

Diazotroph activity across the New England shelf-break front

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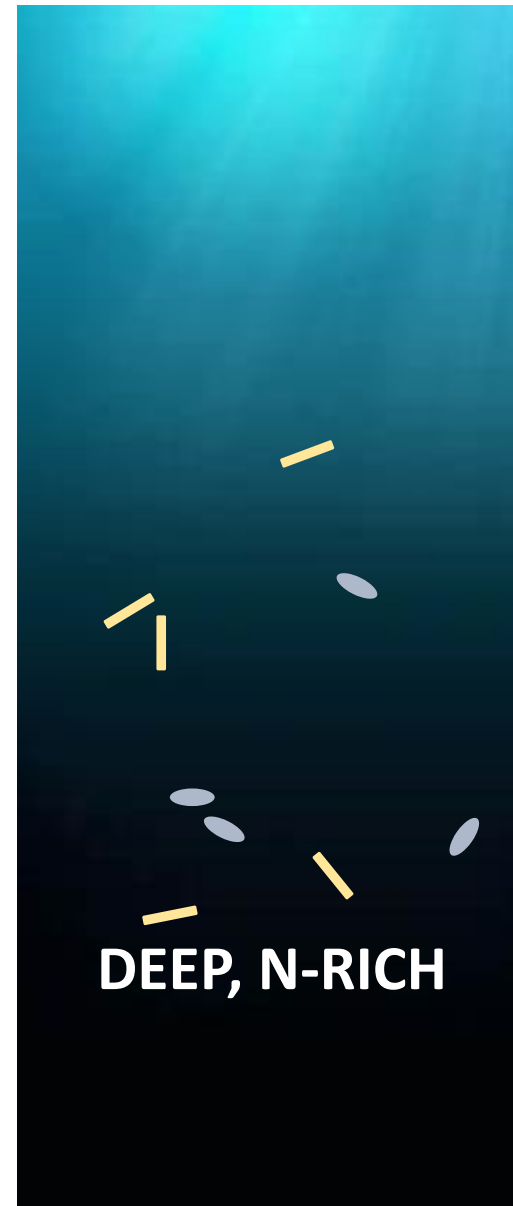
¹Old Dominion University, Norfolk, VA ²Woods Hole Oceanographic Institute, Woods Hole, MA



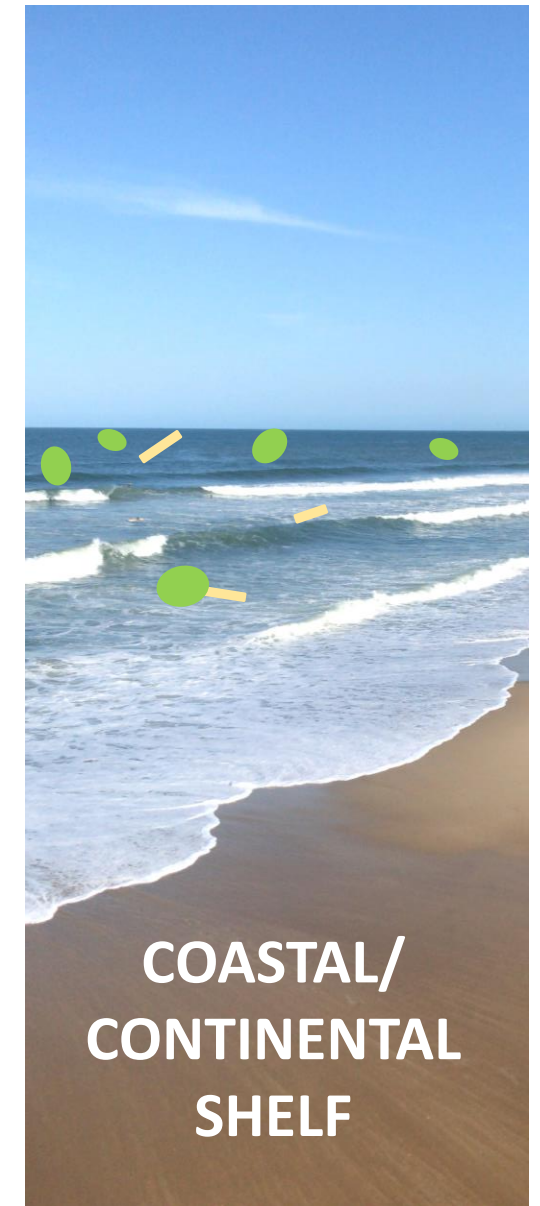
Capone et al. 2008 *NITME*



e.g., Blais et al. 2012 *GBC*

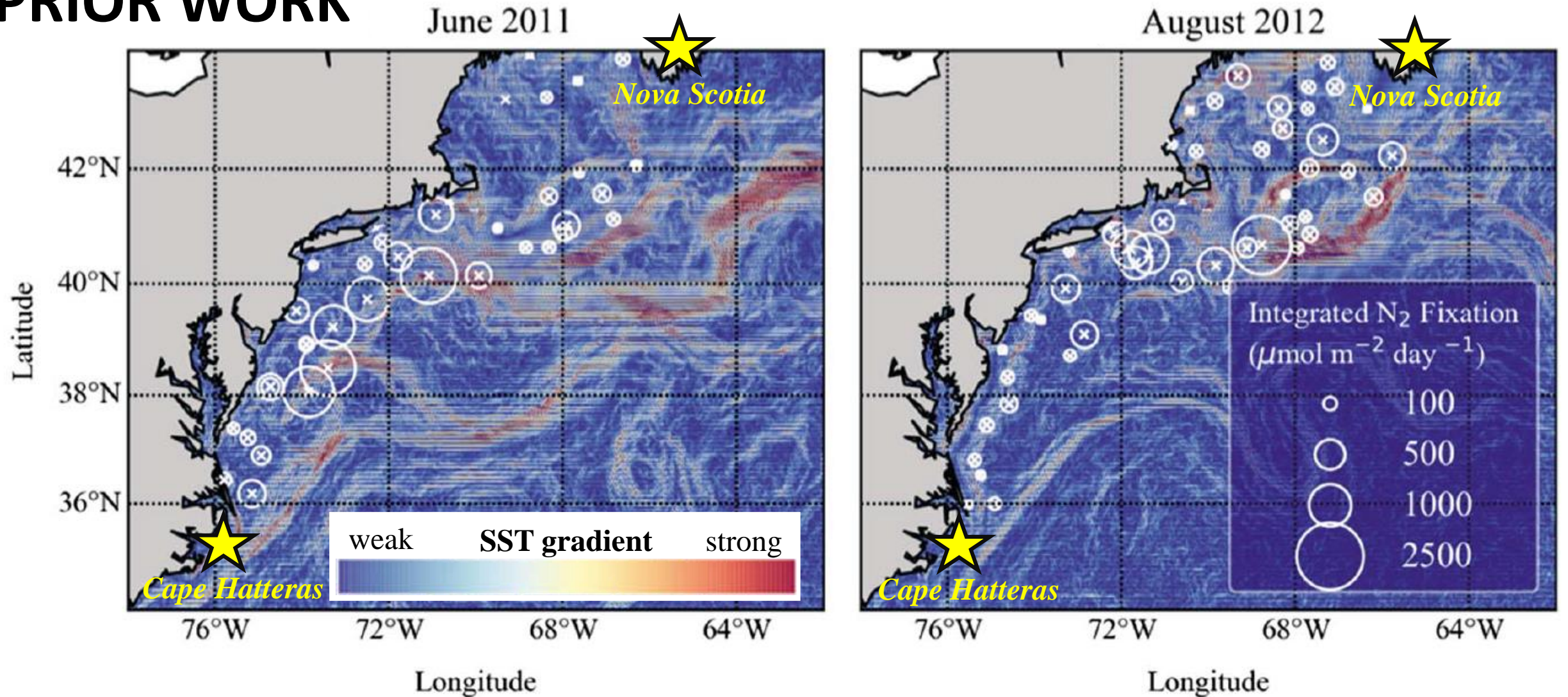


Moisander et al. 2017
Front. Microbiol.



