Biogeochemical processes in Curonian lagoon: state of the art

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Images: R. Paskauskas, R. Pilkaitytè

Introduction

Curonian Lagoon - one of the largest lagoons in Europe

- Surface ~1600 km^2
- Shallow non-tidal
- Small saltwater intrusions from the Baltic
- Freshwater input from nutrient rich Nemunas river (27000 ton N $year^{-1}$)
- Hypertrophic - cyanobacterial blooms, fish death, dystrophy-
- Benthic nitrogen cycling poorly studied
- Limited light penetration due to turbidity/resuspension

Aims

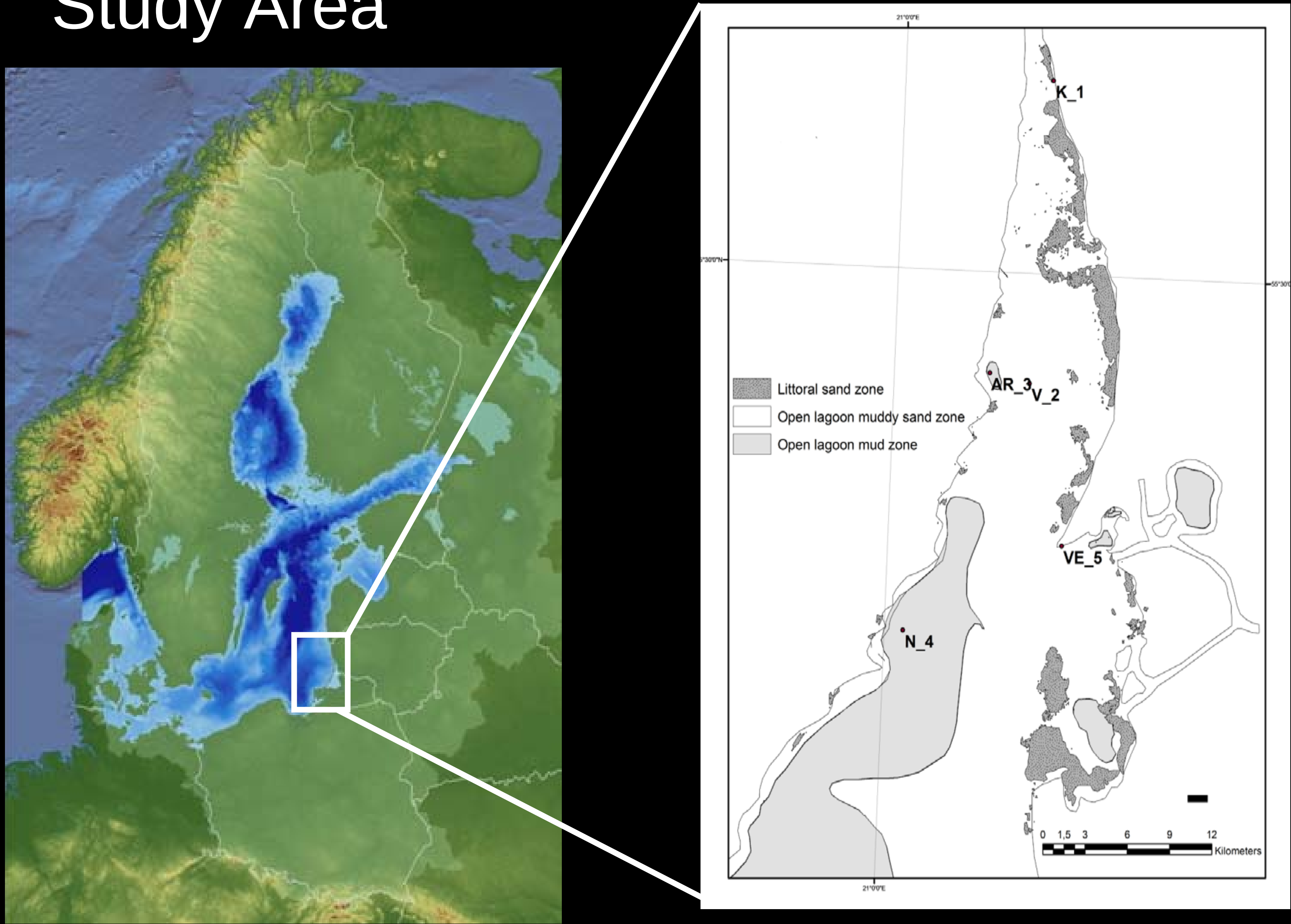
To assess the role of the benthic system for metabolism and nitrogen cycling
To provide data for the setup and calibration of the benthic part of the NPZD model

