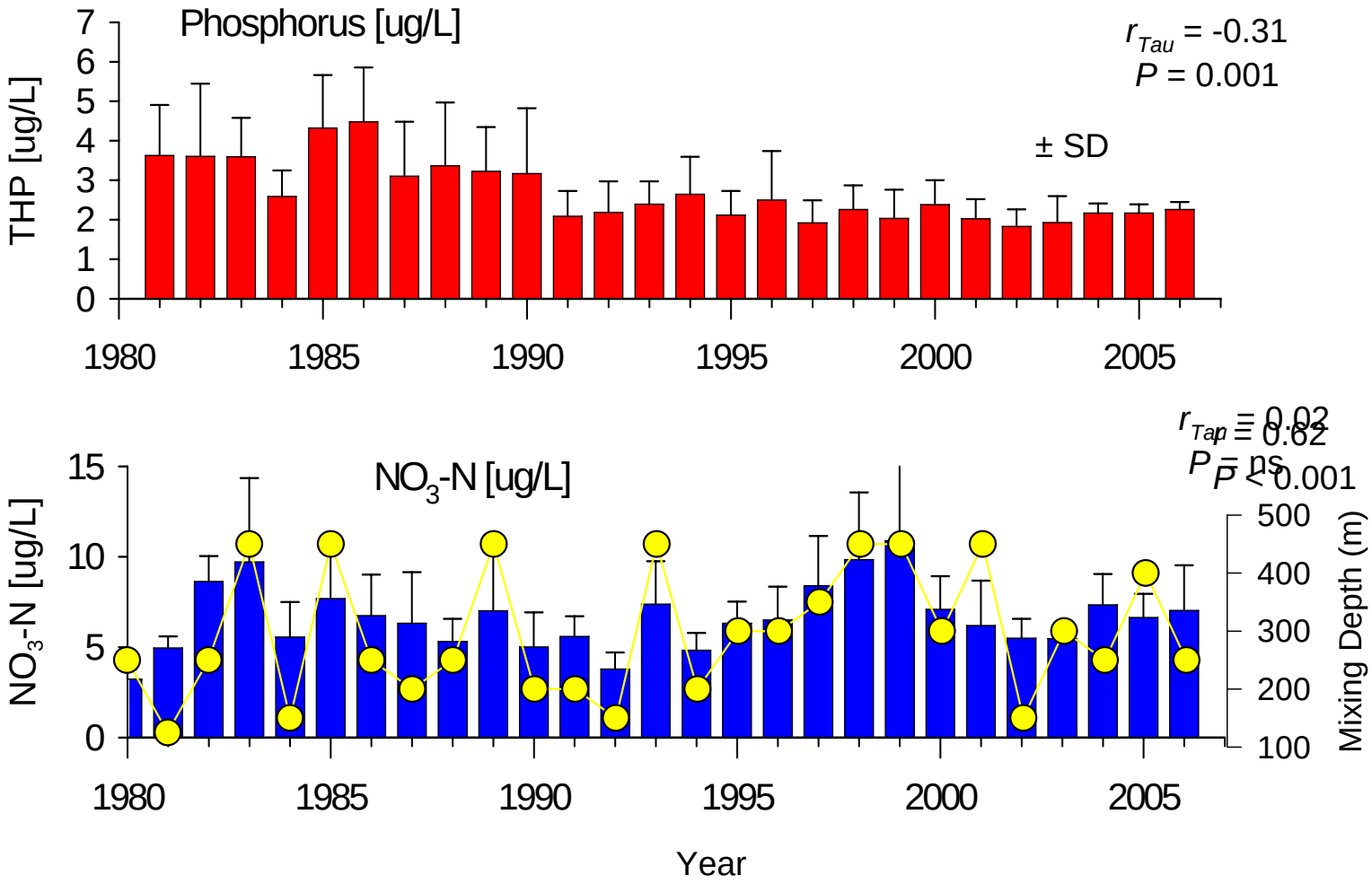


Increasing water temperature

Increasing stratification

Winder M & Hunter DA (2008) *Oecologia* 156.

Macronutrients (0 - 100 m)

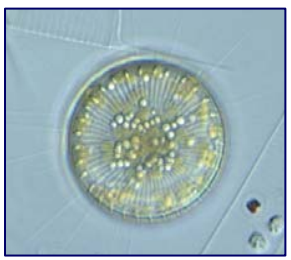
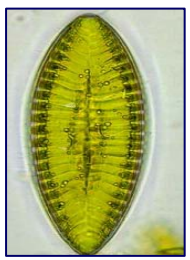
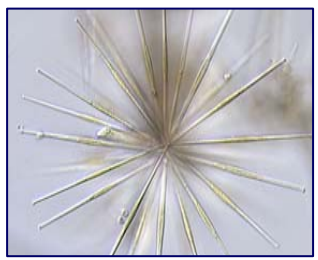
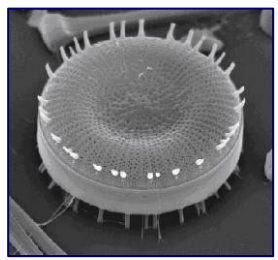


