Sediment nitrogen transformations during an ice-free winter in a large, shallow, eutrophic lake

Mark J. McCarthy

(@MJMcNCycle)

Funding:

EU, European Regional Development Fund, Estonian University of Life Sciences ASTRA project "Value-chain based bio-economy"

(Photo: D.K. Hoffman)

TREIC LAKE

Eesti Maaülikool
Estonian University of Life Sciences

Co-Authors

Wright State University

Silvia E. Newell
Justin A. Myers

Estonian University of Life Sciences

Margot Sepp
Marju Tamm
Lea Tuvikene
Priit Zingel
Tõnu Feldmann
Kalle Olli
Tiina Nõges

Objectives

1. Characterize and quantify water column nitrogen (N) cycling rates in lakes Peipsi and Võrtsjärv (Estonia)

   a. Ammonium (NH_4^+) uptake and regeneration
   b. Nitrification

2. Characterize and quantify sediment–water interface N transformations and O_2 demand in Lake Võrtsjärv

   a. Net nutrient (NO_x, NH_4^+, urea, ortho–P), O_2, and N_2 fluxes
   b. Potential denitrification and DNRA
   c. Possible anammox
   d. N_2 fixation (heterotrophic)

Objectives

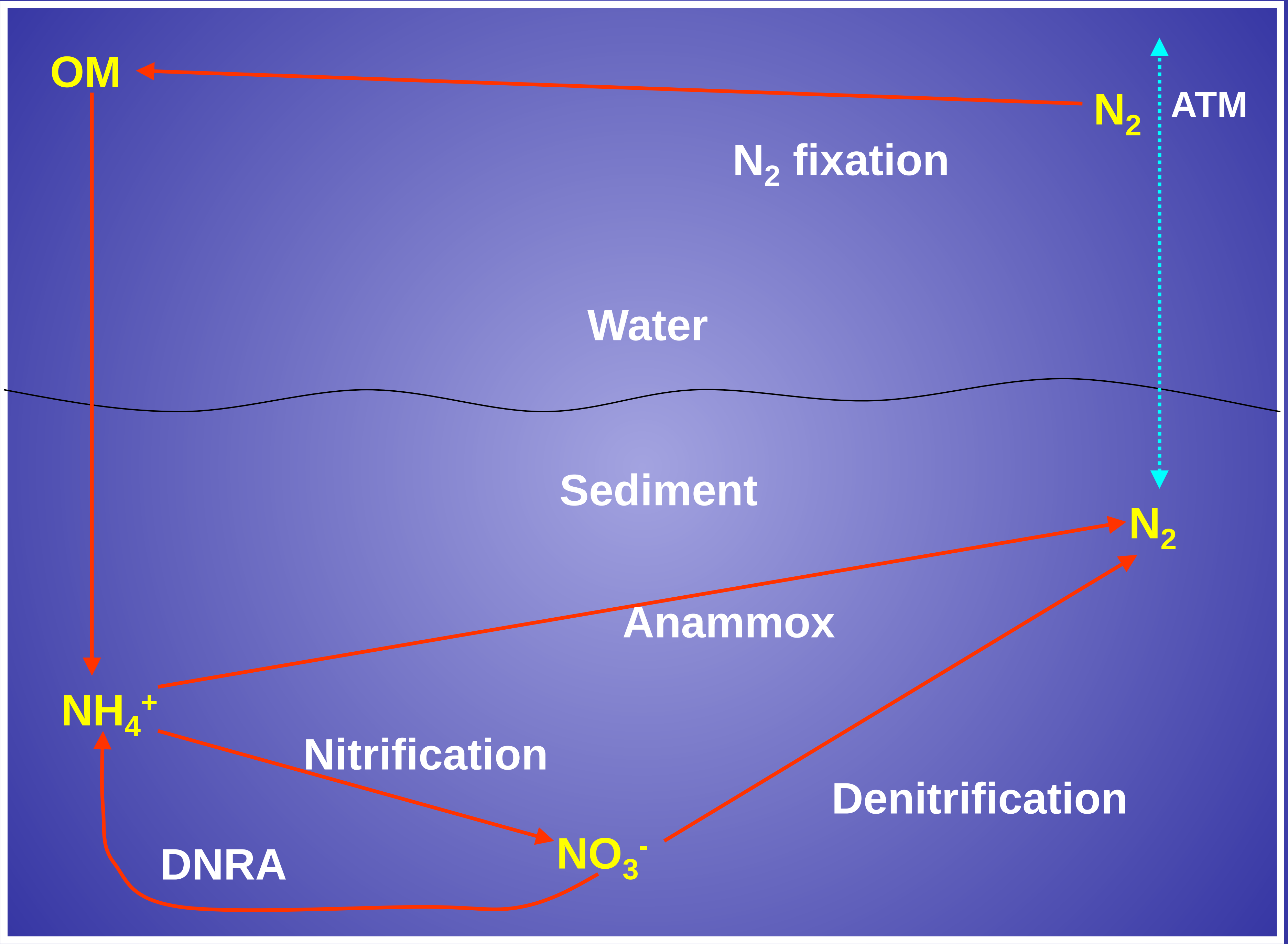
1. Characterize and quantify water column nitrogen (N) cycling rates in lakes Peipsi and Võrtsjärv (Estonia)

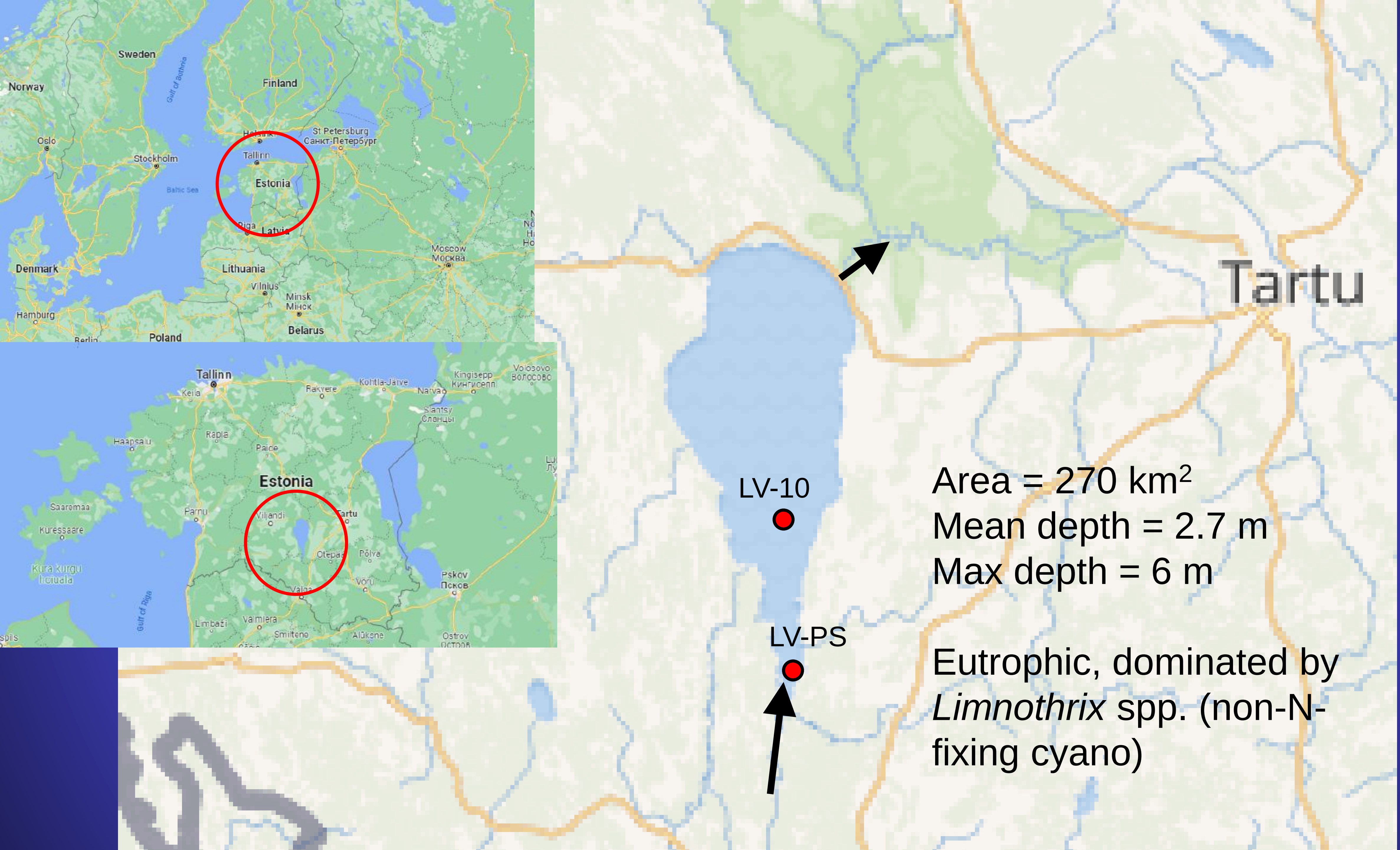
   a. Ammonium (NH_4^+) uptake and regeneration
   b. Nitrification

