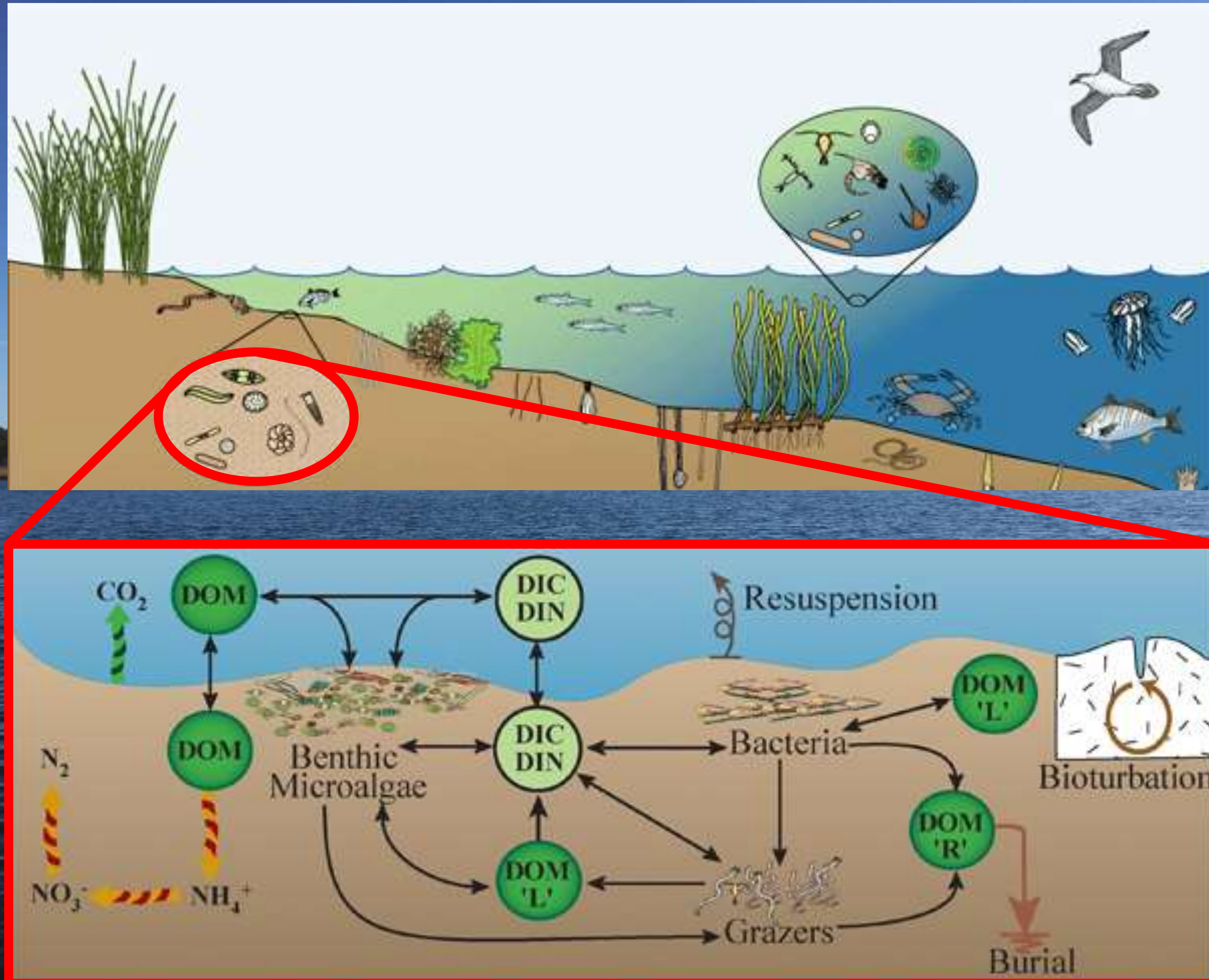
What's Happening in the Mud at the Bottom of the Bay?

Sarah Q. Foster

PhD Candidate
Earth and Environment Department, Boston University

Research at the Reserve Coffee House Series / WBNERR, East Falmouth, MA / 24 April 2018



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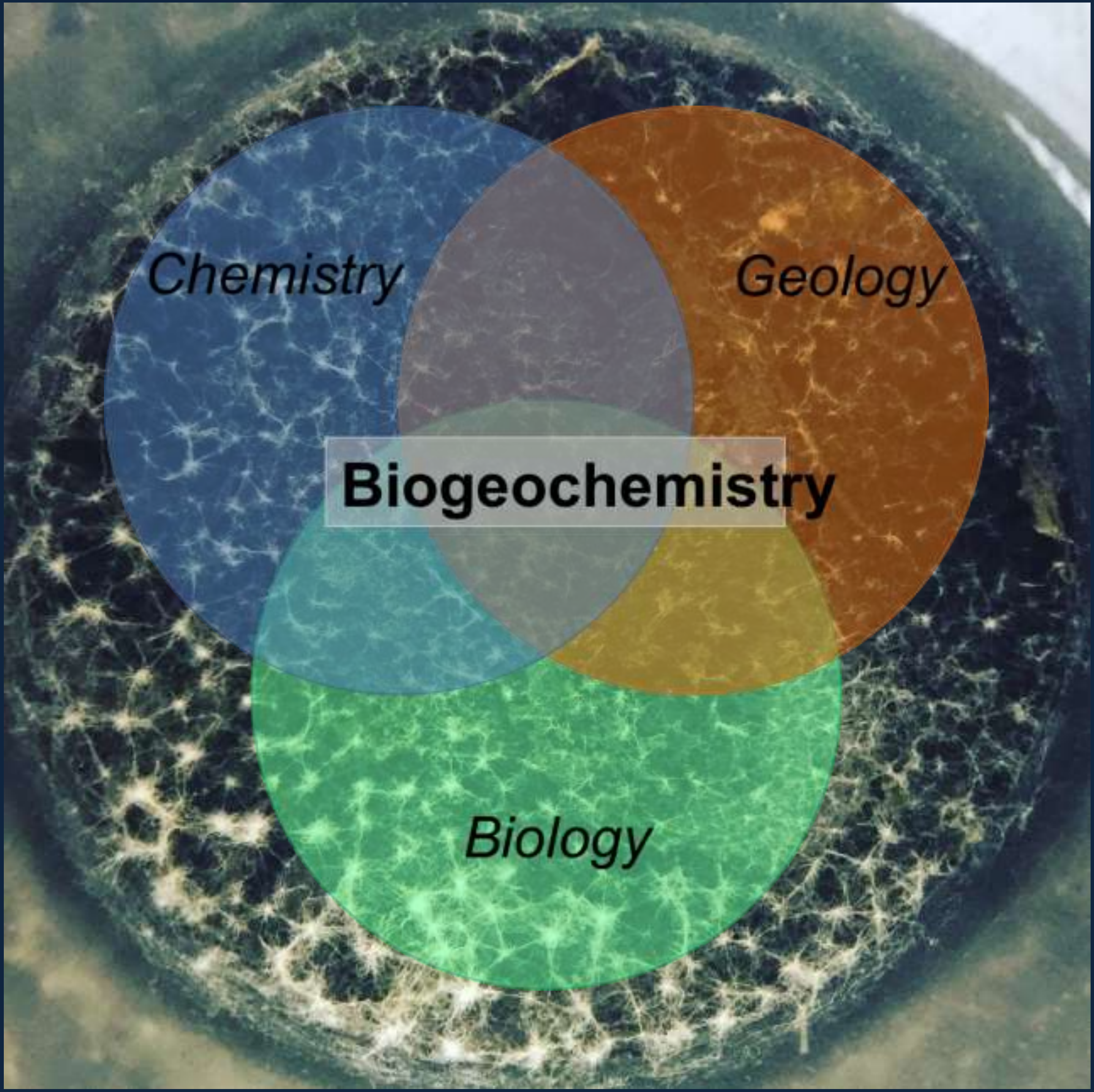

Chemistry
Geology
Biogeochemistry
Biology

Metabolisms

Ecosystems Ecology

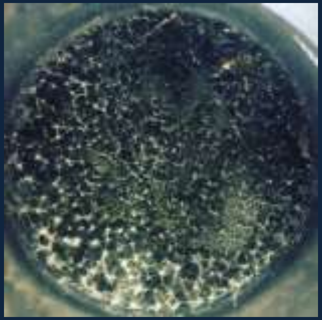
Nutrient Cycles

Microorganisms

Biogeochemistry

Greenhouse Gases

Sediments



Coastal Marine

My Path to Estuarine Ecosystem Science

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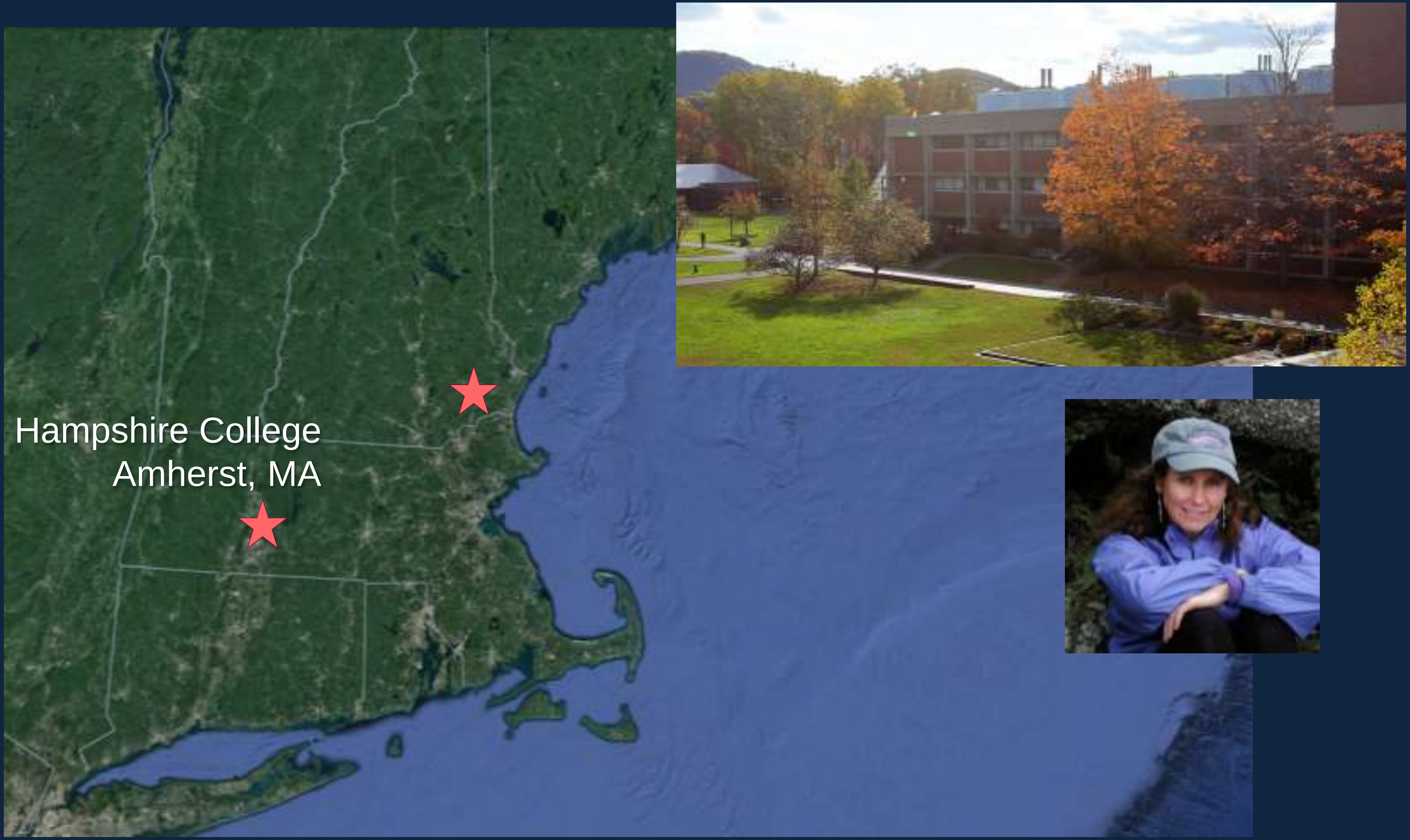

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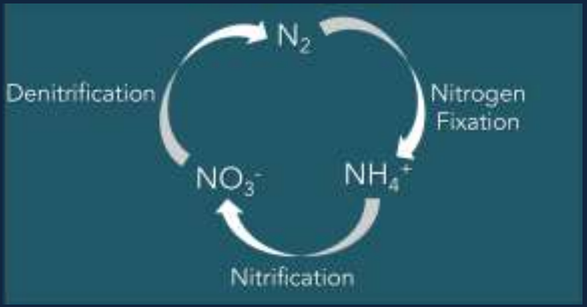

My Path to Estuarine Ecosystem Science

Semester in Environmental Science, MBL, Woods Hole, MA

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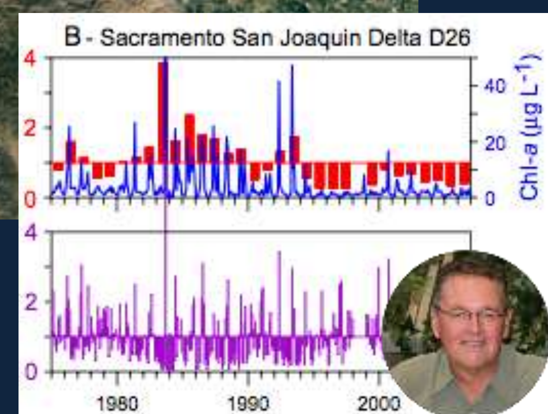

