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High net growth of phytoplankton under the serious nitrogen limitation in the subtropical North Pacific Ocean

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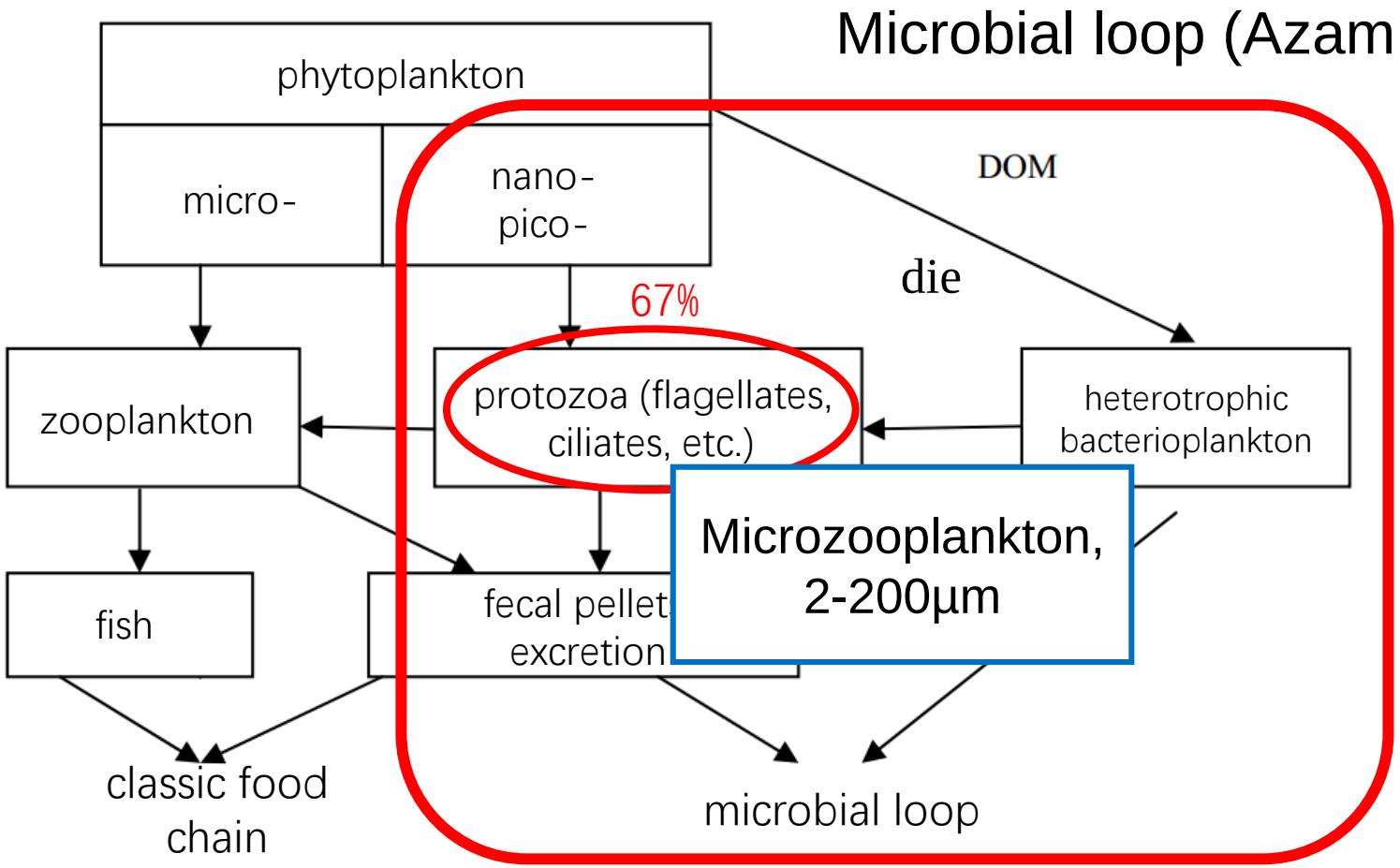
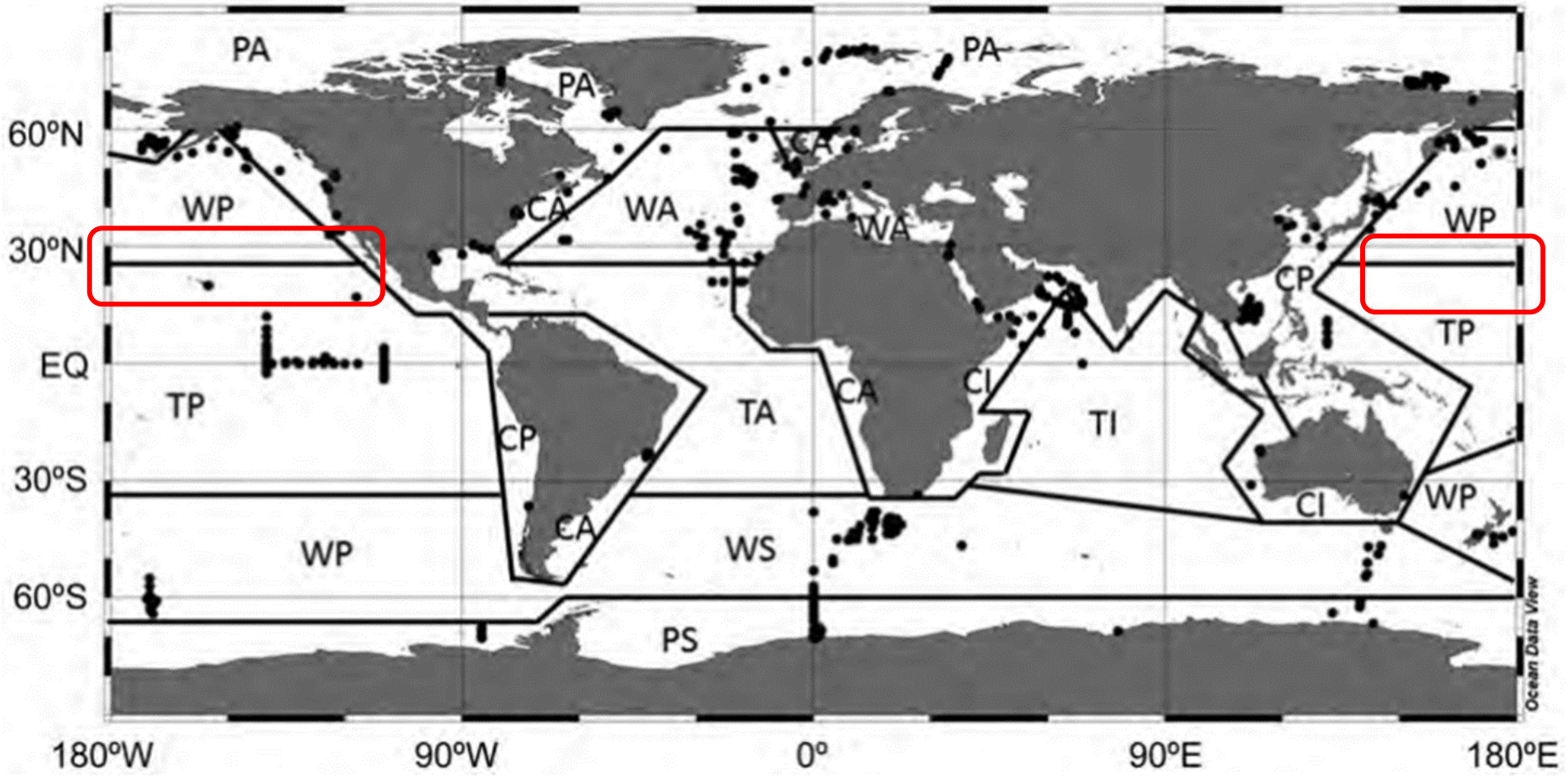
Background – importance of microzooplankton



Microbial loop and its relationship to classic food chain (Ning, 1997)

Background – importance of microzooplankton

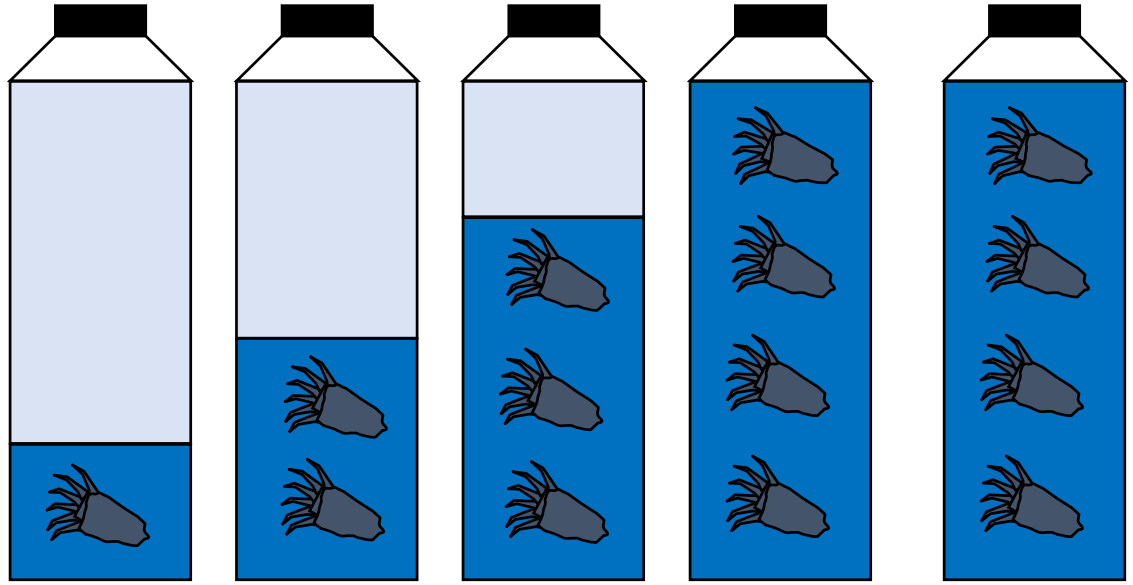
57.7% of the total oceanic surface lacks data on microzooplankton grazing.