In progress

2. Characterize and quantify sediment–water interface N transformations and O_2 demand in Lake Võrtsjärv

   a. Net nutrient (NO_x, NH_4^+, urea, ortho–P), O_2, and N_2 fluxes
   b. Potential denitrification and DNRA
   c. Possible anammox
   d. N_2 fixation (heterotrophic)


OM
N_2
ATM
N_2 fixation
Water
Sediment
N_2
Anammox
NH_4^+
Nitrification
Denitrification
DNRA
NO_3^-

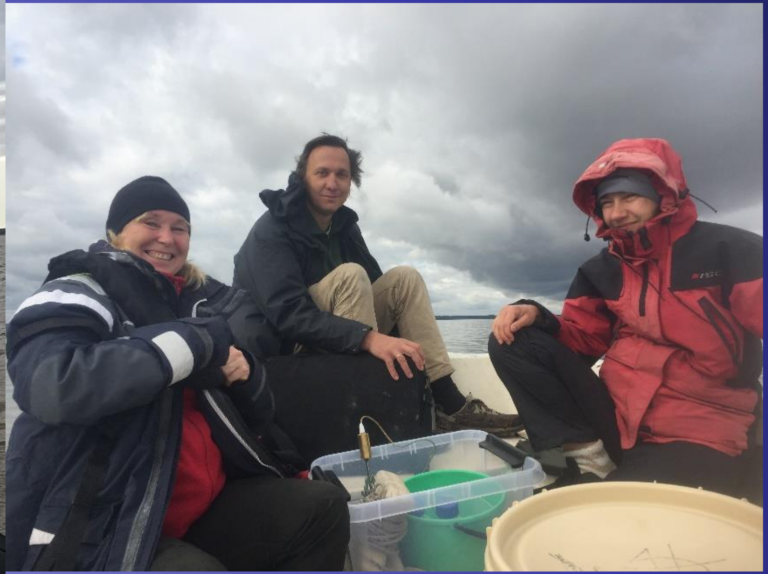


Area = 270 km^2
Mean depth = 2.7 m
Max depth = 6 m

Eutrophic, dominated by *Limnothrix* spp. (non-N-fixing cyano)

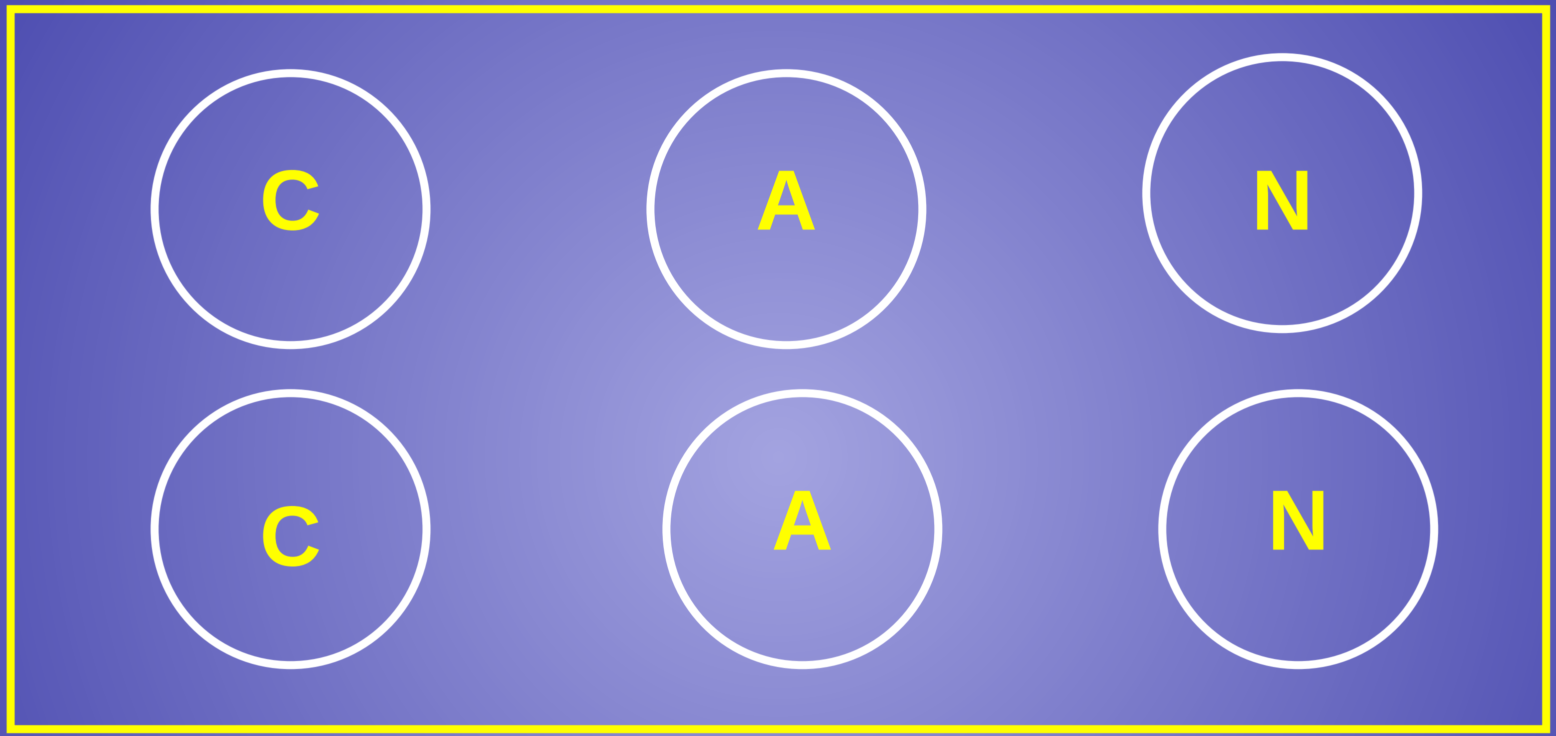






***Collect intact sediment cores and near-bottom water for continuous-flow incubations to measure SWI N fluxes and transformations.**