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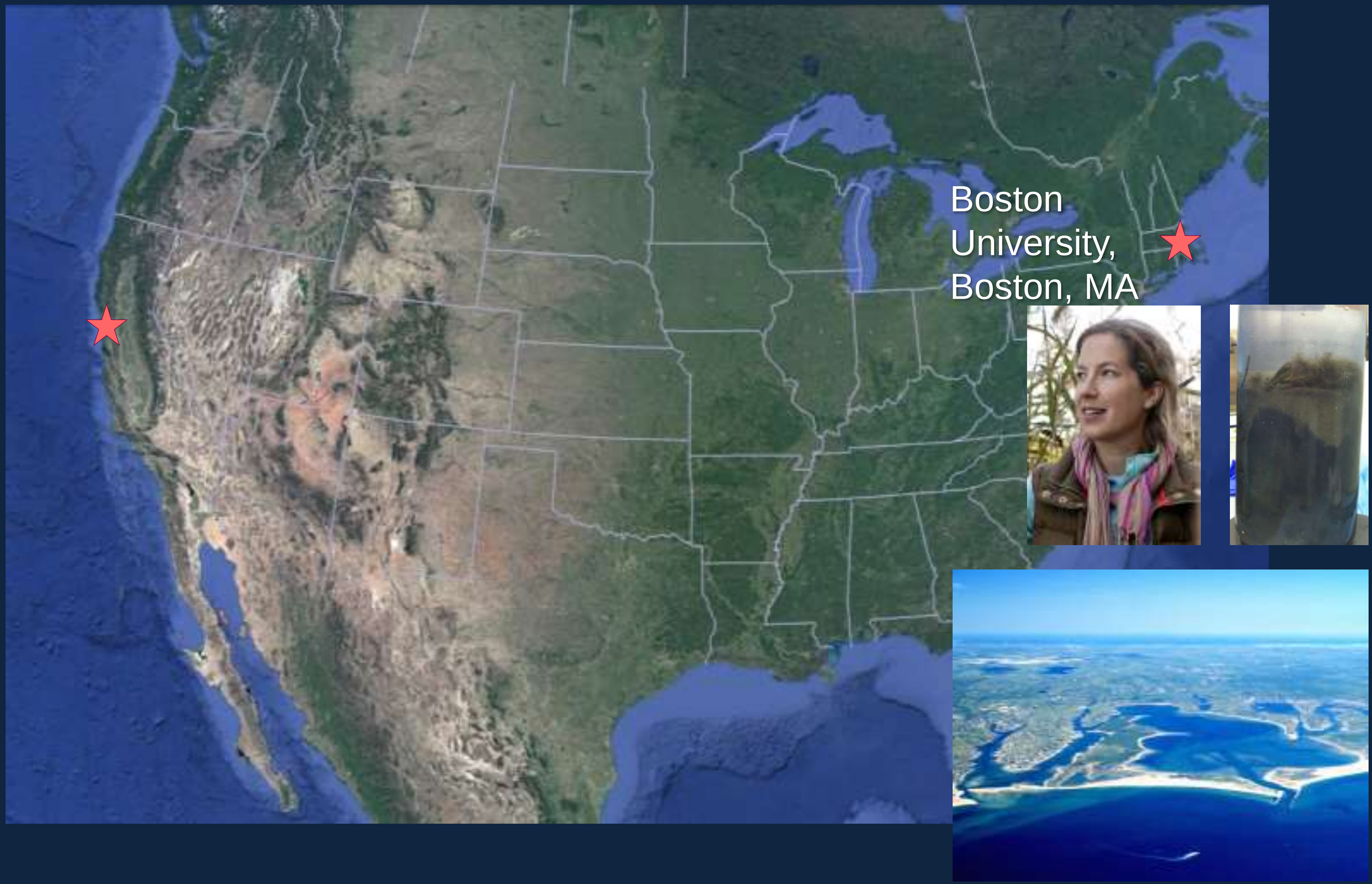
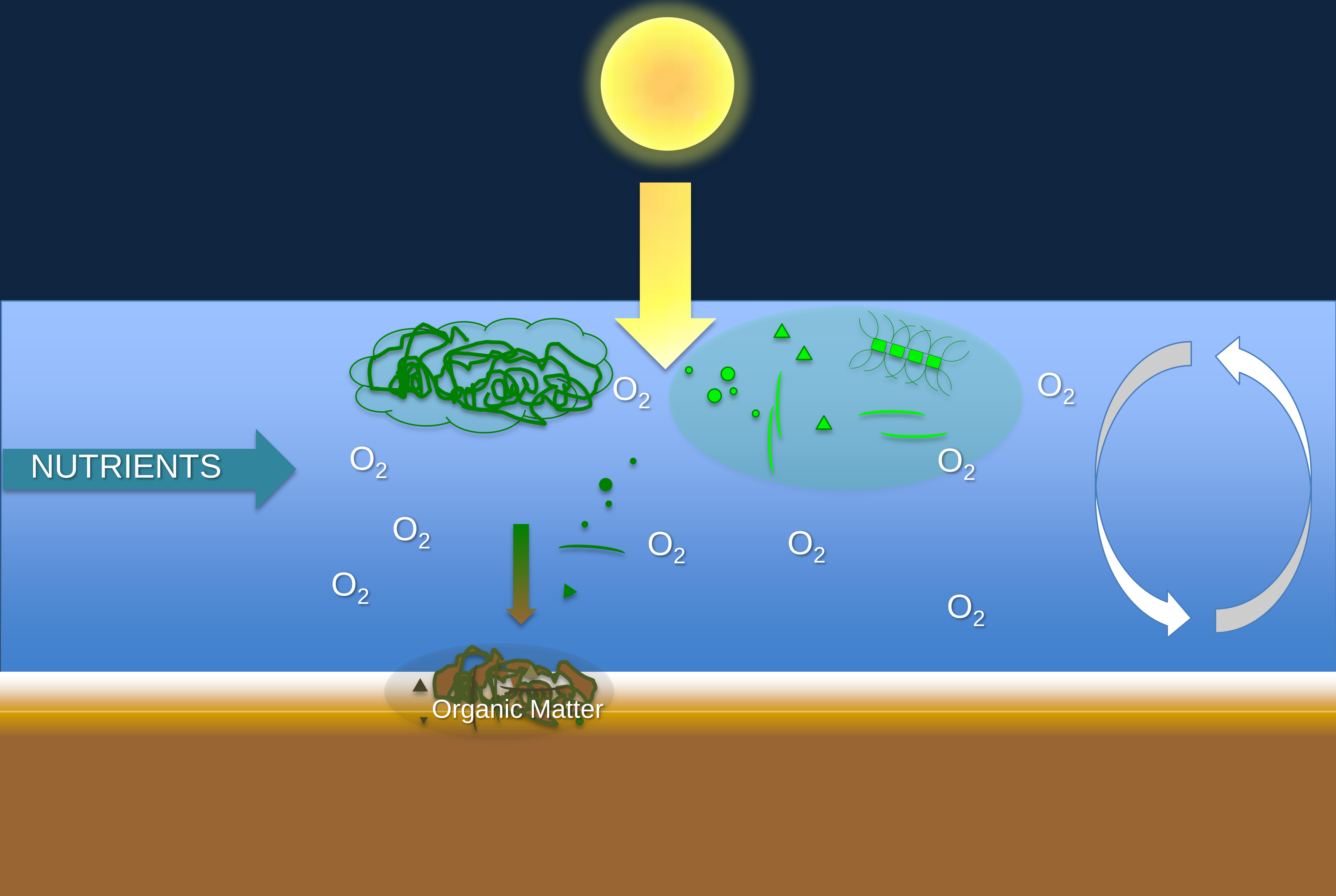
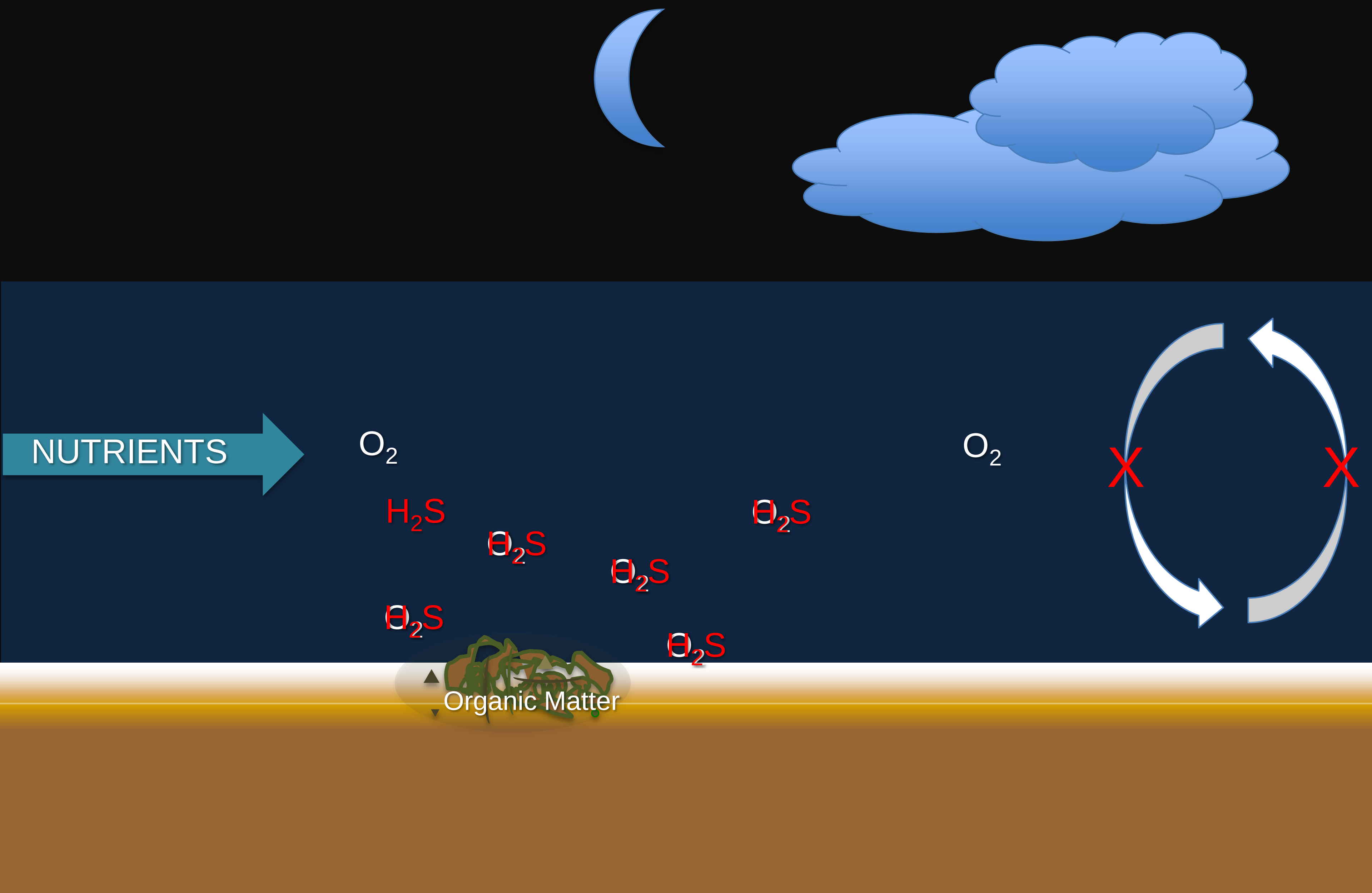


Coastal Nutrient Pollution & Hypoxia

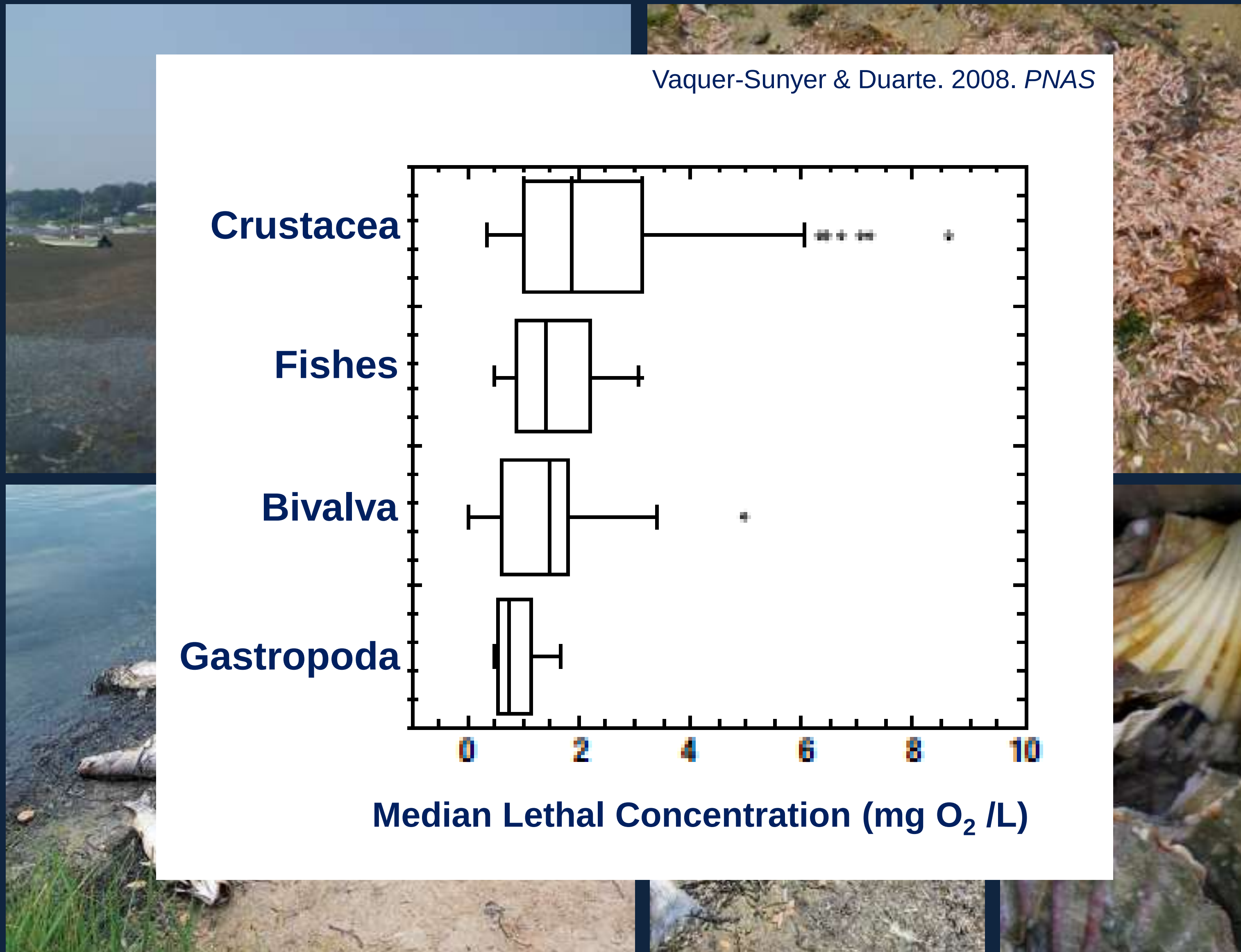


Coastal Nutrient Pollution & Hypoxia

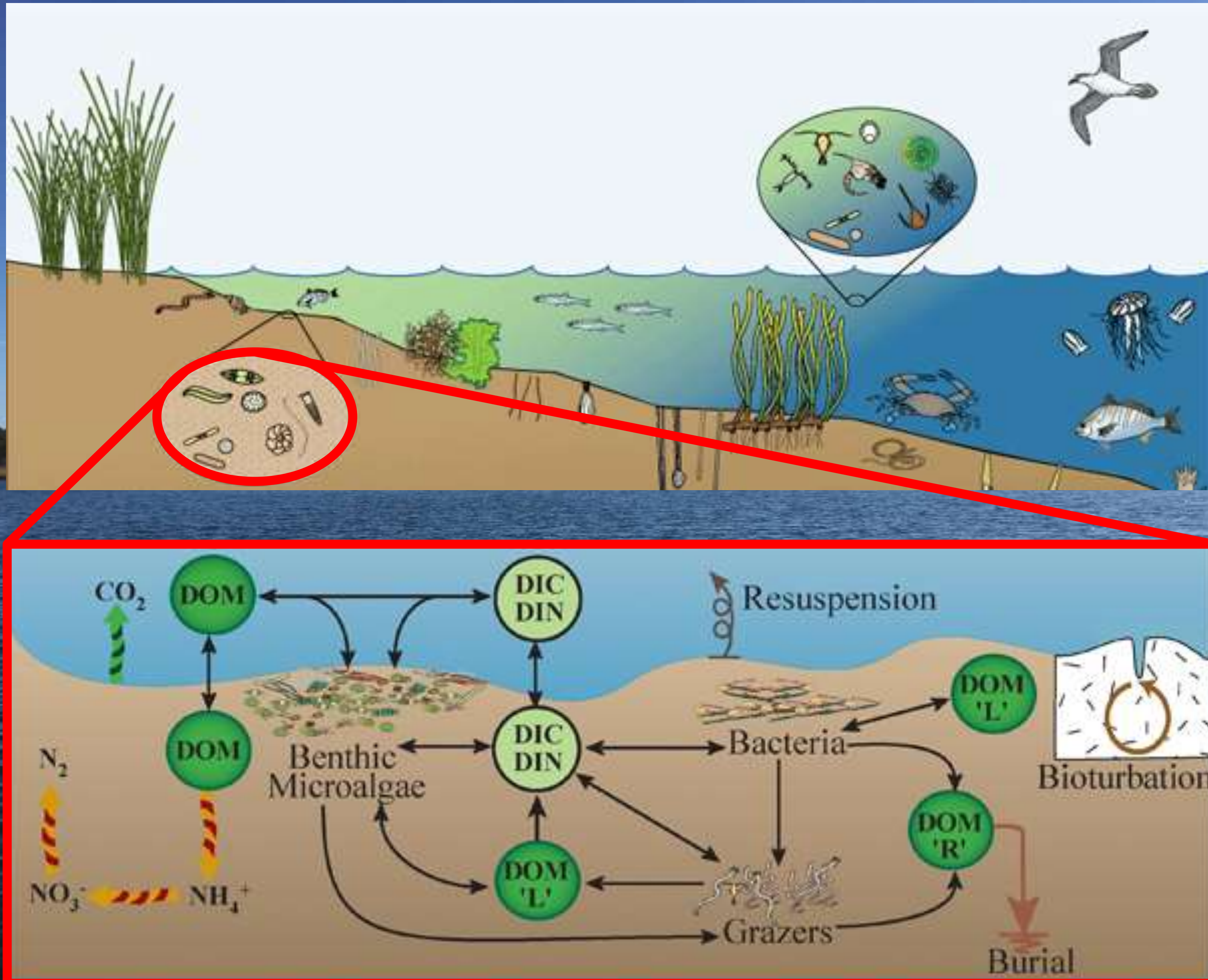








Vaquer-Sunyer & Duarte. 2008. *PNAS*
Crustacea
Fishes
Bivalva
Gastropoda
0
2
4
6
8
10
Median Lethal Concentration (mg O_2 /L)



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What is the impact of hypoxia on benthic microbial processes?

How are sediment biogeochemical fluxes and ecosystem function changed?

