A Future Tale of Two Winters? Sediment-water interface nitrogen dynamics in Lake Võrtsjärv (Estonia) during the ice-free winter 2019/2020

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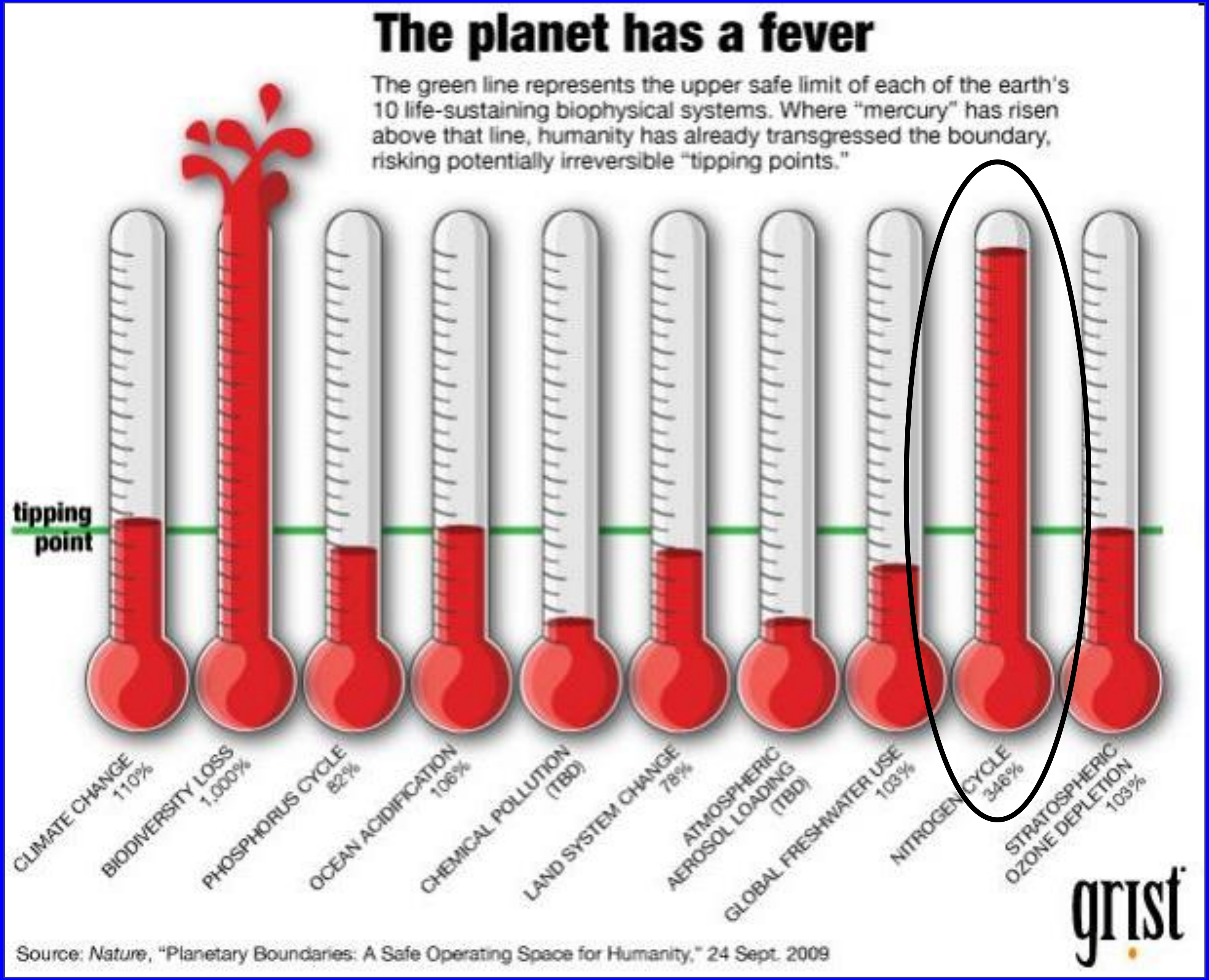
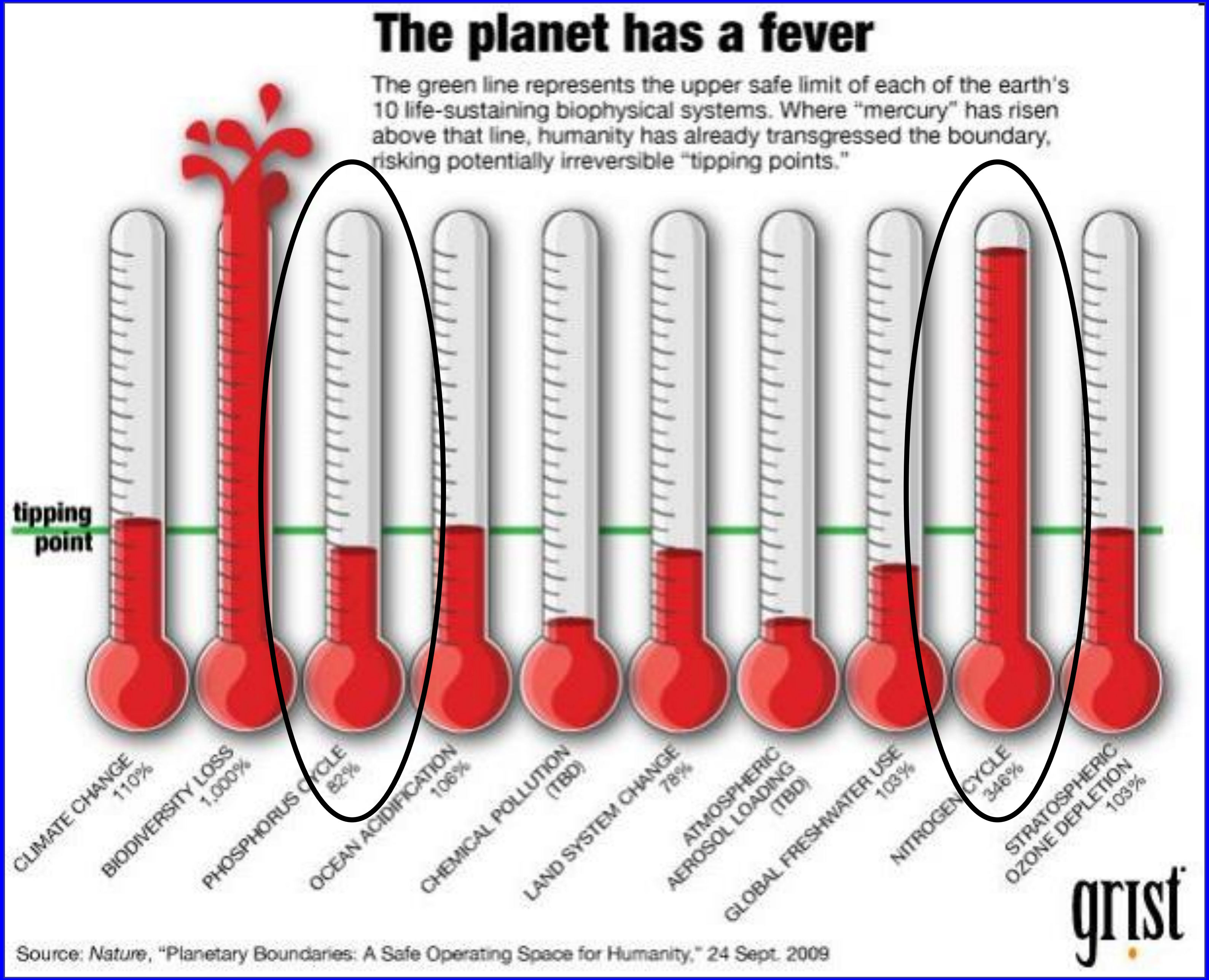
European Union European Regional Development Fund

