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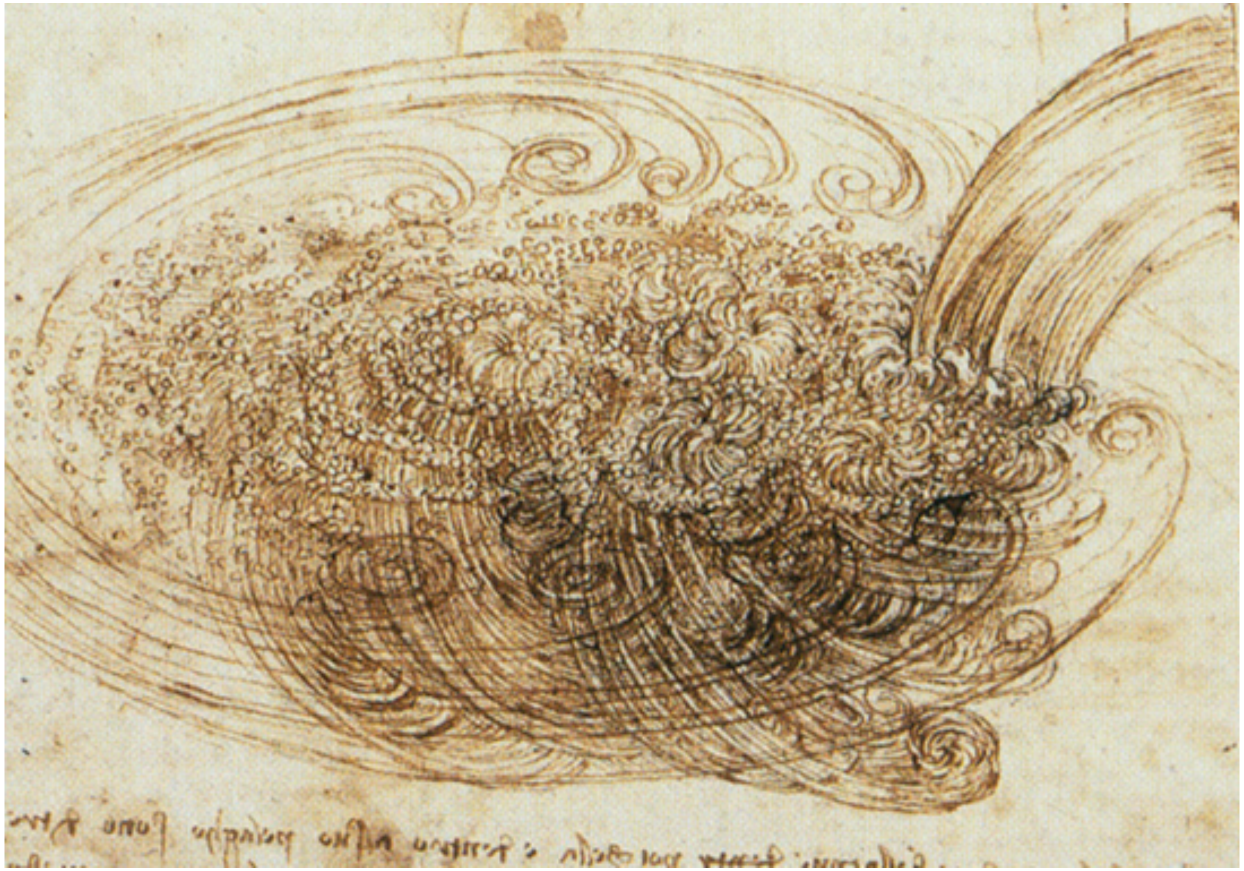
Nutrient supply does play a role on the structure of marine picophytoplankton communities

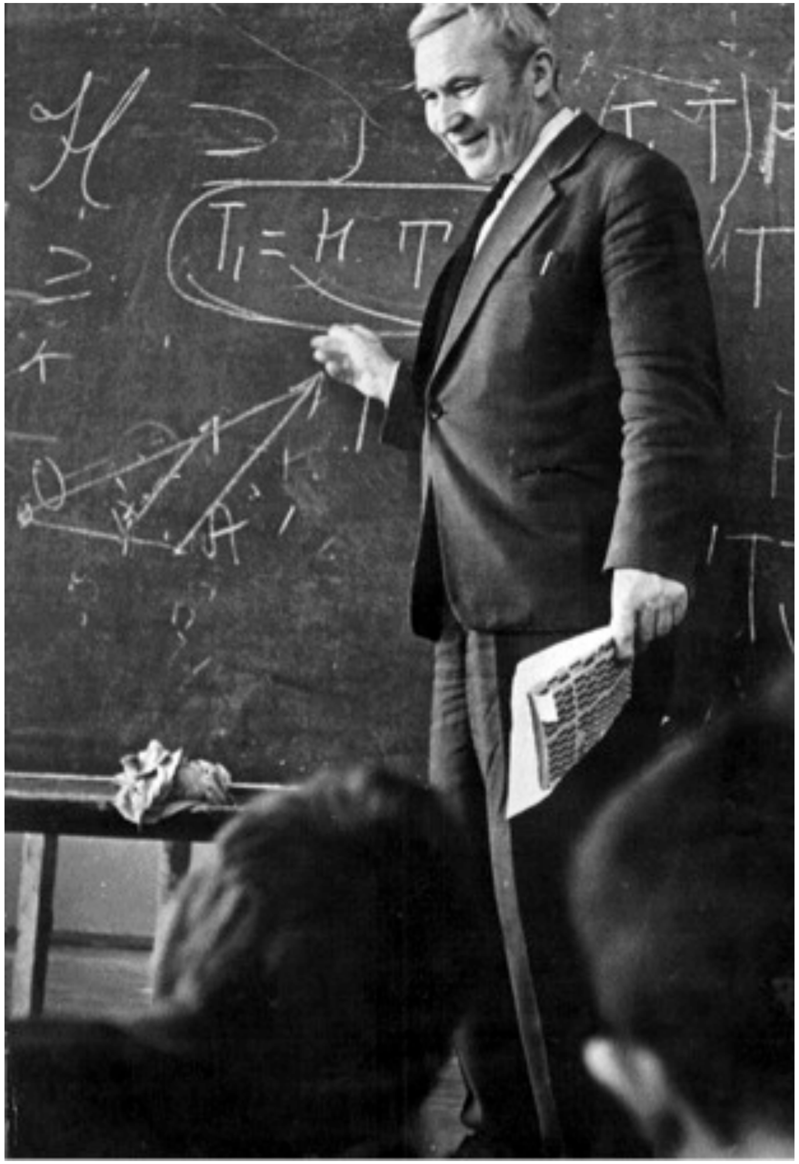
Beatriz Mouriño-Carballido[1], José Luis Otero-Ferrer[1], Susana Agustí[2], Antonio Bode[3], Pedro Cermeño[4], Paloma Chouciño[1], José da Silva[5], Bieito Fernández-Castro[1], Josep Gasol[4], Miguel Gilcoto[6], Rocío Graña[6], Mikel Latasa[7], Luis Lubián[8], Emilio Marañón[1], Xosé Anxelu G. Morán[2], Enrique Moreno-Ostos[9], Víctor Moreira[1], Manuel Ruiz[3], Renate Scharek[7], Sergio Vallina[4], Marta M. Varela[3], Marina Villamaña[1]

1. Universidade de Vigo, Spain
2. King Abdullah University of Science and Technology, Saudi Arabia
3. IEO-Coruña, Spain
4. CSIC-Barcelona, Spain
5. Porto University, Portugal
6. CSIC-Vigo, Spain
7. IEO-Xixón, Spain
8. CSIC-Cádiz, Spain
9. Universidad de Málaga, Spain

