ASLO 2024
Adapting to a Changing World
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BIOGEOCHEMICAL SERVICES OF TWO SUBMERGED MACROPHYTES THAT RELEASE OXYGEN TO THE SEDIMENT VIA RADIAL LOSS FROM ROOTS

Benelli Sara, Cristina Ribaudo, Vincent Bertrin, Marco Bartoli

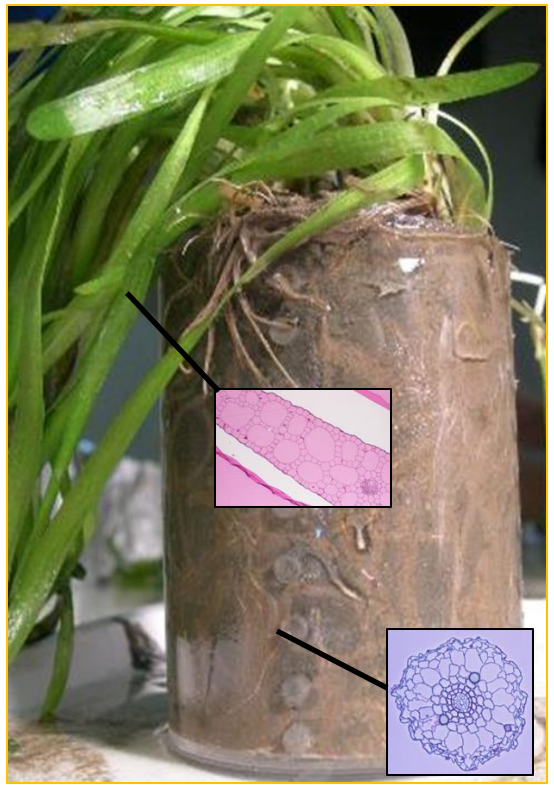
Department of Chemistry, Life Sciences and Environmental Sustainability, University of Parma, Italy

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rewet

Submerged macrophytes and benthic biogeochemistry

- Aquatic plants transport oxygen from the leaves to the roots via the aerenchyma (Armstrong, 1979).



Vallisneria spiralis

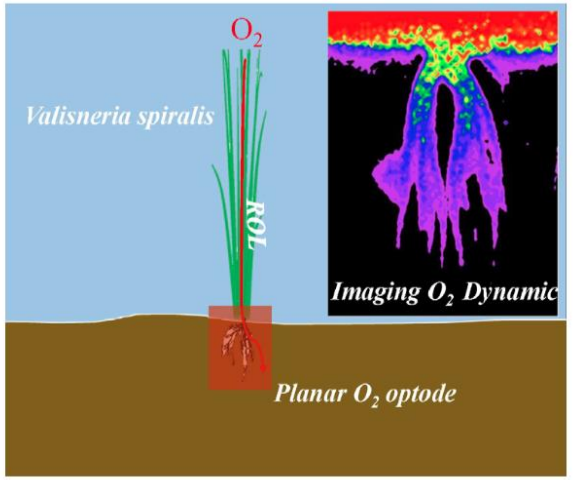


Lobelia dortmanna

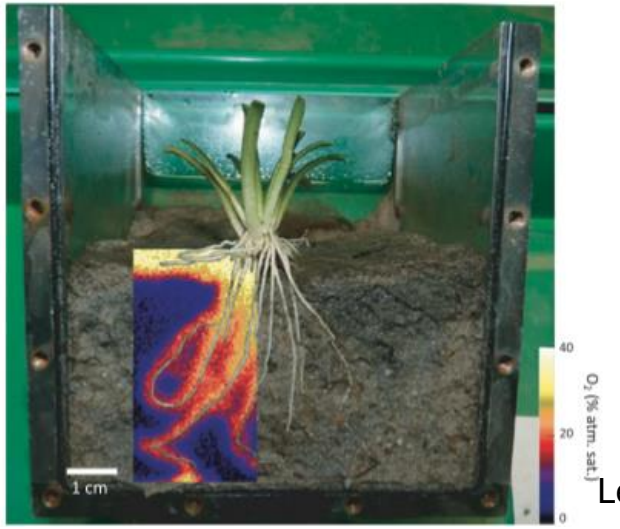
Lindskov Møller and Kaj Sand-Jensen 2008

Submerged macrophytes and benthic biogeochemistry

- Aquatic plants transport oxygen from the leaves to the roots via the aerenchyma (Armstrong, 1979).
- Radial Oxygen Loss (ROL) creates multiple oxic-anoxic interfaces within sediments affecting several biogeochemical processes (Laskov et al., 2006).

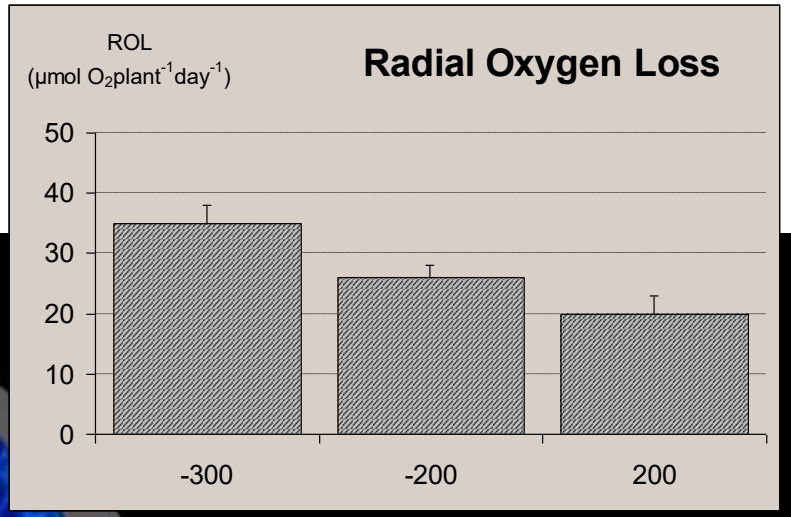


Han et al. 2016



Lenzewski et al. 2018

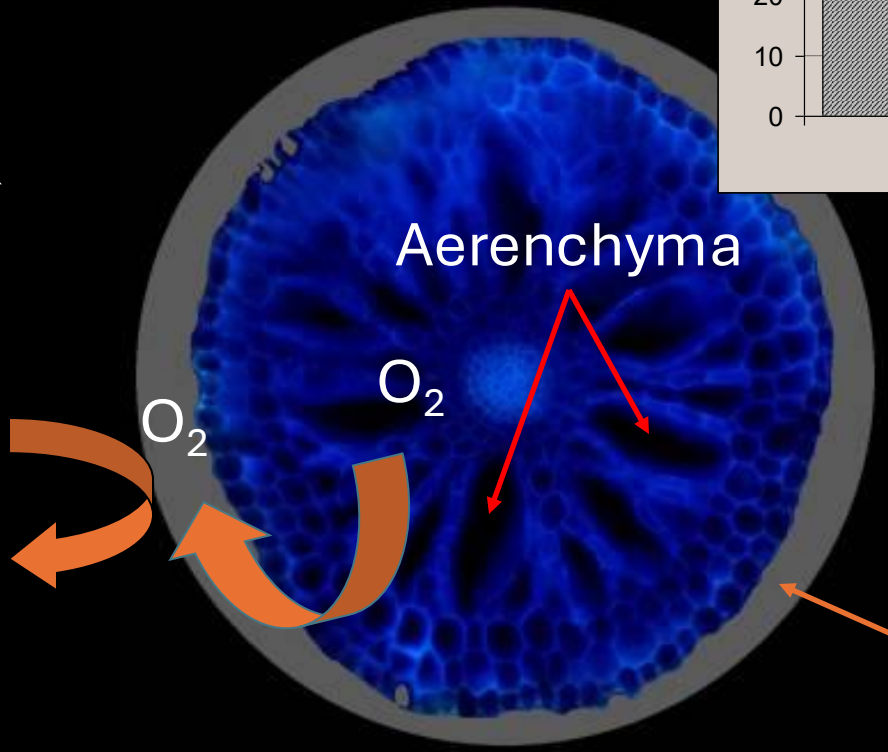
Biogeochemical processes at the sediment/rhizosphere interface



Sediment redox
(Eh, mV)

Coupled reductions & oxidations:

