Nitrogen transformation and respiration rates in the water-column and sediments of selected NGOMEX sites

Wayne S. Gardner[1] and Mark J. McCarthy[1]

With contributions from Hou Lijun[2], Lin Xiao[2], Stephen A. Carini[3], Afonso Souza[1], Jiqing Liu[1], Zhanfei Liu[1] , Nathaniel Ostrom[4], and others

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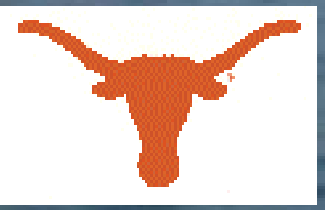
[4]Michigan State University



Thanks to:

NOAA Center for Sponsored Coastal Ocean Research (W. Gardner)

NSF Chemical Oceanography Program

(Z. Liu and N. Ostrom)

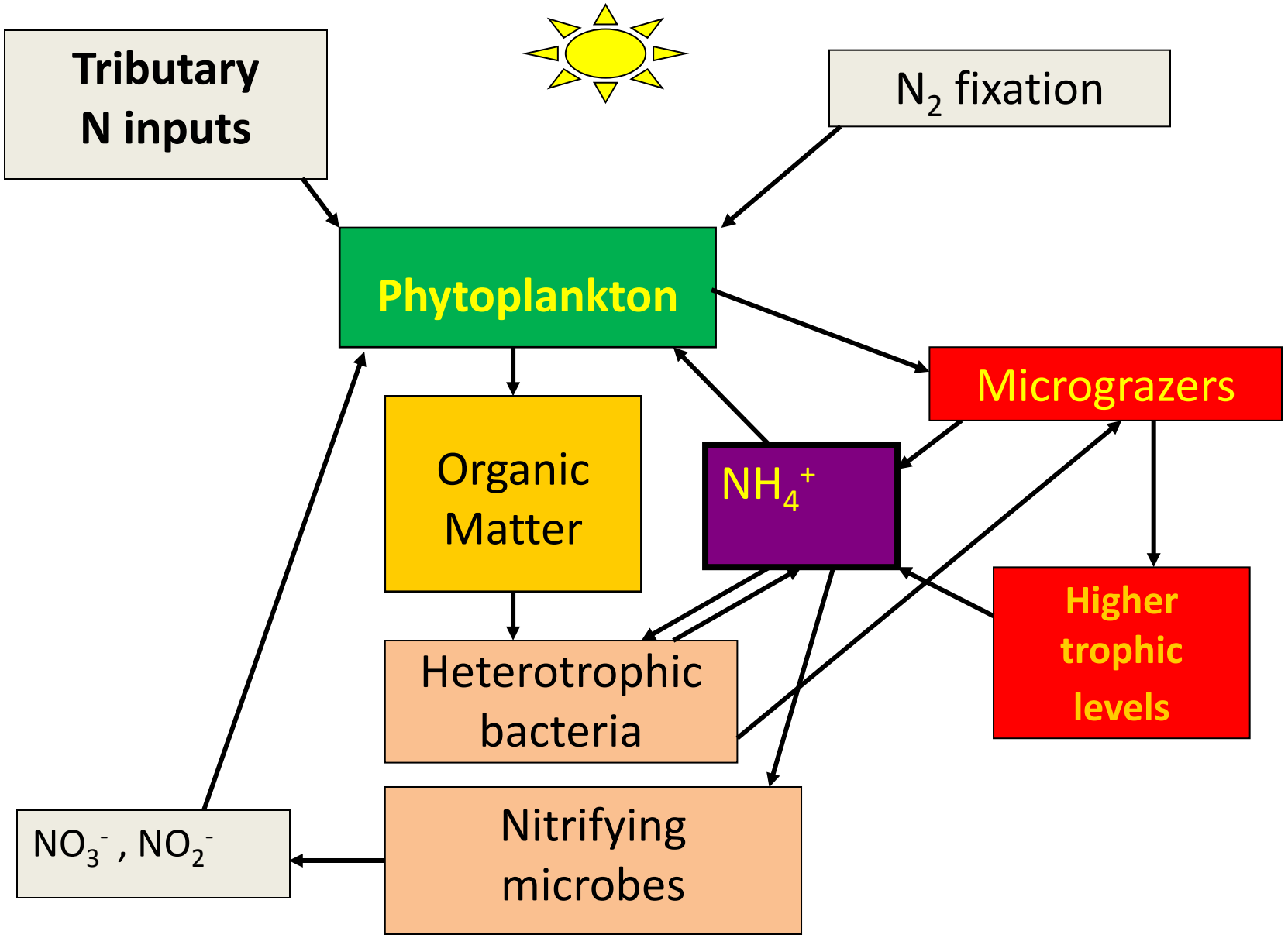
Captain and crew of the R/V Pelican

General NGOMEX Project Goals:

1. Examine mechanisms and rates of major biogeochemical transformations of nitrogen and oxygen, in the water column and at the sediment-water-interface, of the NGOMEX region
2. Develop conceptual biogeochemical model of oxygen removal dynamics
3. Provide process-rate data for mathematical models

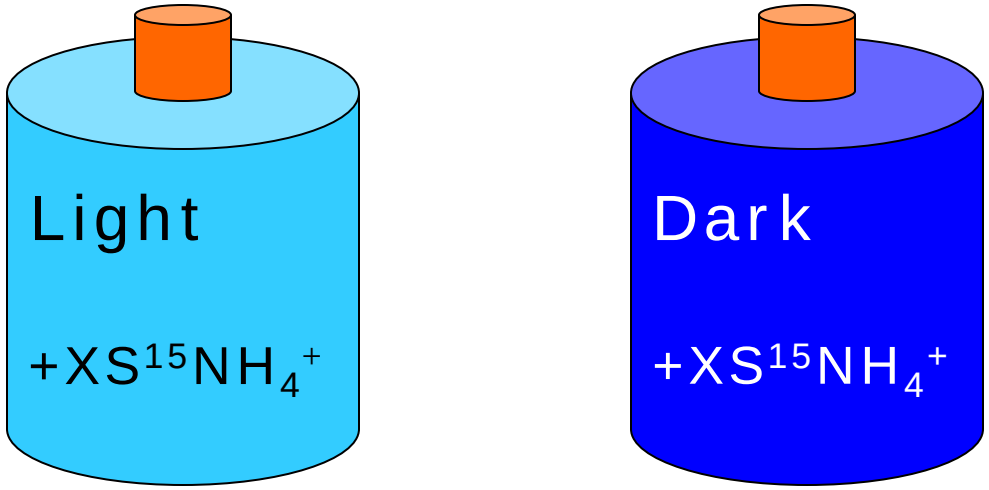
Interactions of N with hypoxia are complex

Water column N processes-photic zone



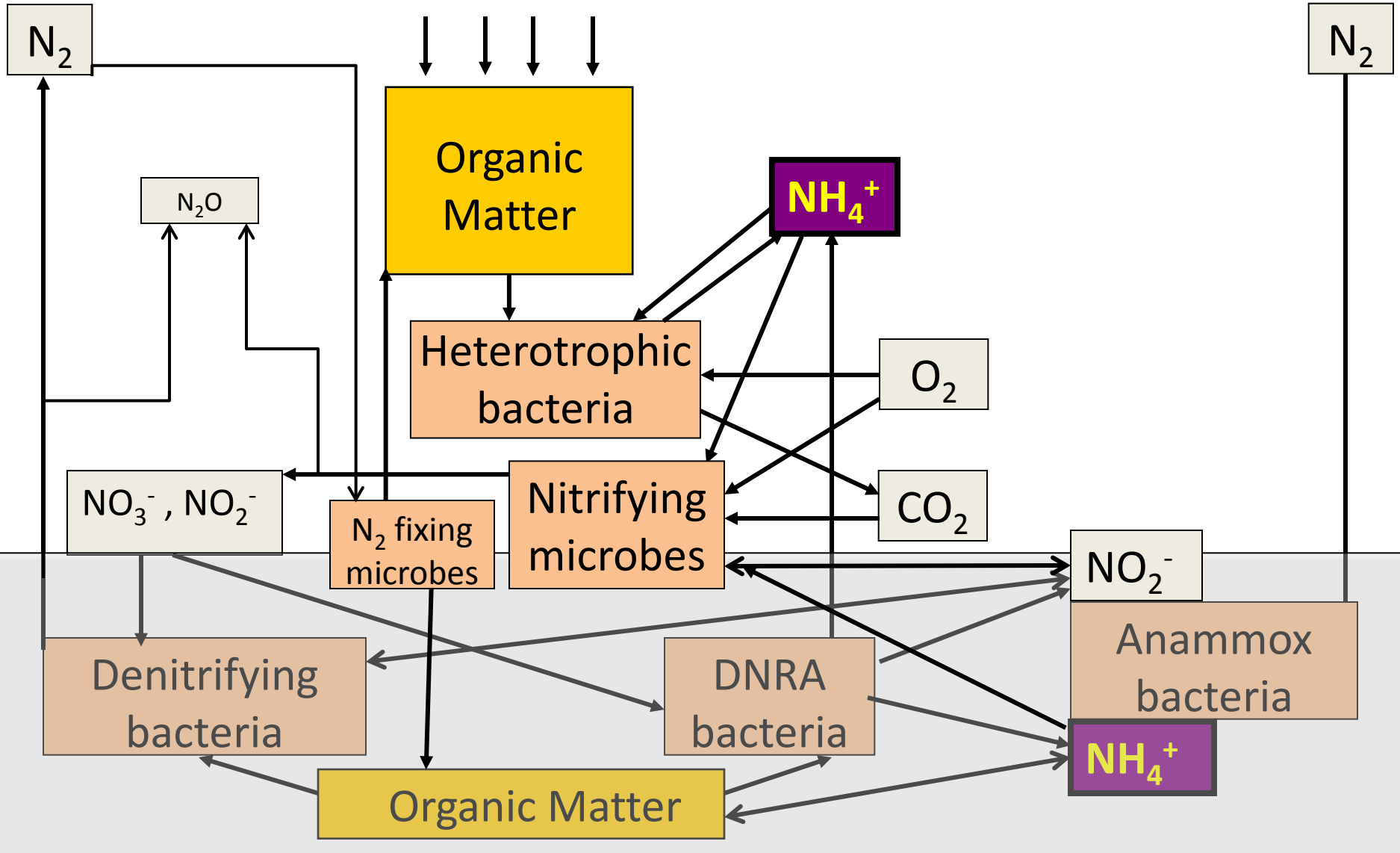
How do we measure these processes?