Sketch of turbulent flow by Leonardo da Vinci

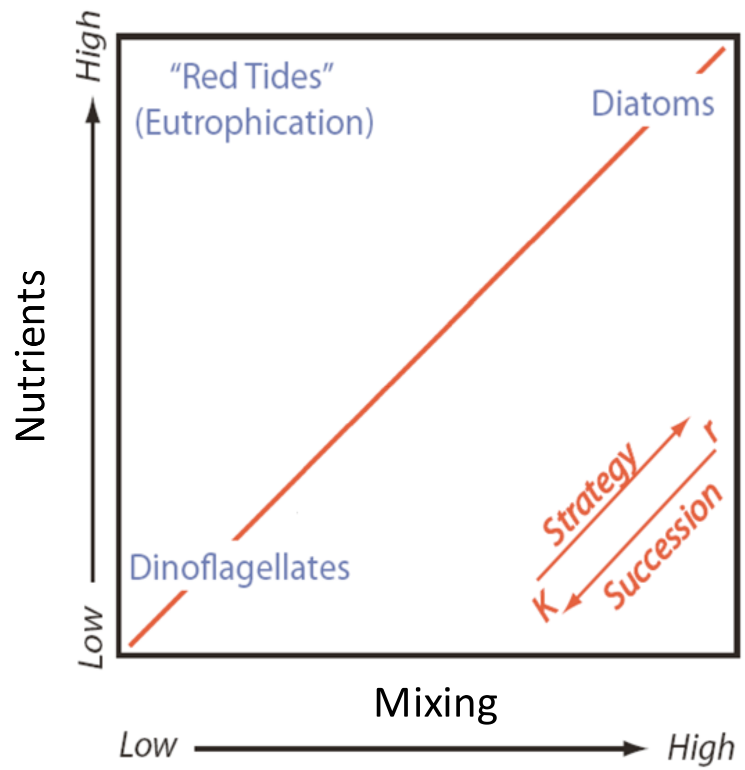


Andrey Nikolaevich Kolmogorov (1903-1987)

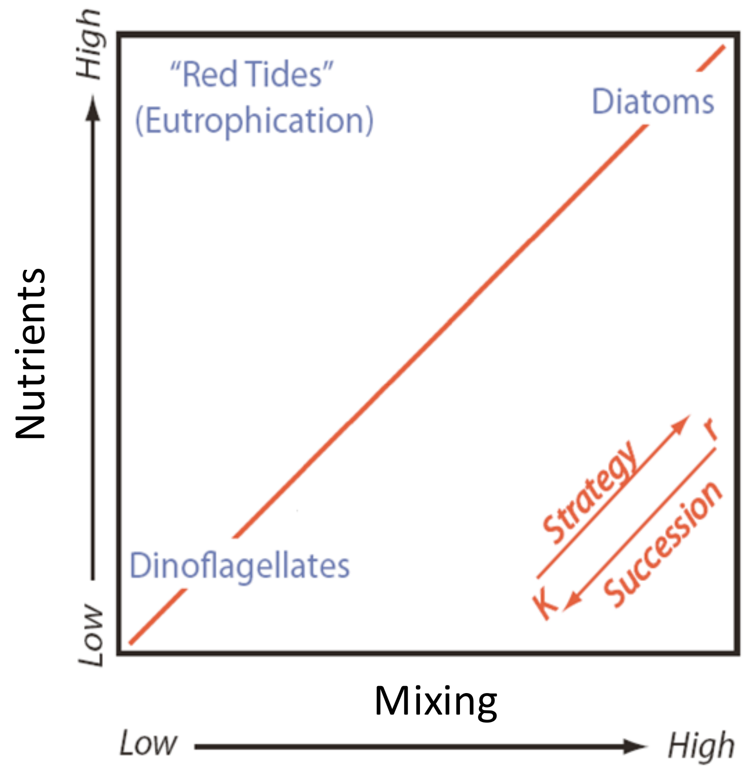


Microstructure turbulence profiler by Miquel Alcaraz (CSIC-Barcelona)

Revisiting the mandala of Margalef (1978)

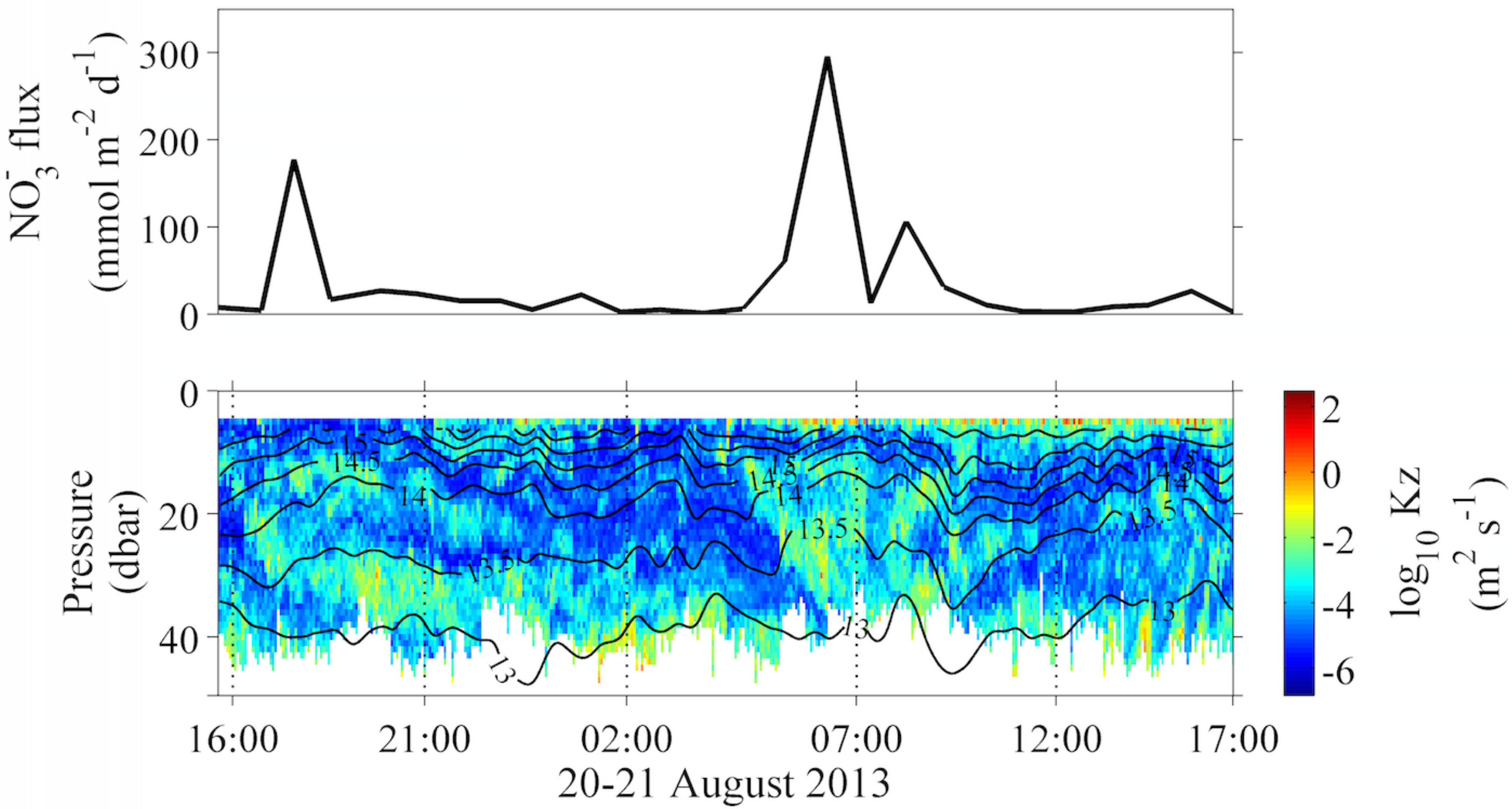


Revisiting the mandala of Margalef (1978)