Investing in your future

Eesti Maaülikool Estonian University of Life Sciences



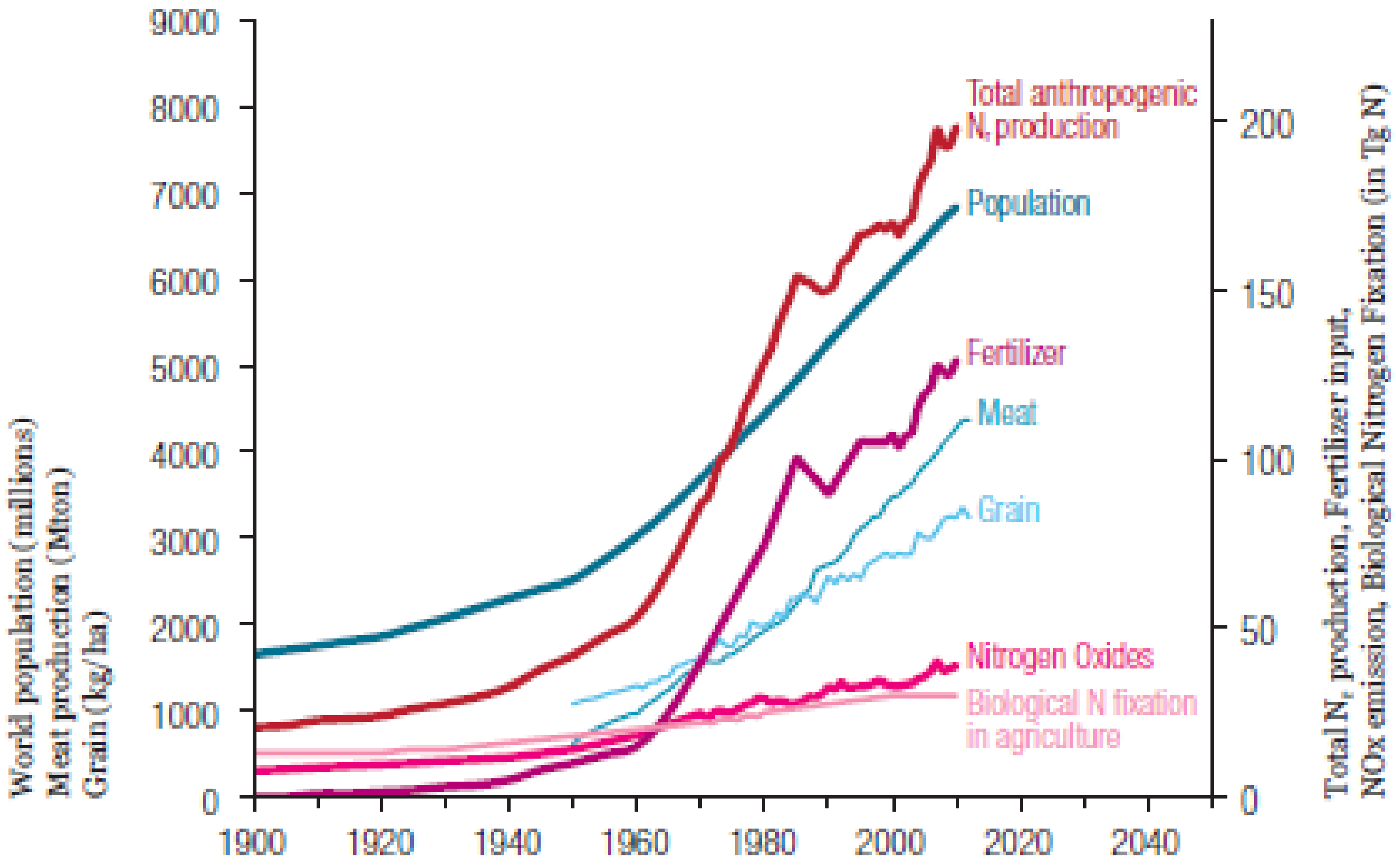
Rockstrom et al. 2009



Slide Courtesy Bob Howarth

Rockstrom et al. 2009

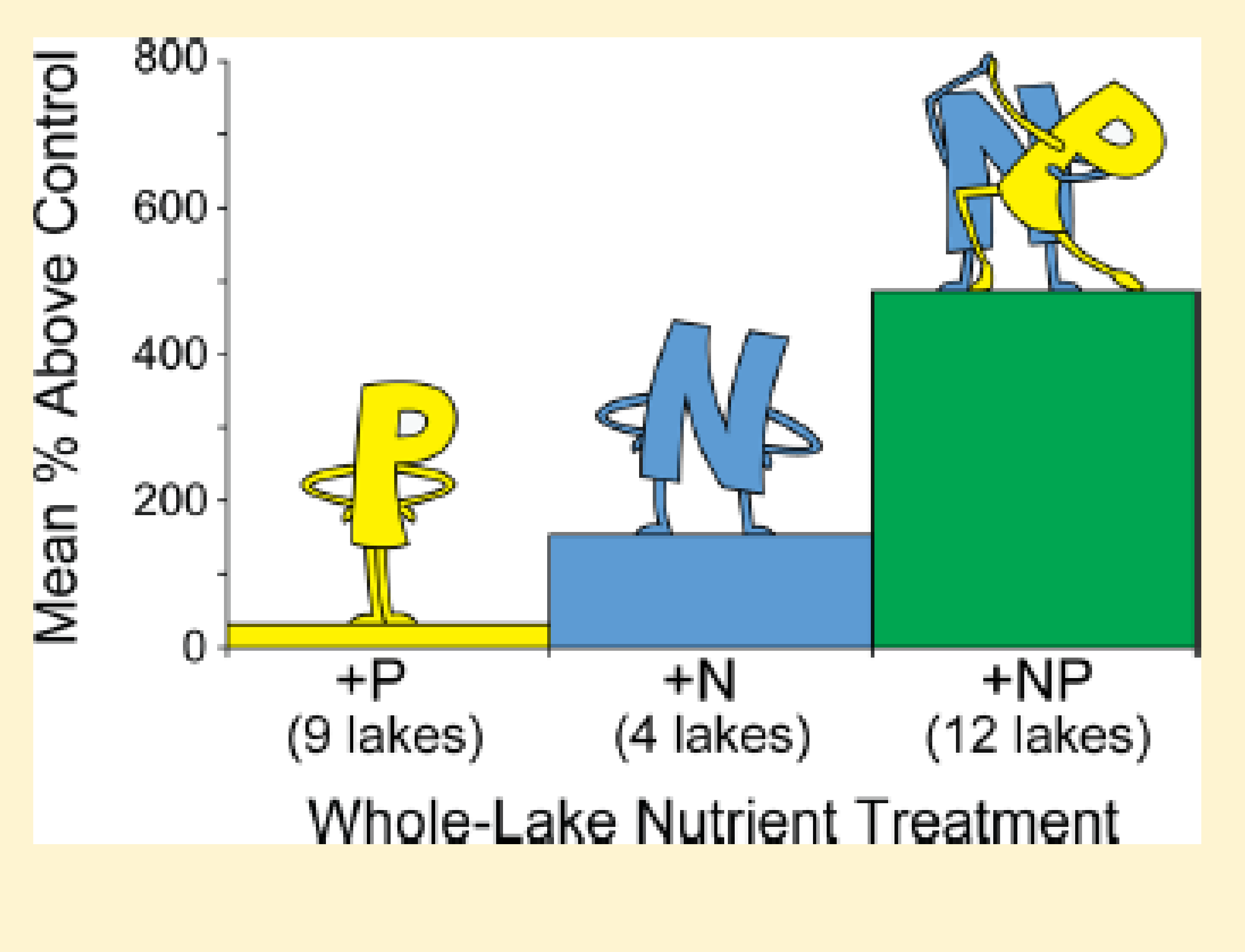
Global trends in nitrogen use per year



(Erisman et al. 2015)

N- and Co-Limitation

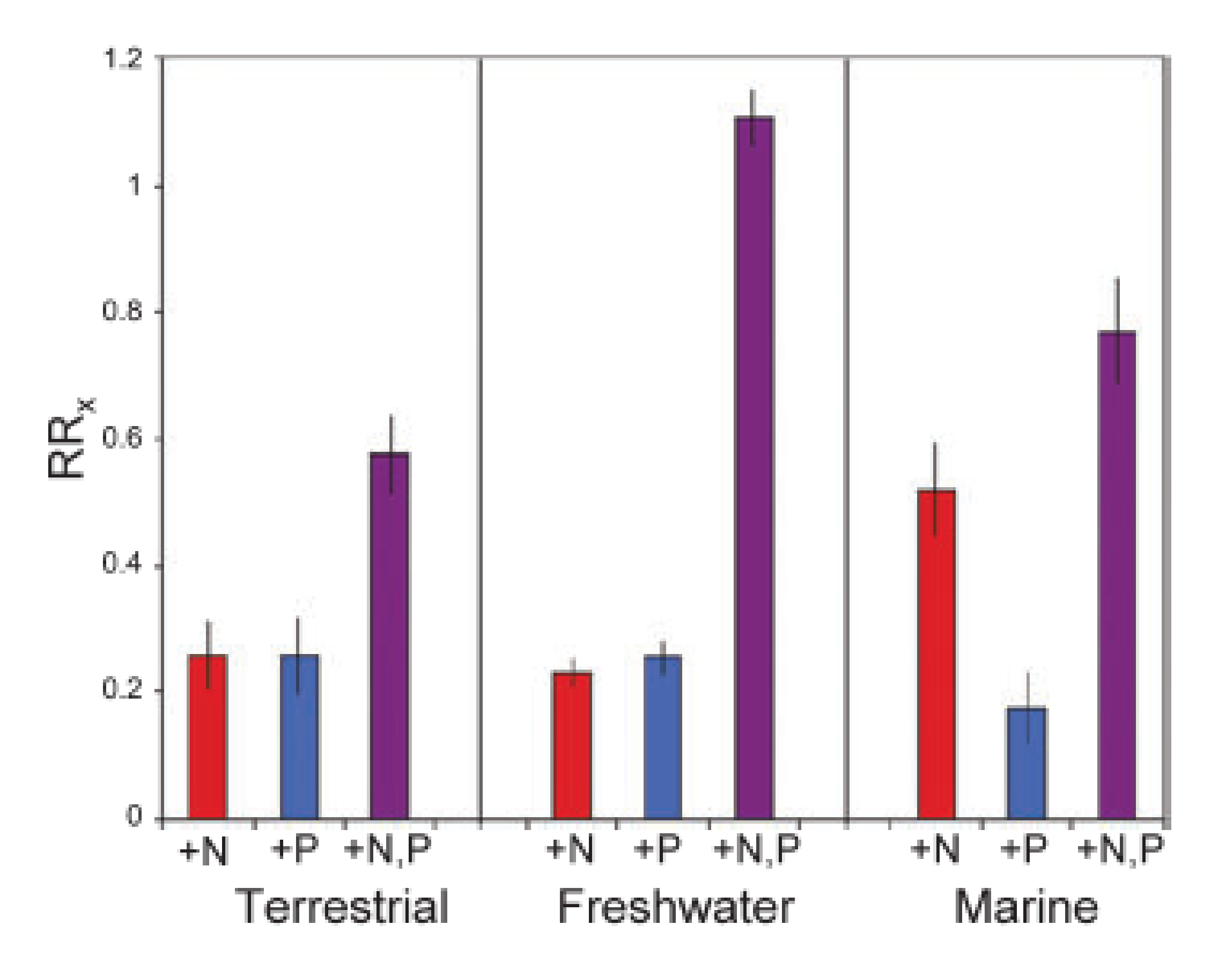
Nutrient Balanced Growth Isn't Just For Bottles (or Lake 227)



(Paerl et al. 2016)

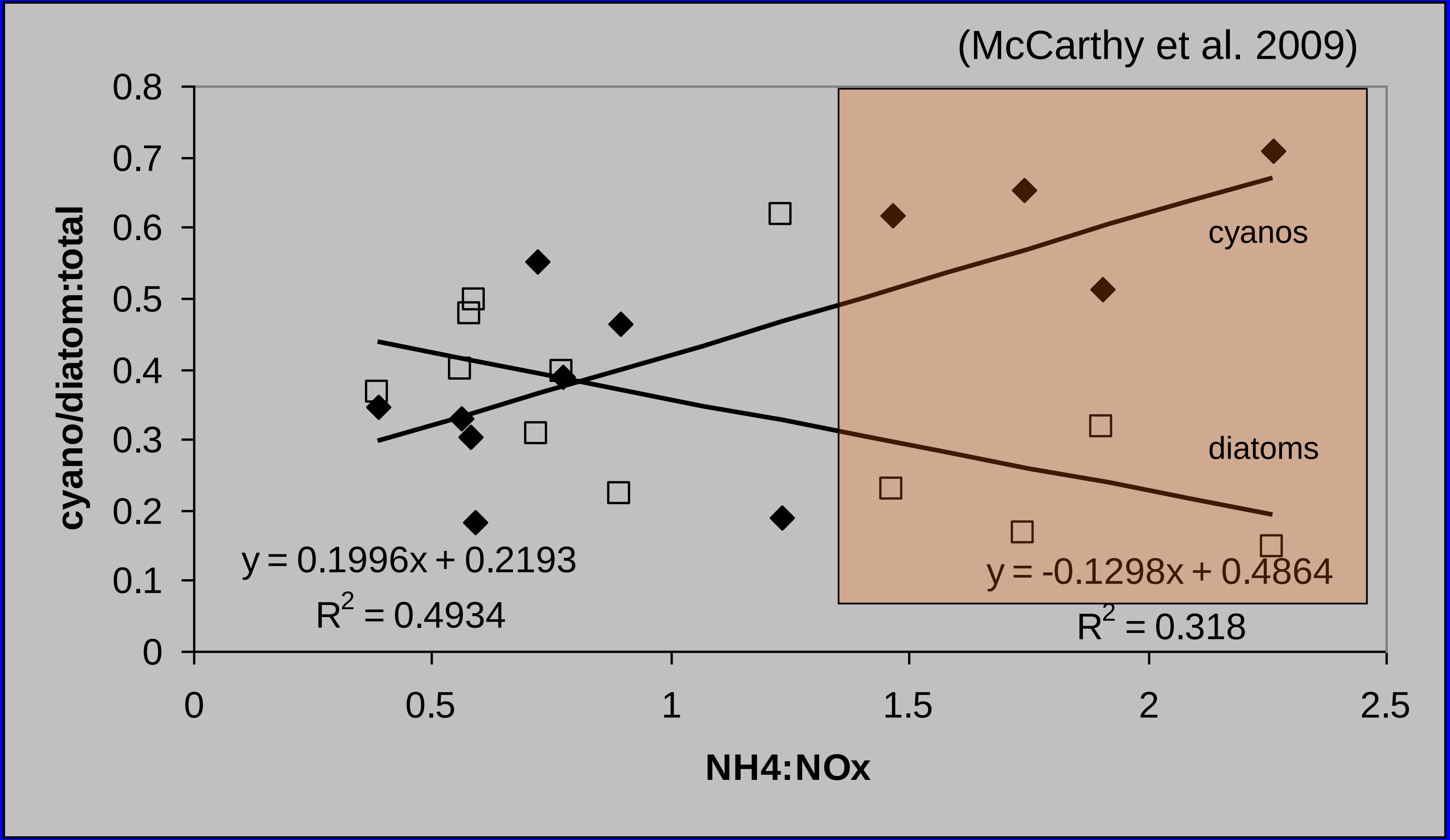
"Nutrient Balanced Growth" is the Rule, Not the Exception

