Seasonality of Bacterial Phylotypes Affected by Bottom-up and Top-down Control in Piburger See, Austria

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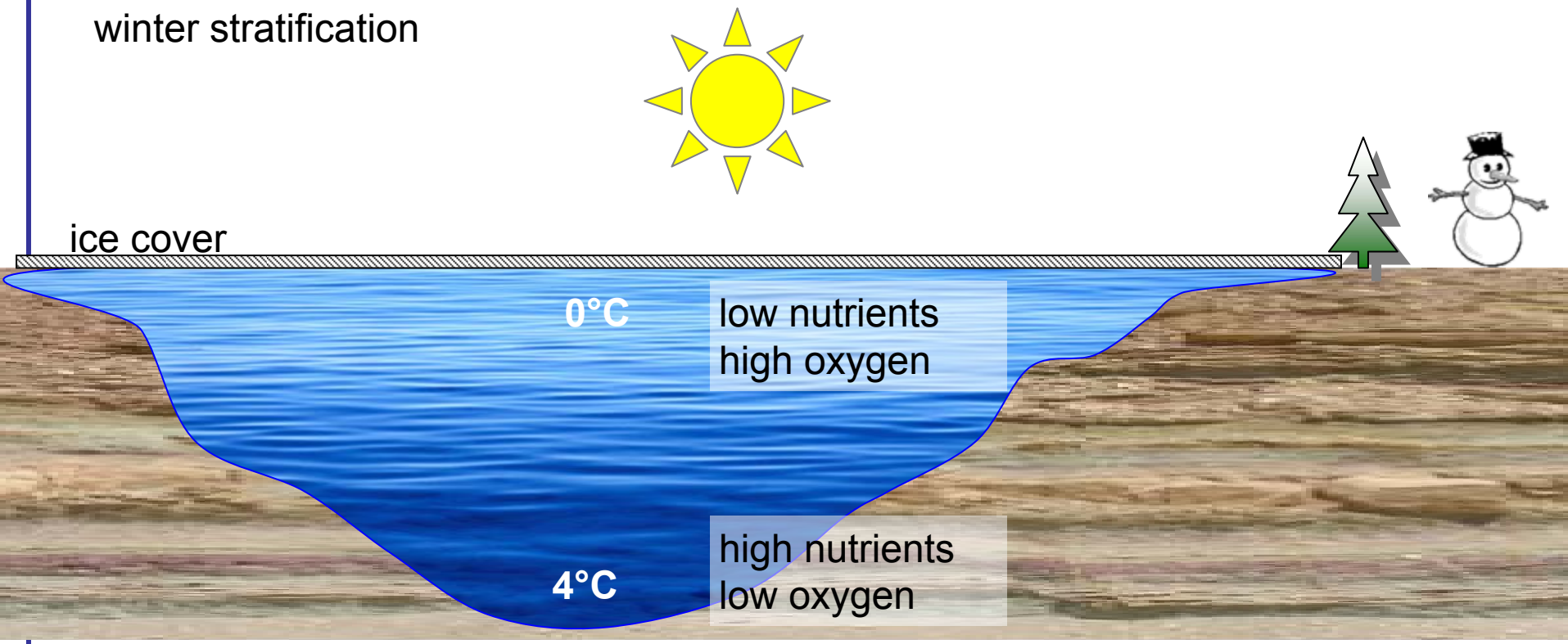
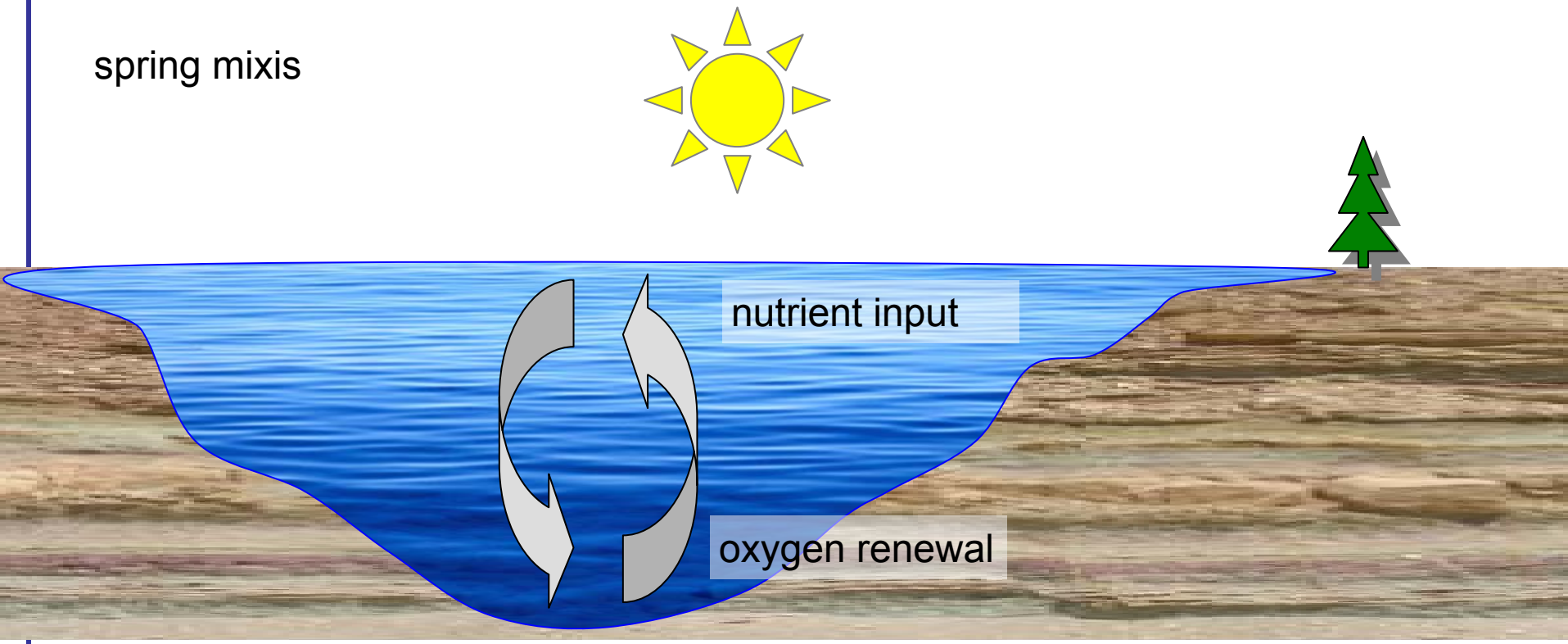
why seasonality of lakes?

winter stratification



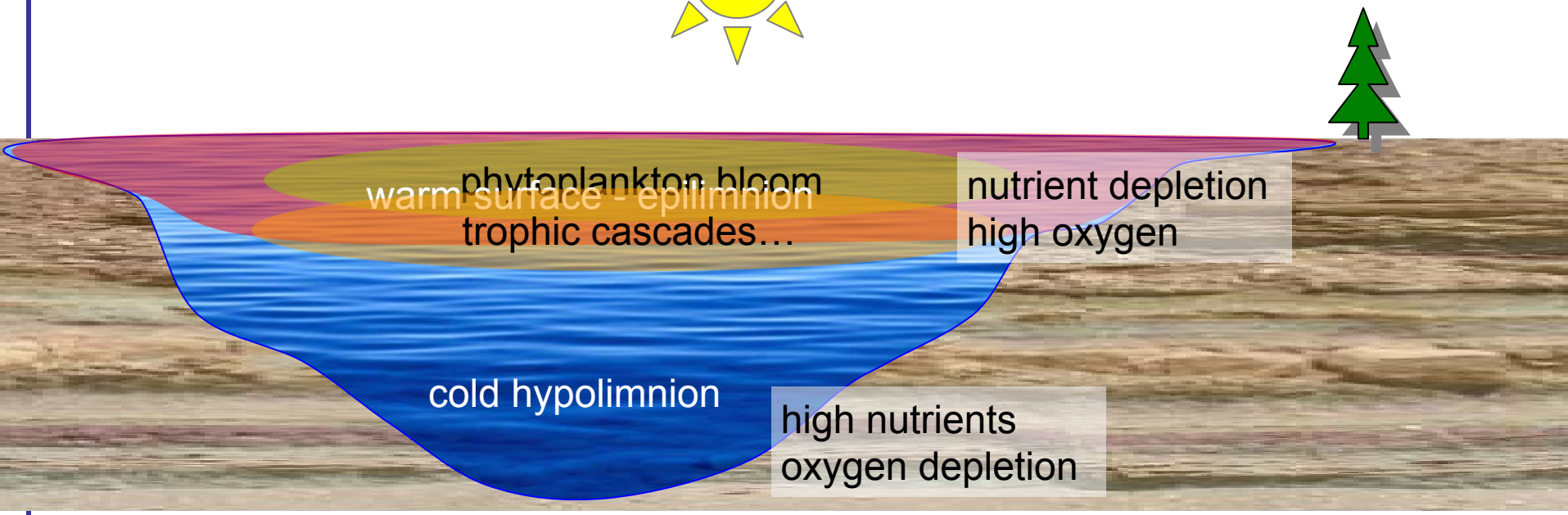
seasonal changes of a dimictic lake

spring mixis



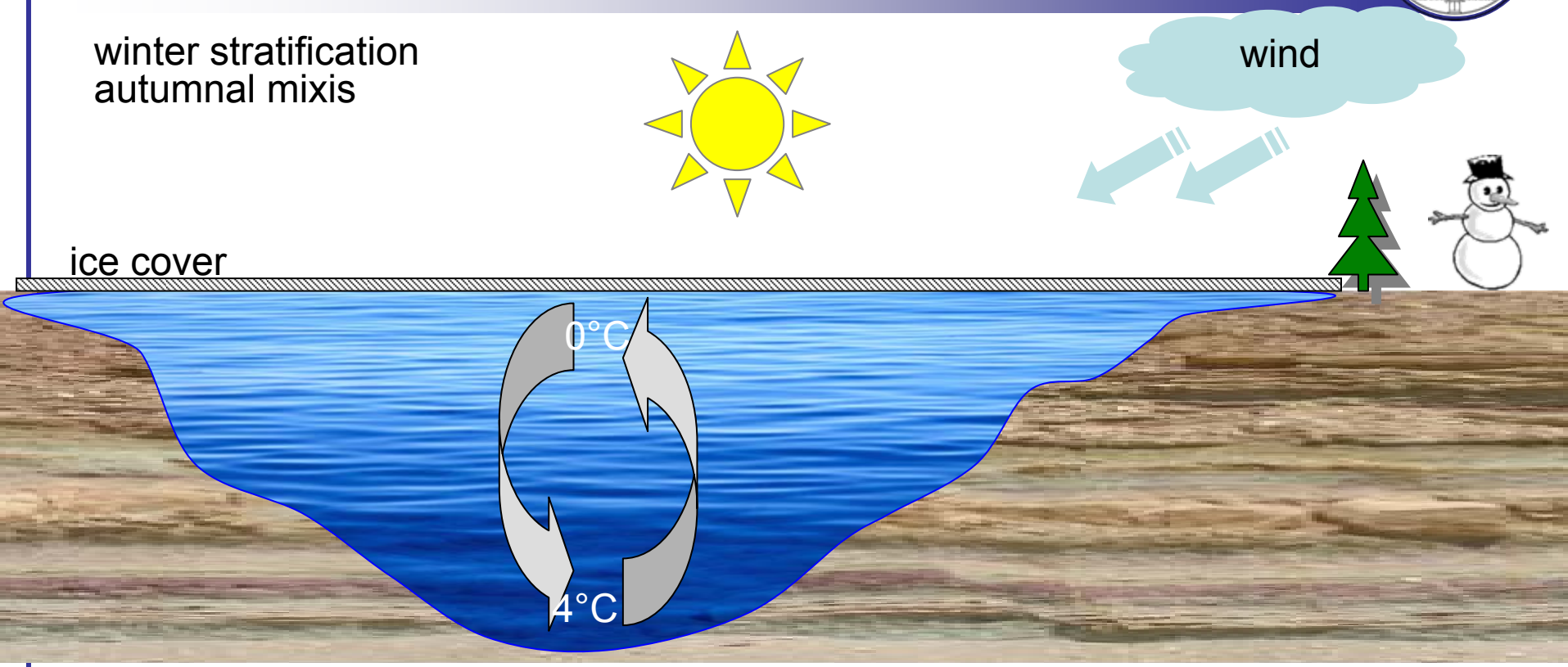
seasonal changes of a dimictic lake

summer stratification

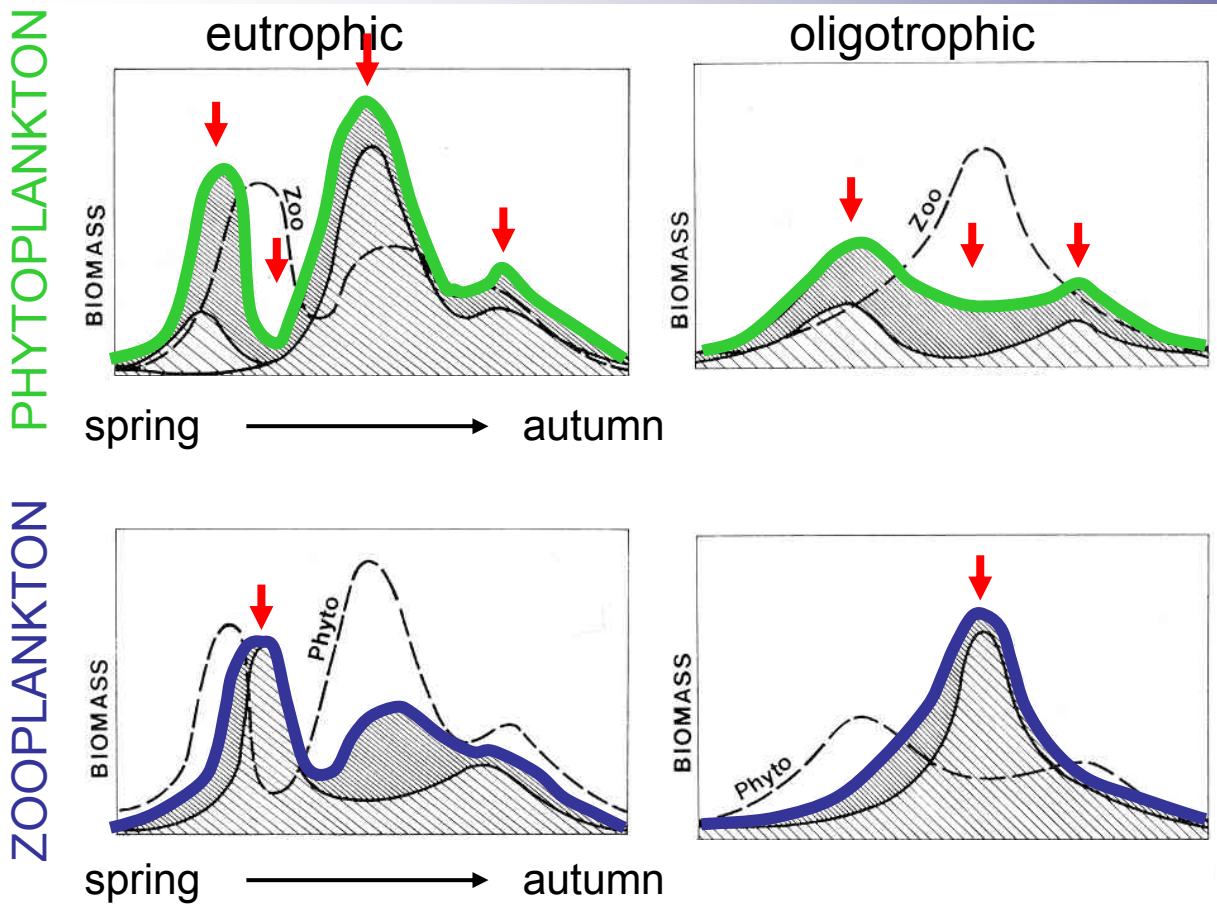


seasonal changes of a dimictic lake

winter stratification
autumnal mixis



seasonal changes of the biota



- phytoplankton spring bloom
- small protists, followed by large crustaceans
- clear water phase
- phytoplankton summer bloom
- phytoplankton autumnal bloom

Sommer et al. (1986)

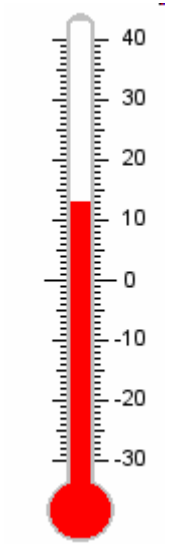
seasonal changes of the biota

…what about bacteria?

general opinion

driving forces for planktonic bacteria are…

…physico-chemical conditions (temperature, light, oxygen…)



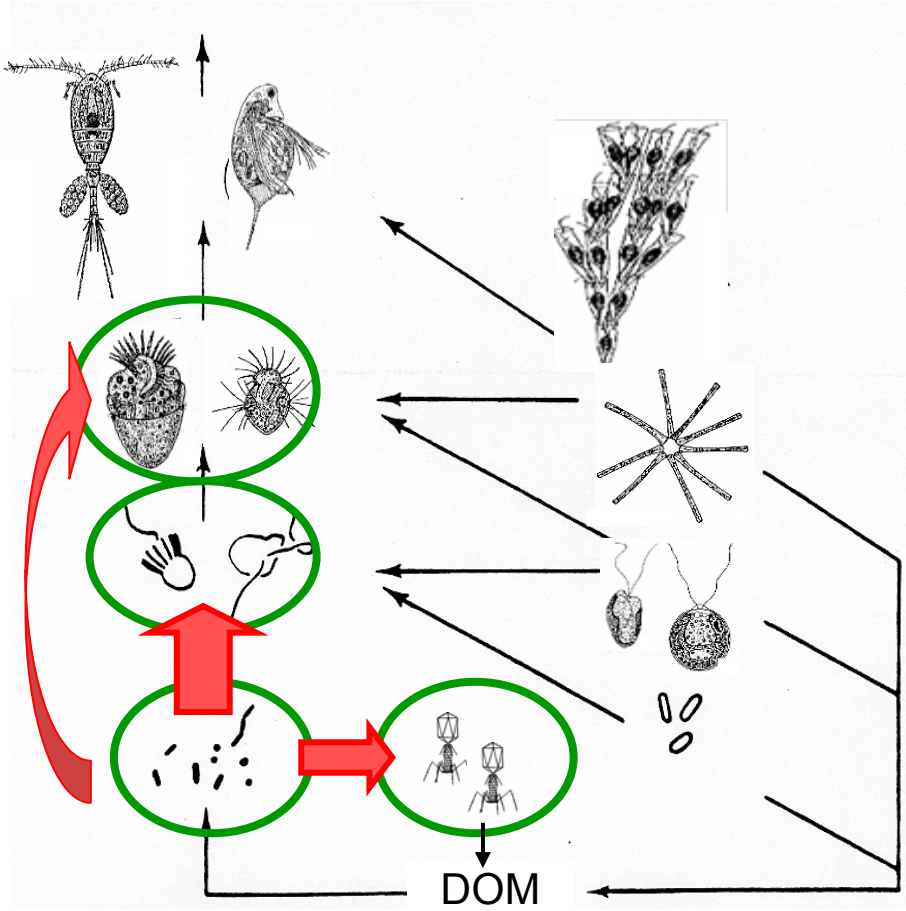
general opinion

driving forces for planktonic bacteria are…

…grazing by bacterivorous protists (mainly HNF)

…viral lysis

→ **top-down control**



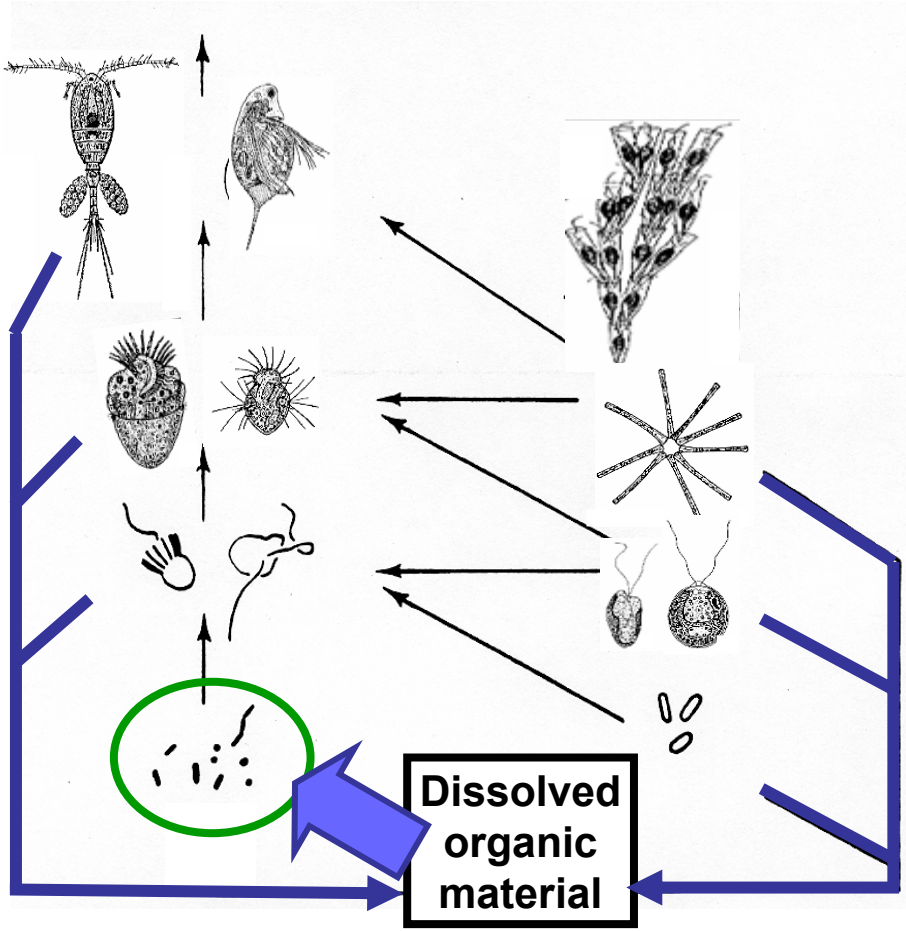
Fenchel et al. (1988), modified by T. Posch

general opinion

driving forces for planktonic bacteria are…

…nutrient availability
(C, P, N)