Methodological difficulties to quantify mixing (Kz) in the field

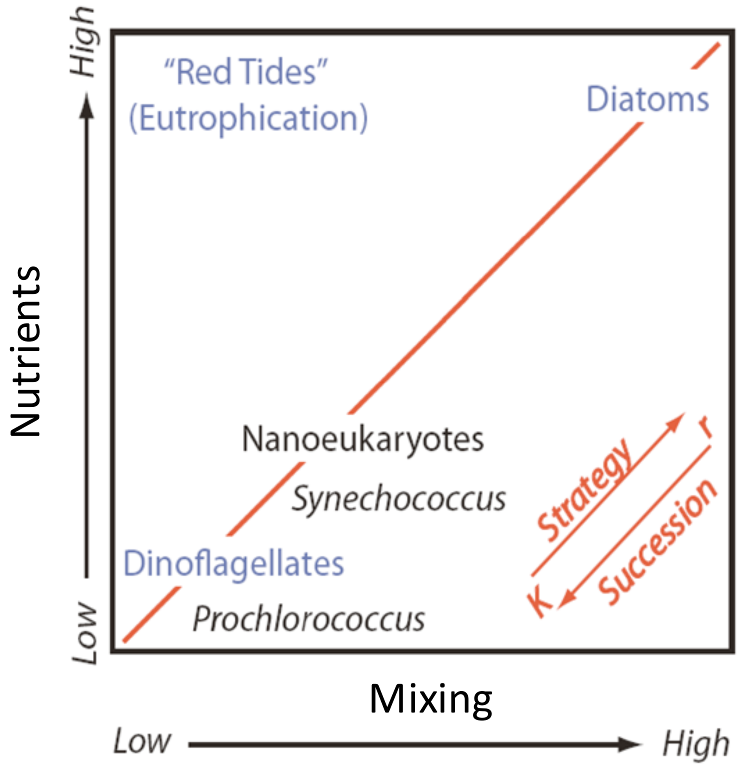
Internal wave mixing and nutrient supply on the shelf off Ría de Vigo (NW Spain)



Villamaña-Rodríguez et al (in prep.)

Mixing and stratification: related but not the same

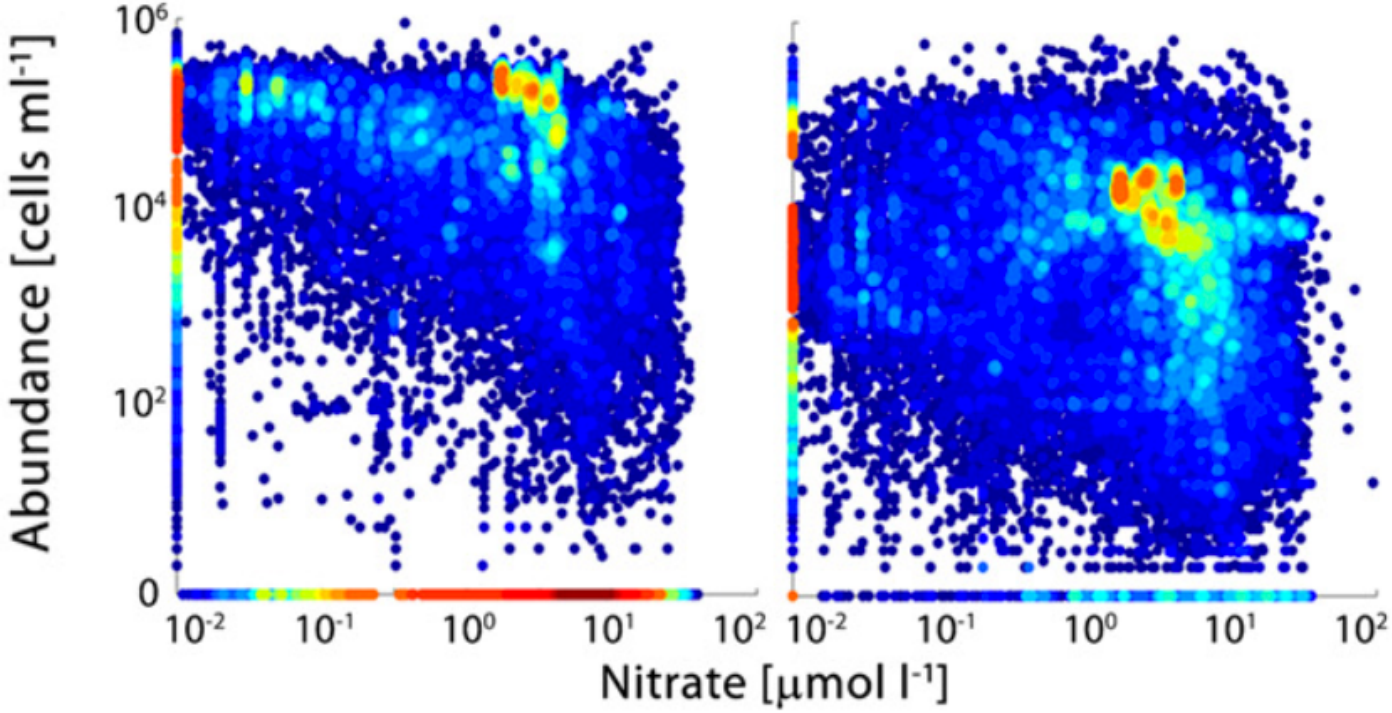
Revisiting the mandala of Margalef (1978)



The picophytoplankton groups were not included in the original diagram

Picoplankton (≤ 2 µm) often dominate primary production, and recent studies suggest a significant contribution to carbon export (Richardson and Jackson, 2007; Guidi et al, 2016)

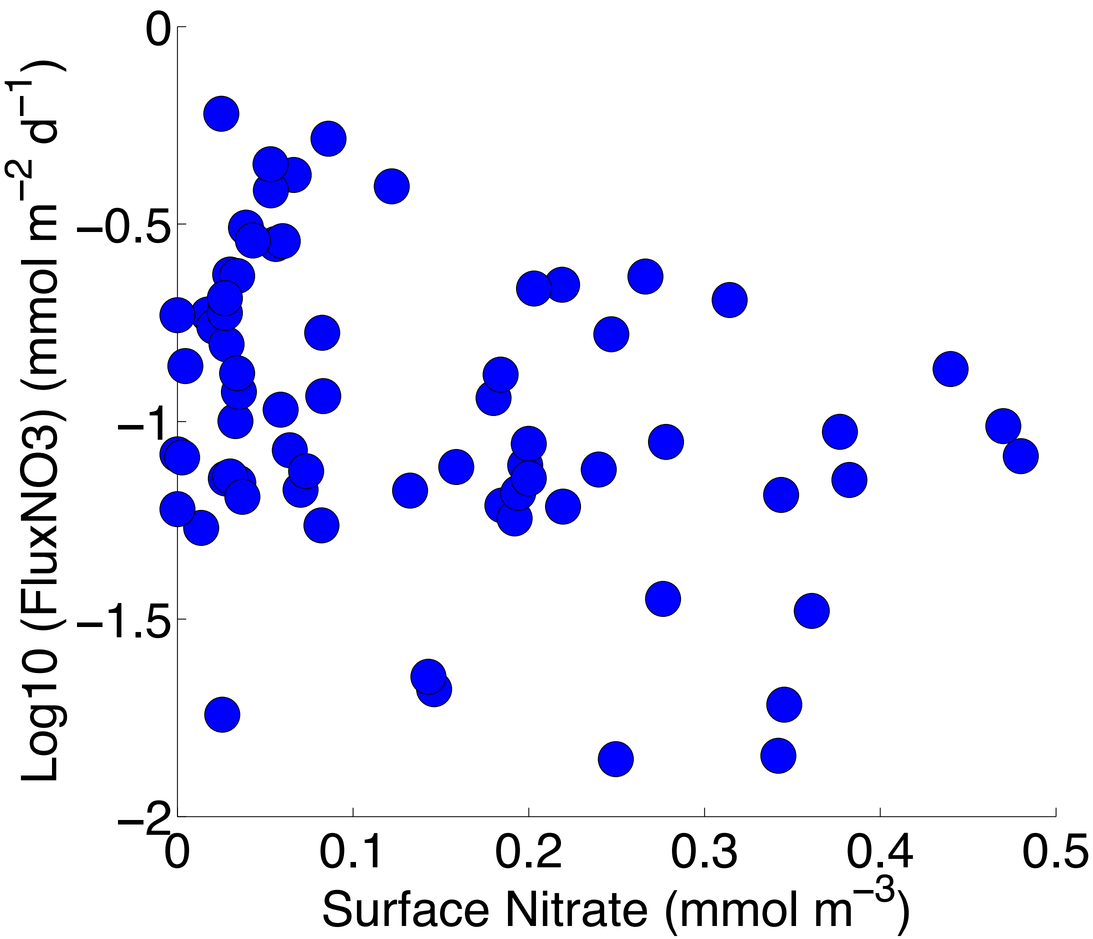
Control factors on *Prochlorococcus* and *Synechococcus* regional distributions