Diatoms

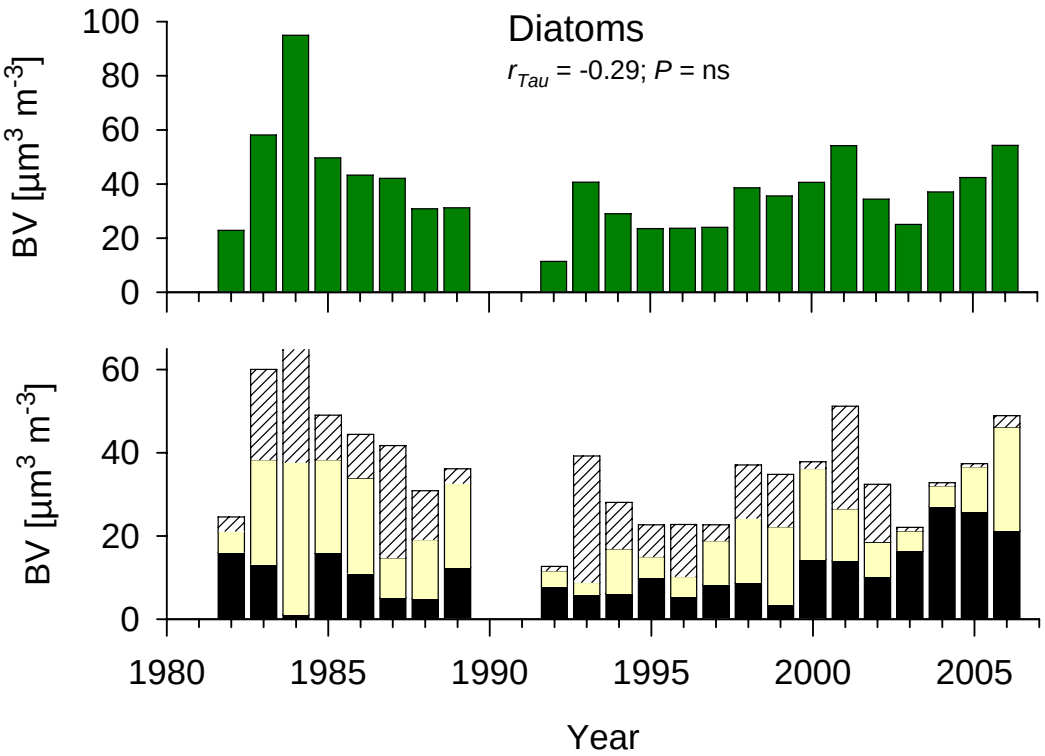
- abundant, high food-quality
- require turbulence to remain suspended
- require high nutrient concentrations
- cells with silica walls
- high sinking rates

→ Diatoms are expected to be replaced by other phytoplankton functional groups with climate warming

[Bopp et al. (2005), Huisman et al(2004)]

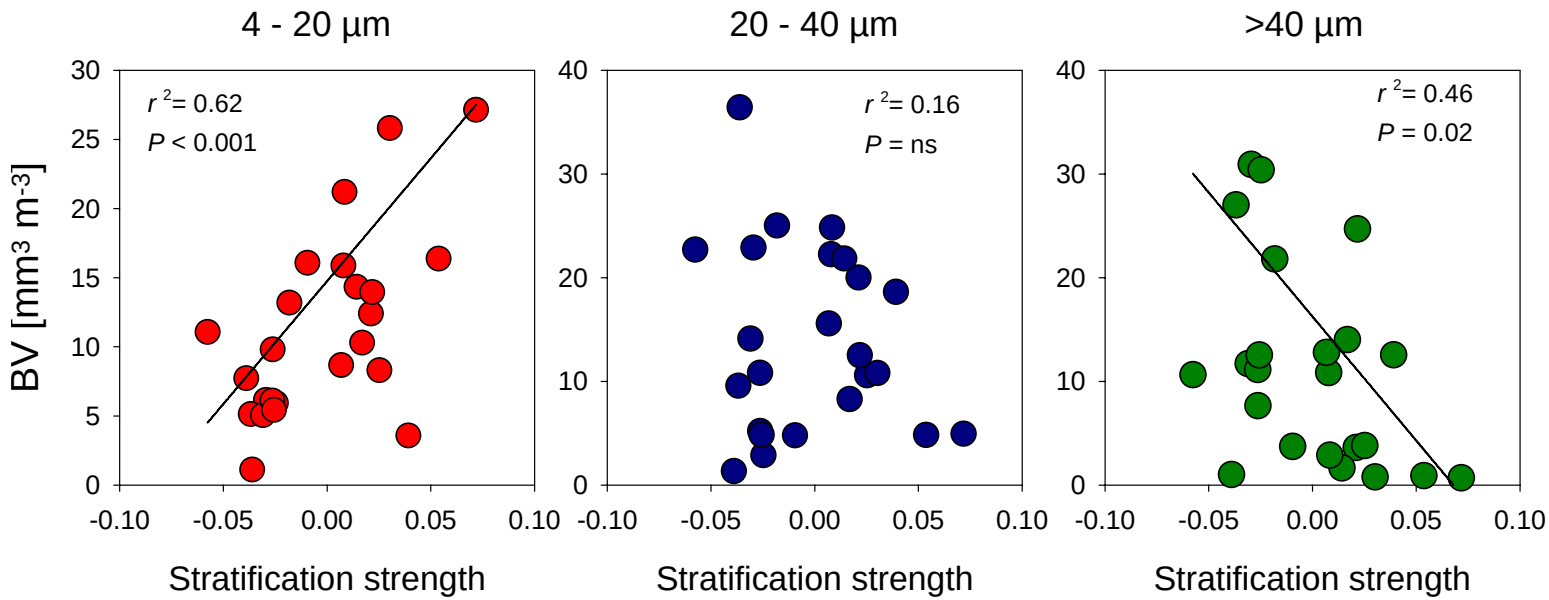
Shift in diatom community structure:
increase of small-sized species



4 - 15 µm; r = 0.24, P=0.018
15 - 40 µm; r = -0.11, P=0.3
> 40 µm; r = - 0.27, P=0.017