Water-column studies



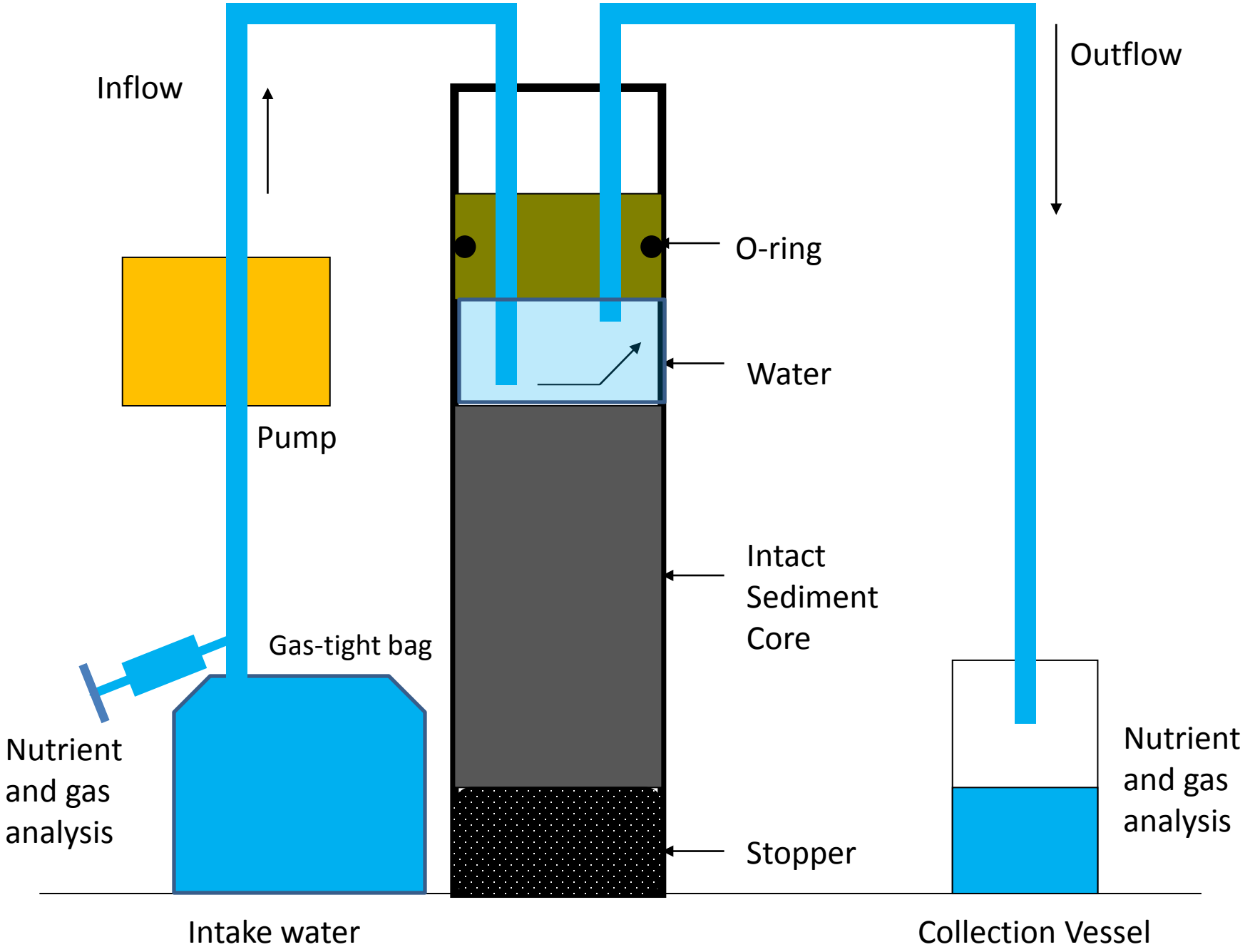
- Estimate water column N-cycling rates by measuring isotope dilution of added $^{15}NH_4^+$ over time (Blackburn 1979)
- Respiration rates by net changes in O_2 concentration in dark gas-tight vials over 24 hours

Near-bottom and sediment-water interface: N-dynamics processes in low-oxygen environments

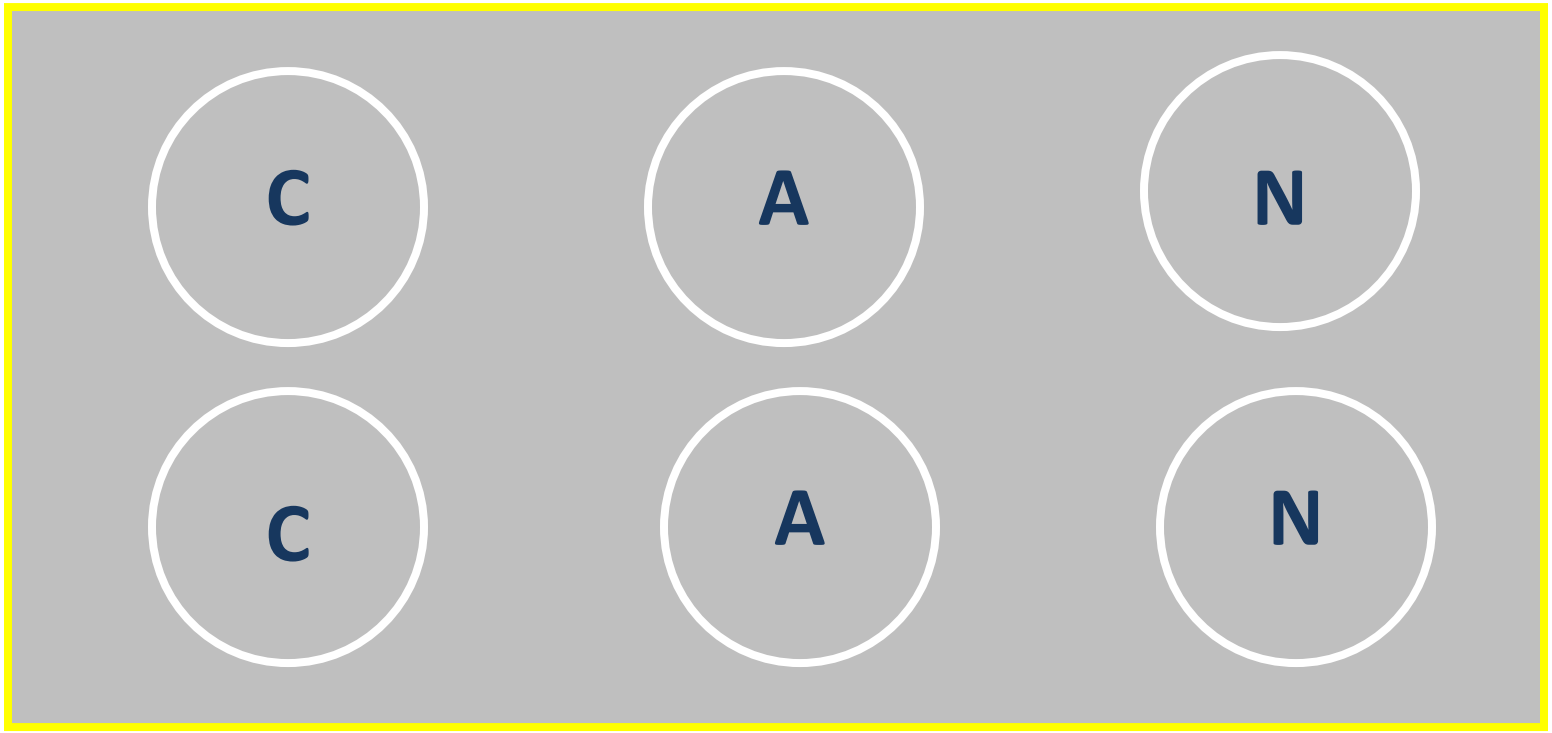


Sediment-water Interface


Collect sediments and "overlying water" gently with HYPOX corer


Inflow
Outflow
O-ring
Water
Pump
Intact
Sediment
Core
Gas-tight bag
Nutrient
and gas
analysis
Stopper
Nutrient
and gas
analysis
Intake water
Collection Vessel