Flombaum et al. (2013, PNAS)

No relationship between nutrient concentration and cell abundance

Nitrate flux versus surface nitrate concentration in oligotrophic regions



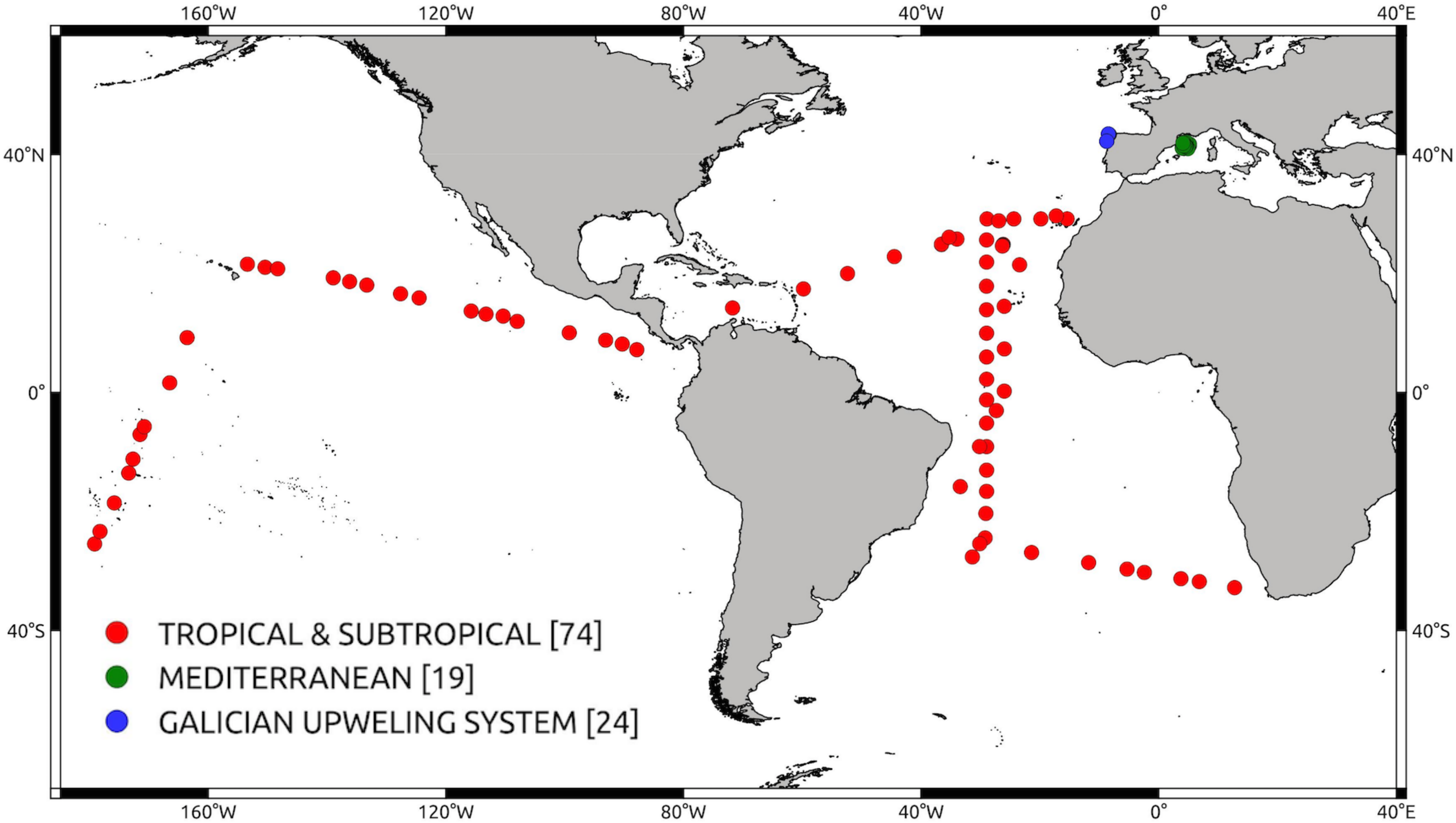
Mouriño-Carballido et al. (2011, L&O)

The variability in nutrient concentration can be disconnected from changes in nutrient supply

Our hypothesis

The Margalef’s mandala also applies within the picoplankton size-class

Data set of microstructure turbulence and picoplankton properties (2006-2013)



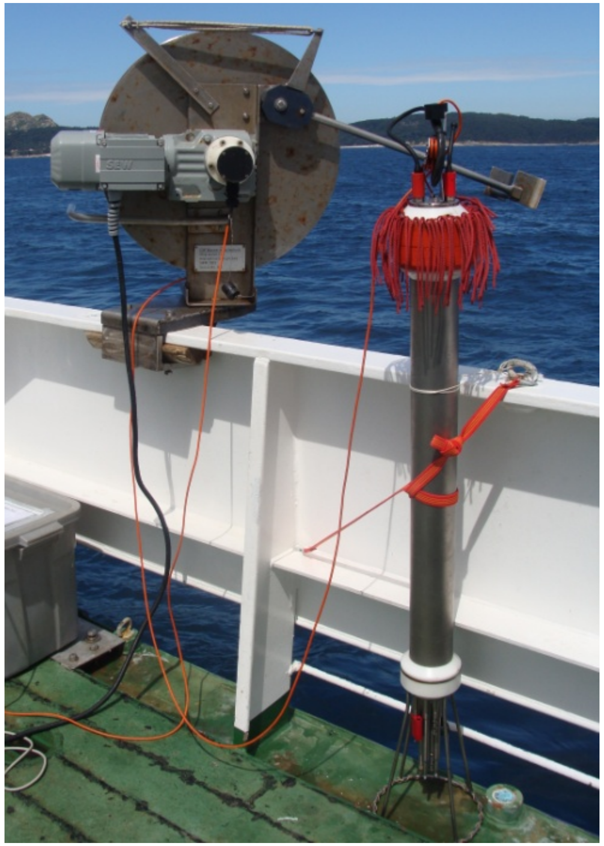
117 Stations:

- Microturbulence (MST profiler, 0-200 m)
- Nitrate concentration (0-200 m)
- Picoplankton abundance and cell properties (Flow cytometry, photic layer) →

Prochlorococcus
Synechococcus
Small picoEuk

How did we quantify vertical mixing (Kz)?

MSS (Micro-Structure-Turbulence) profiler



ISW Wassermesstechnik (http://www.ISW-Wasser.com)

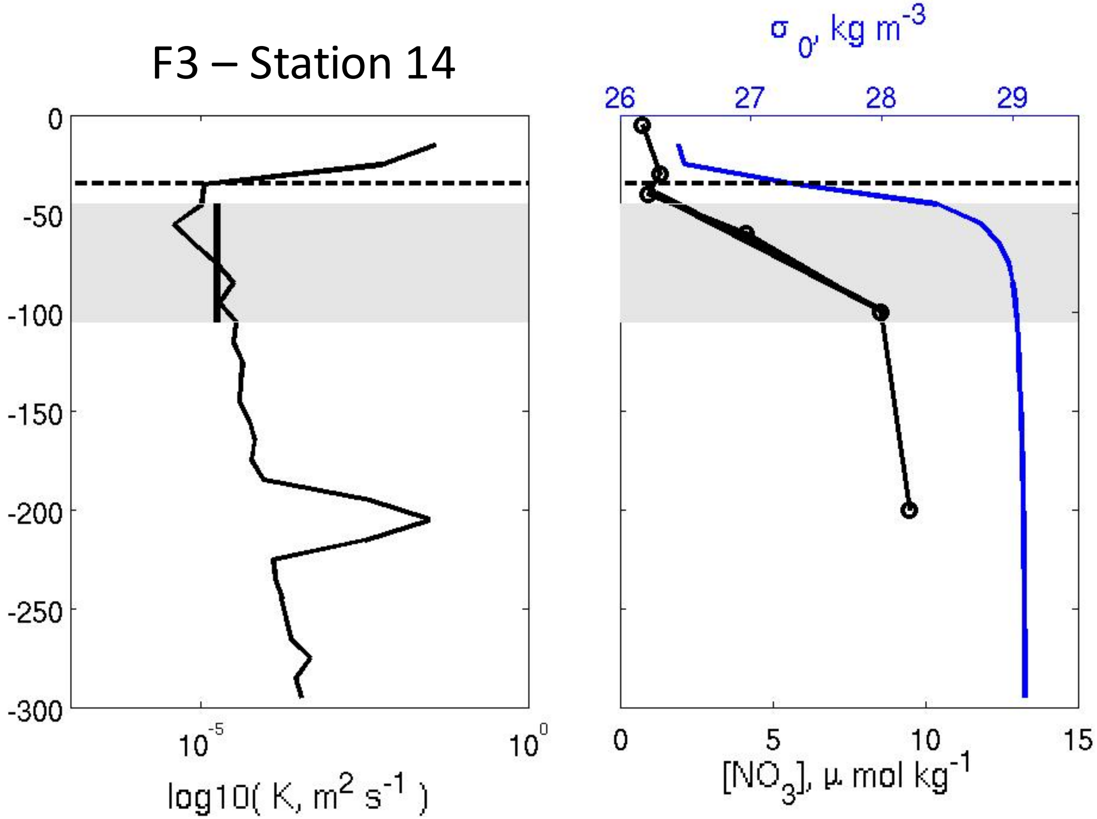
Vertical diffusivity (Kz):