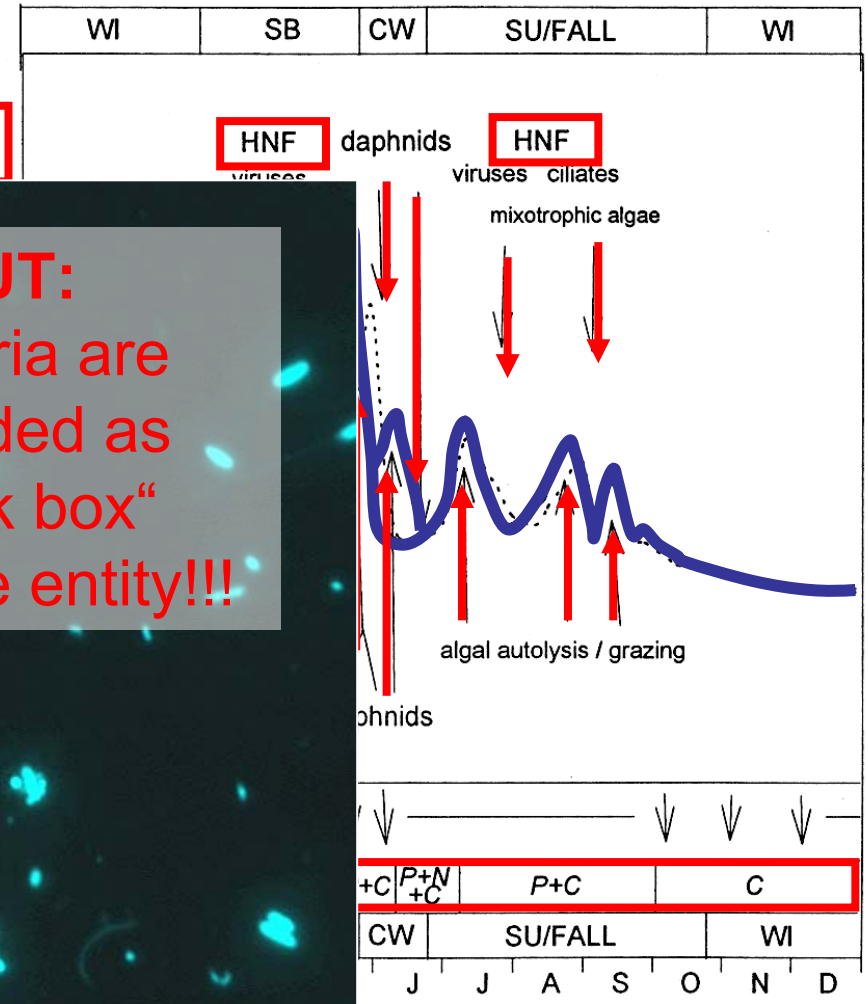
→ **bottom-up control**



Fenchel et al. (1988), modified by T. Posch

seasonality of bacteria

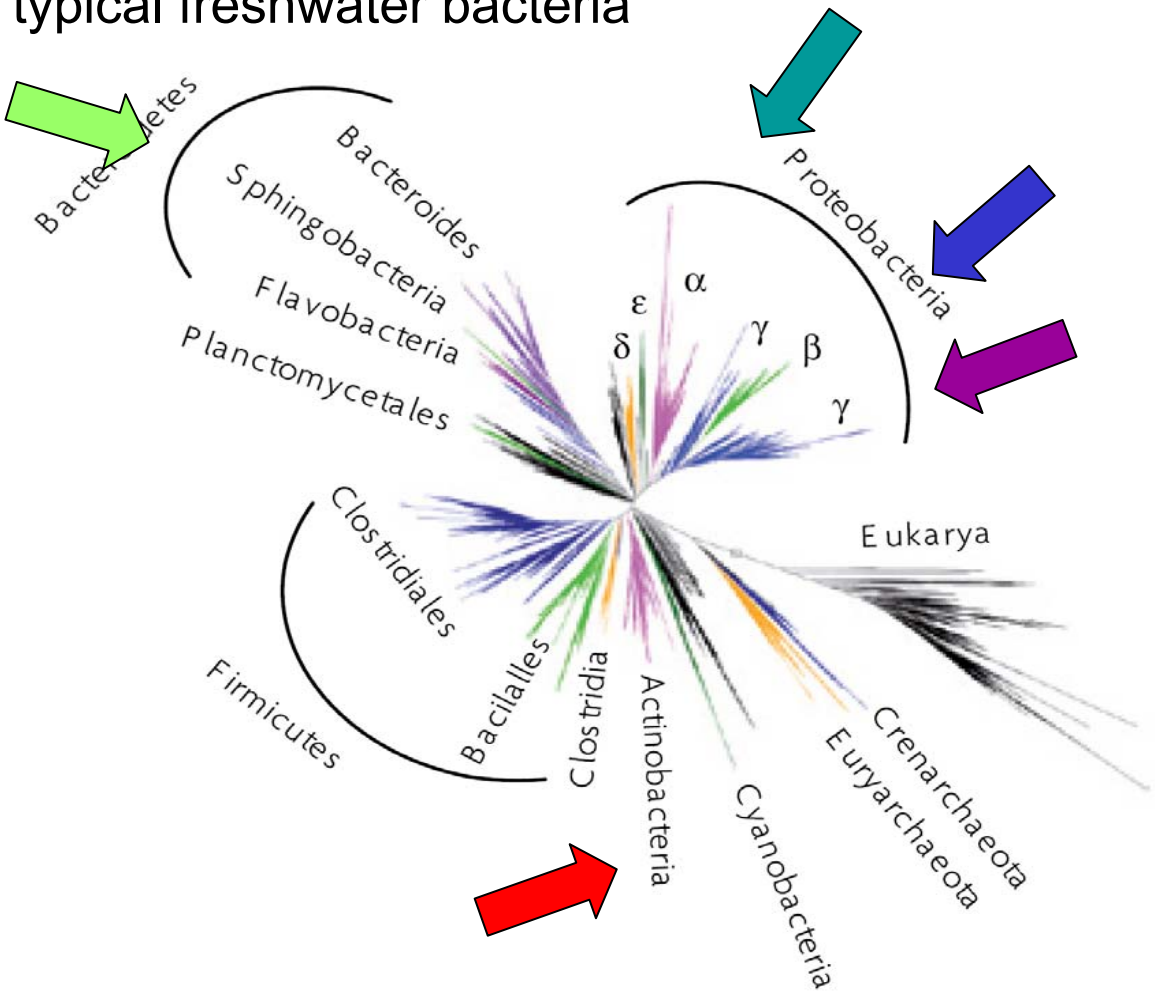
BUT:
bacteria are regarded as „black box“ – as one entity!!!



Simon et al. (1998)

open the „black box“ of bacteria

typical freshwater bacteria



Actinobacteria* & *Betaproteobacteria

→ highly abundant

Cytophaga-Flavobacteria

→ less abundant

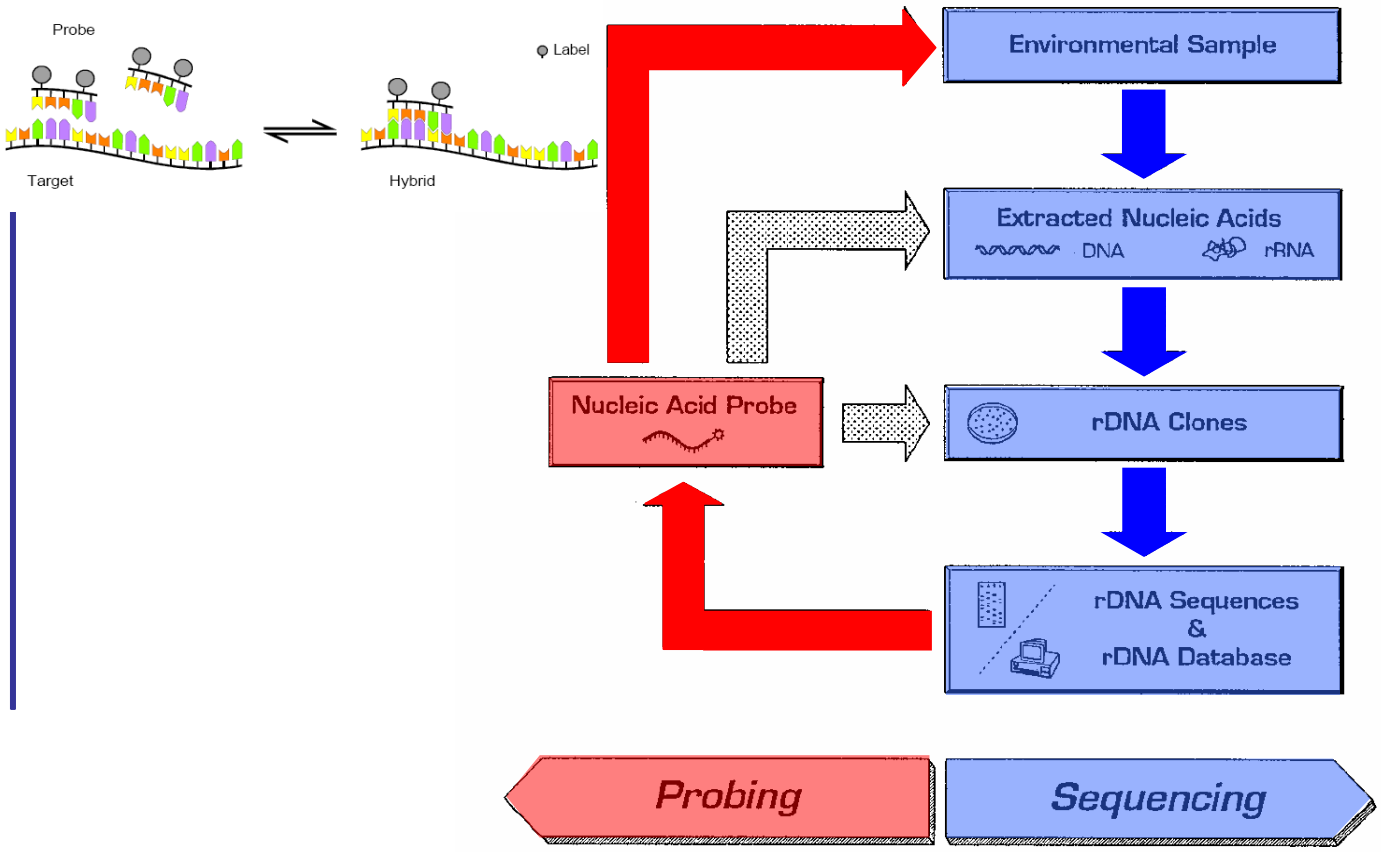
Alphaproteobacteria
Gammaproteobacteria

→ „rarely“ abundant

Fuchs & Amann (2008)

how to study freshwater bacteria?

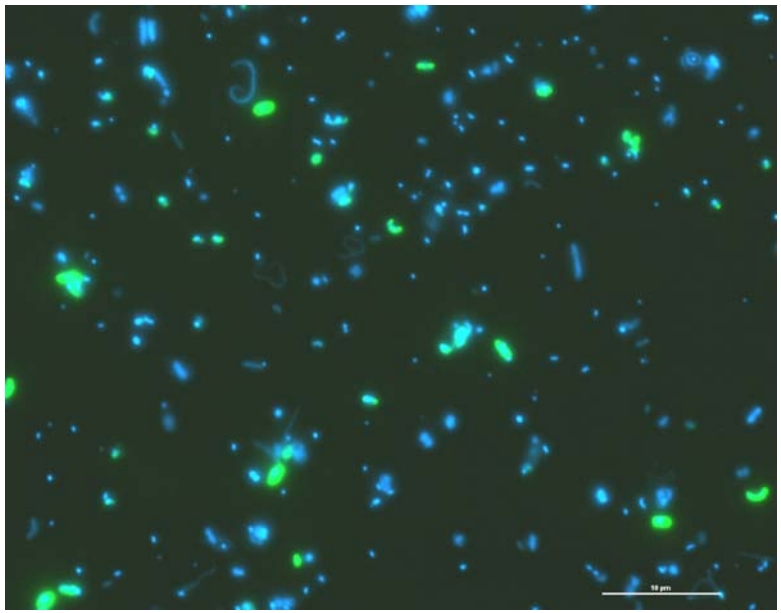
- Cloning and sequencing of 16S rRNA genes
- Fluorescence *in situ* hybridization (FISH)

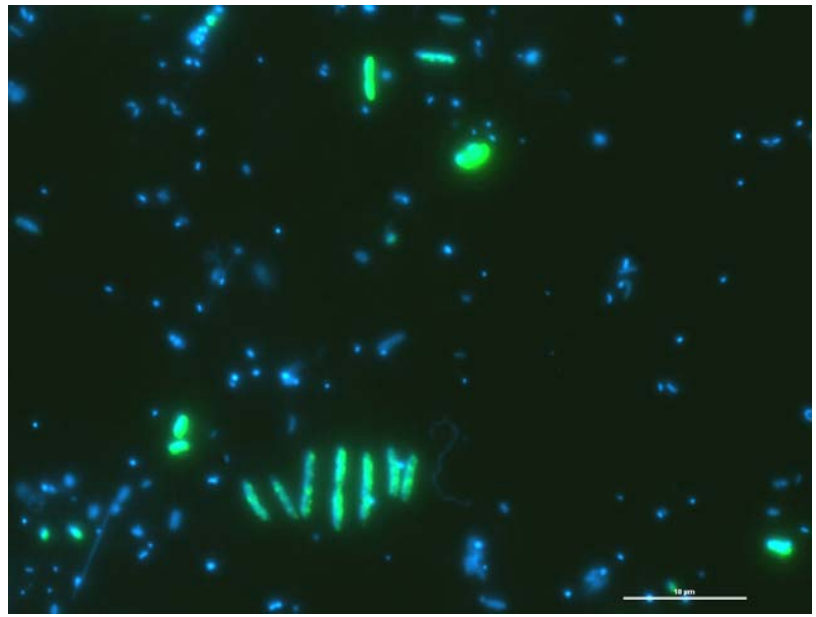


Amann et al. (1995)

how to study freshwater bacteria?

- Cloning and sequencing of 16S rRNA genes
- Fluorescence *in situ* hybridization (FISH)
- CARD-FISH: signal amplification → brighter and stable signal
- Biomass evaluation of bacterial phylotypes (image analysis)
- MAR-FISH: incorporation of radiolabeled substrates („activity“) + FISH





…some aims of my PhD thesis

- Seasonality of bacterial phylotypes - cell numbers, biomass, and “activity” (amino acid incorporation) in Piburger See
- Spatial patterns in the distribution of bacterial phylotypes (depth gradient during stratification)
- Identification of the driving forces for the establishment of different bacterial phylotypes

$\longrightarrow$ lack of knowledge

Tri-phasical approach

observation of
top-down
& bottom-up
control in nature?

SEASONAL MONITORING

Salcher et al. (2008)
Posch et al. (accepted)
Salcher et al. (in prep)

Identification
of the major
effects of
TOP-DOWN and
BOTTOM-UP CONTROL
on natural
bacterioplankton

LAB STUDY (chemostat experiment)

Salcher et al. (2005)

FIELD EXPERIMENT

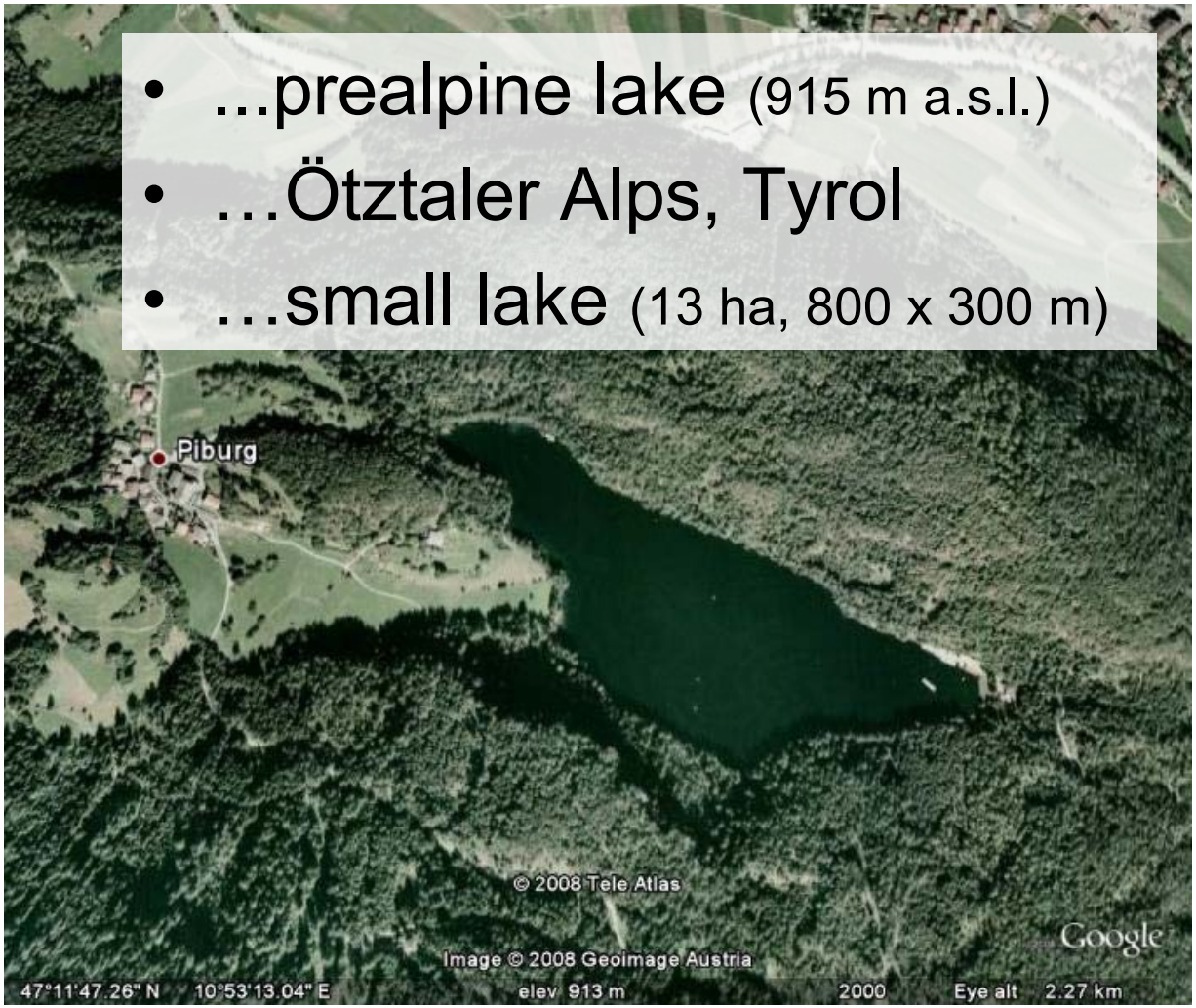
(size fractionation & nutrient enrichment)

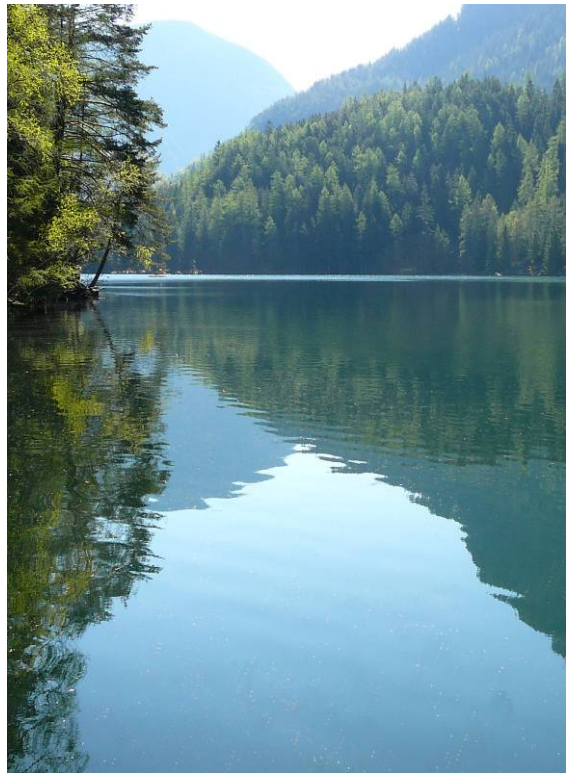
Salcher et al. (2007)
Posch et al. (2007)

Piburger See is...

Piburger See is...

- …prealpine lake (915 m a.s.l.)
- …Ötztaler Alps, Tyrol
- …small lake (13 ha, 800 x 300 m)





Piburger See is...

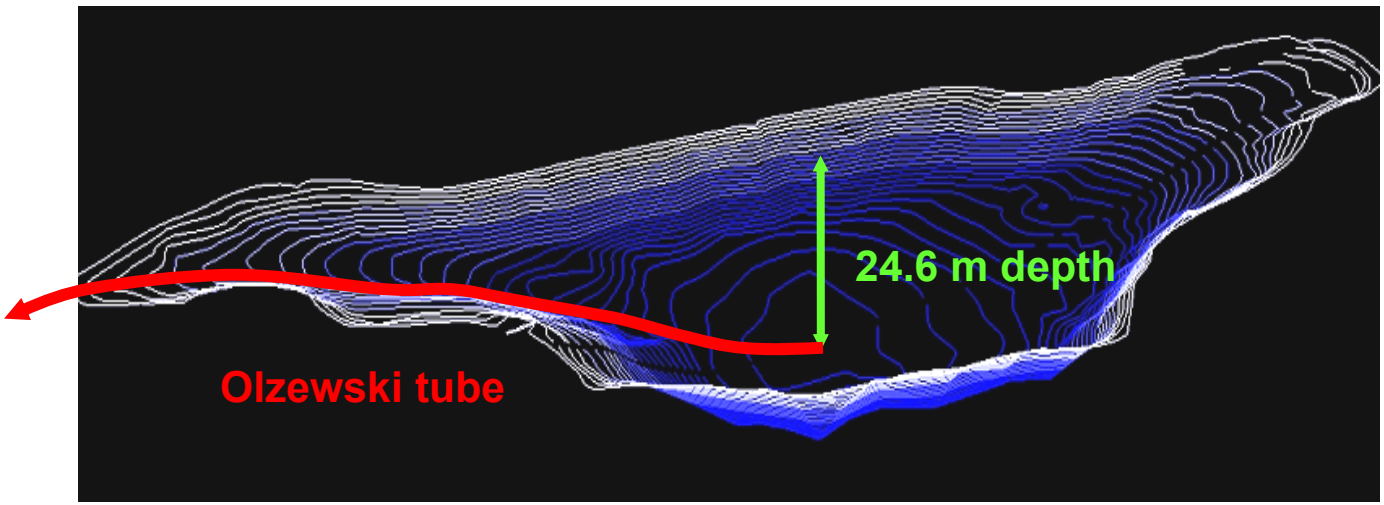
…z_m: 24.6 m

…dimictic: summer stratification → anoxic hypolimnion

…eutrophication in late 1960s

…deep water removal (Olszewski tube) in 1970

…re-oligotrophication → oligo-mesotrophic

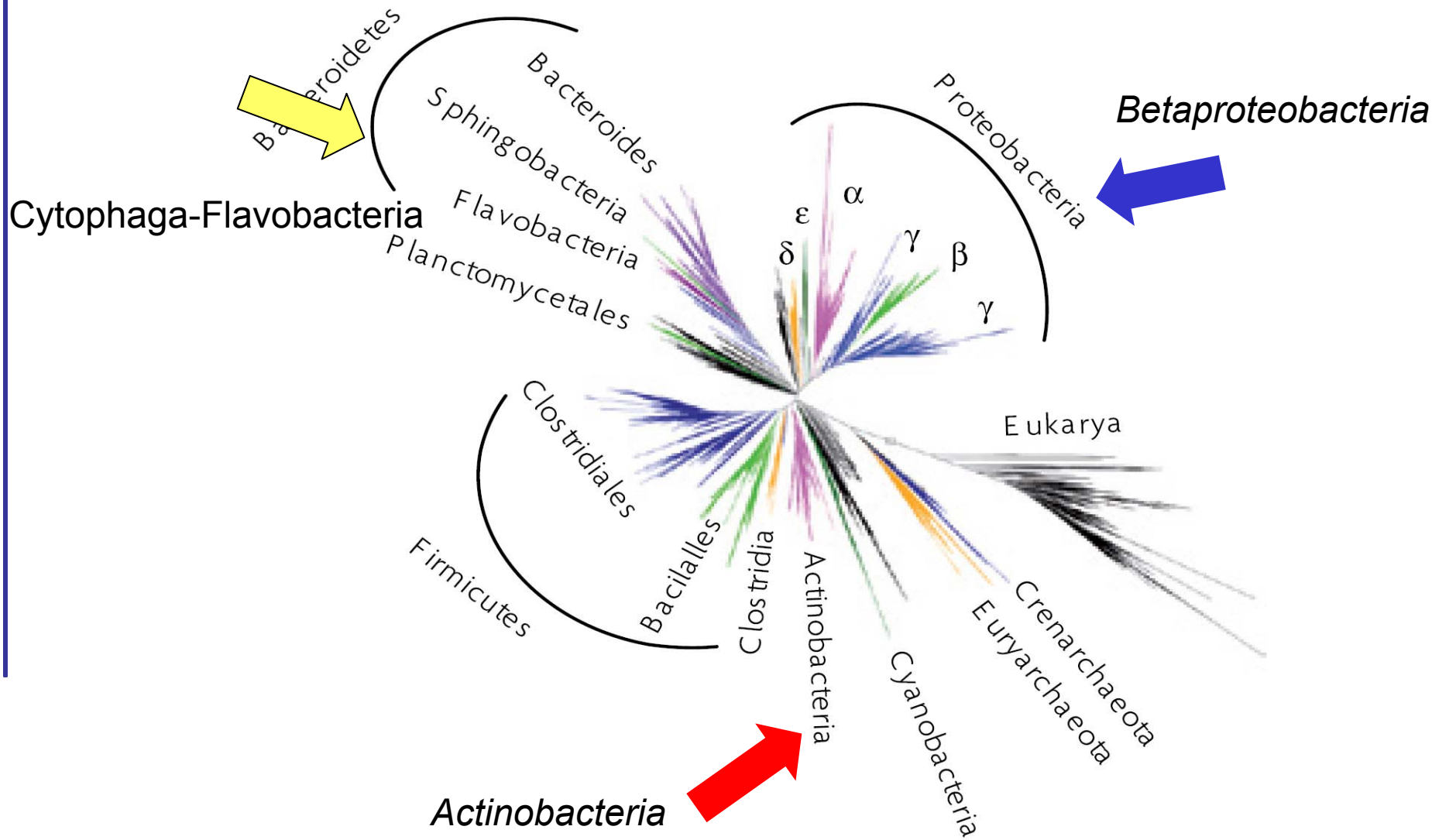


seasonal study

1-year survey (Feb 2005 – Feb 2006)