e.g., Mulholland et al.
2012 *L&O*

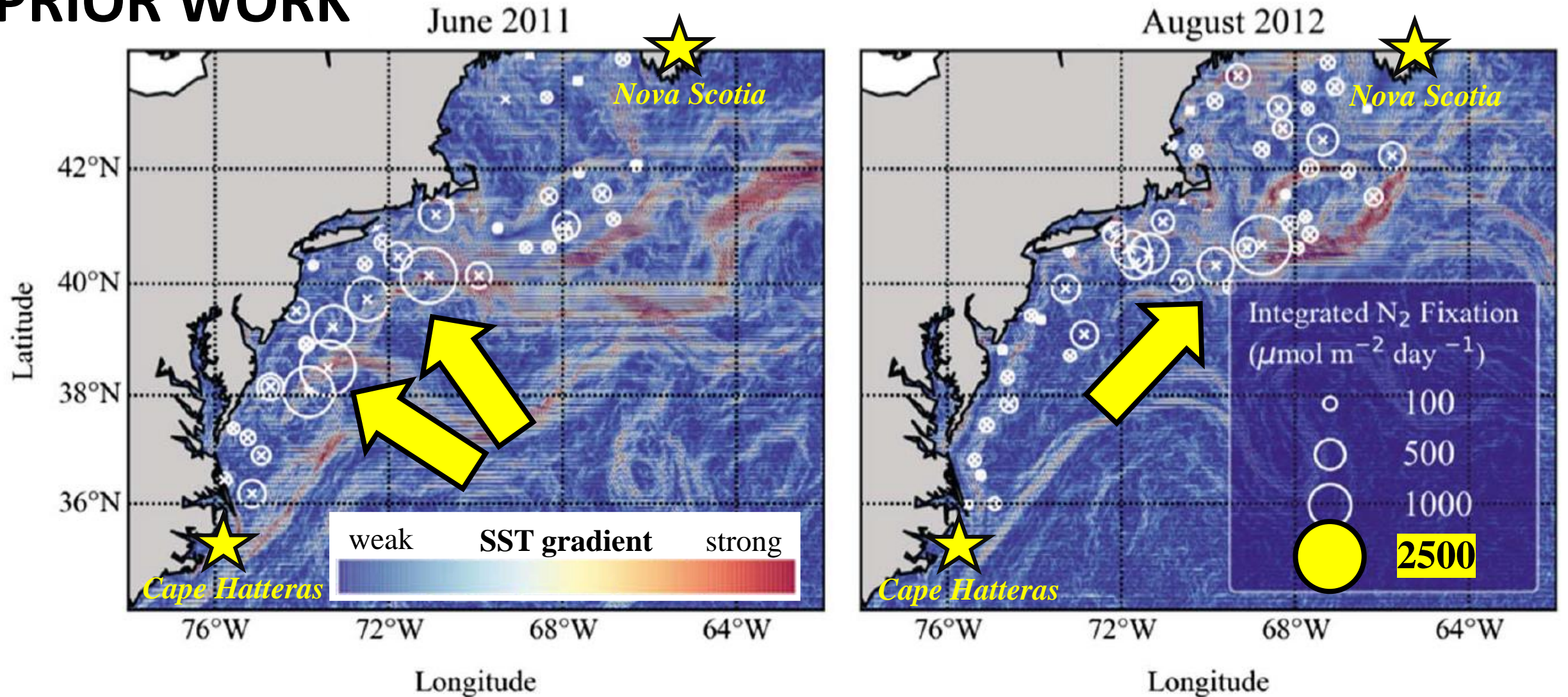
PRIOR WORK



- Seven cruises spanning four seasons on the western North Atlantic continental shelf

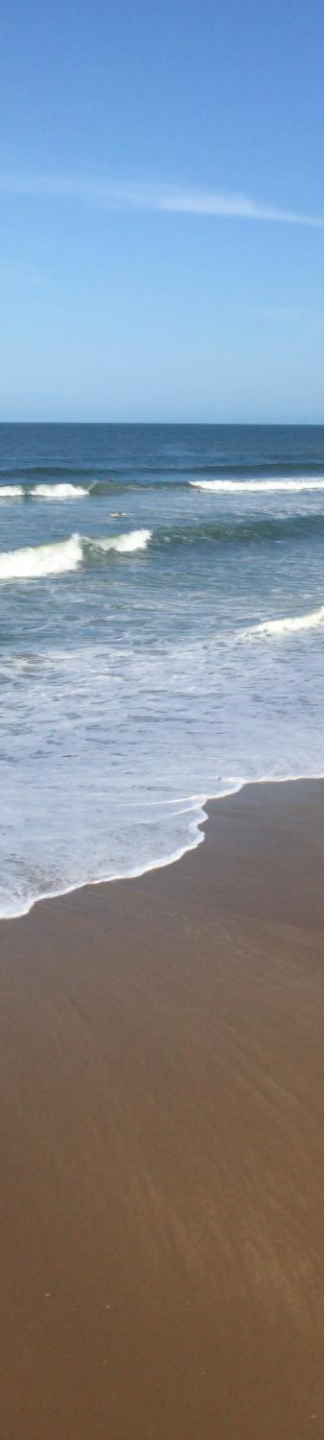
Mulholland et al., 2019 GBC

PRIOR WORK



- Portion of shelf (6.4% of total area) contributes $\sim 0.02 \text{ Tmol N yr}^{-1}$ —equivalent to previous estimate for entire shelf (Nixon et al. 1996 *Biogeochem.*)

Mulholland et al., 2019 GBC

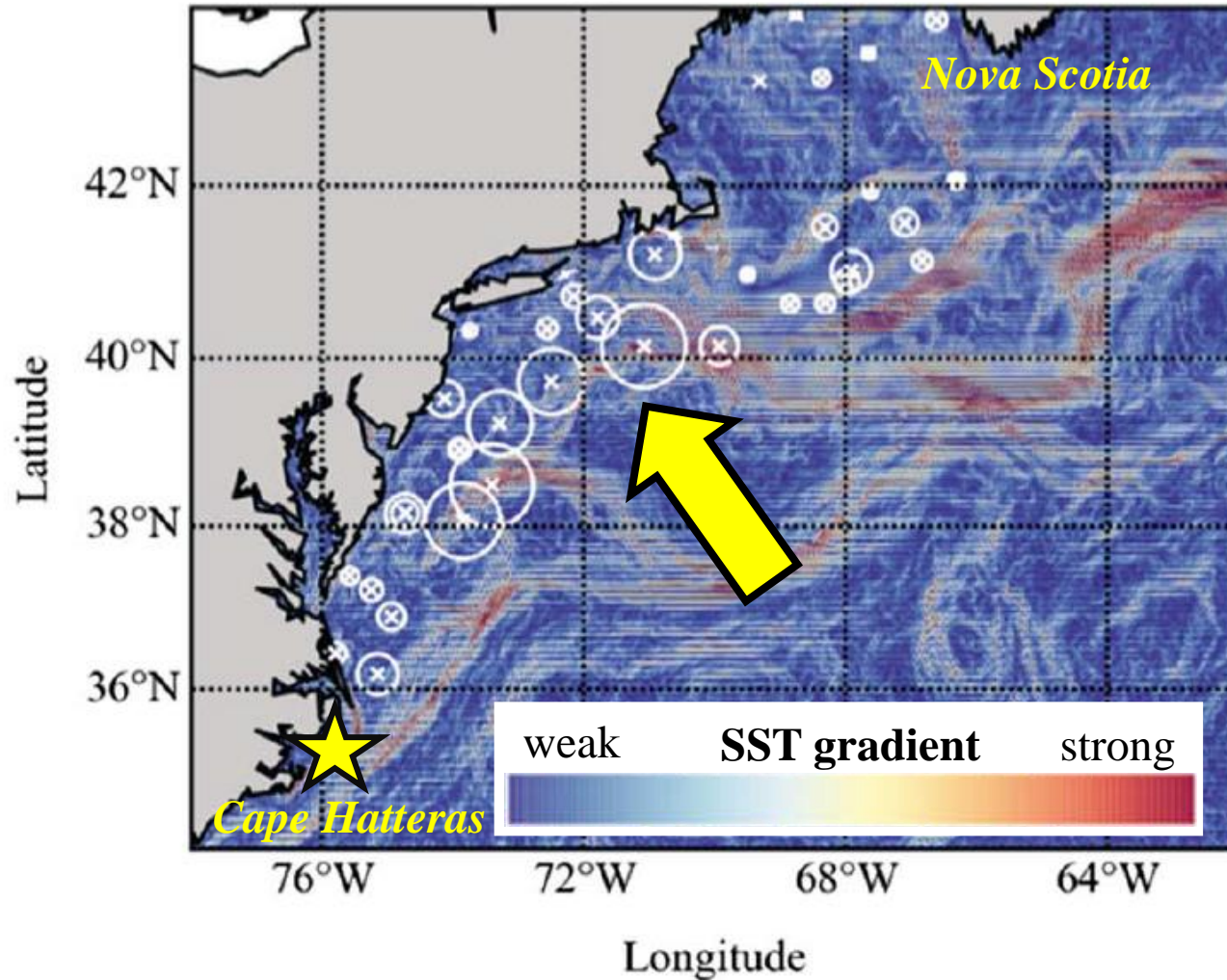


- What physical factors drive the high N_2 fixation rates (NFR) observed in this region?
- Does water mass mixing enhance diazotroph activity at the shelf-break front?
- What physical and chemical factors regulate diazotroph biogeography across the front?
 - Which major groups are active here?
 - What are their ranges and sensitivities?
- Do (sub)mesoscale physical features affect diazotroph community composition, diversity, or activity?