Sediments & Ecosystem Functions

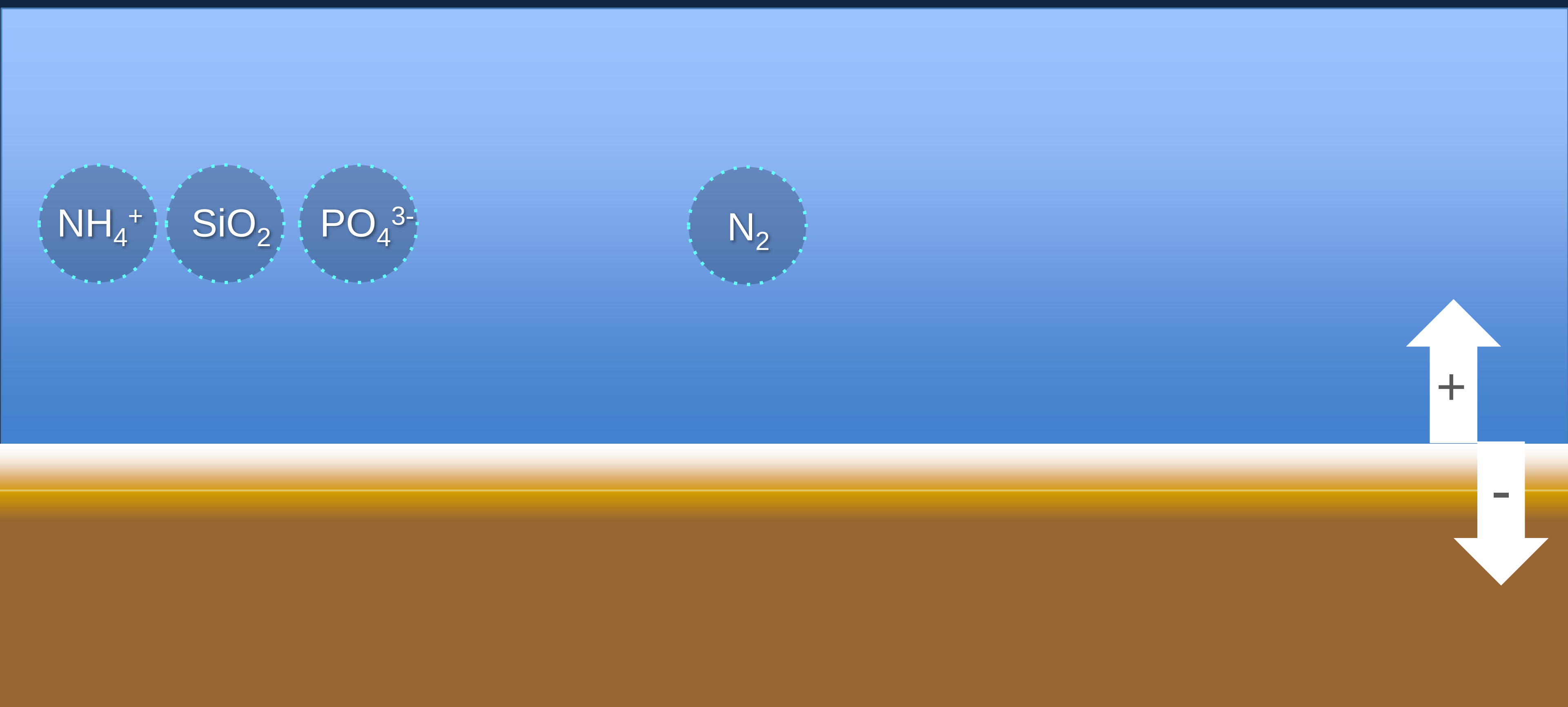
- Nutrient Regeneration
- Removal of Reactive Nitrogen
- Regulation of Greenhouse Gases

Sediments & Ecosystem Functions

- Nutrient Regeneration

Sediments & Ecosystem Functions

- Nutrient Regeneration
- Removal of Reactive Nitrogen



Sediments & Ecosystem Functions

- Nutrient Regeneration
- Removal of Reactive Nitrogen
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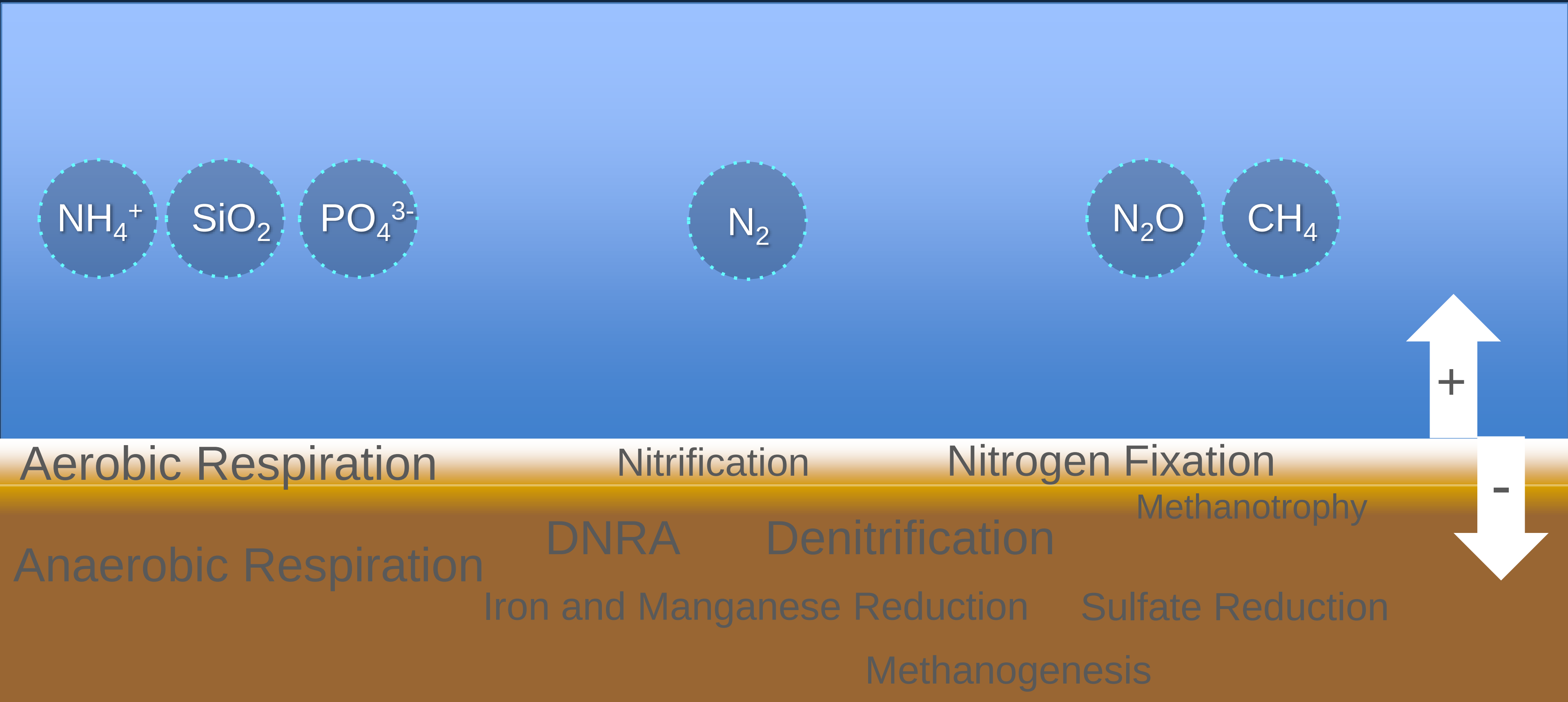
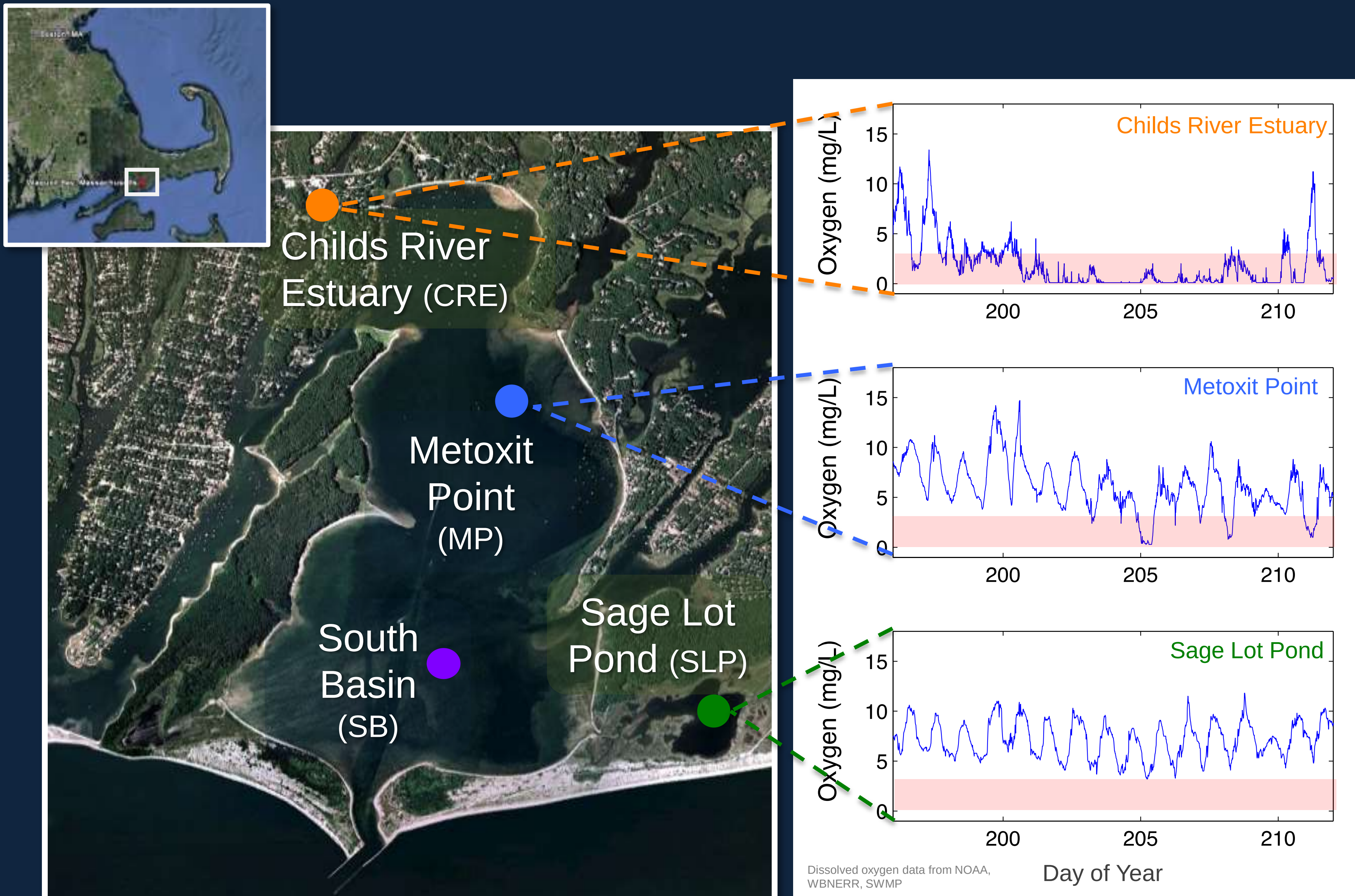


Coastal Hypoxia Locations Across the Globe

Map modified from Rabalais *et al.* (2010), based on data reported by Diaz & Rosenberg (2008) and Levin *et al.* (2009)

"No other environmental variable of such ecological importance to estuarine and coastal marine ecosystems around the world has change so drastically, in such a short period of time, as dissolved oxygen." -Diaz (2001)

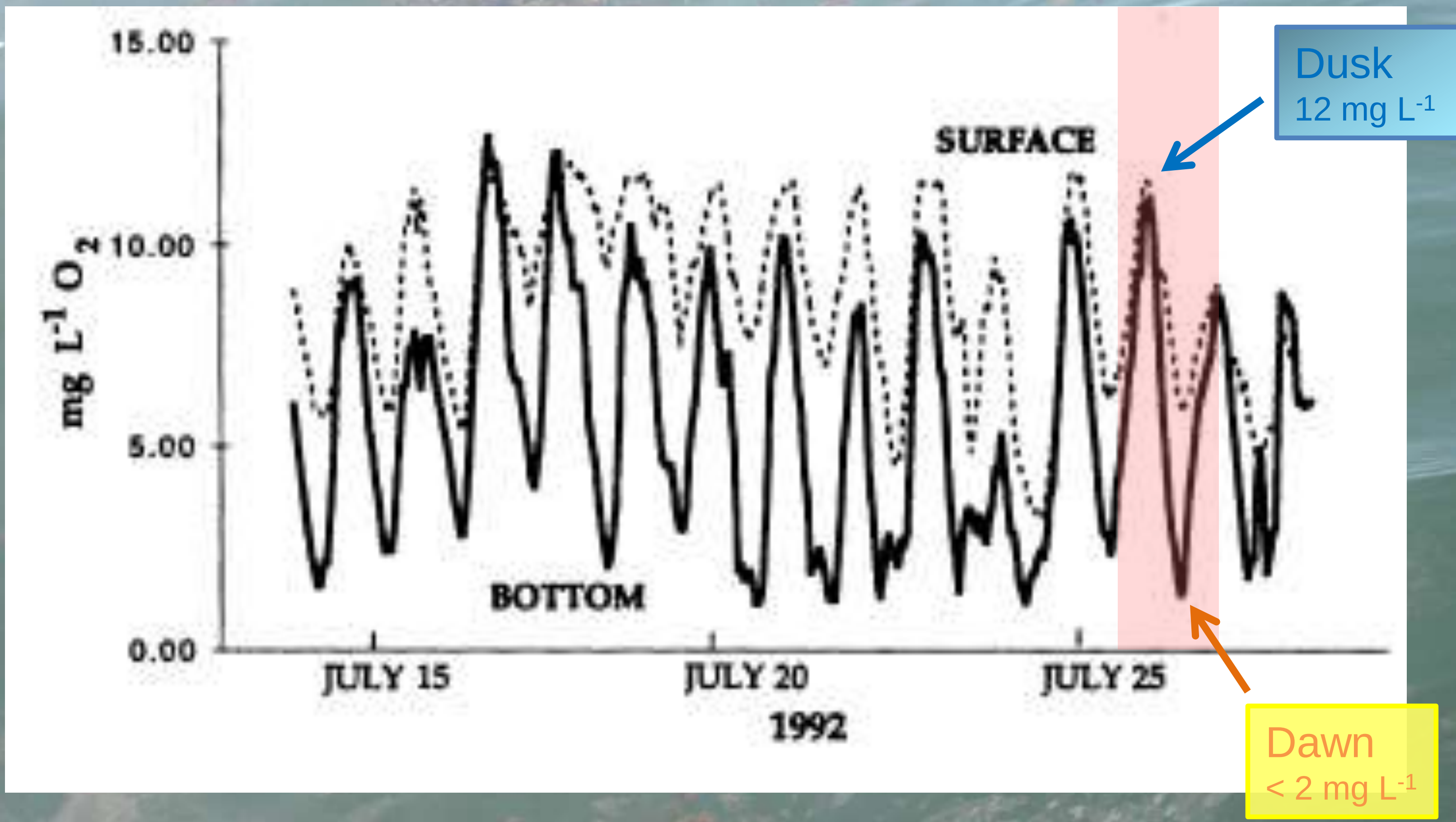
Study Site: Waquoit Bay, Massachusetts



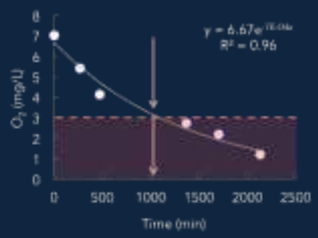
Estuaries Vol. 17, No. 1B, p. 131–139 March 1994

Diel Oxygen Dynamics and Anoxic Events in an Eutrophic Estuary of Waquoit Bay, Massachusetts

CHARLENE D'AVANZO JAMES N. KREMER



Research Questions and Objectives



- <u>Hypoxic Effect</u>

  Does ***hypoxia*** *impact* ***ecosystem functioning*** *by altering rates of benthic nutrient regeneration, greenhouse gas regulation and reactive N removal?*

- <u>Station Effect</u>

  How does the response to hypoxia ***vary across regions*** *that have different oxygen dynamics?*

  Can we see evidence of hypoxic "legacy"?