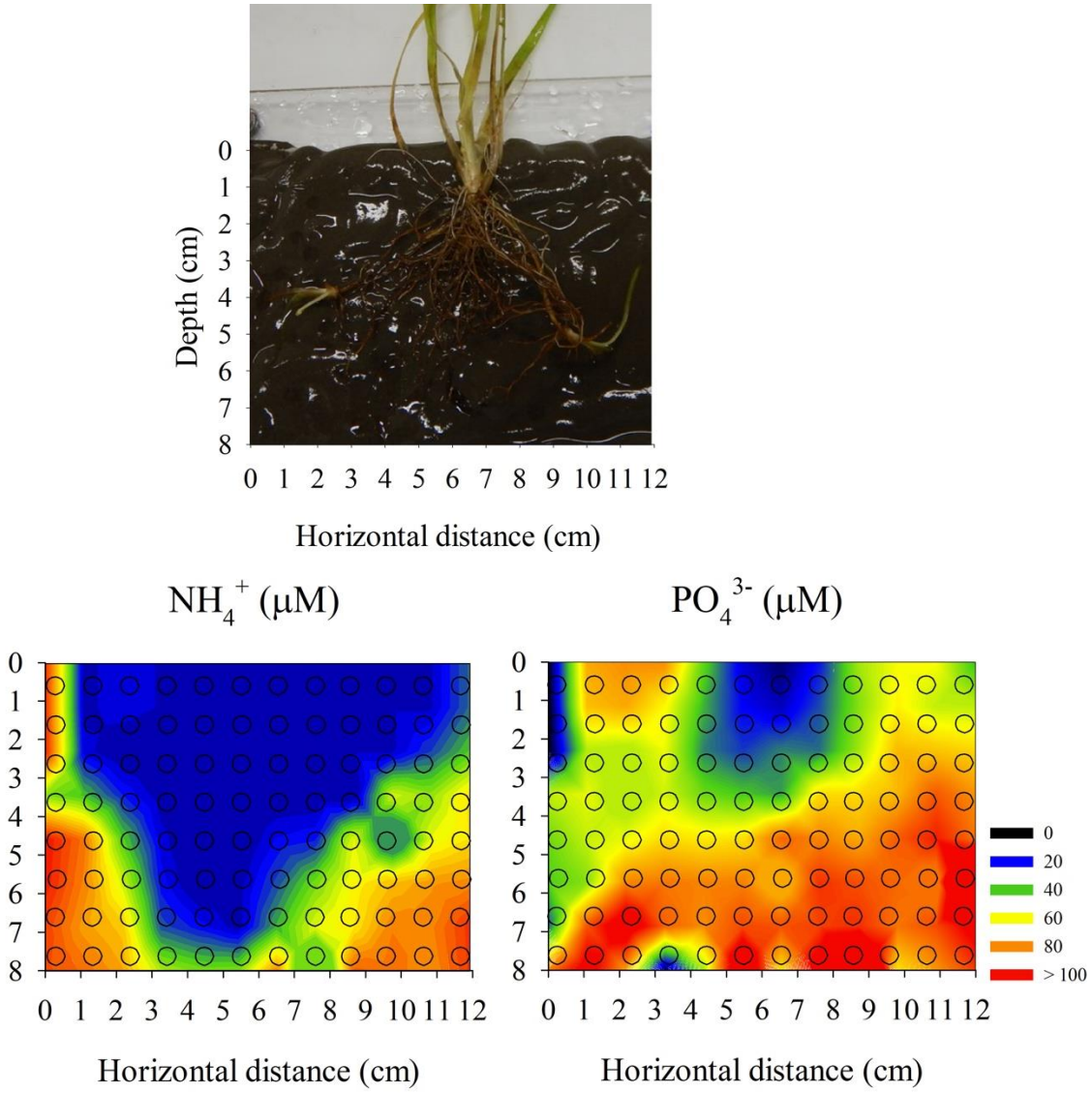
-aerobic respiration
-nitrification
-sulfide oxidation
-iron (2+) oxidation
-CH_4 oxidation



R.O.L.=radial oxygen loss creates an oxic microlayer often <<1mm

Submerged macrophytes and benthic biogeochemistry

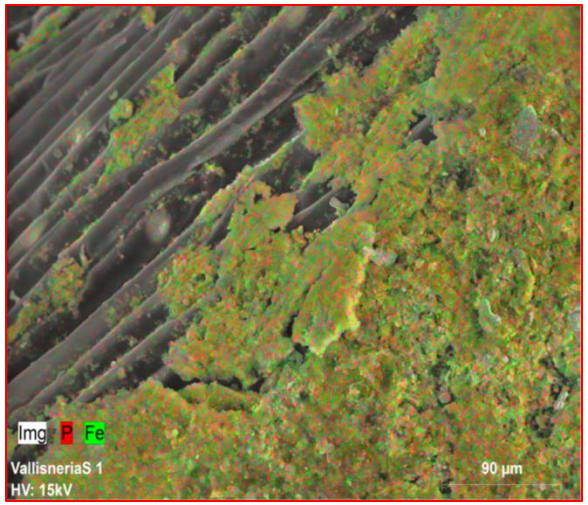
- Aquatic plants transport oxygen from the leaves to the roots via the aerenchyma (Armstrong, 1979).
- Radial Oxygen Loss (ROL) creates multiple oxic-anoxic interfaces within sediments affecting several biogeochemical processes (Laskov et al., 2006).
- Nutrient uptake by plants affects pore water chemistry, sediment processes and benthic-pelagic coupling (Mei et al., 2014; Marzocchi et al., 2019).

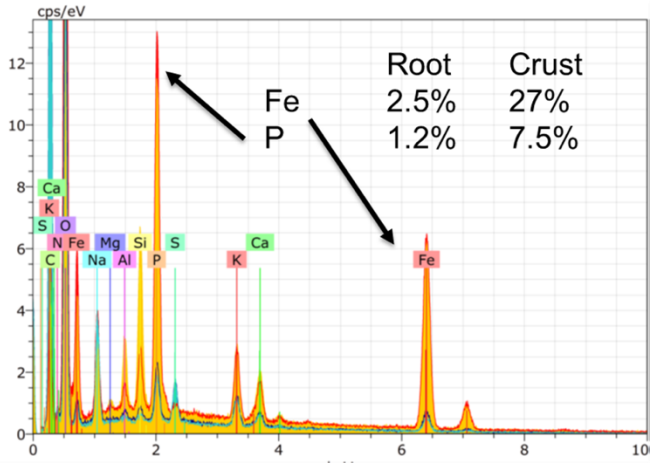


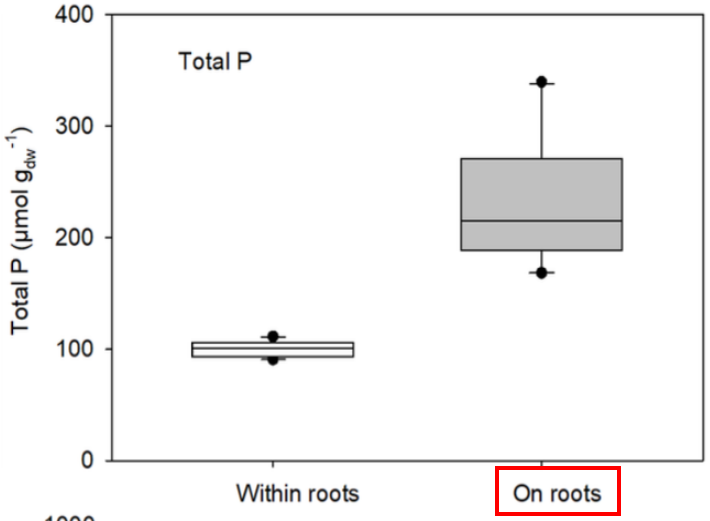
modified from Marzocchi et al., 2019

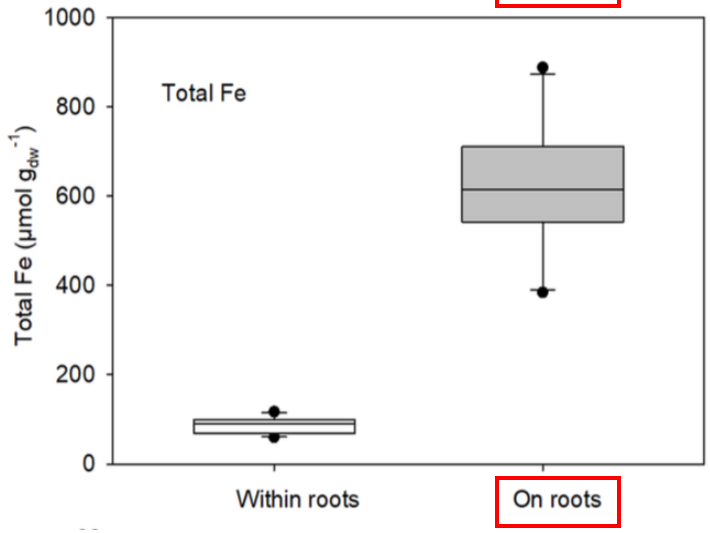
Iron plaques on *Vallisneria spiralis* roots











modified from Marzocchi et al., 2019 and Magri et al., 2023

Does ROL affect O_2, N_2 and CH_4 fluxes?