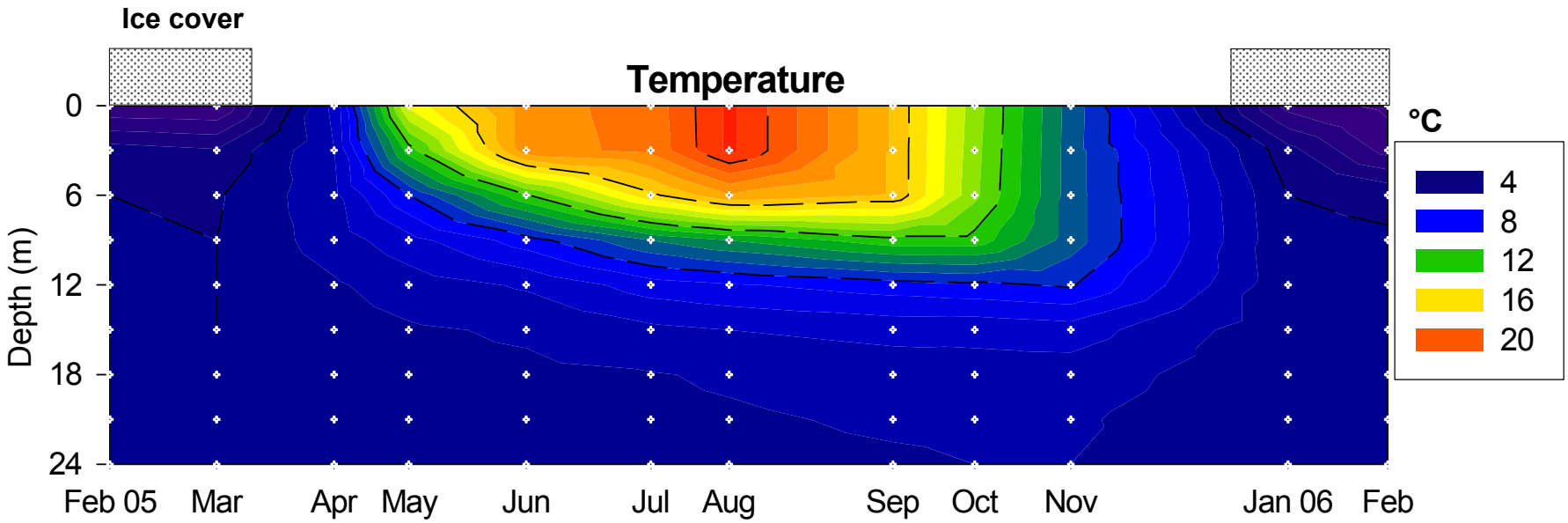
- physico-chemical monitoring
- algal diversity
- numbers of heterotrophic nanoflagellates
- **Bacterial diversity, abundances, biomass, and activity** (cloning & sequencing of 16S rRNA gene, CARD-FISH, image analysis, MAR-FISH with ^{3}H-amino acids)

studied phyla / orders



Amann & Fuchs 2008

environmental conditions



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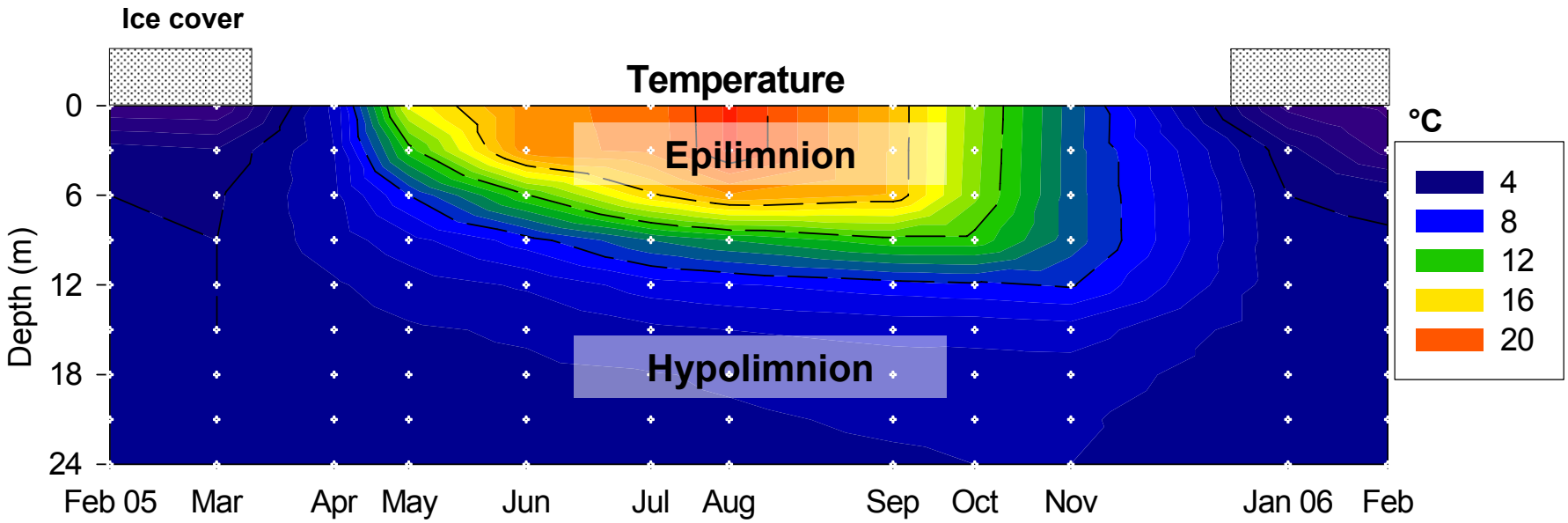

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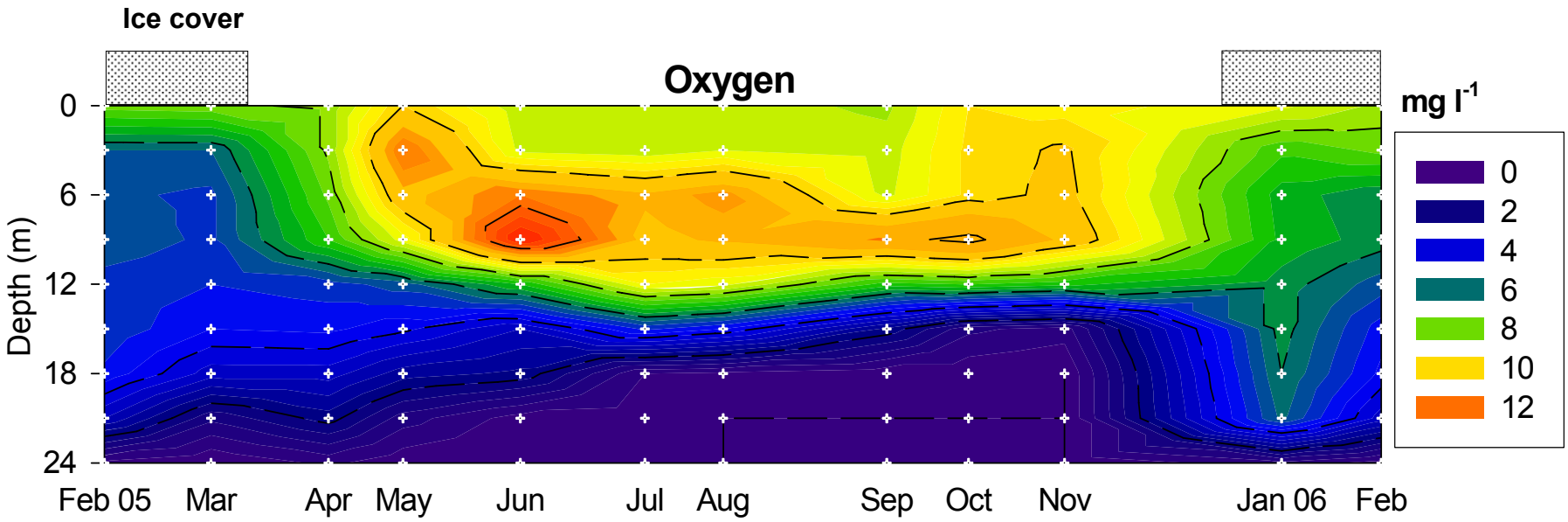

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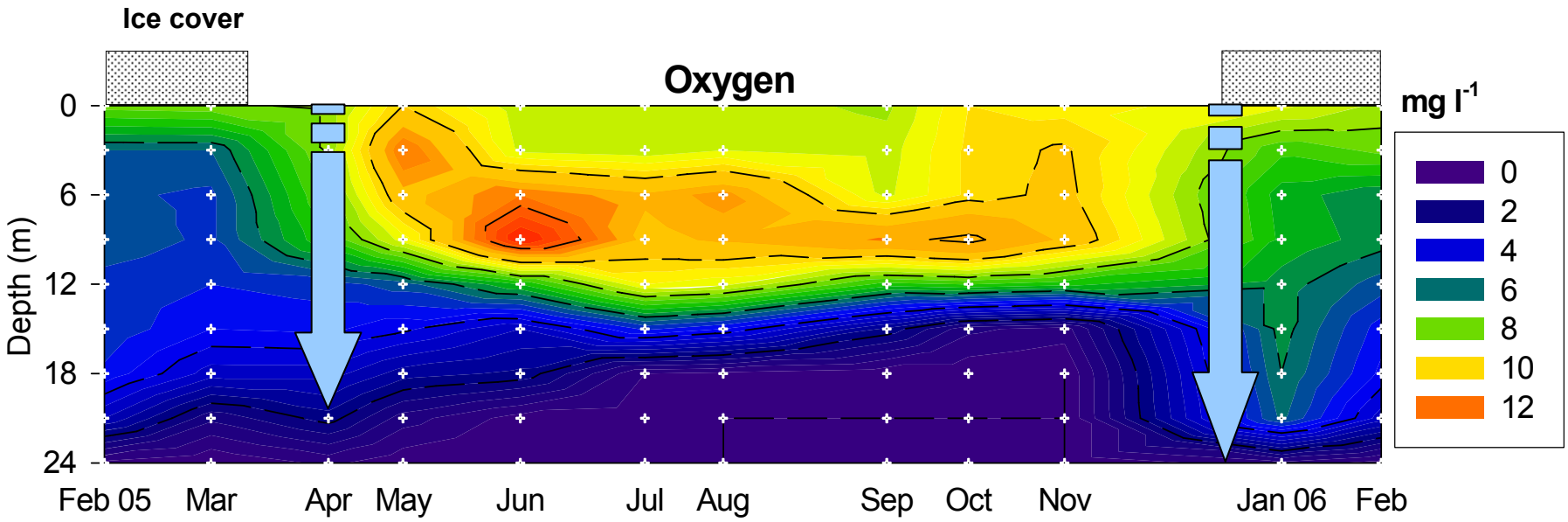

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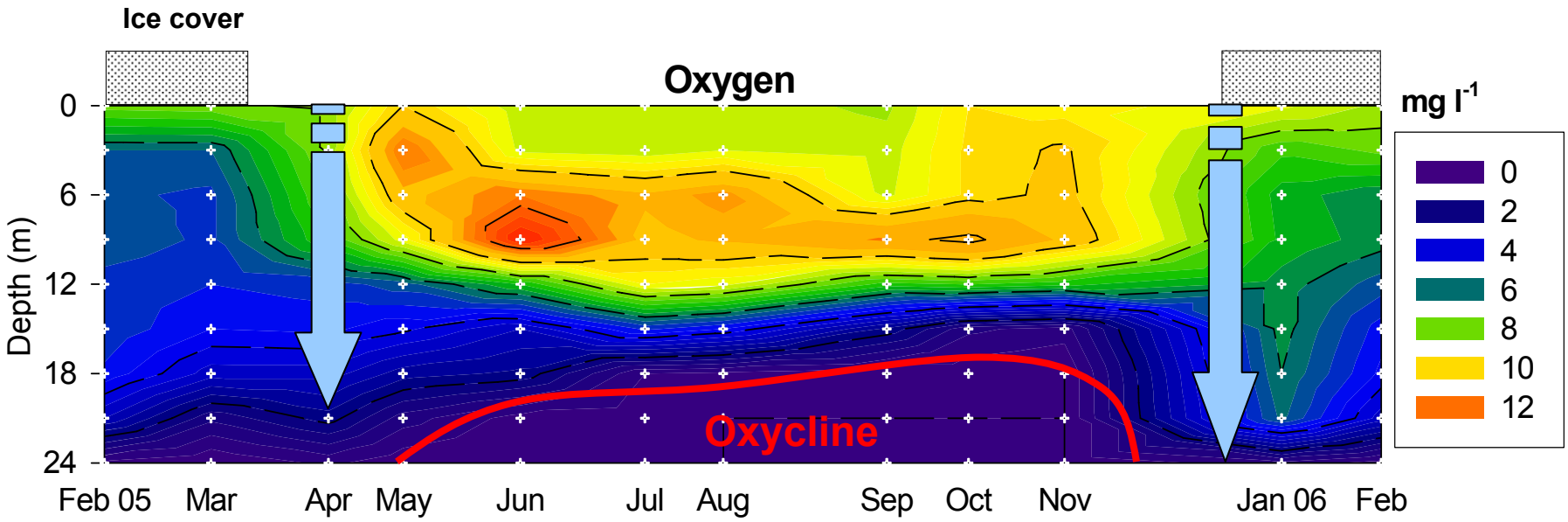

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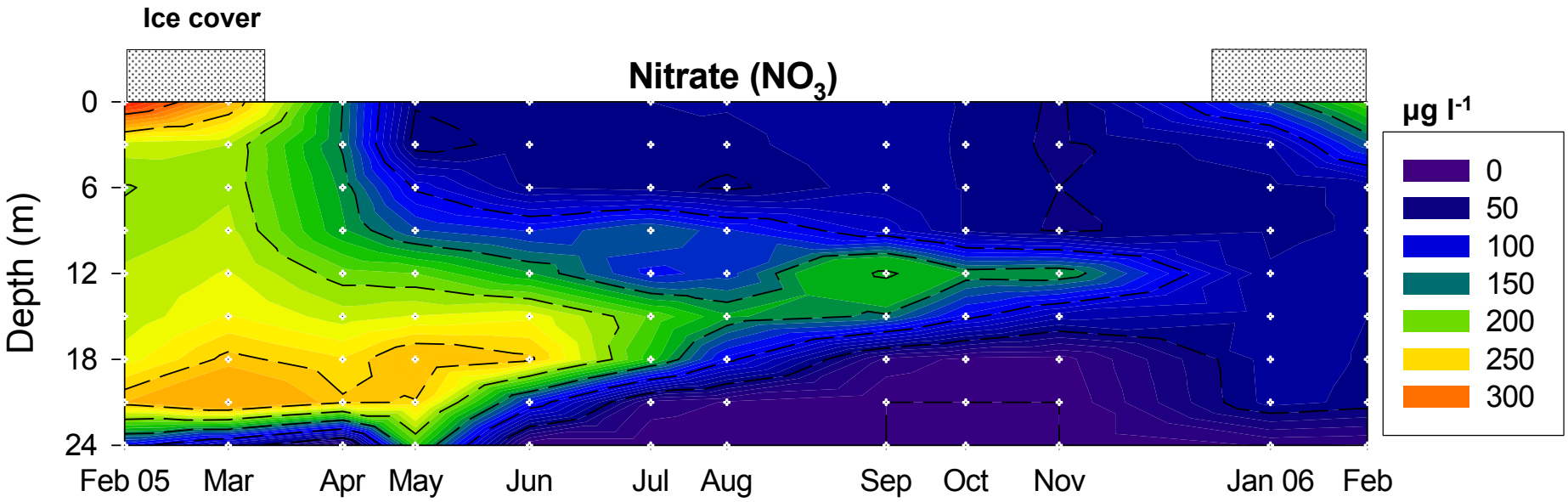

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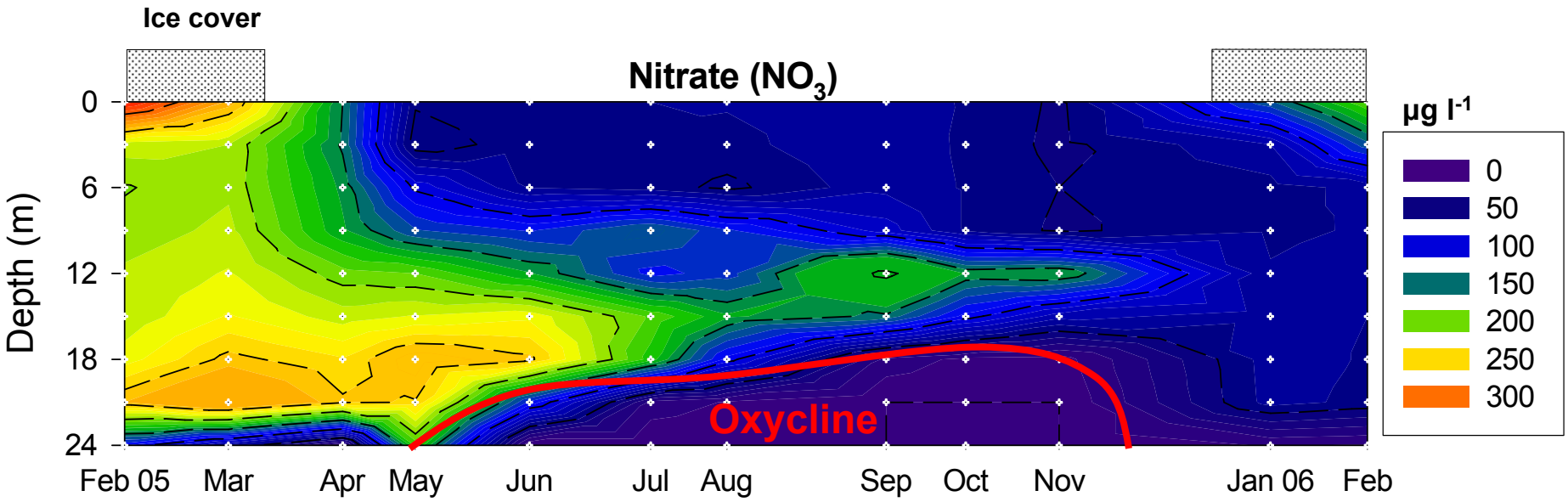

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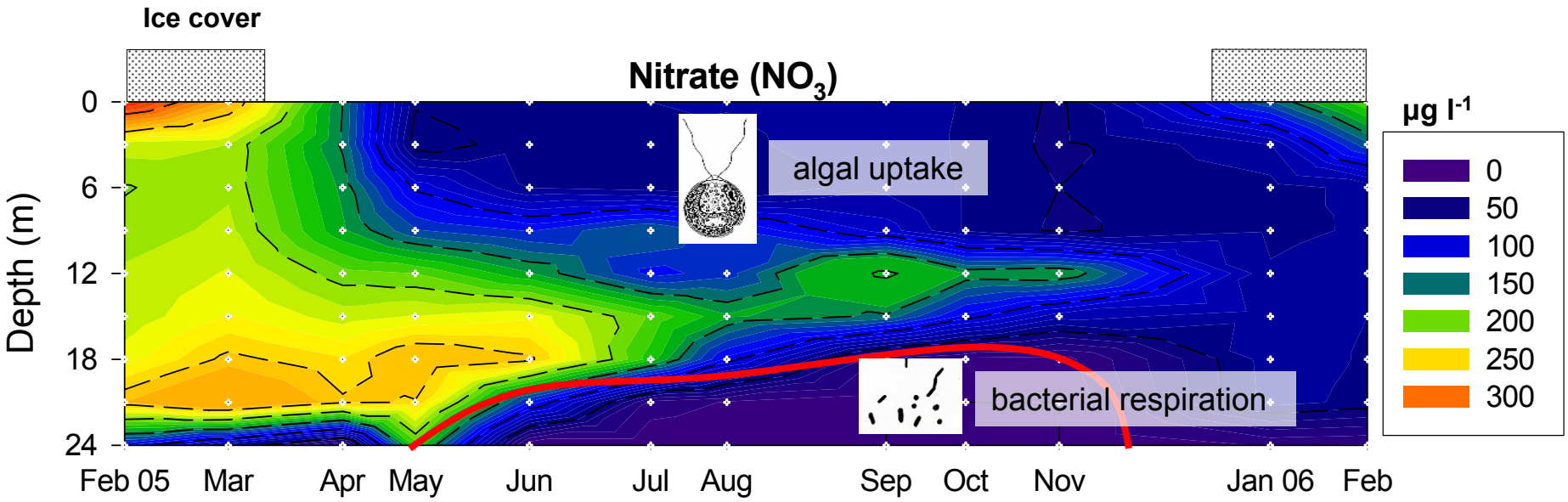

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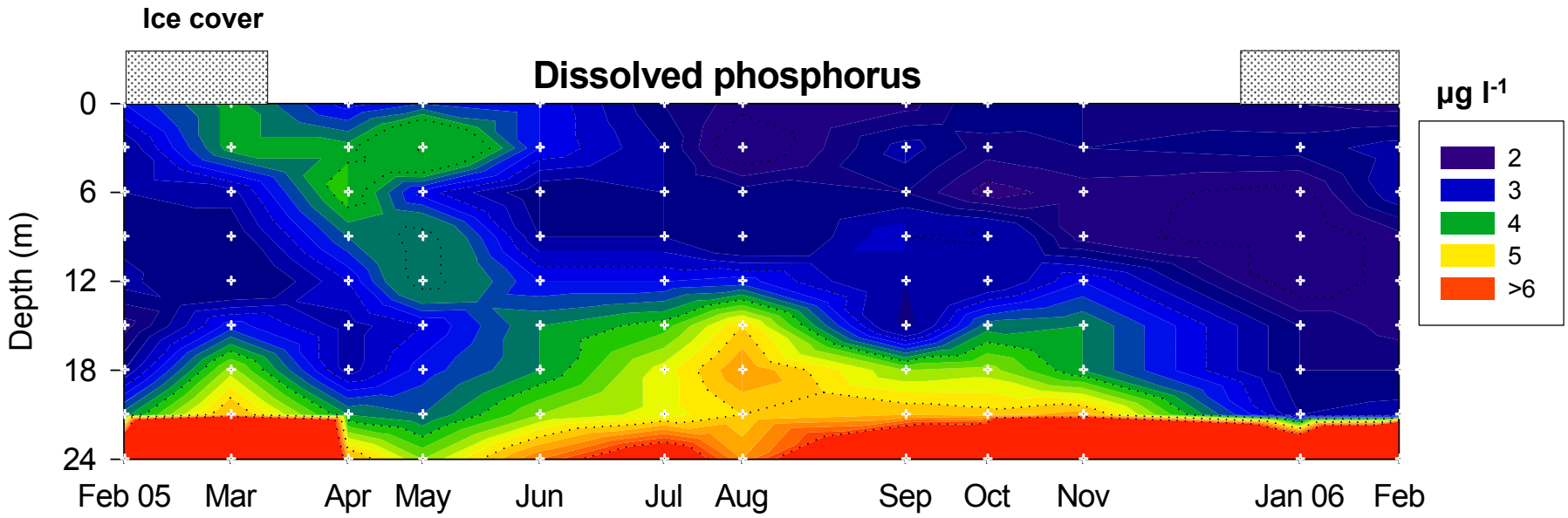

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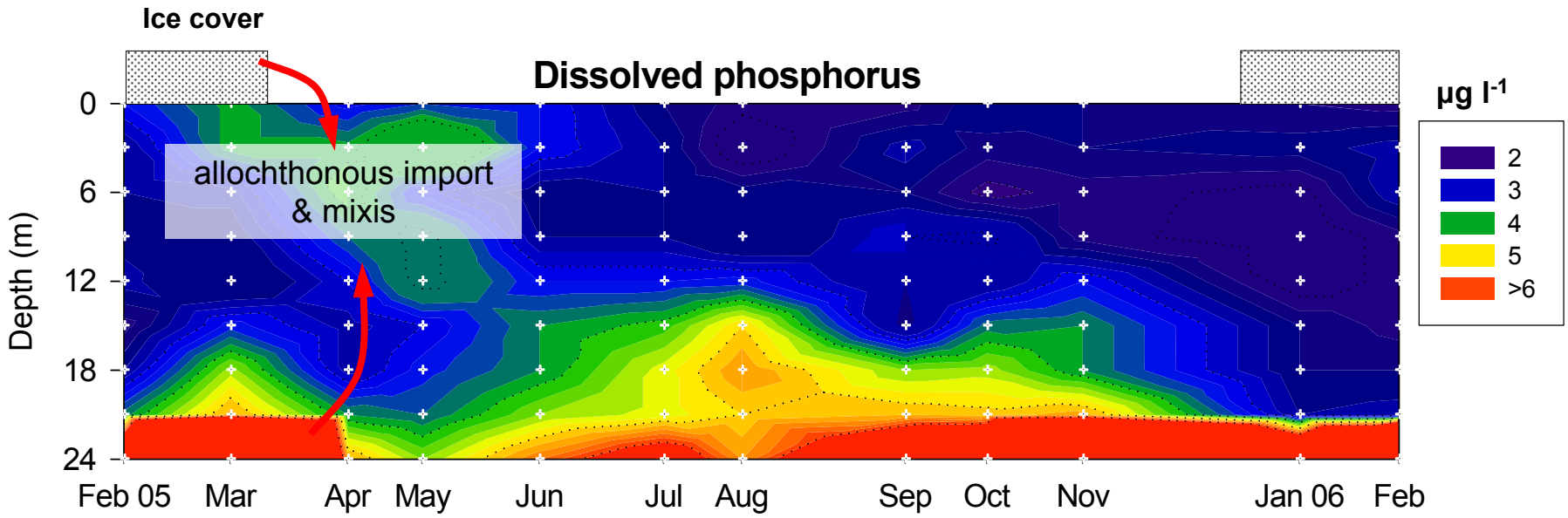