Sediment and Water Collection

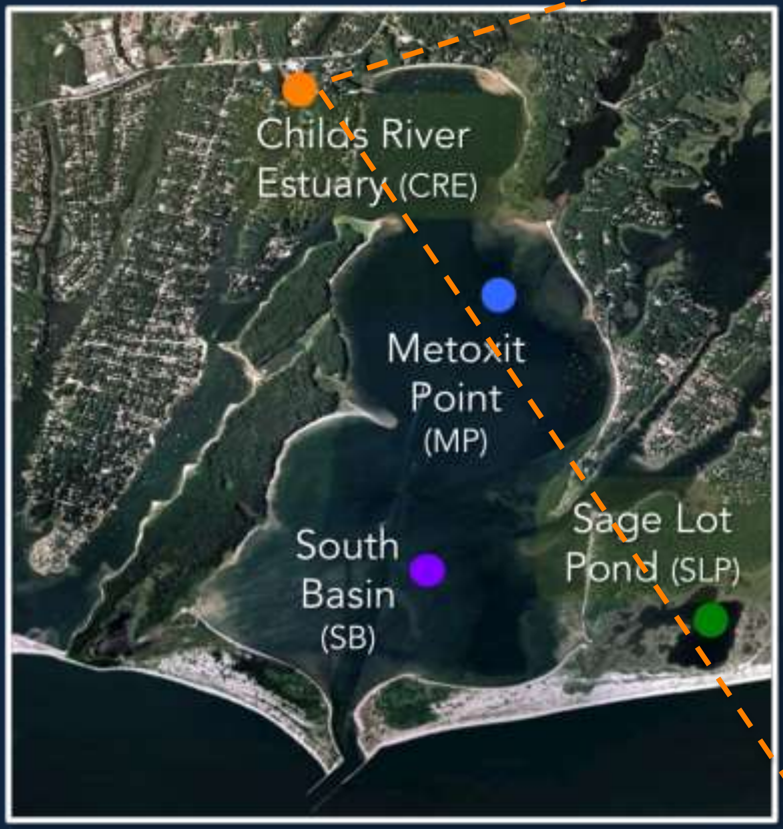
7 sampling dates (summers & early fall 2011-2013), 4 stations








Childs River Estuary (CRE)



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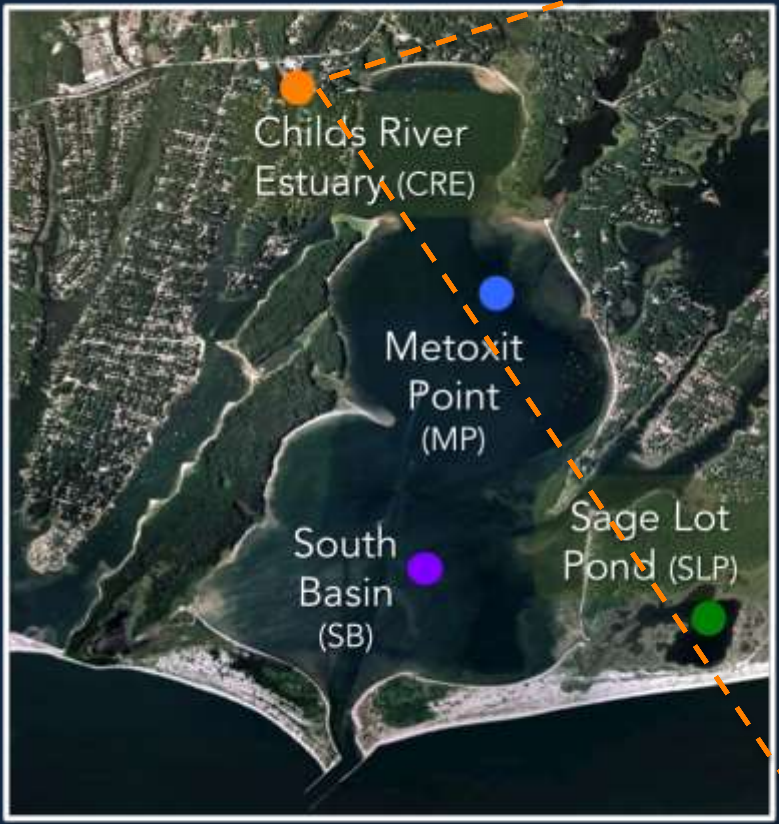
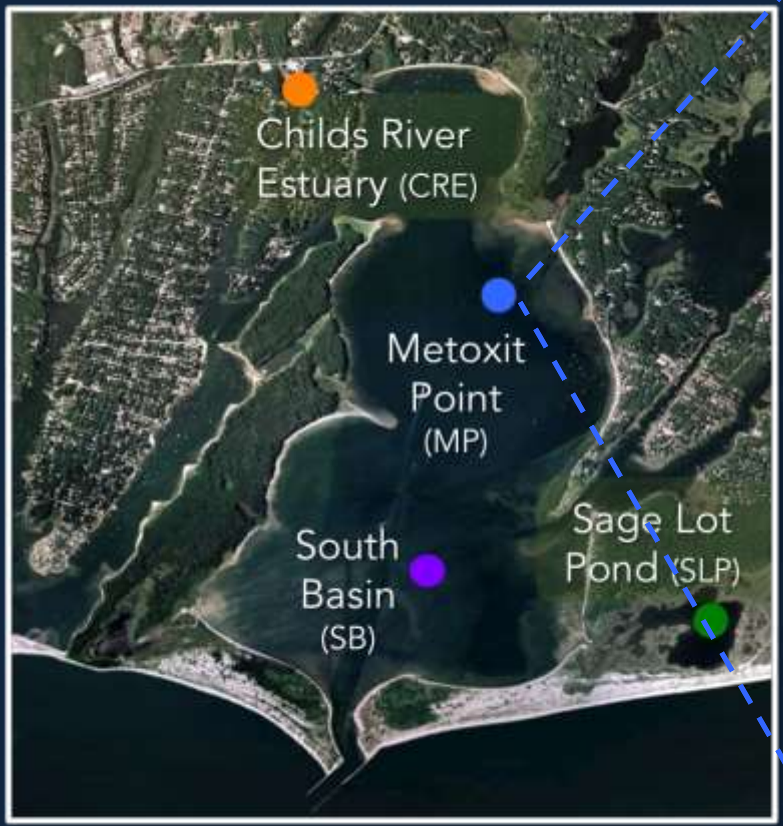


Metoxit Point (MP)



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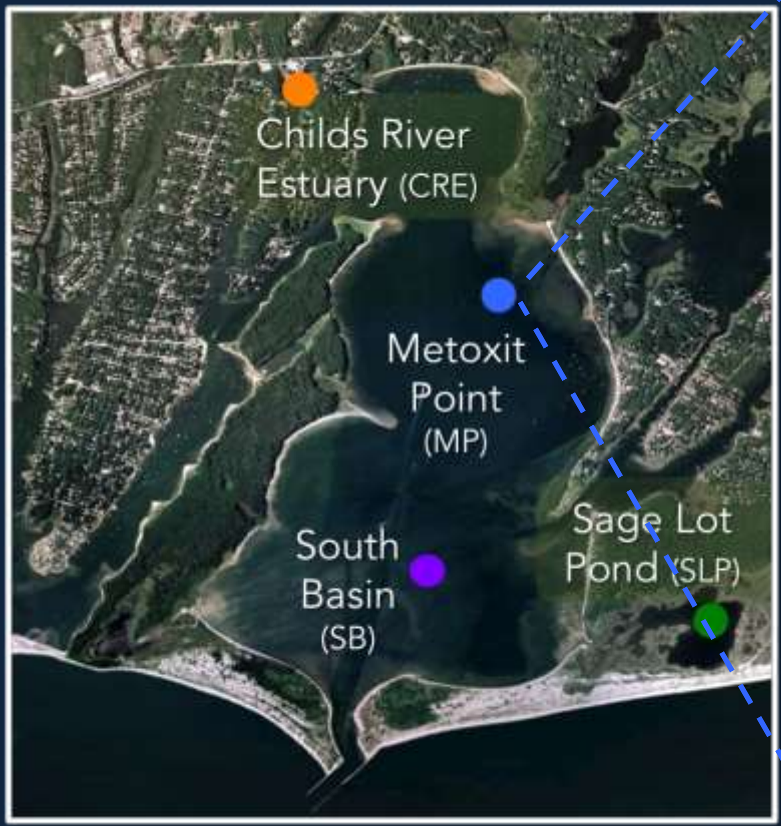


South Basin (SB)

South Basin (SB)

Sage Lot Pond (SLP)

Sage Lot Pond (SLP)

Sediment Characteristics Across Stations

Station	Sediment Characteristics							
	Silt + Clay[1] (%)	Sand[1] (%)	Porosity[2]	C[2] (%)	N[2] (%)	C:N[2]	Chl *a*[3] (mg m^{-2})	Benthic Organism Abundance[4] (individuals m^{-2})
CRE	9-14	86-91	0.76 ± 0.02	4.7 ± 0.3	0.44 ± 0.04	12.9 ± 0.2	90-120	3093 ±441
MP	-	-	0.87 ± 0.02	6.2 ± 0.3	0.82 ± 0.04	9 .1 ± 0.2	-	-
SB	-	-	0.62 ± 0.02	1.2 ± 0.4	0.14 ± 0.05	10.6 ± 0.2	-	-
SLP	2-9	91-97	0.85 ± 0.03	5.9 ± 0.4	0.62 ± 0.05	11.3 ± 0.3	50-90	24213 ±3277

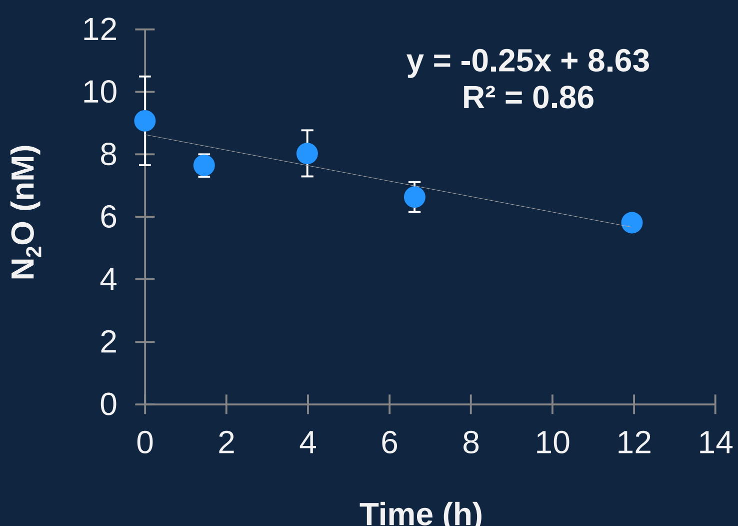
[1]Carmichael and Valiela 2004, 2005; [2]Foster and Fulweiler 2014, *in prep*; [3] Lever and Valiela 2005; [4] Fox et al. 2009

Overview Field and Lab Methods

Water and Sediment Core Collection

Incubation

Sediment Flux Calculation



Sample Concentration Analysis

SEAL Nutrient Autoanalyzer

$[NH_4^+]$ $[SiO_2]$ $[PO_4^{3-}]$

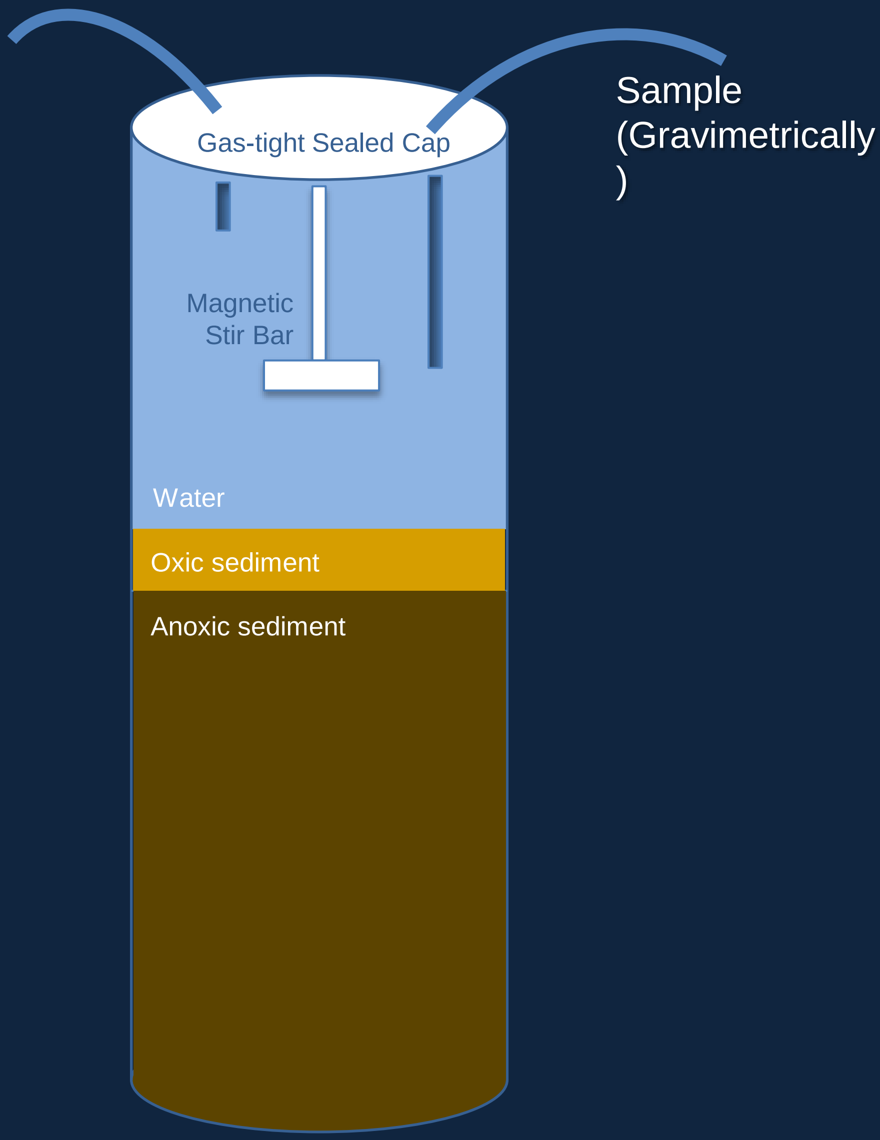
Membrane Inlet Mass Spec (MIMS)