-Flux of dissolved oxygen and nutrients
at deep and shallow sites within the Lagoon

-Role of benthic microalgae as regulators of processes and exchange rates at the sediment-water interface

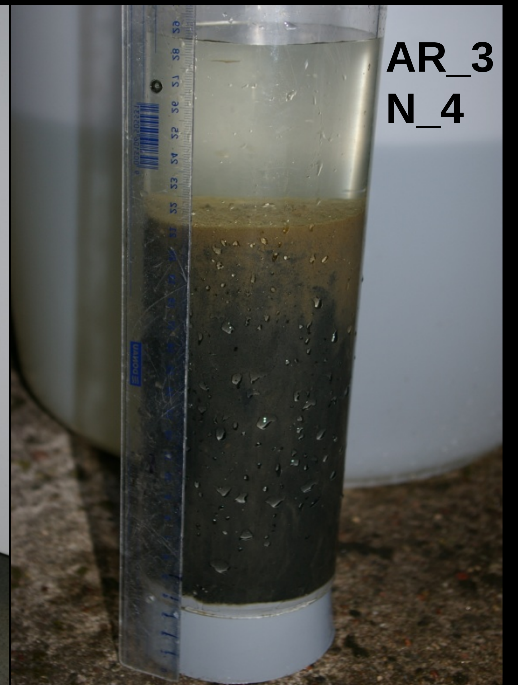
-Fraction of river-associated nitrogen load removed by surface sediments via dissimilative NO_3^- reduction.

Study Area


K_1
AR_3
V_2
VE_5
N_4
Littoral sand zone
Open lagoon muddy sand zone
Open lagoon mud zone
0 1,5 3 6 9 12
Kilometers

Sedimentary environments

Sedimentary environment	**Littoral sand zone**		**Open lagoon muddy sand**	**Open lagoon mud**	
Relative area in the lagoon (%)	<1		~54	~44	
Study site	K_1	VE_5	V_2	AR_3	N_4
Water depth (m)	1	1	1.7	2.5	3.5
Sediment type	Fine sand		Fine sand	Fine muddy sand	