(Schmoker *et al*., 2013)

Methods – dilution technique (Landry & Hassett, 1982)

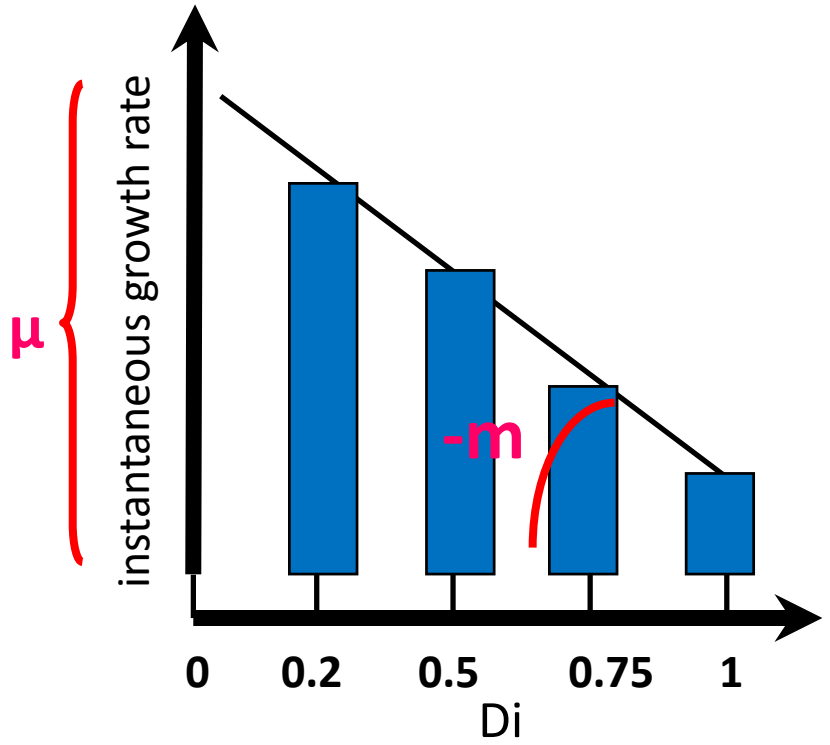
A commonly used technique in which natural seawater is diluted with particle-free water at different proportions .



Di (proportion of natural seawater)	20%	50%	75%	100%	100%
	Nutrient addition: 0.5 µmol L^{-1} **NH_4Cl**, 0.03 µmol L^{-1} **KH_2PO_4** (final concentration)				Without nutrient

natural seawater | particle-free seawater

24-h incubation with simulative environment

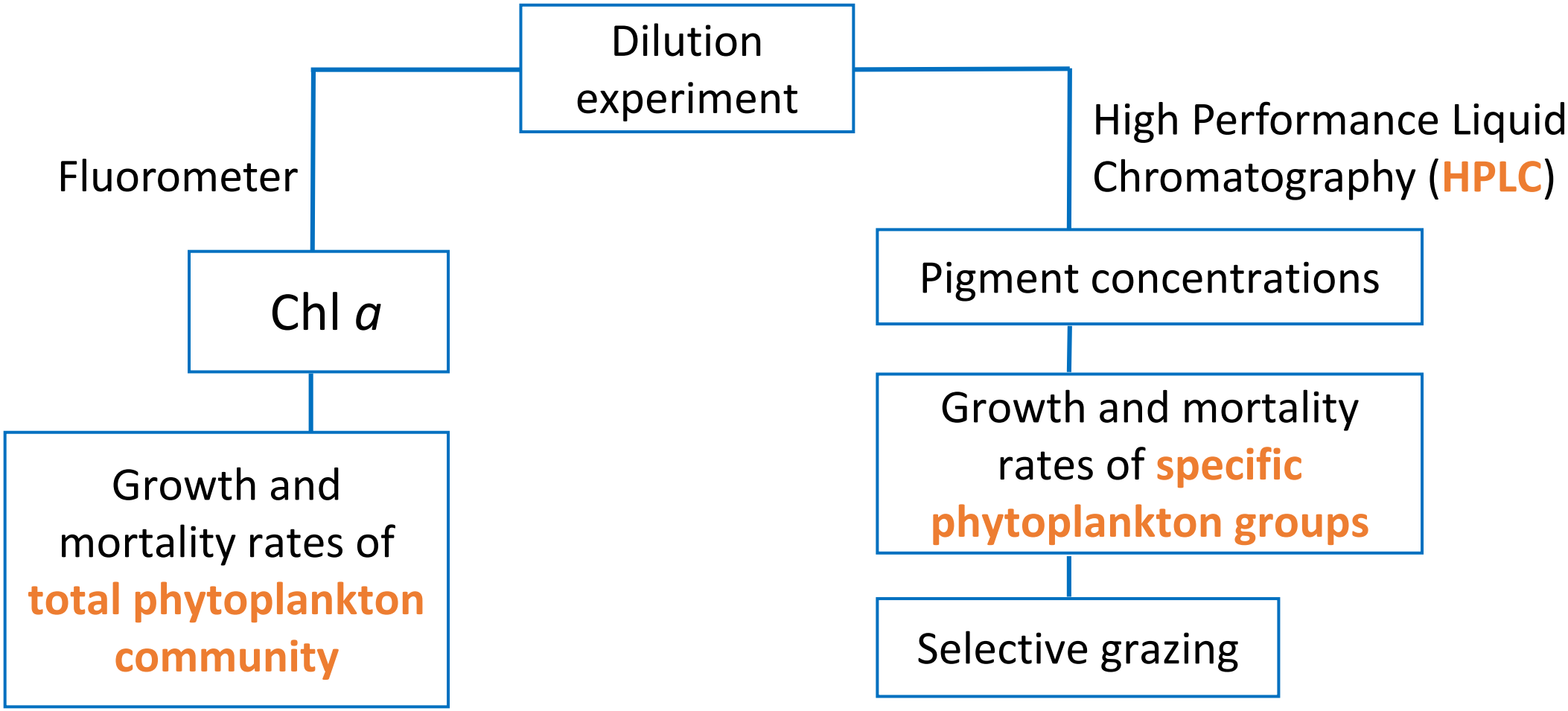


μ_0 = phytoplankton growth rate **with additional nutrient**

µ = phytoplankton growth rate **without additional nutrient**

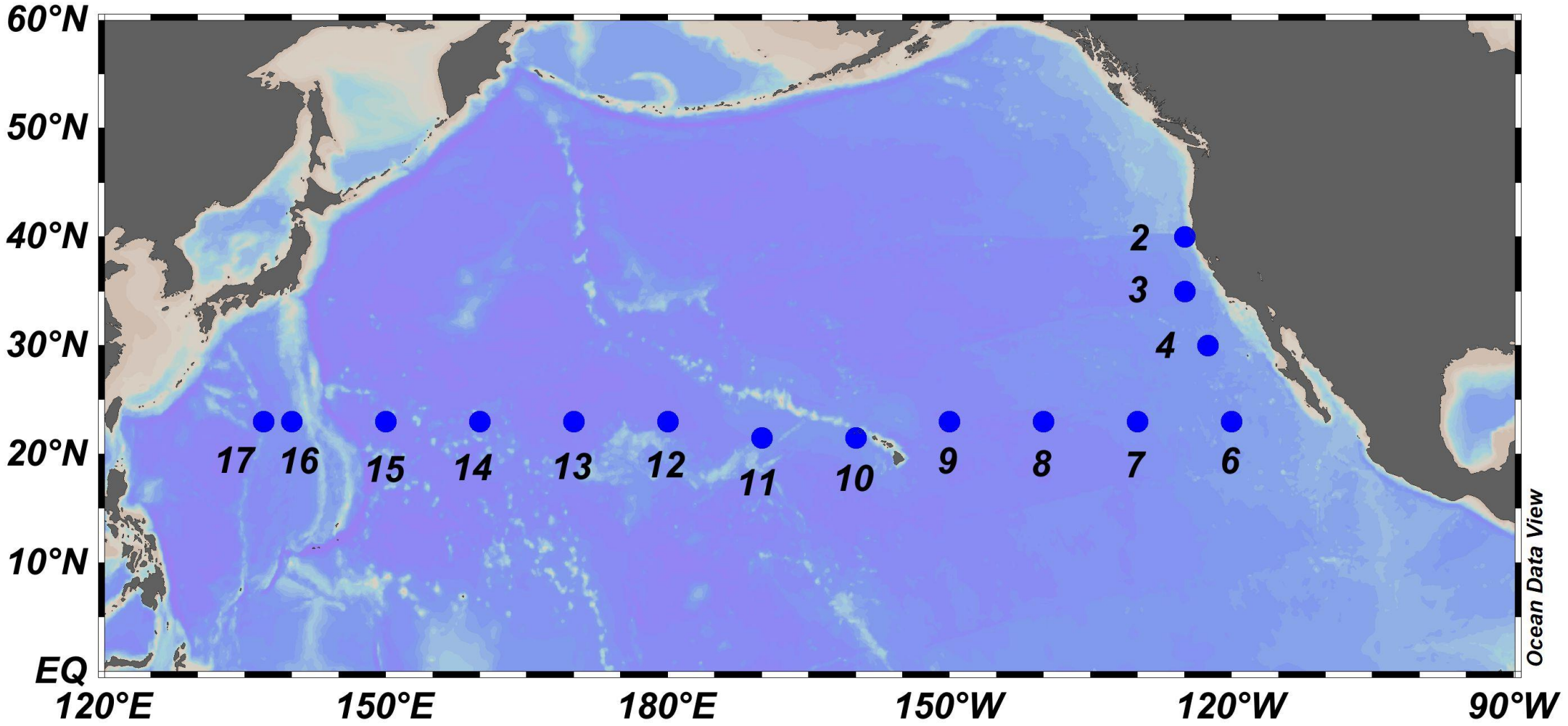
m = microzooplankton grazing rate

Methods – dilution technique (Landry & Hassett, 1982)