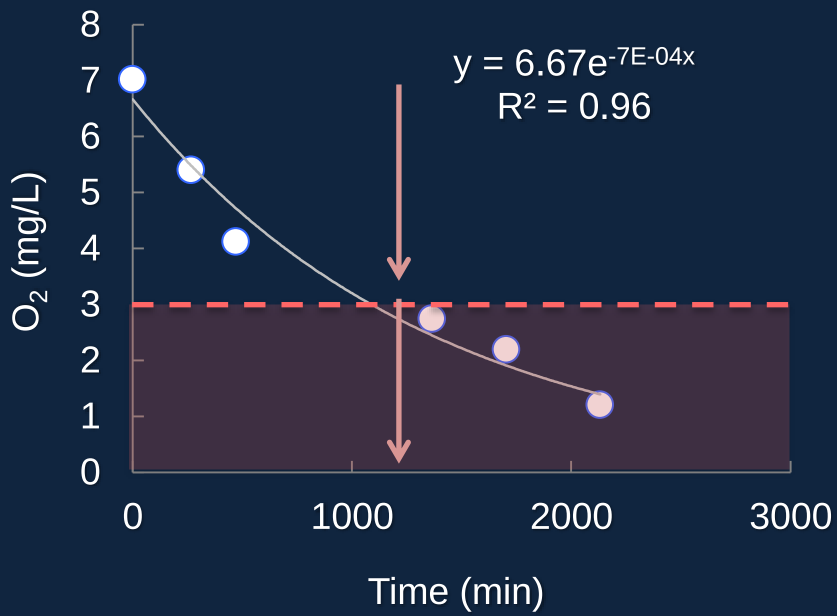
$[N_2]$

Gas Chromatograph

$[N_2O]$ $[CH_4]$

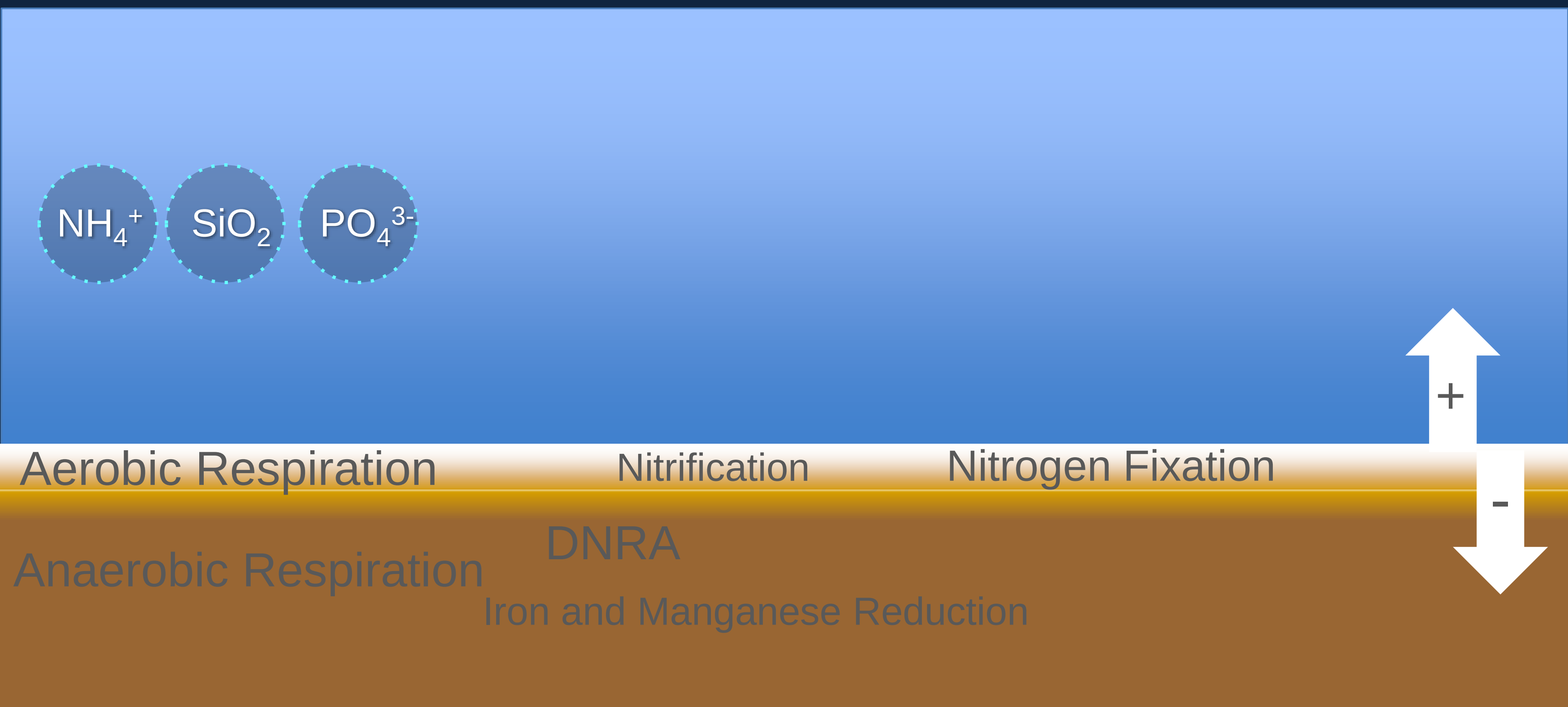
Hypoxic Static Core Experiments



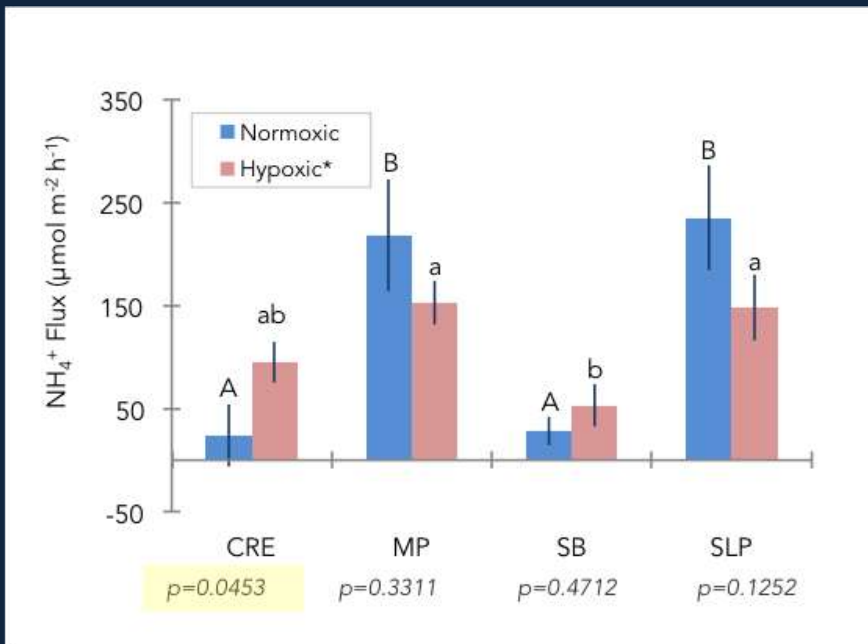


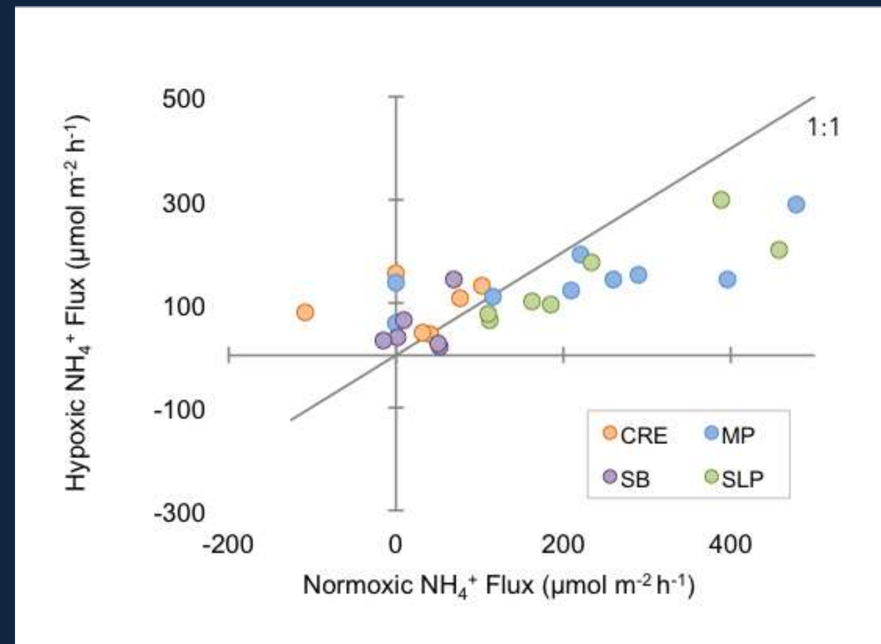
Sediments & Ecosystem Functions

- Nutrient Regeneration: NH_4^+, SiO_2, PO_4^{3-}



Sediment Ammonium (NH_4^+) Flux

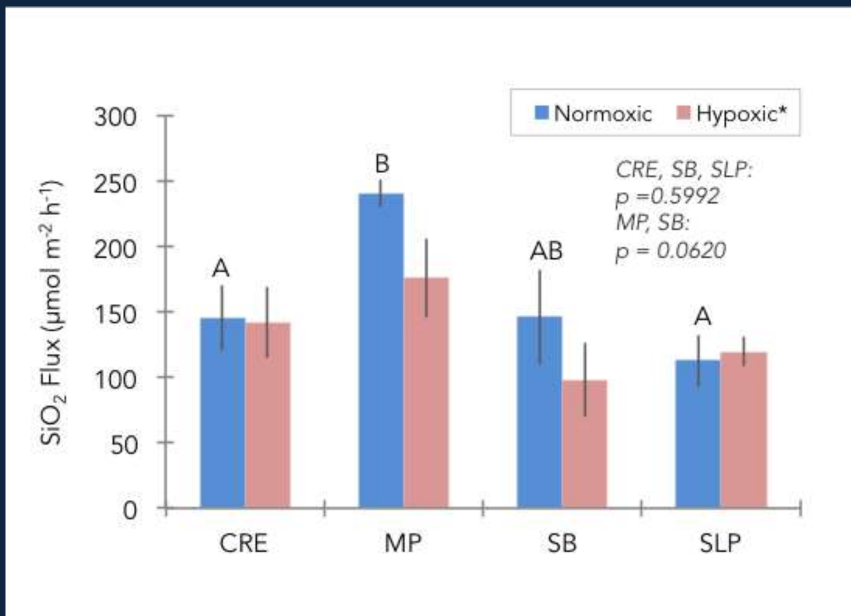


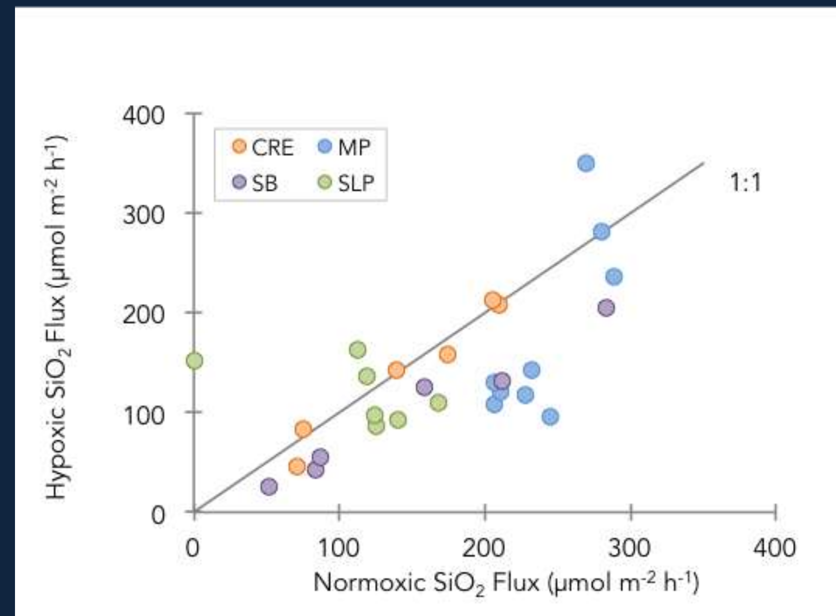


- <u>Hypoxic Effect</u>
  - Station grouped: only CRE (*p=0.0453*)
  - Individual cores: none *(p=0.3481)*
- <u>Station Effect</u>: Related to O_2 uptake

Foster and Fulweiler, *manuscript in preparation*

Sediment Silica (SiO_2) Flux

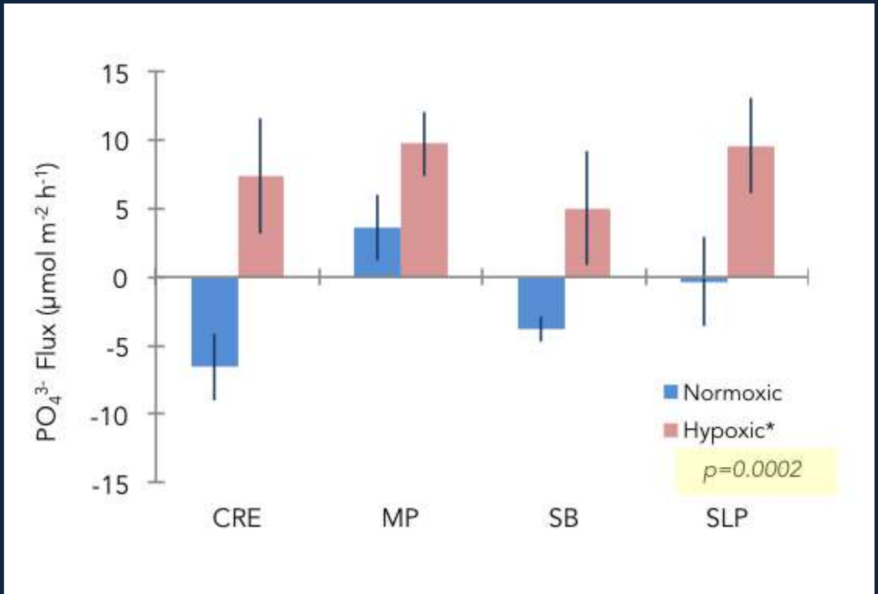


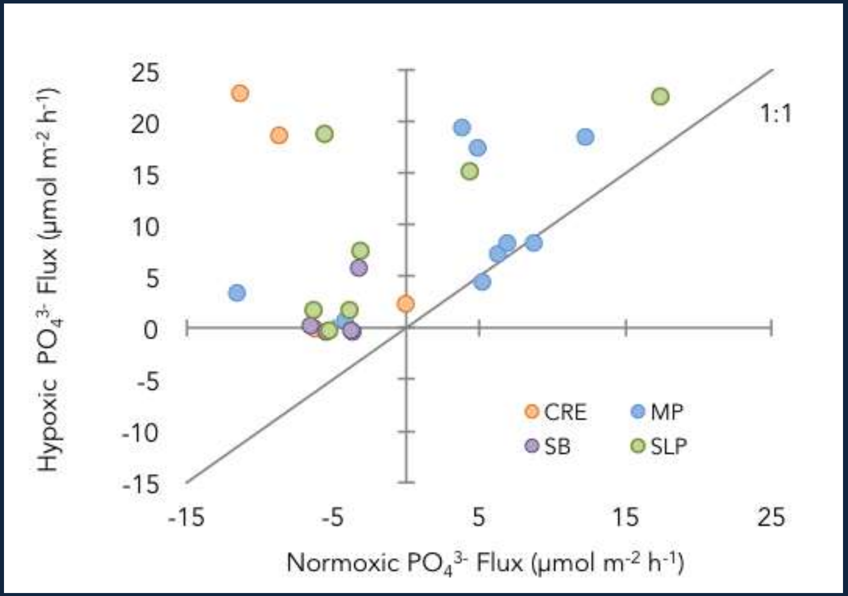


- <u>Hypoxic Effect</u>
  - Station grouped: none
  - Individual cores: hypoxic < normoxic *(p=0.0029)*
- <u>Station Effect</u>: MP highest normoxic rates

Foster and Fulweiler, *manuscript in preparation*

Sediment Phosphate (PO_4^{3-}) Flux



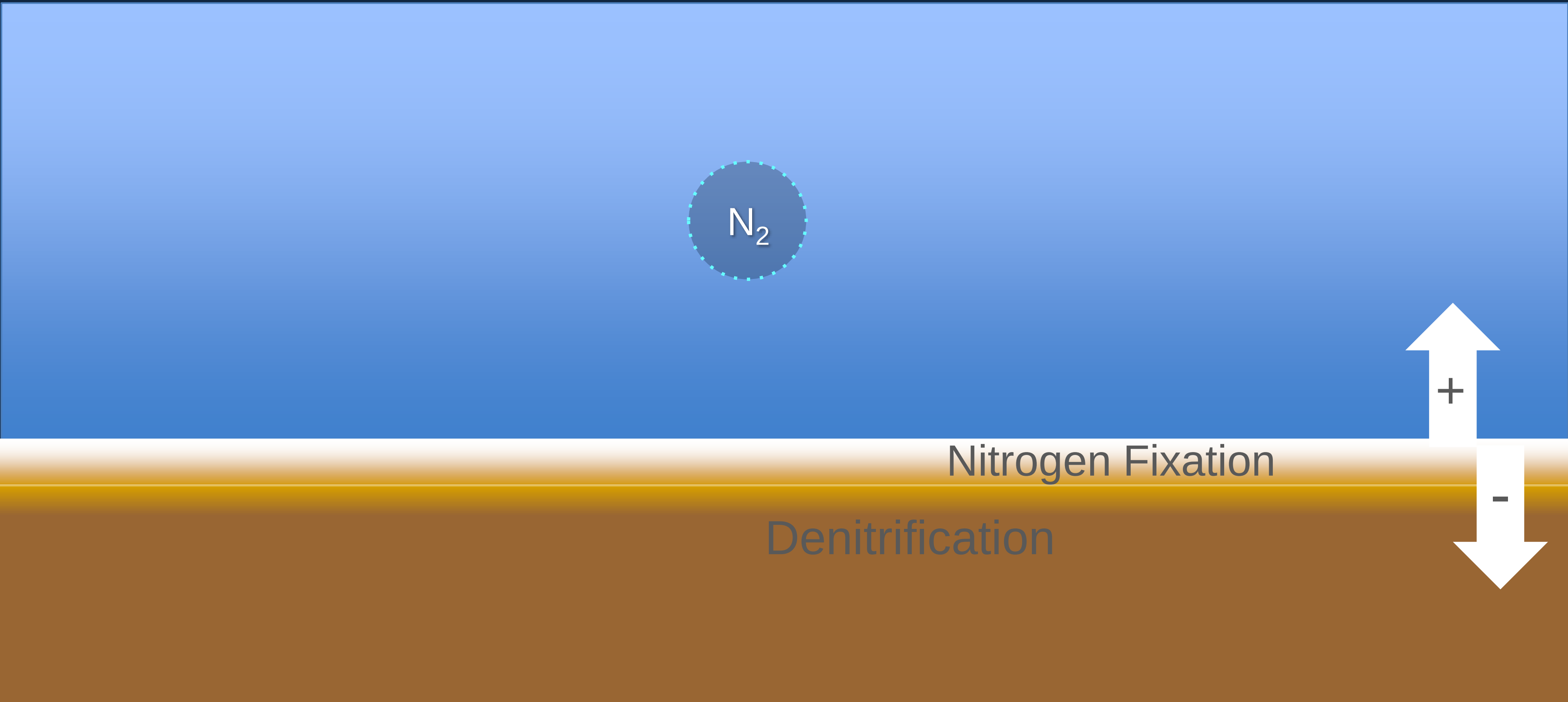


- <u>Hypoxic Effect</u>
  - Station grouped: hypoxic > normoxic *($p=0.0002$)*
  - Individual cores: hypoxic > normoxic *($p<0.0001$)*
- <u>Station Effect</u>: None