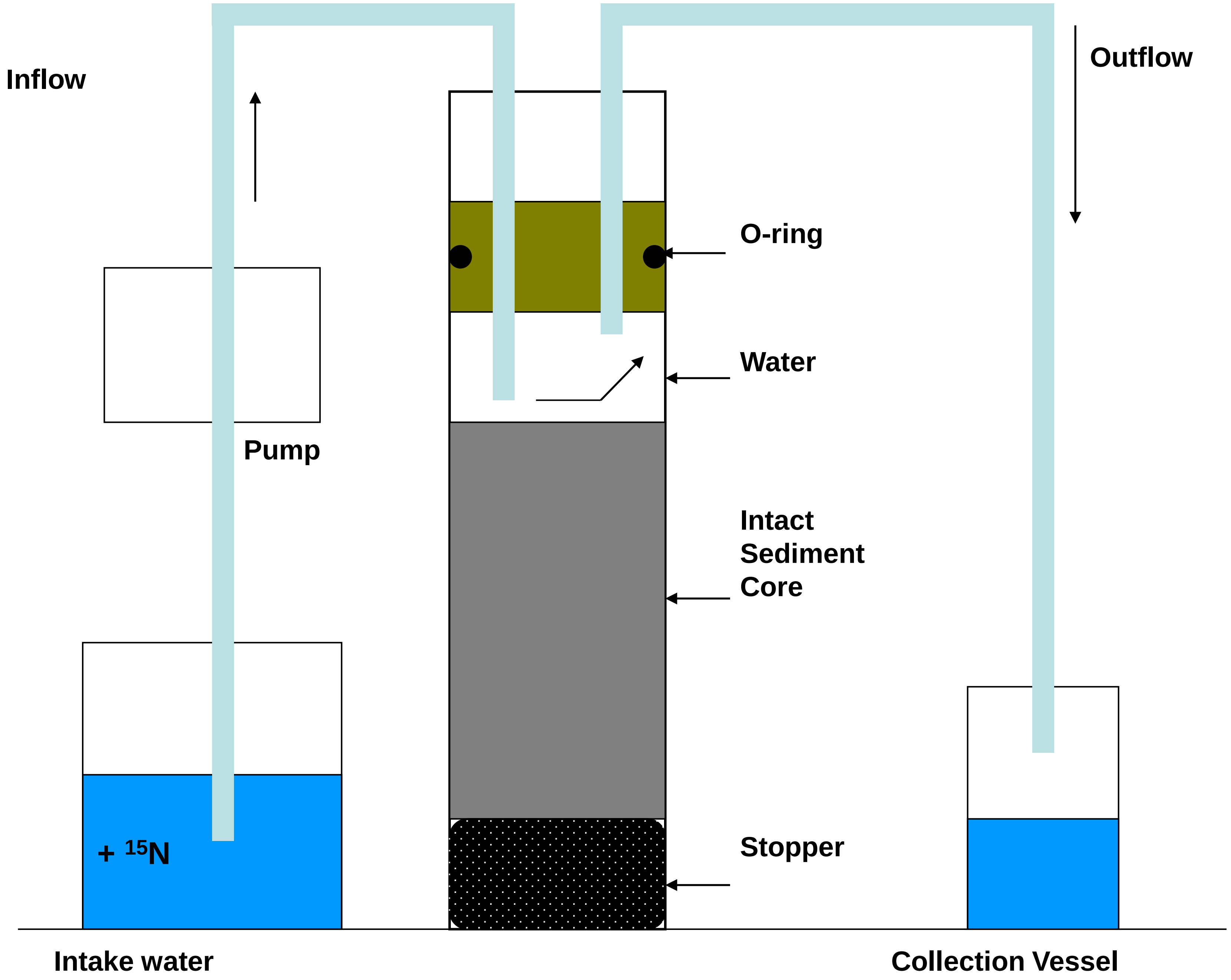
Incubation Design



C = Control (no isotope addition)

A = $^{15}NH_4^+$ addition (ammonium)

N = $^{15}NO_3^-$ addition (nitrate)



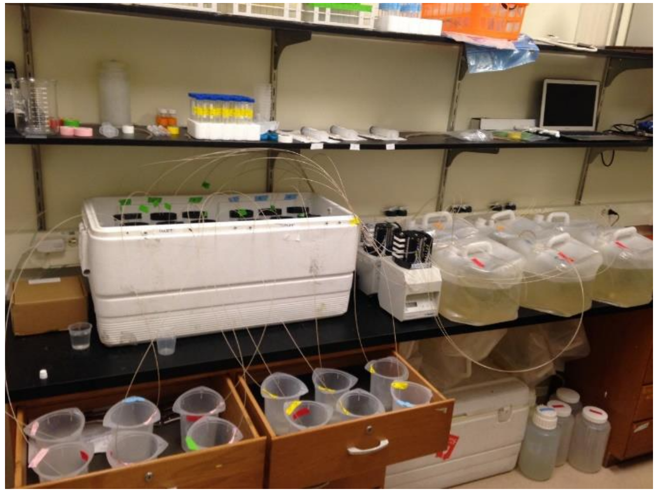
Inflow
Outflow
O-ring
Water
Pump
Intact
Sediment
Core
+ ^{15}N
Stopper
Intake water
Collection Vessel

Methods: Intact sediment core incubations

- Sample inflow reservoirs and core outflows daily for:

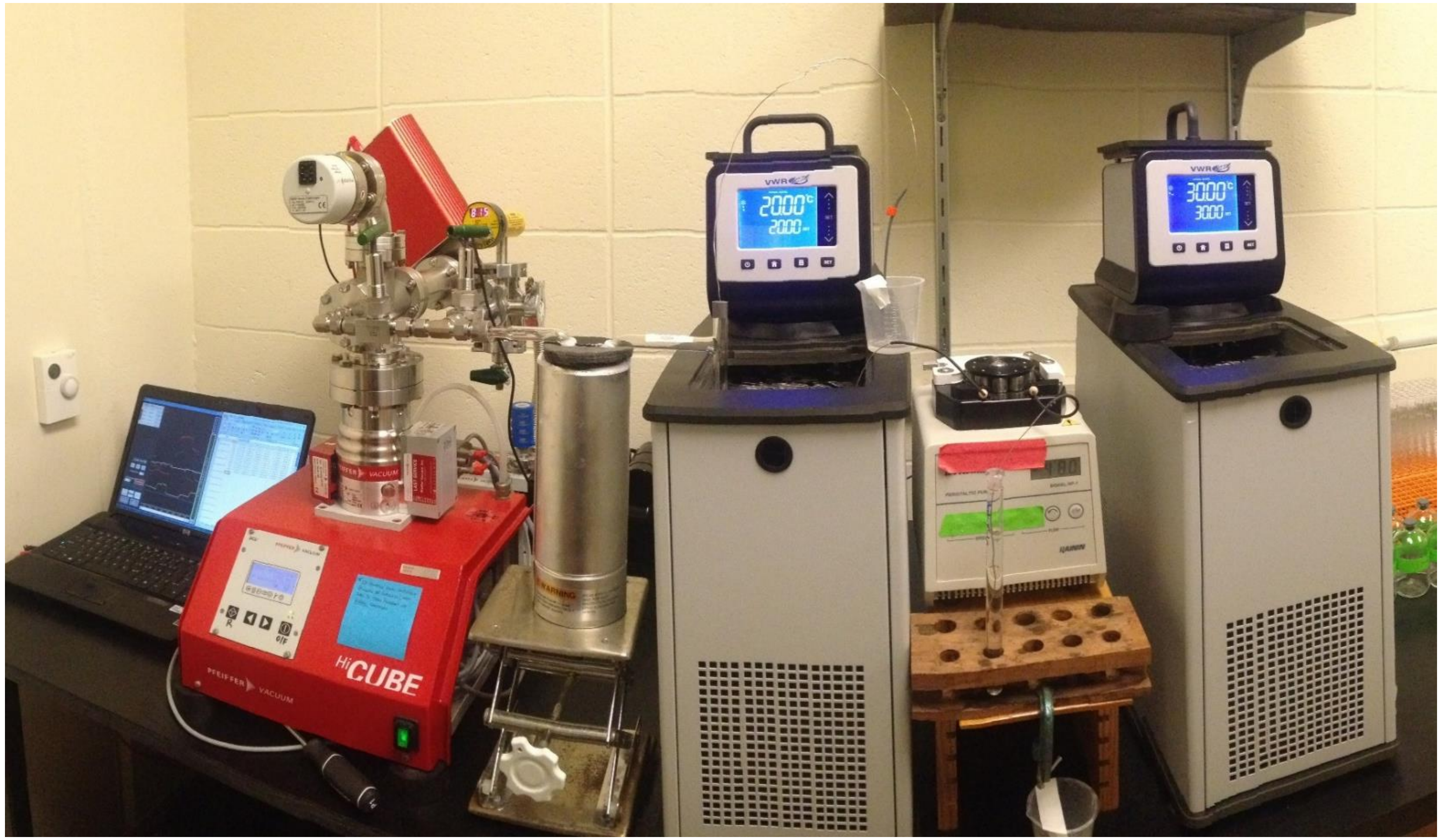
- Nutrients (filtered 0.22 µm) PO_4^{3-}, NH_4^+, NO_3^-, NO_2^-, urea

- Dissolved gases O_2, $^{28, 29, 30}N_2$



Methods: Membrane Inlet Mass Spectrometry

- C cores
  - Net $^{28}N_2$, O_2, nutrient fluxes
- A cores
  - $^{15}NH_4^+ + ^{14}NO_2^- \rightarrow ^{29}N_2$
  - Possible anammox
- N cores
  - $^{15}NO_3^- \rightarrow ^{29,30}N_2$
  - Denitrification
  - $^{15}NO_3^- \rightarrow ^{15}NH_4^+$
  - DNRA (OX-MIMS)



Objectives

1. Characterize and quantify water column nitrogen (N) cycling rates in lakes Peipsi and Võrtsjärv

   a. Ammonium (NH_4^+) uptake and regeneration
   b. Nitrification

In progress

2. Characterize and quantify sediment–water interface N transformations and O_2 demand in Lake Võrtsjärv

   a. Net nutrient (NO_x, NH_4^+, urea, ortho–P), O_2, and N_2 fluxes
   b. Potential denitrification and DNRA **Not detected so far**
   c. Possible anammox
   d. N_2 fixation (heterotrophic) **Not detected so far**