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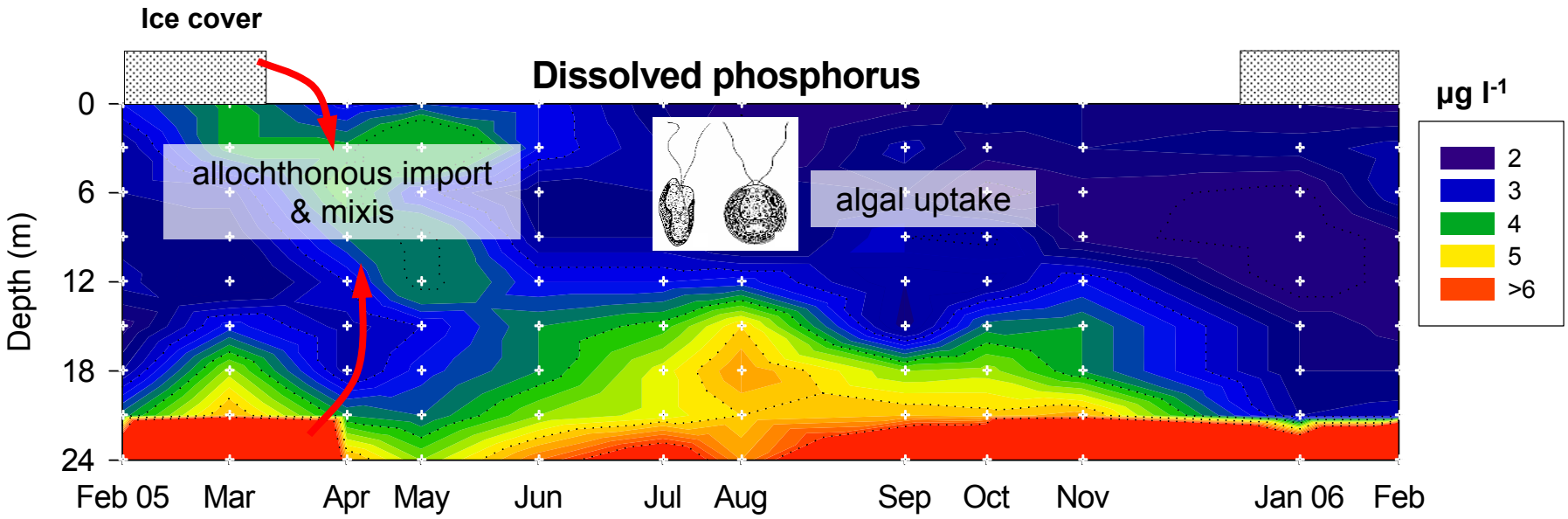
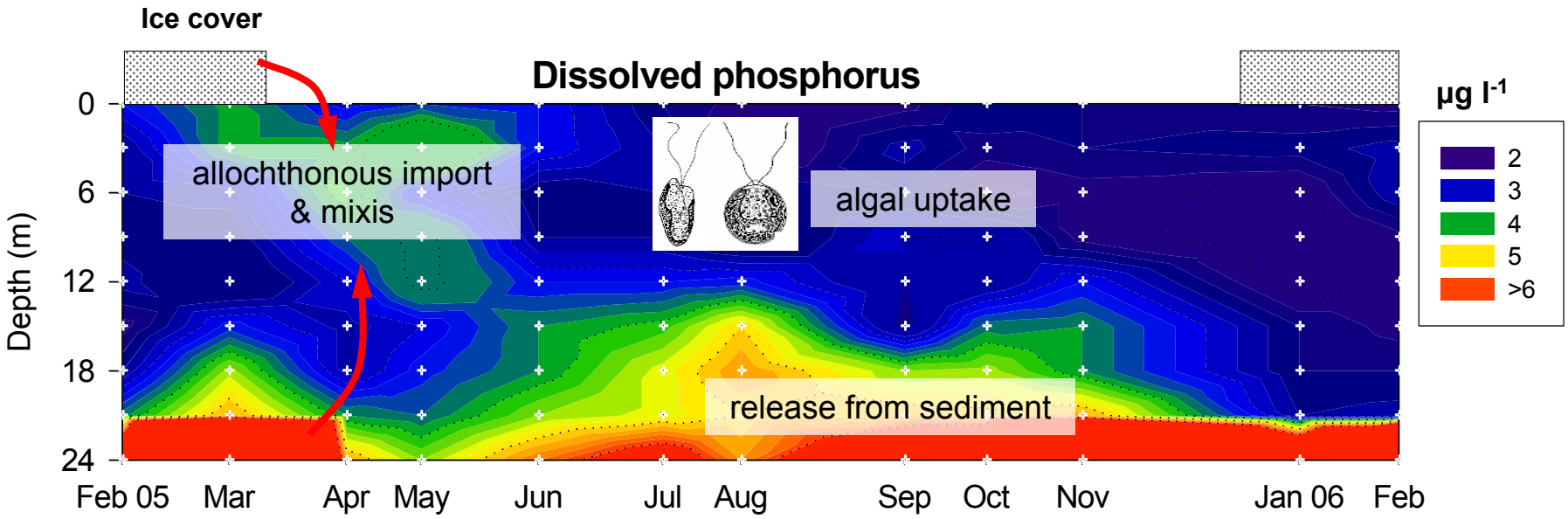
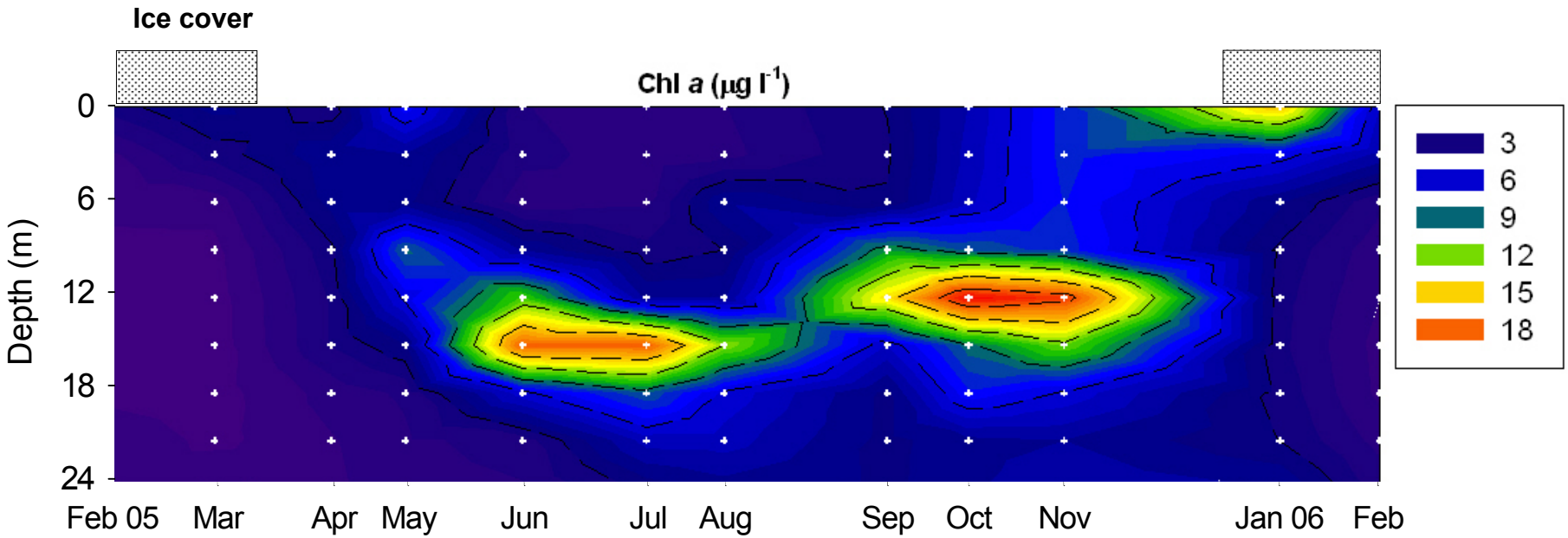


environmental conditions

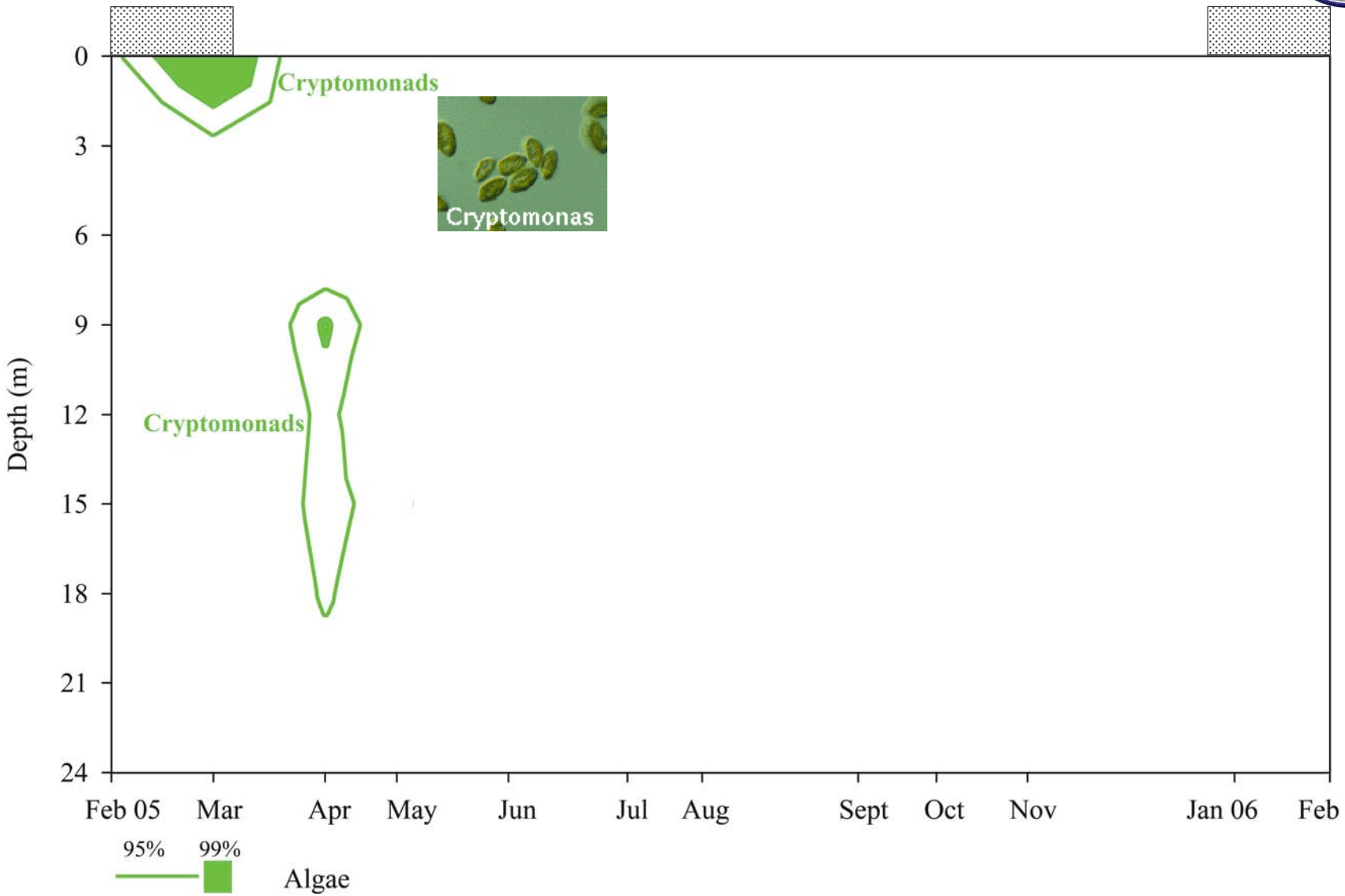


environmental conditions

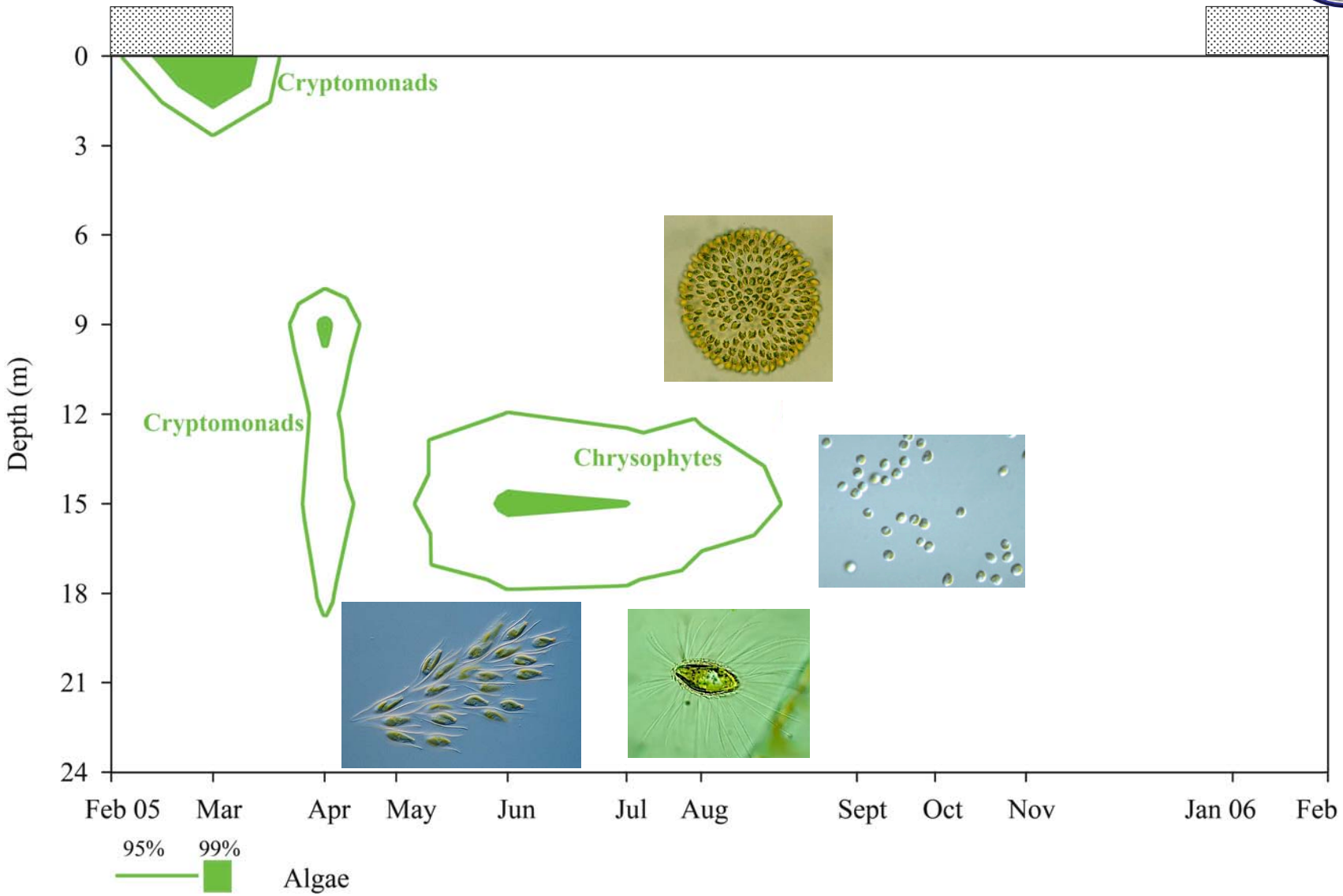


...which algae?