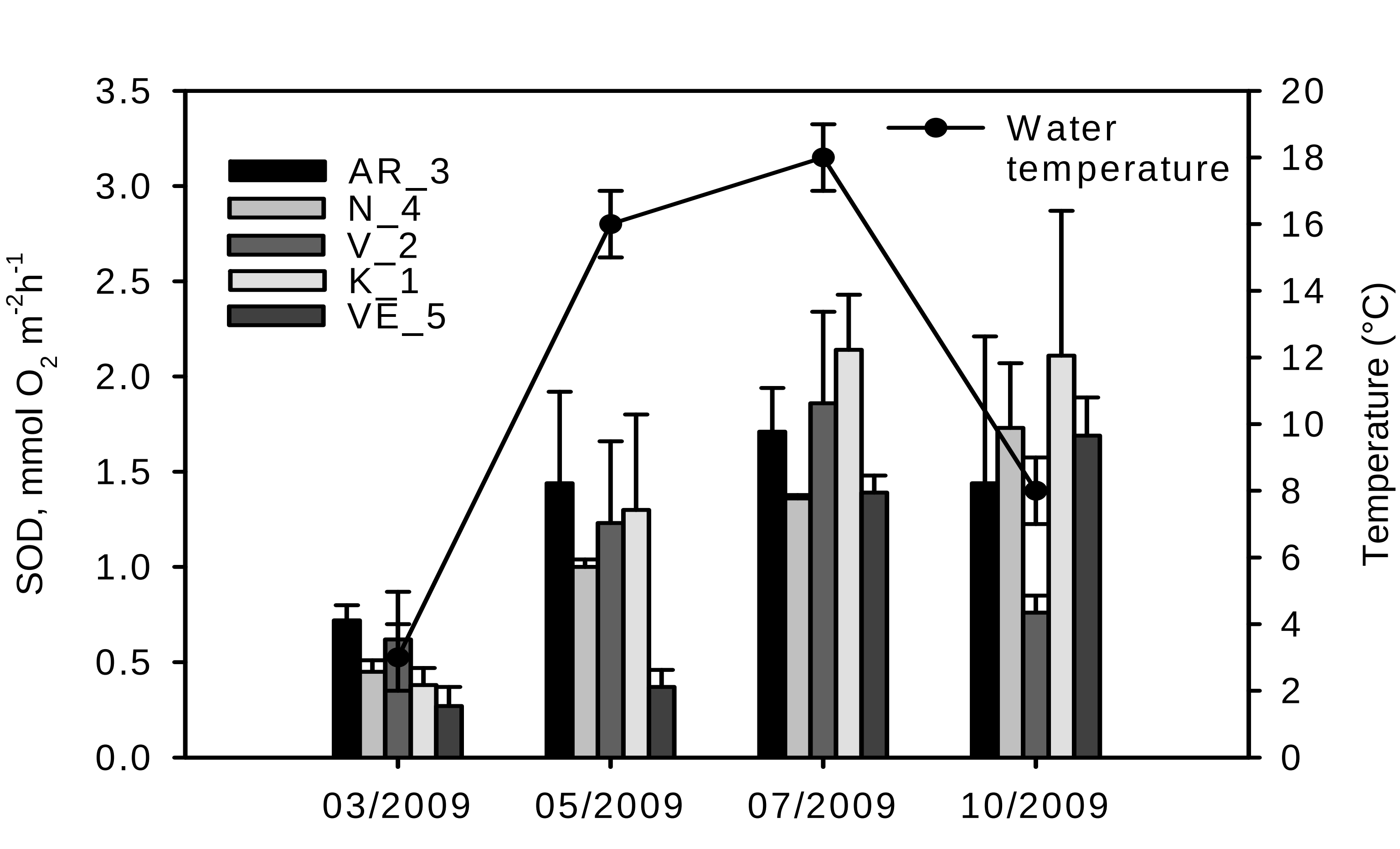


Material and methods

- Four field campaigns (March, May, July and October 2009), just after ice cover melting and in full summer till autumn.
- Measurements done in intact cores (5 replicates, one station per site) simulating in situ conditions.
- Oxygen microprofiling in dark (3 replicates per site)
- Light and dark fluxes (Dalsgaard et al., 2000).
- Denitrification (revised IPT, Risgaard-Petersen et al. 2003).

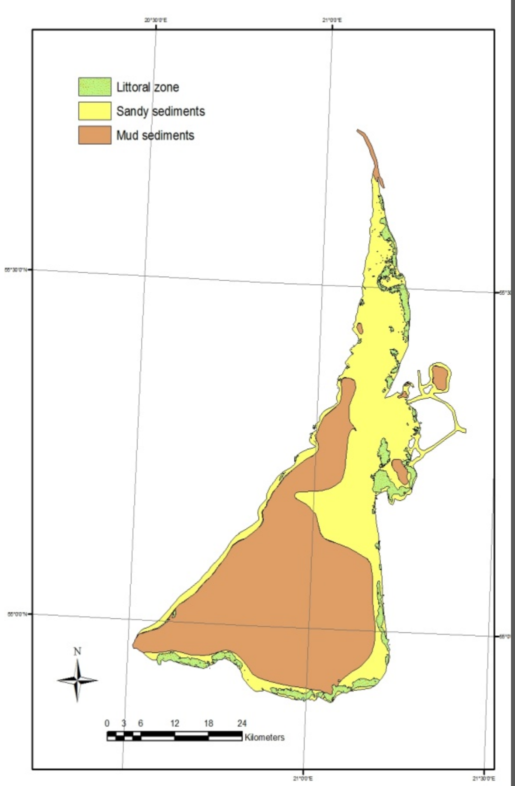
Summarized data

TOTAL O_2 UPTAKE: seasonal and spatial variation



Increase of sediment oxygen demand from March to July is likely due to a combination of higher water temperatures and increased organic matter input to surface sediments after the spring phytoplankton blooms. However from July to October the sediment oxygen uptake remains elevated primary due organic input.