$$Kz = 0.2 \frac{\varepsilon}{N^2}$$ Osborn (1980)

ε Dissipation rate of turbulent kinetic energy

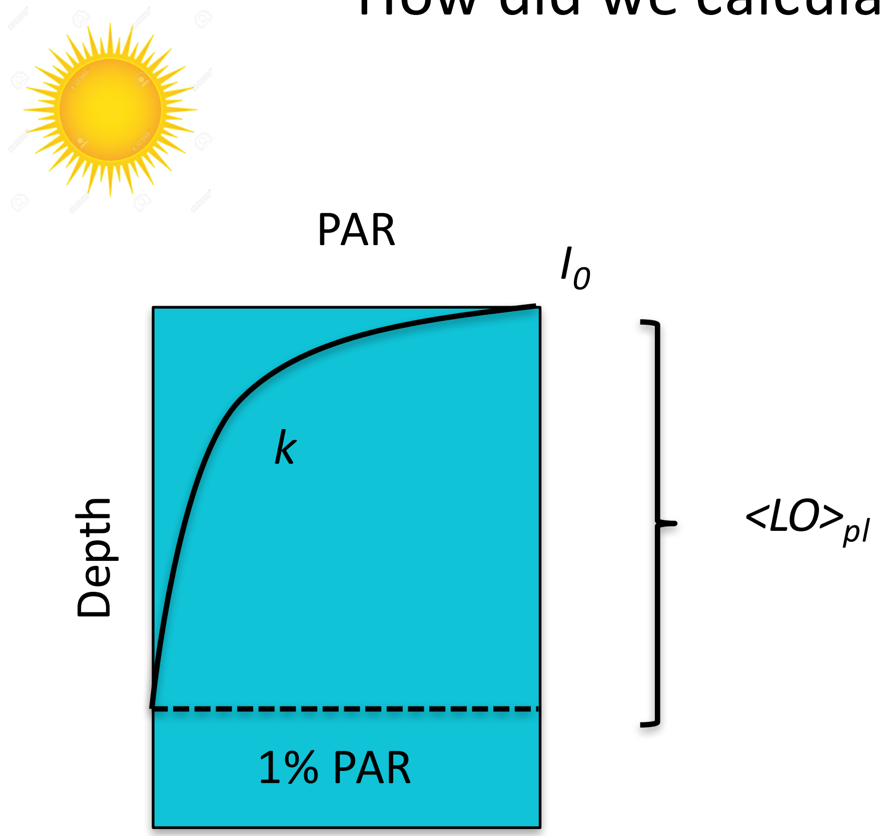
N Brünt Väissälä frequency

How did we calculate the diffusive transport of nitrate across the nutricline?



$$Flux_{nut} = \langle K_z \rangle \frac{d\,[nut]}{dz}$$

How did we calculate light availability (LA)?



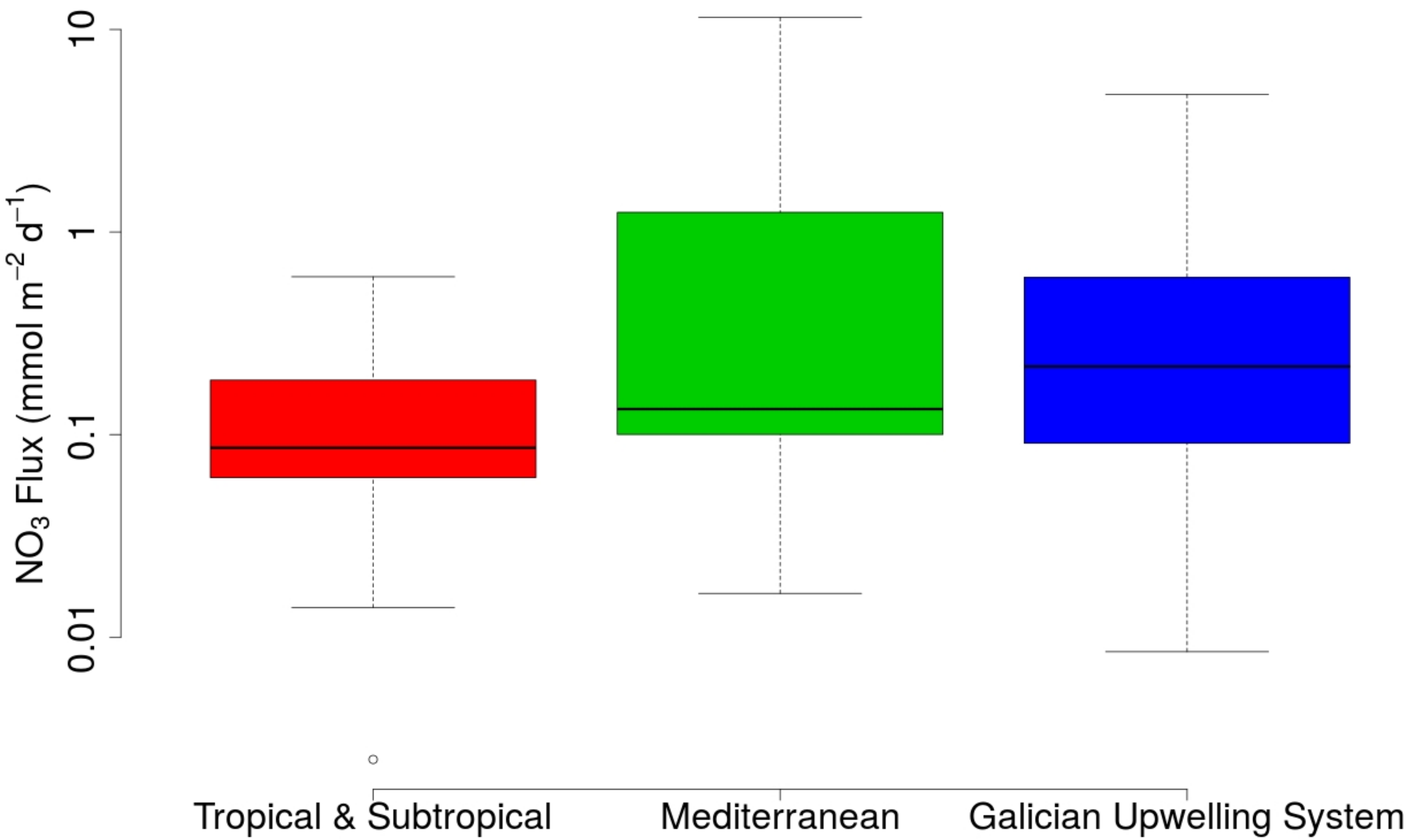
$$LA = \frac{I_0}{k \cdot <LO>_{\mathrm{pl}}}\left(1 - \exp^{-k \cdot <LO>_{\mathrm{pl}}}\right)$$