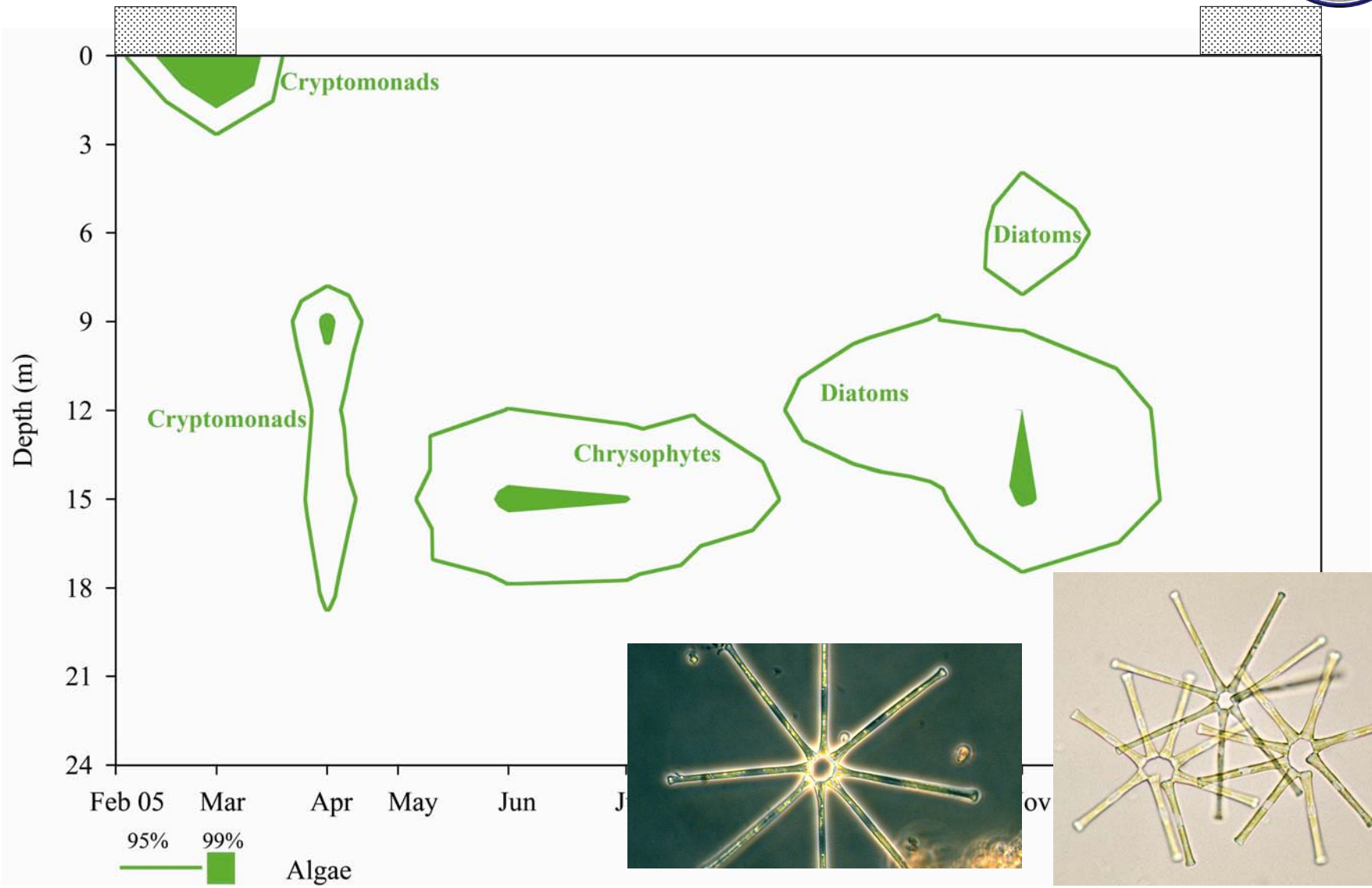
spatio-temporal distribution of algae



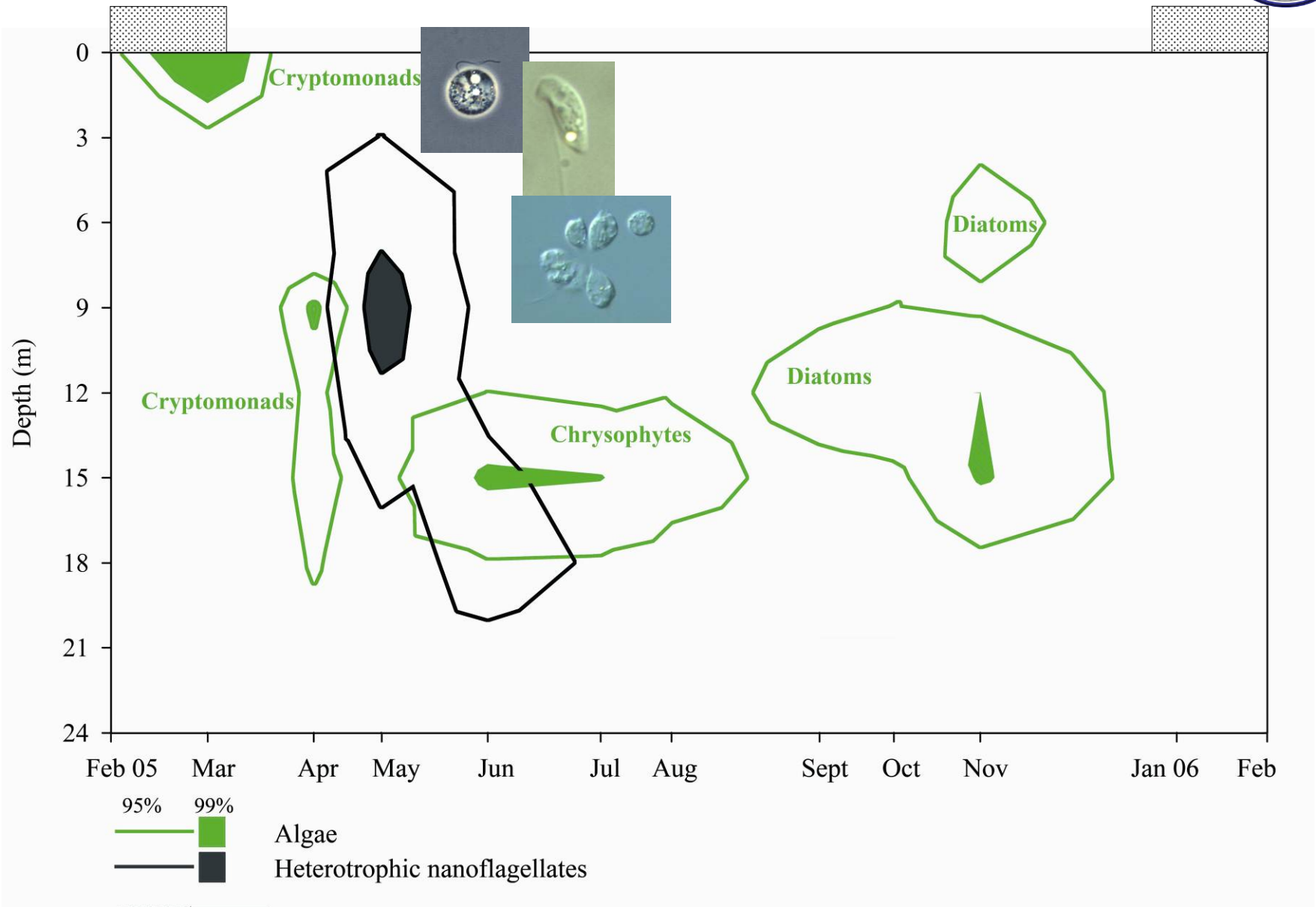
spatio-temporal distribution of algae



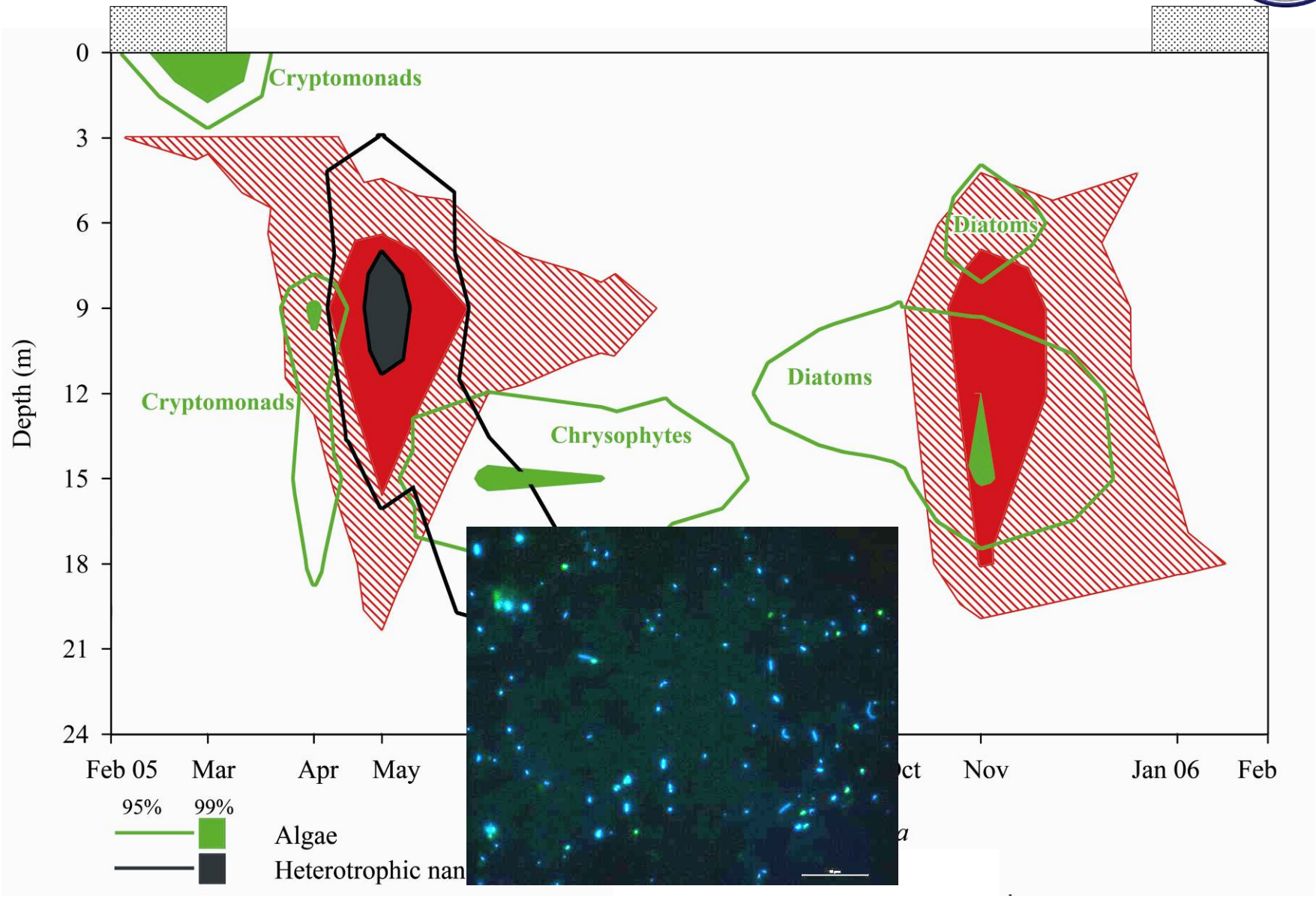
spatio-temporal distribution of algae



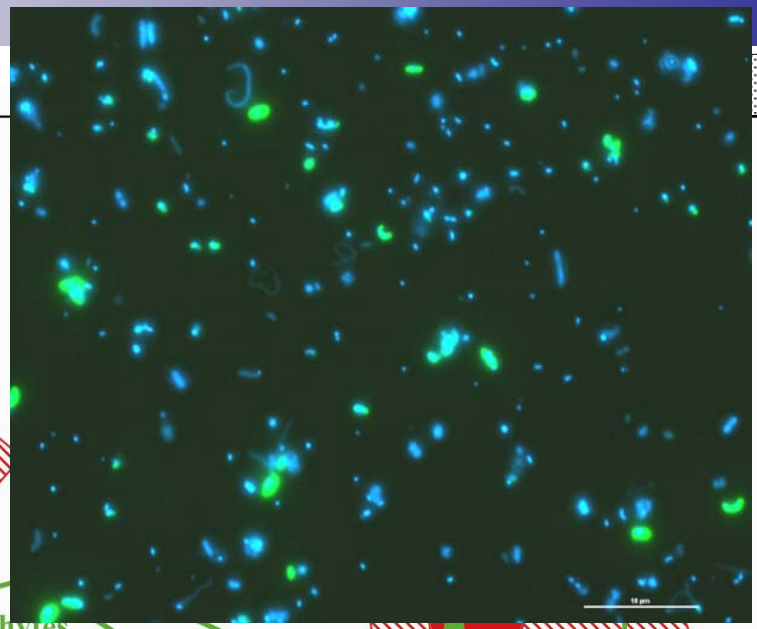
…and heterotrophic flagellates



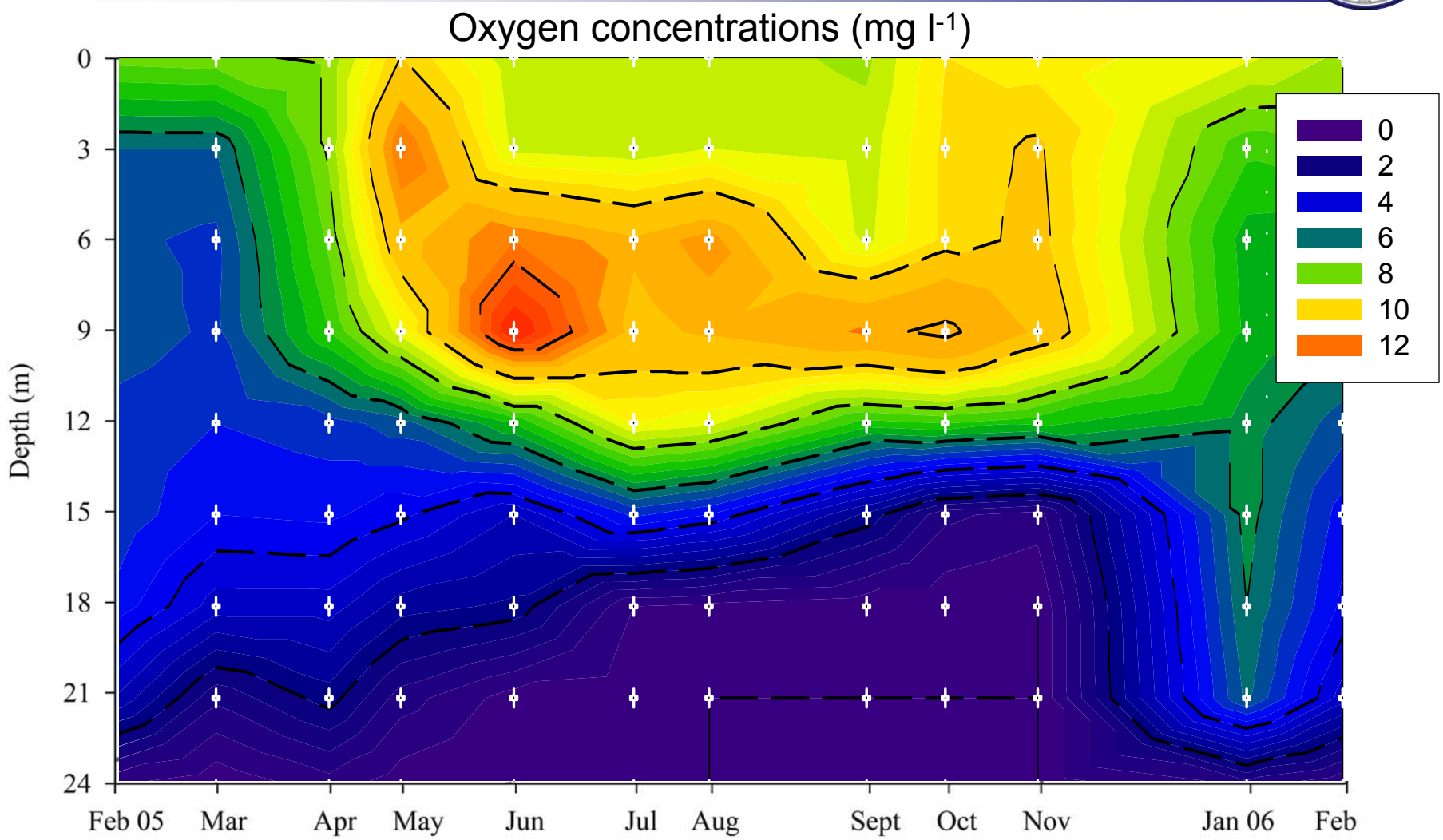
…*Actinobacteria,*



…and *Betaproteobacteria*



environmental factor - oxygen



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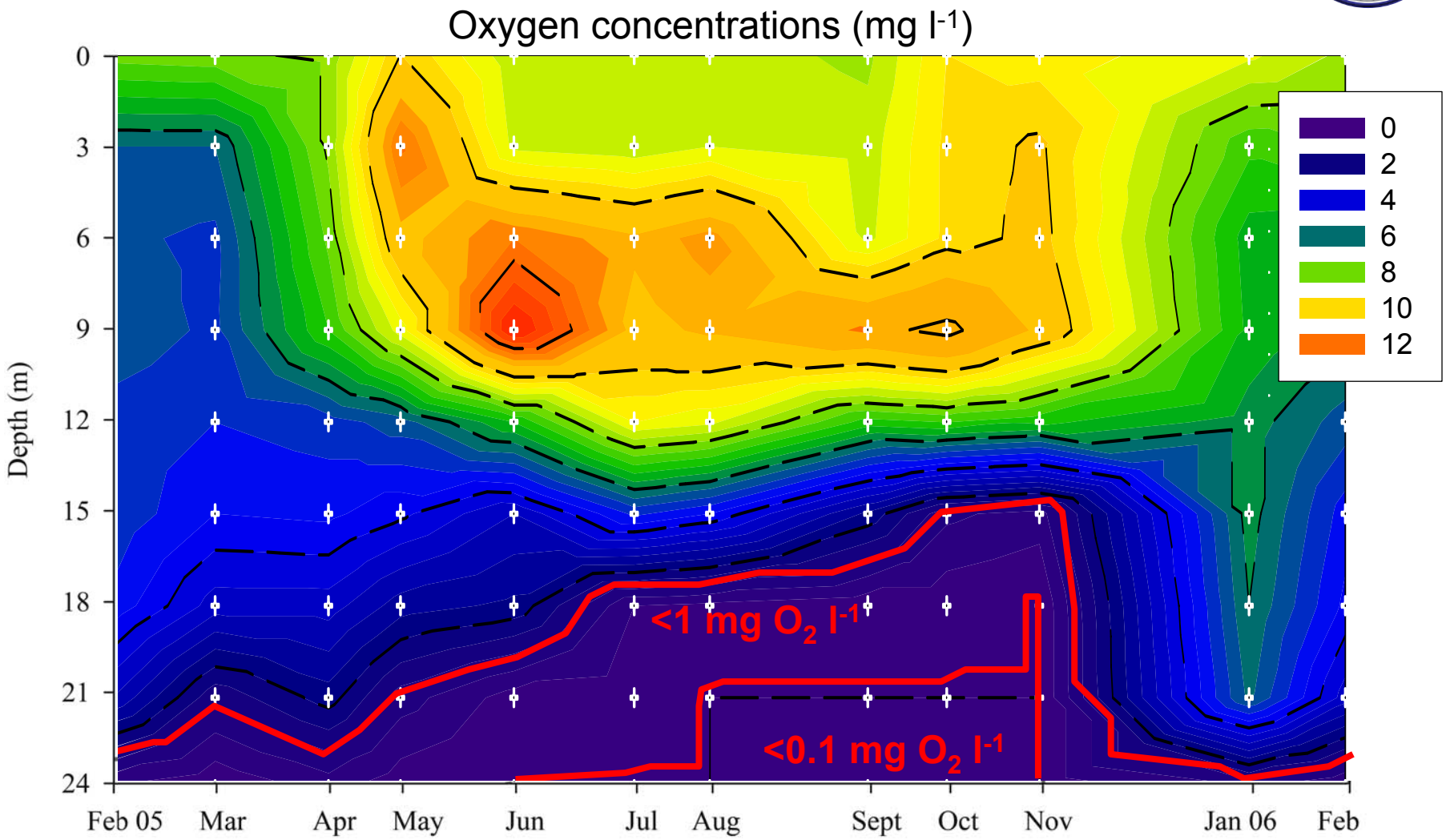
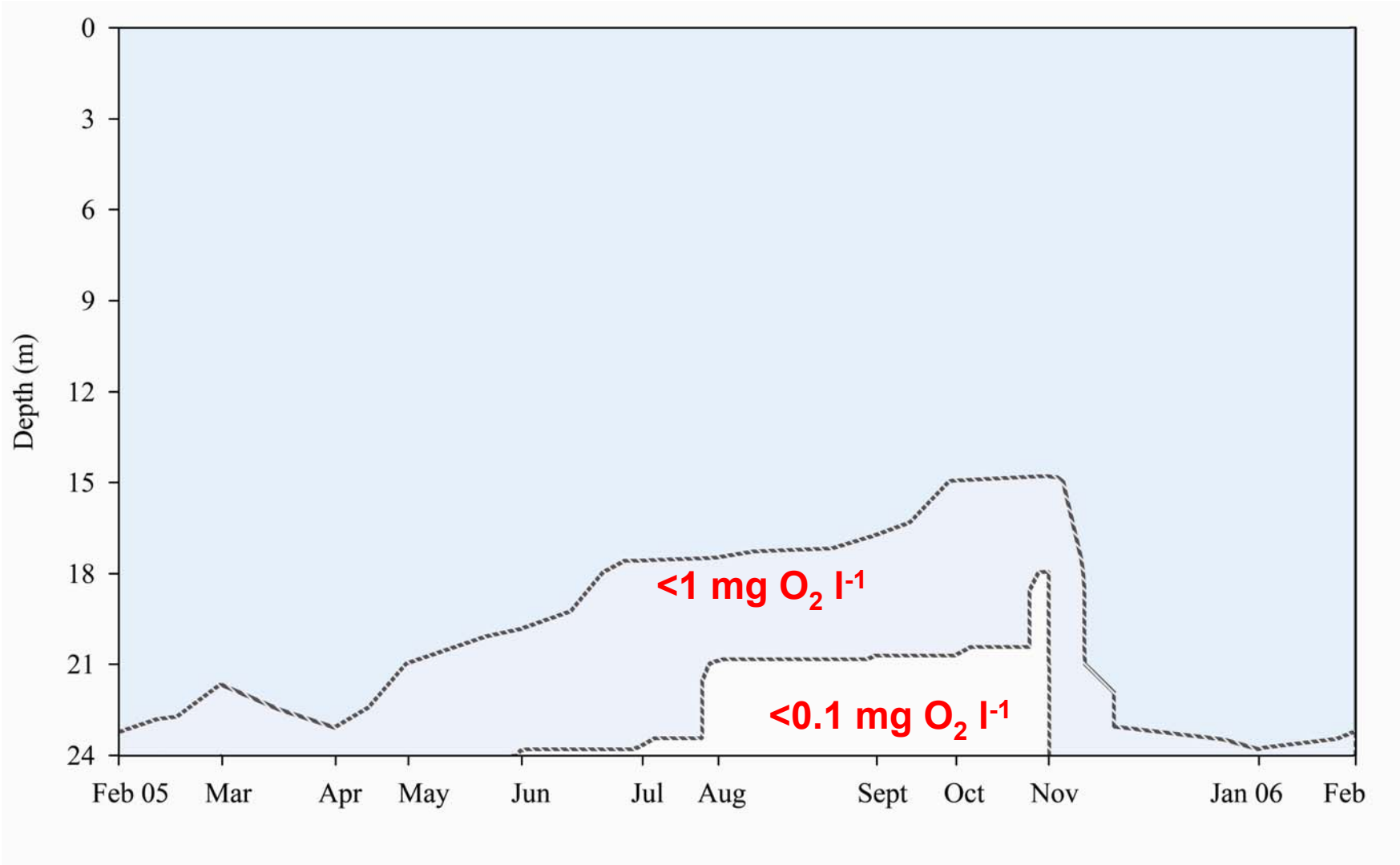
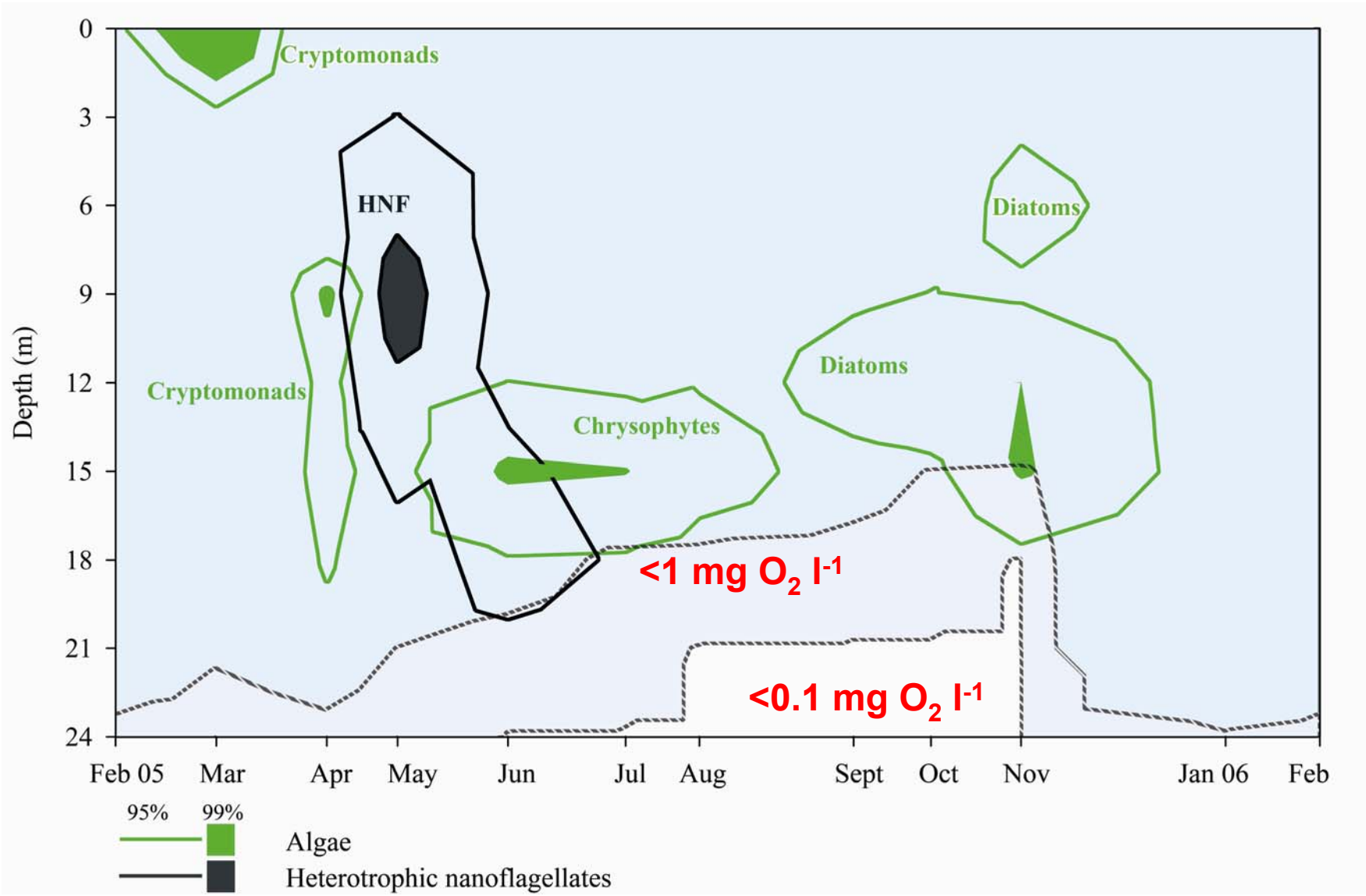


environmental factor - oxygen



spatial distribution of organisms



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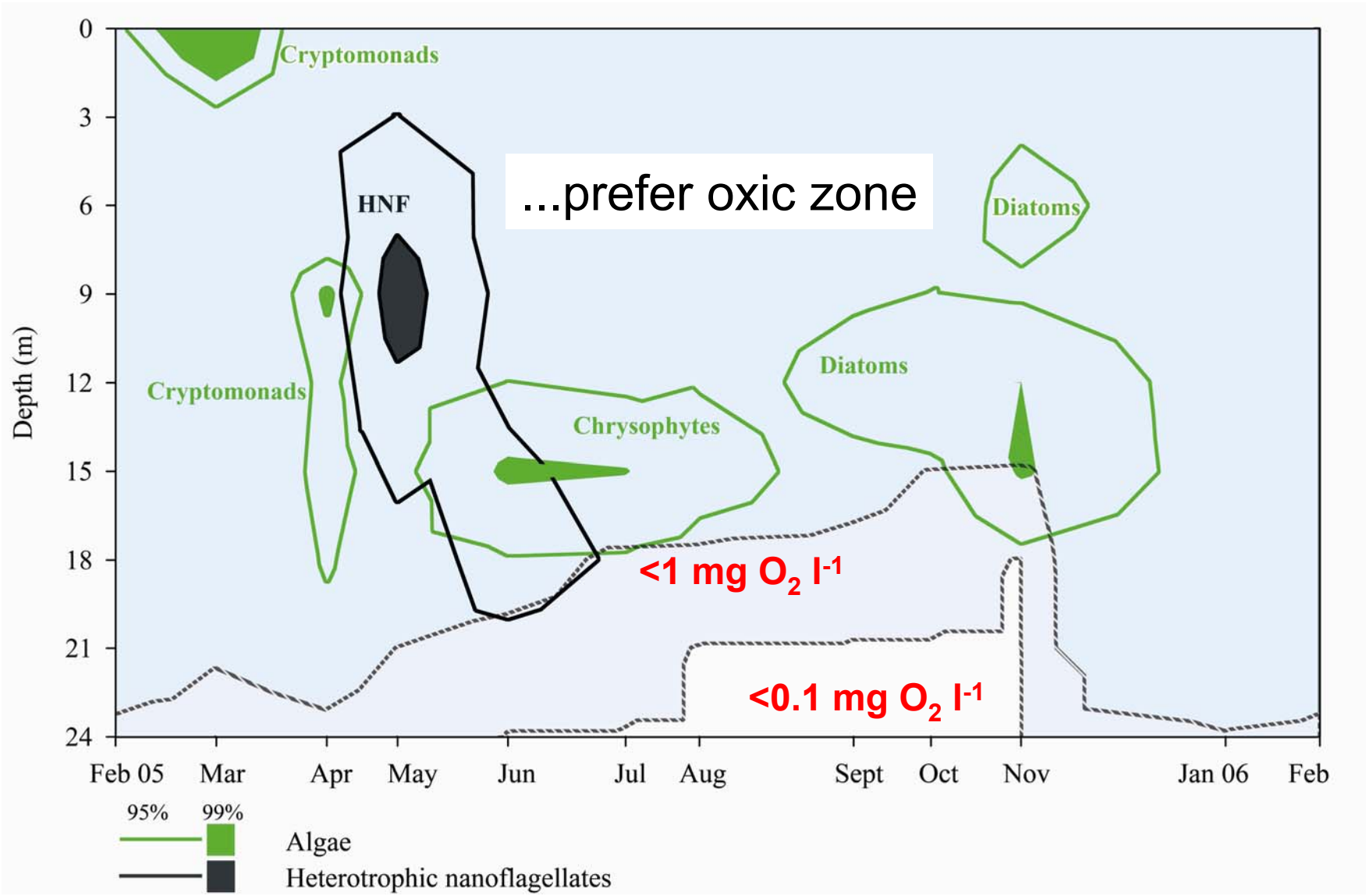