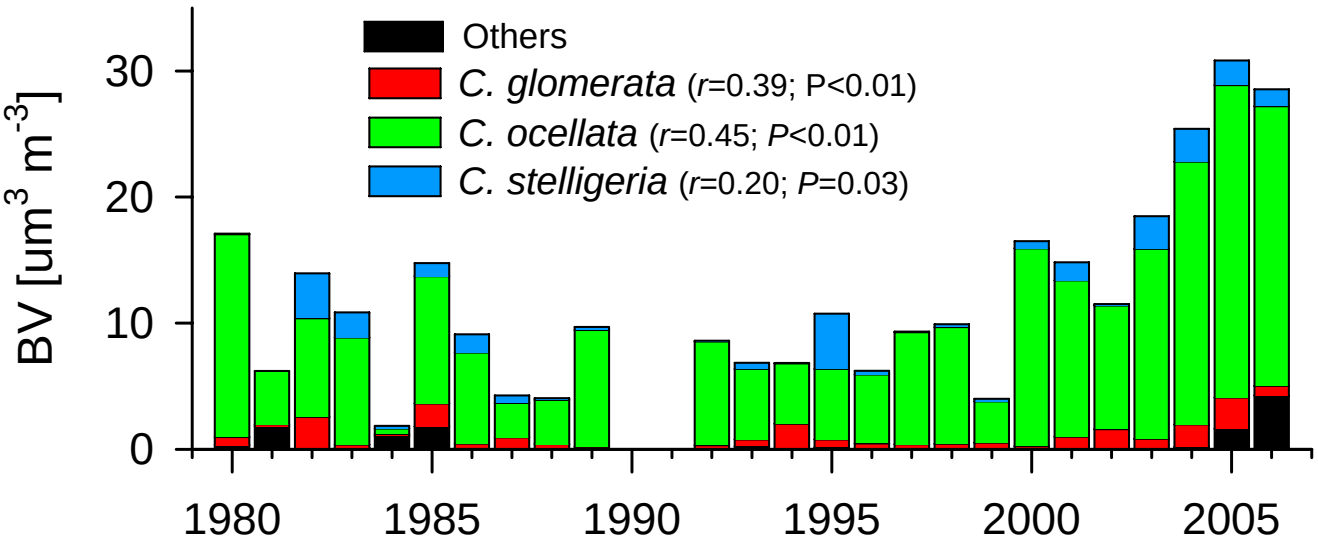
Winder et al. (2009) Prc. Roy. Soc. Lond. B