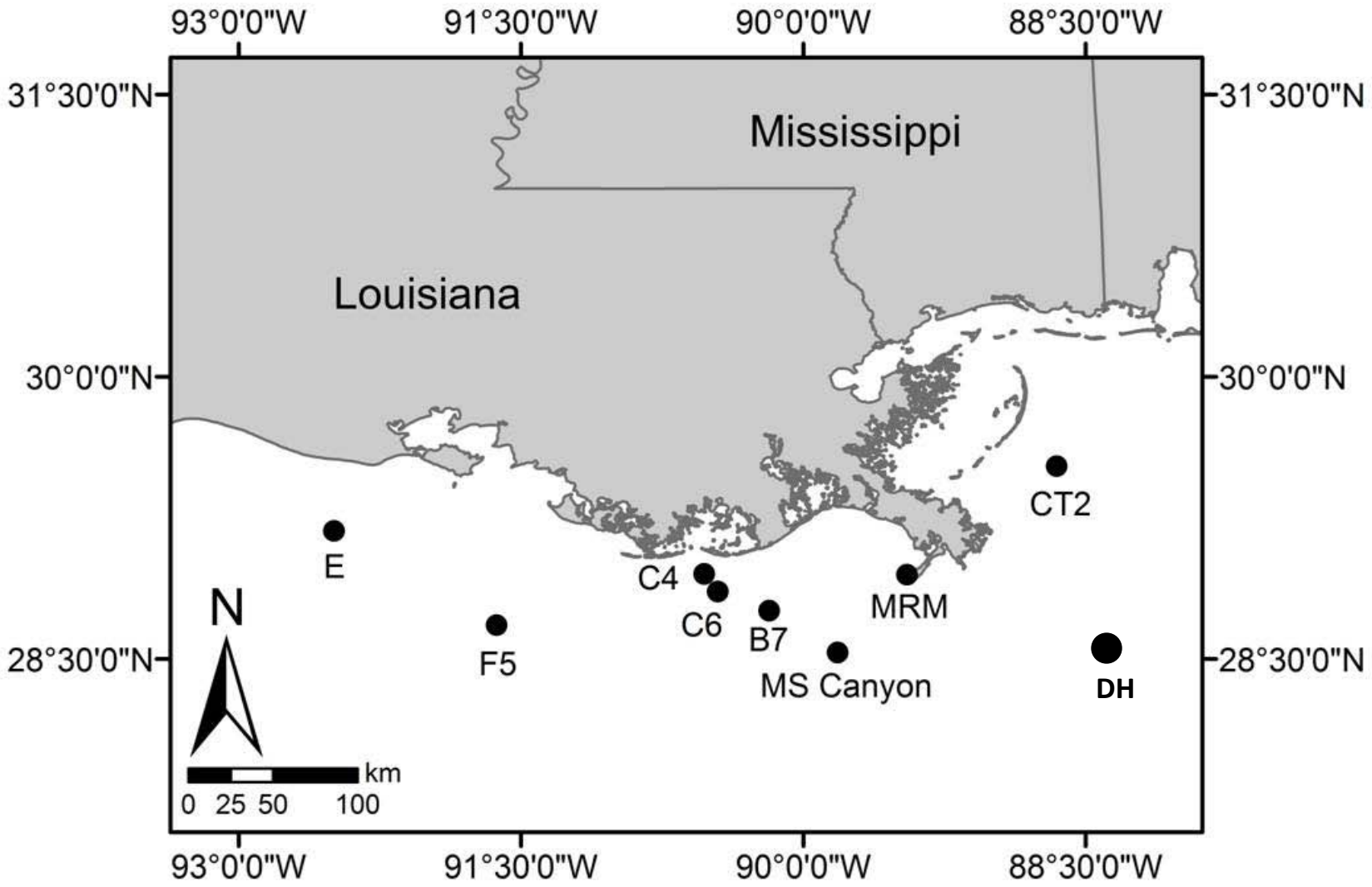
Six-Core CAN Experimental Design



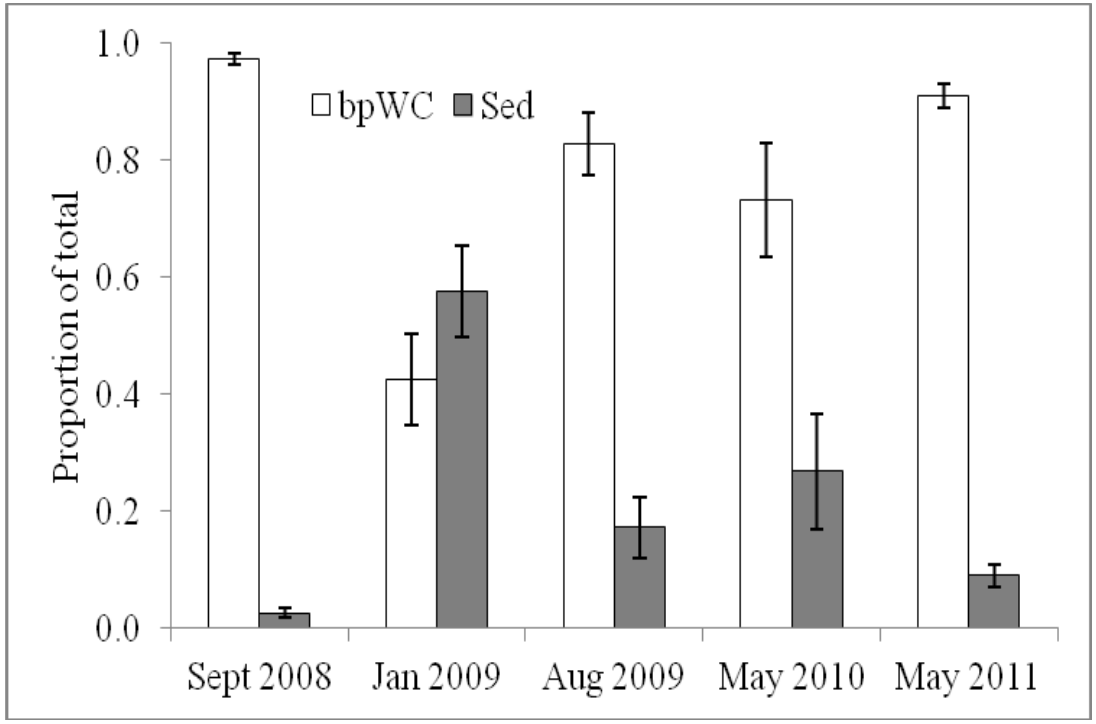
C = Control (no isotope addition)

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

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


93°0'0"W
91°30'0"W
90°0'0"W
88°30'0"W
31°30'0"N
30°0'0"N
28°30'0"N
Mississippi
Louisiana
E
F5
C4
C6
B7
MRM
MS Canyon
CT2
DH
N
km
0 25 50 100

Does most respiration causing hypoxia occur in the lower water column or at the sediment-water interface?
(Data from McCarthy et al. In preparation)

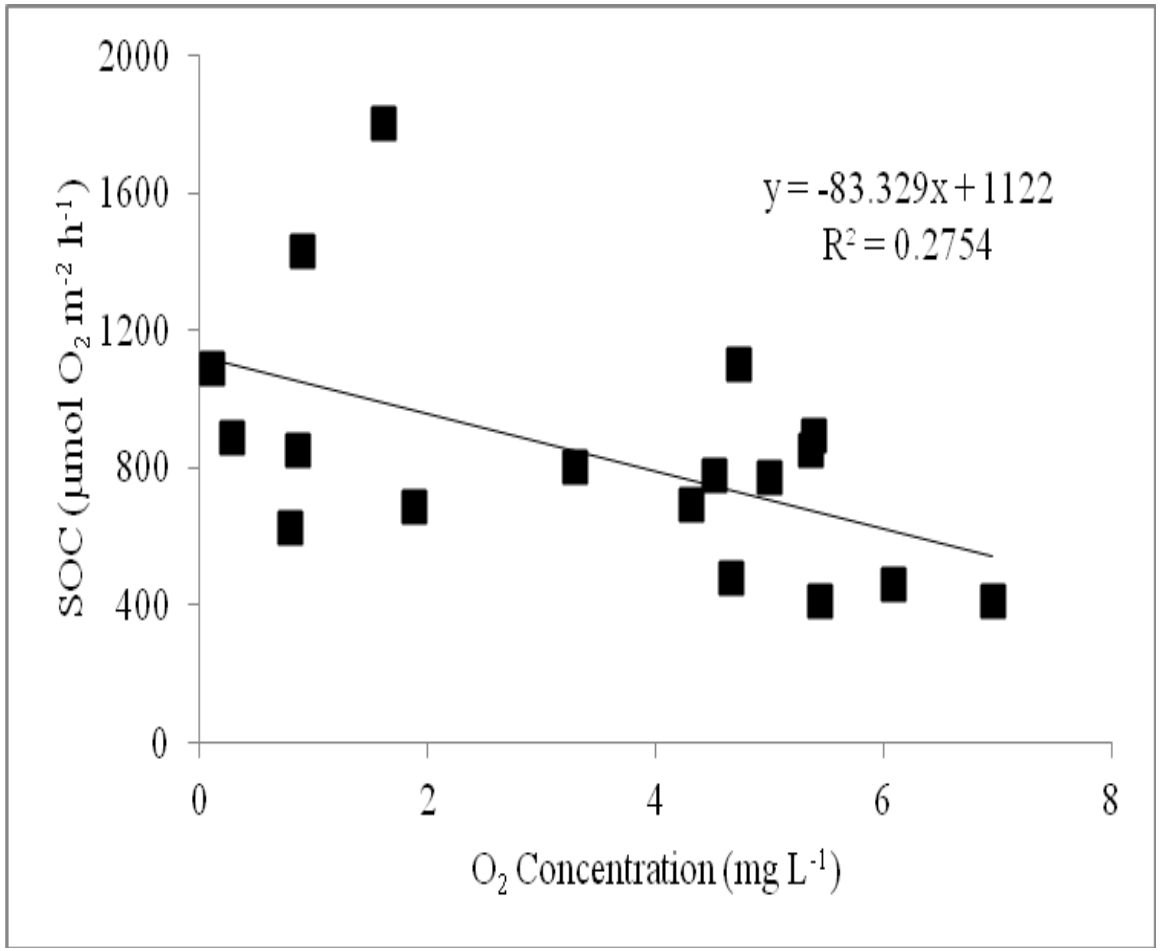


Mean percentage of total below-pycnocline respiration:

Water Column: ca. 75%

Sediment-water Interface: ca. 25%

Note that these results are similar to Murrell & Lehrter (2010), but not to those from O_2 isotope studies



- SOC related negatively (r^2 = 0.275; p = 0.025) to bottom-water O_2
- May reflect SOC contribution to low bottom-water O_2, as opposed to the common assumption that bottom-water O_2 determines SOC