Freshwater submersed rooted macrophytes

Lobelia dortmanna





Oligotrophic environments characterized by low nutrients level and sandy sediments:

[NO_3^-] = 5-10 µM

OM content = 0.3 %

Vallisneria spiralis





Eutrophic environments with high availability of nutrients and of labile organic matter:

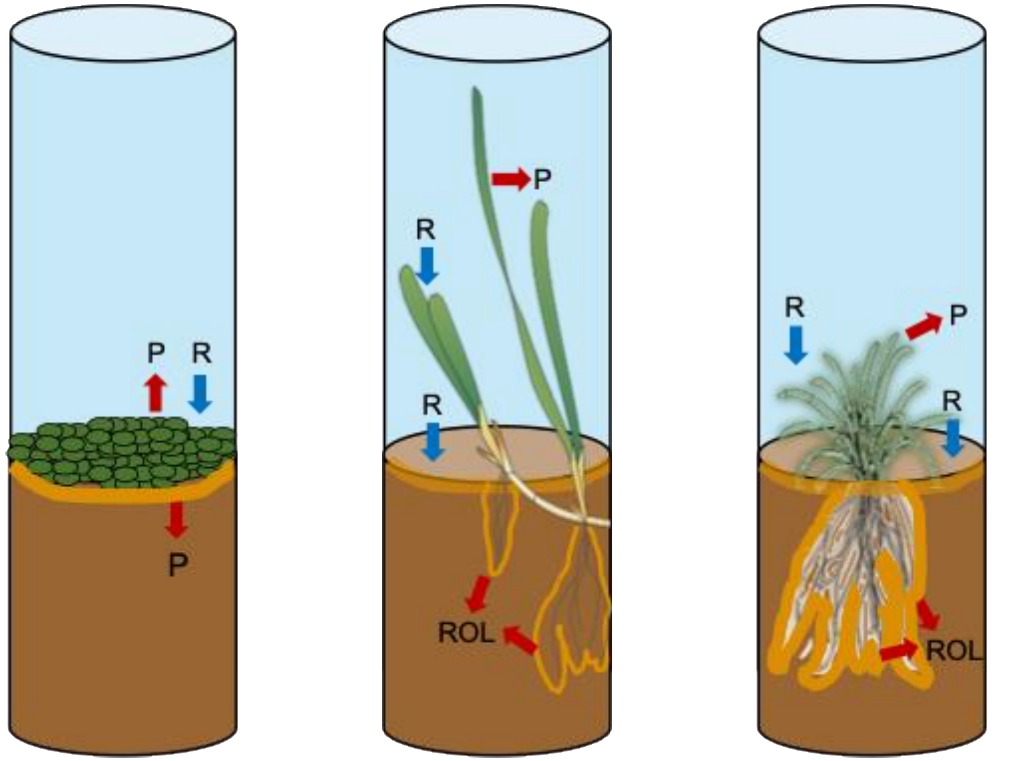
[NO_3^-] = 150-250 µM

OM content = 10 %

Experimental conditions

1. Measurement of O_2, CH_4 and N_2 net fluxes at the sediment-water interface in intact sediment cores under light and dark conditions and calculation of the daily budget.

2. Measurement of denitrification by means of $^{15}NO_3$ addition to the water phase of cores (Isotope Pairing Technique) under light and dark conditions.



sediment + microalgae

sediment + *V. spiralis*

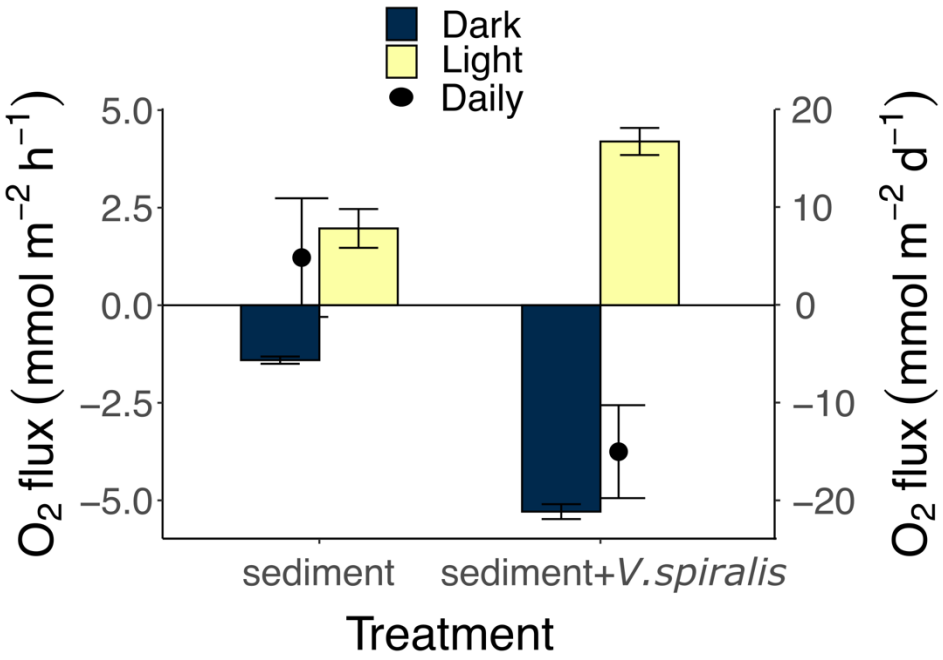
sediment + *L. dortmanna*

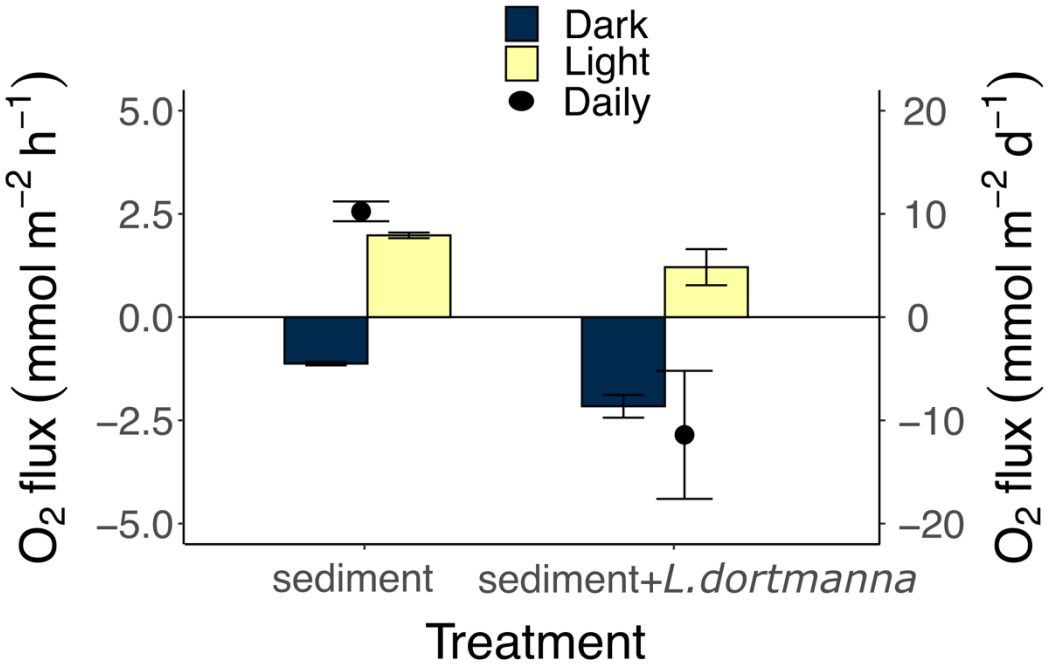
P = O_2 production
R = O_2 respiration
ROL = radial O_2 loss