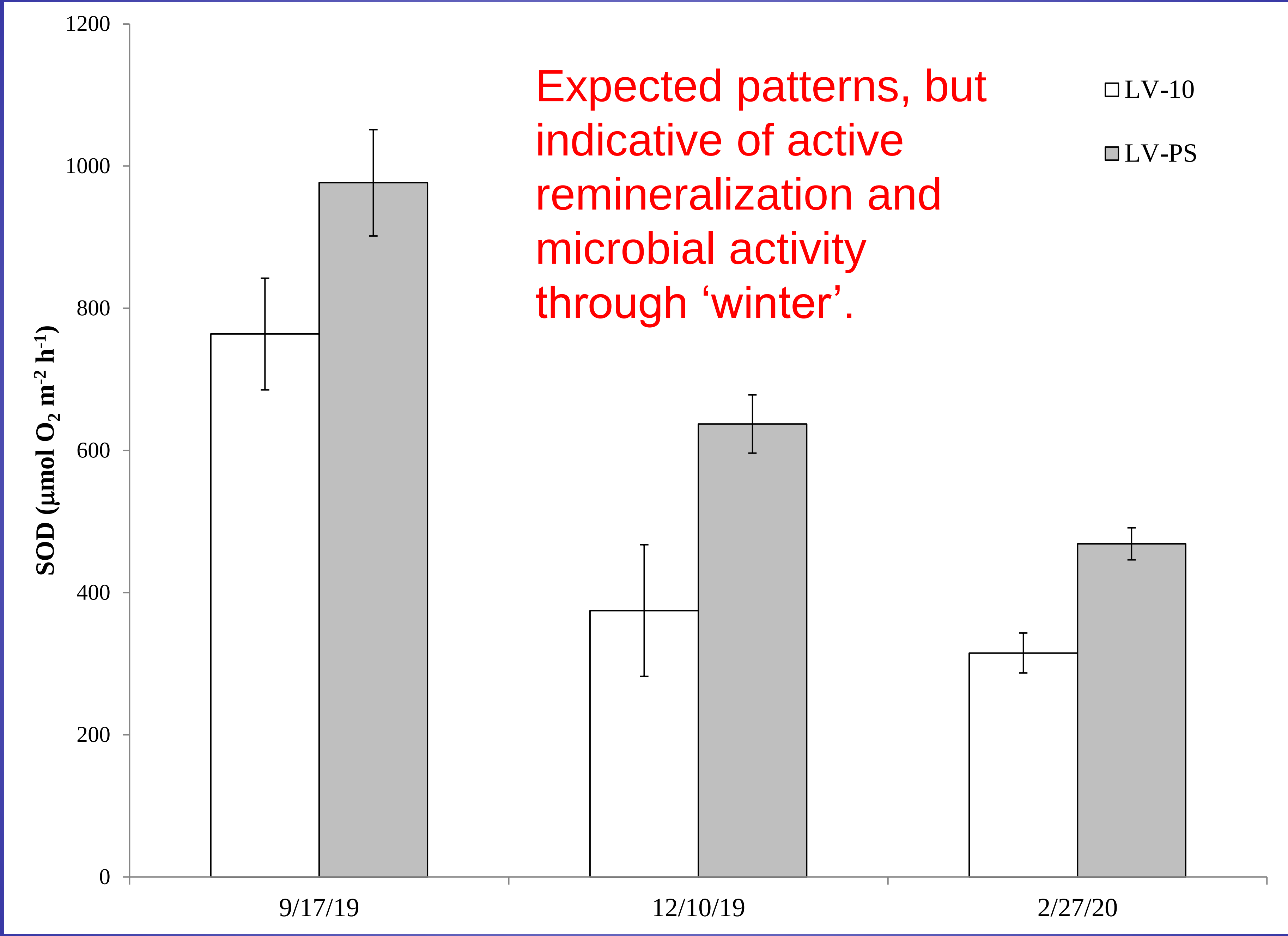
Objectives

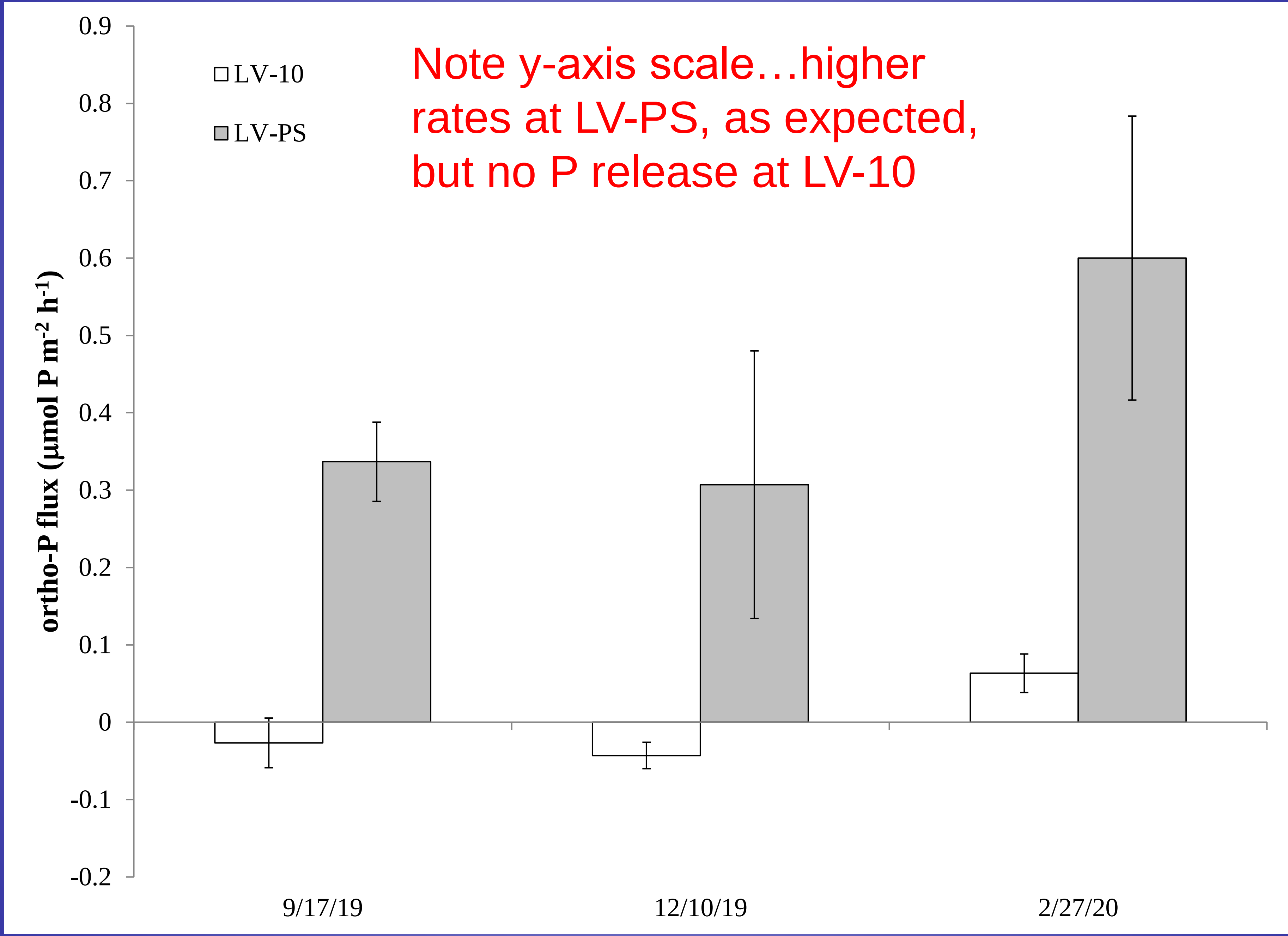
1. Characterize and quantify water column nitrogen (N) cycling rates in lakes Peipsi and Võrtsjärv

   a. Ammonium (NH_4^+) uptake and regeneration
   b. Nitrification

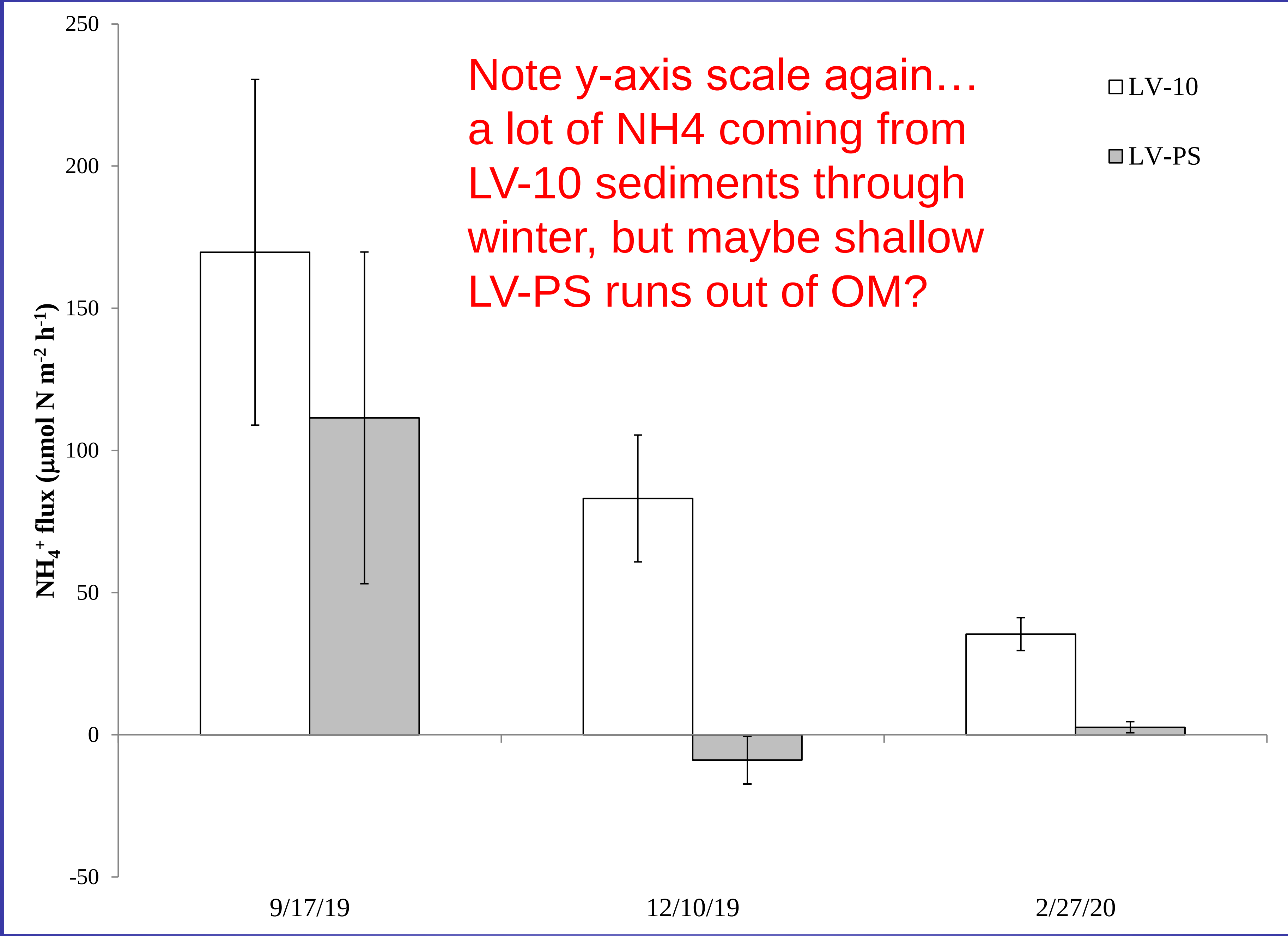
2. Characterize and quantify sediment–water interface N transformations and O_2 demand in Lake Võrtsjärv