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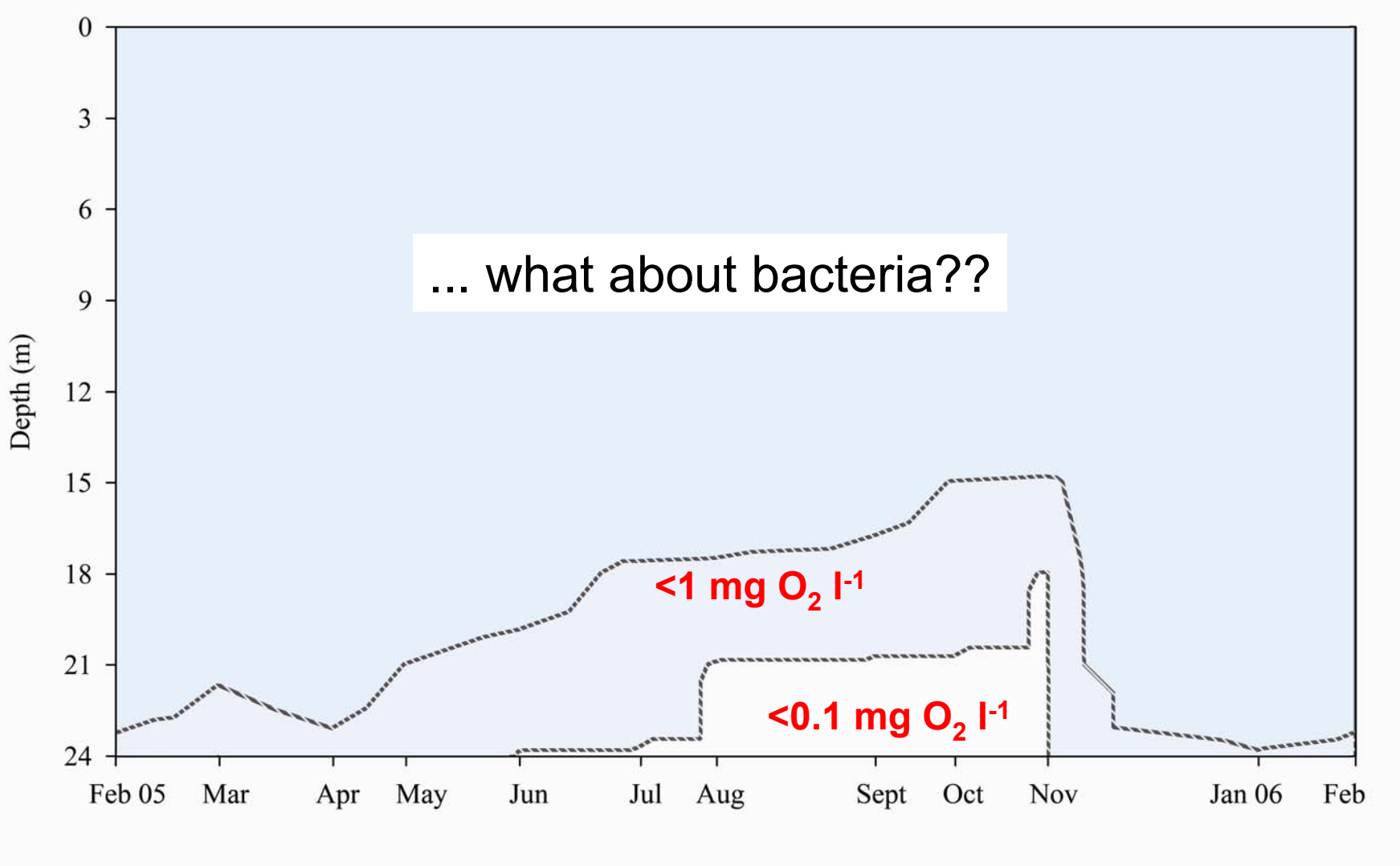

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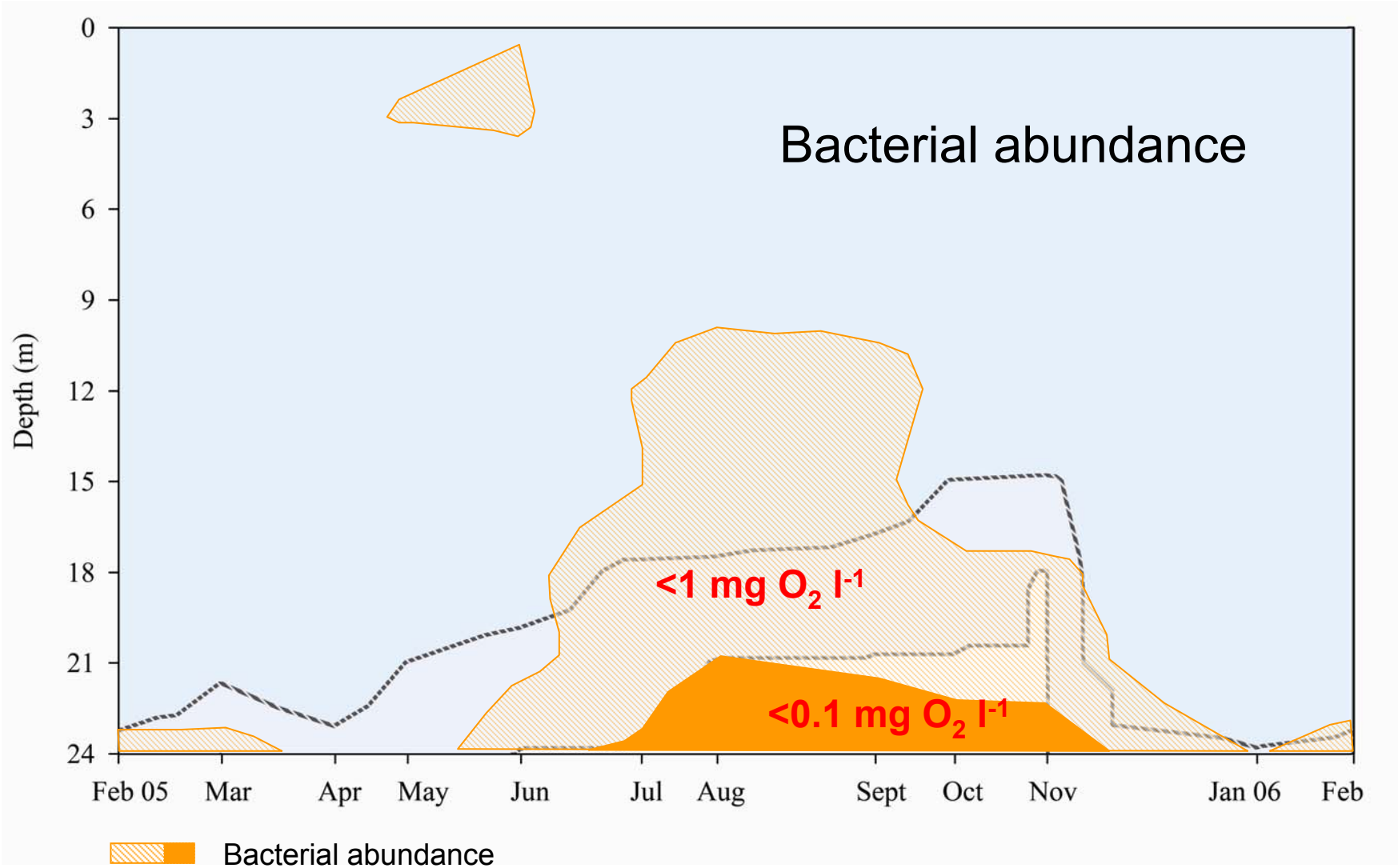

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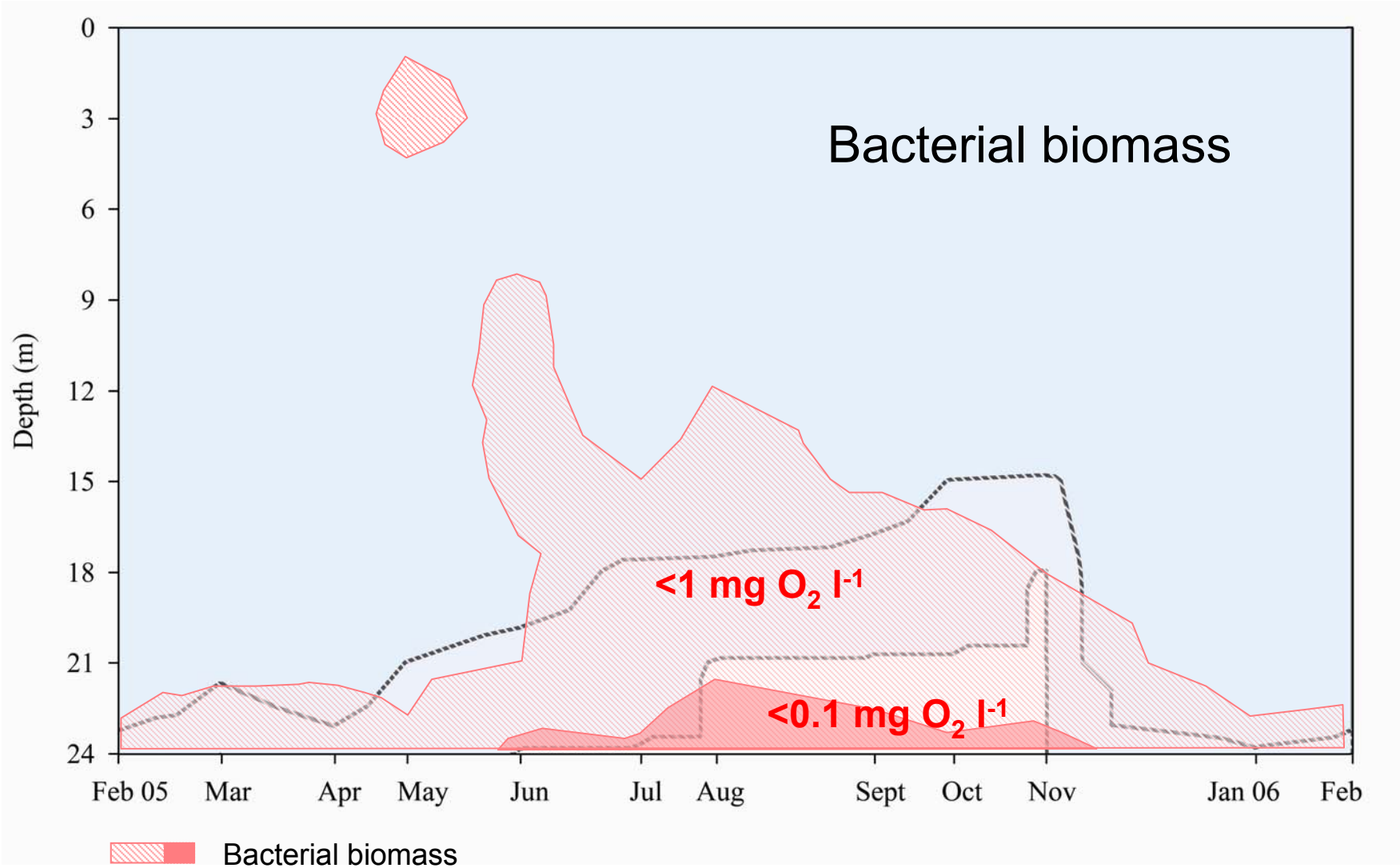

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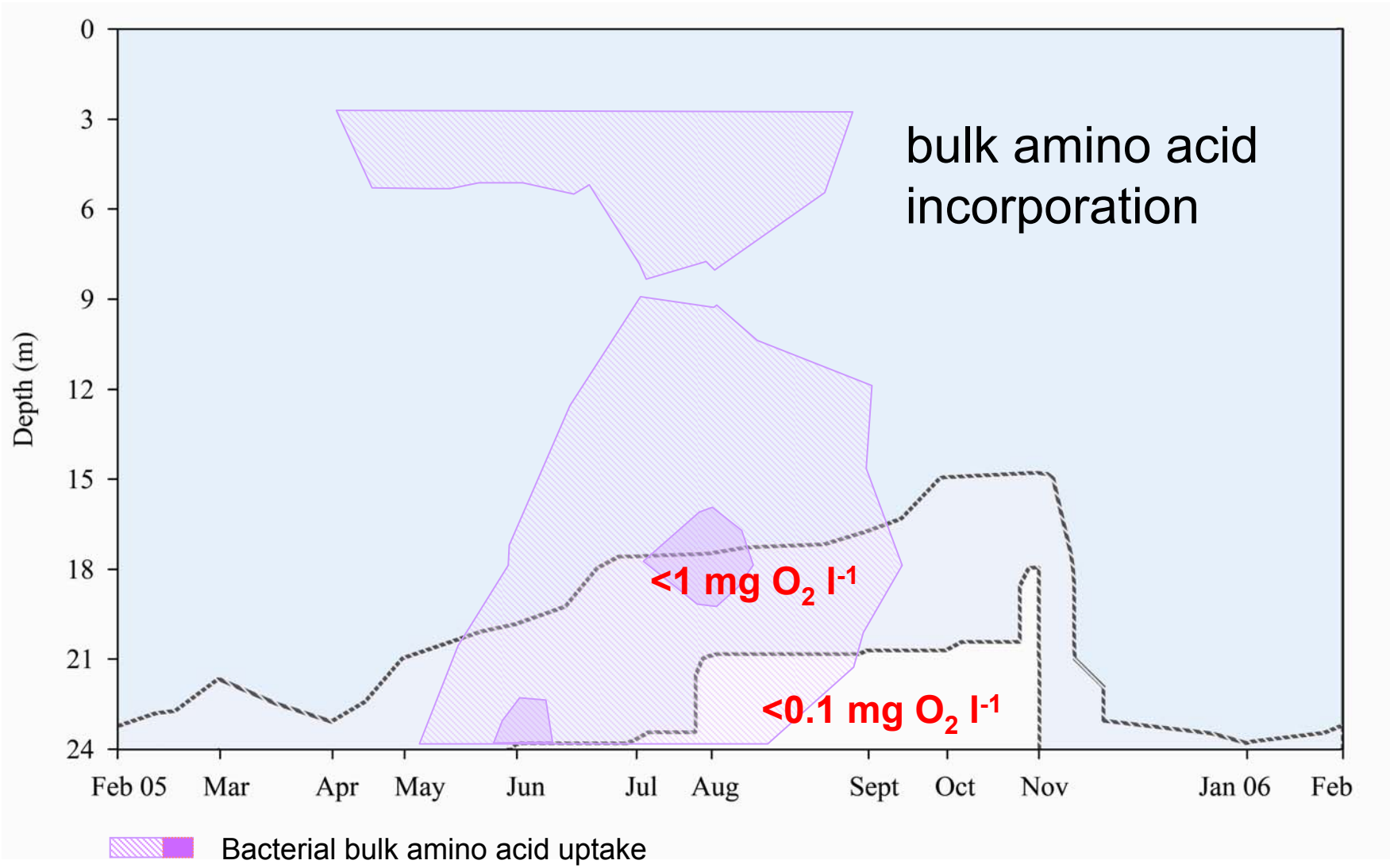

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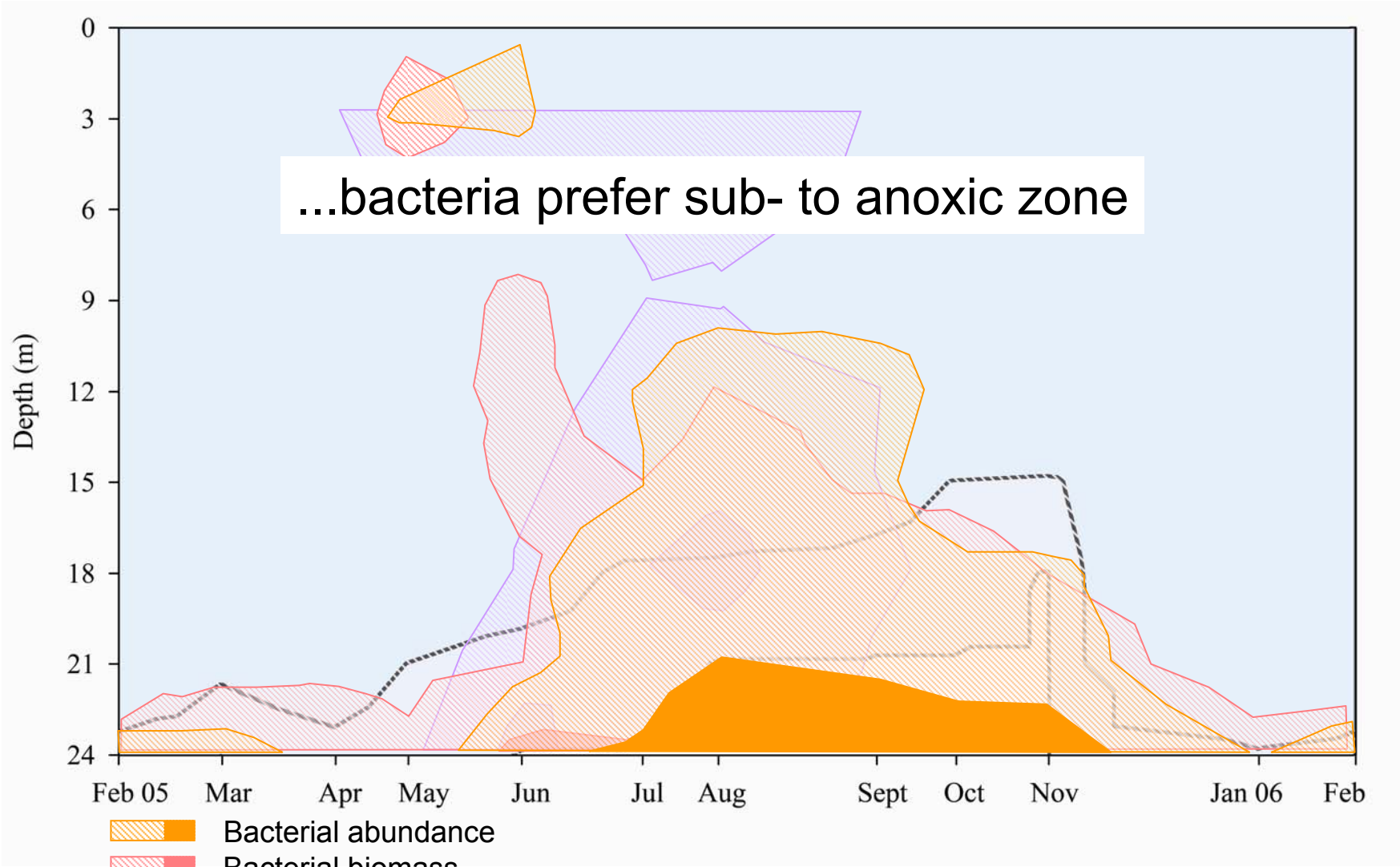

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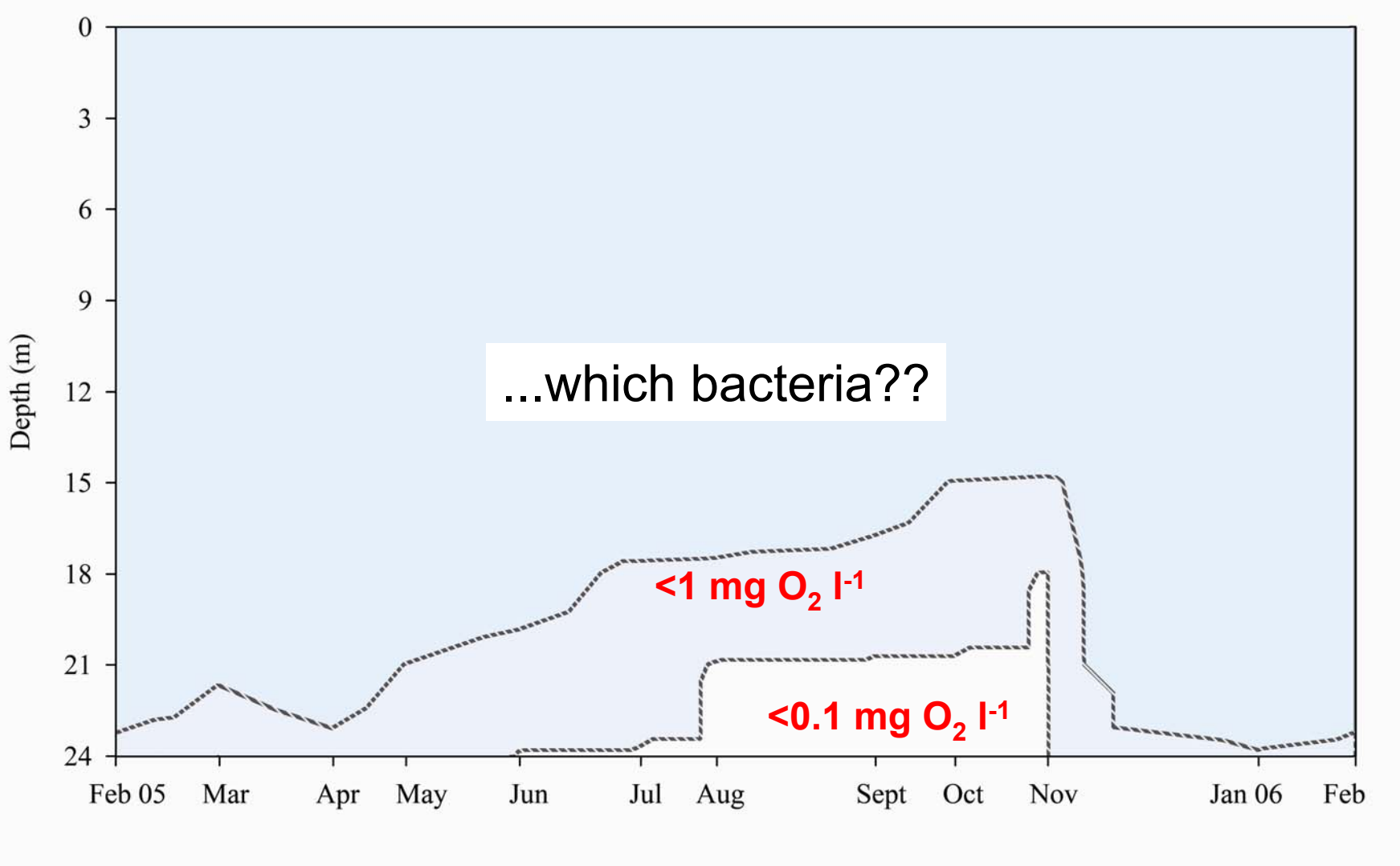

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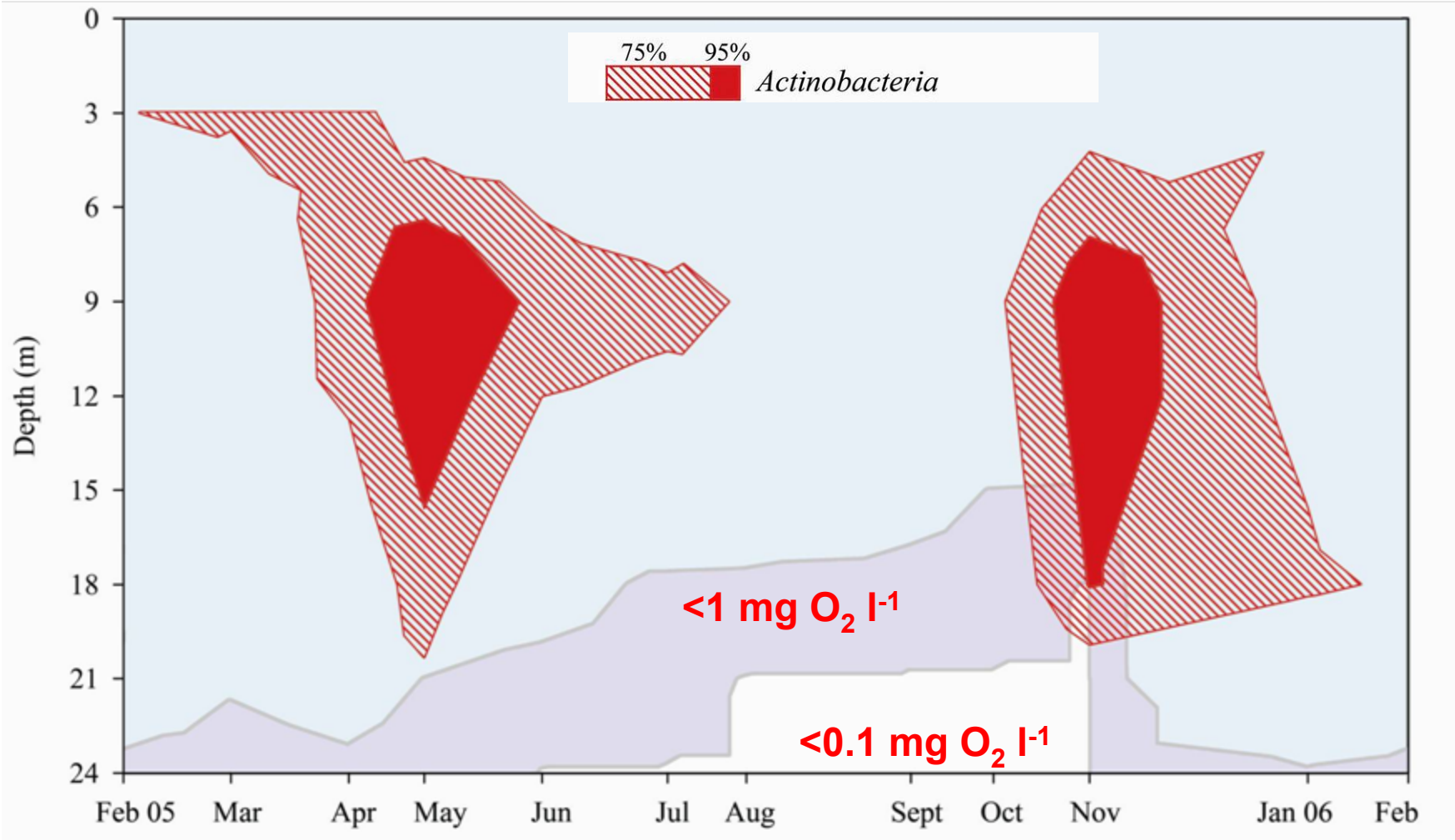