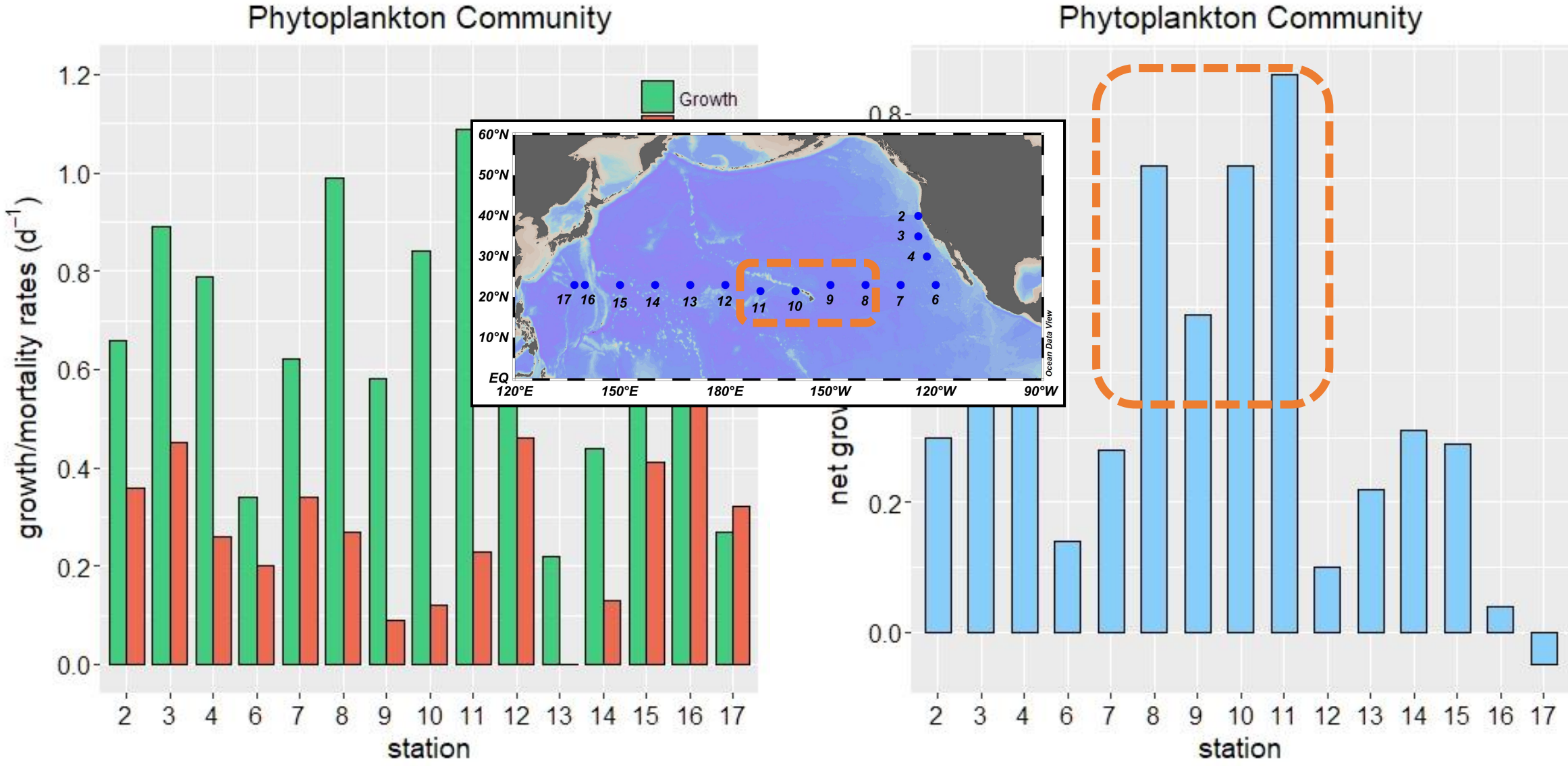


Methods – study stations

Surface water (**10m**), station 2-17, **August-October**, 2017



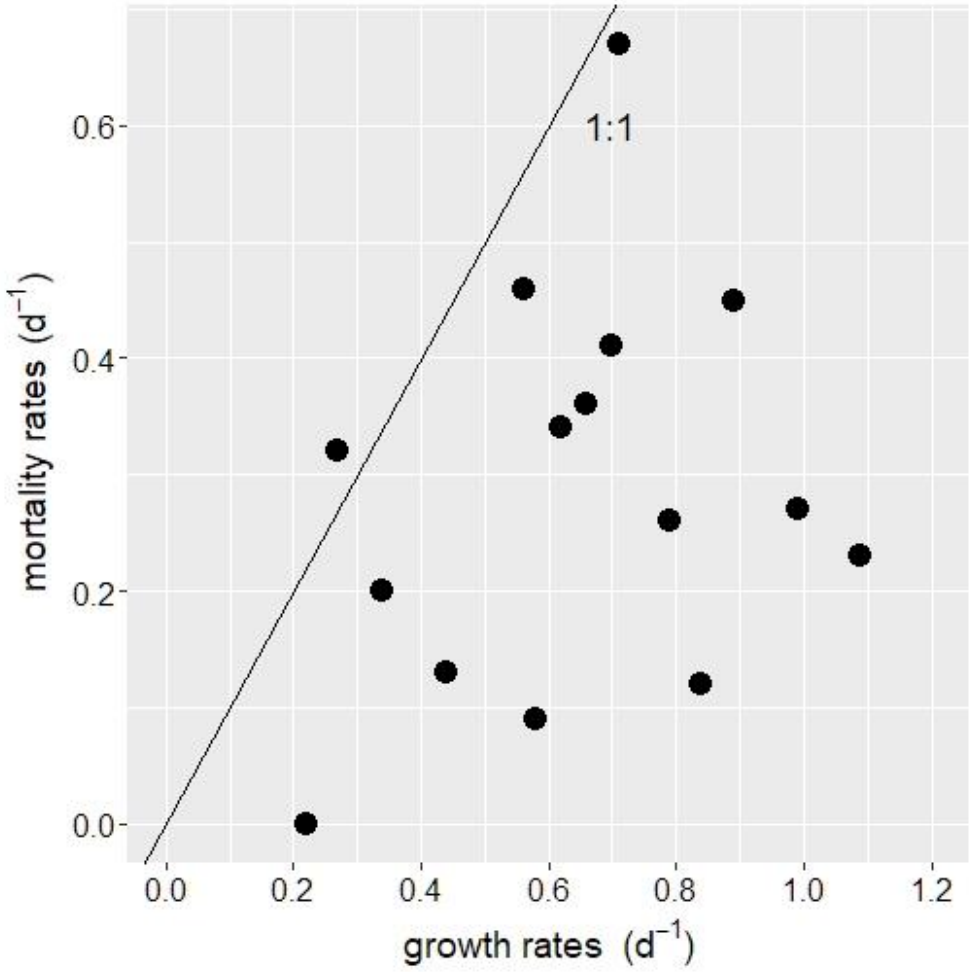
Main results – growth and mortality of phytoplankton community