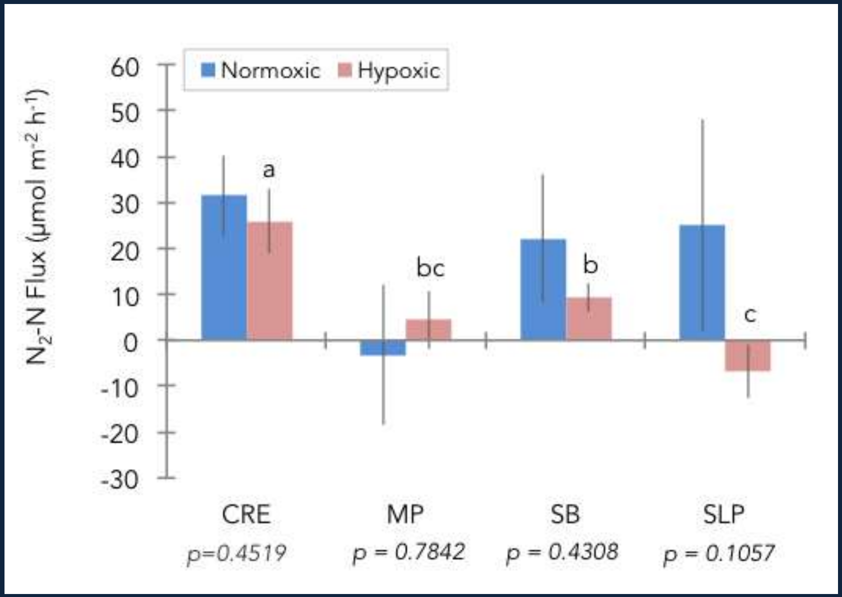
Foster and Fulweiler, *manuscript in preparation*

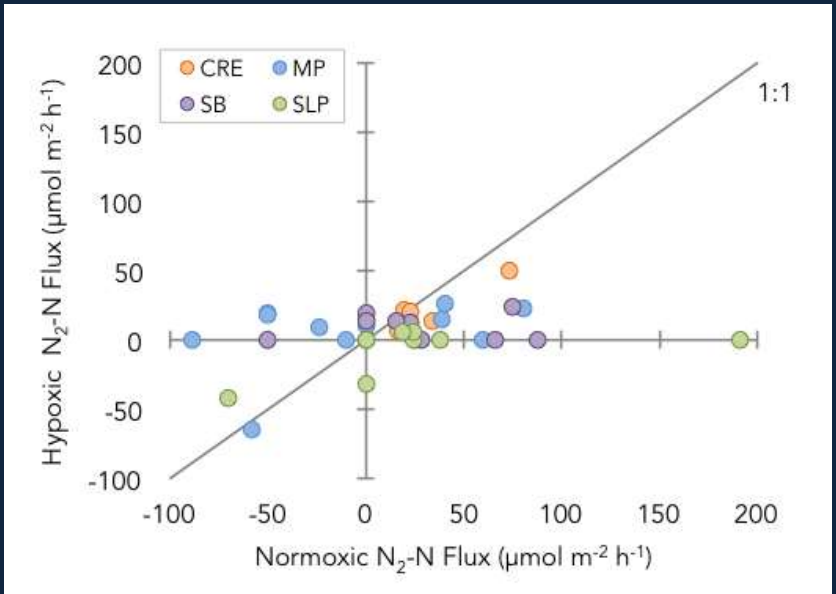
Sediments & Ecosystem Functions

- Removal of Reactive Nitrogen: N_2



Sediment Di-Nitrogen (N_2) Flux



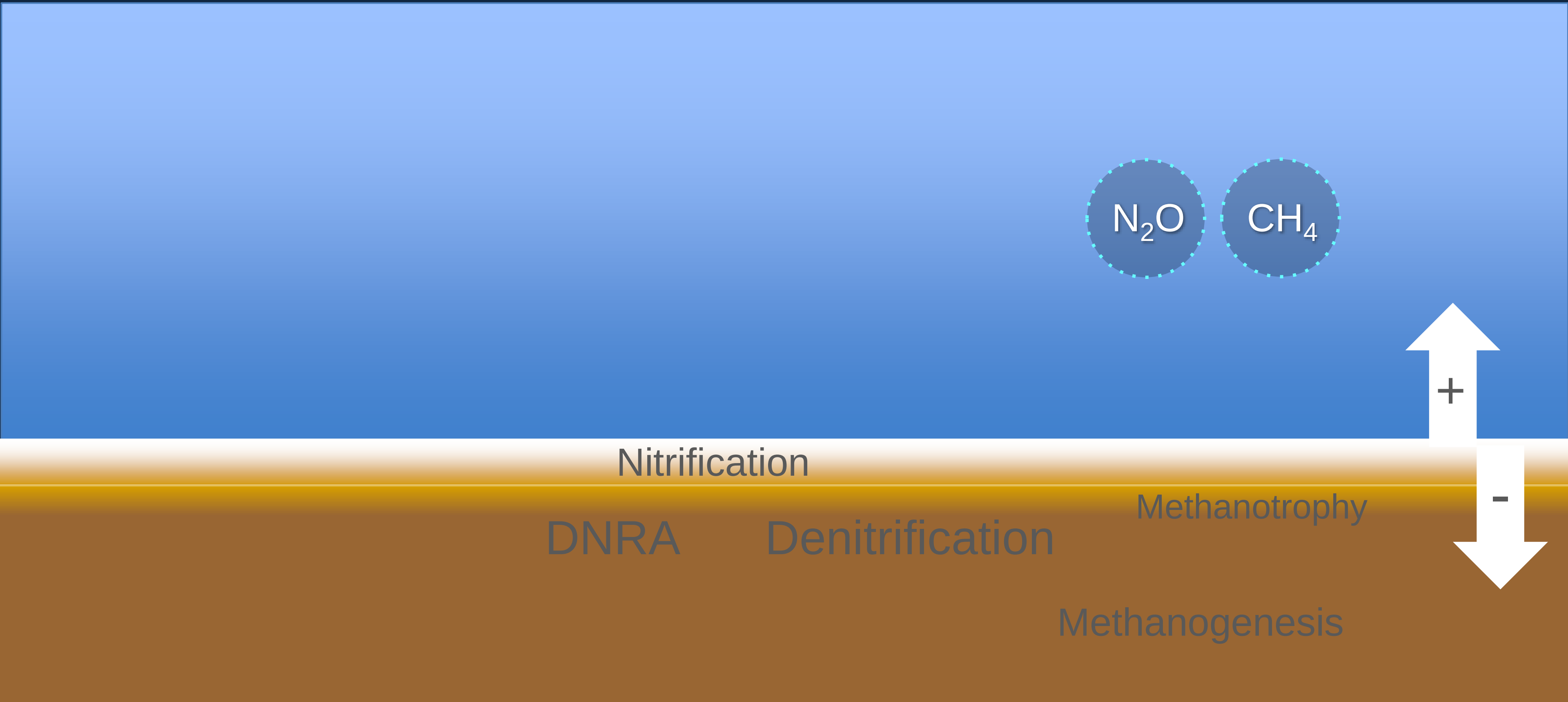


- <u>Hypoxic Effect</u>
  - Station grouped: none
  - Individual cores: none *($p=0.1778$)*
- <u>Station Effect</u>: CRE highest hypoxic fluxes, SLP lowest

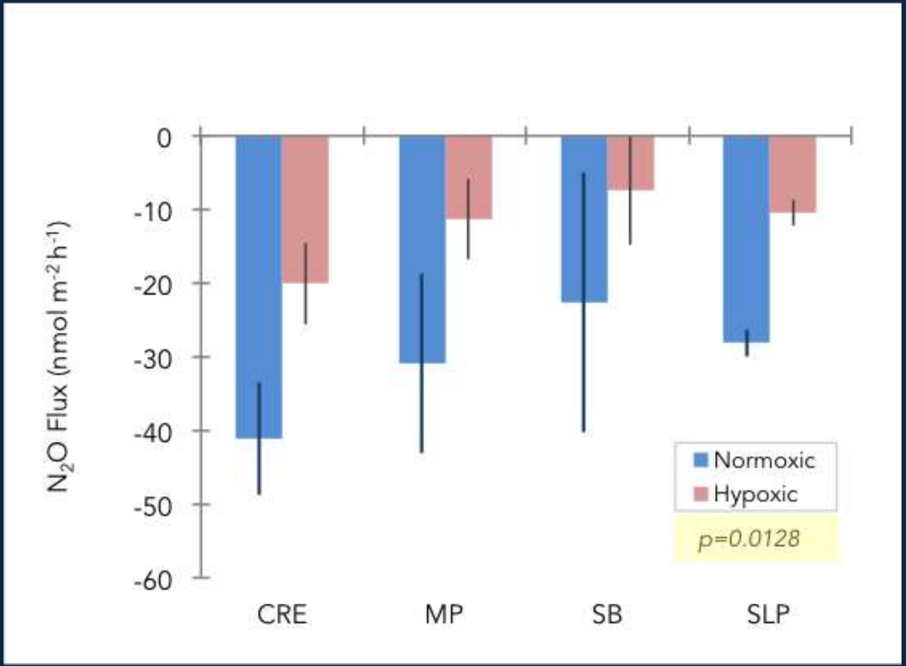
Foster and Fulweiler, *manuscript in preparation*

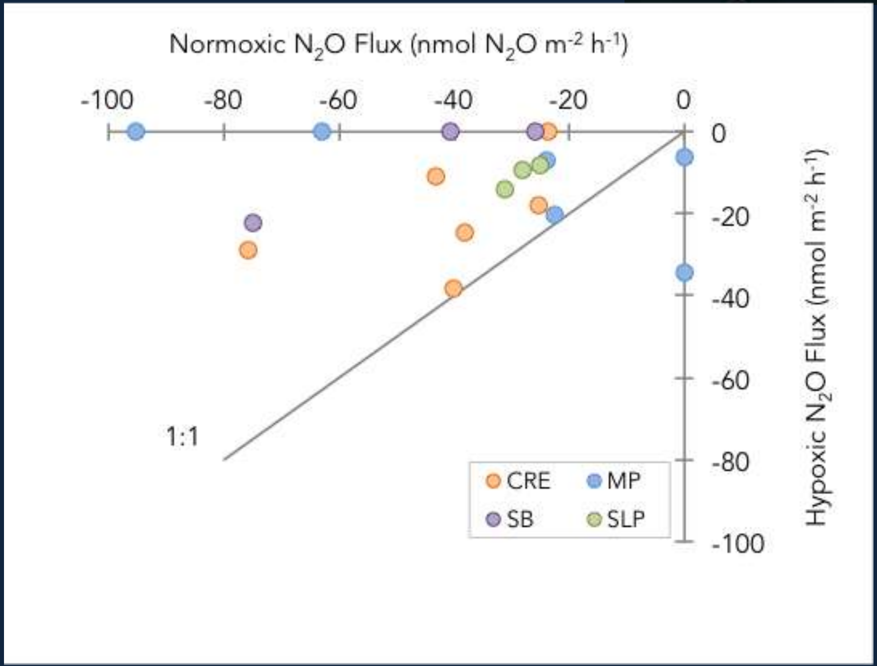
Sediments & Ecosystem Functions

- Regulation of Greenhouse Gases: N_2O, CH_4



Sediment Nitrous Oxide (N_20) Flux



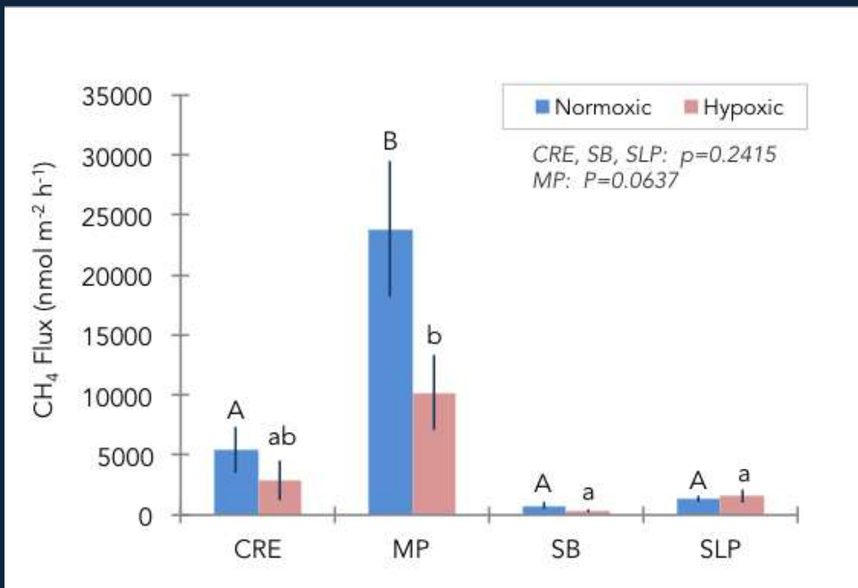


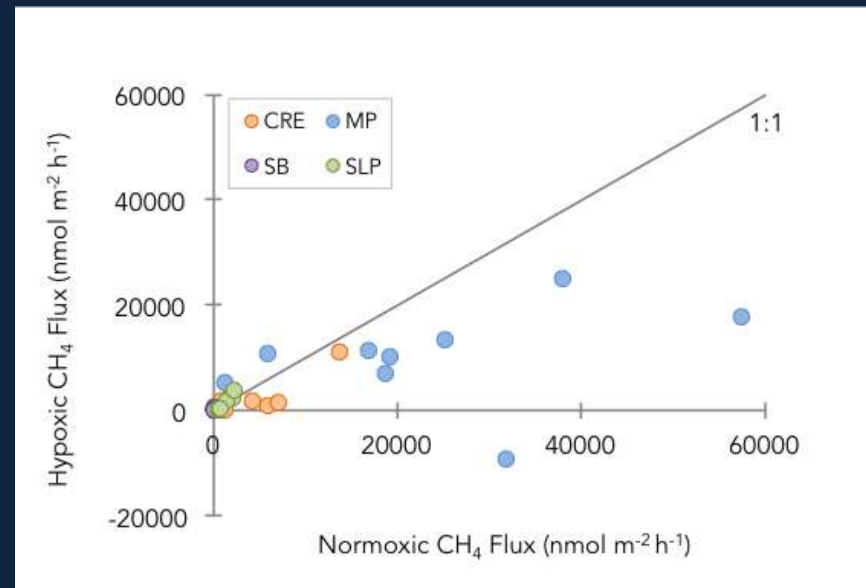
- Hypoxic Effect
  - Station grouped: uptake reduced by 57% *(p=0.0128)*
  - Individual cores: hypoxic uptake < normoxic *(p=0.0006)*