Stratification explains high variance in small- and large-sized diatoms

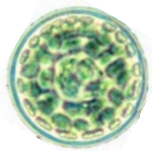


Winder et al. (2009) Prc. Roy. Soc. Lond. B

Lake warming favors small-sized *Cyclotella* species

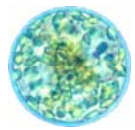


C. ocellata



12 µm

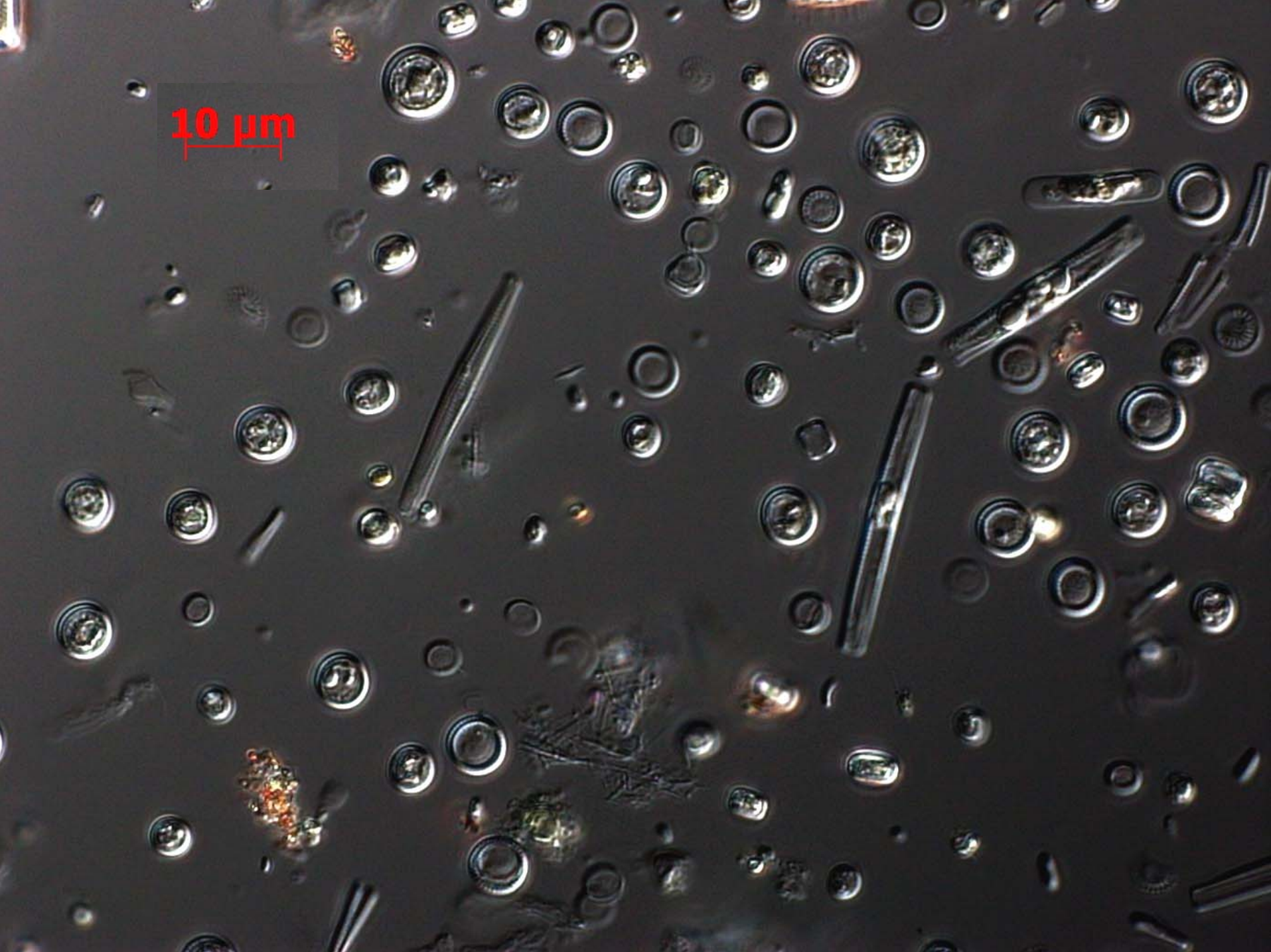
C. stelligeria



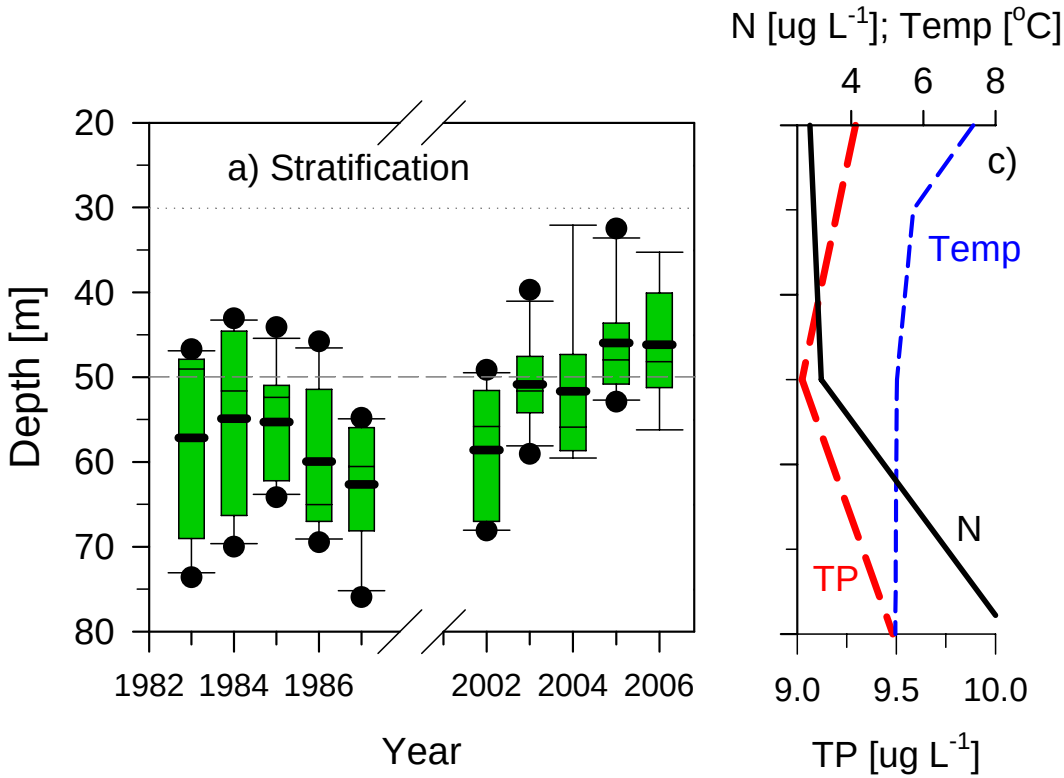
7 µm

C. glomerata

5 µm

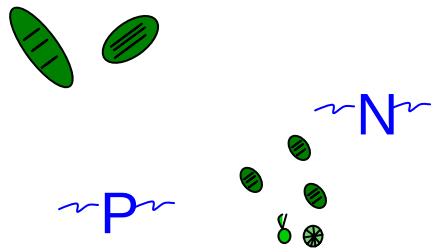

10 µm