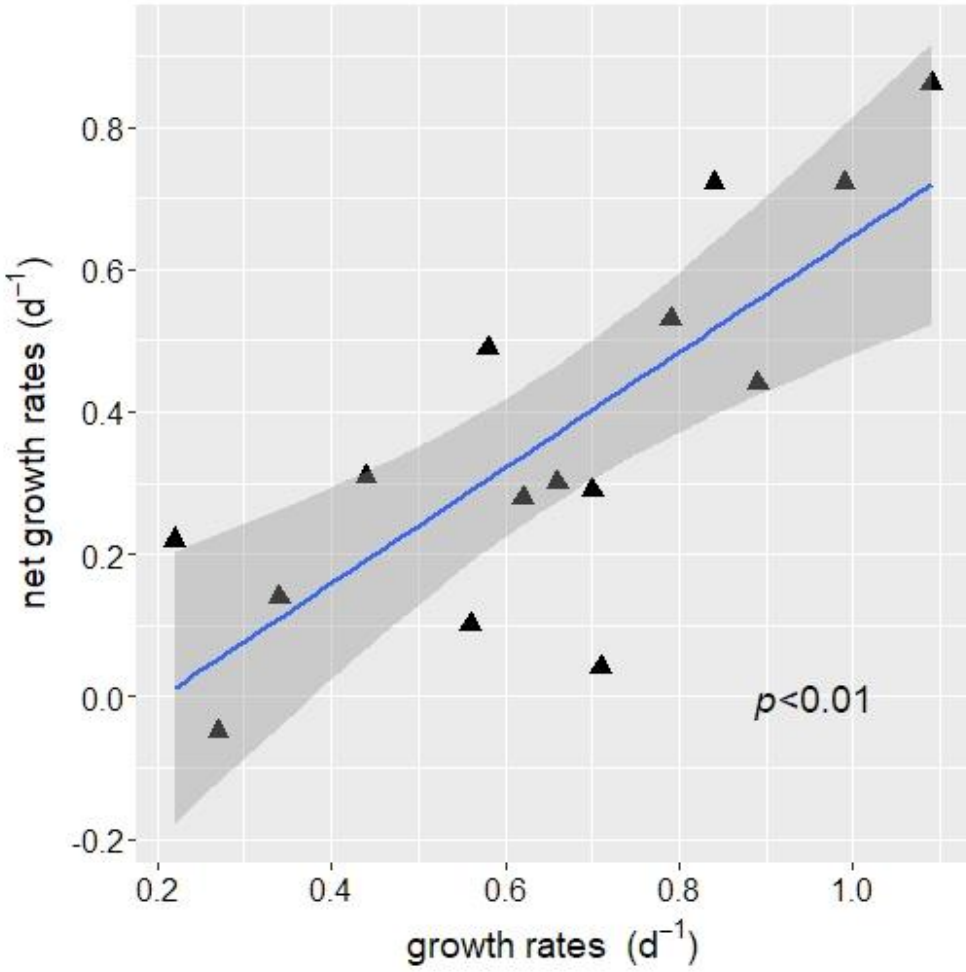
*net growth = growth - mortality

Main results – growth and mortality of phytoplankton community

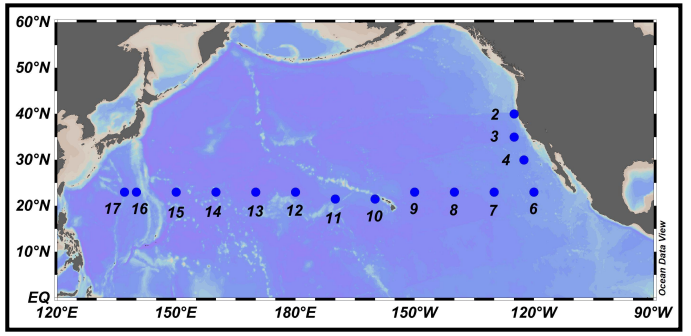
- Microzooplankton grazed **47.5%** (mortality/growth) phytoplankton daily production.



- Positively correlated;
- Microzooplankton grazing may could not the control factor on phytoplankton growth.



Main results – nutrient concentration



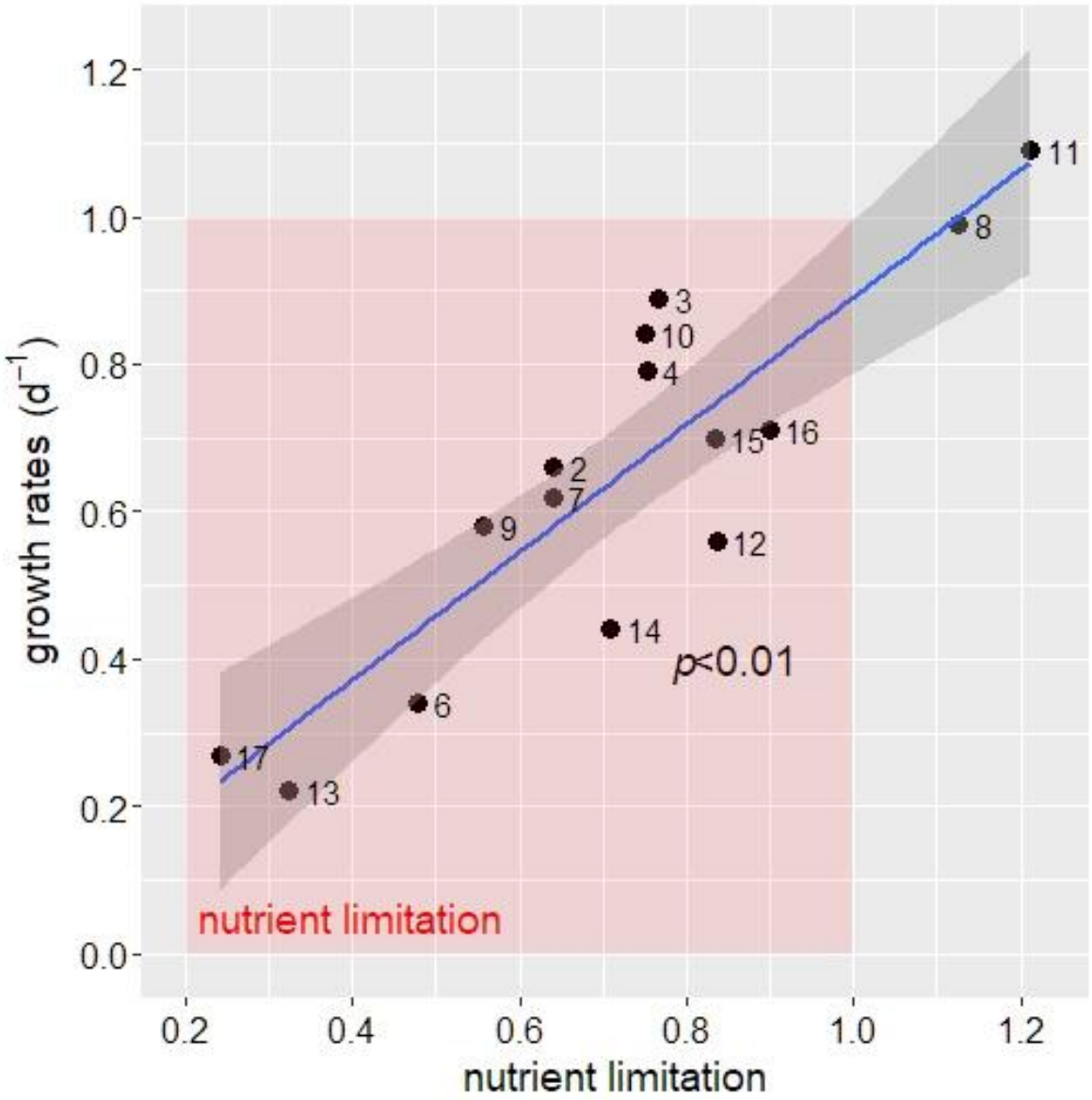
which concentration is lower than the detection limit

Station	4	6	7	8	9	10	11	12	13	14	15	16	17
NO_3^- (nM)	<3	<3	<3	3	<3	4	<3	<3	3	3	<3	3	<3
NO_2^- (nM)	3	2	3	3	2	2	<2	<2	3	2	2	<2	<2
NH_4^+ (nM)	<4	19	16	10	25	<4	<4	7	16	27	38	<4	37
$PO4_3^-$ (nM)	238	186	170	70	102	65	38	28	7	<3	<3	<3	3
$Si(OH)_4$ (nM)	1916	1585	1541	1314	1101	1125	977	1003	1027	1006	1234	1106	1060
DIN:P	0.01	0.11	0.11	0.23	0.26	0.09	0.00	0.25	3.14				12.33

Additional nutrient in dilution experiment

Nitrogen limitation

Main results – growth and mortality of phytoplankton community



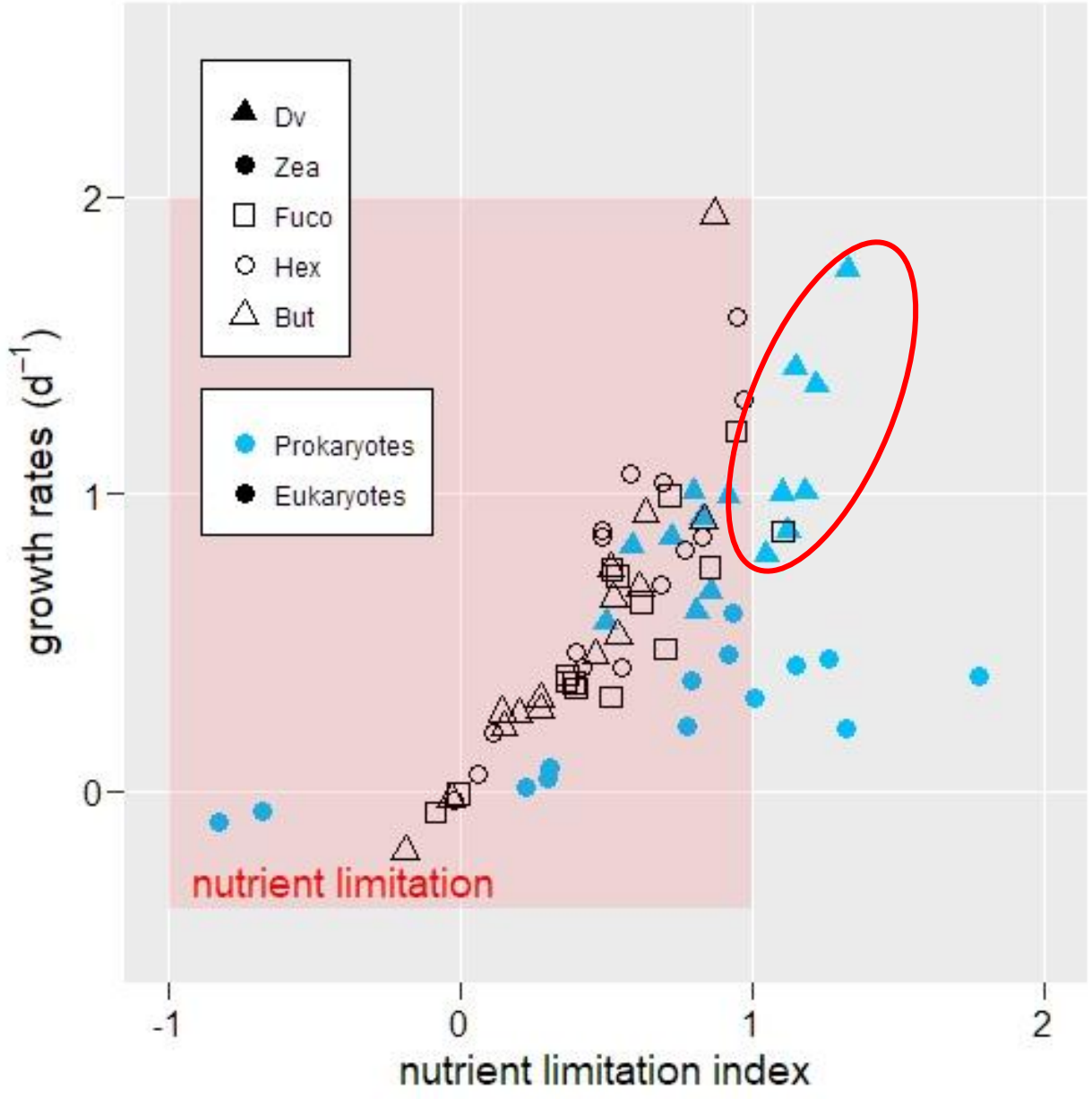
nutrient limitation index

$$= \frac{\text{growth rate without nutrient addition}}{\text{growth rate with nutrient}}$$