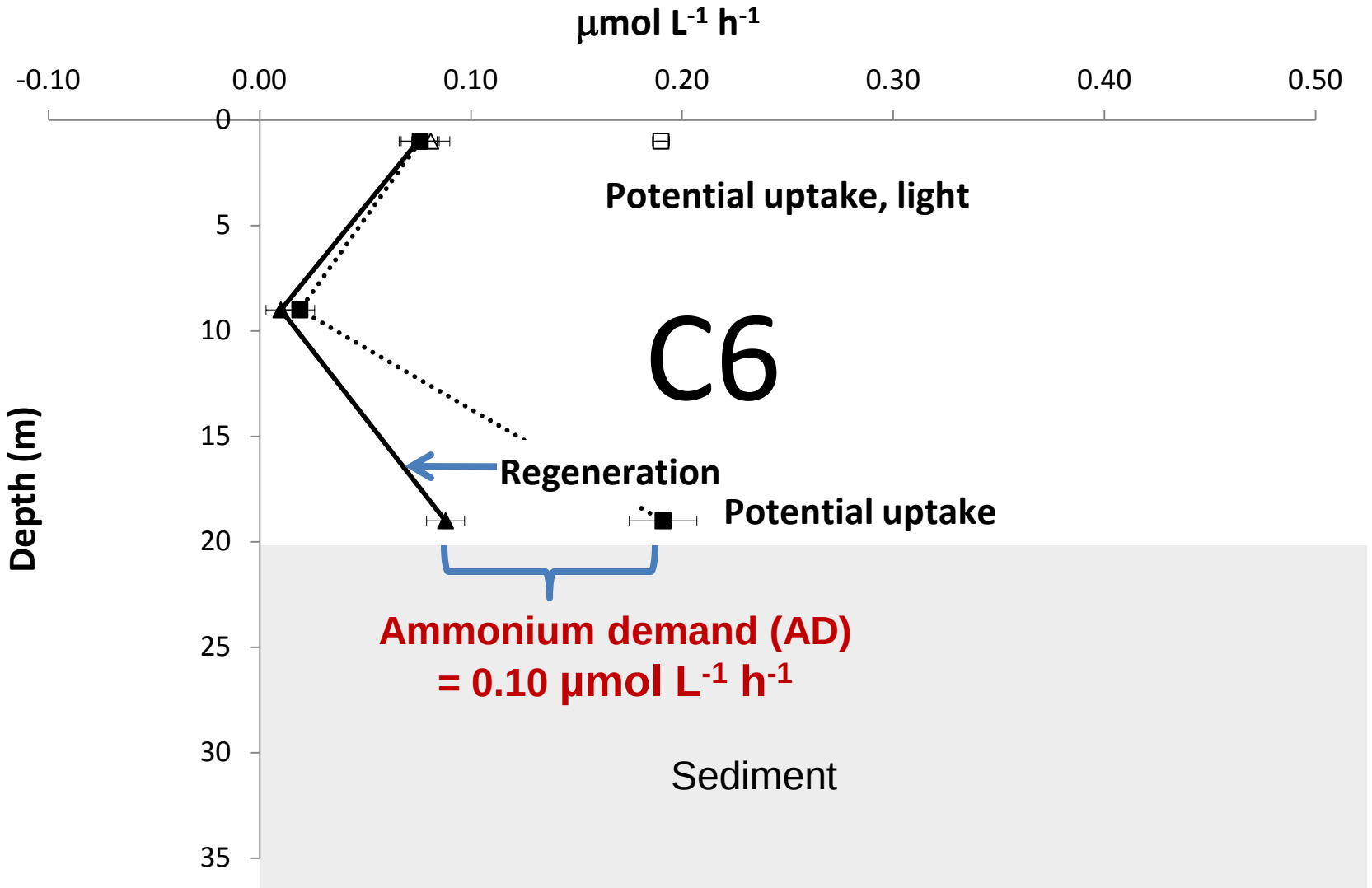
NH_4^+-cycling question:

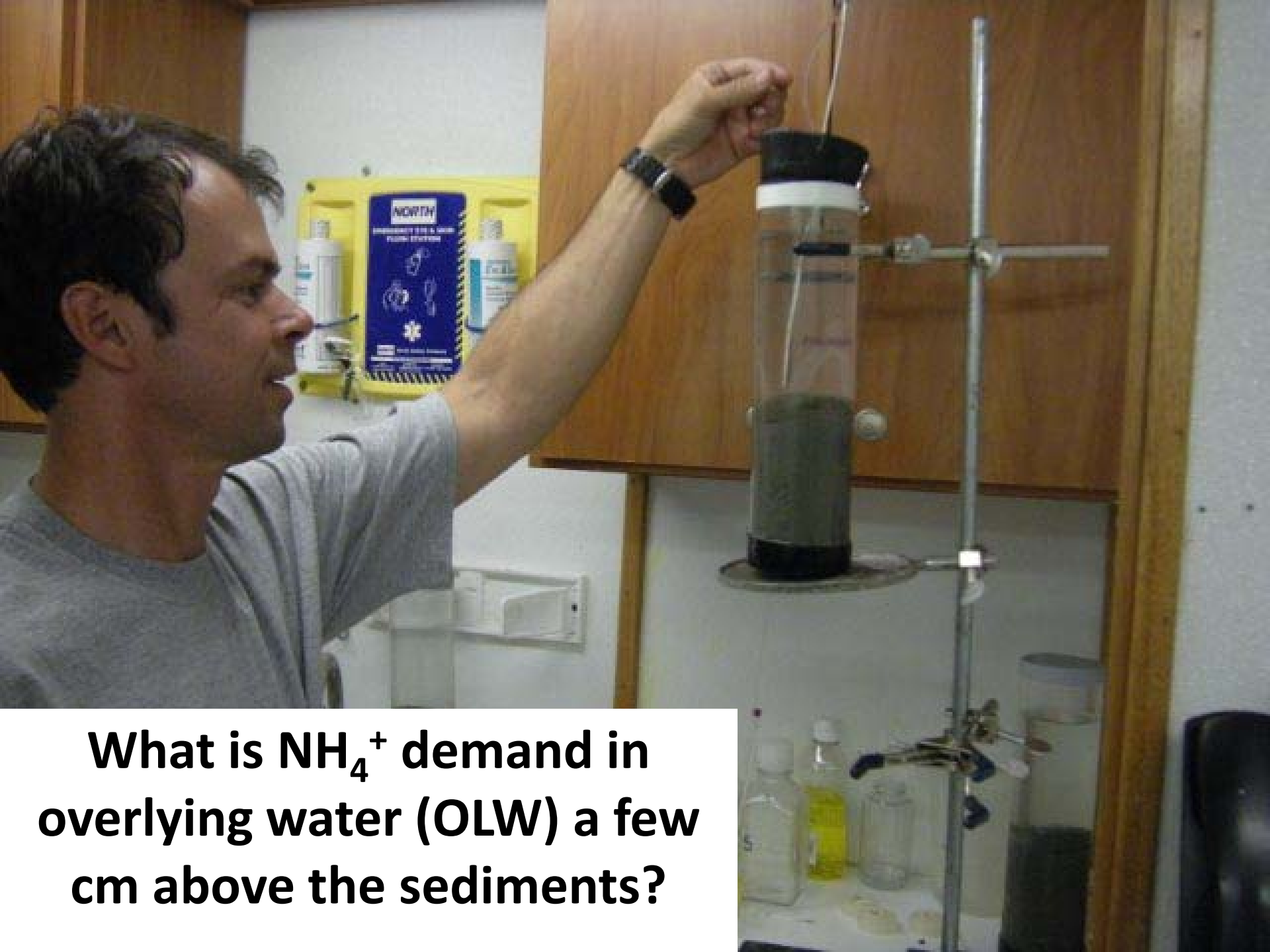
Does NH_4^+-availability limit microbial processes consuming O_2 in NGOMEX?

- **Water column**
- **Sediment-water interface**

Consider "Ammonium Demand" as an indicator of N-limitation

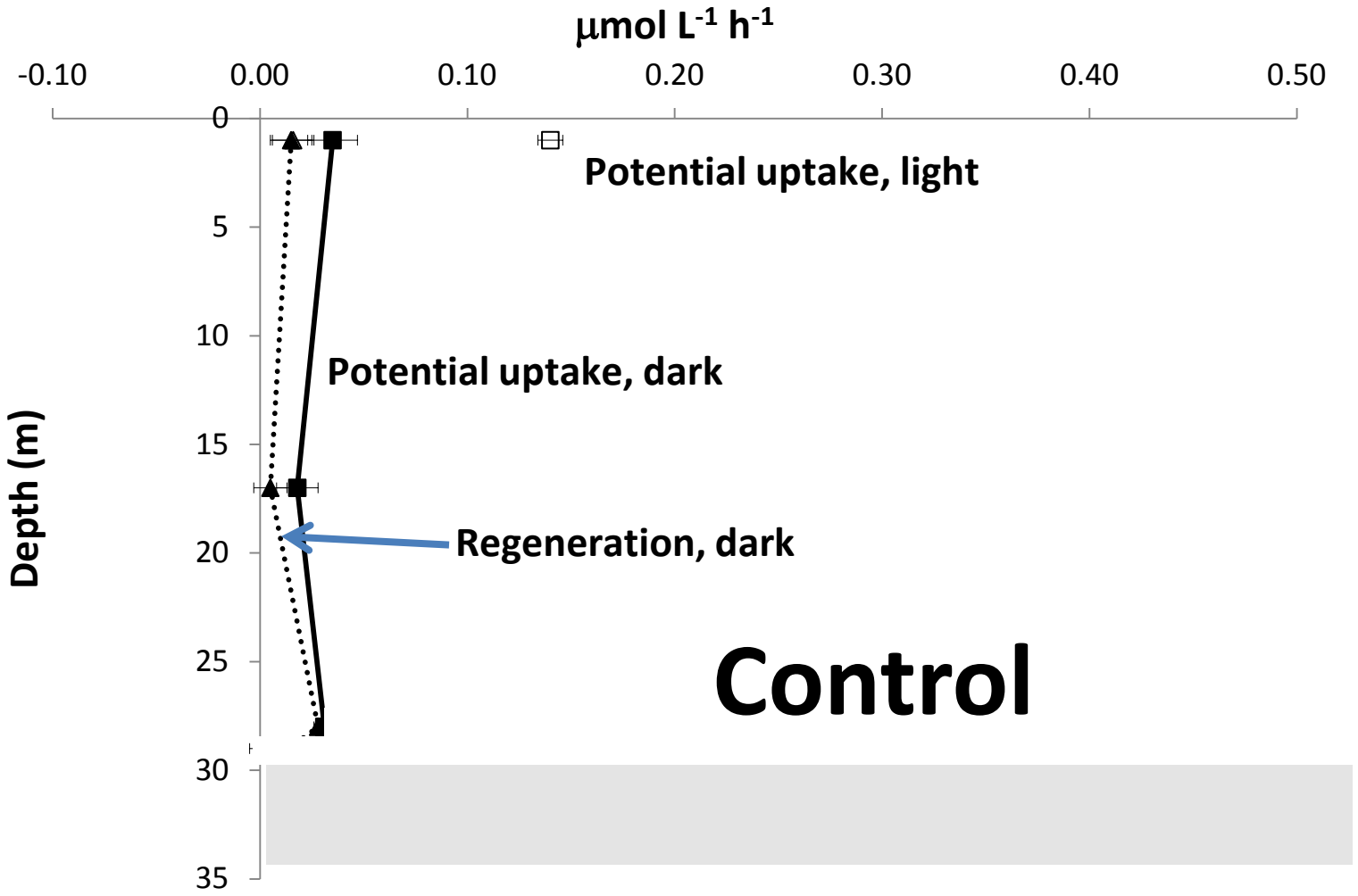
Regeneration and potential uptake rates for NH_4^+ July 2008