- Station Effect: None

Foster and Fulweiler, *manuscript in preparation*

Sediment Methane (CH_4) Flux



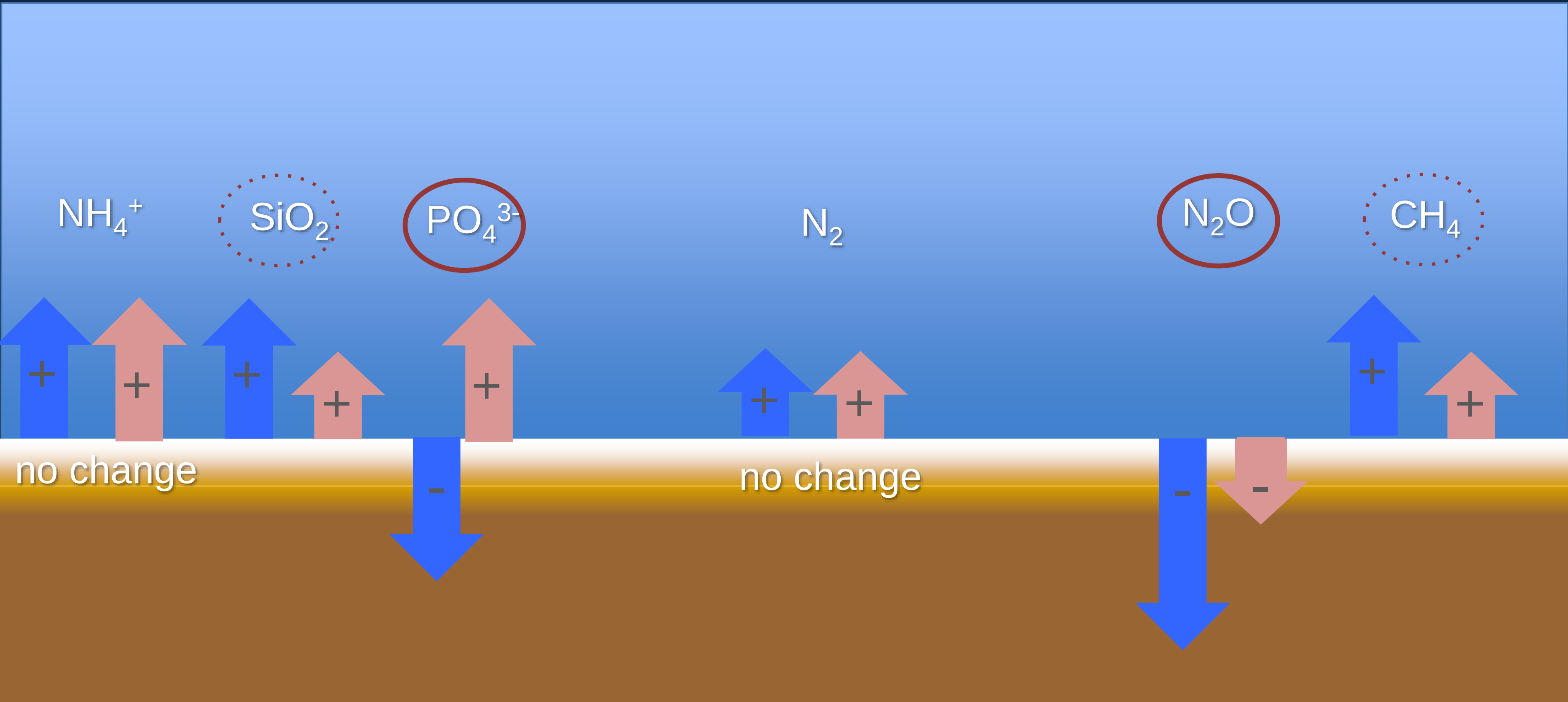


- <u>Hypoxic Effect</u>
  - Station grouped: none
  - Individual cores: hypoxic < normoxic *($p=0.0043$)*
- <u>Station Effect</u>: MP 100 – 1000x higher

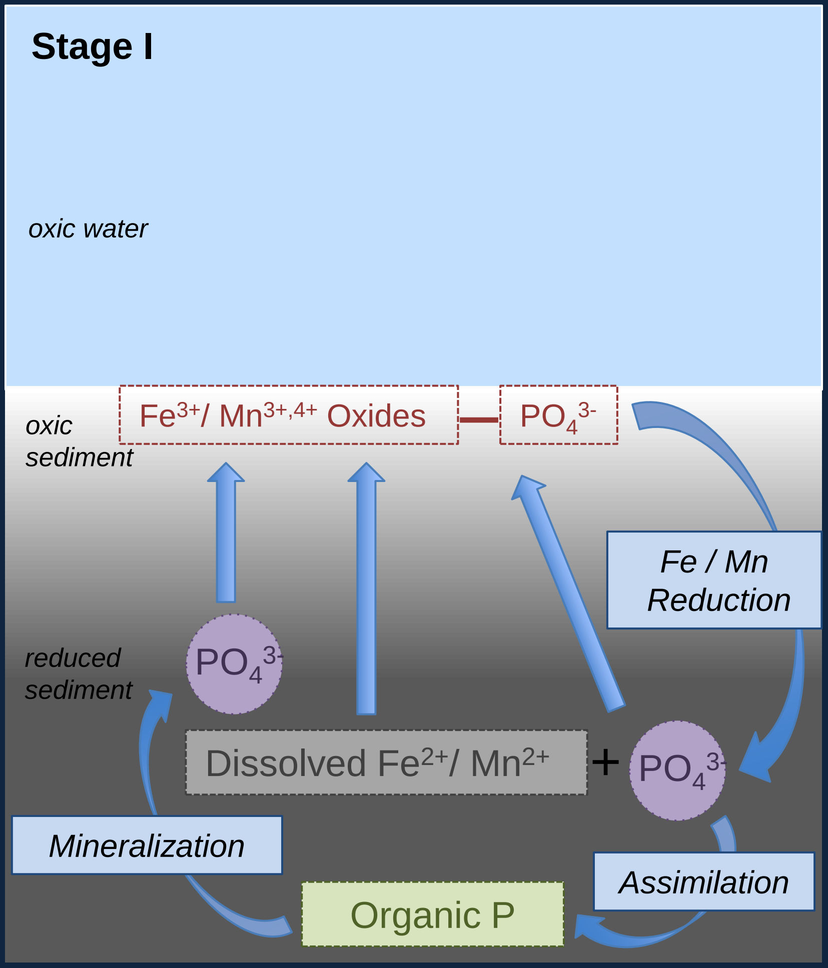
Foster and Fulweiler, *manuscript in preparation*

Hypoxia Impacts on Ecosystem Functions

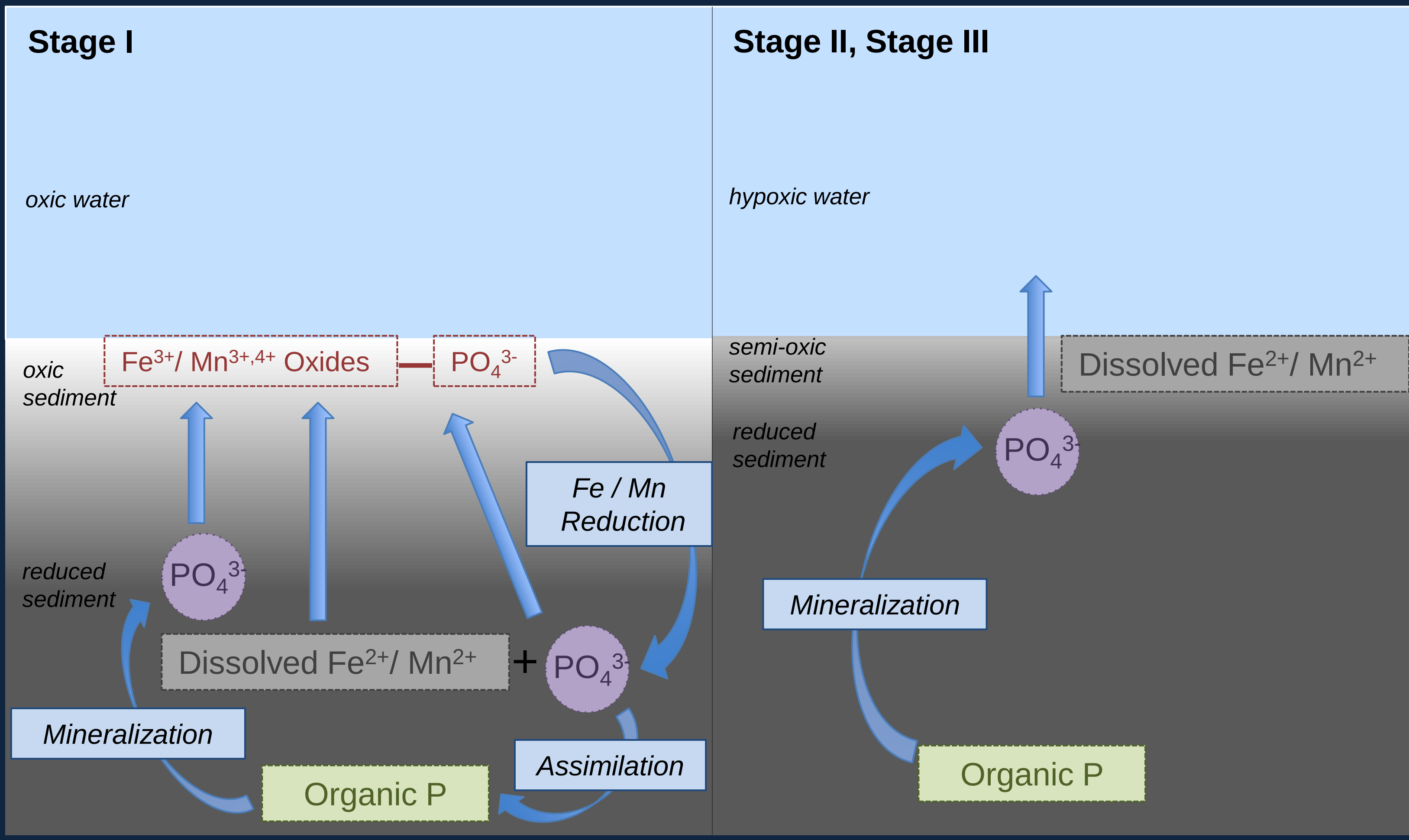
- Nutrient Regeneration: NH_4^+, SiO_2 , PO_4^{-3}
- Removal of Reactive Nitrogen: N_2
- Regulation of Greenhouse Gases: N_2O, CH_4



Hypoxia Impacts on Phosphate (PO_4^{3-}) Fluxes

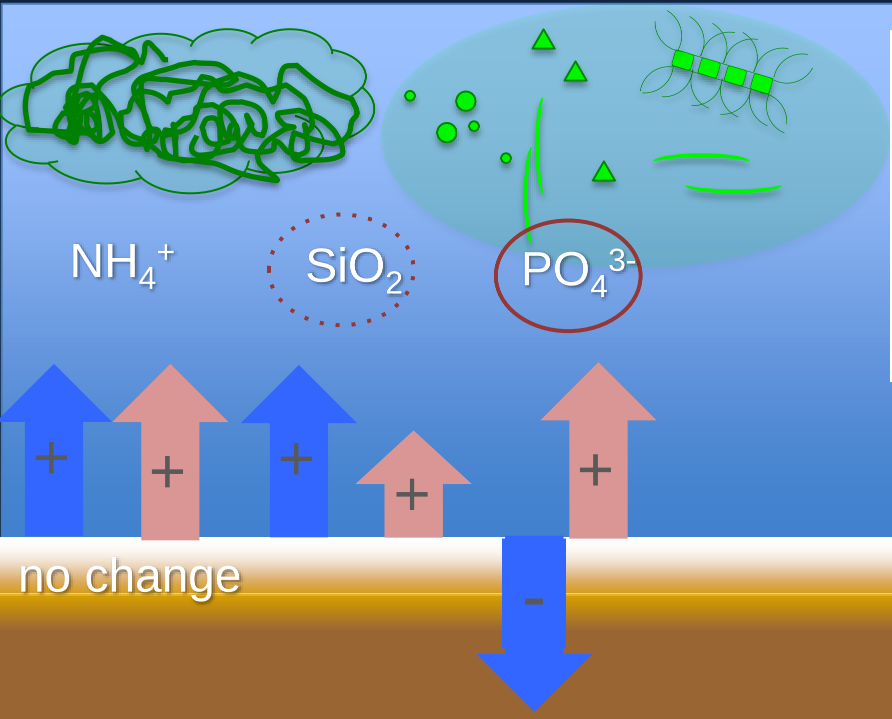


Hypoxia Impacts on Phosphate (PO_4^{3-}) Fluxes



Hypoxia Impacts on Ecosystem Functions

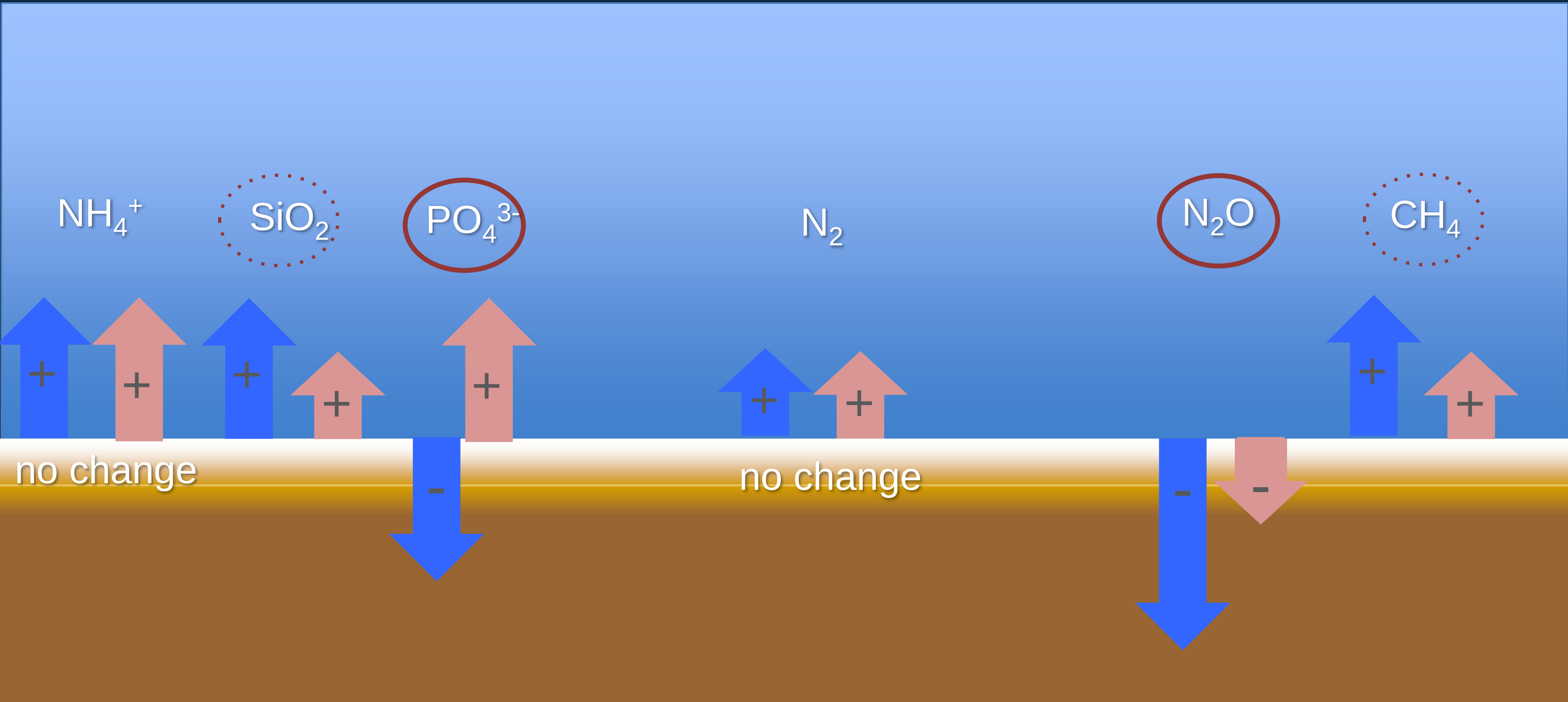
- Nutrient Regeneration → Ratios Altered
  - Impact rate of primary production
  - Change primary producer community structure
  - Impact microbial processes in sediments



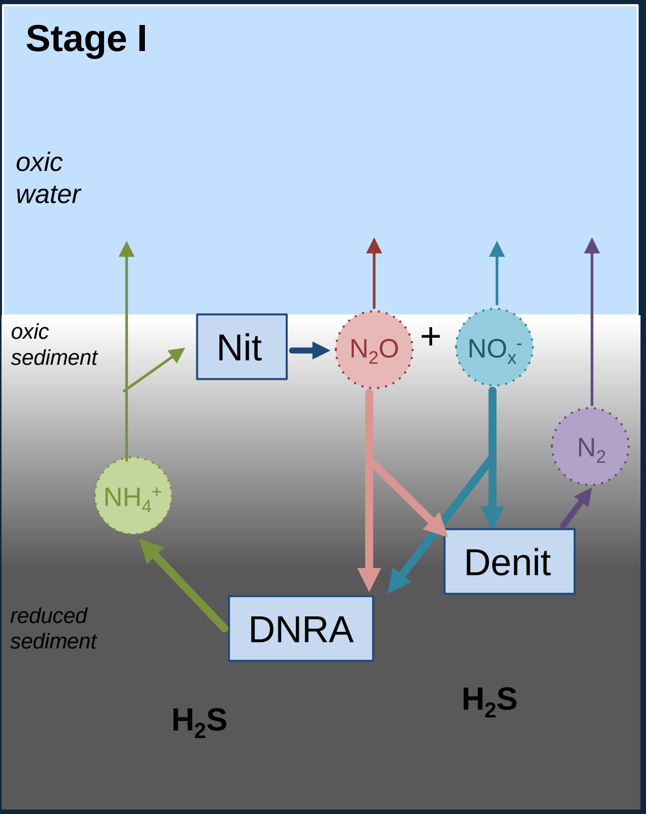
Ratio	Normoxic	Hypoxic	Difference	p
N:P	34.6	17.5	49%	0.0008
Si:P	49.6	25.4	49%	0.0035
N:Si	0.62	0.64	3%	0.4233