$$LO = (\varepsilon N^{-3})^{1/2}.$$

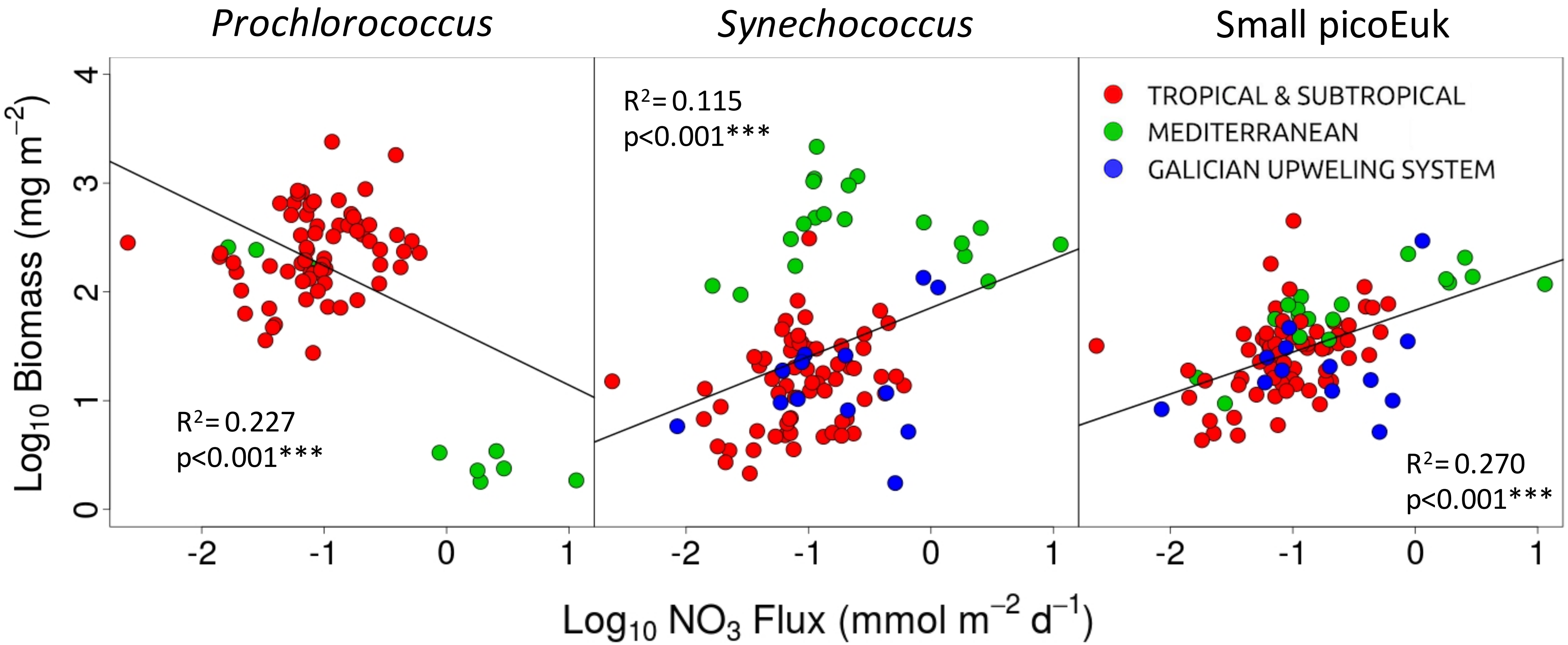
I_0	Surface PAR (Photosynthetic Active radiation)
k	Light Extintion Coefficient
$<LO>_{pl}$	Averaged photic layer Osmidoz Scale
ε	Dissipation rate of turbulent kinetic energy
N	Brünt Väissälä frequency

What did we find…?

Variability in nitrate diffusive fluxes



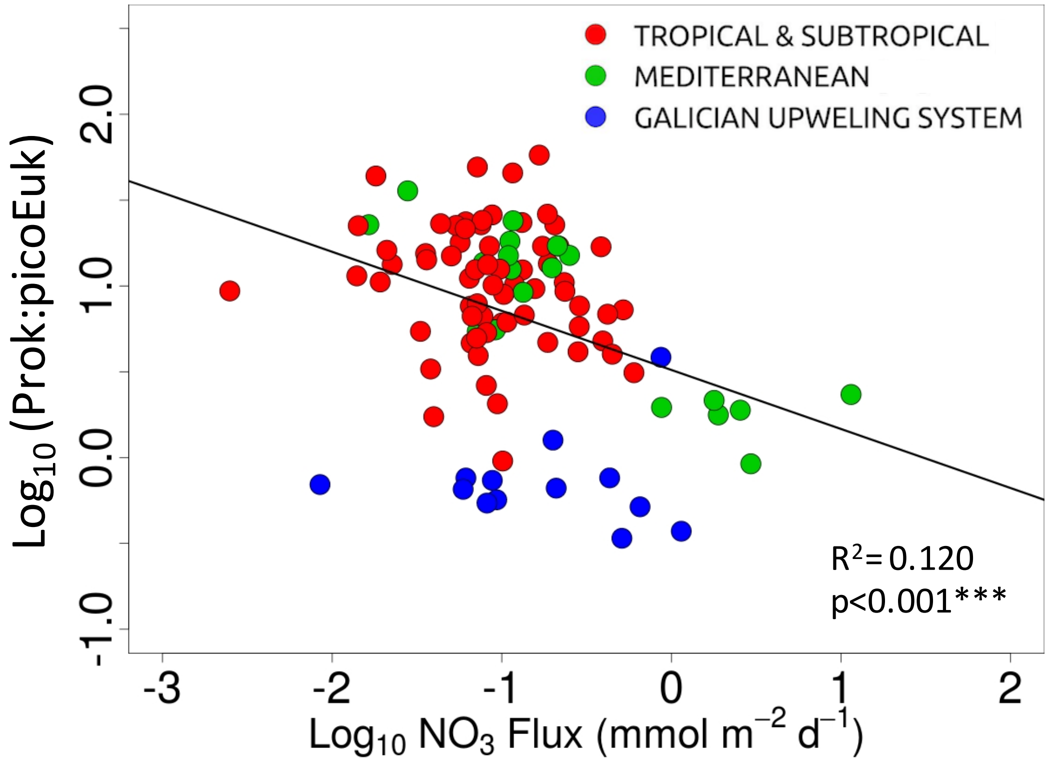
Photic layer depth-integrated picoplankton biomass vs NO_3 diffusive flux



Prochlorococcus biomass was high when NO_3 supply was low, whereas that of *Synechococcus* and picoeukaryotes increased at high supply

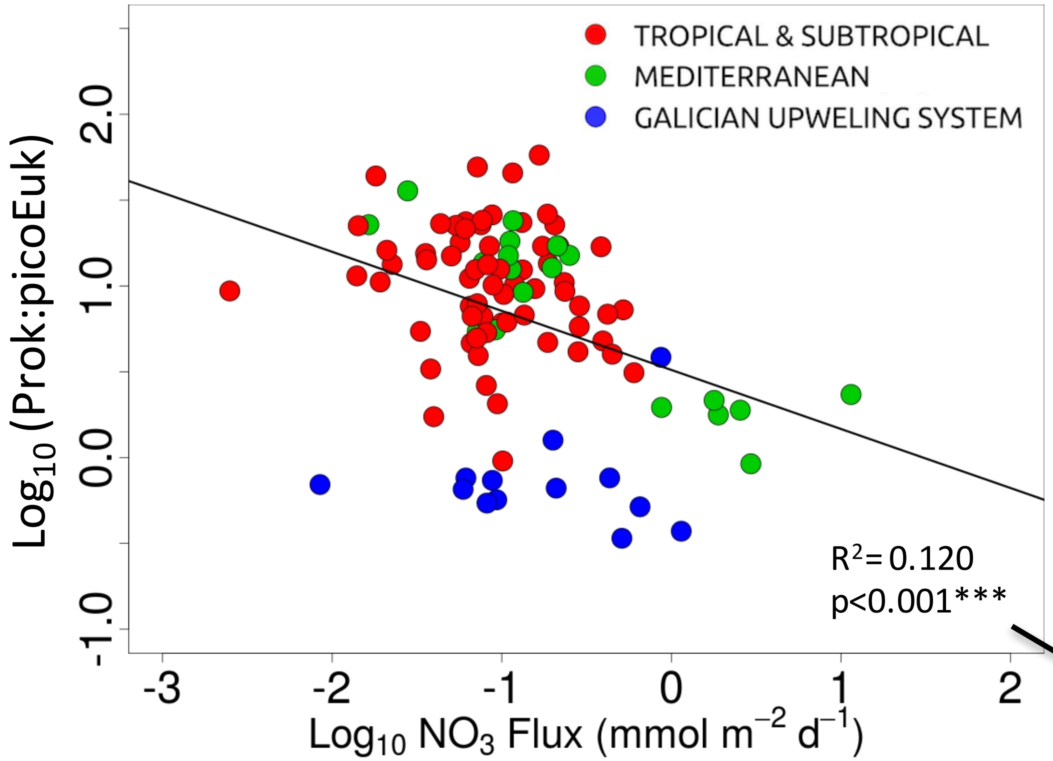
The fate of the carbon fixed in the upper layer depends on the composition of the picoplankton groups (ratio prokaryotes to picoeukaryotes) (Corno et al., 2007)