The risk of hypoxia in the Curonian Lagoon: sediment respiration projection



Zone	Area, km^2	Total O_2 uptake, mol h^{-1}			
		March	*May*	*July*	*October*
Littoral sand zone	96.4	-31.7	-67.5	-173.5	-183.2
Open lagoon muddy sand	594.7	-336.6	-832.6	-1189.4	-475.8
Organic muddy area	879.0	-497.5	-879.0	-1318.5	-1318.5
Total	1570.1	-865.8	**-1779.1**	**-2681.4**	-1977.5

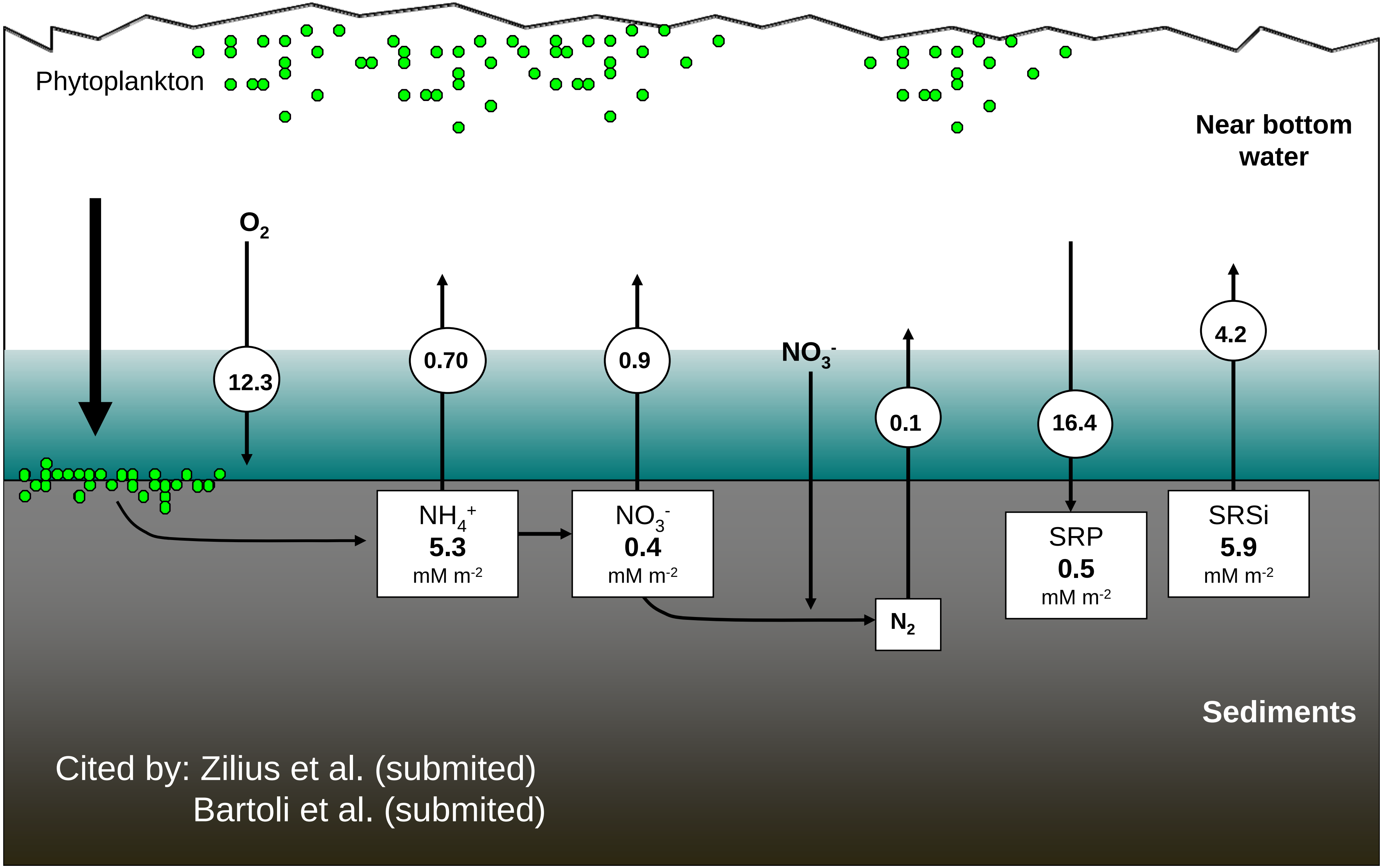
On average sediments have a low potential to deplete oxygen in the water column: it would take from 10 to 20 days, assuming irrelevant reareation and limited production.