Hypoxia Impacts on Ecosystem Functions

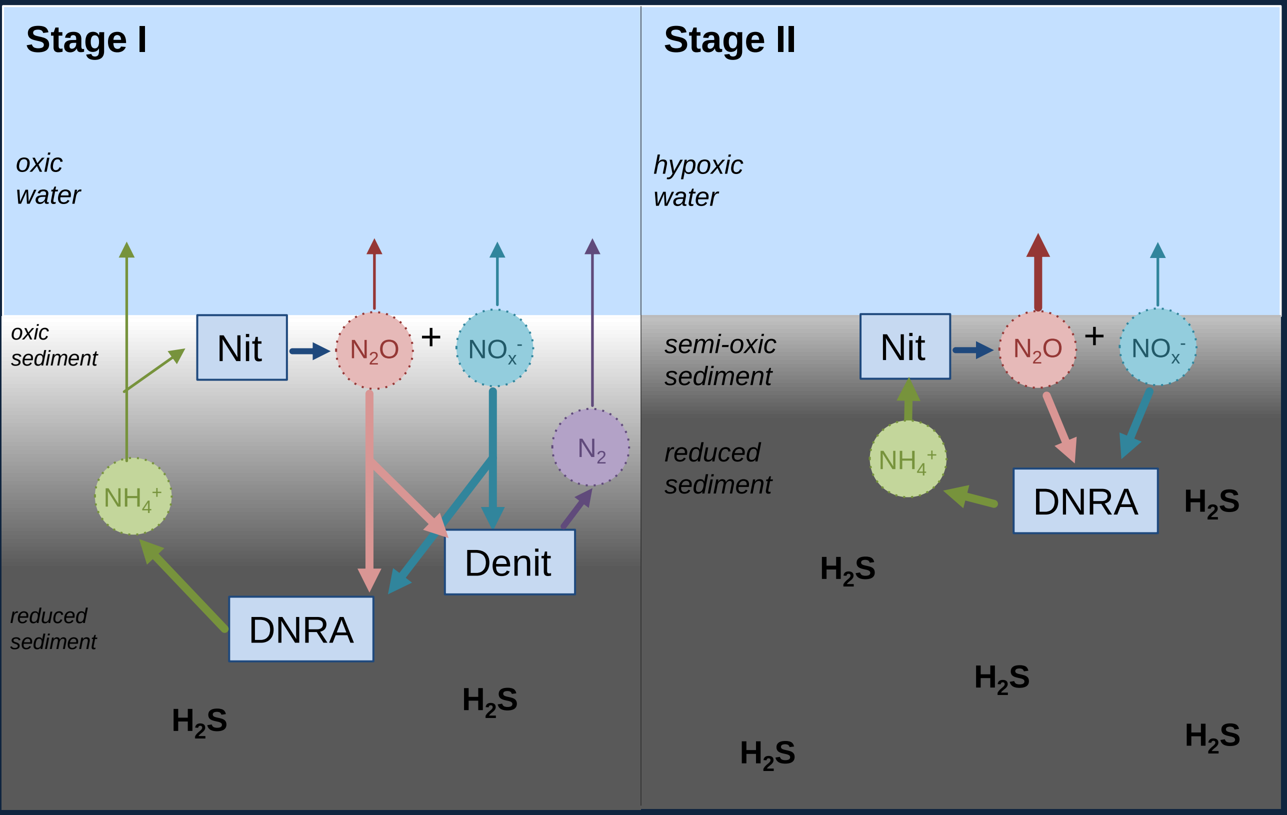
- Nutrient Regeneration: NH_4^+, SiO_2 , PO_4^{-3}
- Removal of Reactive Nitrogen: N_2
- Regulation of Greenhouse Gases: N_2O, CH_4



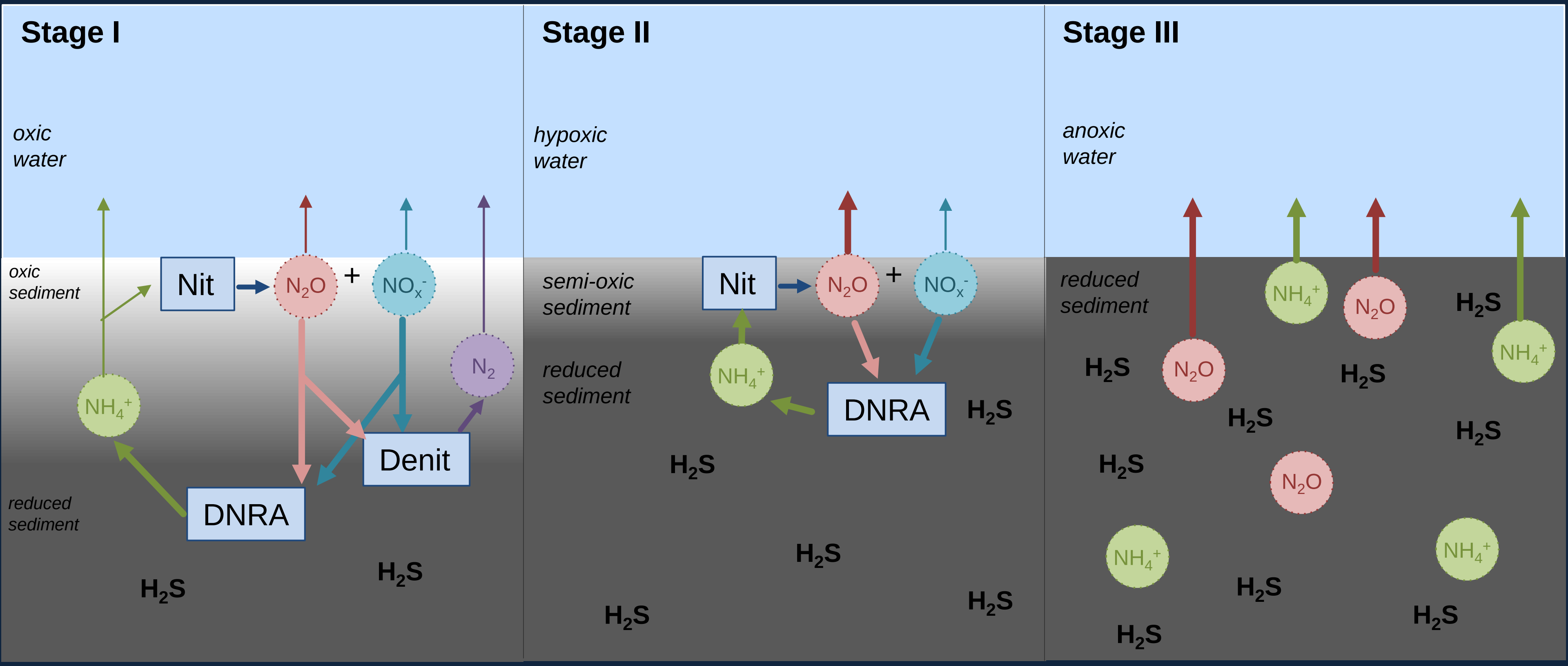
Hypoxia Impacts on Nitrous Oxide (N_2O) Fluxes



Hypoxia Impacts on Nitrous Oxide (N_2O) Fluxes

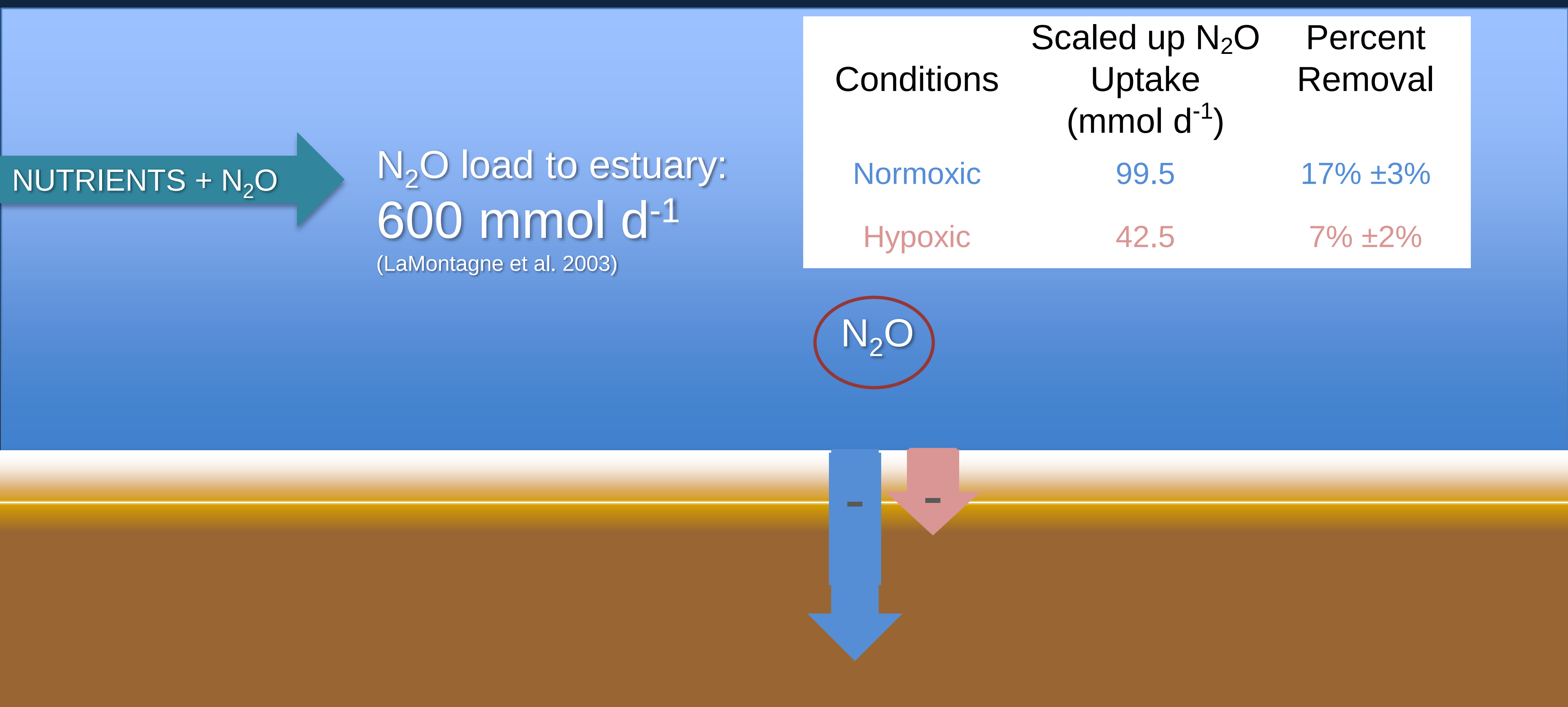


Hypoxia Impacts on Nitrous Oxide (N_2O) Fluxes



Hypoxia Impacts on Ecosystem Functions

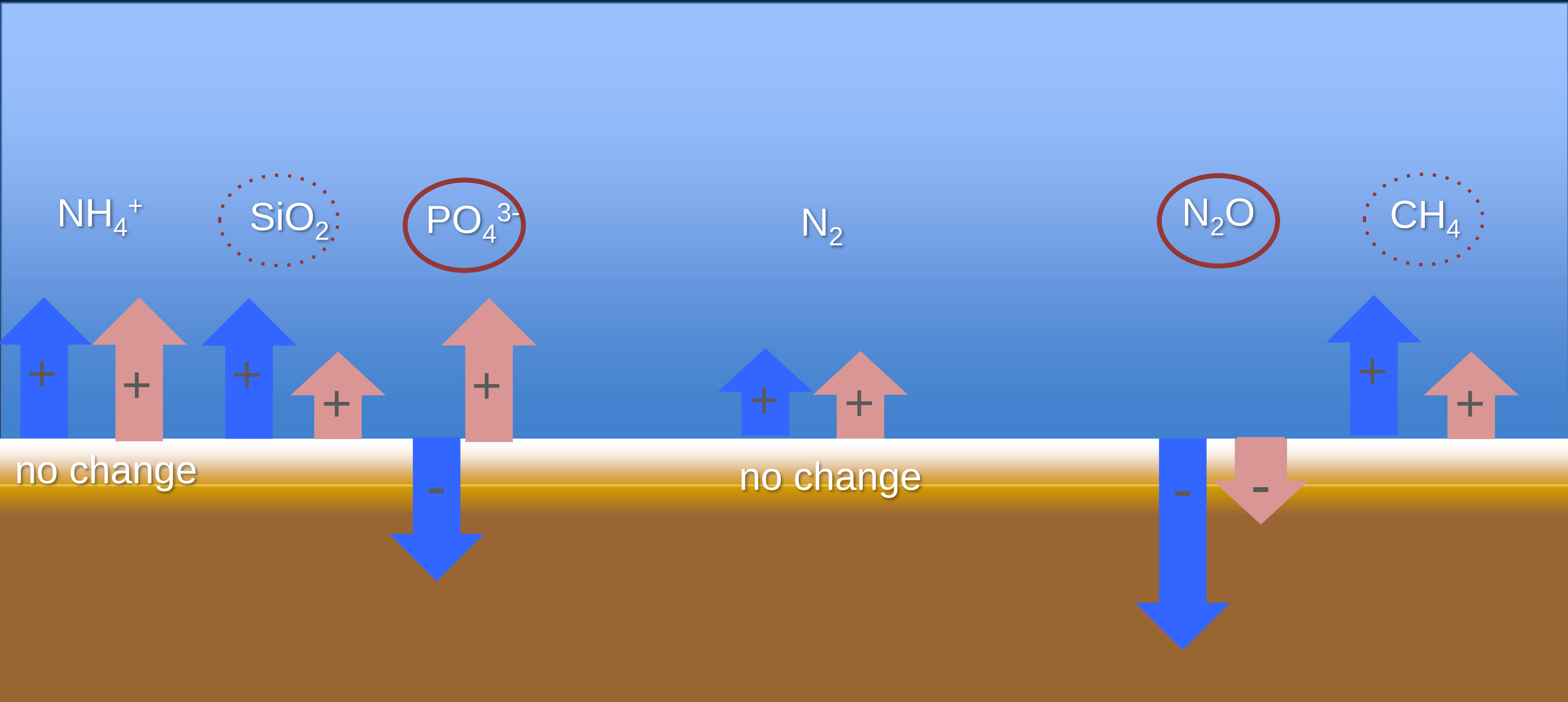
- Regulation of Greenhouse Gases → N_2O uptake decreased
  - Diminished ecosystem service



Conditions	Scaled up N_2O Uptake (mmol d^{-1})	Percent Removal
Normoxic	99.5	17% ±3%
Hypoxic	42.5	7% ±2%

Hypoxia Impacts on Ecosystem Functions

- Nutrient Regeneration: NH_4^+, SiO_2, PO_4^{-3}
- Removal of Reactive Nitrogen: N_2
- Regulation of Greenhouse Gases: N_2O, CH_4



Implications for Waquoit Bay

- Short-term mild hypoxia alters some sediment fluxes
- BUT some processes are resilient!
- Import to establish specific hypoxic thresholds

Acknowledgements

- Field and Lab:

  Waquoit Bay National Estuarine Research Reserve (WBNERR)

  Chris Weidman, MaryKay Fox, Alison Lescher, Jordan Mora, Jim Rassman

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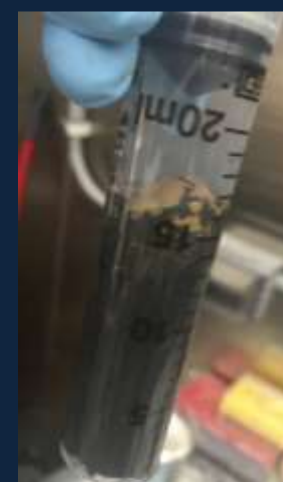
Questions or Comments?





Contact: sqfoster@bu.edu