Ratio Prokaryote to picoEukaryote biomass vs NO_3 fluxes



The ratio Prok to picoEuk biomass decreases with increasing nutrient supply

Generalized Additive Models (GAM): NO_3 Flux, Light availability (LA), Temperature (T)



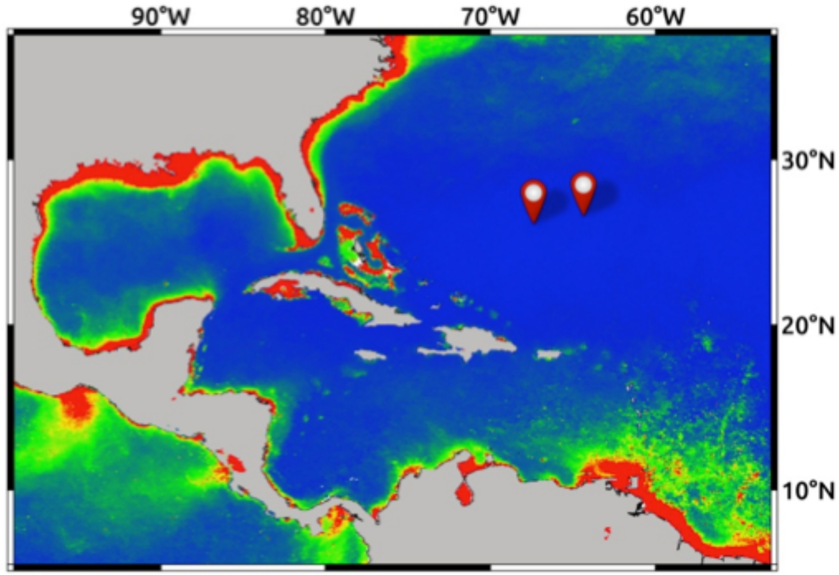
× 3.2

Log_{10} (Prok:picoEuk)=-0.220*Log10 (**NO_3 Flux**)-s(**LA**)+0.028**T**

R^2(adj)=0.389
p<0.05*

Light availability and temperature do also play a role

Chemostat competion experiments



Picoplankton groups:

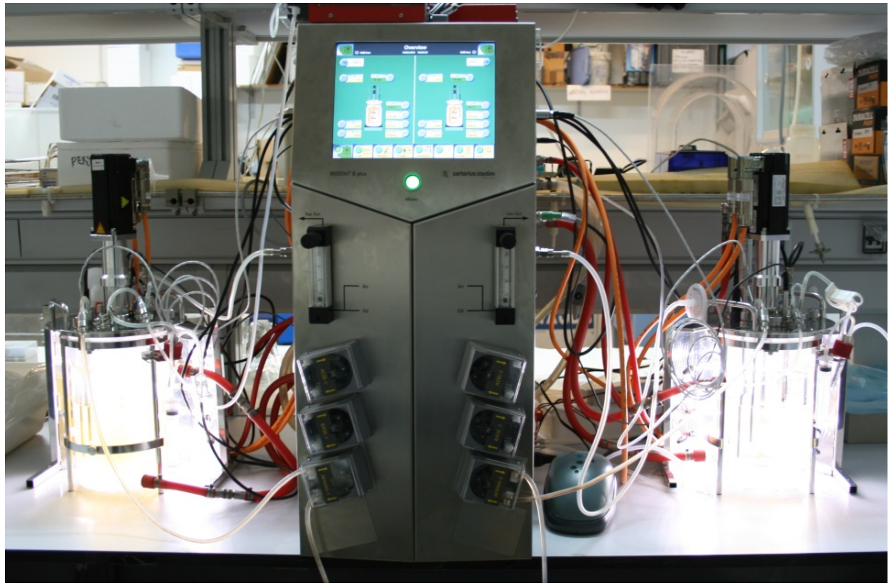
- *Synechococcus sp.* (RCC-2366)
- *Micromonas pusilla* (RCC-450)

Fully-acclimated populations:

- Media: modified PCR-S11 (N:P=5:1; 50 μM NO_3)
- Light: 100 μmol m^{-2} s^{-1}
- Temperature: 21ºC
- Steady-state (Dilution rate: 0.225 d^{-1})

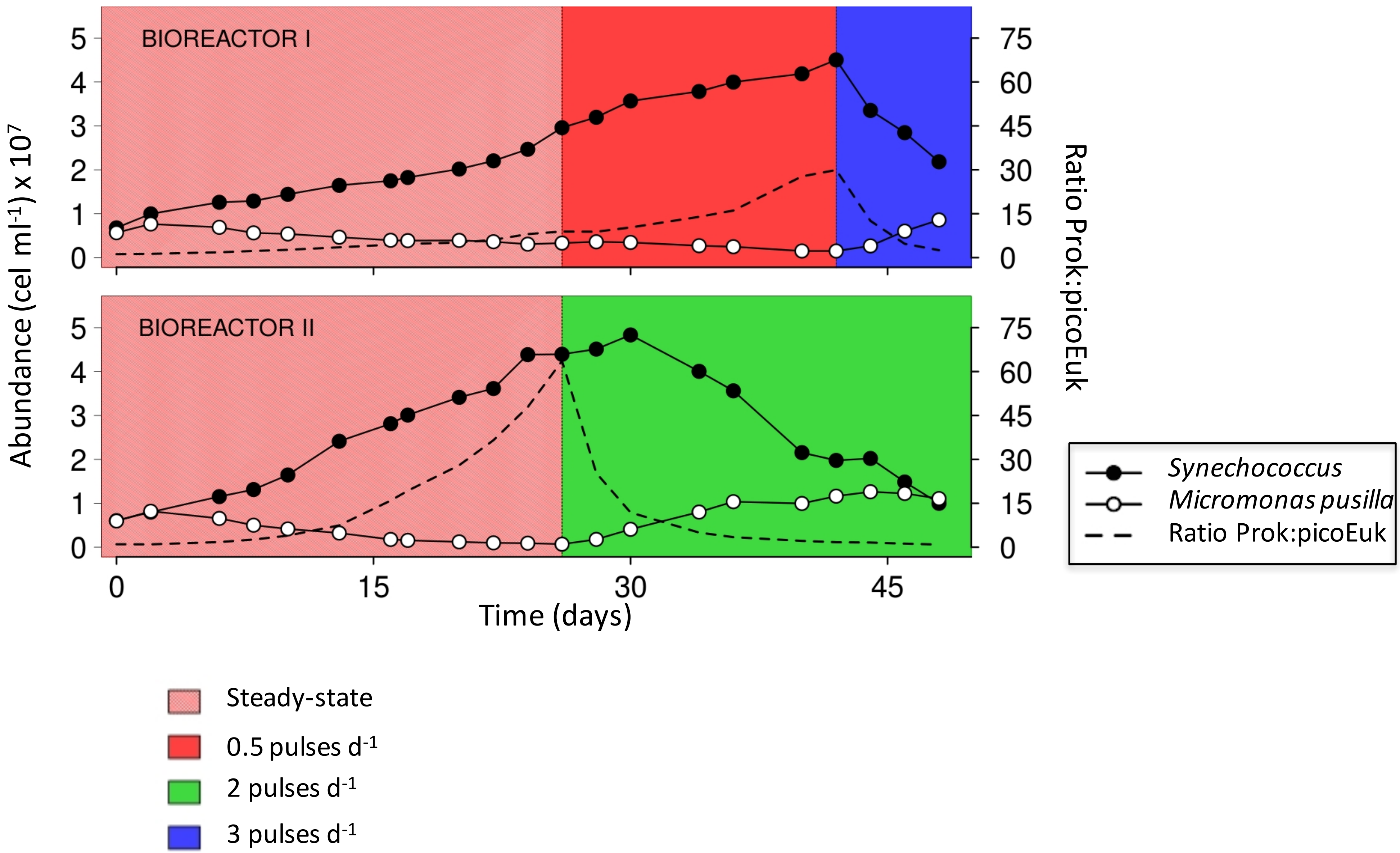
Nutrient perturbations ($\Delta NO_{3:}$ 5 μM):