Net O_2 fluxes







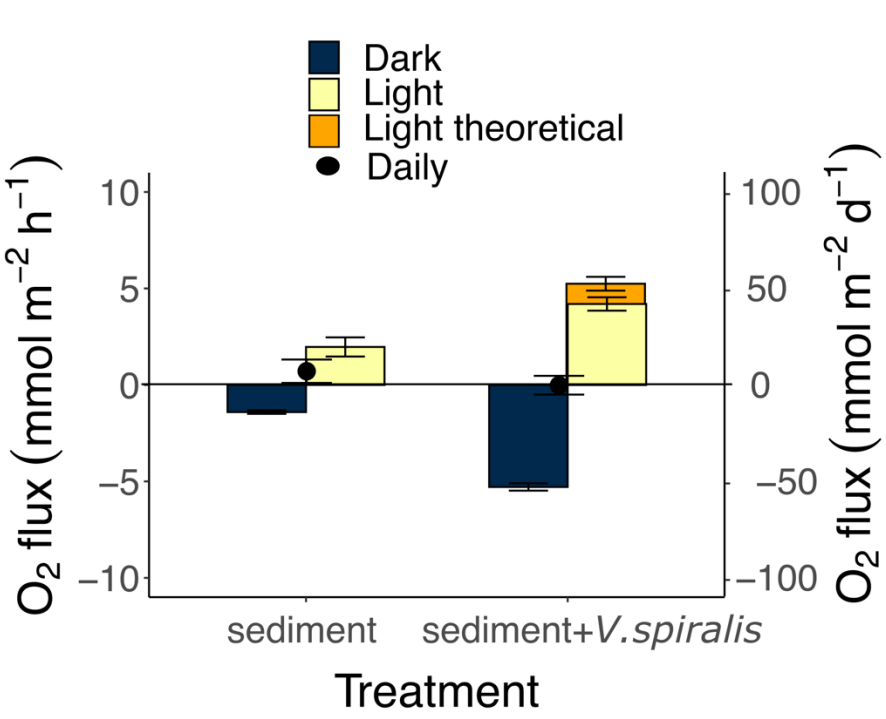


Eutrophic | **Oligotrophic**

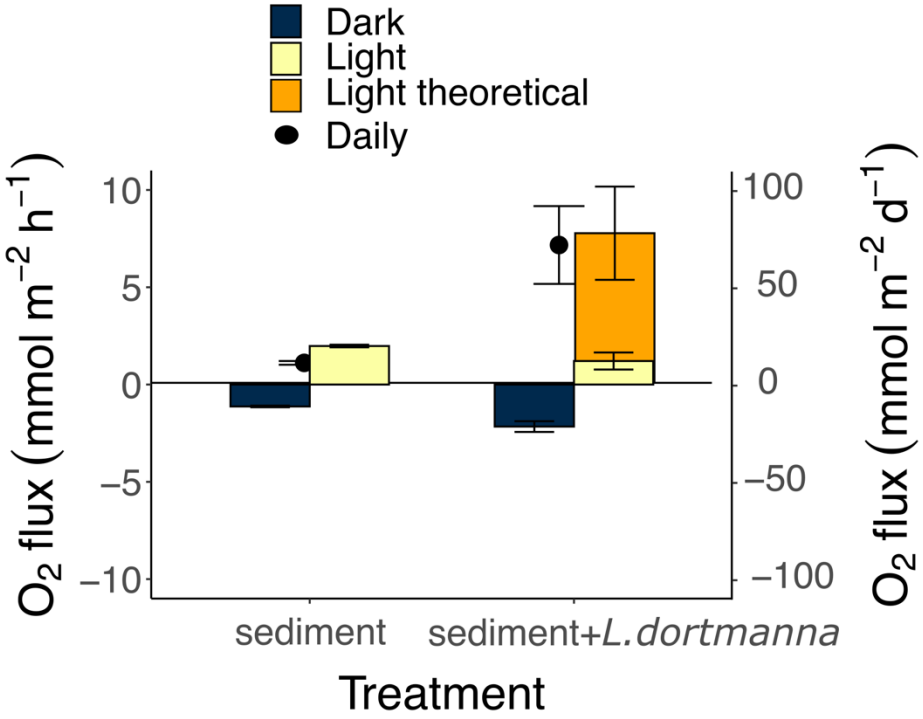
Net O_2 fluxes + ROL







Eutrophic

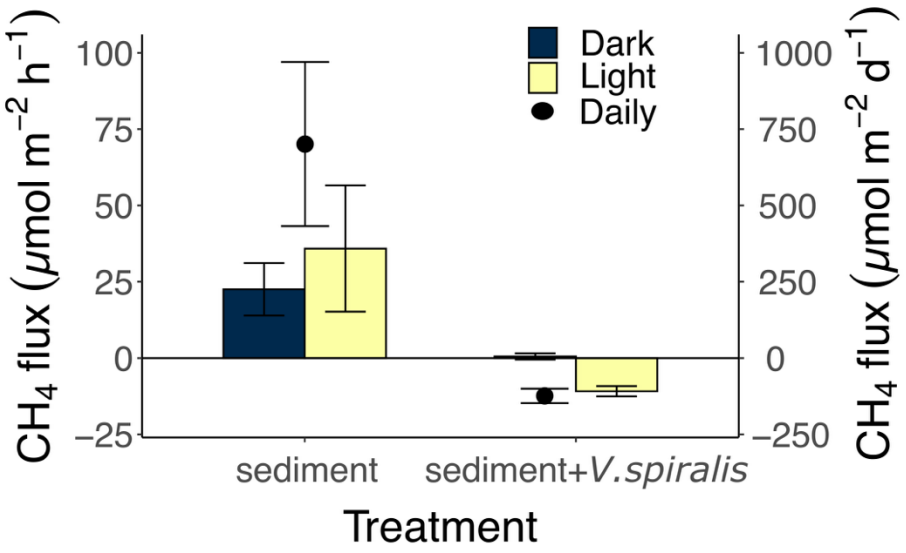


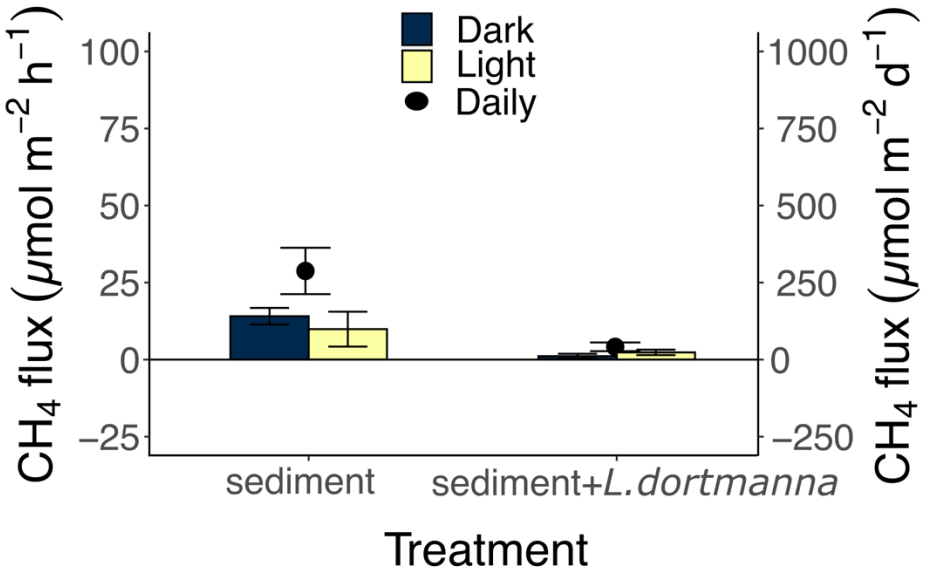
Oligotrophic

Net CH_4 fluxes









Eutrophic | **Oligotrophic**

LIMNOLOGY AND OCEANOGRAPHY
Letters

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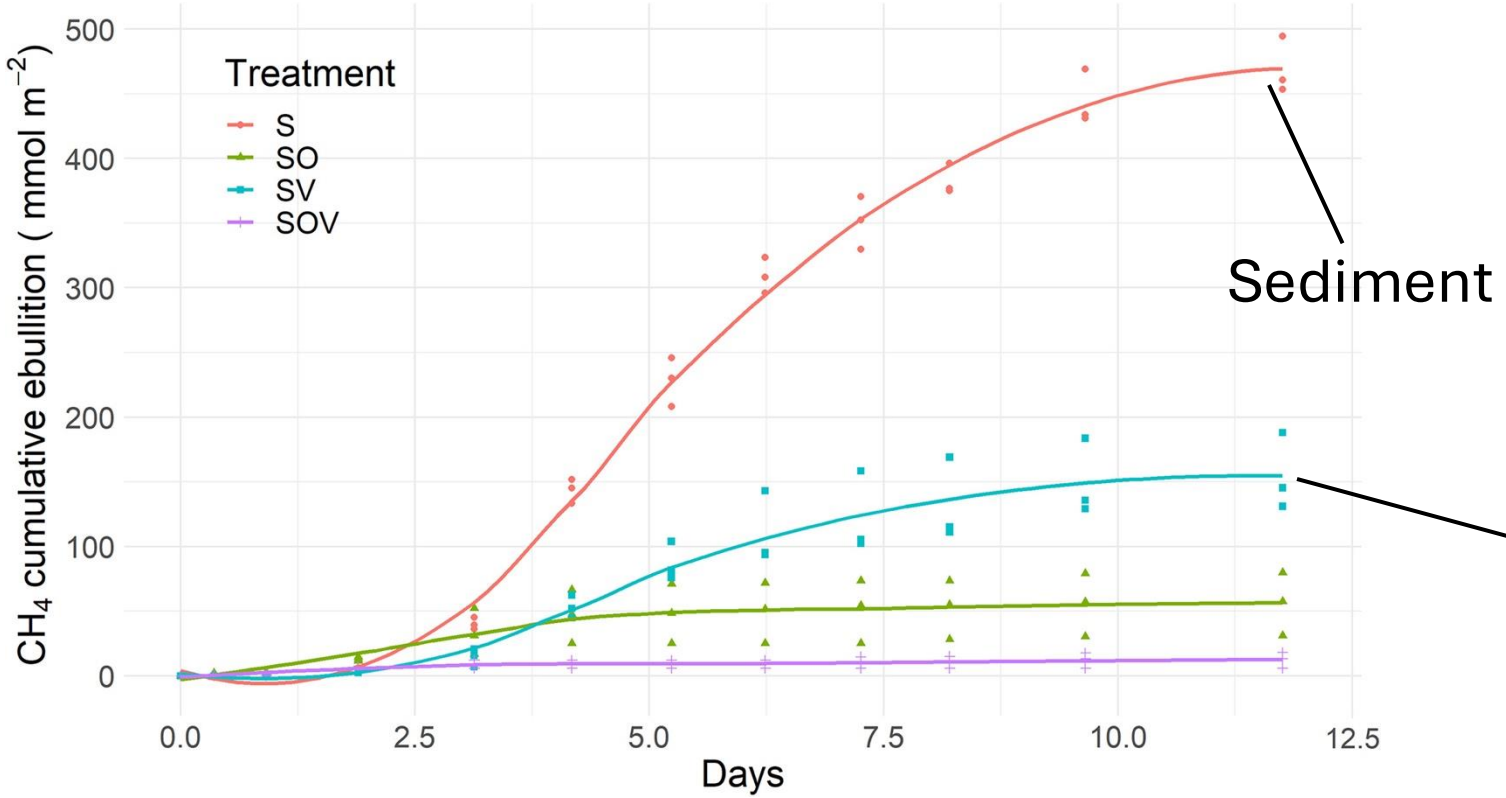
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doi: 10.1002/lol2.10207