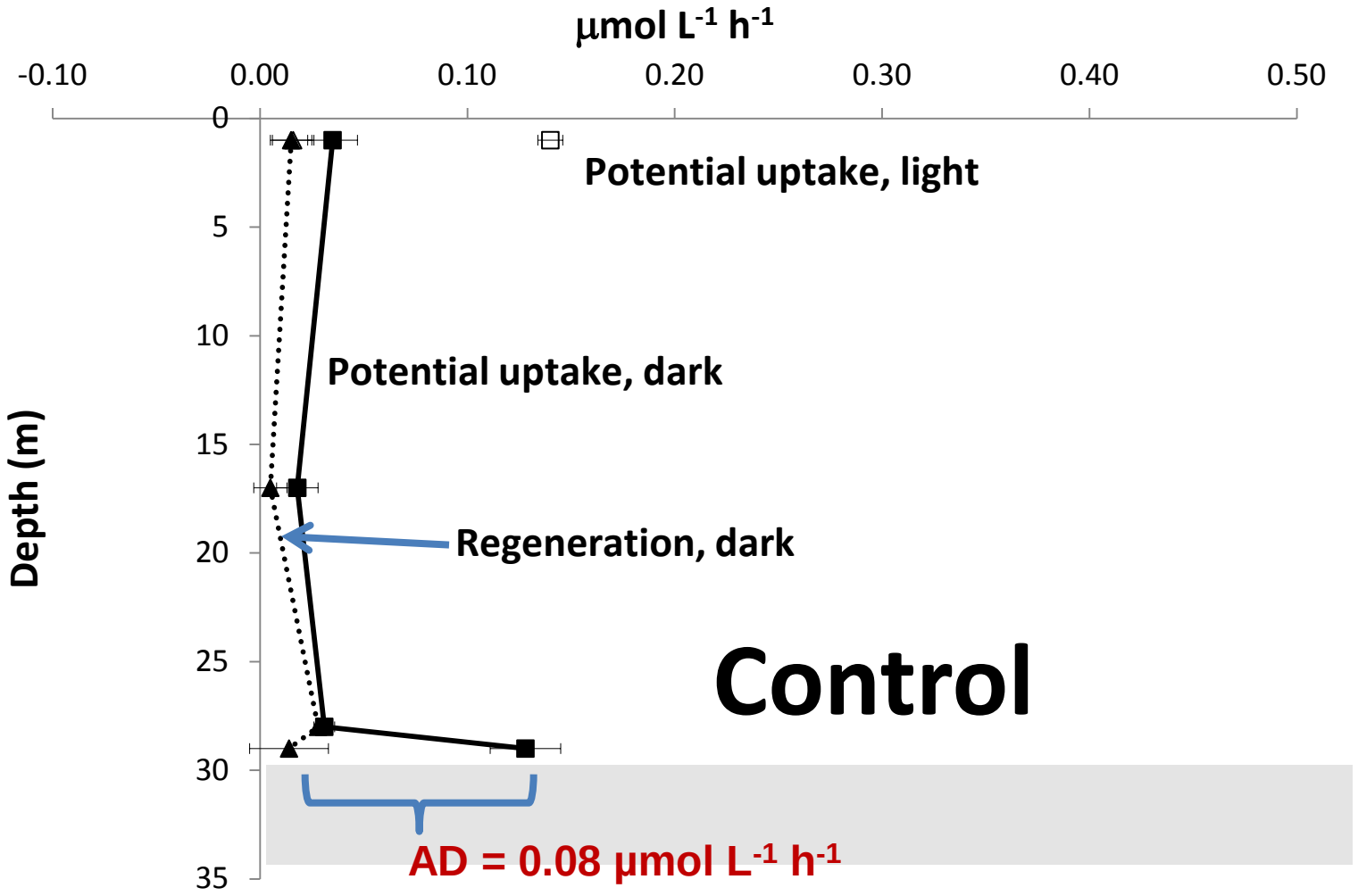


What is NH_4^+ demand in overlying water (OLW) a few cm above the sediments?

Regeneration and potential uptake rates for NH_4^+ September 2008



Regeneration and potential uptake rates for NH_4^+ September 2008



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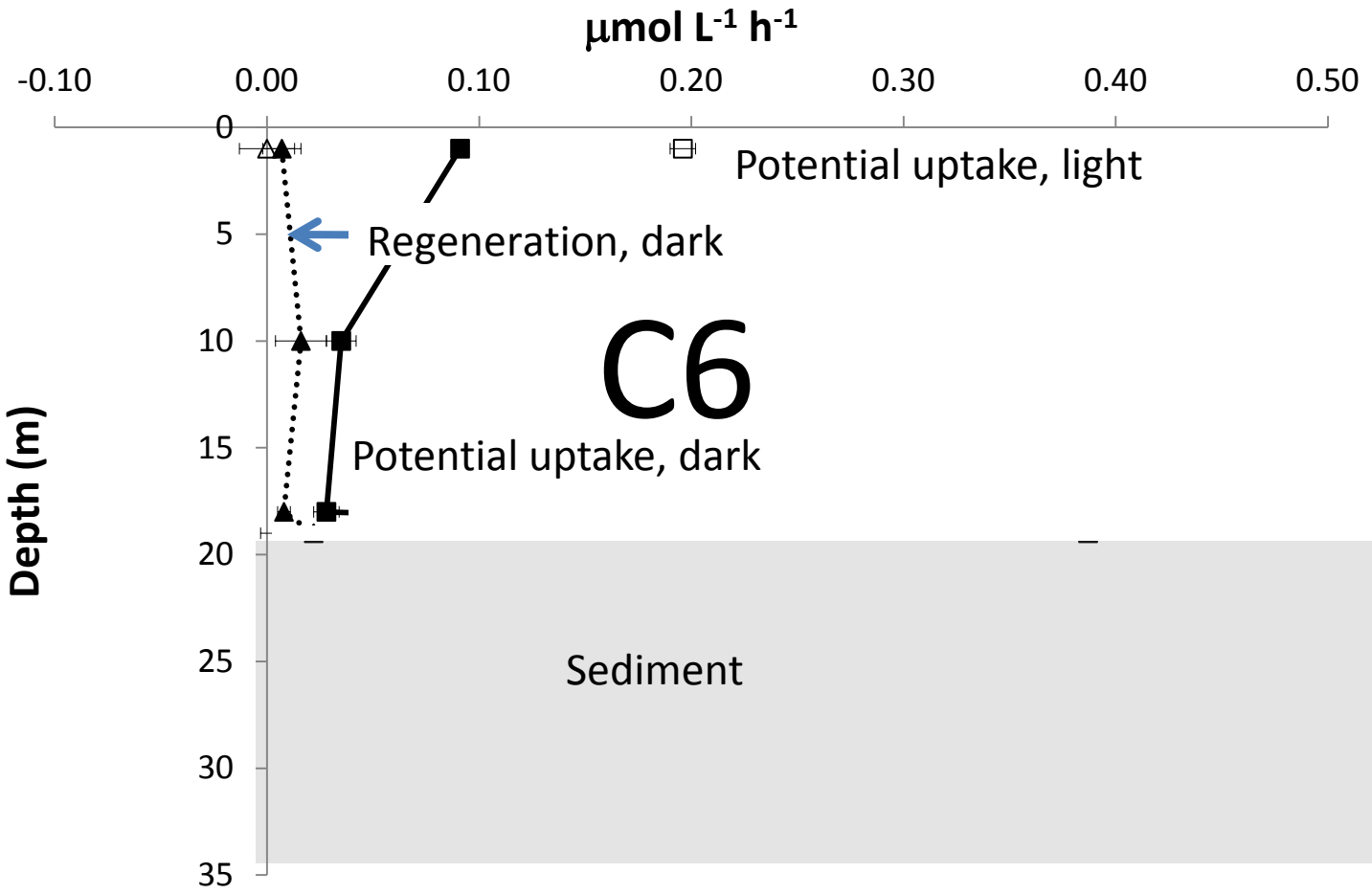