(And N 'limitation' is just as likely as P 'limitation' in freshwaters)

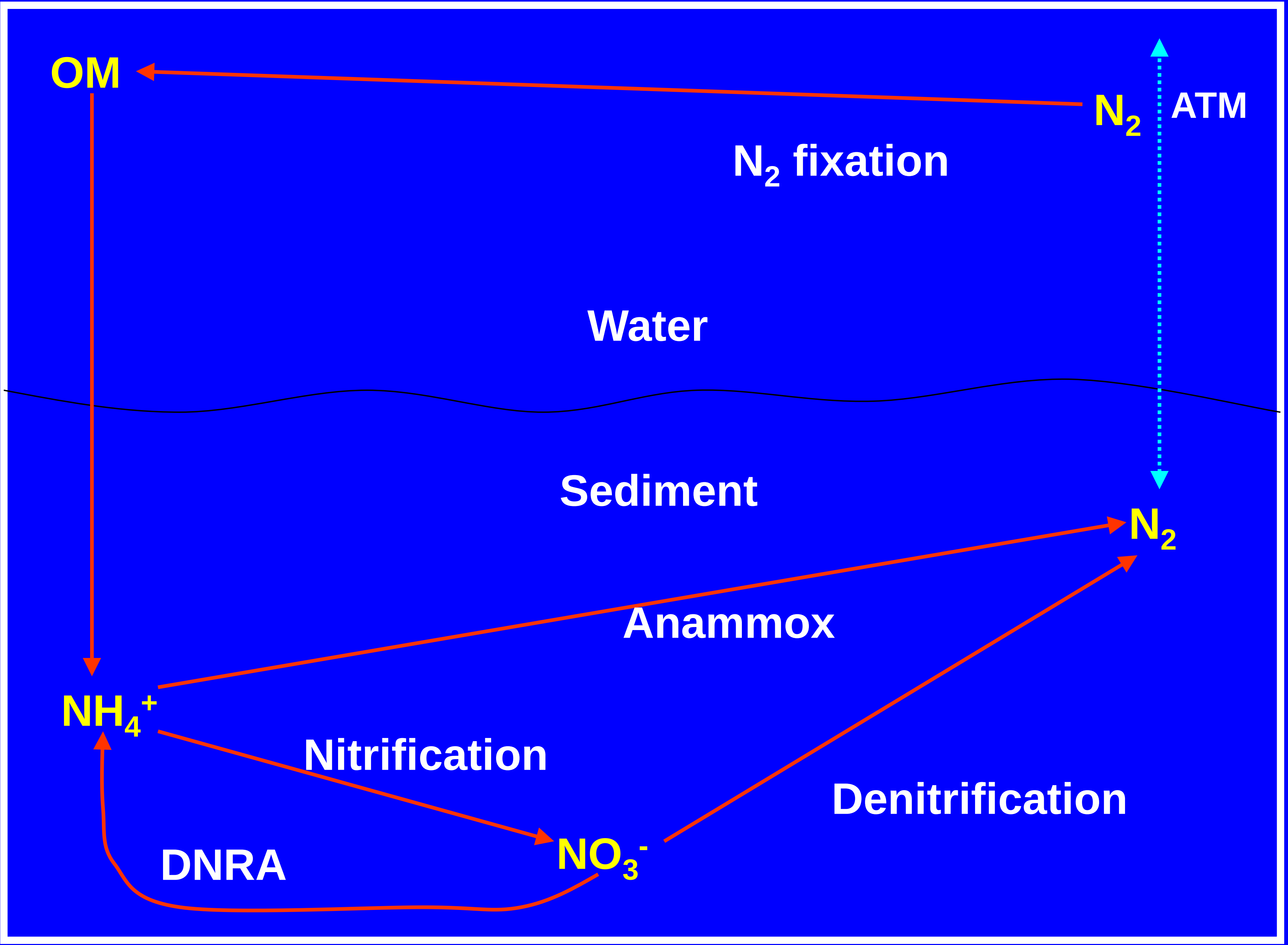


(Elser et al. 2007)

N Form Matters, Too



Large spread at high NH4:NOx


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

Winter 2018/2019

Objectives:

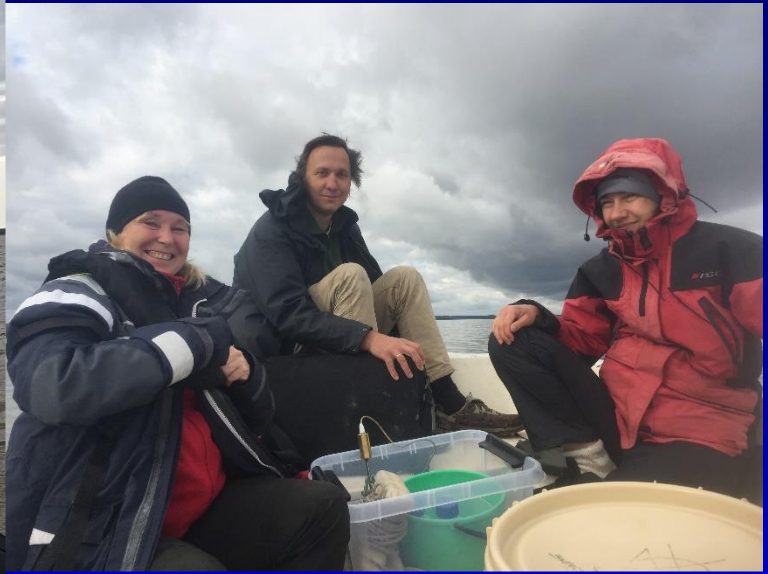
1. Determine denitrification/anammox, N fixation, DNRA, SOD, and inorganic N and urea fluxes across the sediment-water interface under ice in Lake Võrtsjärv (Estonia).

2. Determine ammonium (NH_4^+) cycling rates, including nitrification, regeneration, and potential uptake, under ice in Lakes Võrtsjärv and Peipsi (Estonia).

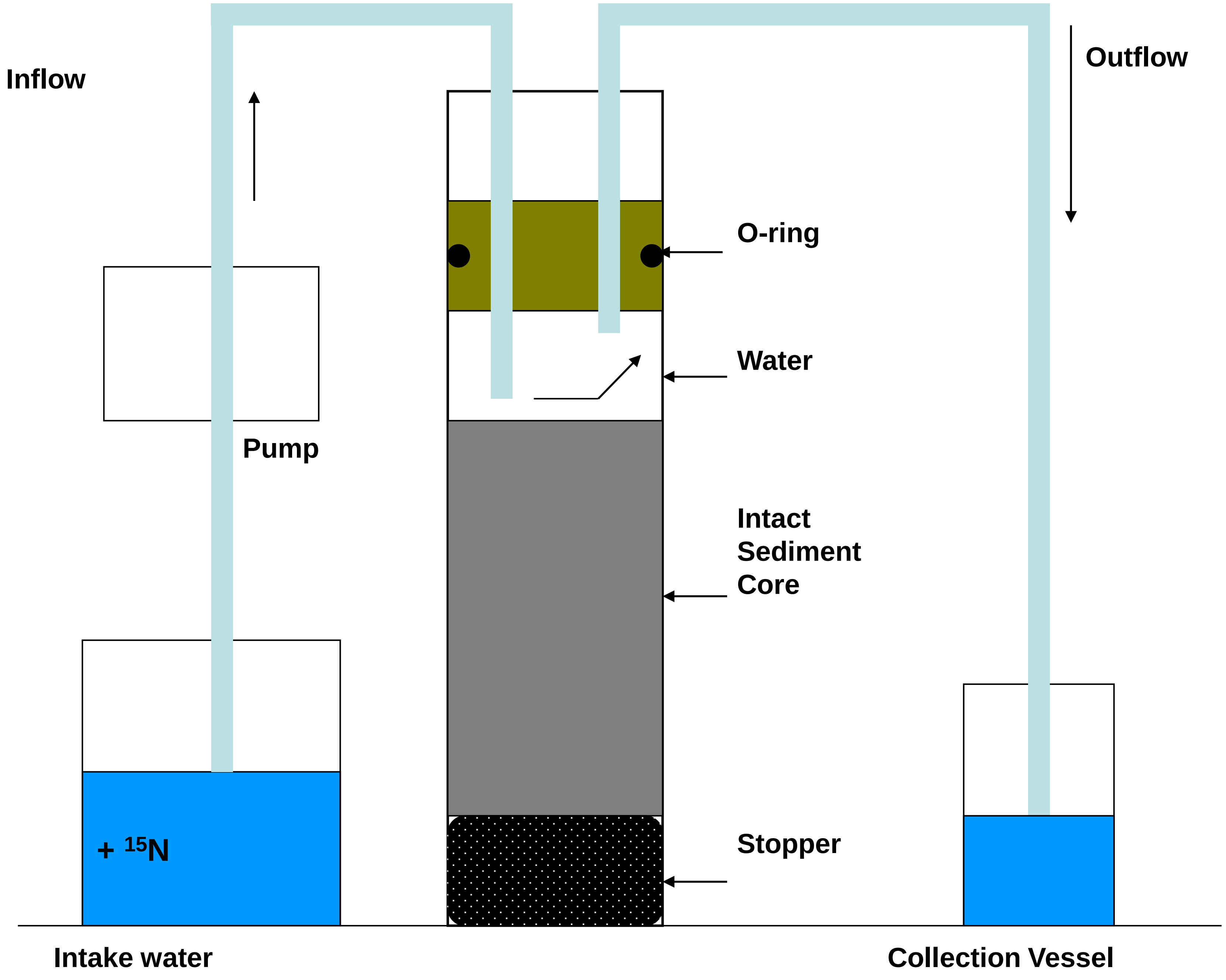

Gulf of Finland
Baltic Sea
Tallinn
ESTONIA
Lake Peipus
RUSSIA
LATVIA
Gulf of Riga
Võrtsjärv
Tartu
LV-10
LV-PS