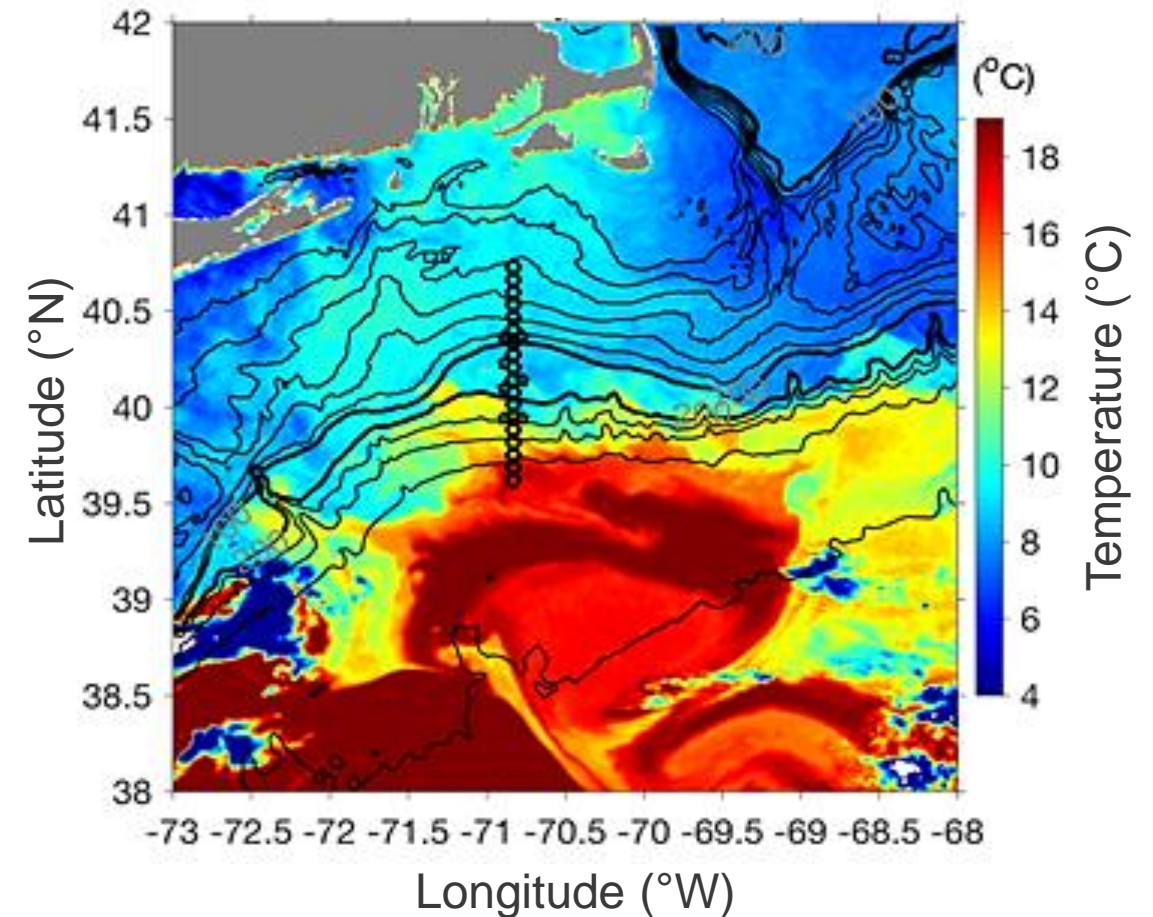
[Sequencing data coming soon...!]

STUDY SITE

Mulholland et al., 2019 GBC



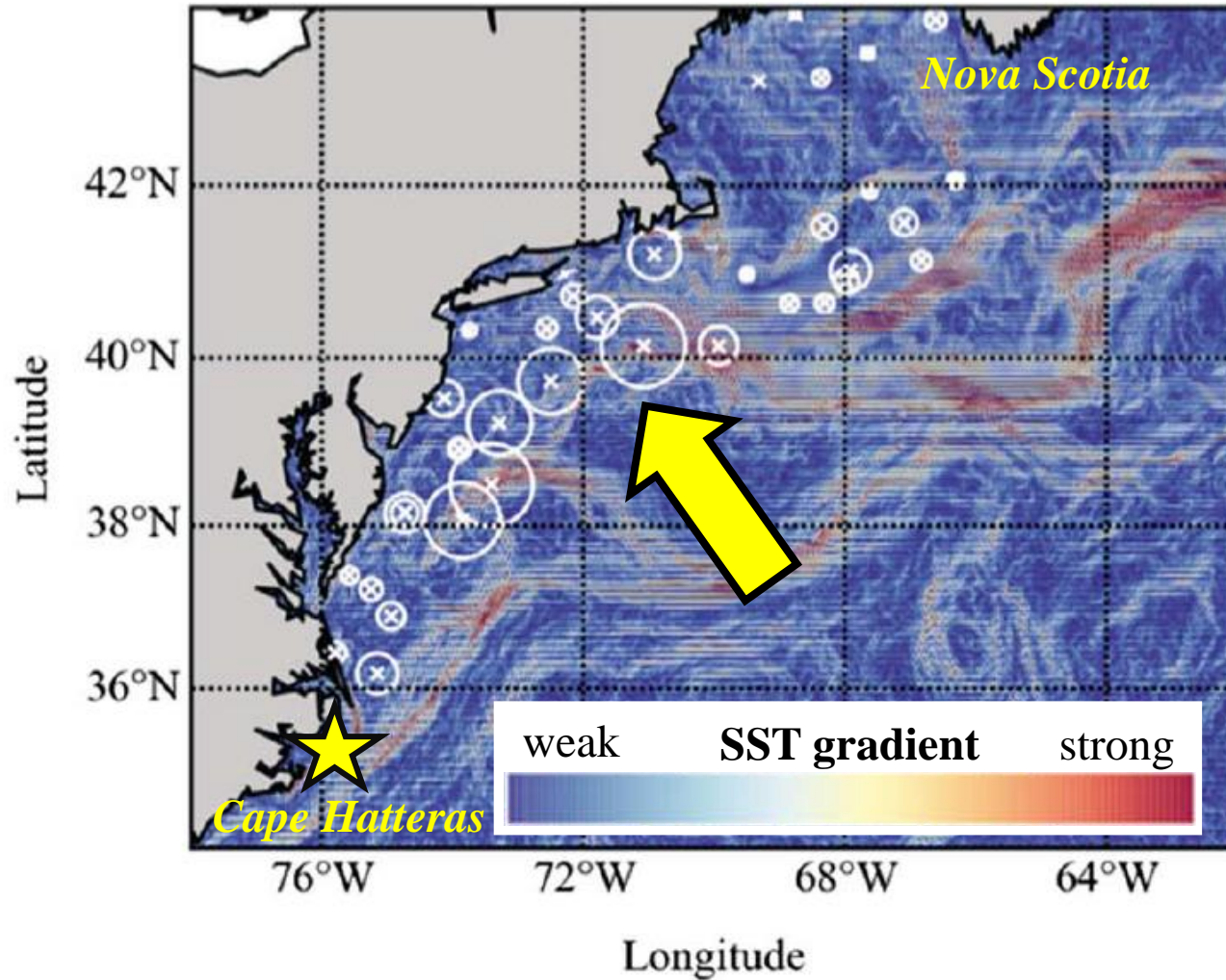
NOAA-19 SST, Rutgers Coastal Ocean Observation Lab; courtesy of W. Zhang (WHOI)



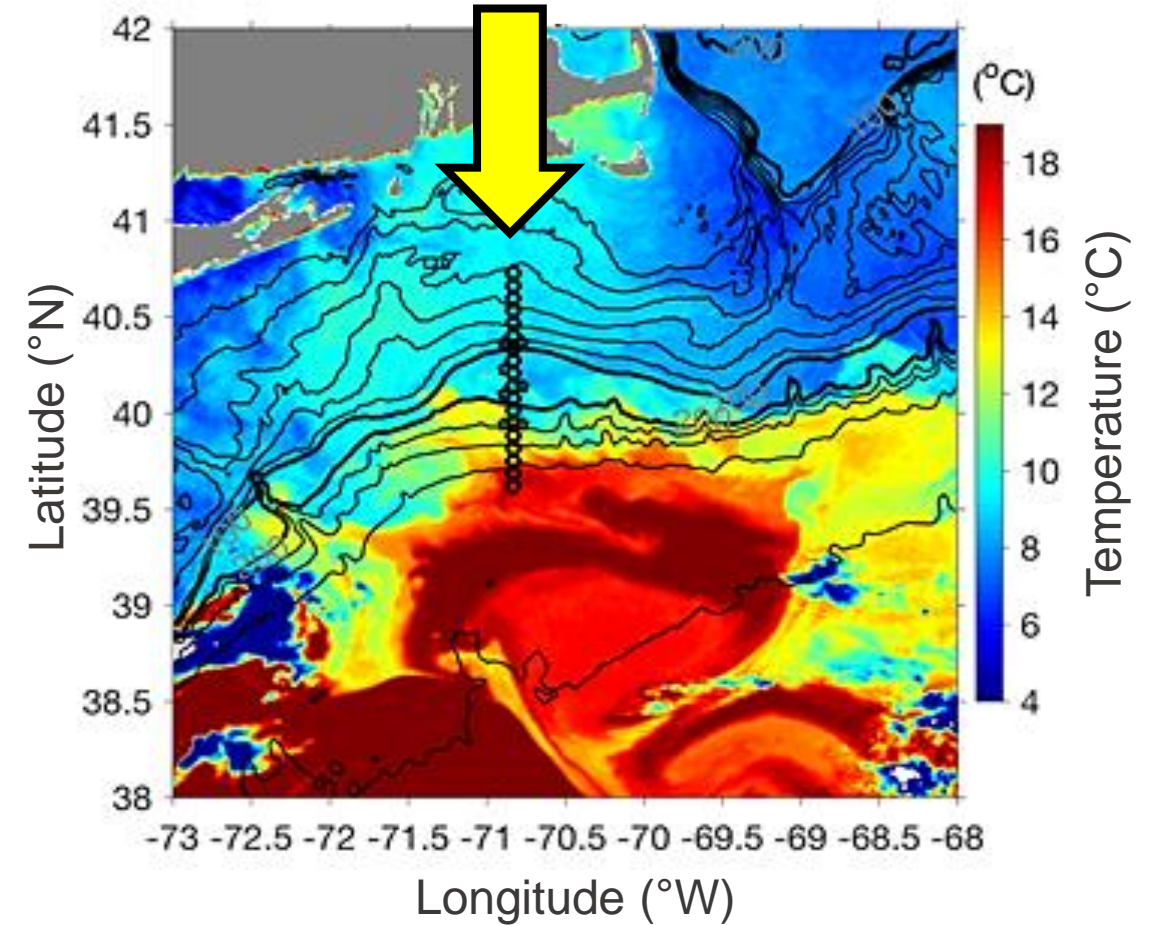
- Two 14-day cruises across shelf-break front: spring (May 2019, *NOAA vessel Ron Brown*) and summer (July 2019, *R/V Thompson*)