Phytoplankton (when chl *a* values exceed to 100 µg l^{-1}) respiration in the water column during night hours can have a major role, with rates over 50 mmol $m^{-2}h^{-1}$.

Oxygen can be consumed more than 25 times faster!

Daily oxygen and nutrient exchange at sediment-water interface

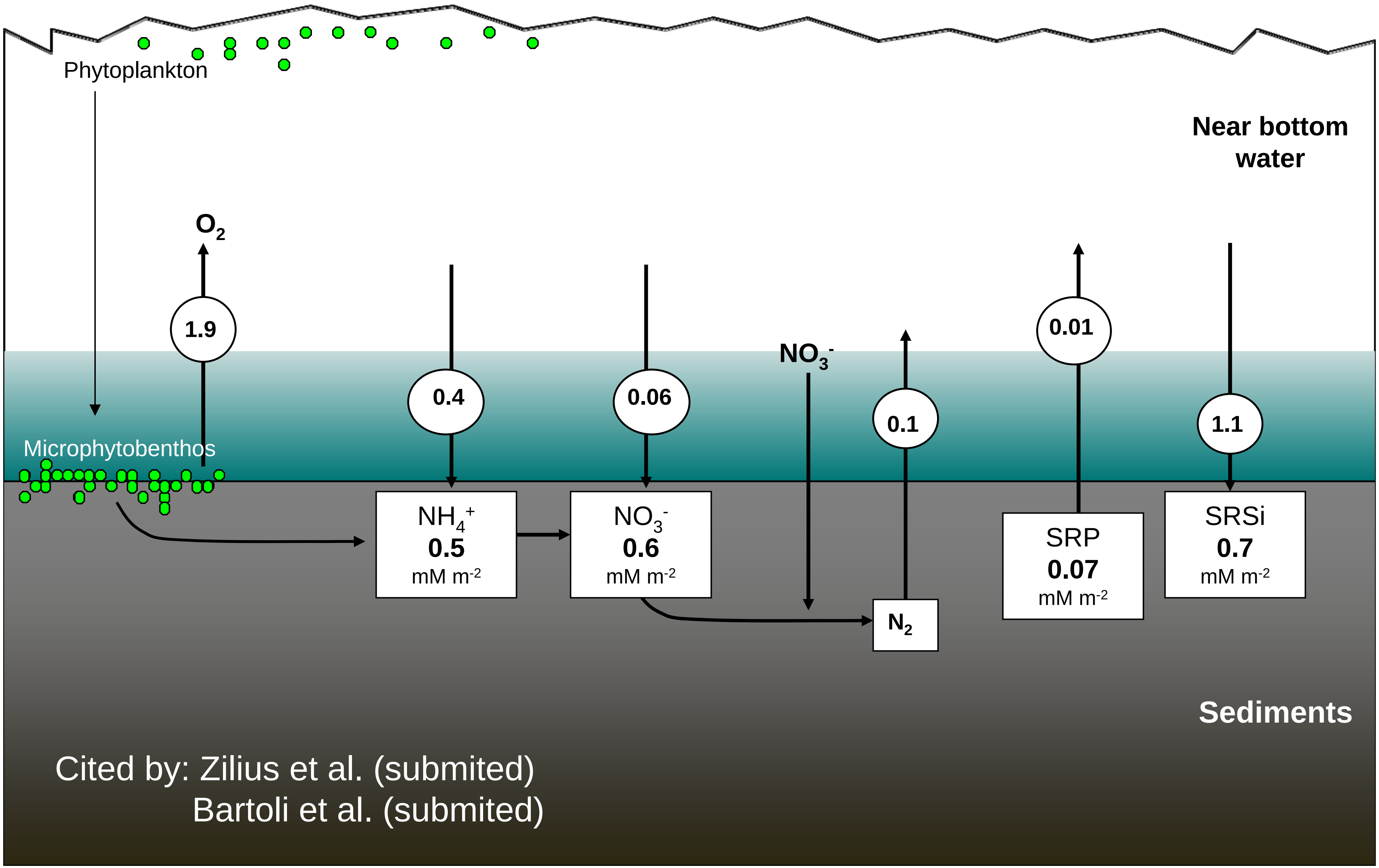