Winter 2019/2020



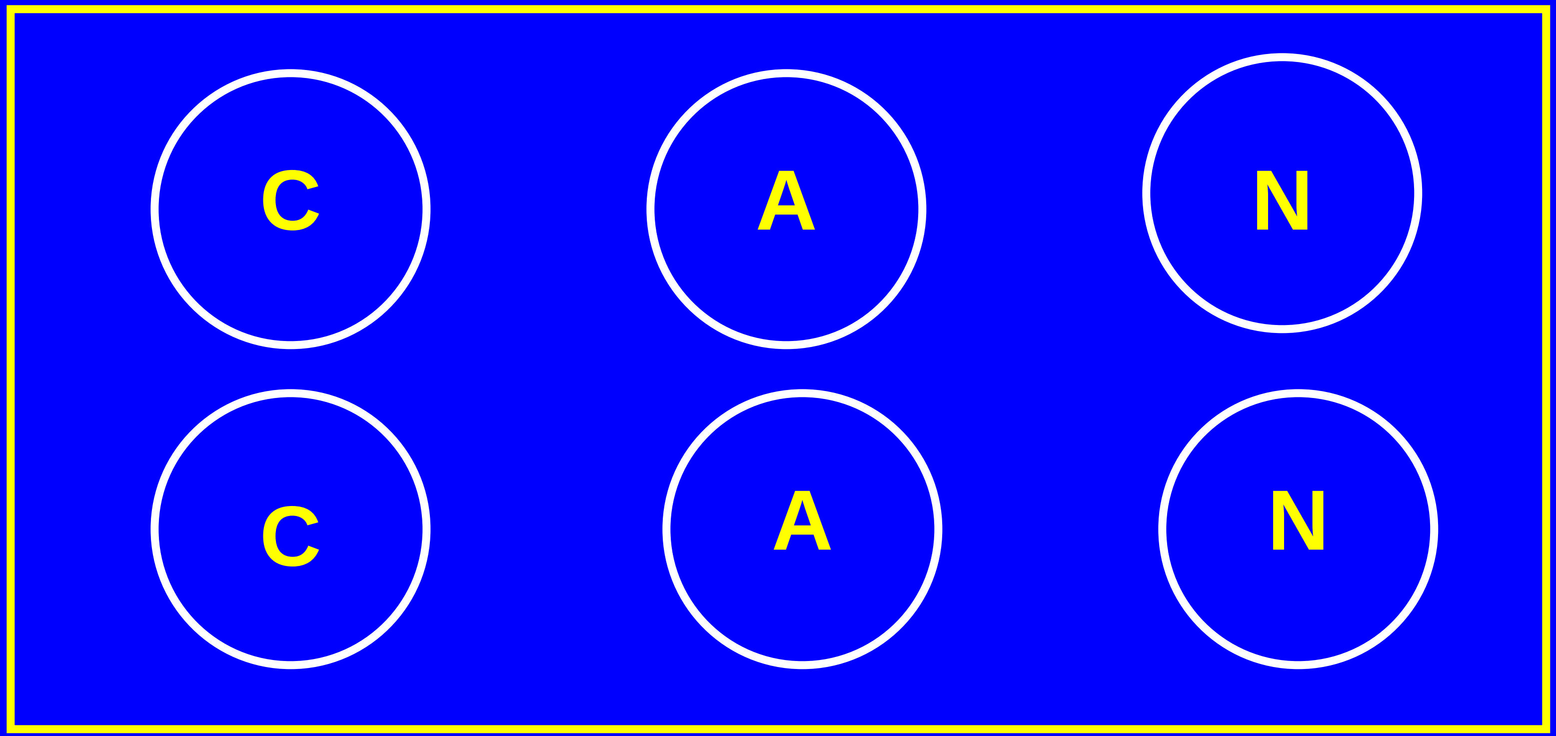



***Collect intact sediment cores and near-bottom water for continuous-flow incubations to measure SWI N fluxes and transformations.**


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

Eesti Maaülikool
EMÜ
Estonian University of Life Sciences

Incubation Design



C = Control (no isotope addition)

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

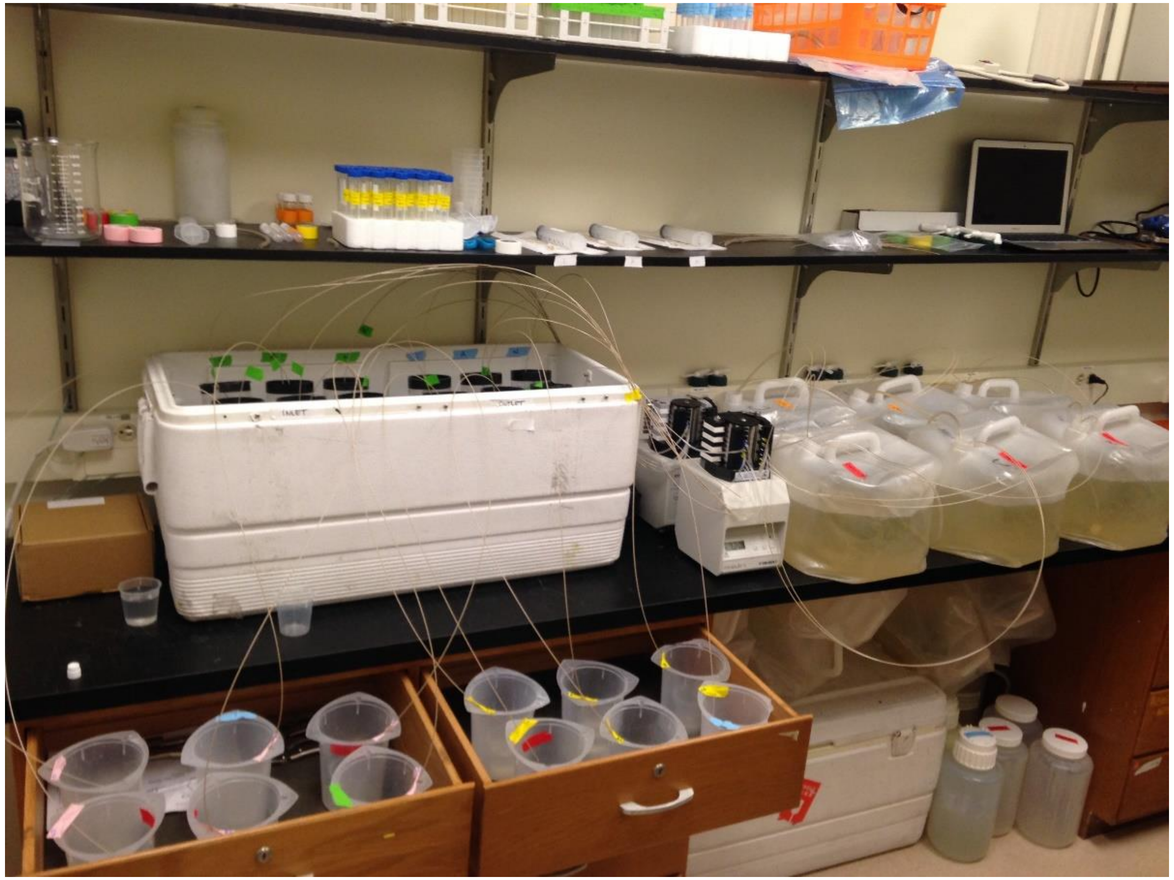
N = $^{15}NO_3^-$ addition (nitrate)