STUDY SITE

Mulholland et al., 2019 GBC



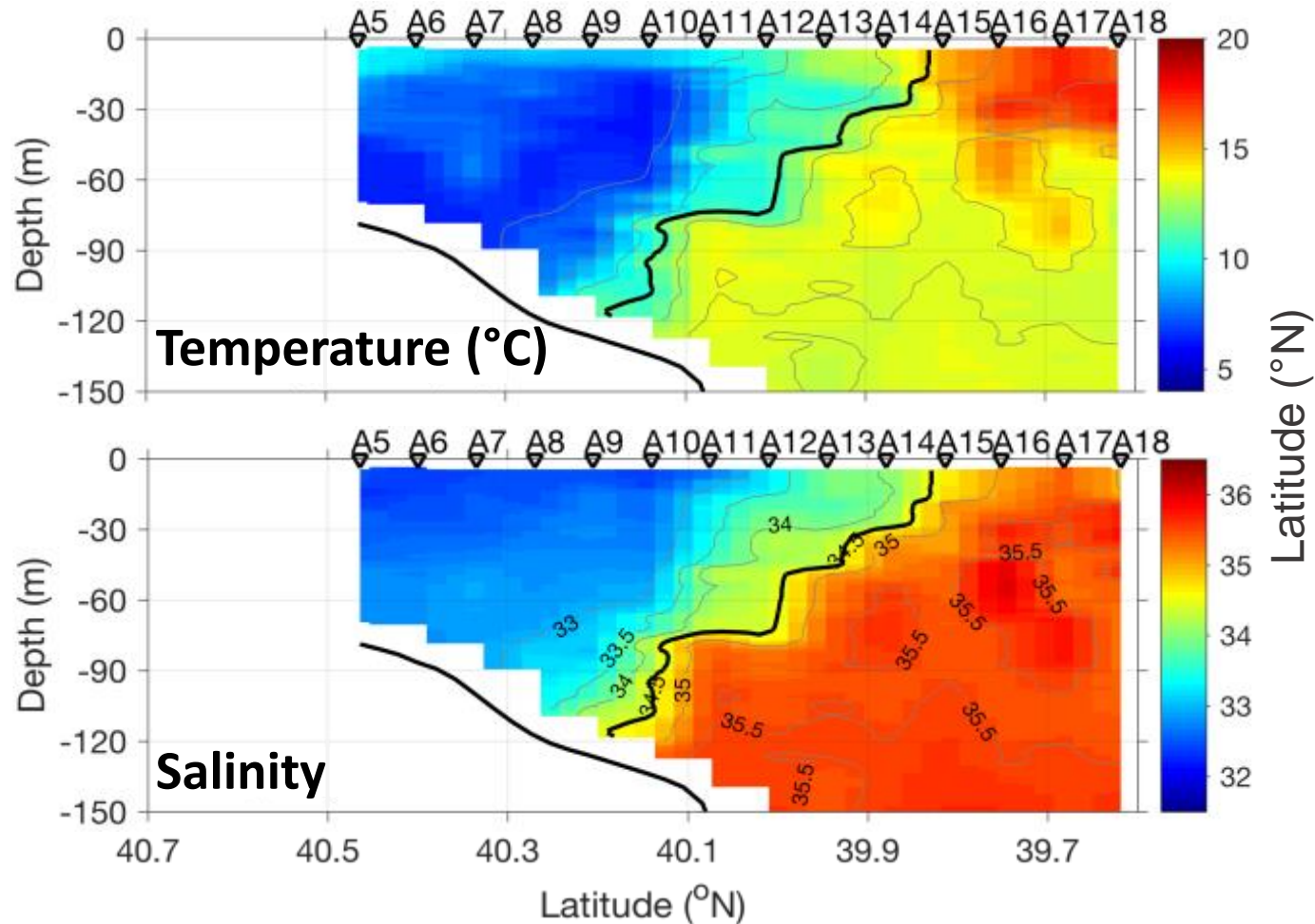
NOAA-19 SST, Rutgers Coastal Ocean Observation Lab; courtesy of W. Zhang (WHOI)



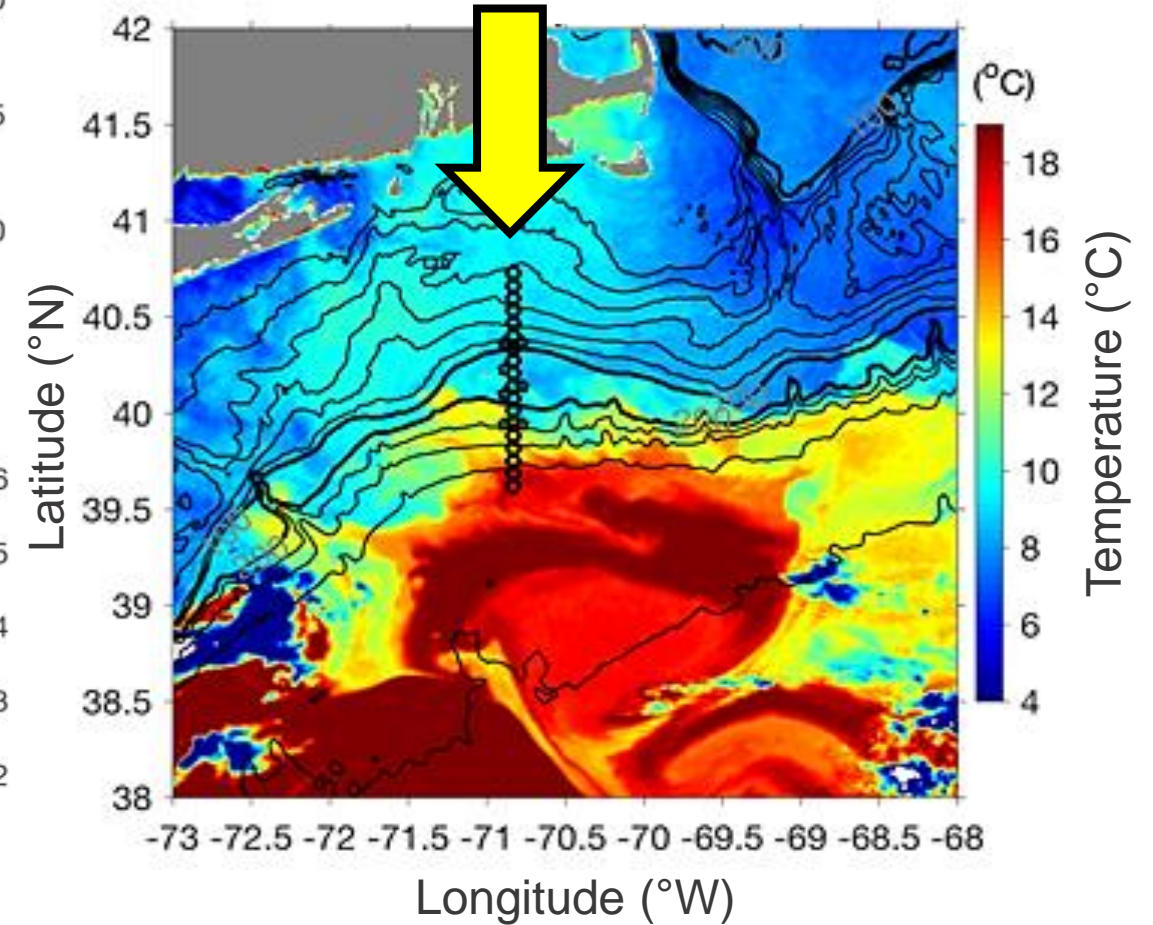
- Repeatedly occupied stations extending across the shelf-break front aligned with the Ocean Observatories Initiative Pioneer Array