LETTER

Worms and submersed macrophytes reduce methane release and increase nutrient removal in organic sediments

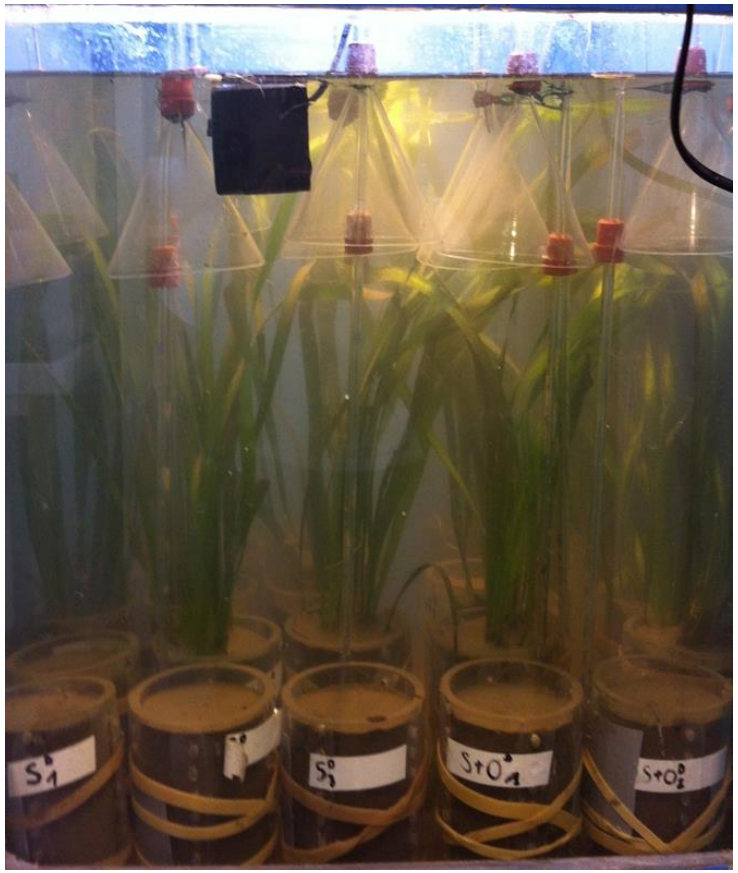
Sara Benelli [1,2]* *Marco Bartoli* [2,3]

[1]Water Research Institute (CNR-IRSA) National Research Council, Verbania Pallanza, Italy; [2]Department of Chemistry, Life Sciences and Environmental Sustainability, University of Parma, Parma, Italy; [3]Marine Research Institute, University of Klaipeda, Klaipeda, Lithuania