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, $^{28, 29, 30}N_2$, N_2O

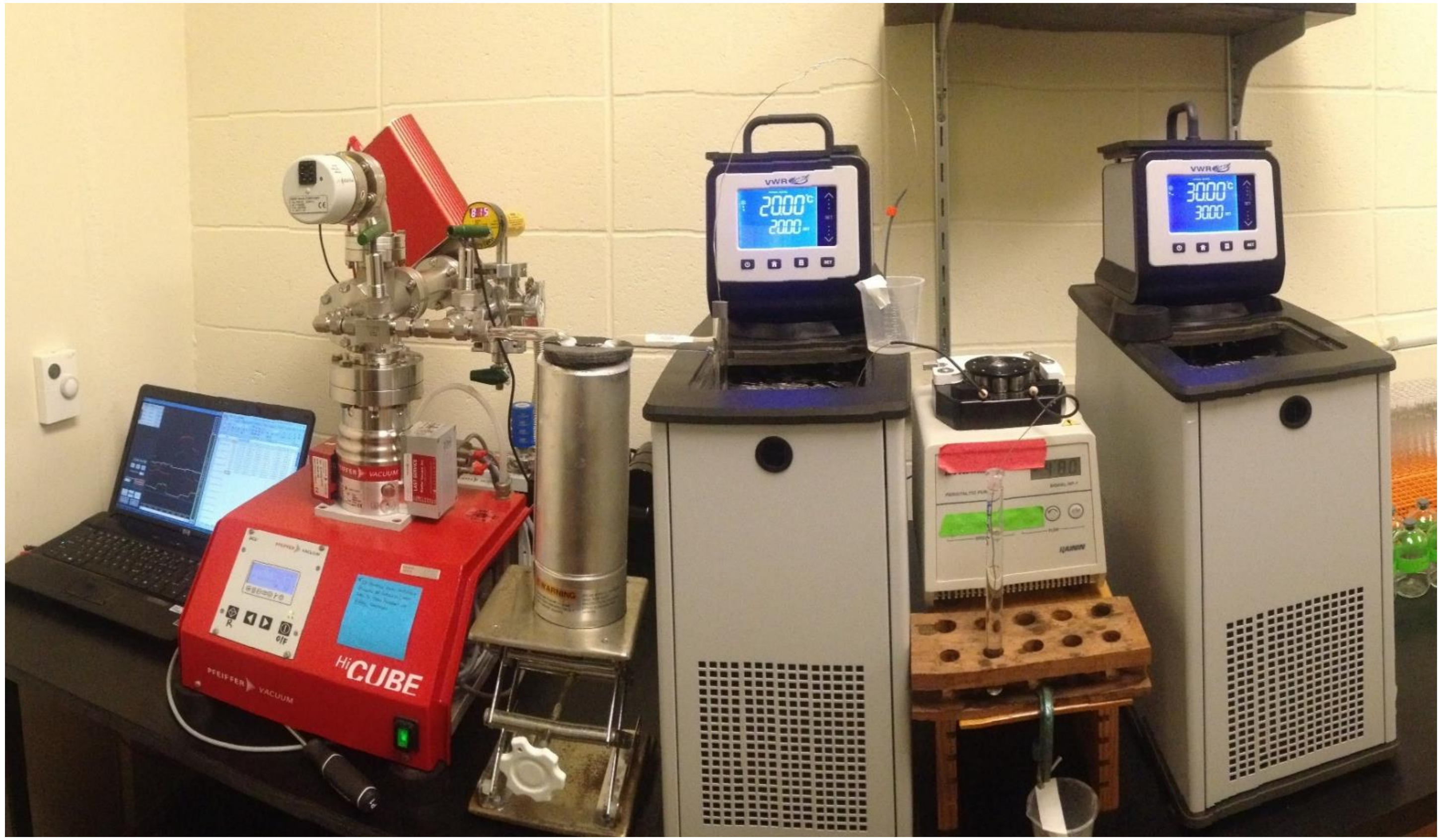


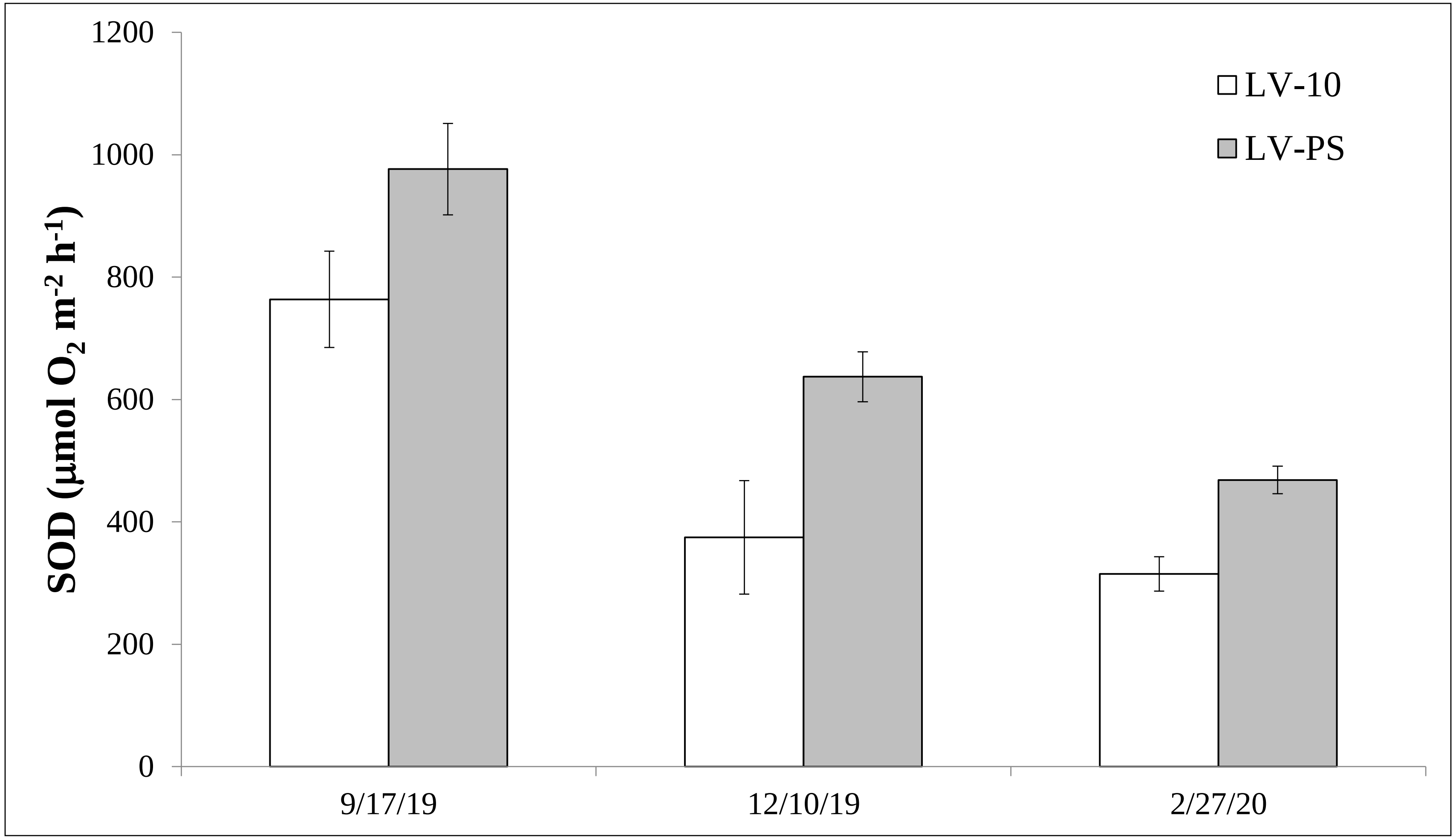
Methods: Lachat Quikchem 8500

- Nutrients measured by flow injection analysis
- PO_4^{3-}, NH_4^+, NO_3^-, NO_2^-, urea
    - Ambient concentrations
    - Sediment core fluxes

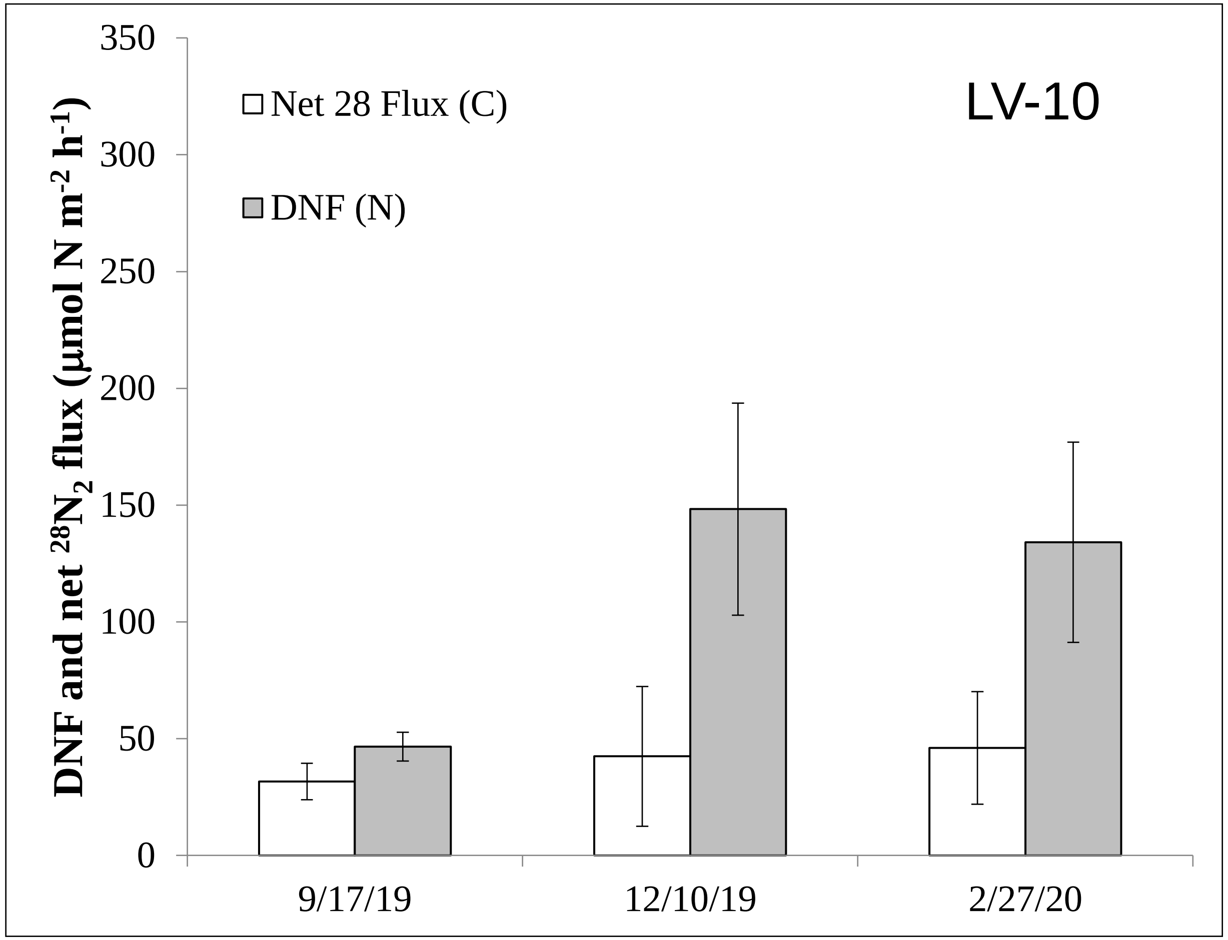
Methods: Membrane Inlet Mass Spectrometry

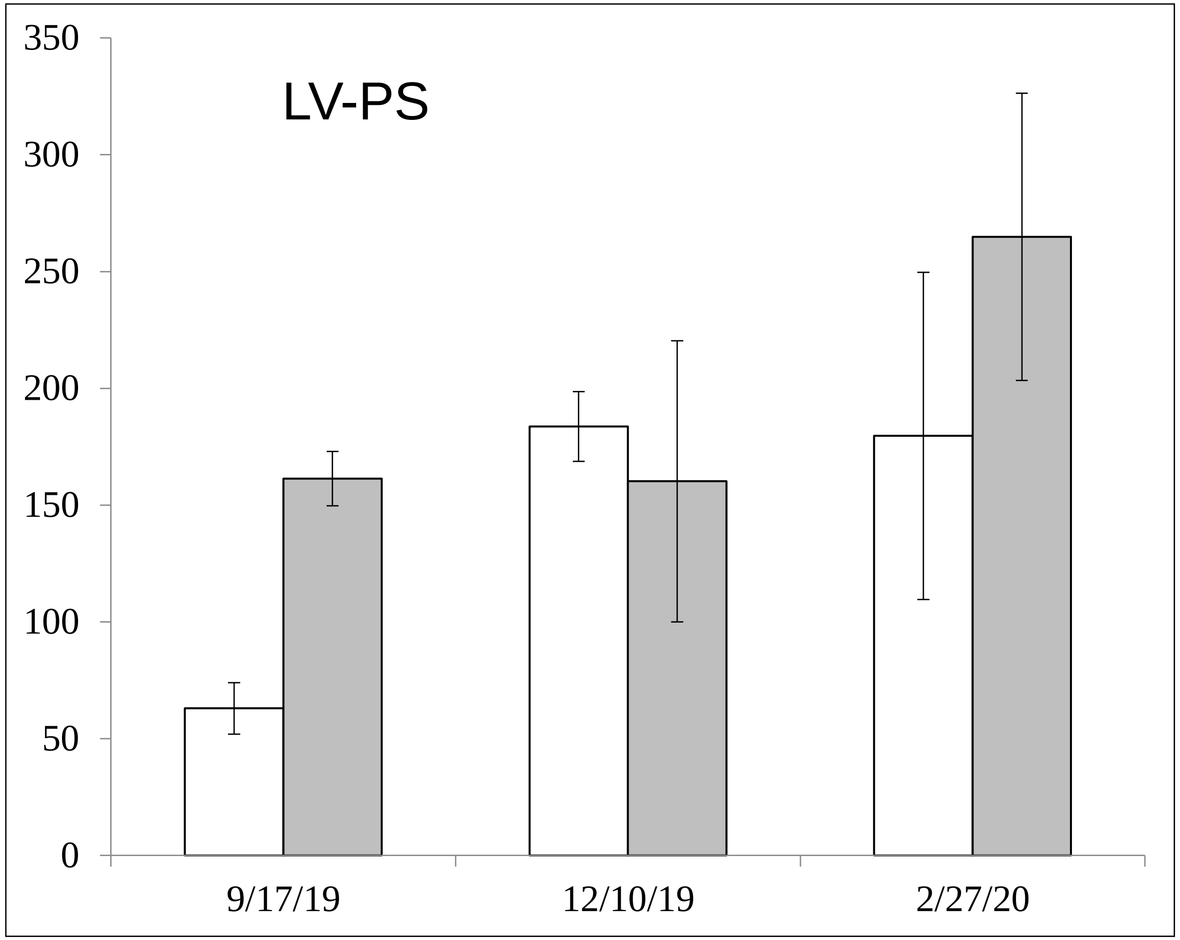
- C cores
  - Net $^{28}N_2$ flux, O_2
- A cores
  - $^{15}NH_4^+ + ^{14}NO_2^- \rightarrow ^{29}N_2$
  - Possible anammox
- N cores
  - $^{15}NO_3^- \rightarrow ^{29,30}N_2$
  - Denitrification
  - $^{15}NO_3^- \rightarrow ^{15}NH_4^+$
  - DNRA (OX-MIMS)