   a. Net nutrient (NO_x, NH_4^+, urea, ortho–P), O_2, and N_2 fluxes
   b. Potential denitrification and DNRA
   c. Possible anammox → **0–4% of total N_2 production**
   d. N_2 fixation (heterotrophic)

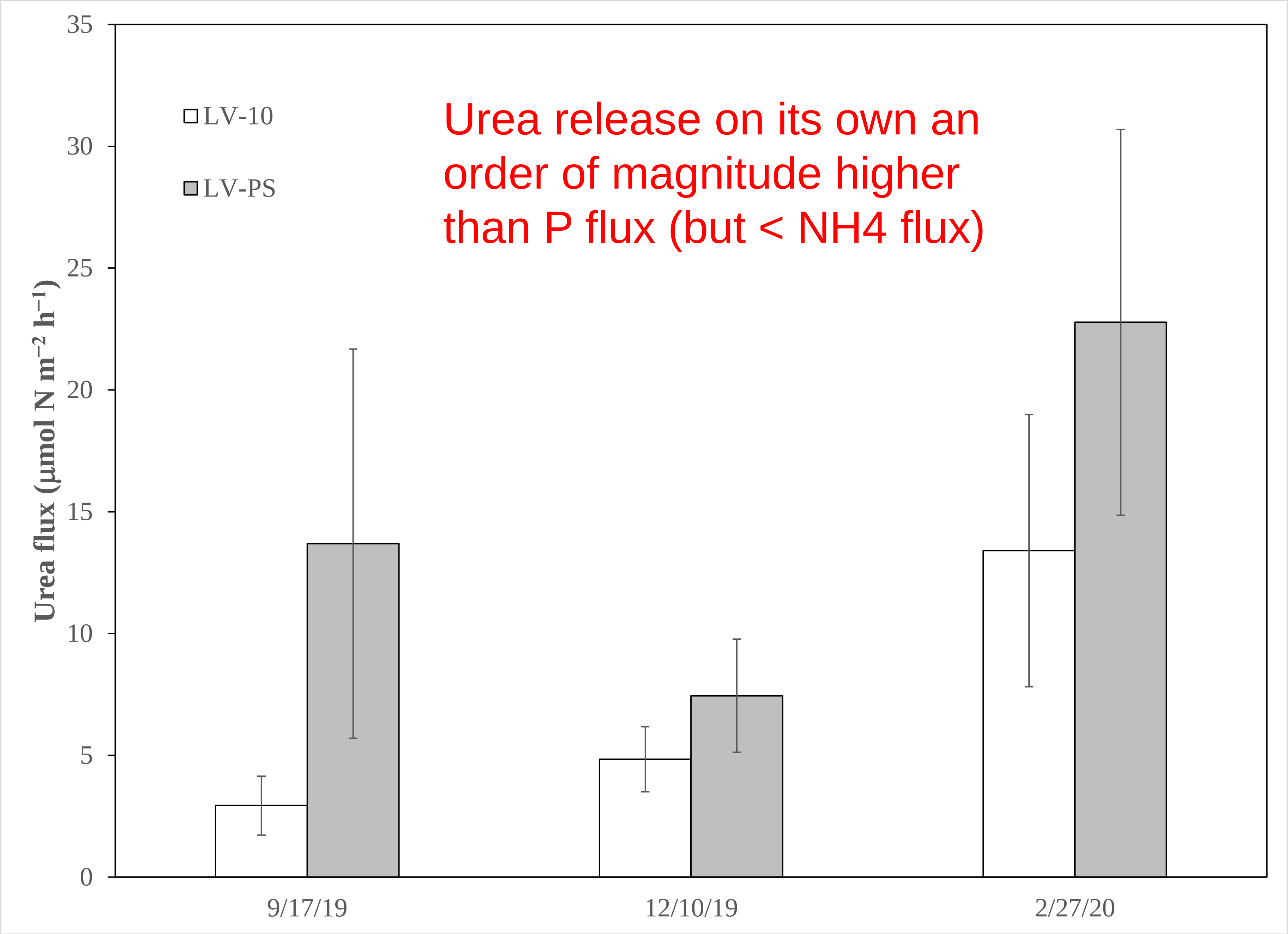

Expected patterns, but indicative of active remineralization and microbial activity through 'winter'.
LV-10
LV-PS
SOD (µmol O2 m-2 h-1)
1200
1000
800
600
400
200
0
9/17/19
12/10/19
2/27/20