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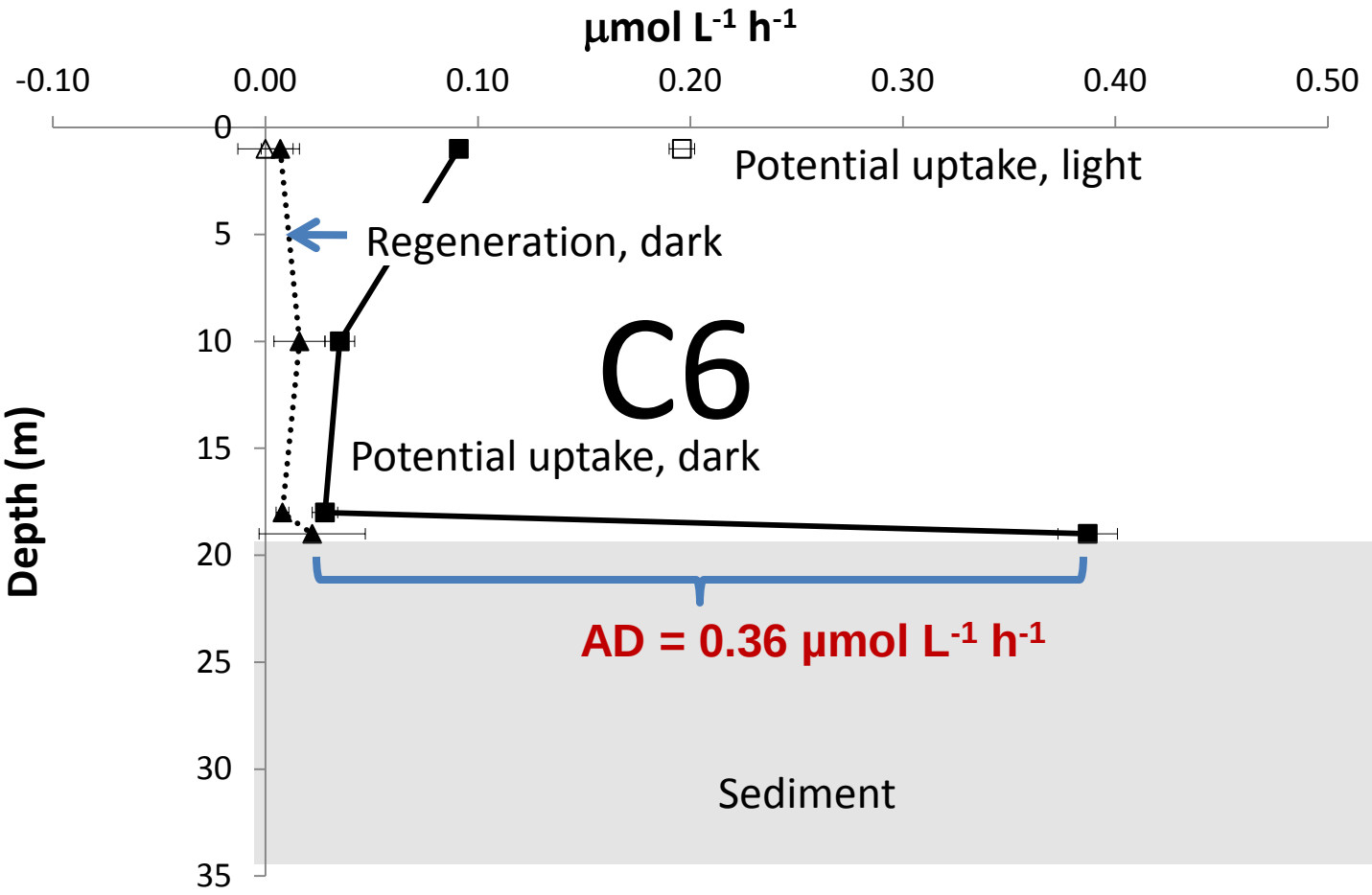
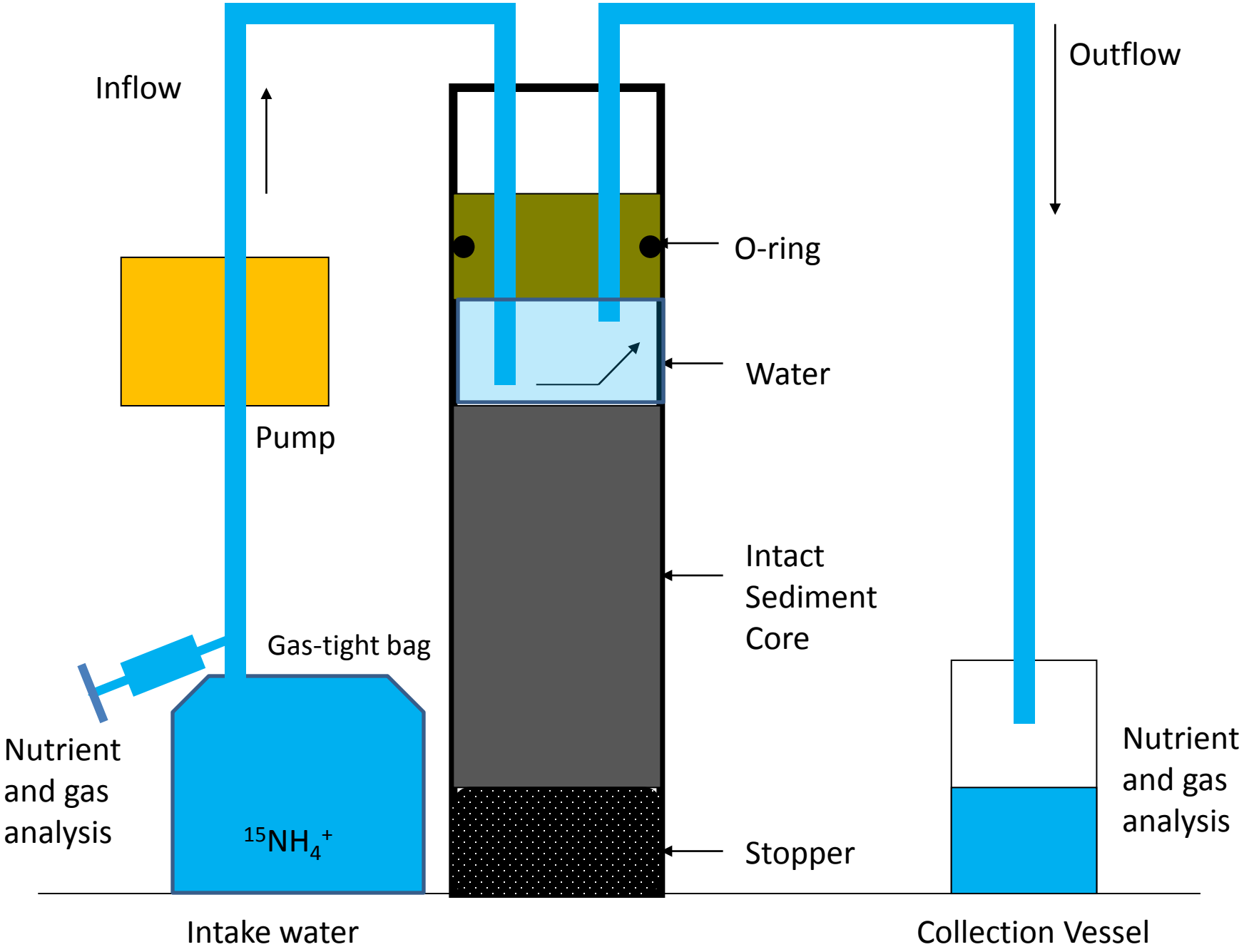


Important Conclusion

Isotopic rate measurements of N-transformation rates are more meaningful than measurements of concentrations or net changes

New approach: Do similar isotope-dilution calculations at the sediment-water interface with units of "µmol N m^{-2} h^{-1}"

Lin, X., M. J. McCarthy, S. A. Carini, W. S. Gardner. 2011. **Net, actual, and potential sediment–water interface NH_4^+ fluxes in the northern Gulf of Mexico (NGOMEX): Evidence for NH_4^+ limitation of microbial dynamics.** Continental Shelf Research 31 (2011) 120–128


Inflow
Outflow
O-ring
Water
Pump
Intact
Sediment
Core
Gas-tight bag
Nutrient
and gas
analysis
$^{15}NH_4^+$
Stopper
Nutrient
and gas
analysis
Intake water
Collection Vessel

REG

Regeneration or Demand

SAD

NET

Flux

SWI

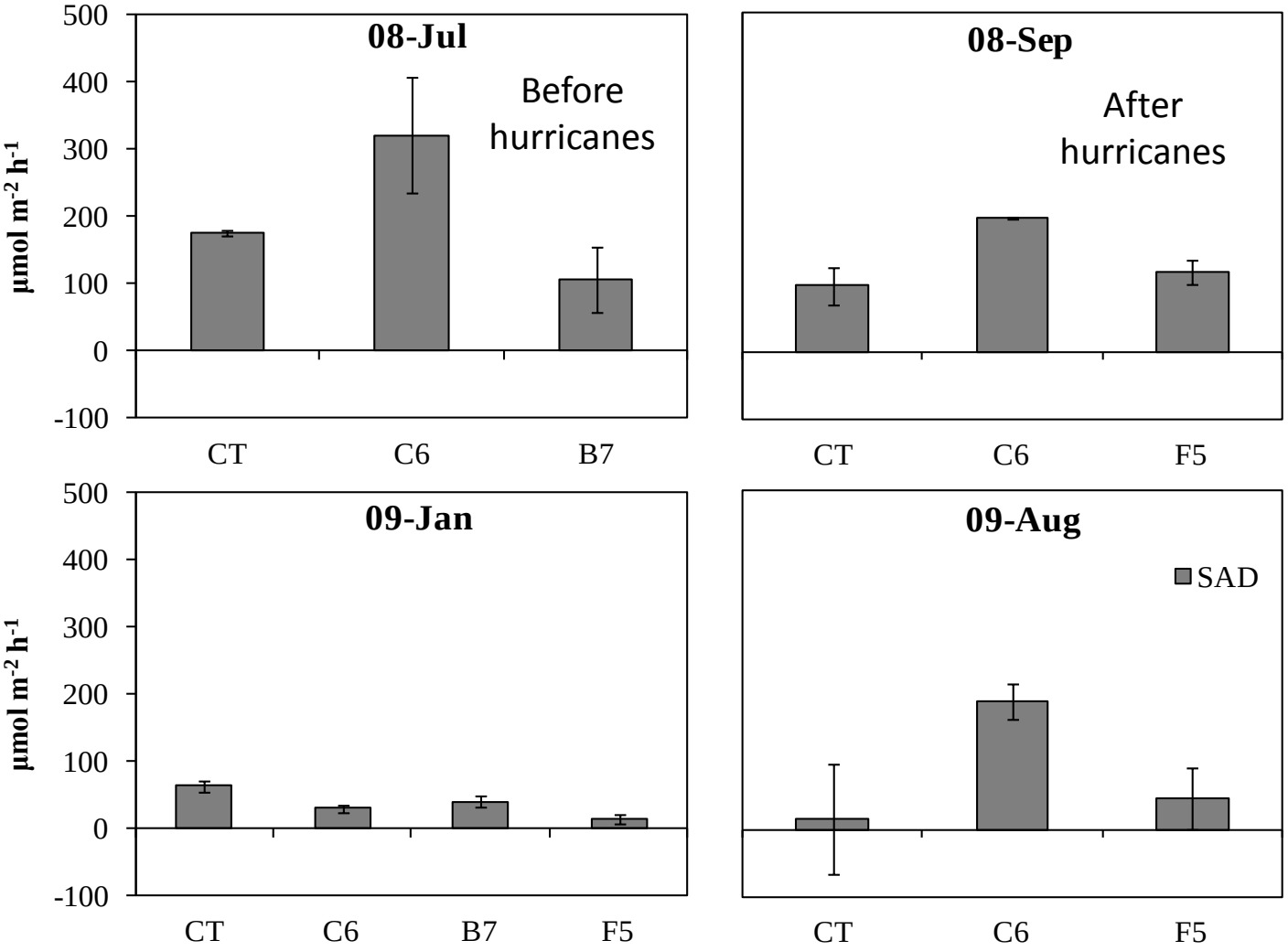
Uptake

↓

U_{act}

U_{pot}

SAD in NGOMEX stations



“SAD” Conclusions

1. Net flux underestimates actual regeneration flux
2. SAD values indicated NH_4^+ limitation of microbial activities

Where did the NH_4^+ go?