Sediment

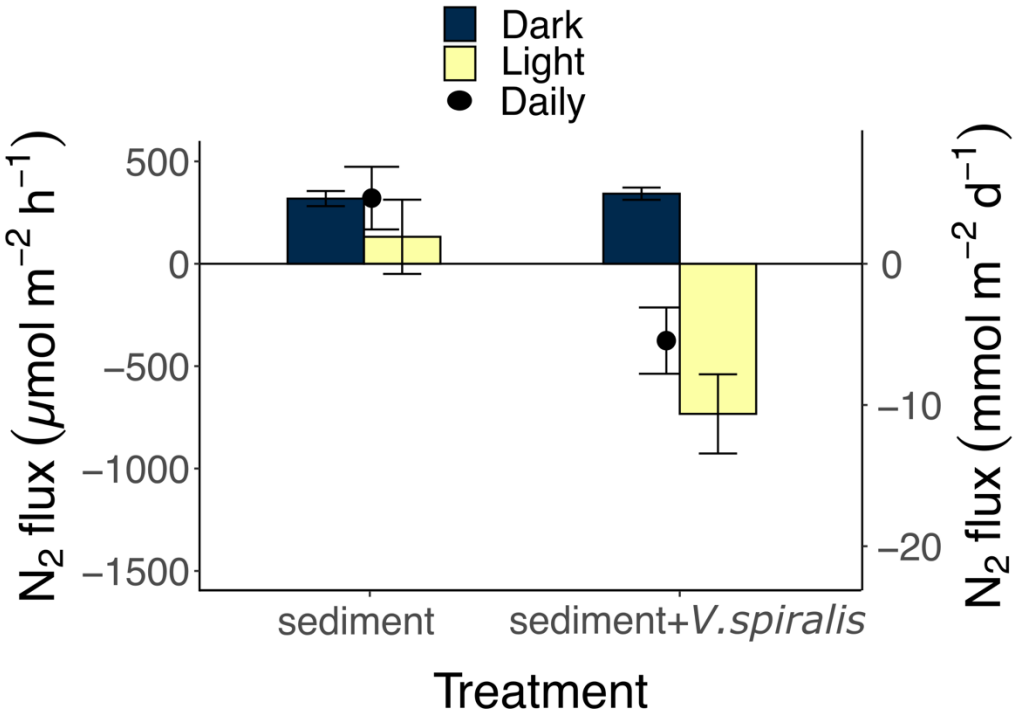
Sediment+*V.spiralis*: -60%

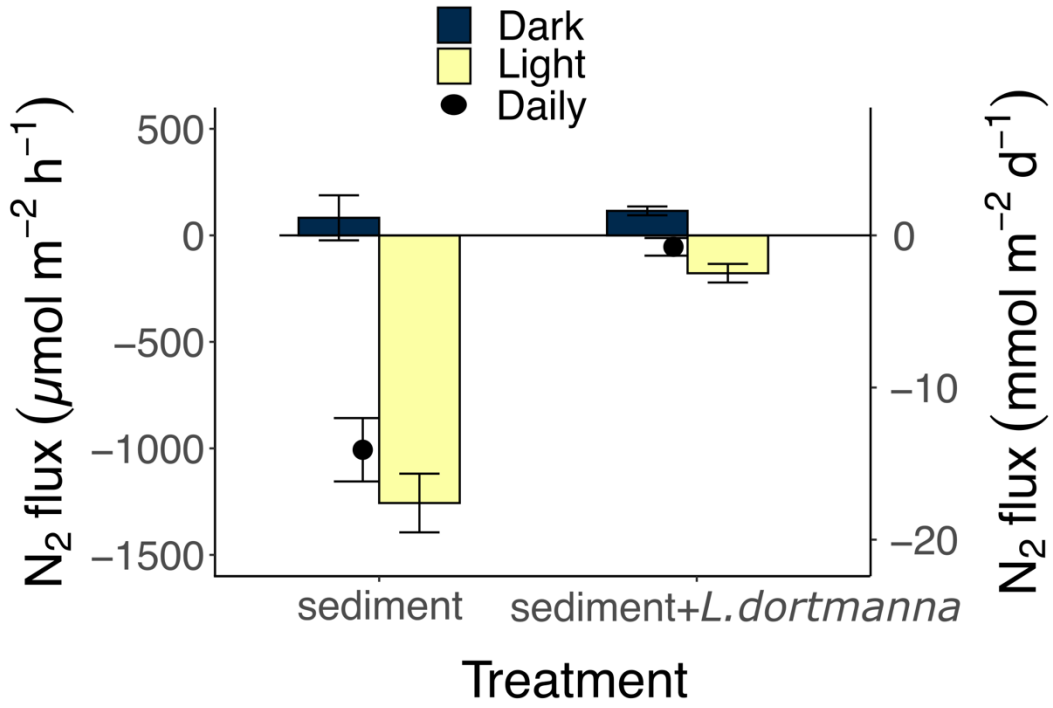


Net N_2 fluxes





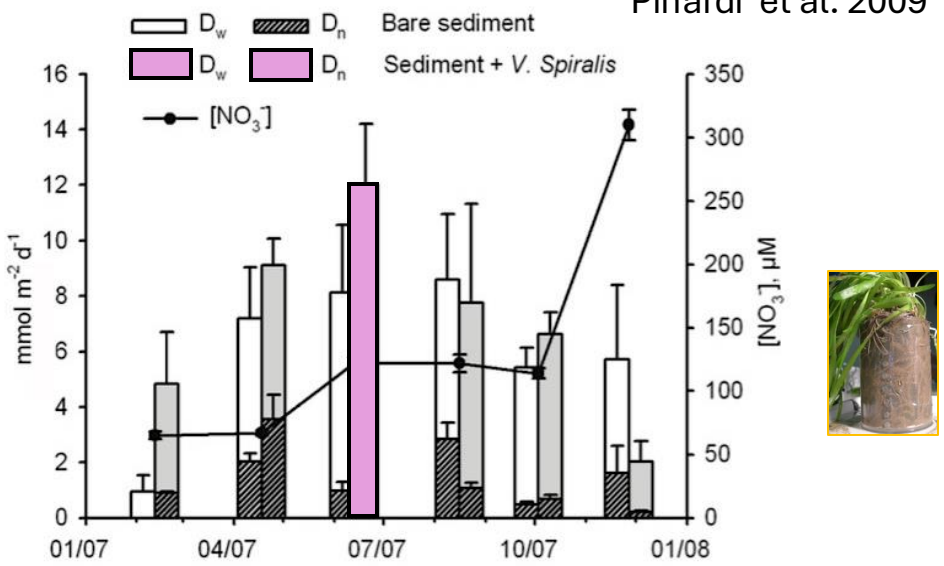




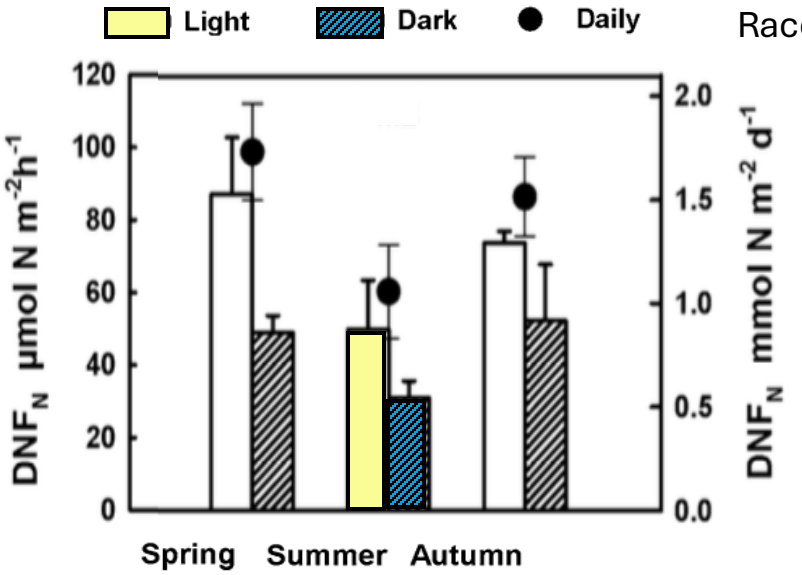
Eutrophic | **Oligotrophic**

Denitrification

Pinardi et al. 2009

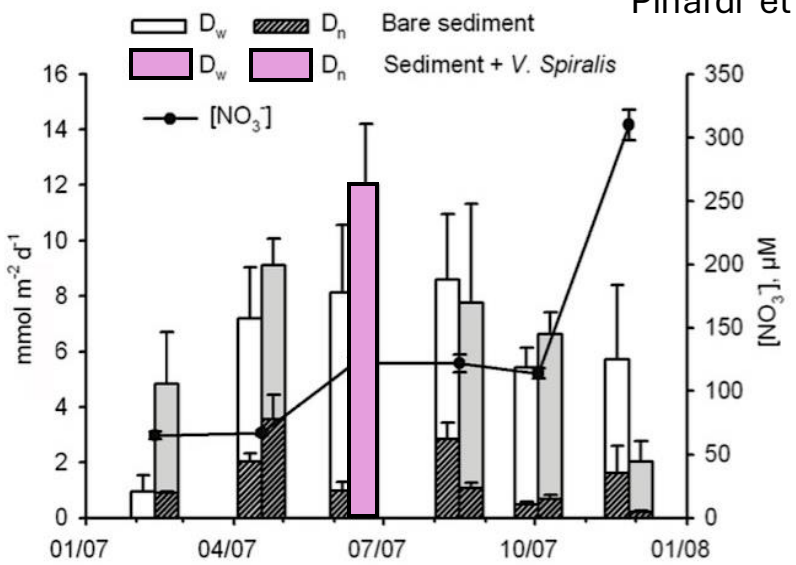


Racchetti et al. 2017



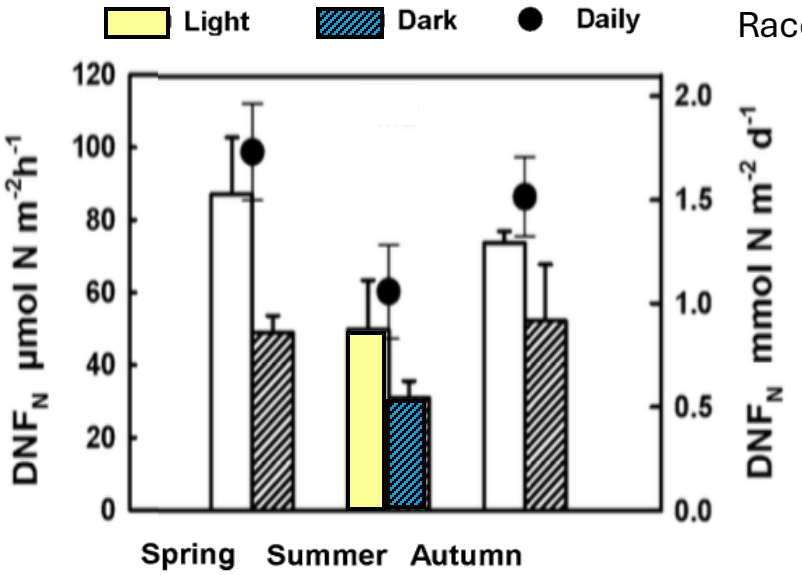
Denitrification

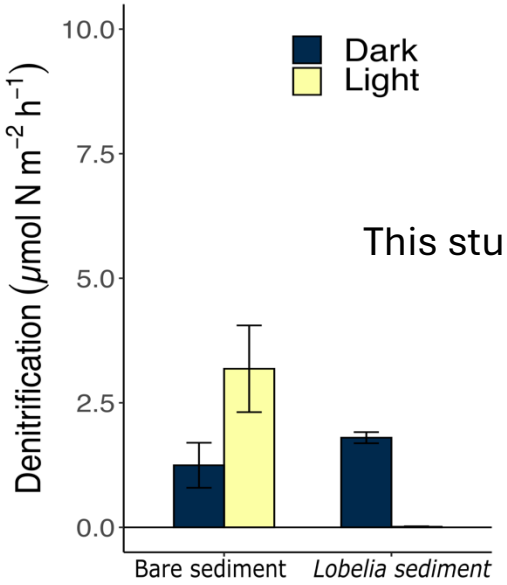
Pinardi et al. 2009





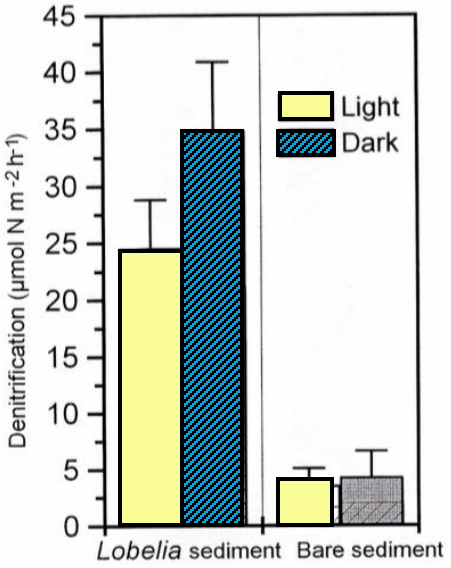
Racchetti et al. 2017





This study



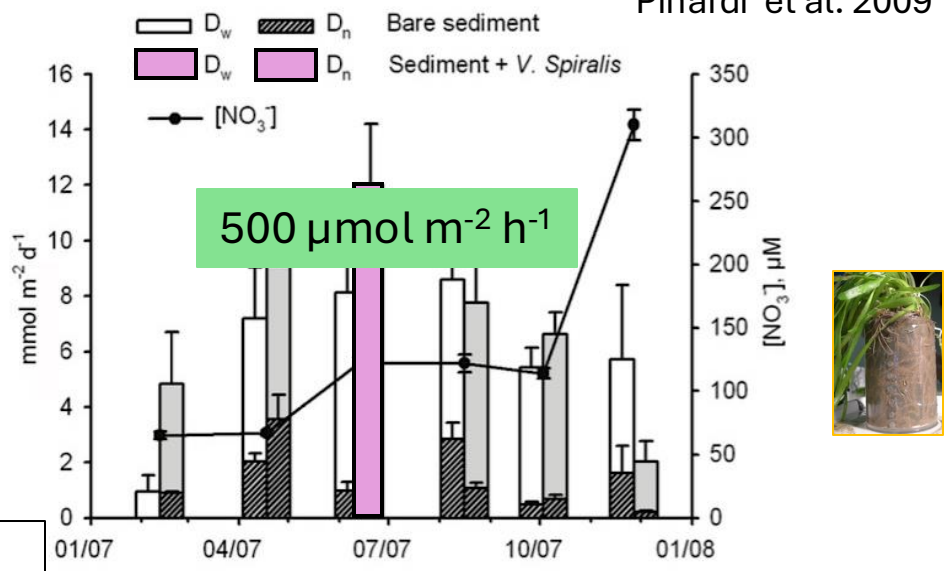


Risgaard-Petersen and Jensen 1997

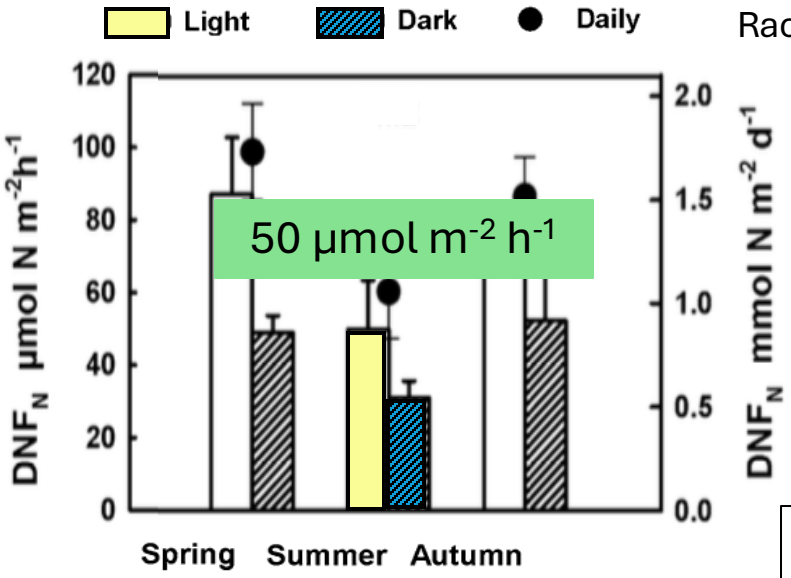
Denitrification

surface denitrification

Pinardi et al. 2009



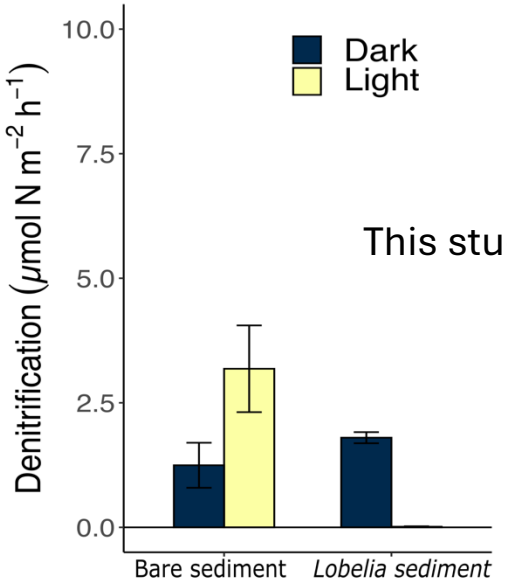