>1, no obvious limitation

<1, nutrient limitation

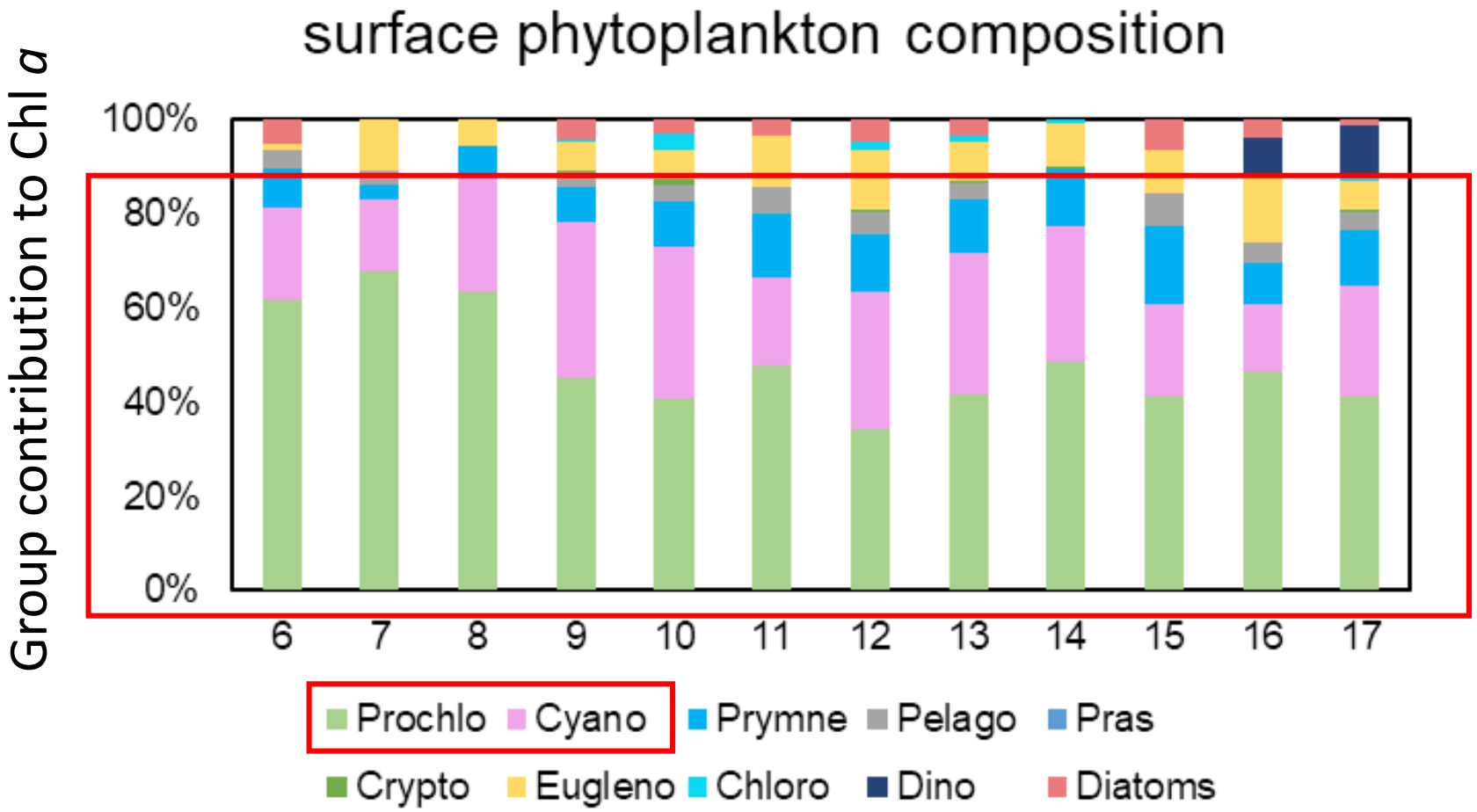
Main results – specific pigments



Low nutrient support high growth?

- The **prokaryotic phytoplankton** cells are efficient in acquiring nutrients because of their extremely small sizes;
- and could possess a low-nutrient half-saturation growth constant;
- might have **adapted to the oligotrophic environment**.

Main results – phytoplankton community composition

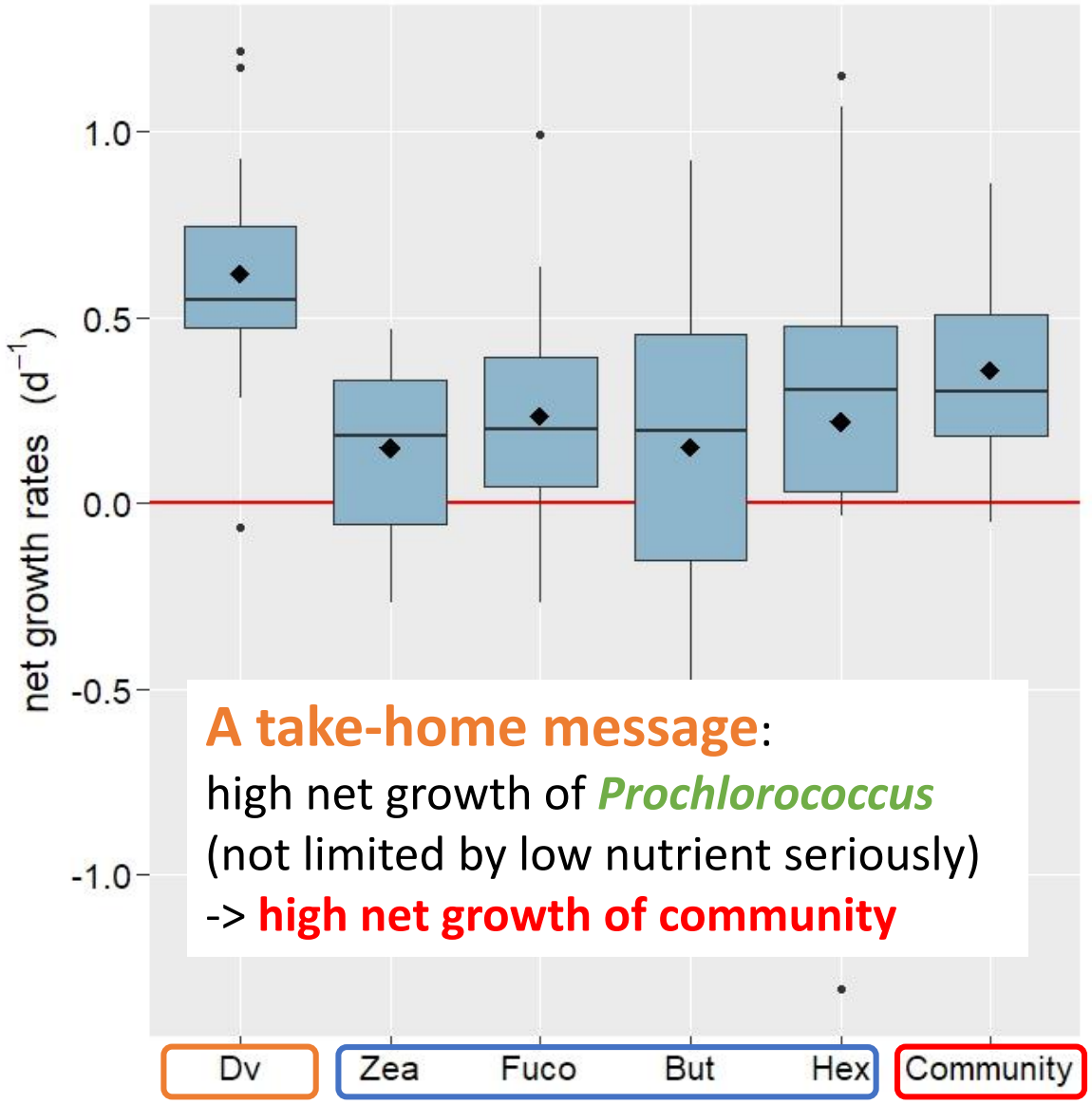


prokaryotic phytoplankton:

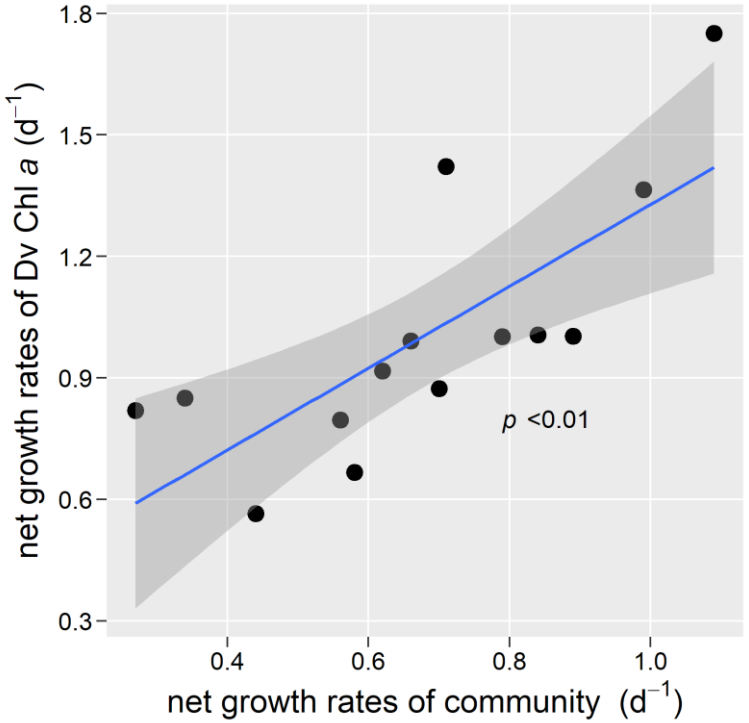
Prochlorococcus (Dv Chl *a*)

Synechococcus (Zeaxanthin)

Main results – specific pigments



A take-home message:
high net growth of ***Prochlorococcus***
(not limited by low nutrient seriously)
-> **high net growth of community**



- **Prokaryotic phytoplankton** (dominant ***Prochlorococcus*** represented by Dv Chl *a*) :
  higher net growth
- **Eukaryotic phytoplankton**
  (e.g. diatoms represented by Fucoxanthin):
  lower growth + high mortality
  → lower net growth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Thanks for watching!