Diatoms reside at shallower depth in recent years



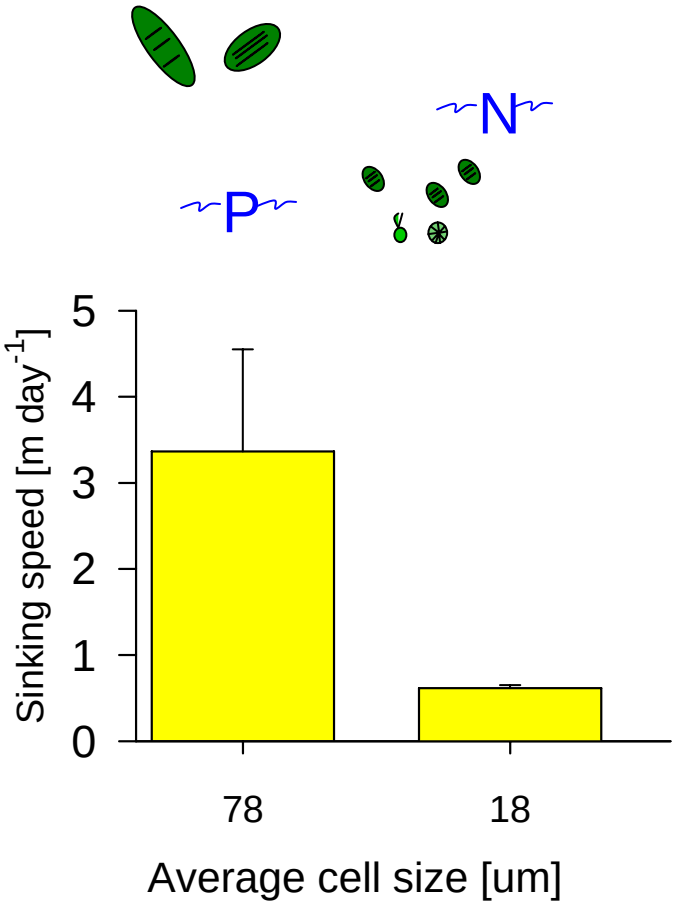
ANOVA: $F_{(62,1)} = 8.46$, $P = 0.005$

Success of small-sized cells



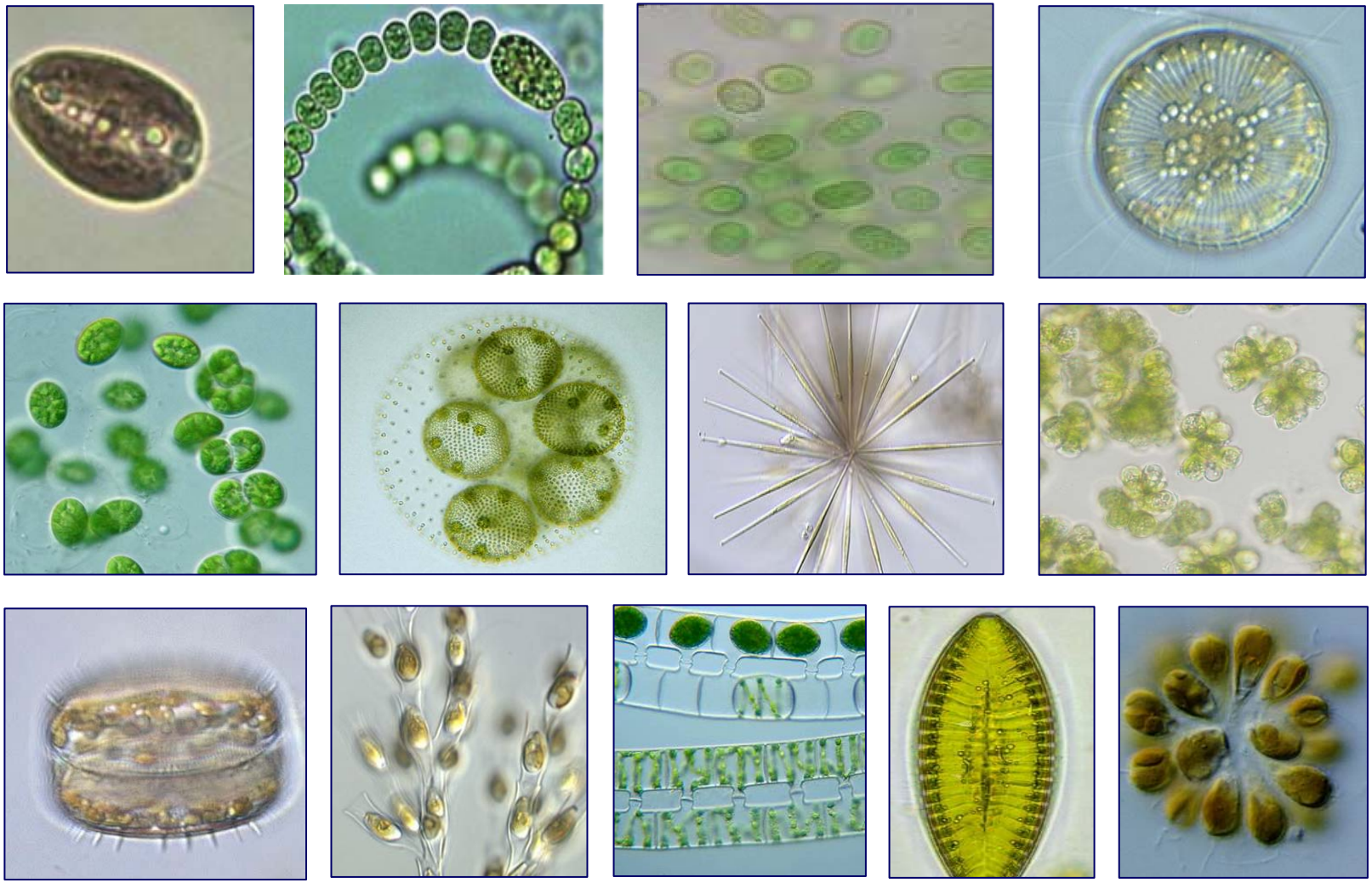
- better competitors under nutrient-limited conditions
- higher turnover rates

Success of small-sized cells



- better competitors under nutrient-limited conditions
- higher turnover rates
- reduced sinking speed

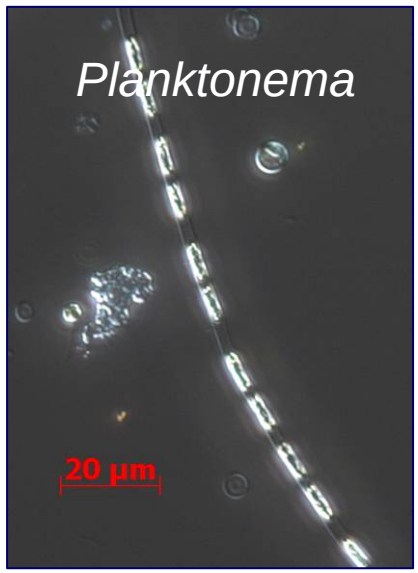
What about other phytoplakton groups?