STUDY SITE

Courtesy of W. Zhang (WHOI)

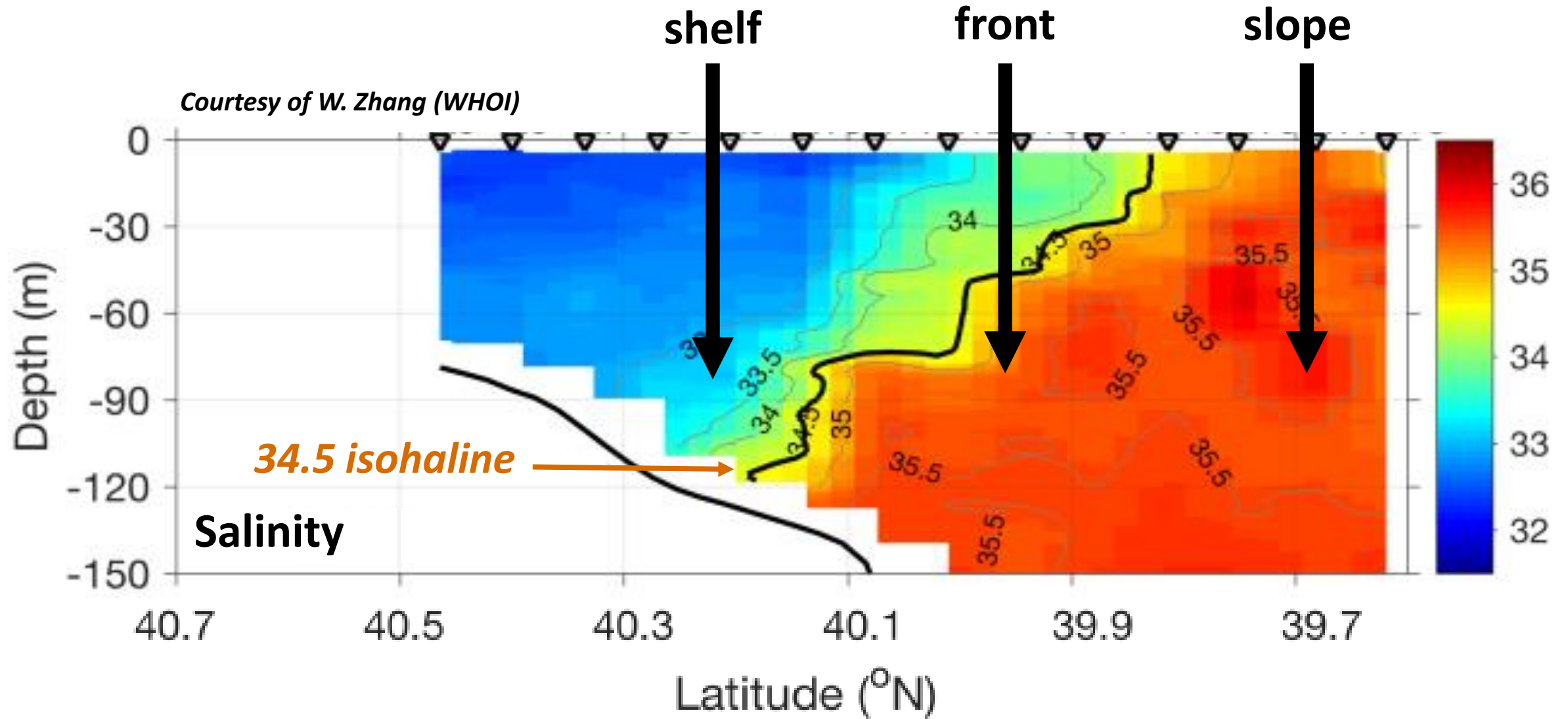


NOAA-19 SST, Rutgers Coastal Ocean Observation Lab; courtesy of W. Zhang (WHOI)



- Repeatedly occupied stations extending across the shelf-break front aligned with the Ocean Observatories Initiative Pioneer Array

SAMPLE COLLECTION



- Measured NFR across shelf-break mixing zone

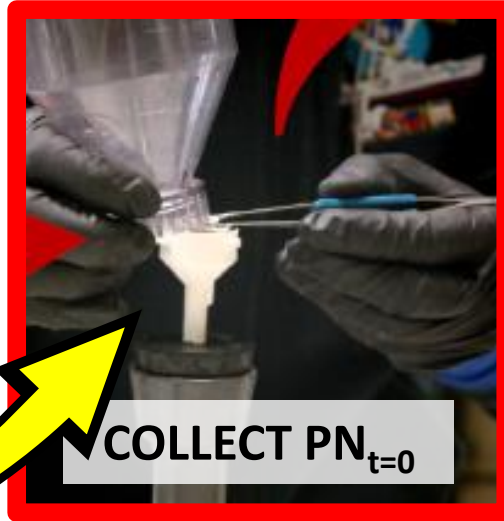
NFR MEASUREMENT

$$NFR = \frac{A_{PN_{t=f}} - A_{PN_{t=0}}}{A_{N_2} - A_{PN_{t=0}}} \times \frac{[PN]}{t}$$

See: White, Granger, Selden *et al.* 2020. *L&O: Methods*.



×3

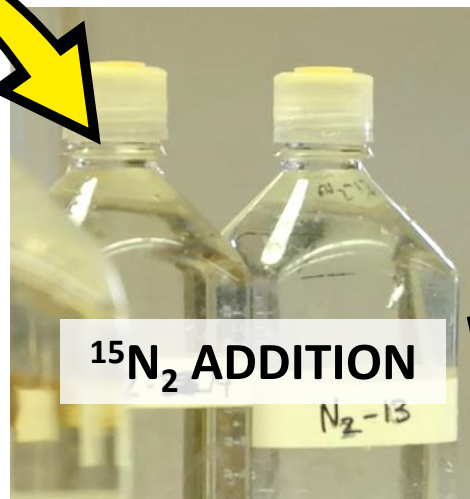


mass & ¹⁵N
enrichment

N₂ GAS ALIQUOT

¹⁵N enrichment

×3



24 h INCUBATION



mass & ¹⁵N
enrichment

NFR CALCULATION

$$N_2 \text{ fixation rate (NFR)} = \frac{A_{PN_{t=f}} - A_{PN_{t=0}}}{A_{N_2} - A_{PN_{t=0}}} \times \frac{[PN]}{t} \quad (\text{nmol } NL^{-1}d^{-1})$$

$$\text{Specific uptake rate (SUR)} = \frac{A_{PN_{t=f}} - A_{PN_{t=0}}}{A_{N_2} - A_{PN_{t=0}}} \times \frac{1}{t} \quad (d^{-1})$$

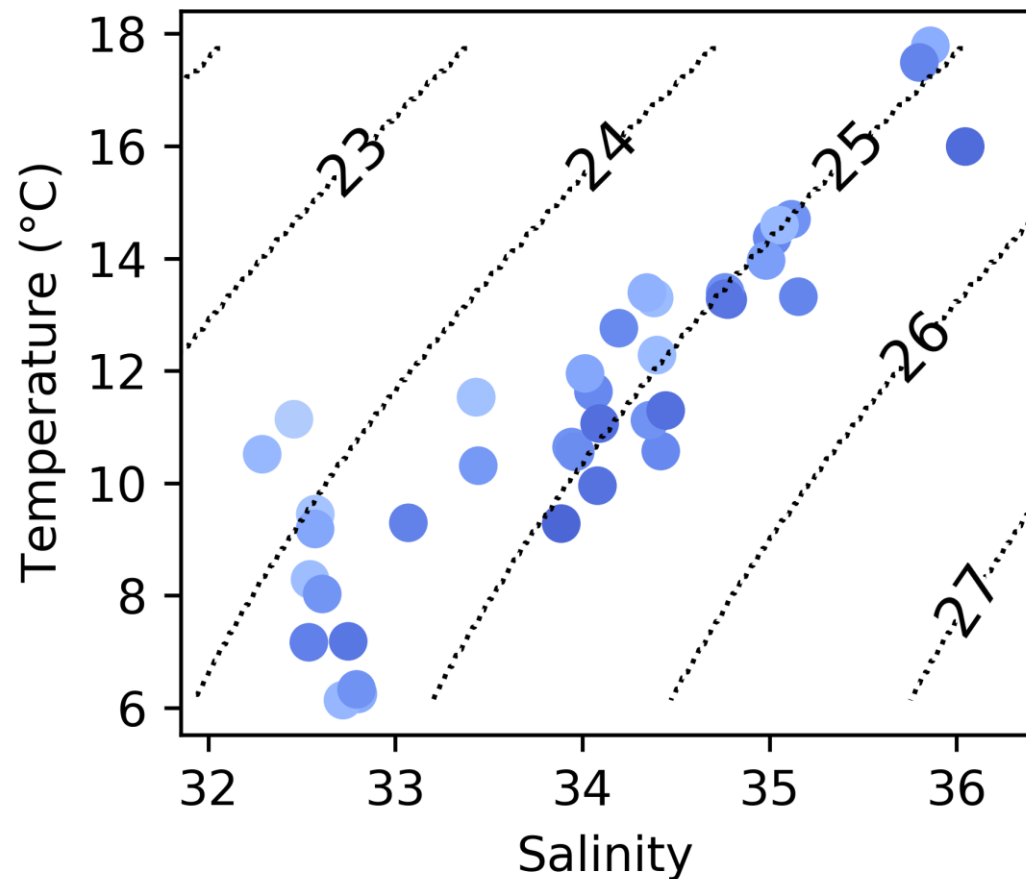
Specific rate of N_2 uptake by particles in the incubation bottle