Three assumptions:

1. Phytoplankton growth rates must be independent of the dilution level;
2. The ingestion rate of microzooplankton must be linearly proportional to their concentration;
3. The changes in the density of phytoplankton over time follow an exponential model.

$$P_t = P_0 \times e^{t(k-g)}$$

$$1/t \ln(P_t/P_0) = k - Di*g$$

$$\ln(P_t/P_0) \sim Di$$

Contents

- Research background
- Methods
- Main results

Growth and mortality rates calculated from specific pigments

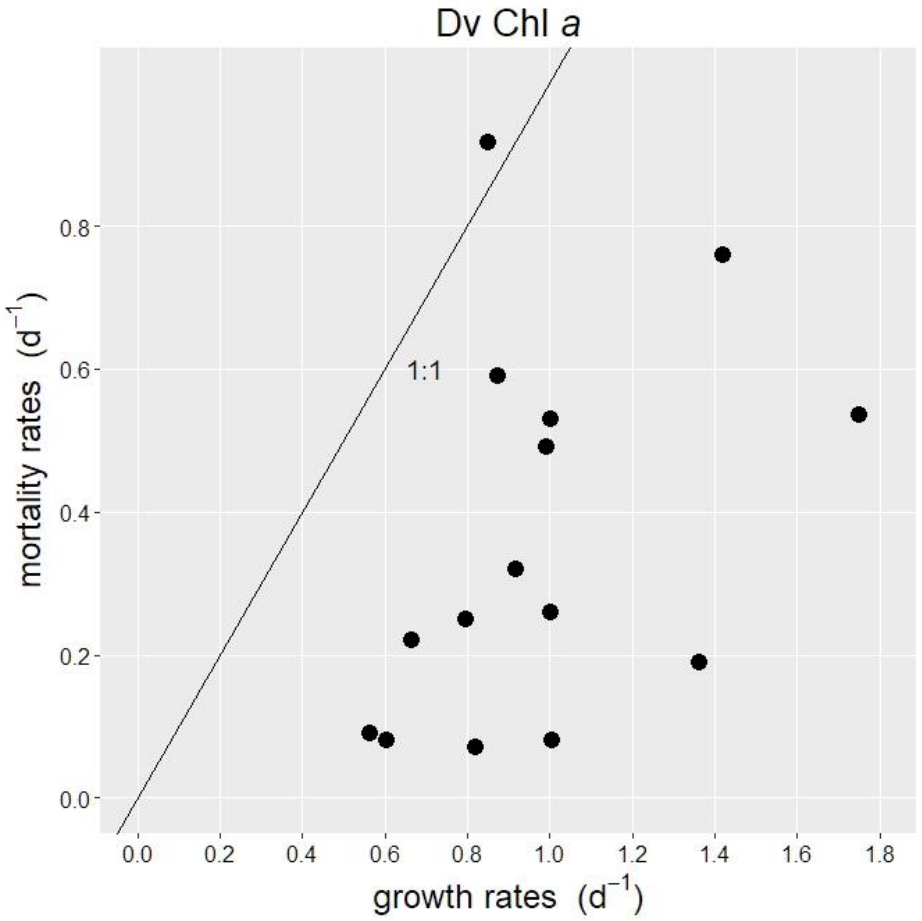
Pigment	Abbreviation	Phytoplankton group
Fucoxanthin	Fuco	Diatoms
19'-hexanoyloxyfucoxanthin	Hex	Haptophytes
19'-butanoyloxyfucoxanthin	But	Pelagophytes
Zeaxanthin	Zea	*Synechococcus*
Divinyl chlorophyll *a*	Dv	*Prochlorococcus*

Eukaryotes

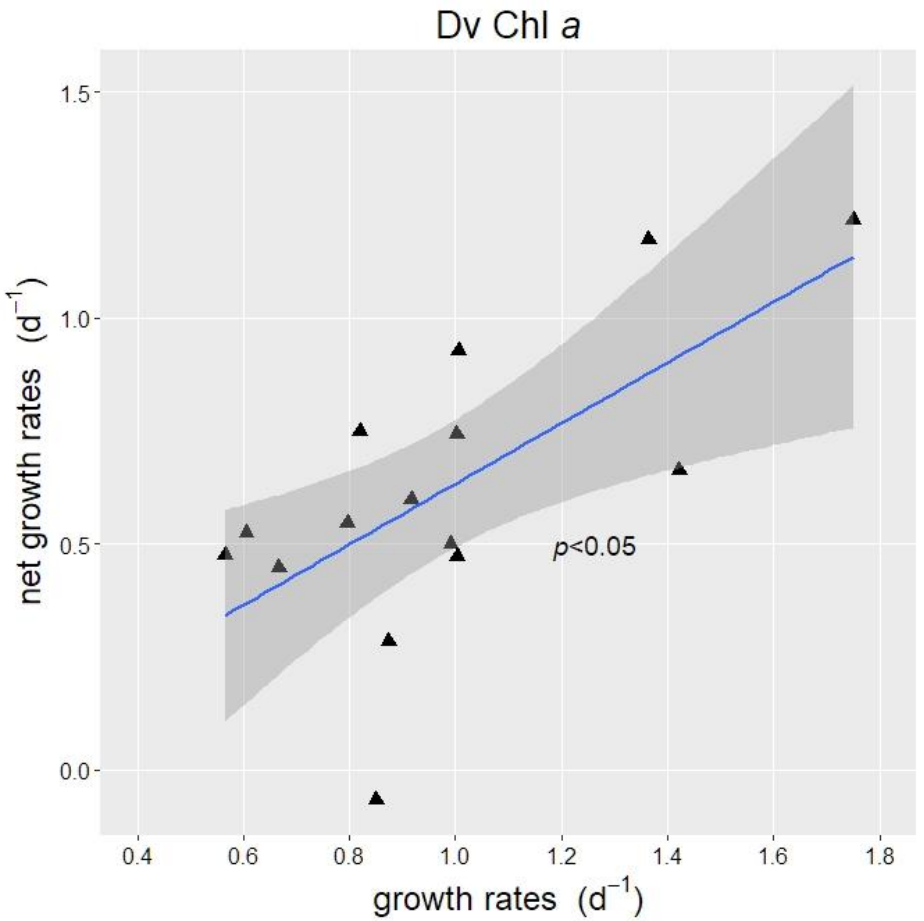
Prokaryotes

Specific pigments – prokaryotic phytoplankton

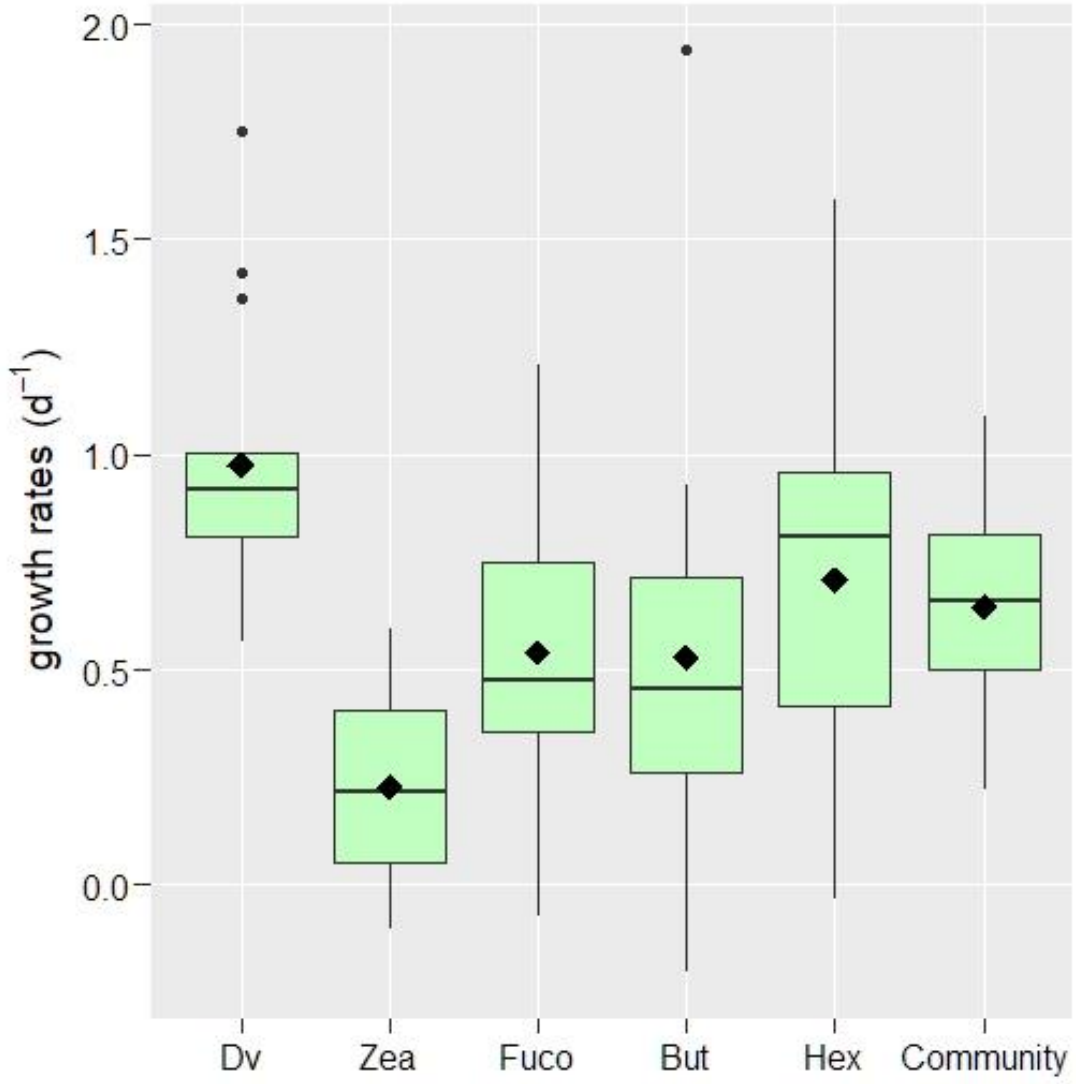
- No correlation;
- Microzooplankton grazed 36.4% daily production