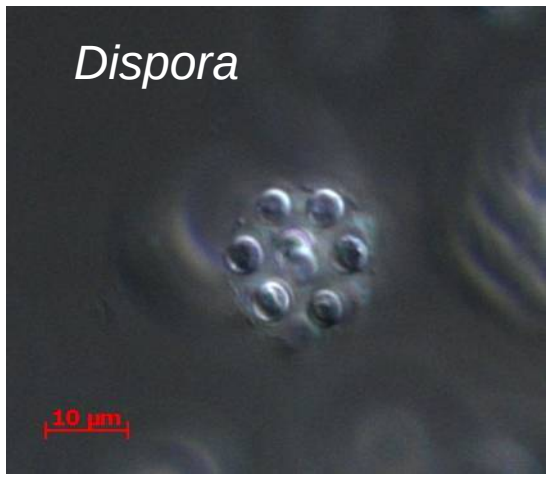


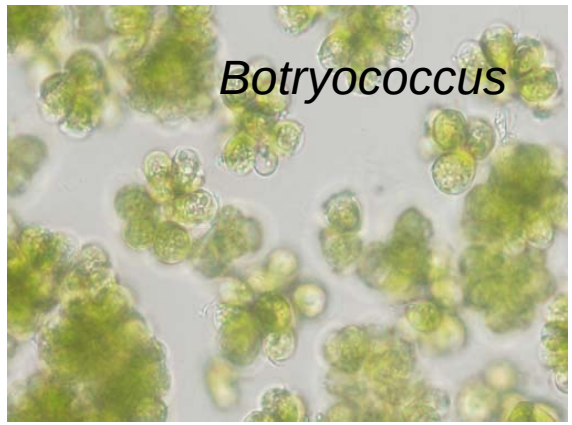
Green algae

Increased

- filamentous and
- colonial cell types





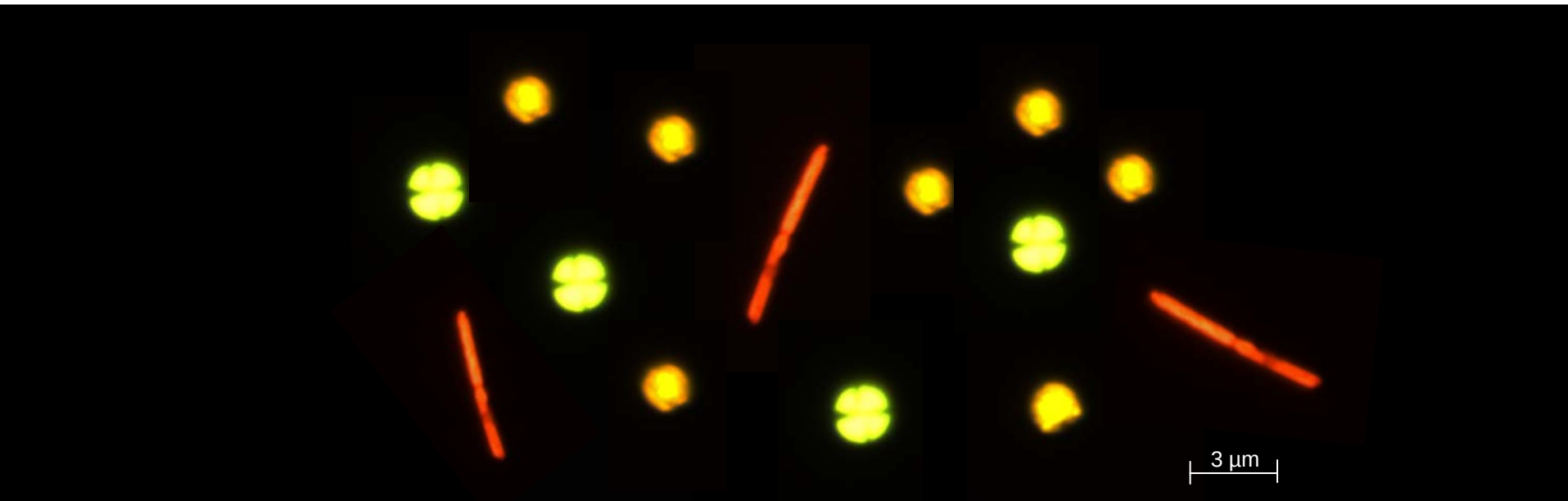


→ form resistance

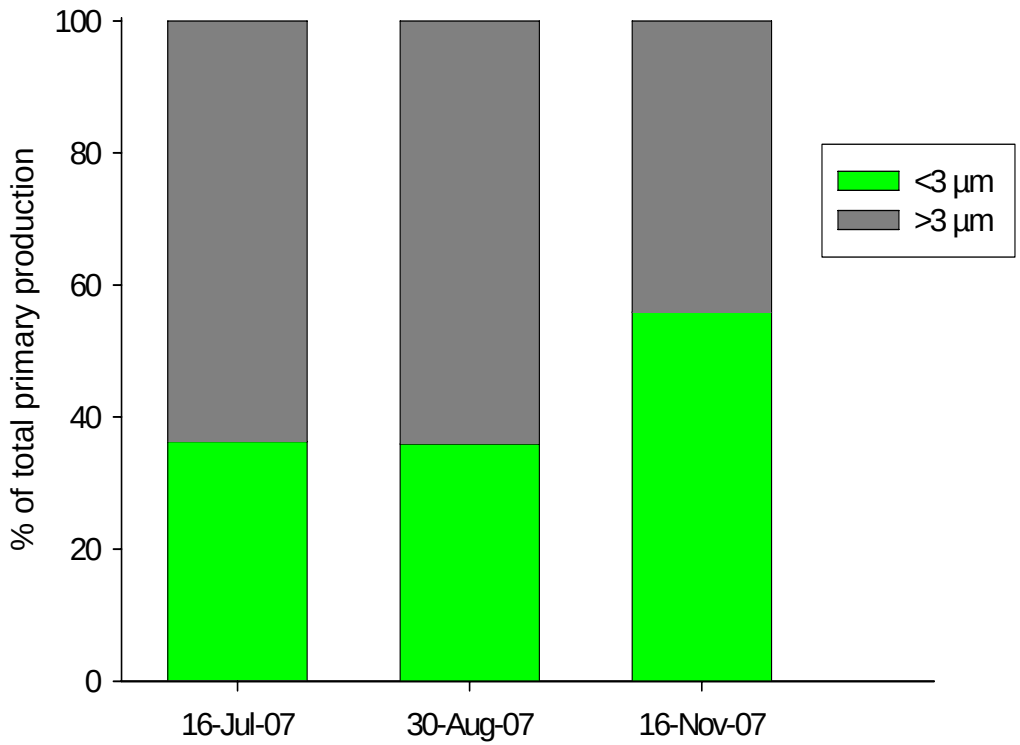
→ mucilaginous sheath and oil inclusion

How does change in mixing affect the smallest algae?