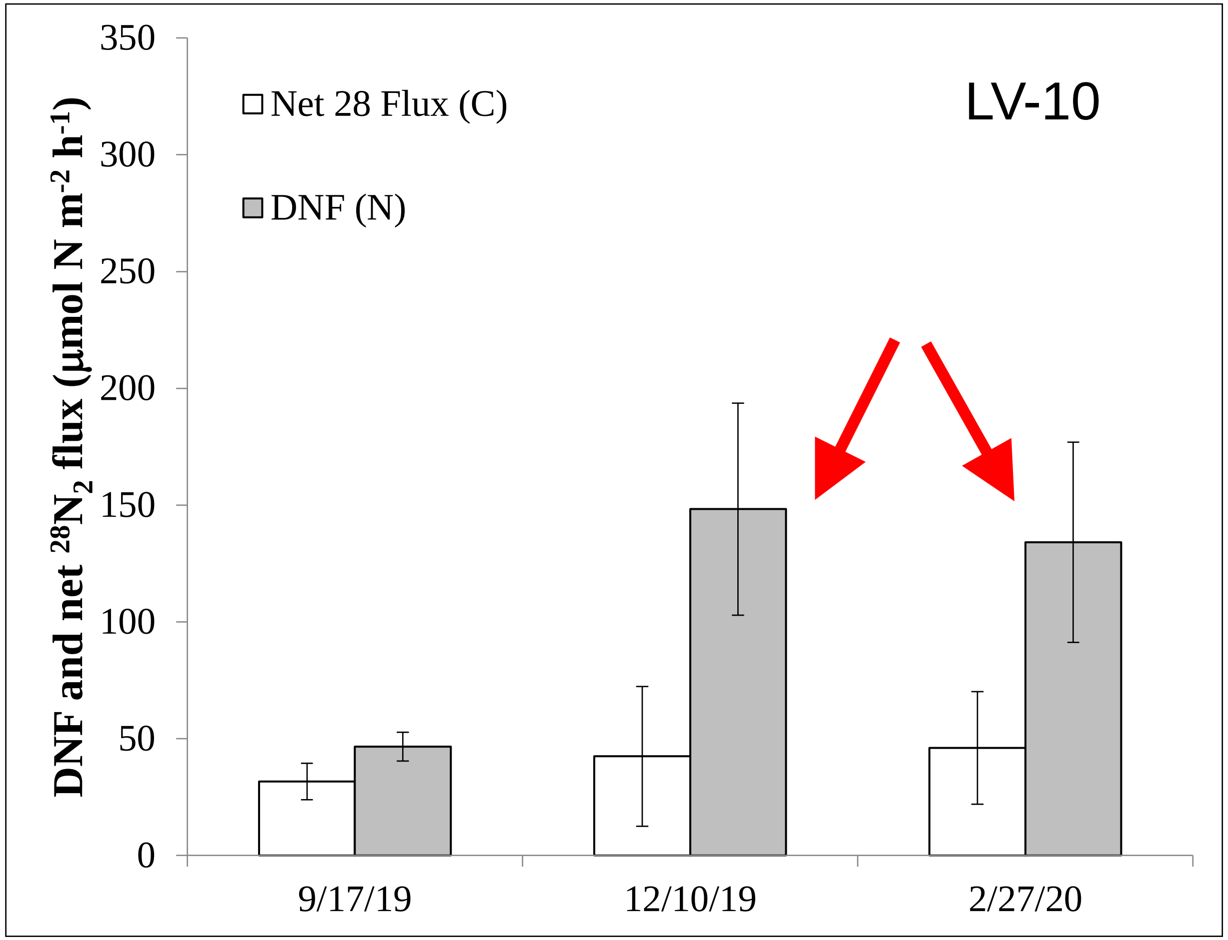


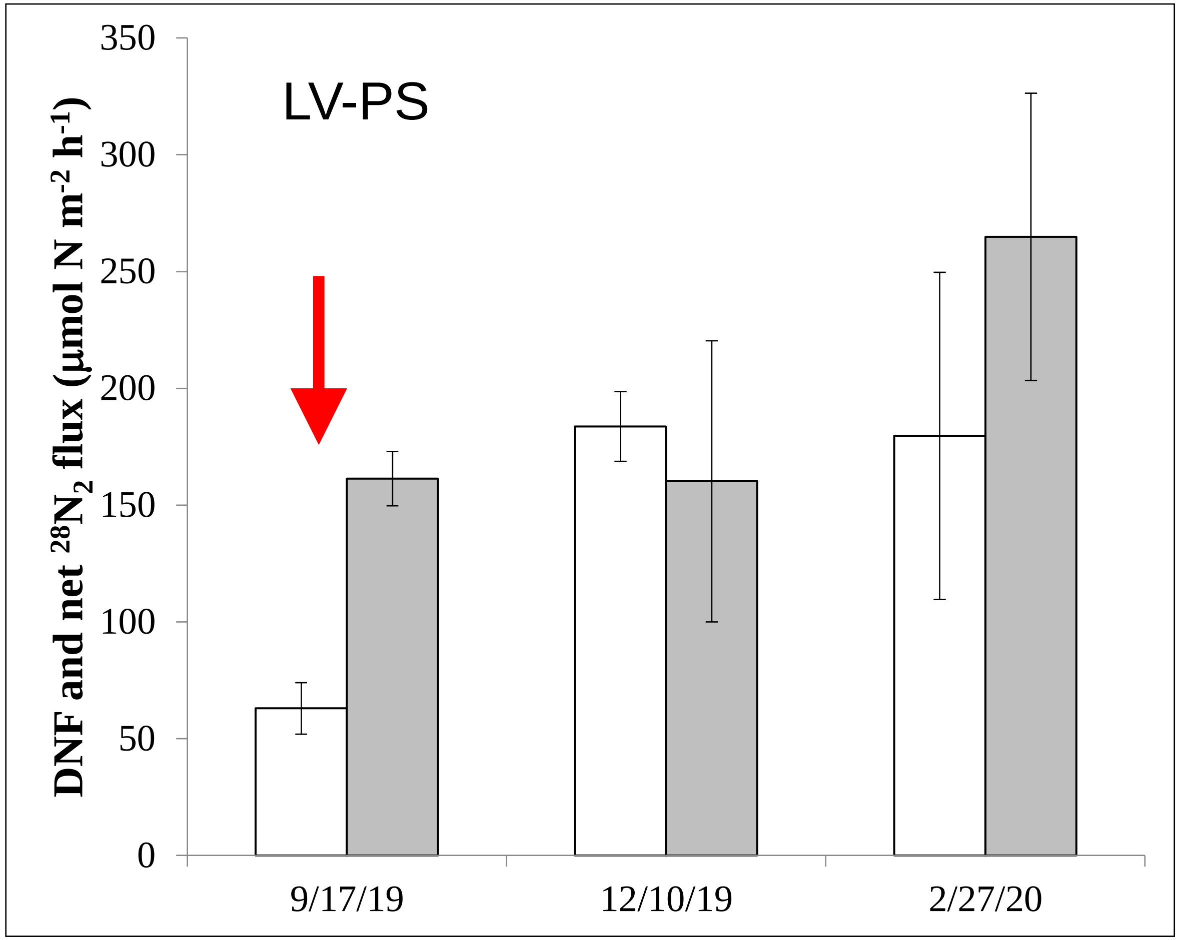
*Consistent decrease in SOD from fall through winter; consistently higher SOD (28-70%) near river input (more OM/macrophyte biomass); SOD lower in LV than many other temperate, eutrophic lakes (e.g., Lake Erie, Lake Champlain).



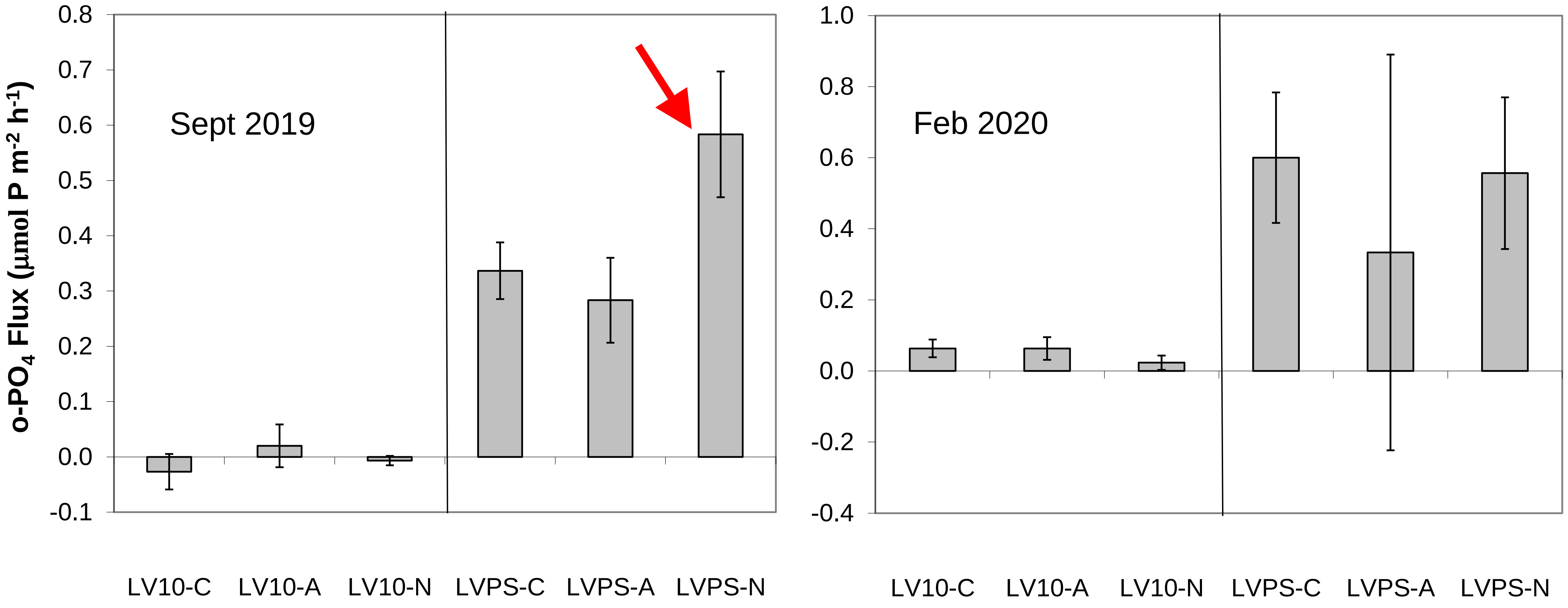


*Consistent in situ denitrification rates (net $^{28}N_2$ flux) at LV-10, but higher potentials (DNF = potential denitrification) in winter. However, near river input at LV-PS, higher in situ denitrification in winter, but little or no change in potential (little or no measurable N fixation; 0 – 3% anammox contribution).