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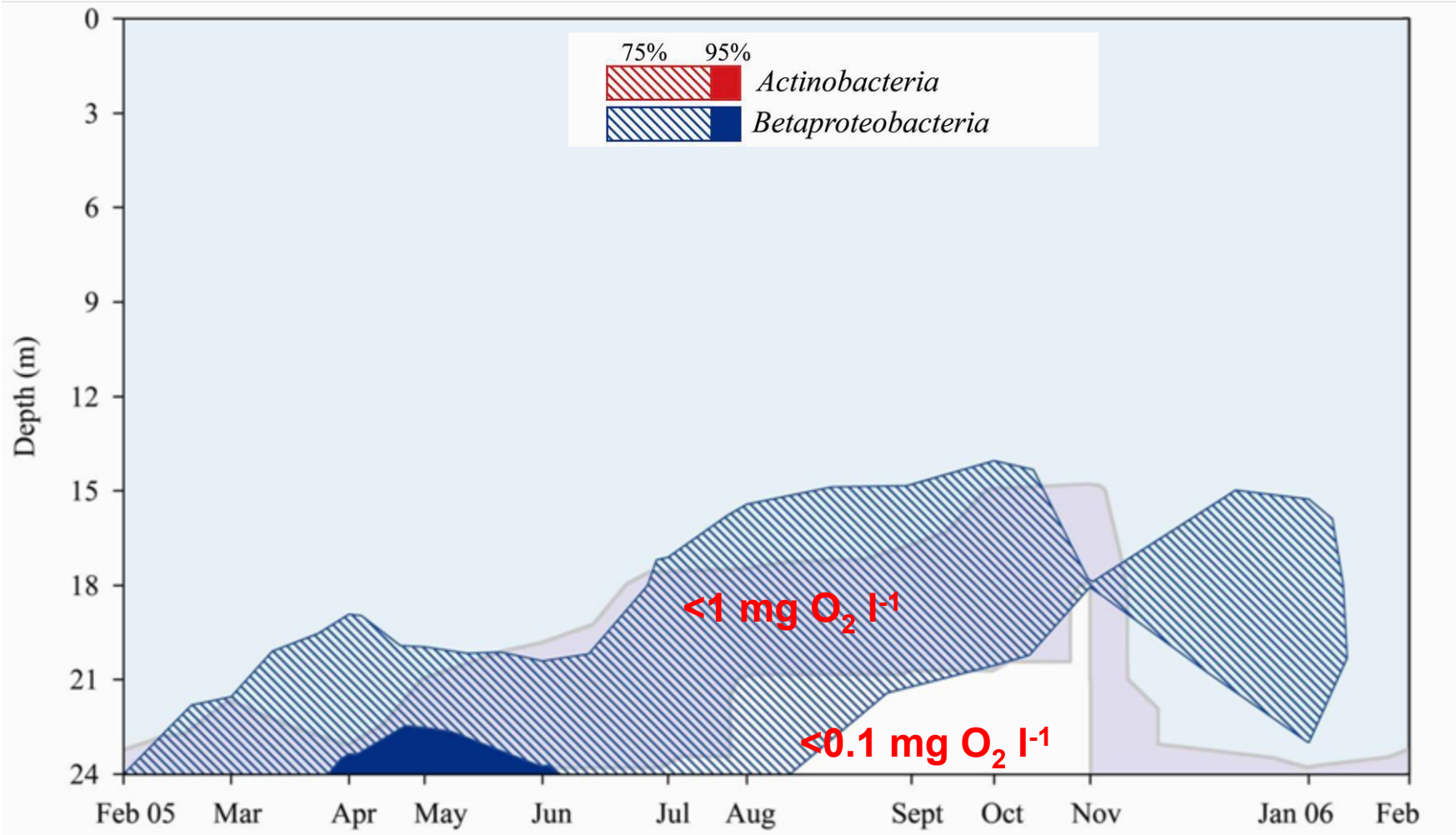

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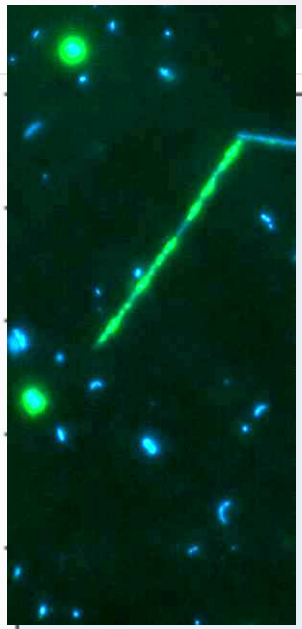
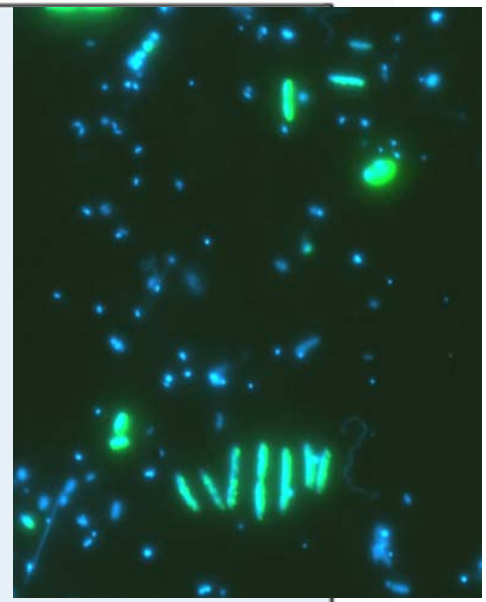




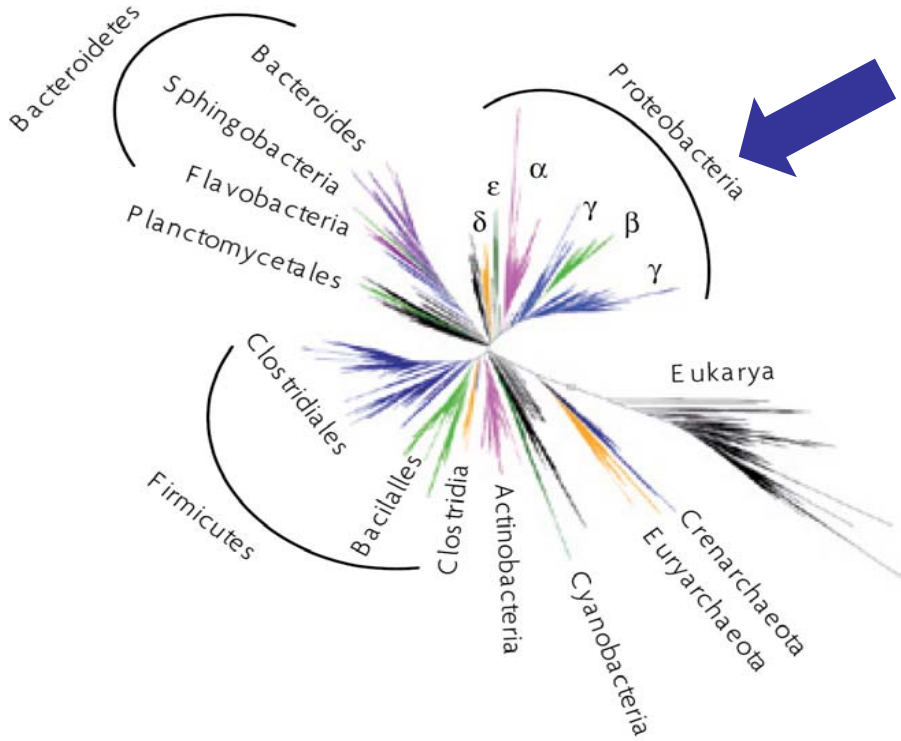
are such lineages homogeneous?

taxonomic resolution of presented data:

- phyla / oders!!
- might harbour distinct populations with very different physiology / habitat preference

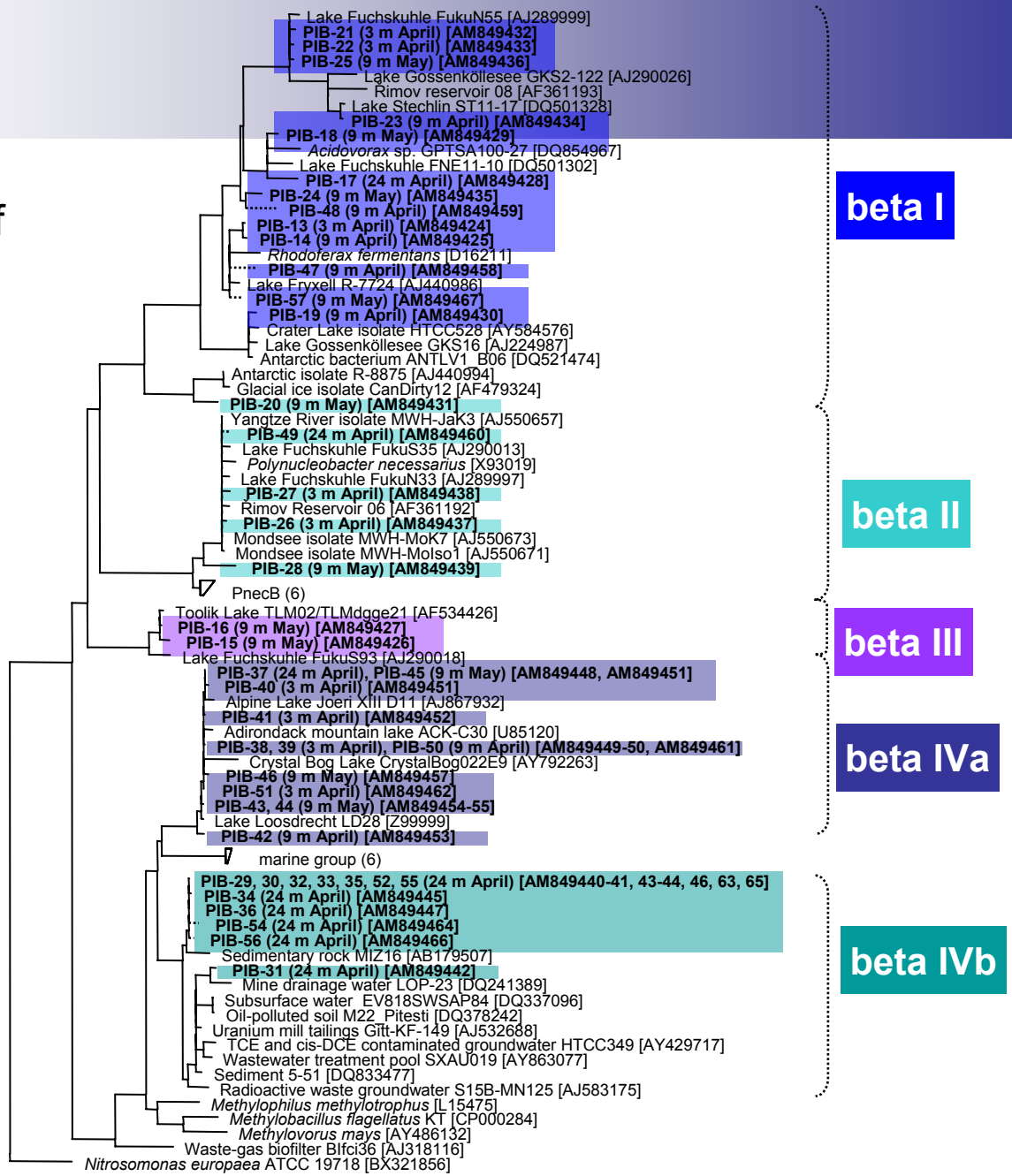
…one example of finer taxonomic resolution:

Betaproteobacteria



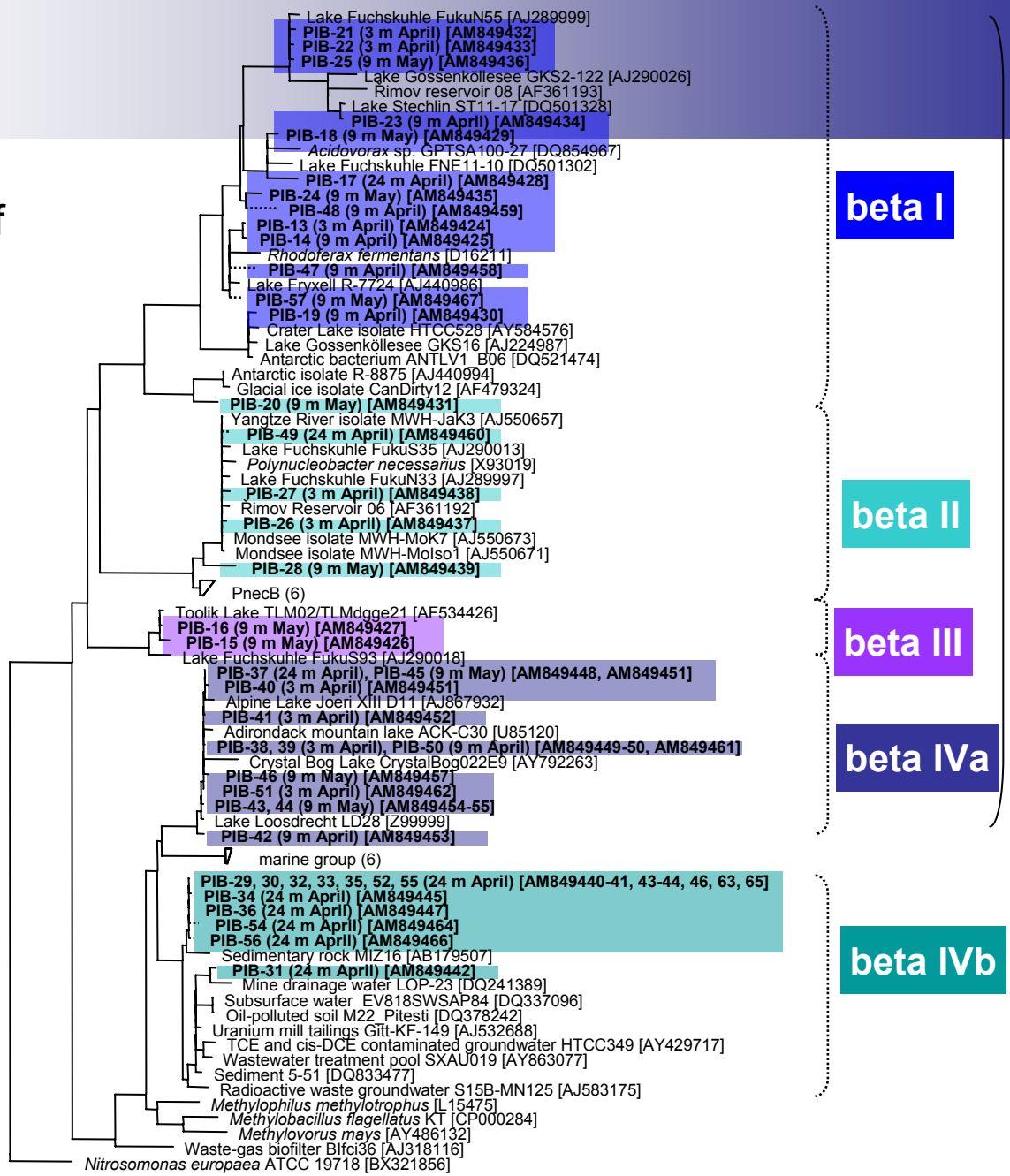
phylogeny

4 clone libraries of
16S rRNA gene



phylogeny

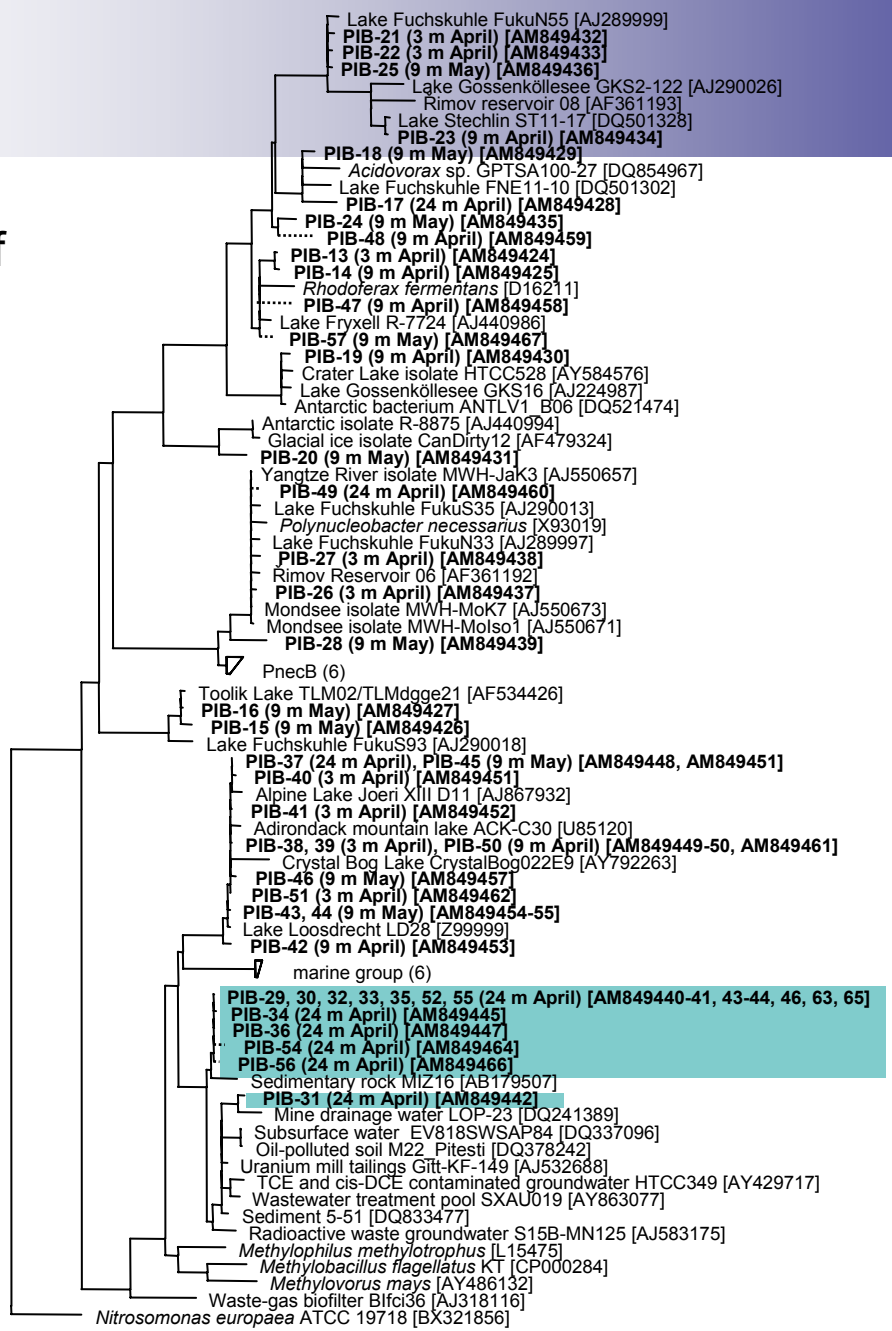
4 clone libraries of
16S rRNA gene



ubiquitous freshwater lineages (Glöckner et al. 2000)

phylogeny

4 clone libraries of 16S rRNA gene



ubiquitous freshwater lineages (Glöckner et al. 2000)

...no sequences from freshwater

...all from anoxic 24 m depth!

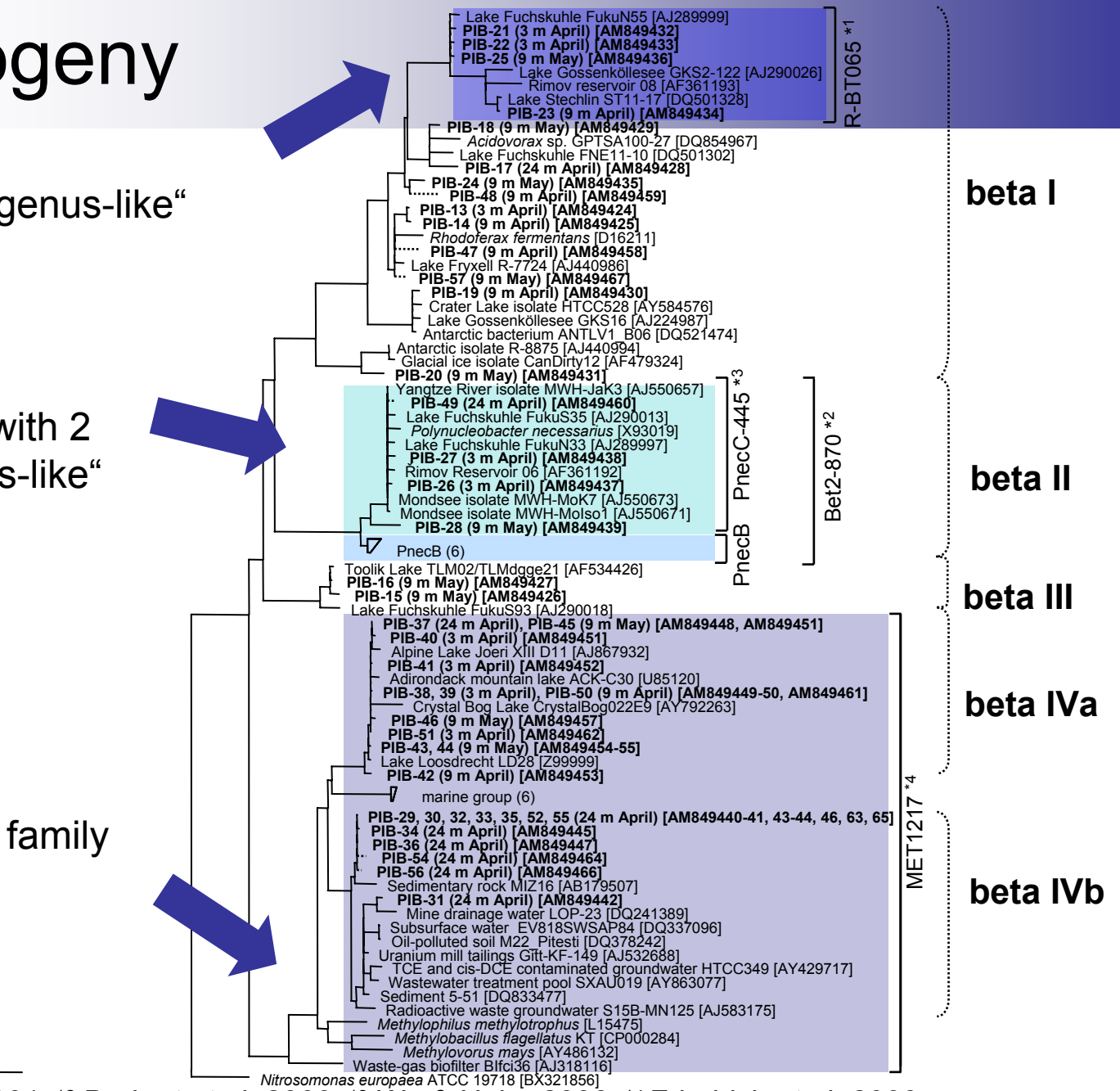
„new freshwater“ lineage

phylogeny

„genus-like“

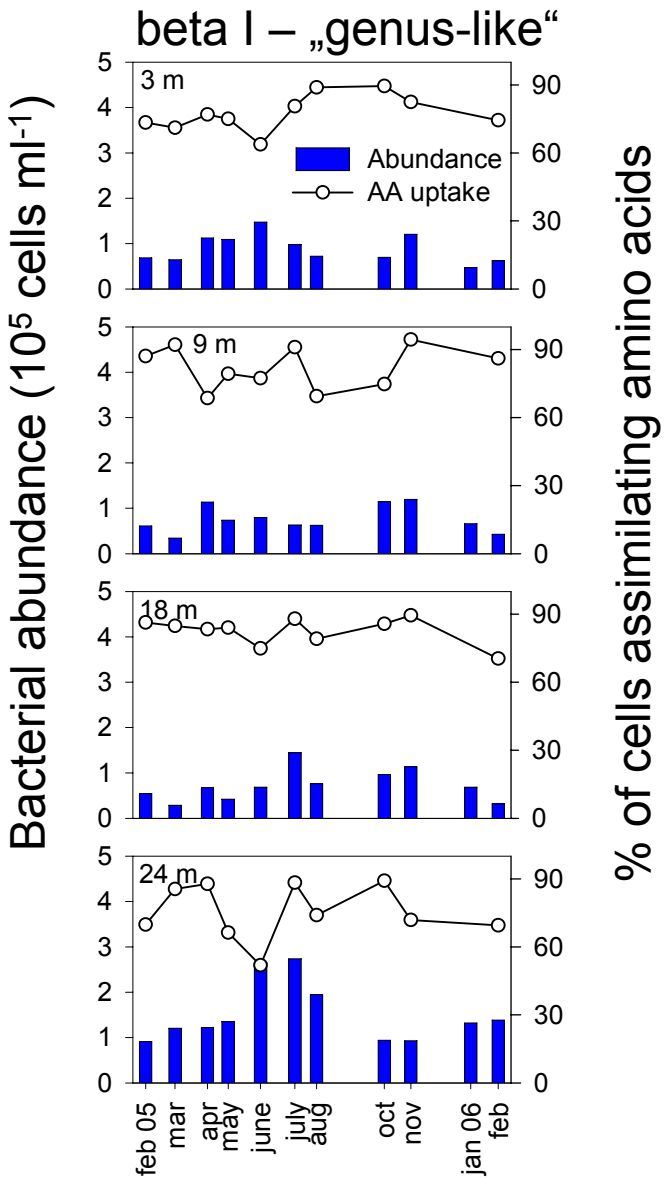
genus with 2 „species-like“

family



*1 Simek et al. 2001; *2 Burkert et al. 2003; *3 Wu & Hahn 2006; *4 Friedrich et al. 2003