Mud bottom



Cited by: Zilius et al. (submited)
Bartoli et al. (submited)

Daily oxygen and nutrient exchange at sediment-water interface

Littoral sand



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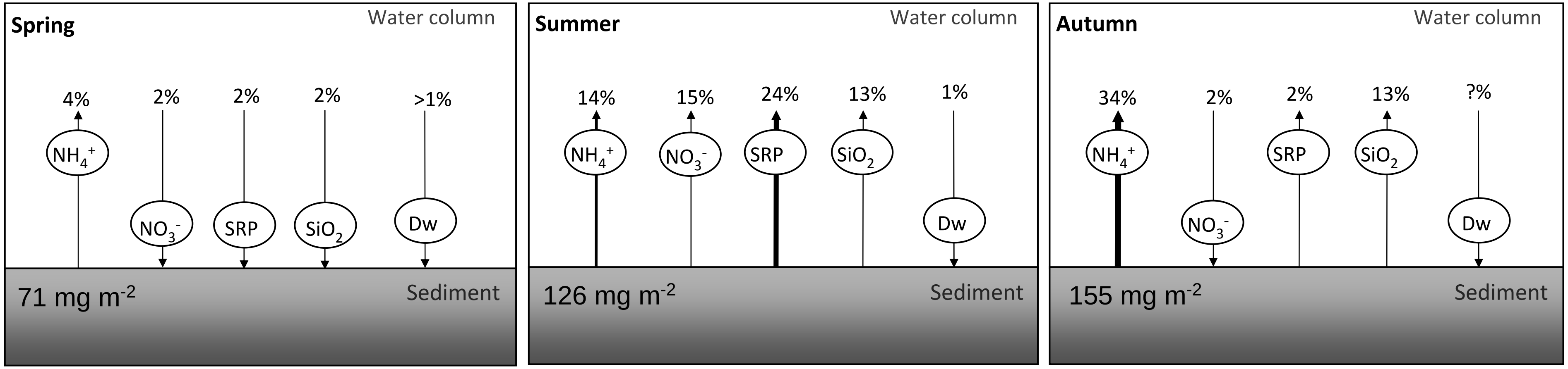
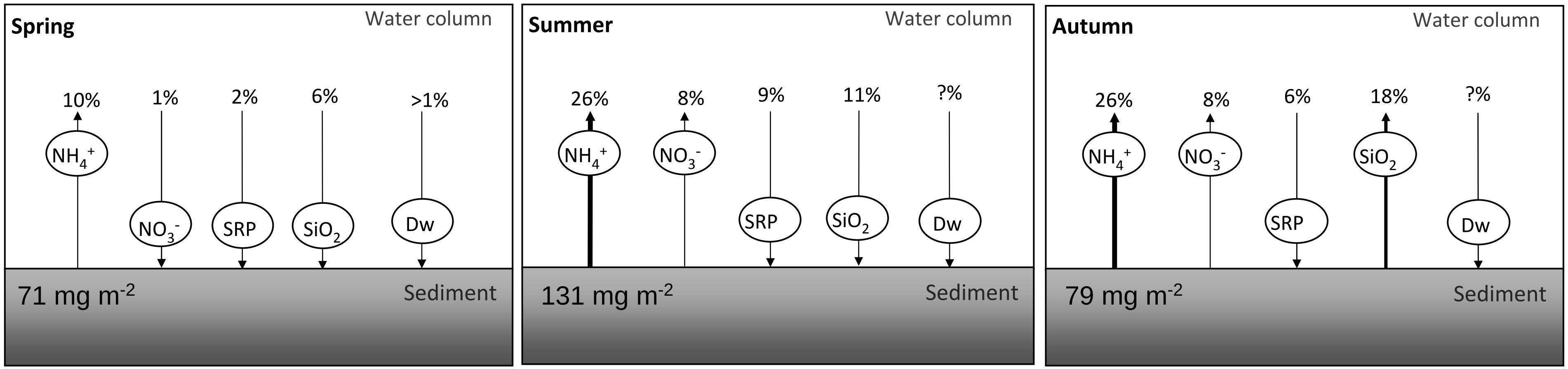
Bartoli et al. (submited)