~ rate of N transport from N_2 to particulate N (i.e., plankton)

~ inverse of PN turnover time due to N_2 fixation

N₂ FIXATION ACROSS SHELF-BREAK FRONT

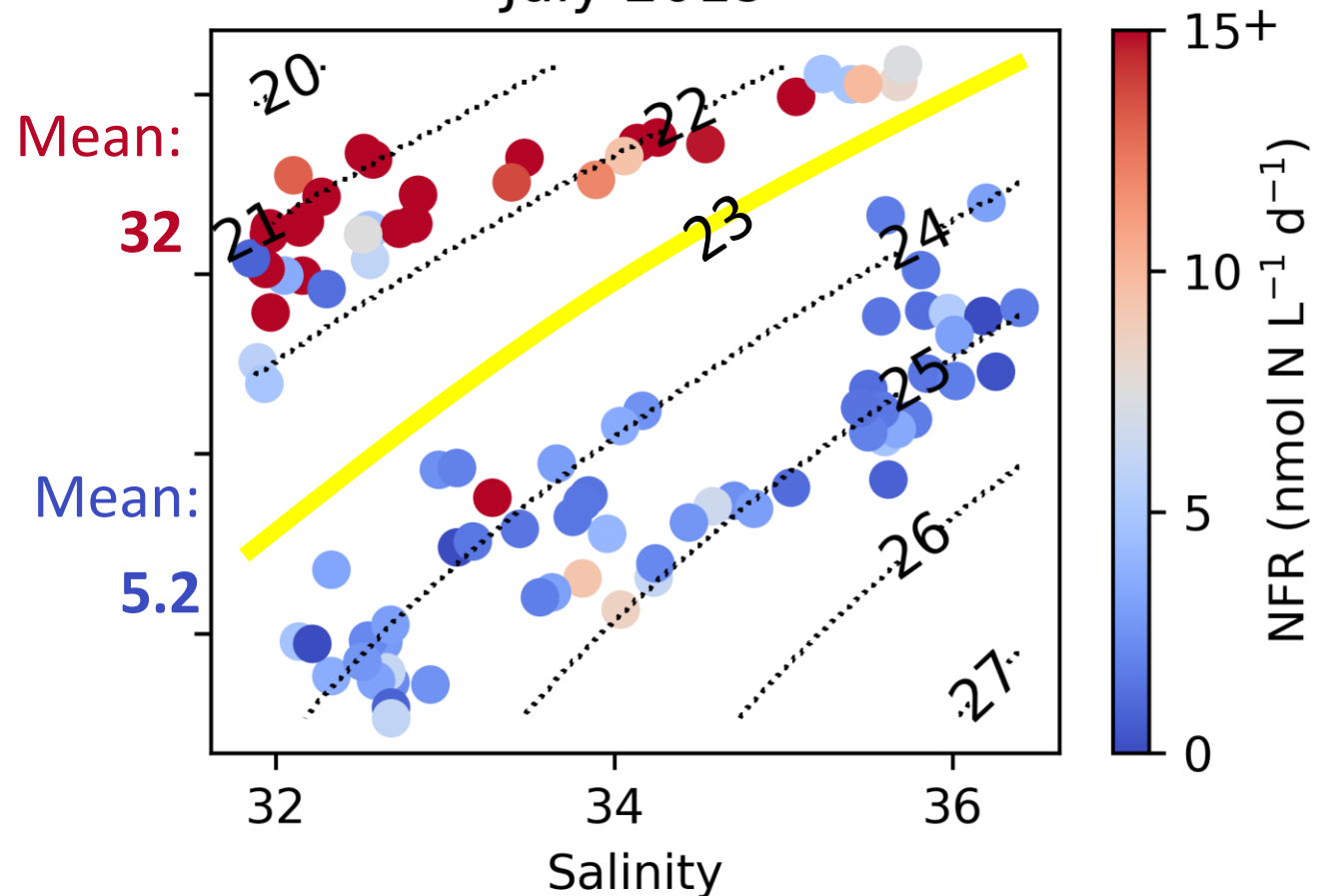
May 2019



Overall mean = **2.8 nmol N L⁻¹ d⁻¹**

Range = 0.9 – 5.3 nmol N L⁻¹ d⁻¹

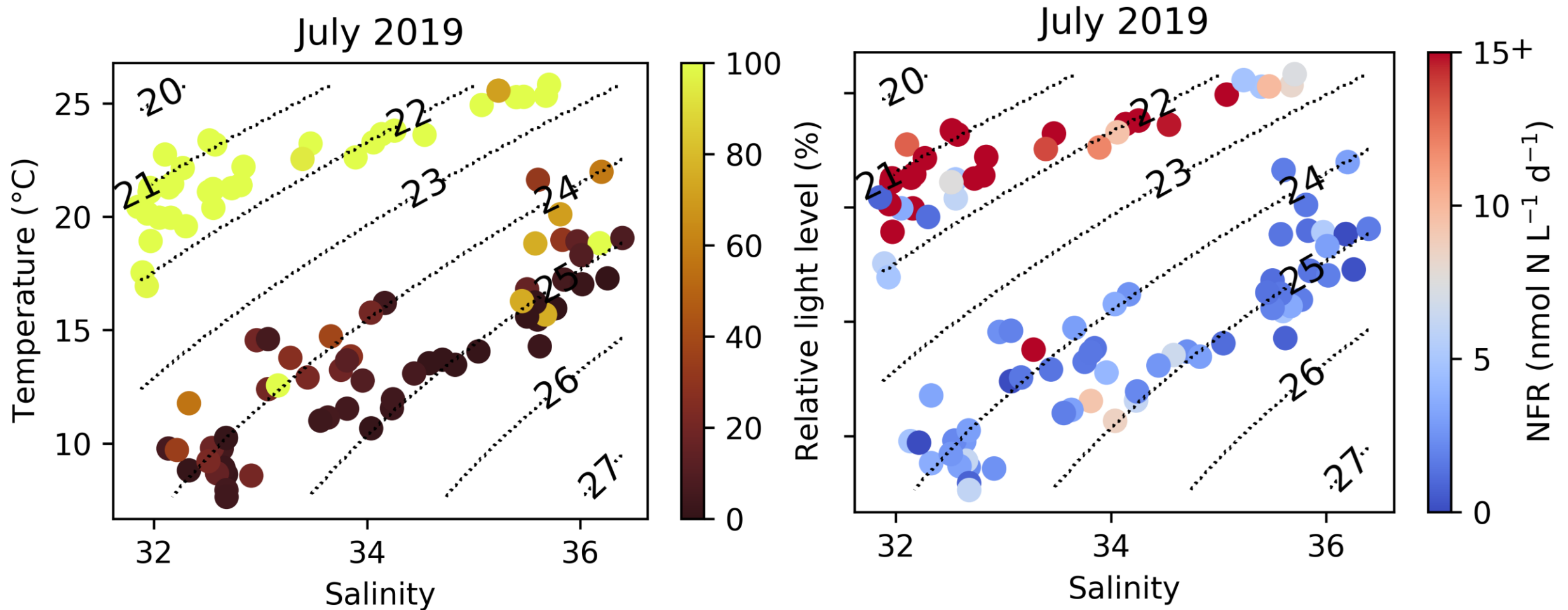
July 2019