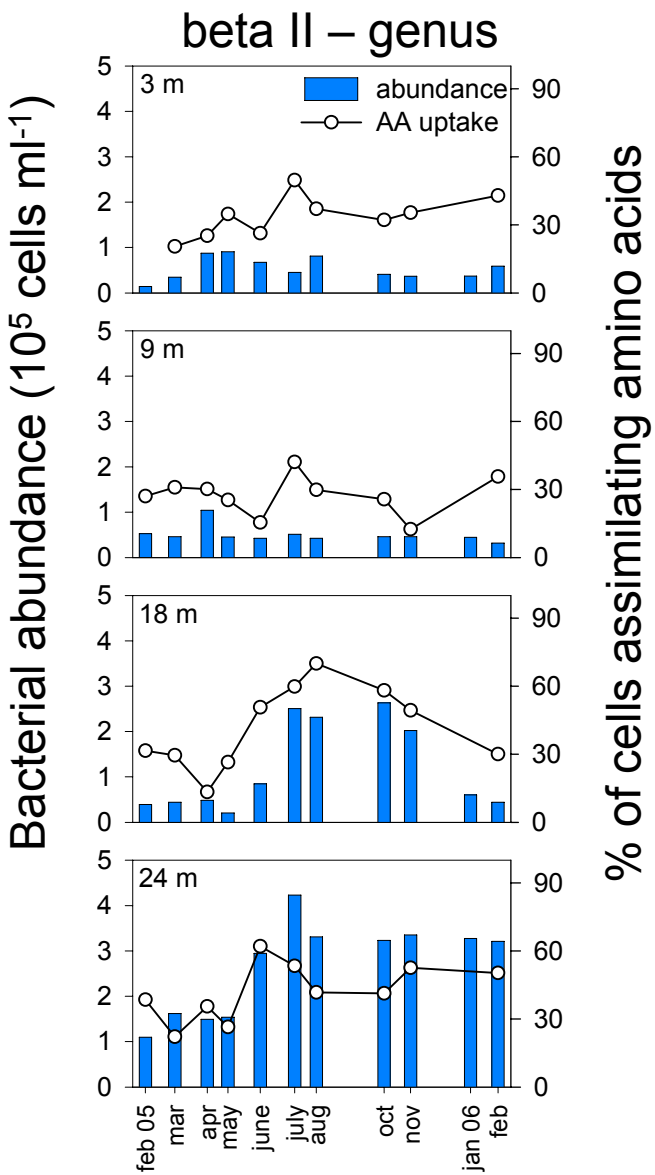
spatio-temporal distribution



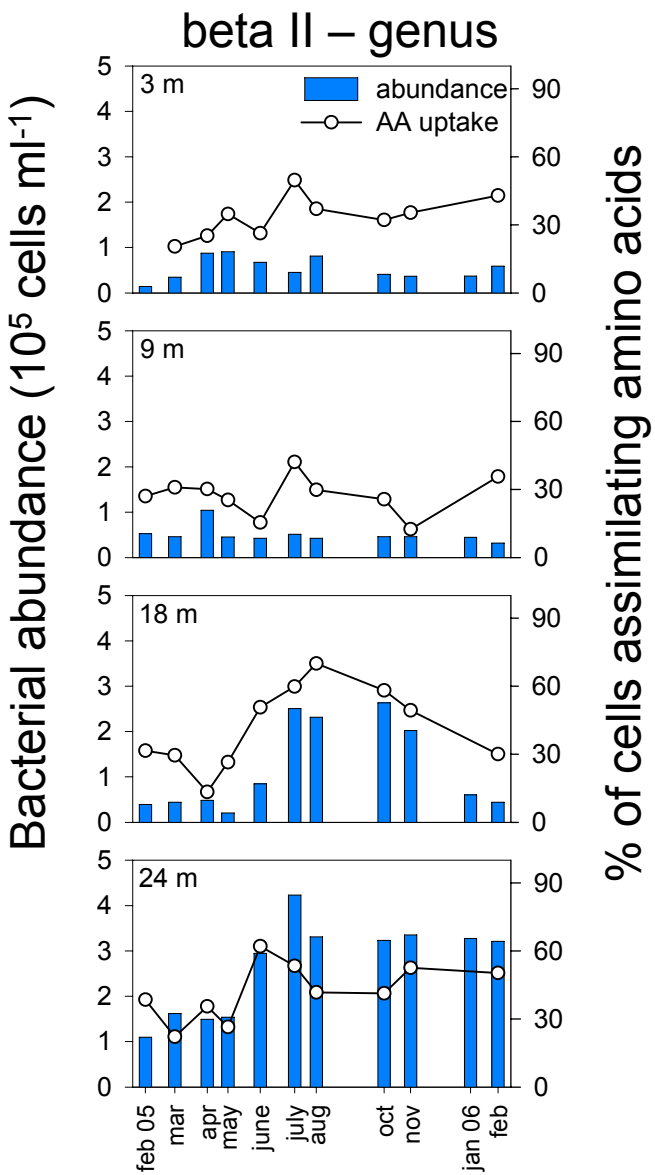
abundant throughout the whole water column

very effective in amino acid uptake (>80% of all beta I)

spatio-temporal distribution

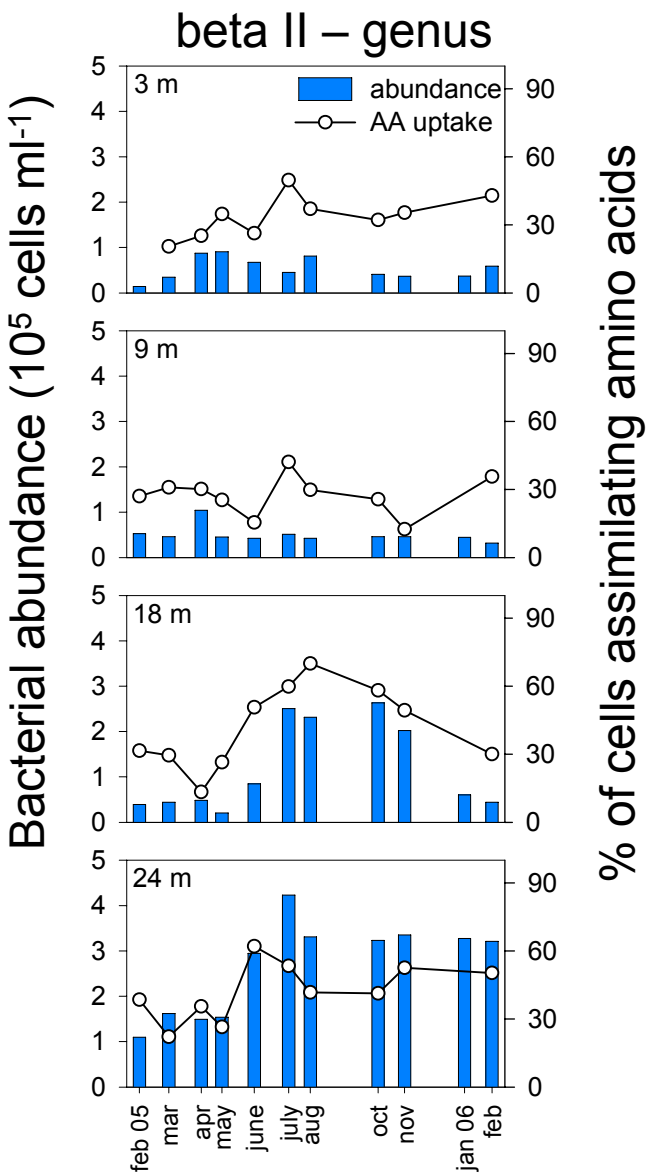


spatio-temporal distribution

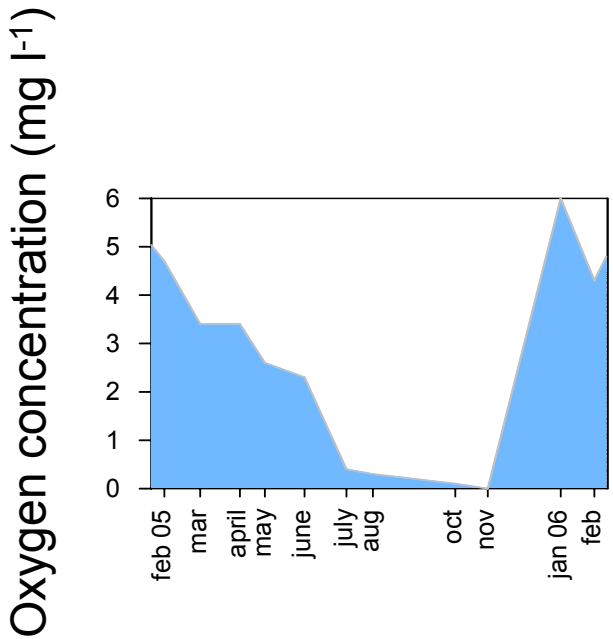


pronounced seasonality
in 18 & 24 m depth

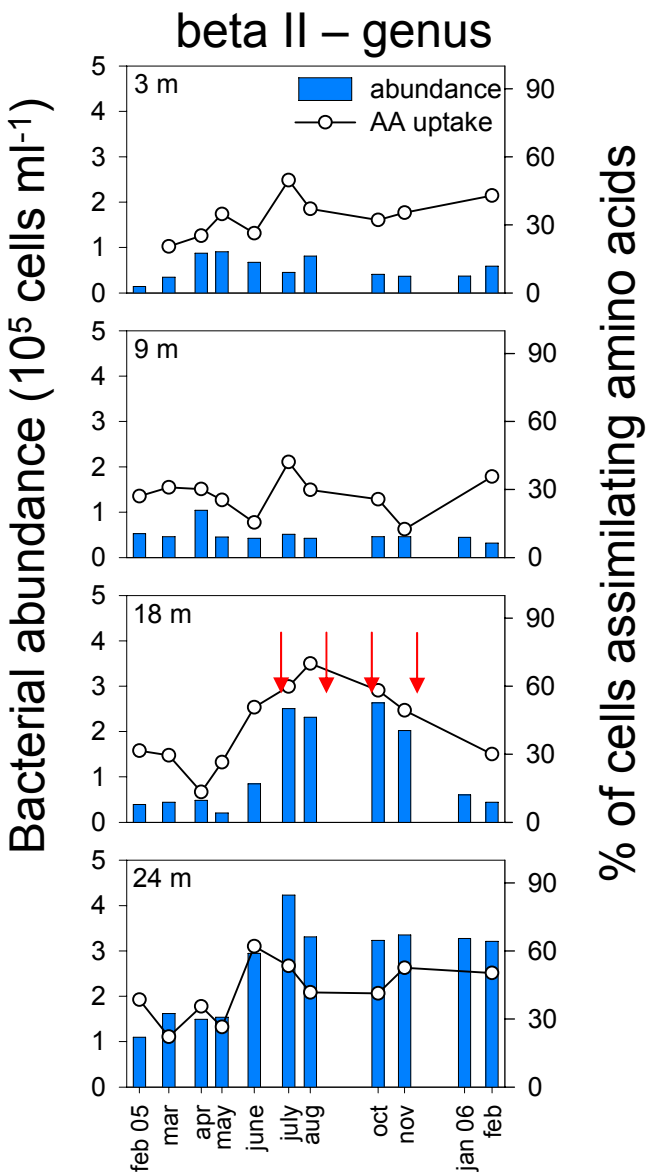
spatio-temporal distribution



pronounced seasonality
in 18 & 24 m depth

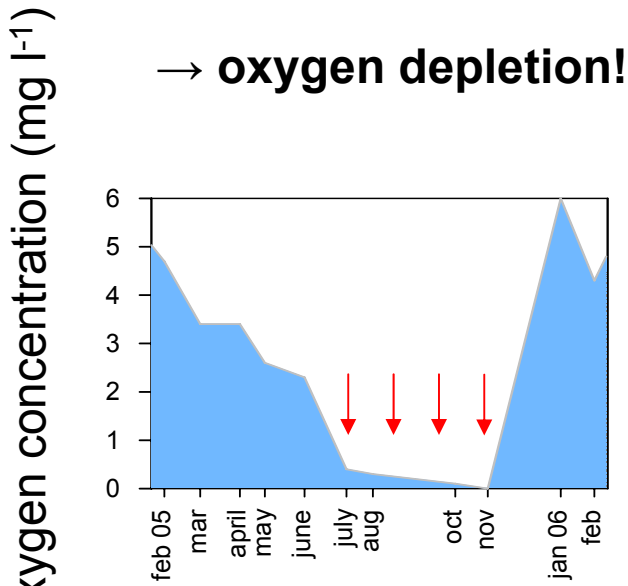


spatio-temporal distribution

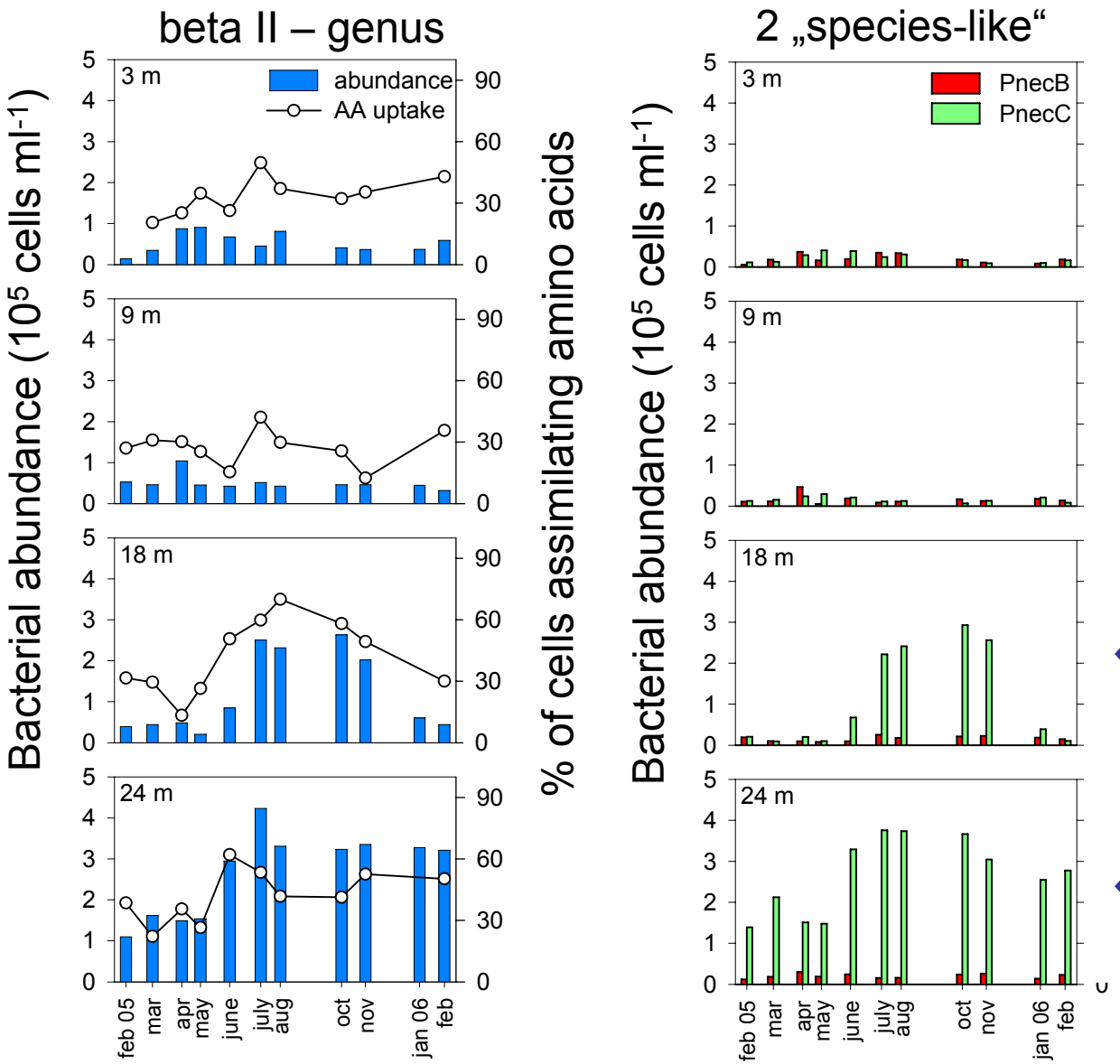


pronounced seasonality
in 18 & 24 m depth

→ **oxygen depletion!**



spatio-temporal distribution



most of anaerobic beta II belong to one species!

summary….

…pronounced seasonality of bacteria

…even more pronounced spatial patterns

…driving forces for the establishment of different bacterial populations…

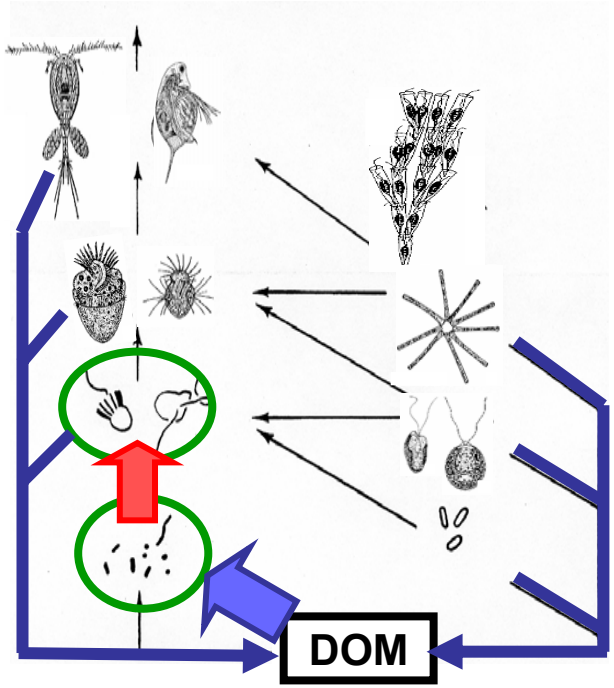
TOP-DOWN & BOTTOM-UP

…*Actinobacteria* seem to be less affected by grazing

…*Betaproteobacteria* seem to be highly vulnerable to grazing by HNF

→ experimentally confirmed

…*Actinobacteria* profit from *Asterionella* bloom (adapted to special exudates?)



Fenchel et al. (1988), modified by T. Posch

OXYGEN CONCENTRATION...

...bacteria are most abundant in sub- to anoxic zone

- cell numbers
- biomass
- amino acid incorporation (“activity”)

...mainly *Cytophaga-Flavobacteria* (anoxic)

...& *Betaproteobacteria* (suboxic)

BETAPROTEOBACTERIA

…inhomogeneous order which differs in spatio-temporal distribution

…some bacteria were abundant in whole water column

…others had their maximum in anoxic hypolimnion

…even 2 closely related species differed completely

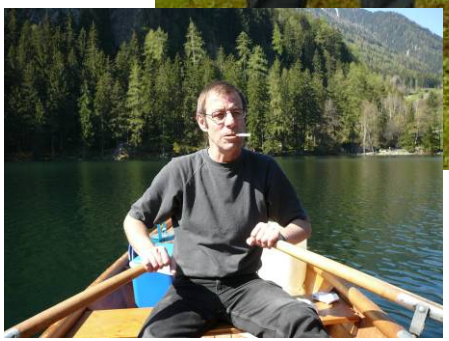
…spatio-temporal niche separation triggered mainly by **oxygen concentrations**

acknowledgements

Thomas Posch

Jakob Pernthaler

acknowledgements



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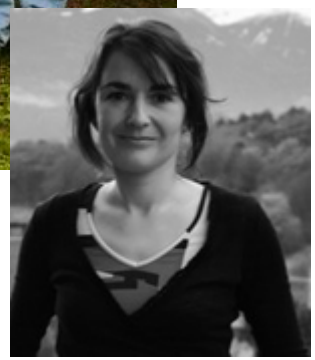


acknowledgements

…financial support

Austrian Science Fund – Project ZFP175540

Max-Planck-Institute for Marine Microbiology

University of Zurich

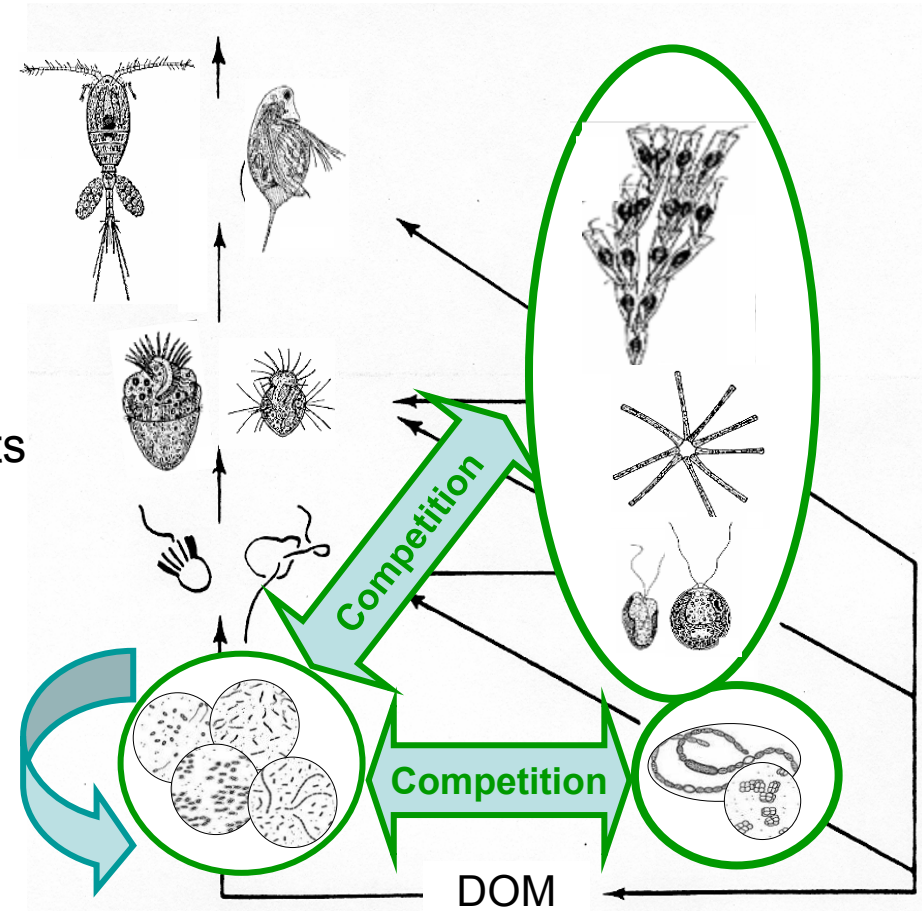
ongoing research

another driving force for planktonic bacteria might be…

…competition for limiting nutrients

- between different bacteria
- between bacteria and algae
- between bacteria and mixotrophic protists

SNF-project:
Competition as driving force for bacterioplankton successions in Lake Zurich (SNF 3100A0-117765)



Fenchel et al. (1988), modified by T. Posch

FNSNF
Fonds national suisse
Schweizerischer Nationalfonds
Fondo nazionale svizzero
Swiss National Science Foundation

…thank you for your attention…