- 0.5 pulses d^{-1}
- 2 pulses d^{-1}
- 3 pulses d^{-1}

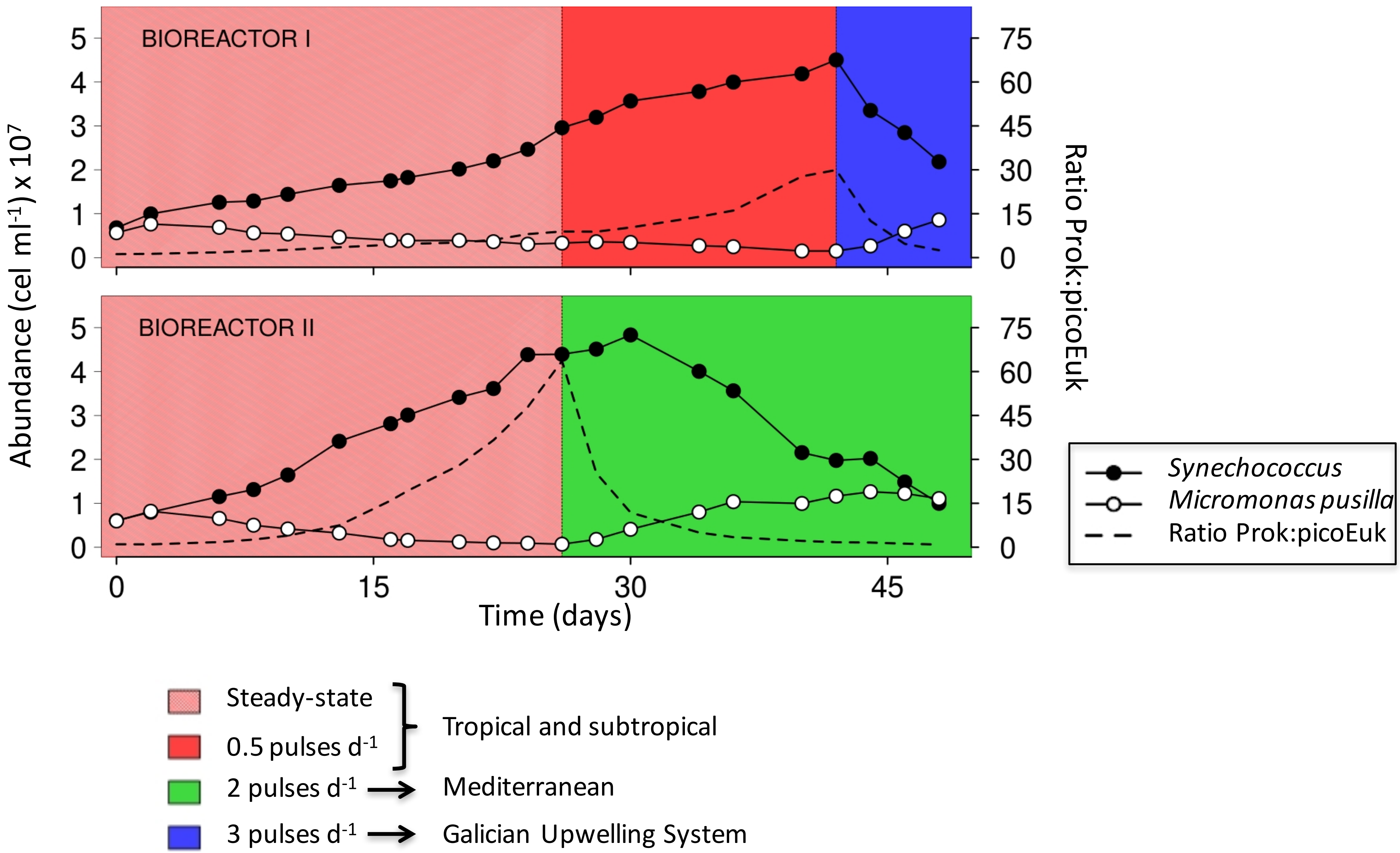


Sartorius Biostat Plus

Population dynamics under nitrate-limiting and nitrate-pulsing conditions



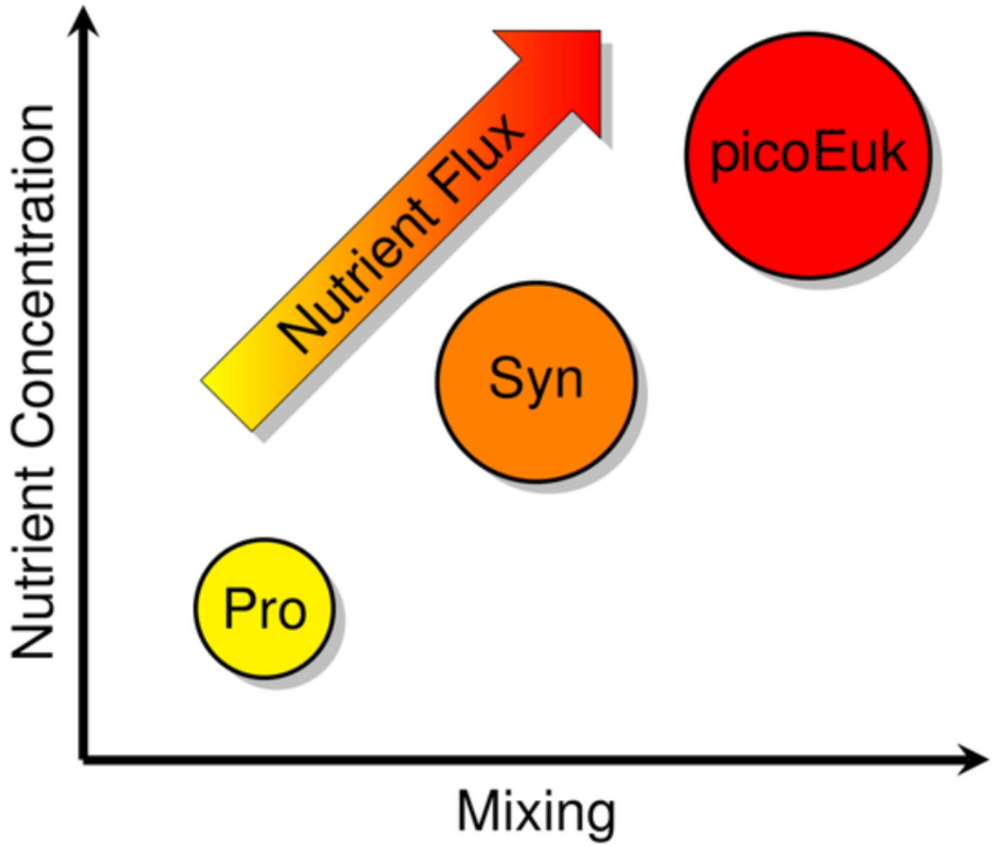
Population dynamics under nitrate-limiting and nitrate-pulsing conditions



Our hypothesis

The Margalef's Mandala also applies within the picoplankton size-class

Dominance of picophytoplankton groups to biomass



Mouriño-Carballido et al. (2016, MEPS)

Due to differences in nutrient uptake abilities, picophytoplankton groups exhibit different behaviour to nutrient supply

Thanks to…

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