What about nitrification?

-Consumes NH_4^+ and O_2

-Difficult to measure via tracer techniques

-Data scarce

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An isotope dilution method to measure nitrification rates in the northern Gulf of Mexico and other eutrophic waters

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University of Texas Marine Science Institute, 750 Channel View Drive, Port Aransas, TX 78373, USA

Estimated percentage of regenerated ammonium nitrified

(O_2 + NH_4^+ → NO_2^- → NO_3^-)

Nitrification data from S. Carini data

July 2008

	Hypoxic site	Control site
Near surface	80	9
Middle depth	100	0
1 m above bottom	14	0
Few cm above bottom	0	0

Nitrification as estimated percentage of total oxygen consumption

(O_2 + NH_4^+ → NO_2^- → NO_3^-)

July 2008

	Hypoxic site	Control site
Near surface	13	1
Middle depth	25	1
1 m above bottom	14	17
Few cm above bottom	NA	NA

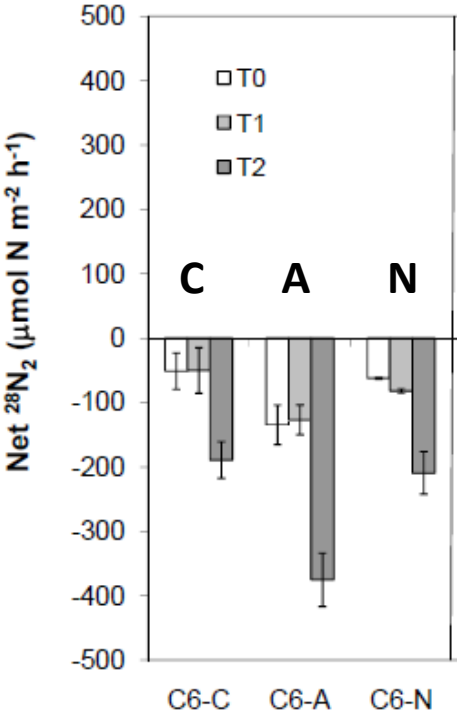
How important is denitrification?

N_2 gas fluxes

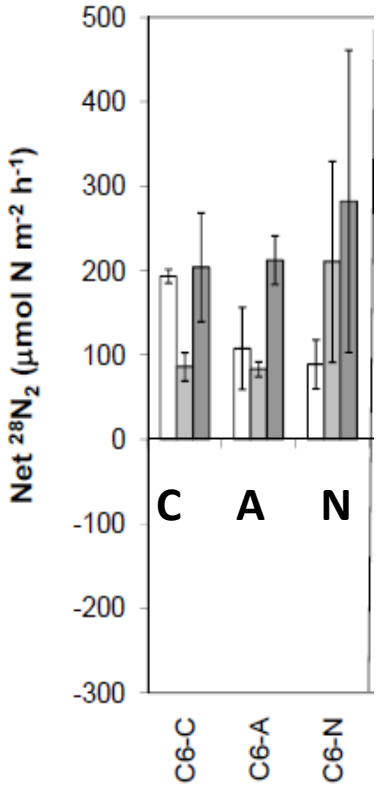
(Caused by: denitrification/ Anammox, or N_2-fixation)