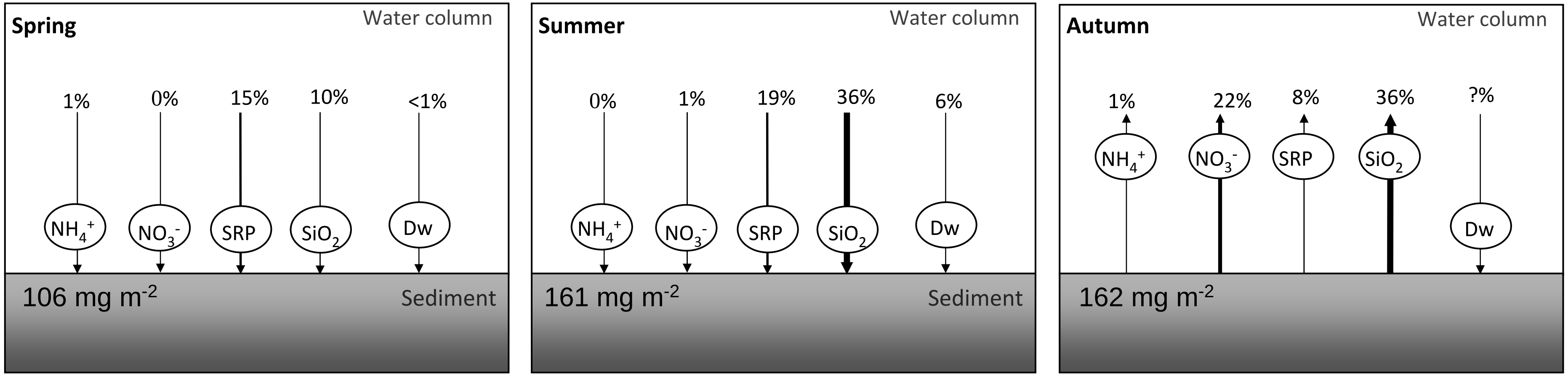
Open lagoon mud zone (Water column 3 m)