Overall mean = **11 nmol N L⁻¹ d⁻¹**

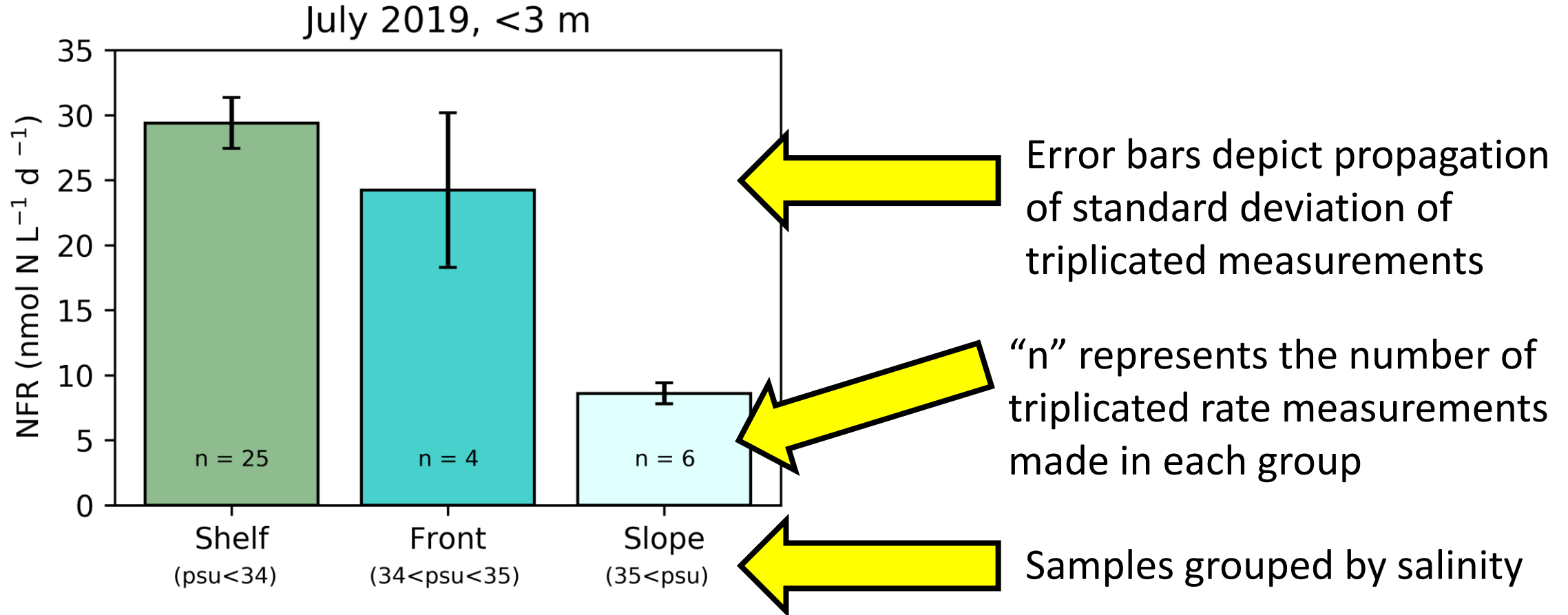
Range = BDL – 197 nmol N L⁻¹ d⁻¹

N₂ FIXATION ACROSS SHELF-BREAK FRONT



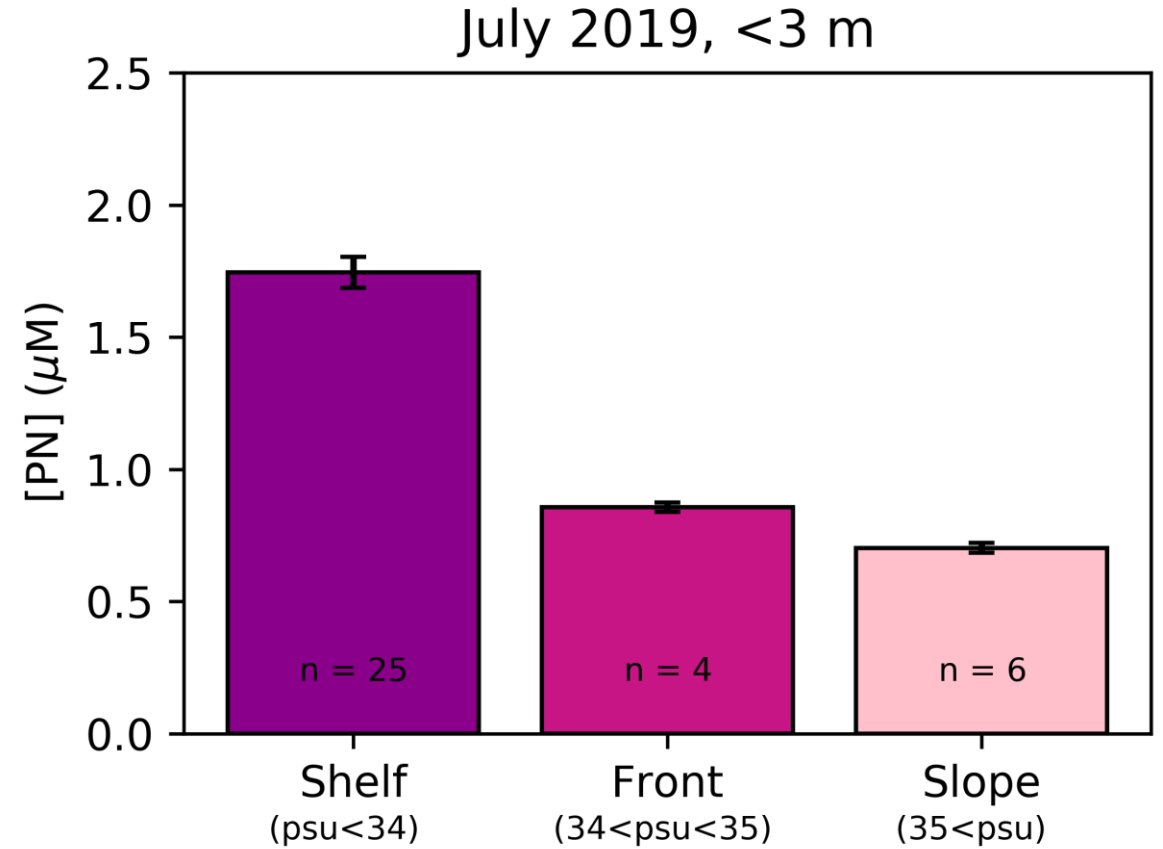
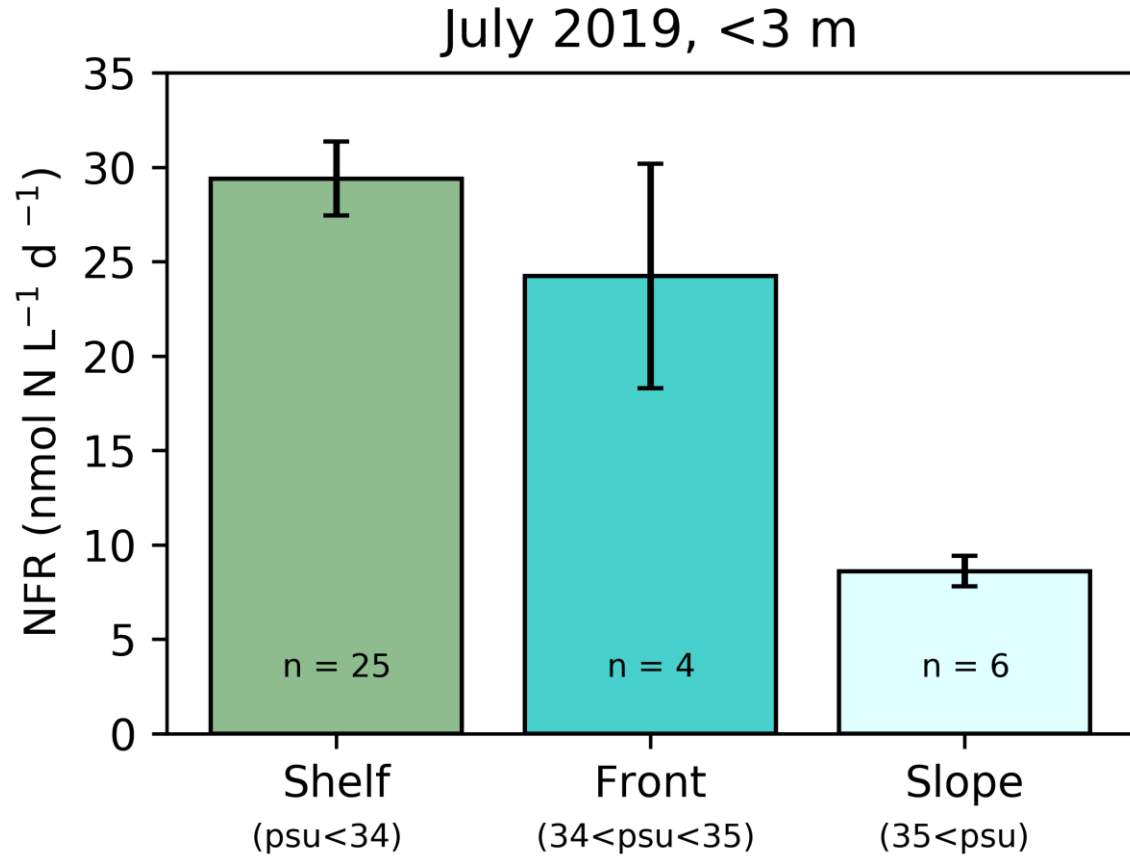
- High NFR (**Mean = 32 ± 2 nmol N L⁻¹ d⁻¹**) primarily occurred in warm, **well-lit**, nitrate-deplete stratified surface waters (<3 m)