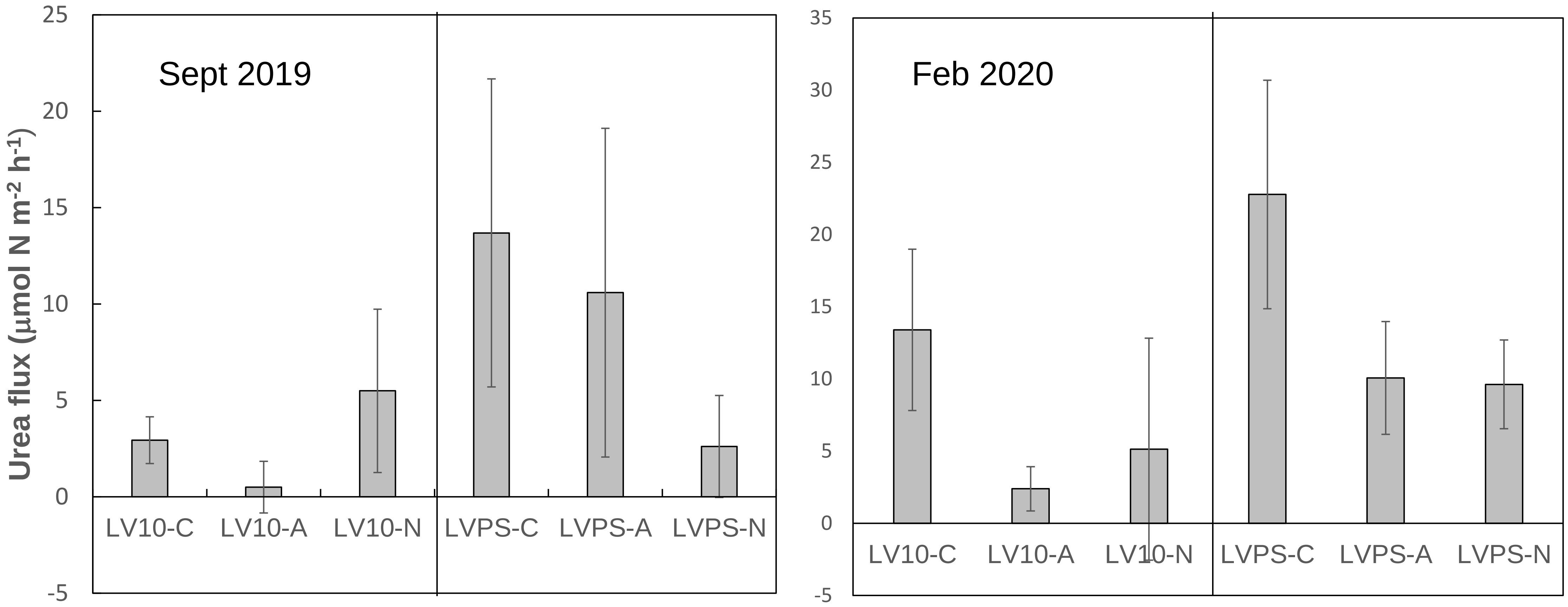




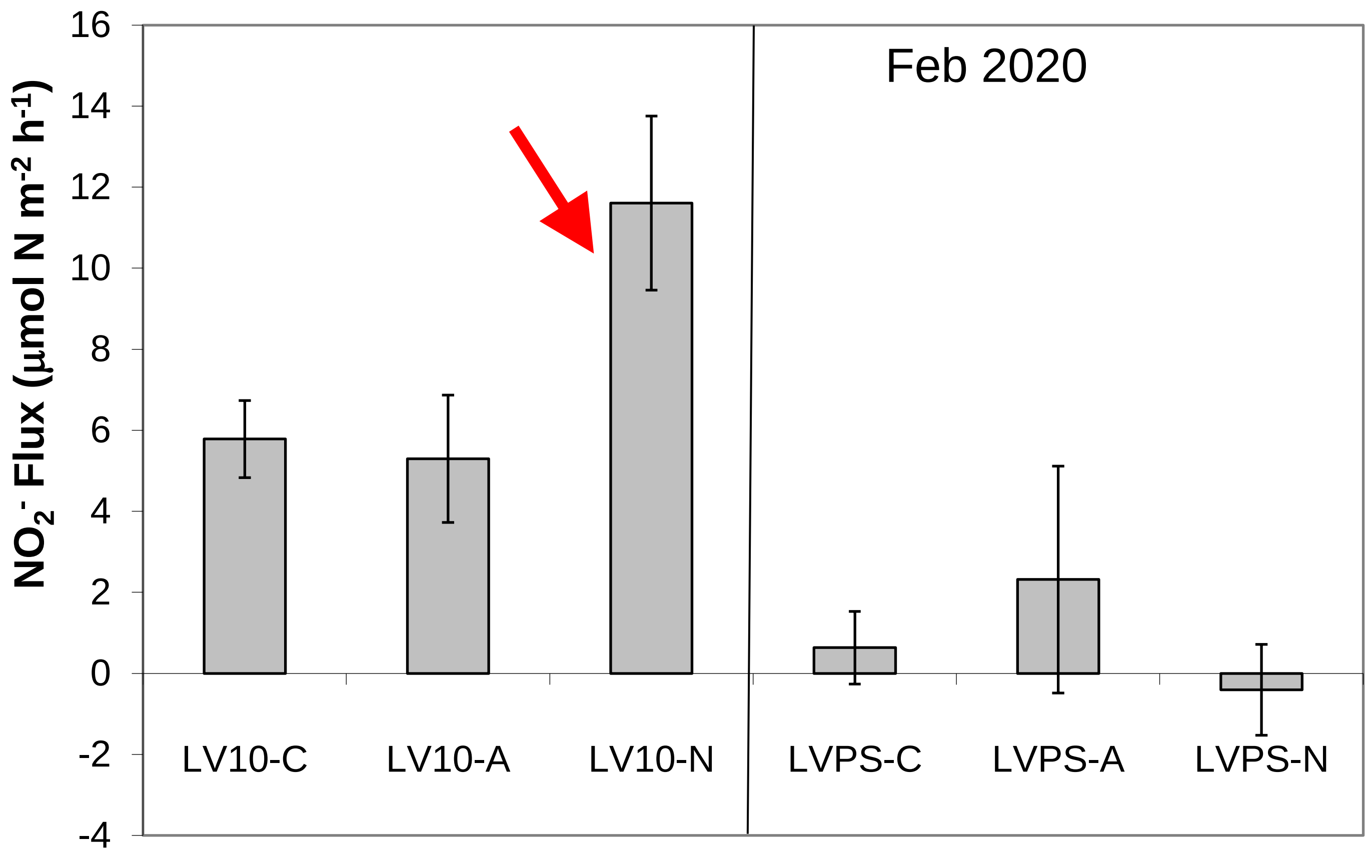
*Opposite patterns at the two sites --- clear stimulation of N_2 production with NO3 addition near inputs (LV-PS) in Sept (low in situ N), and in main basin in winter (high in situ N; 0 - 3% maybe via anammox; little or no measurable N fixation).



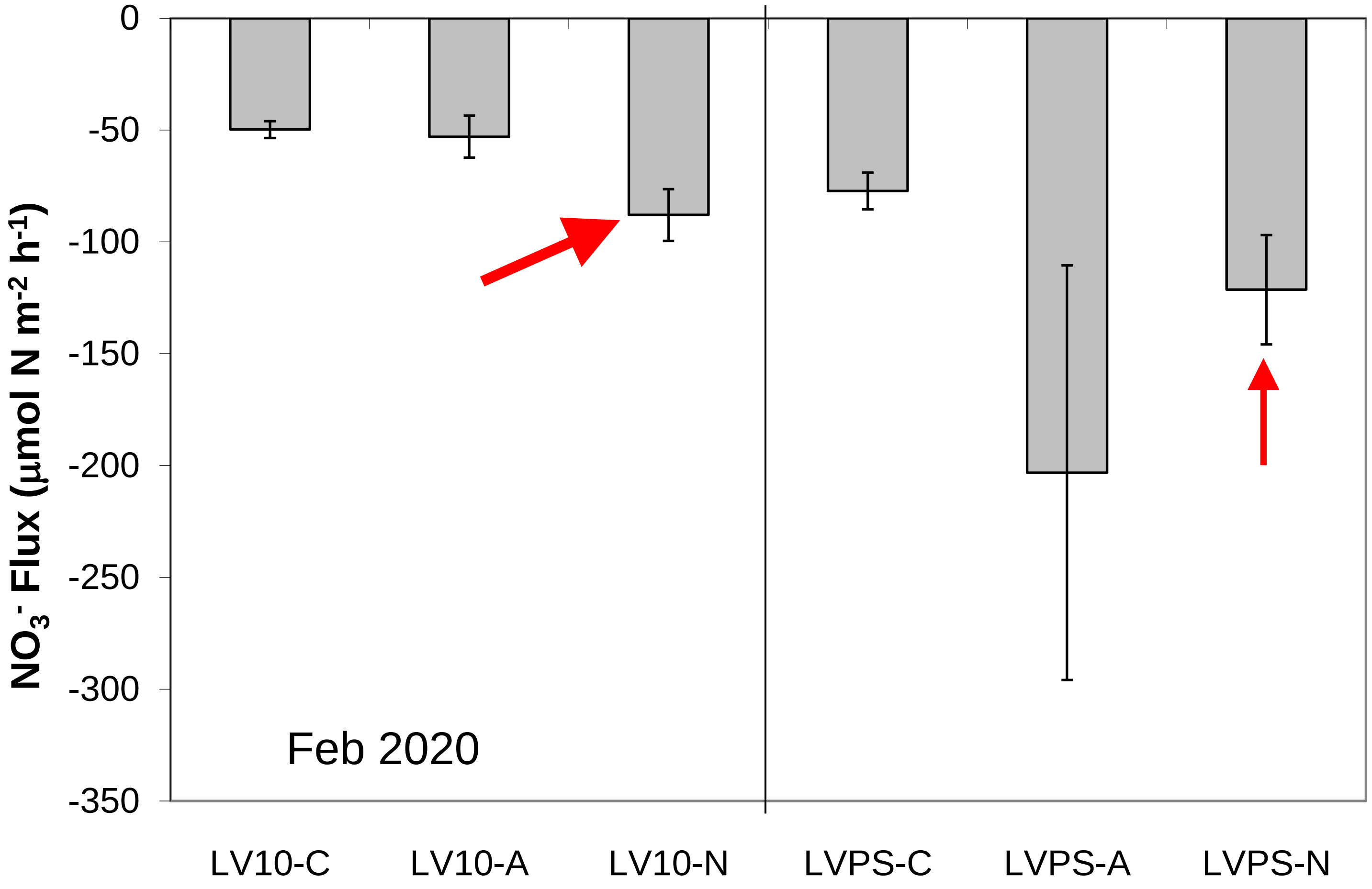
*Note slight difference in y-axis scales --- internal P loading nil or minimal during these sampling events (no surprise, likely a different story in summer, and under ice?); possible stimulation of P release in Sept 2019 with NO3 addition near river input, perhaps worthy of additional investigation (see Smolders et al. 2010, Biogeochem. 98: 1-7). No results yet from Dec 2019.