- Contribute substantially of total primary production in oligotrophic systems
- Picophytoplankton: 0.2 - 3 µm in size
  - Picoeukaryotes (high chlorophyll content)
  - Picocyanobacteria (low chlorophyll content)



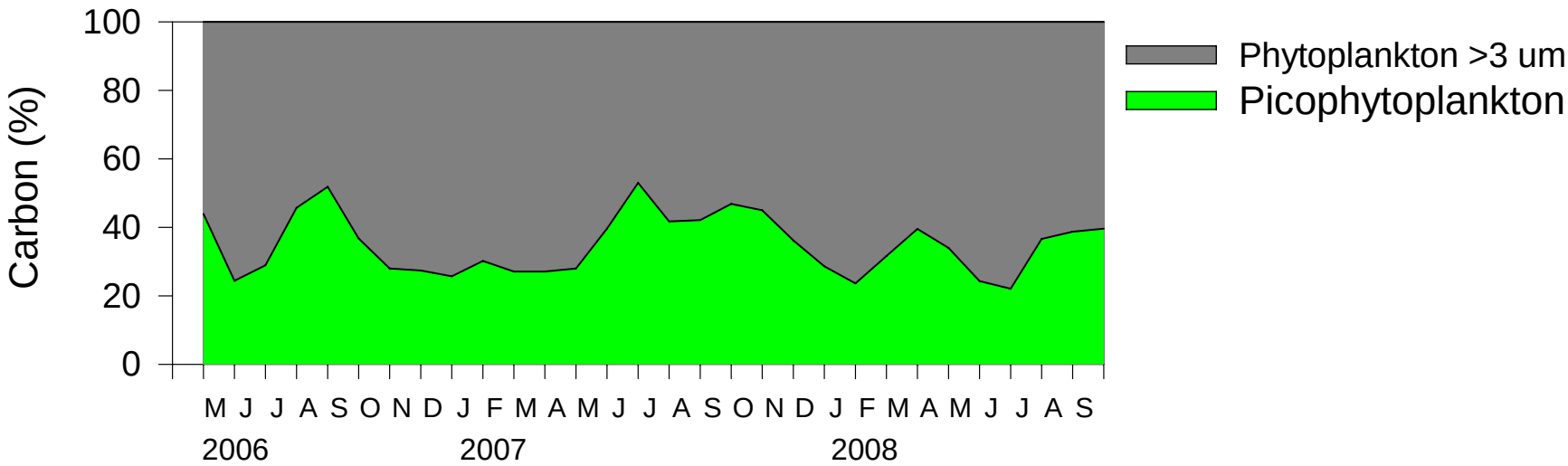
Picophytoplankton contribute ~40 % to total primary production

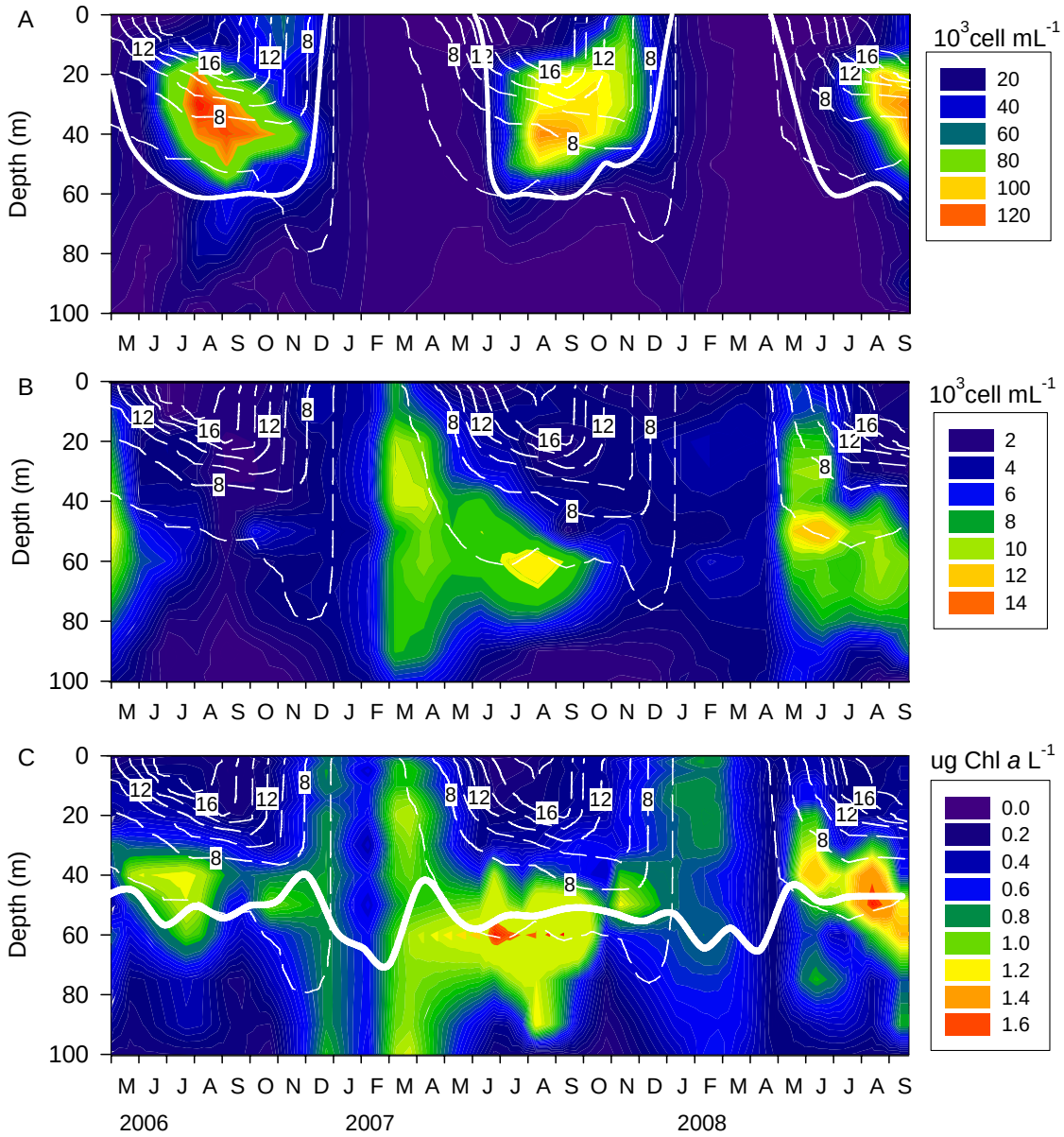


Small-sized cells

- high turnover rate
- scatter light more effectively – contribute to clarity loss