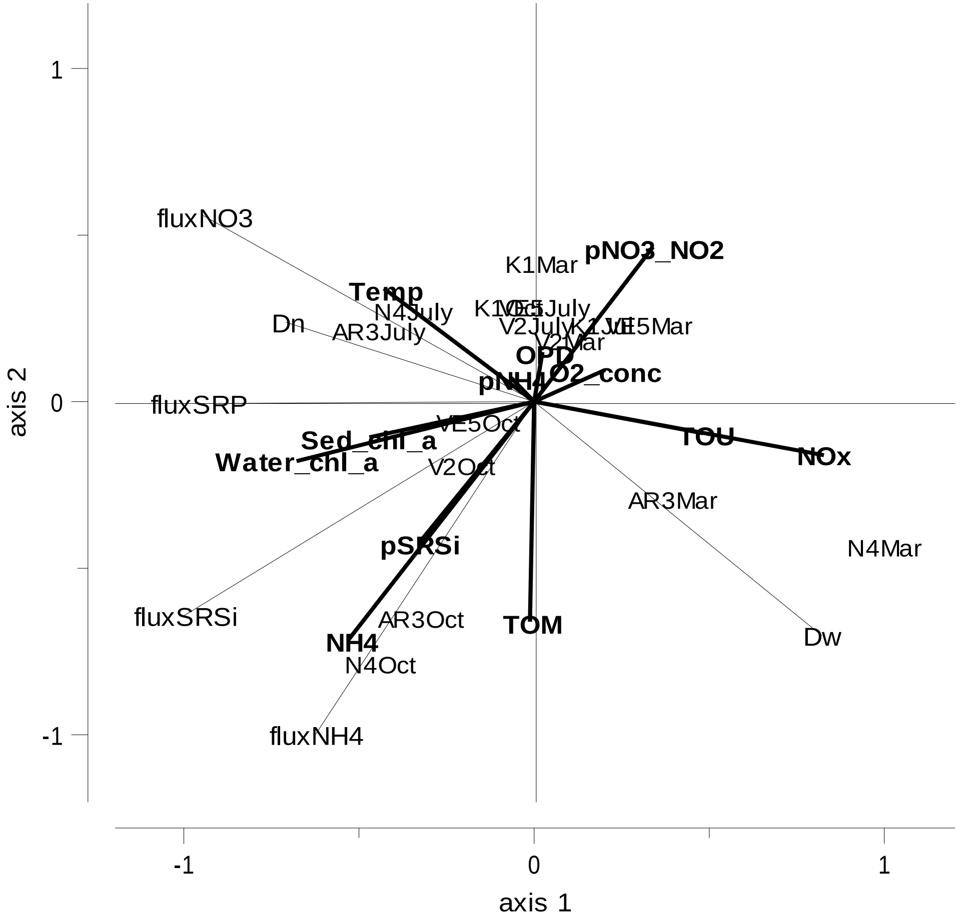
Open lagoon muddy sand zone (Water column 1.7 m)



Littoral sand zone (Water column 1 m)



Driving factors in nutrient exchange at the sediment-water interface and their cycling



Explained variance 69%

A complex regulating the nutrient cycling and exchange at sediment–water interface:

1) water NO_3^-
2) water chl a and O_2 , sediment chl a
3) water NH_4^+ and TOM

General conclusions

- Organic carbon sources differ between the principal sedimentary environments and thus could have implication for studying oxygen and nutrient exchange at sediment–water interface their cycling there.
- Total oxygen uptake rates in poor organic sandy sediments are comparable or even higher than those at organic-rich sites. This demonstrates faster benthic metabolism response and possibly higher turnover rates of fresh organic matter in shallow littoral sand rather than in deeper areas after sedimentation pulses of pelagic organic matter.
- In increasing benthic metabolism and organic material flux to surface sediments considerably reduce oxygen penetration depth into sediments overall lagoon.
- In shallower sediments settled “microphybenthos” has an nimportant role in oxygen and nutrient exchange at sediment water interface as well as denitrification capacity.

General conclusions

– In spring high amount of bio-available nitrogen delivered into Curonian lagoon by Nemunas River is initial trigger for further biogeochemical processes in the Curonian lagoon.

– Large seasonal variations occurring in the denitrification, primarily is caused by the dramatic variations in the NO_3^- load in the Curonian lagoon.

– Sediments have an effect on nutrient pool in overlaying water column in summer, however it has less importance spring and autumn.

Publications

Zilius et al. BENTHIC OXYGEN UPTAKE IN THE SHALLOW EUTROPHIC LAGOON (CURONIAN LAGOON, THE BALTIC SEA, LITHUANIA) accepted in Hydrobiologia

Bartoli et al. The role of the bottom sediments in N cycling in the shallow eutrophic lagoon (prepared for Biogeochemistry)

Zilius et al. Seasonal nentho-pelagic nutrient fluxes in the in the shallow eutrophic lagoon (prepared for Oceanological and Hydrobiological Studies)

Messages to the stakeholders

- Bottom sediment processes could contribute to the local anoxia events in the Curonian lagoon. However, pelagic cyanobacteria blooms is the most important factor.
- Denitrification rates are in the range typical for estuarine systems and are higher than nitrogen fixation rates. Curonian lagoon is the sink for nitrogen