Experiments by
Mark McCarthy

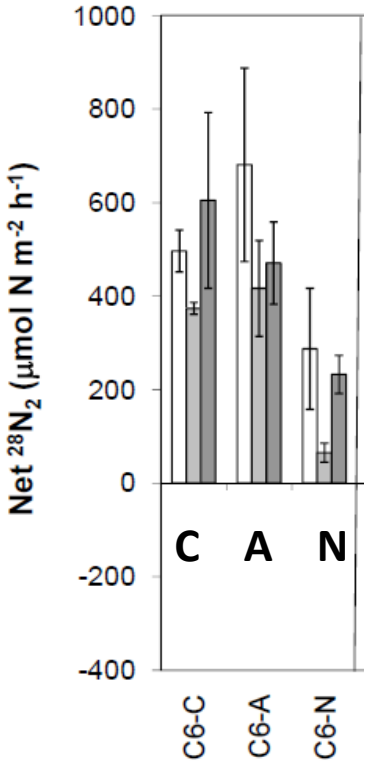
Examples of N_2 flux patterns



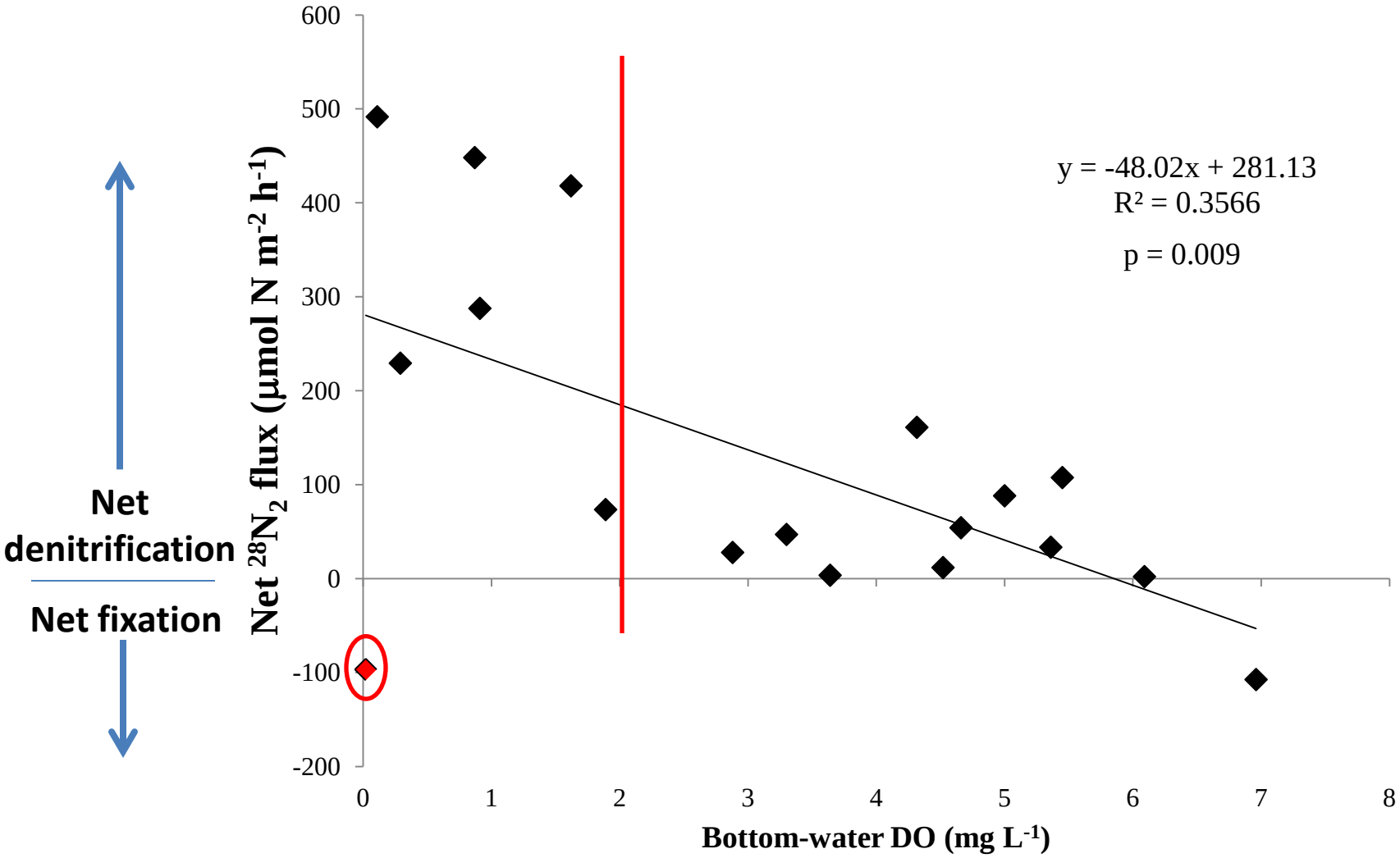
Net N_2-fixation
July 2008



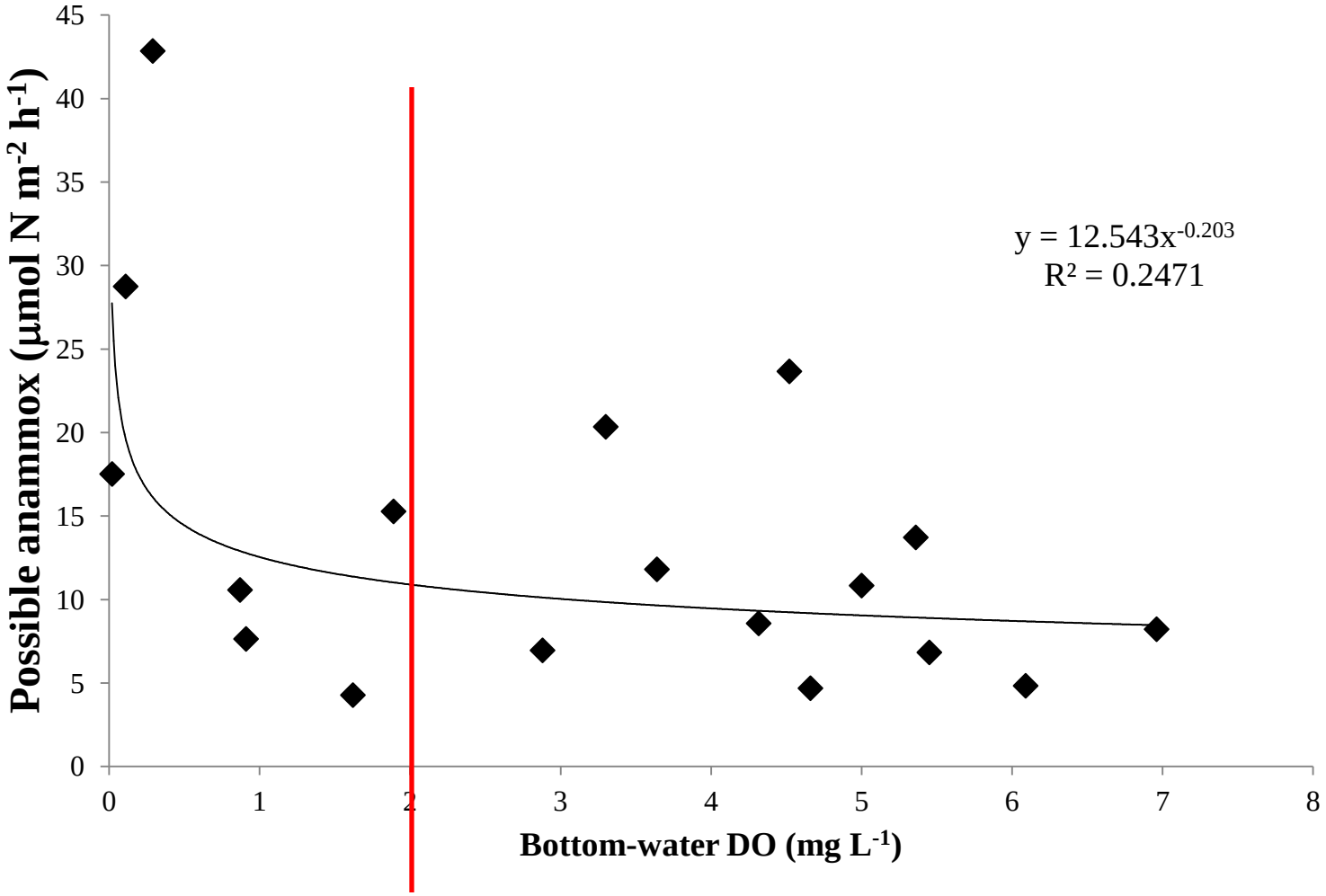
Net denitrification
January 2009



Net denitrification
August 2009



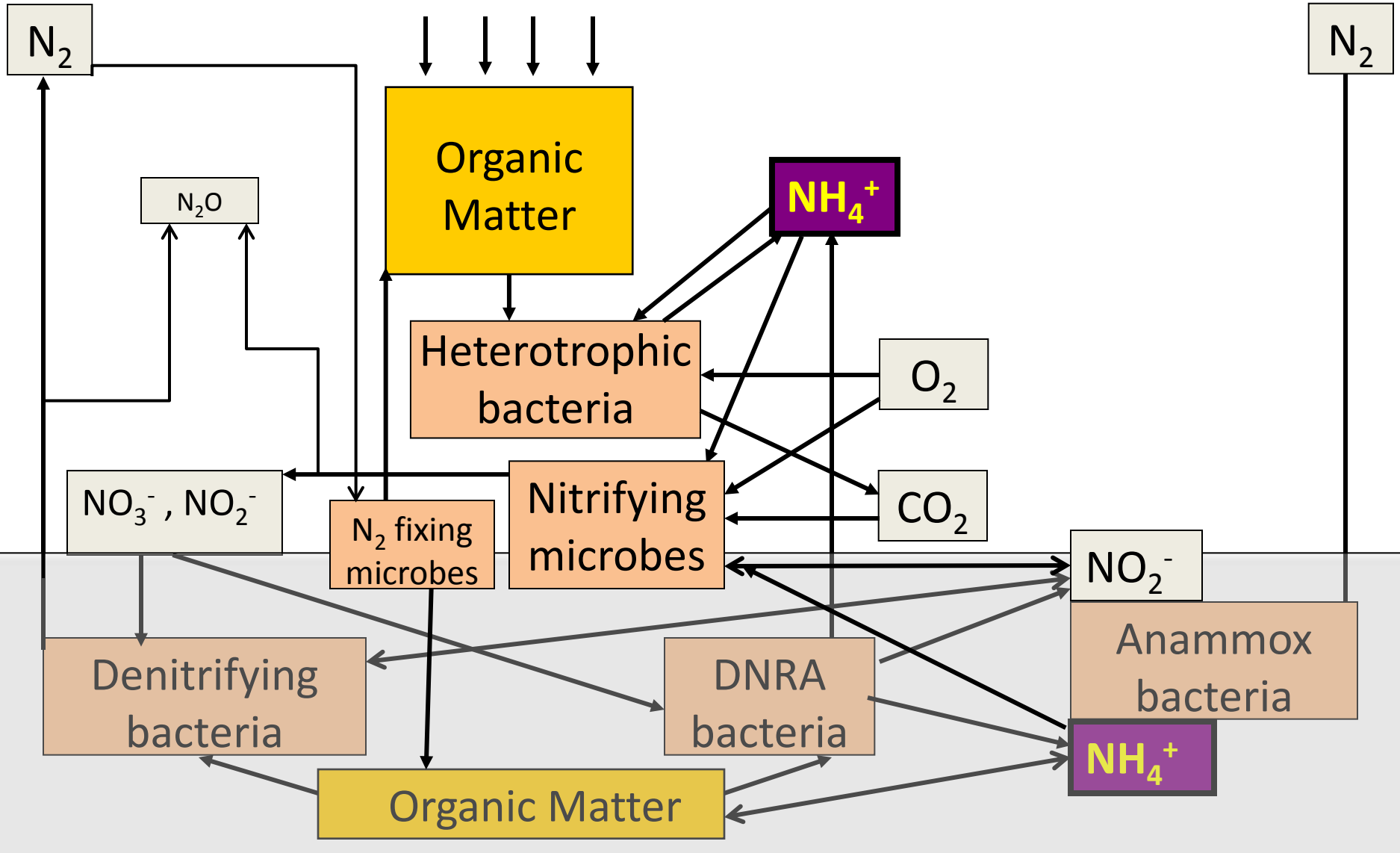
Higher net $^{28}N_2$ flux at lower DO



What about potential Anammox?

Small relative to denitrification

Near-bottom and sediment-water interface: N-dynamics processes in low-oxygen environments



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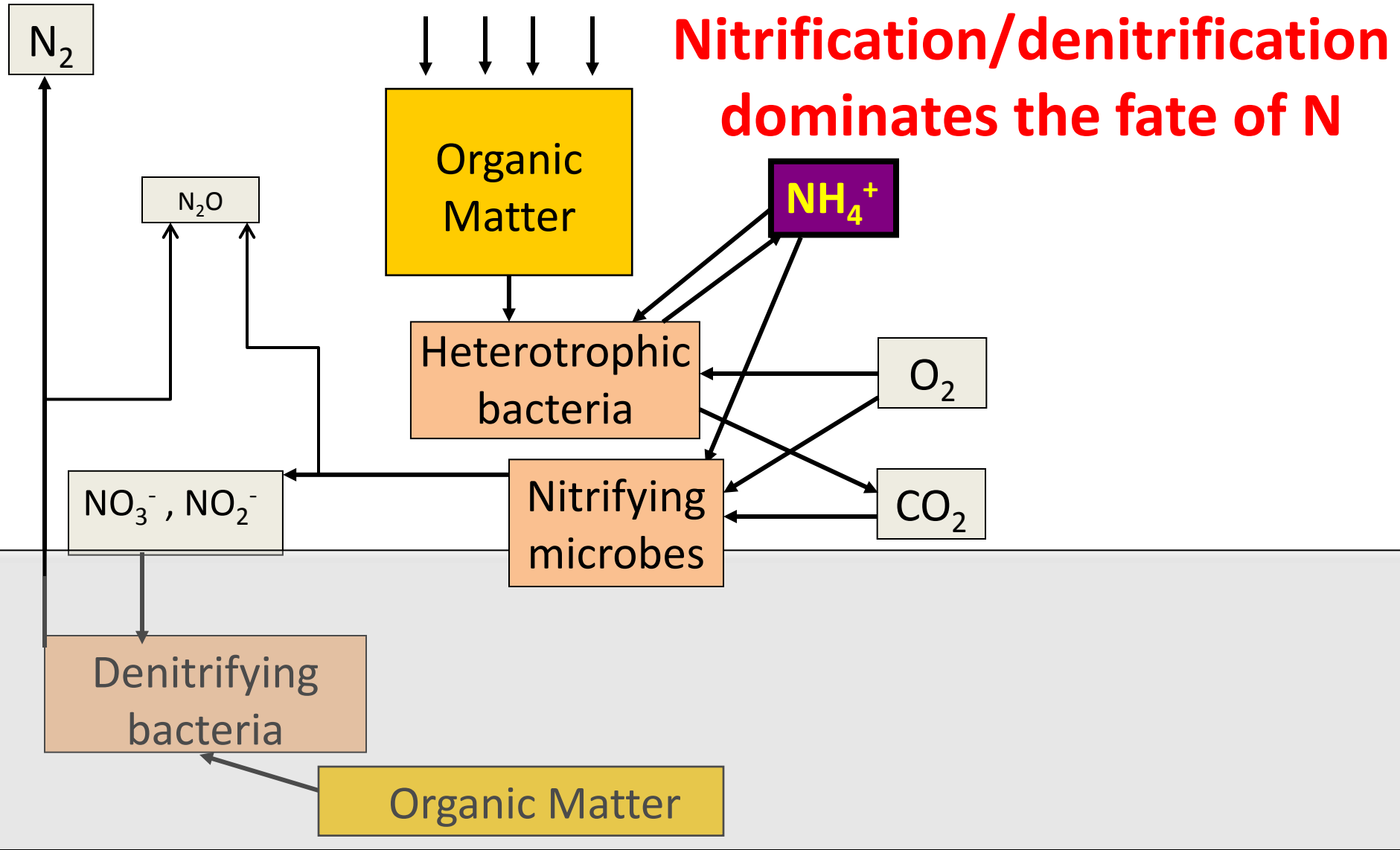

Conclusion:
Nitrification/denitrification drives the system to apparent N-limitation in hypoxic regions


Gulf of Mexico
Questions?