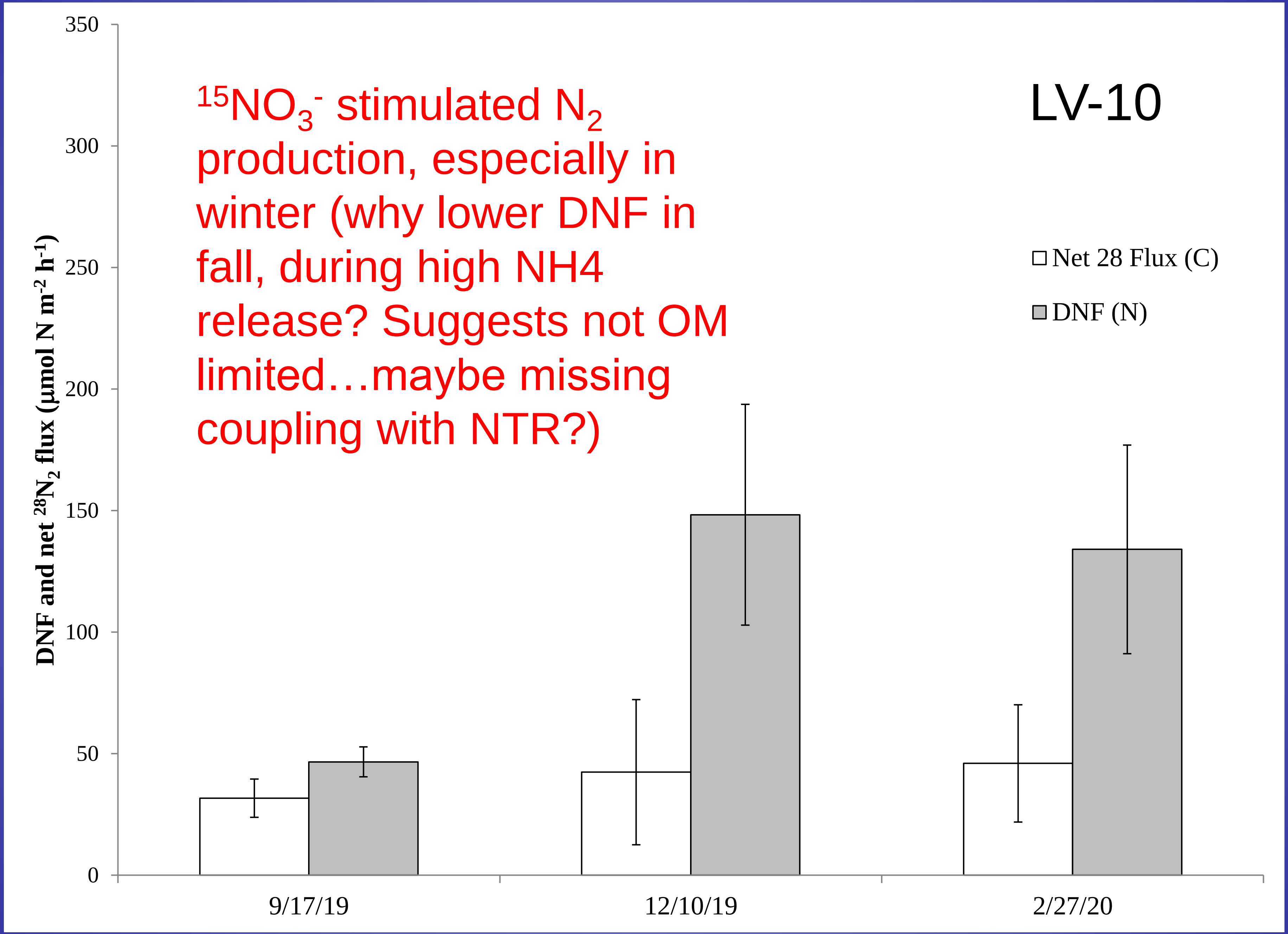


Note y-axis scale…higher rates at LV-PS, as expected, but no P release at LV-10
LV-10
LV-PS
ortho-P flux (µmol P m-2 h-1)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
9/17/19
12/10/19
2/27/20

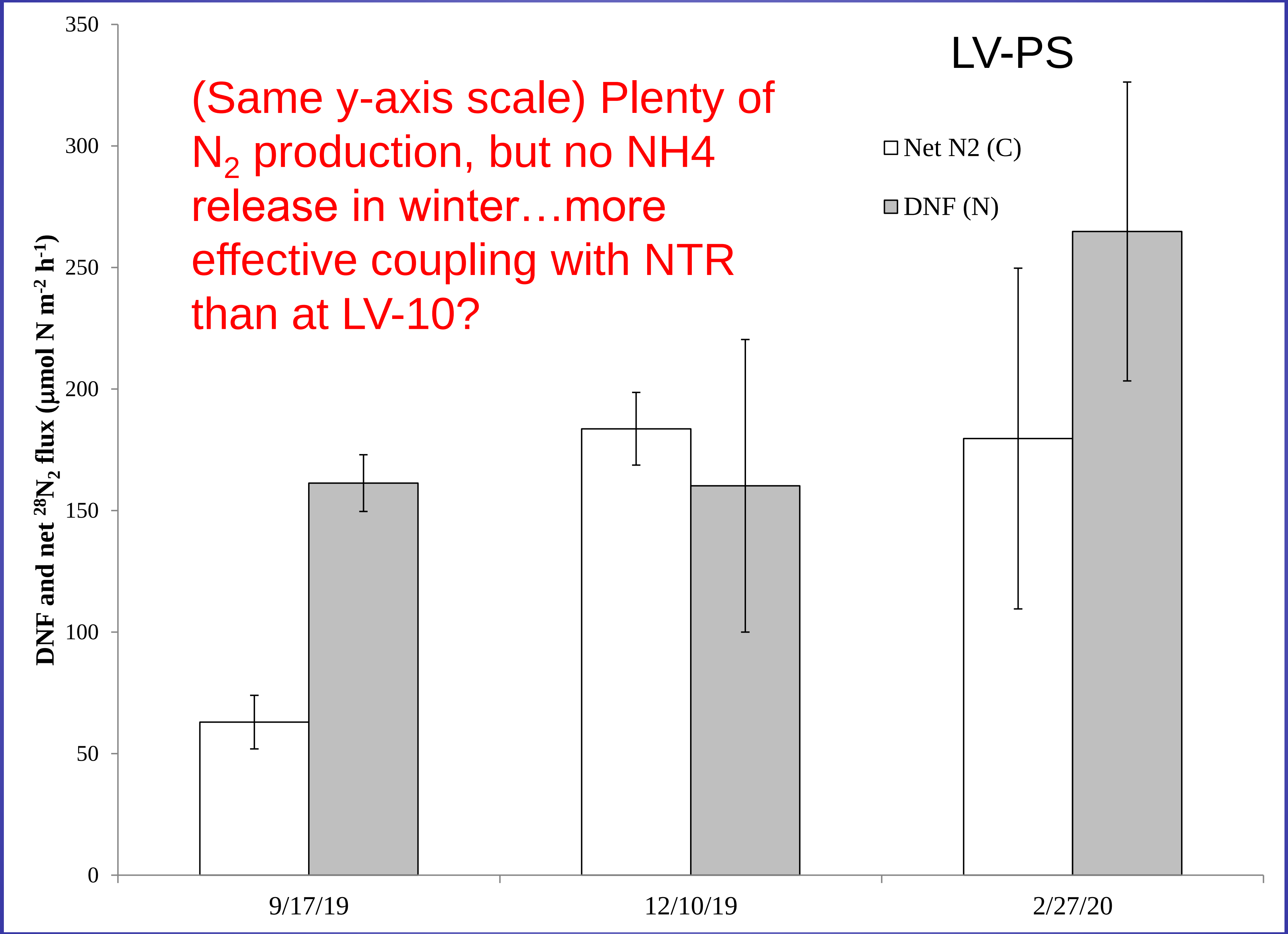


Note y-axis scale again… a lot of NH4 coming from LV-10 sediments through winter, but maybe shallow LV-PS runs out of OM?
LV-10
LV-PS
NH4+ flux (µmol N m-2 h-1)
250
200
150
100
50
0
-50
9/17/19
12/10/19
2/27/20


35
30
25
20
15
10
5
0
Urea flux (µmol N m⁻² h⁻¹)
LV-10
LV-PS
Urea release on its own an order of magnitude higher than P flux (but < NH4 flux)
9/17/19
12/10/19
2/27/20



350
300
250
200
150
100
50
0
DNF and net 28N2 flux (µmol N m-2 h-1)
15NO3- stimulated N2 production, especially in winter (why lower DNF in fall, during high NH4 release? Suggests not OM limited…maybe missing coupling with NTR?)
LV-10
Net 28 Flux (C)
DNF (N)
9/17/19
12/10/19
2/27/20


LV-PS
(Same y-axis scale) Plenty of N2 production, but no NH4 release in winter…more effective coupling with NTR than at LV-10?
Net N2 (C)
DNF (N)
DNF and net 28N2 flux (µmol N m-2 h-1)
350
300
250
200
150
100
50
0
9/17/19
12/10/19
2/27/20

Observations/Questions

1. Microbes are clearly active during winter in Võrtsjärv (historically mild winter? No ice, but water temps still 1.2 ˚C…what about more ‘normal’ winter with ice?).