500 µmol m^{-2} h^{-1}



Racchetti et al. 2017

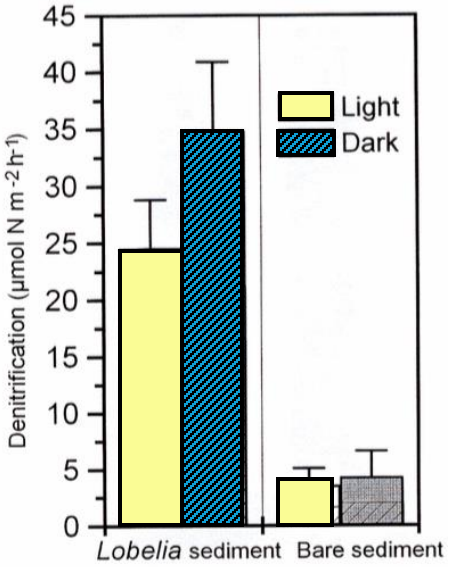
50 µmol m^{-2} h^{-1}

coupled nitrification–denitrification



This study

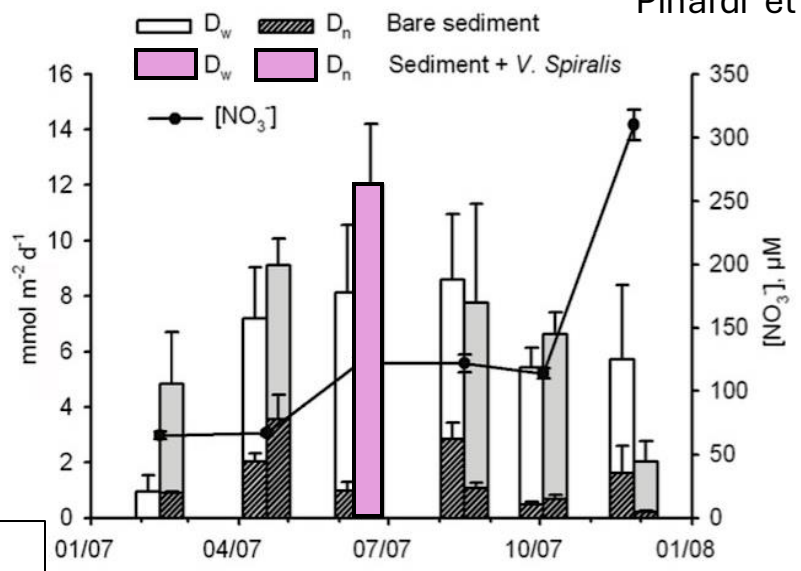




Risgaard-Petersen and Jensen 1997

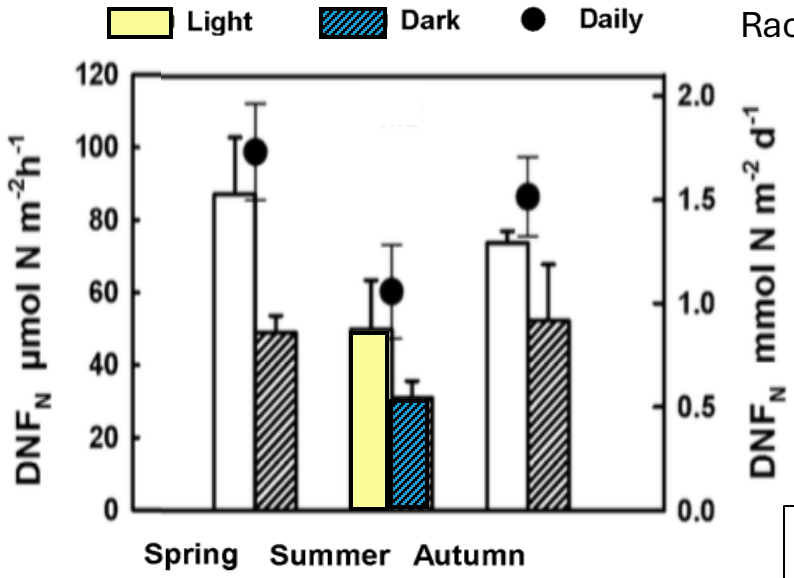
Denitrification

Pinardi et al. 2009



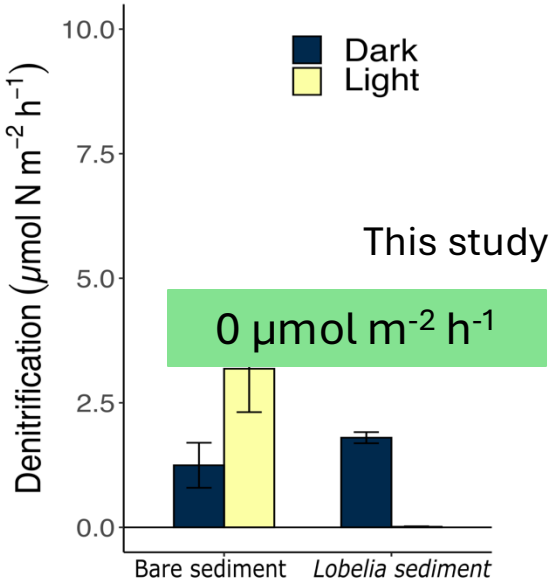


Racchetti et al. 2017



surface denitrification

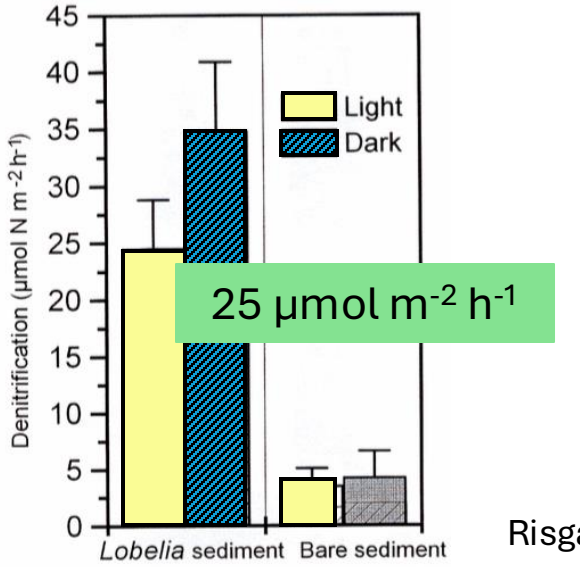
coupled nitrification–denitrification



This study

0 µmol m^{-2} h^{-1}





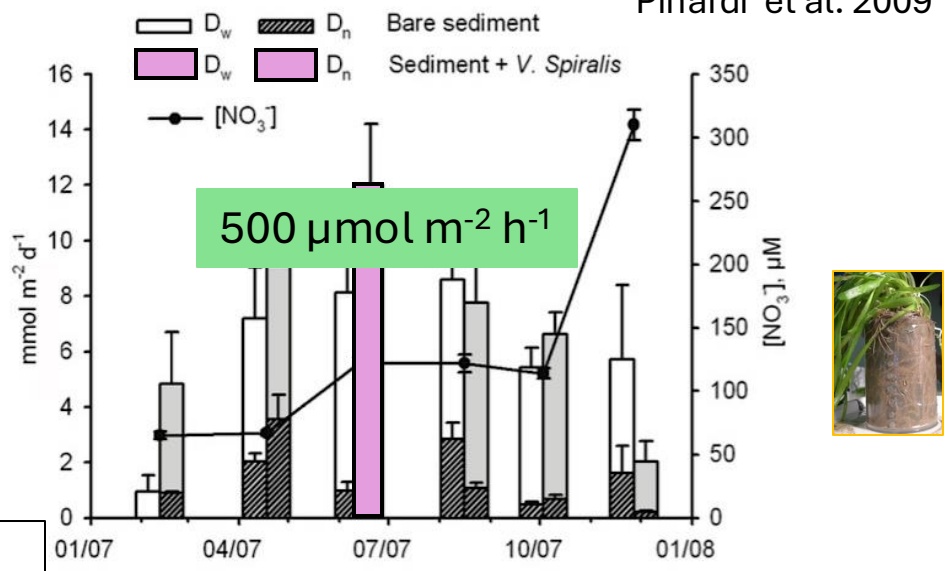
25 µmol m^{-2} h^{-1}

Risgaard-Petersen and Jensen 1997

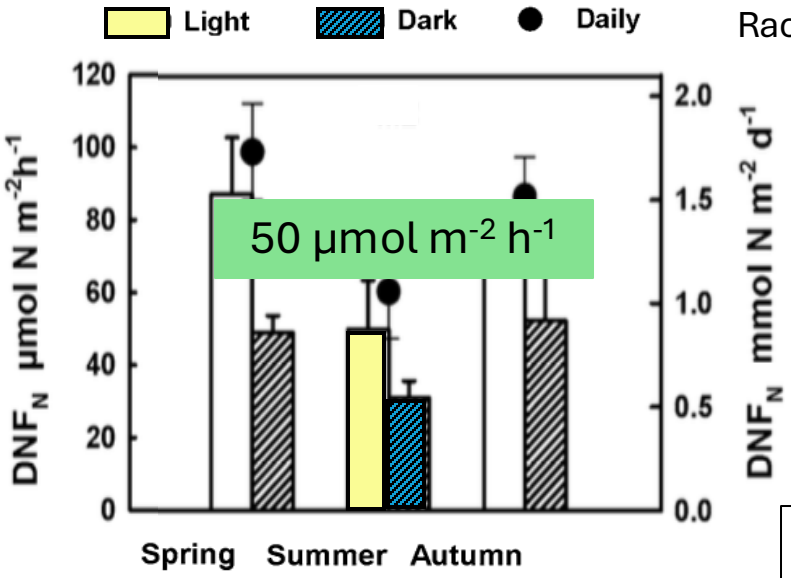
Denitrification

surface denitrification

Pinardi et al. 2009



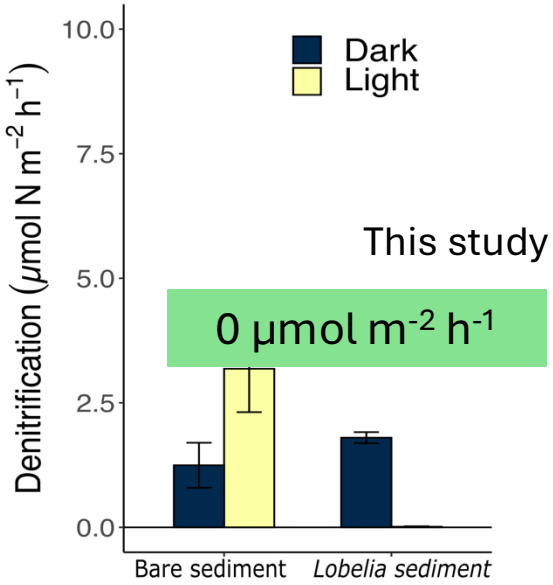
500 µmol m^{-2} h^{-1}