*Note slight difference in y-axis scale --- Lake Võrtsjärv sediments were releasing an appreciable amount of urea (highly bioavailable organic N form) at these times. Similar rates observed in summer in Lake Erie (see Boedecker et al. 2020, J Great Lakes Res 46: 920-932), but few, if any, other rates for comparison (who measures SWI N fluxes, much less urea?). No results yet from Dec 2019.



*Lake Võrtsjärv sediments in the main basin, but not near the river input, were releasing an appreciable amount of NO2 in late winter. NO3 additions to water overlying main basin sediments stimulated NO2 release, likely due to incomplete denitrification, but cannot rule out incomplete nitrification (or DNRA, unlikely). No results yet from Sept or Dec 2019.



*Lake Võrtsjärv sediments were a consistent NO3 sink (denitrified). No robust differences between sampling locations. Adding NO3 stimulated NO3 uptake in the main basin, and maybe near the river input. Net NO3 flux in main basin nearly identical to estimated denitrification rate, but NO3 influx ~50% of denitrification near river input (coupled NTR/DNF). No results yet from Sept or Dec 2019.

*NH4 results not ready yet, but preliminary data indicate sediment NH4 releases ~150-300 μmol N m^{-2} h^{-1} near river input and ~30-60 μmol N m^{-2} h^{-1} in the main basin.

That's internal N loading, and it's important, too!!! Especially if cyanos are a problem!!! Don't forget about legacy N loads!!! (e.g., see Van Meter et al. 2017, Global BGC Cycles 31: 2-23).

Take Home Message

Internal nutrient loads are not just a P story. Internal N cycling (fueled by external loads!) is often the main source of NH_4 for sustaining biomass and toxin production in non-N-fixing cyanobacteria blooms.

At the same time, the N cycle provides the best defense against excessive N loading via denitrification. BUT, denitrification is less efficient as N loads increase (e.g., Mulholland et al. 2008; Gardner & McCarthy 2009).

Next Steps

- Finish analyzing nutrient data for SWI fluxes
- Water column NH4 cycling results (regeneration, uptake, nitrification)
- Water column O_2 respiration results
- Incorporate mechanistic rate data into ongoing watershed/lake models (Dr. Fabien Cremona, EMU)
- Do an ice dance in Nov 2021…stay tuned!

- Finish analyzing

- Water column N take, nitrification)

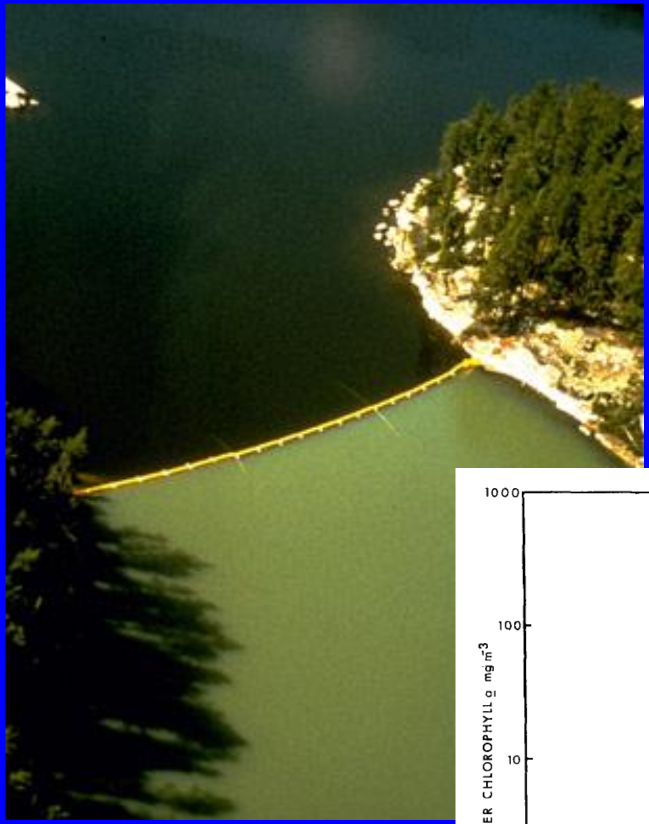
- Water column O

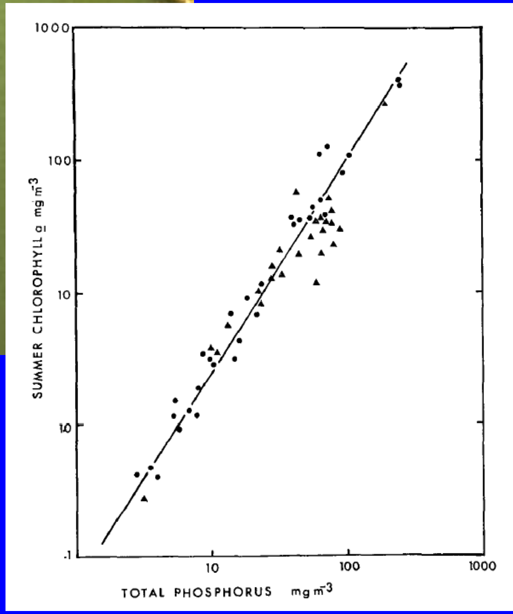
- Incorporate me ershed/lake

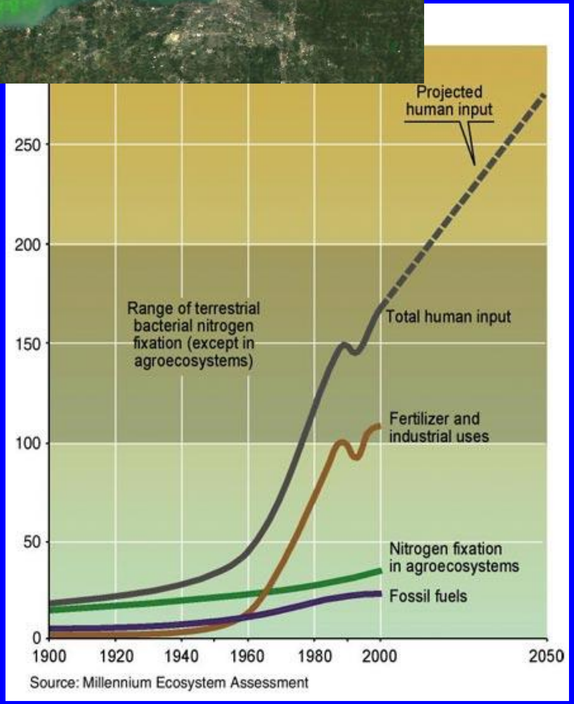
  models (Dr. Fab

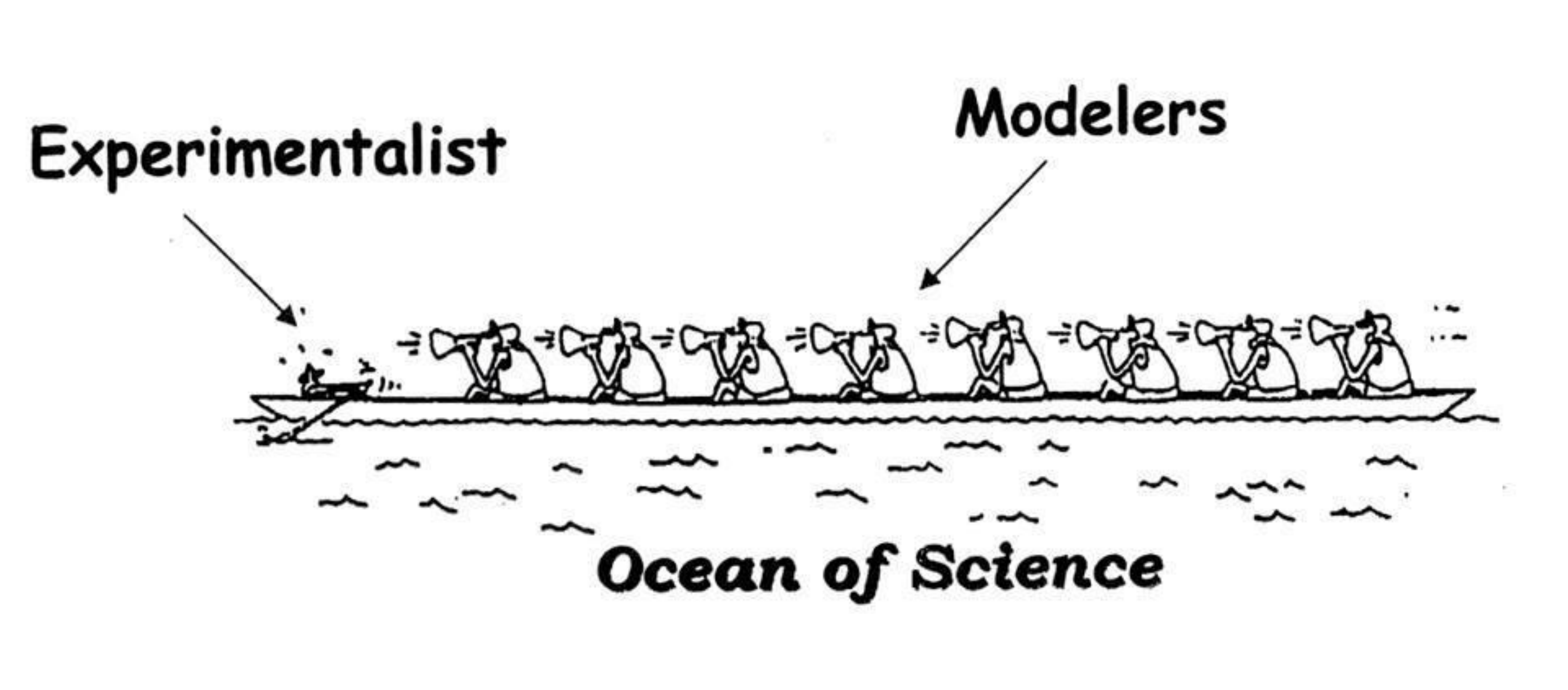
- Do an ice dance

“We can’t solve 21st century problems with 20th century science” --- Dr. Bob Heath, IAGLR, 2014-05-28








Experimentalist
Modelers
Ocean of Science

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