Picophytoplankton contribute ~40 % to total phytoplankton biomass





Picocyanobacteria

→ peak above deep chlorophyll maxima

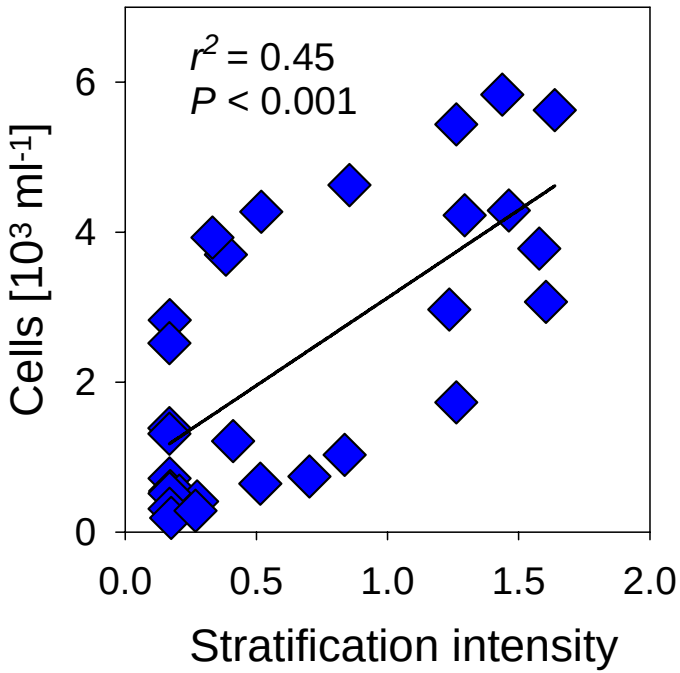
Picoeukaryotes

→ similar pattern than chlorophyll

Chlorophyll

→ deep chlorophyll maxima

Picocyanobacteria dominate under intensified stratification



→ will likely increase with climate warming

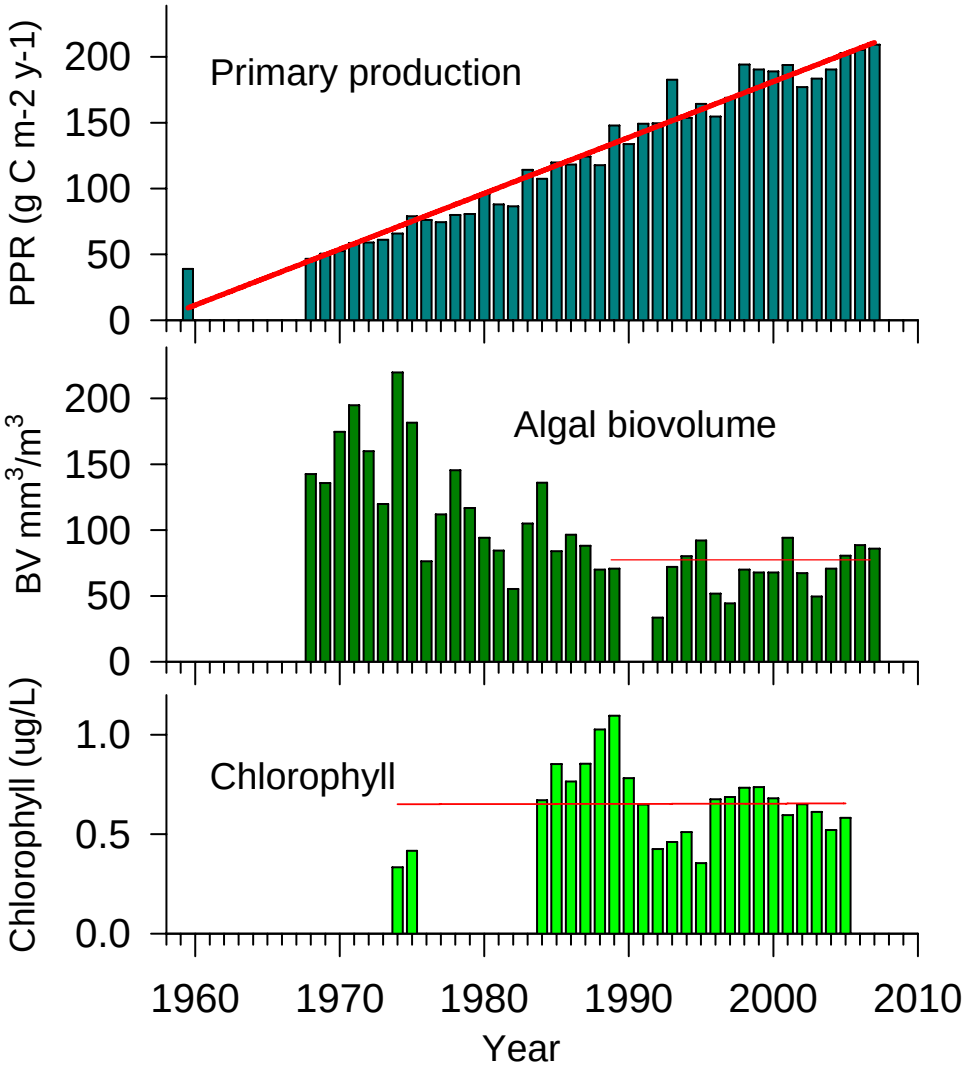
Climate impacts on phytoplankton

- **Climate warming favors**
  - small-sized diatoms
  - filamentous and colonial green algae
  - likely picophytoplankton

  → altered species composition
- **Change in algal species composition**
  - primary productivity rates
  - alters vertical position in the water column
  - fate and transport of carbon

  → affect food-web interactions and water transparency

Can a shift in algal species composition explain the increase in primary production?



Adaptation Strategies

- Climate governs intensity of water mixing and stratification – nationwide effort
- Improved water quality/clarity – allowed large-sized cells to flourish
- Encourage diverse populations that will enhance the ability of species to adapt to changes

Acknowledgements

Charles Goldman

Geoff Schladow · John Reuter

Debbie Hunter · Brant Allen · Bob Richards

Patty Arneson · Scott Hackley · Peter Hunter

Tina Hammell · Anne Liston · TERC team

Brandon Carter · John Zehr

Lake Tahoe Interagency
Monitoring Program (LTIMP)