2. Not much P flux from sediments, especially compared to N (pattern maybe reversed in warmer months?).

3. Anammox, DNRA, and N fixation do not seem to be very important this time of year.

4. Why no NH4 flux at LV-PS in winter? Lots of N_2 production, so microbes are active…maybe more efficient coupling with NTR (unlike LV-10), so accumulated OM → NTR → DNF?

What's Next?

1. Water column rates

2. Sample more during 'normal' winter and warmer months

3. Use ^{15}N amendments to tease apart the role of coupled remineralization-nitrification-denitrification to help explain why sediments were a more efficient N sink at some times and places than others.

ASLO Association for the Sciences of Limnology and Oceanography

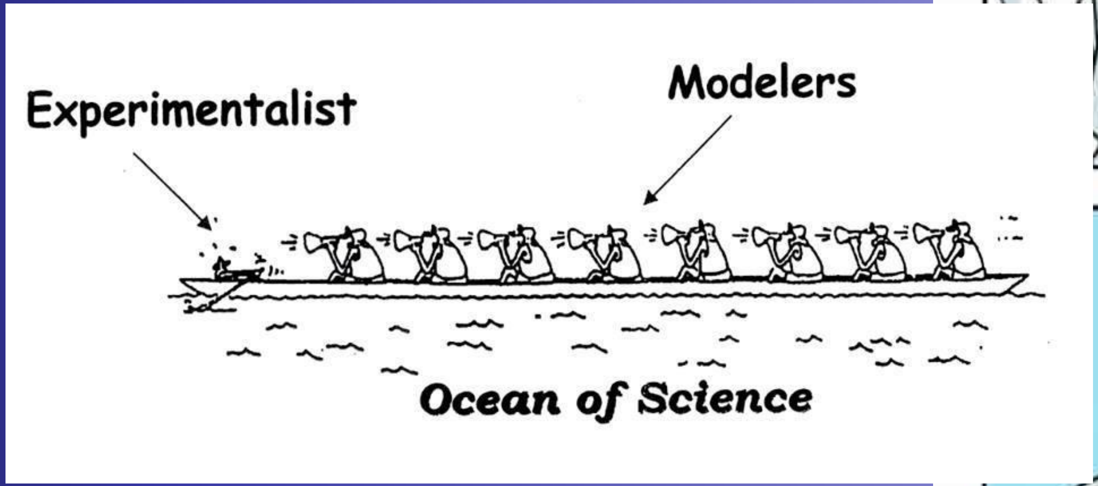
For Members | Meetings | Support ASLO Programs | Employment

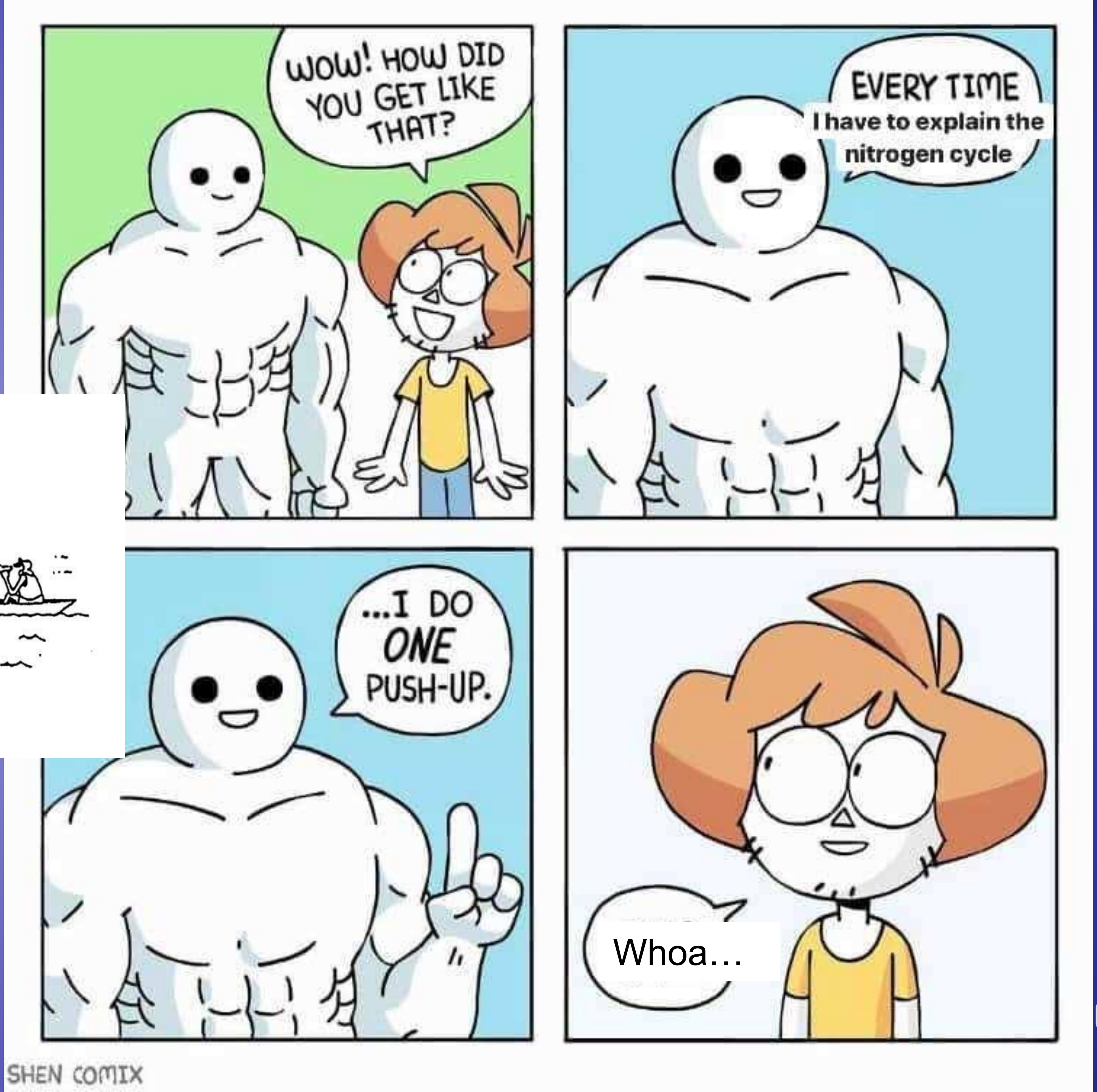
Career Center › Job Postings List Results ›

0692: PhD Student in Aquatic Nitrogen Cycling/Eutrophication/Cyanobacteria

mark.mccarthy@emu.ee

Twitter @MJMcNCycle


Experimentalist
Modelers
Ocean of Science


WOW! HOW DID YOU GET LIKE THAT?
EVERY TIME I have to explain the nitrogen cycle
...I DO ONE PUSH-UP.
Whoa…
SHEN COMIX

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 951963