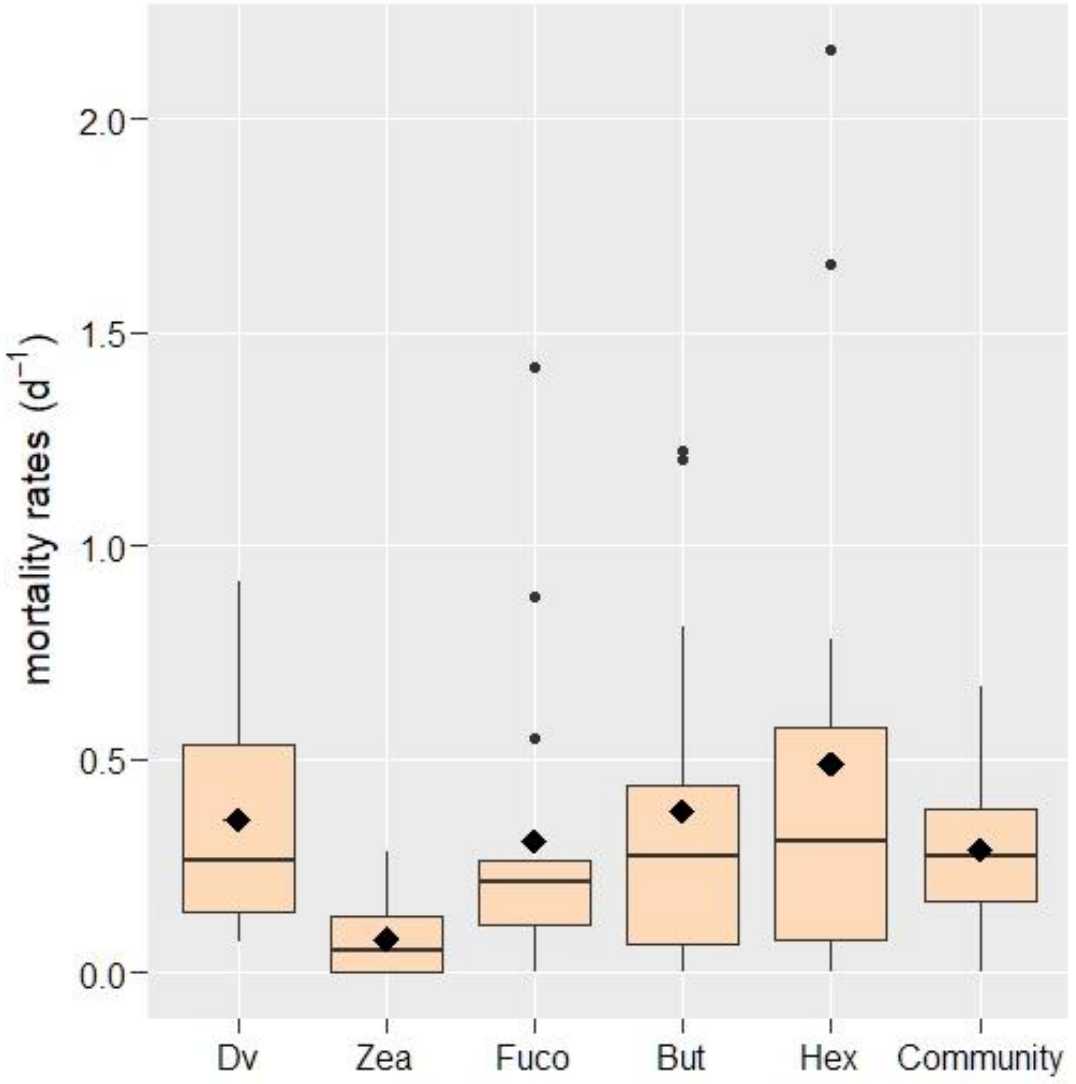


- Positive correlated;
- Bottom-up control;
- Biomass accumulation



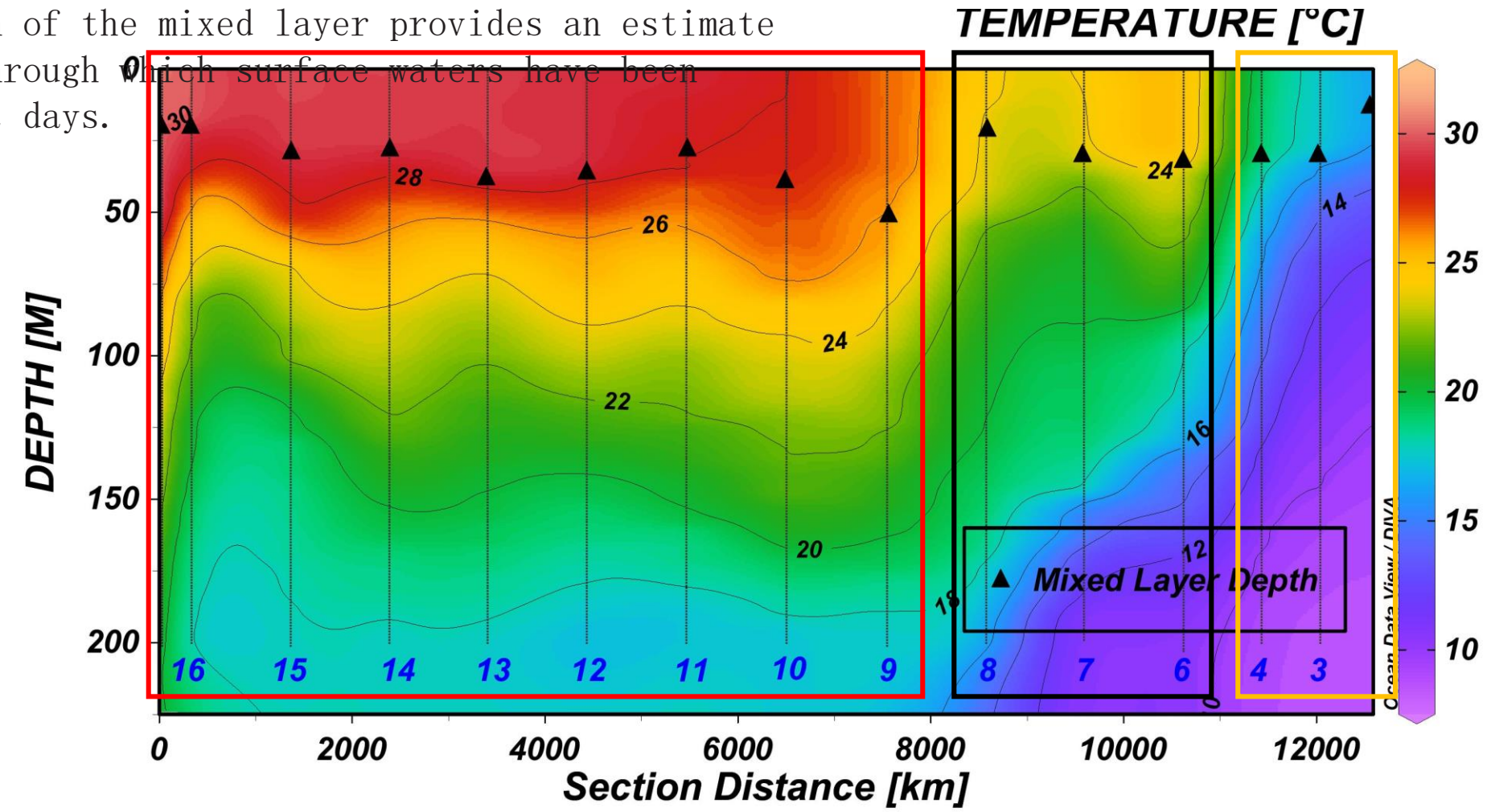
Further discussion – higher growth rate?