Racchetti et al. 2017

50 µmol m^{-2} h^{-1}

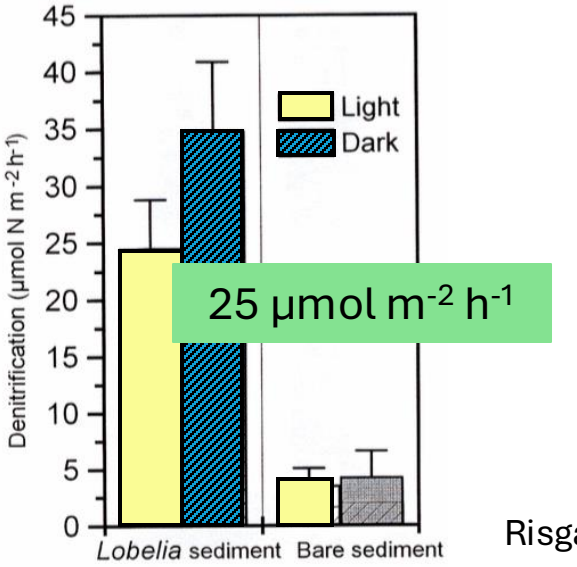
coupled nitrification–denitrification



This study

0 µmol m^{-2} h^{-1}





25 µmol m^{-2} h^{-1}

Risgaard-Petersen and Jensen 1997

Conclusions

- Carbon and oxygen cycles are uncoupled when plants display ROL
- Oxygen transport to sediments via roots reduces methanogenesis and increases CH_4 consumption
- Denitrification was higher in the presence of macrophytes due to ROL, which increases the nitrification and then denitrification

Submerged macrophytes displaying ROL oxidize the rhizosphere, favor N removal and reduce CH_4 emissions



RESILIENT WETLANDS

EXPLORING THE ROLE OF
INLAND WETLANDS & PEATLANDS
IN MITIGATING CLIMATE CHANGE

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