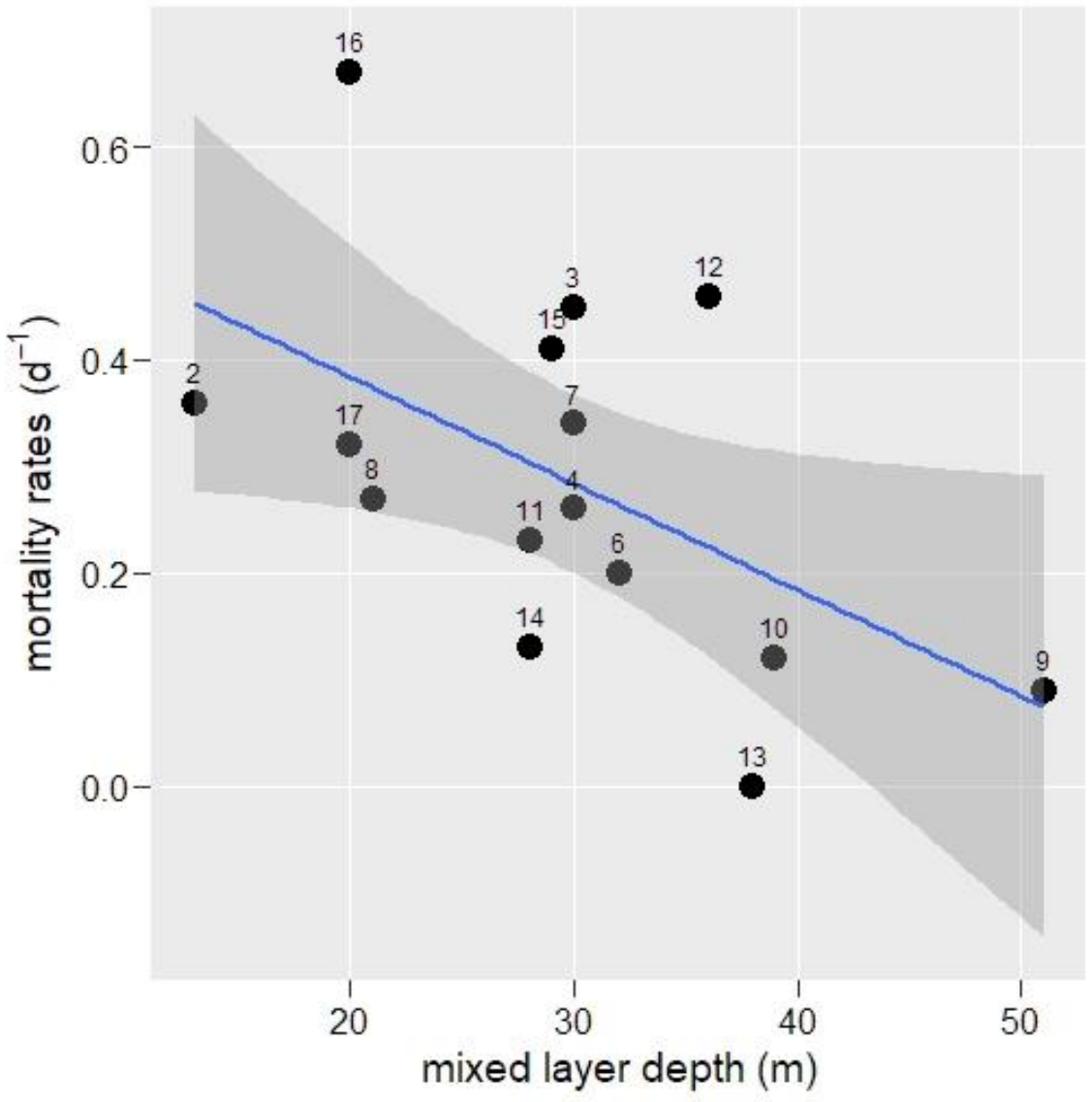


Further discussion – low microzooplankton grazing?

- Mixed Layer Depth (MLD) – determined as the depth at which the temperature difference with respect to the surface was 0.5°C.
- This definition of the mixed layer provides an estimate of the depth through which surface waters have been mixed in recent days.



Further discussion – low microzooplankton grazing?

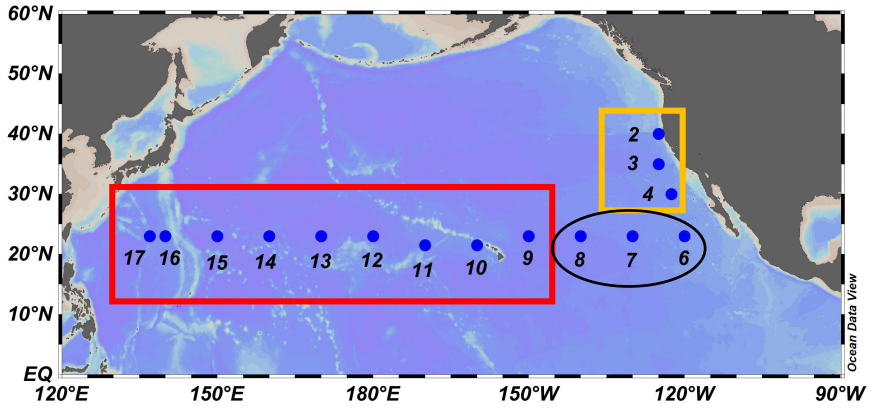


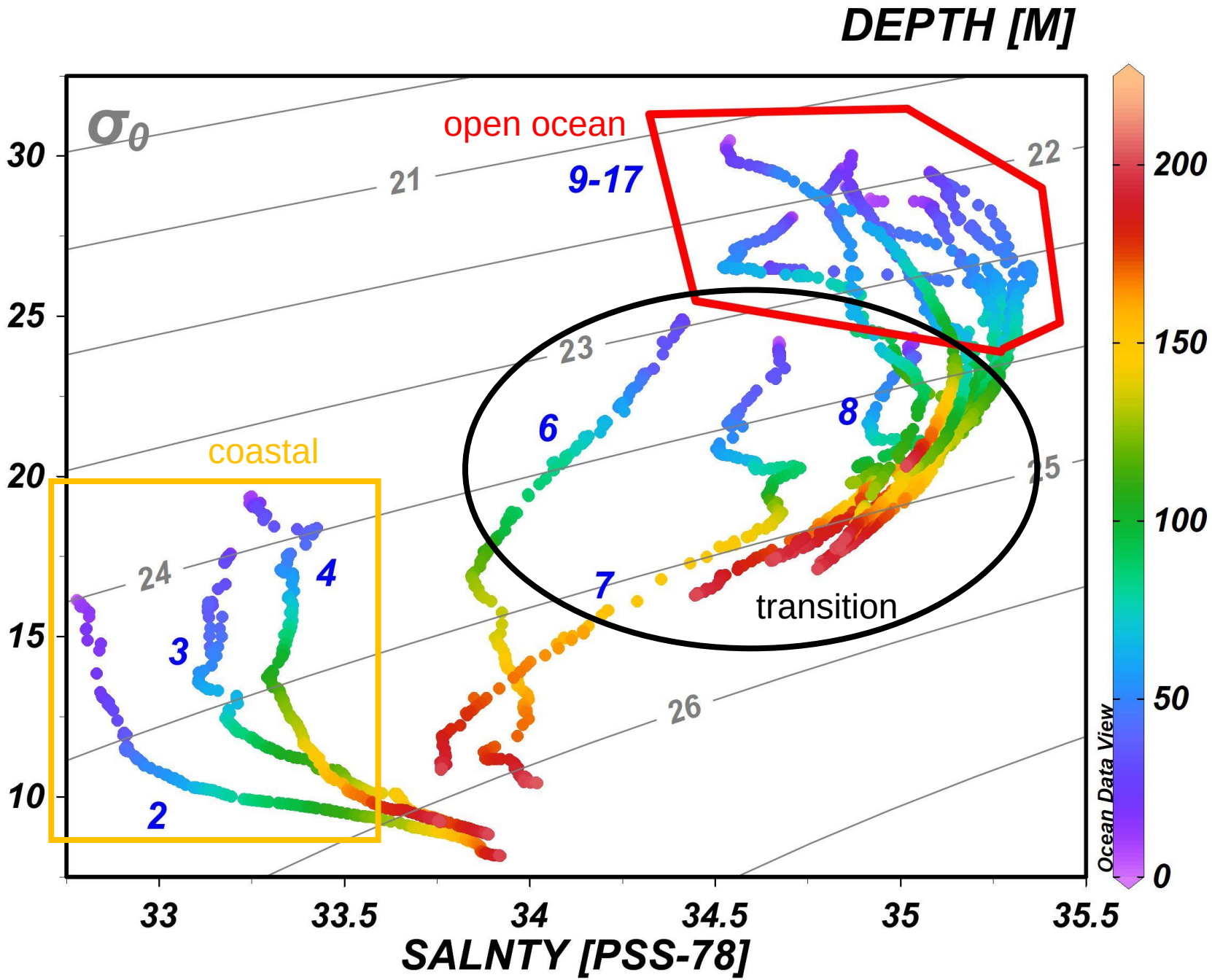
- When vertical mixing occurs, the particle-poor subsurface waters dilute the surface water within the euphotic zone, acting as a **natural "dilution" experiment**.

Three assumptions:
1. Phytoplankton growth rates must be **independent** of the dilution level; 2. The ingestion rate of microzooplankton must be linearly proportional to their concentration;

- The grazer biomass and grazing impact on phytoplankton decreases and the net growth rate of phytoplankton becomes positive and phytoplankton biomass accumulates.

T-S diagram


60°N
50°N
40°N
30°N
20°N
10°N
EQ
120°E
150°E
180°E
150°W
120°W
90°W
17 16 15 14 13 12 11 10 9
8 7 6
2 3 4
Ocean Data View


DEPTH [M]
σ0
open ocean
9-17
coastal
transition
2
3
4
6
7
8
21
22
23
24
25
26
30
25
20
15
10
33
33.5
34
34.5
35
35.5
SALNTY [PSS-78]
ntial Temperature θ [degC]
200
150
100
50
0
Ocean Data View