N₂ FIXATION IN STRATIFIED UPPER LAYER



- NFR highest in **shelf waters**

N₂ FIXATION IN STRATIFIED UPPER LAYER

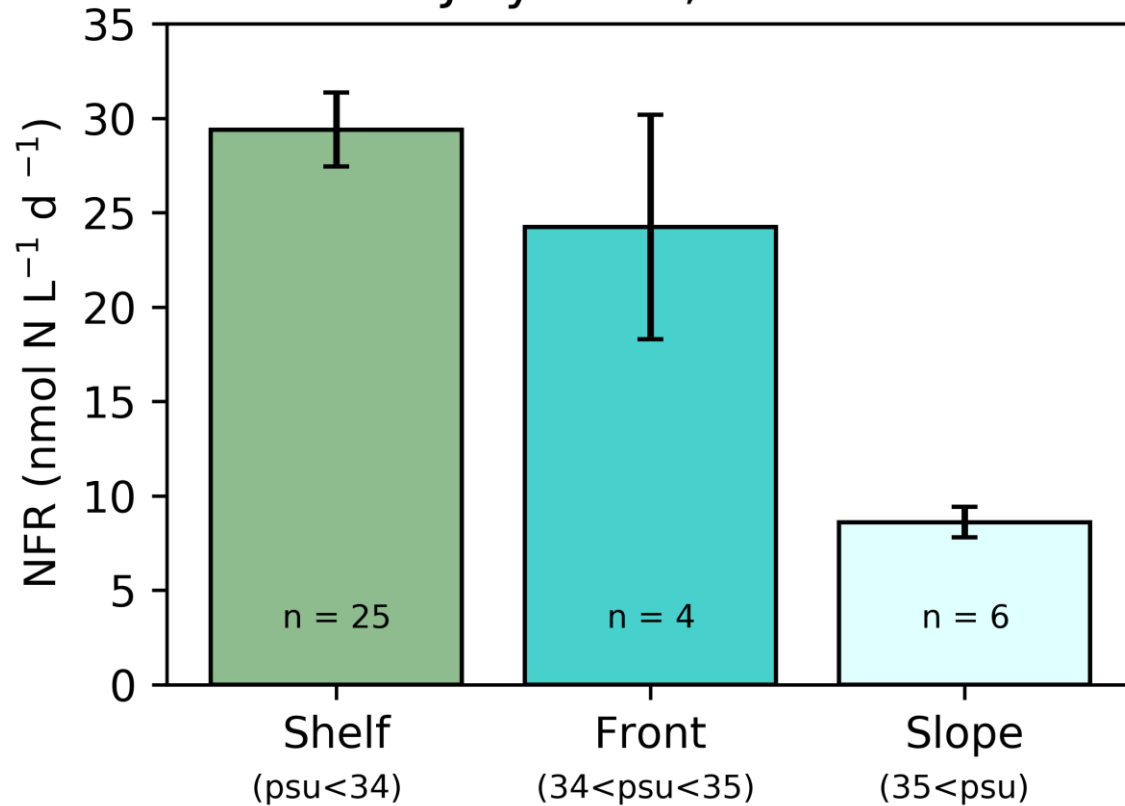


- NFR highest in **shelf waters** where biomass and **particulate N** concentrations were high

N₂ FIXATION IN STRATIFIED UPPER LAYER

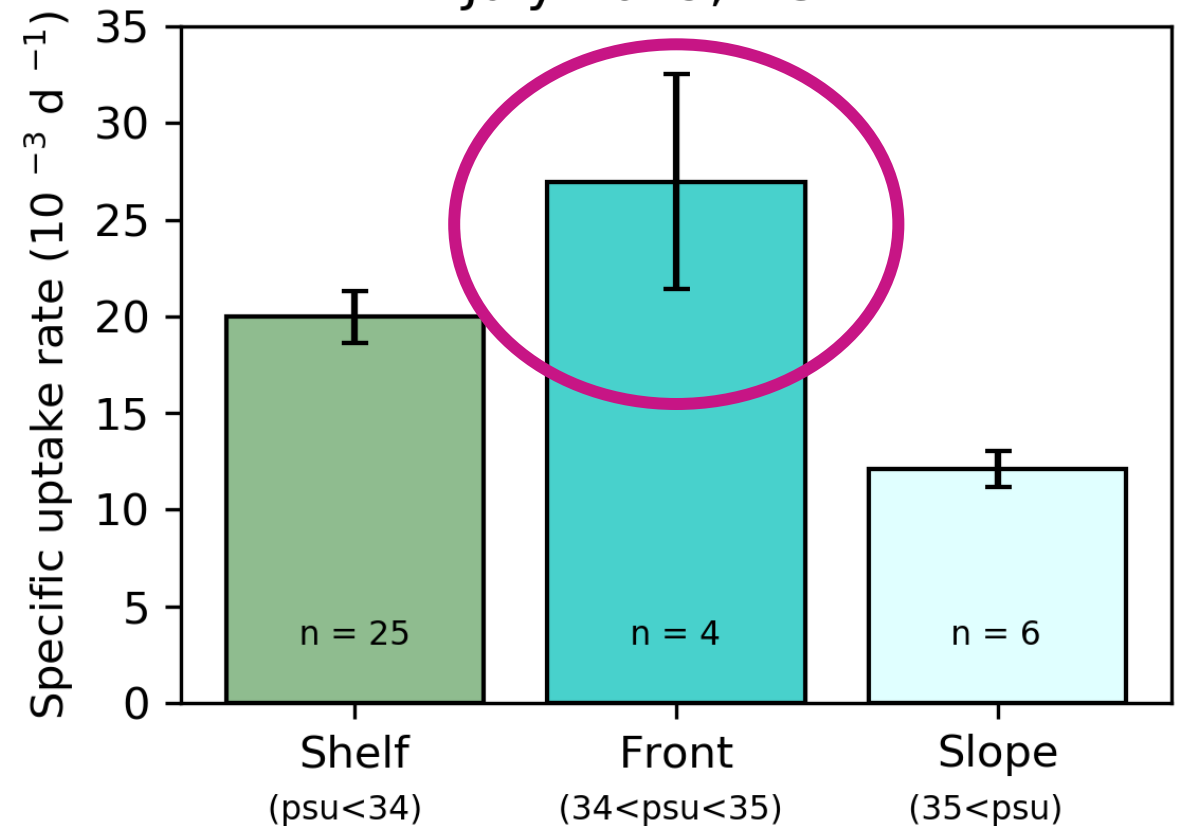
N₂ fixation rate

July 2019, <3 m



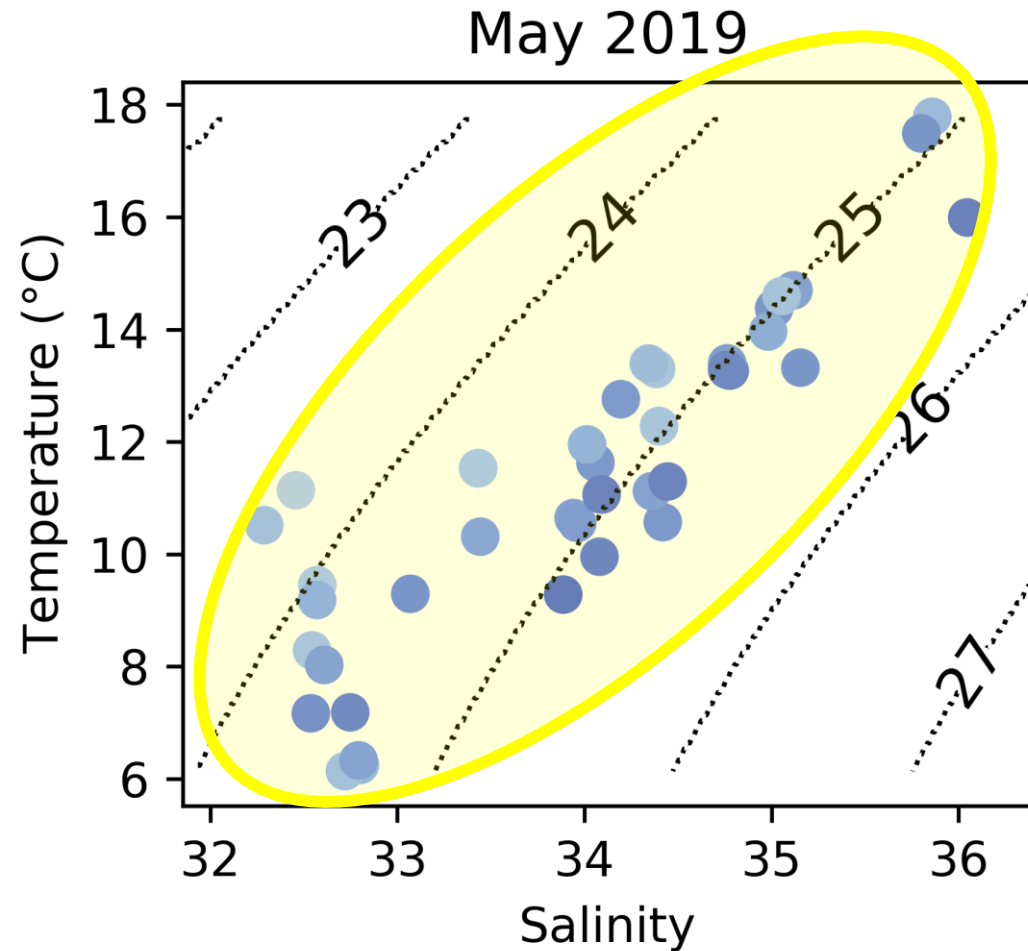
Specific uptake rate

July 2019, <3 m



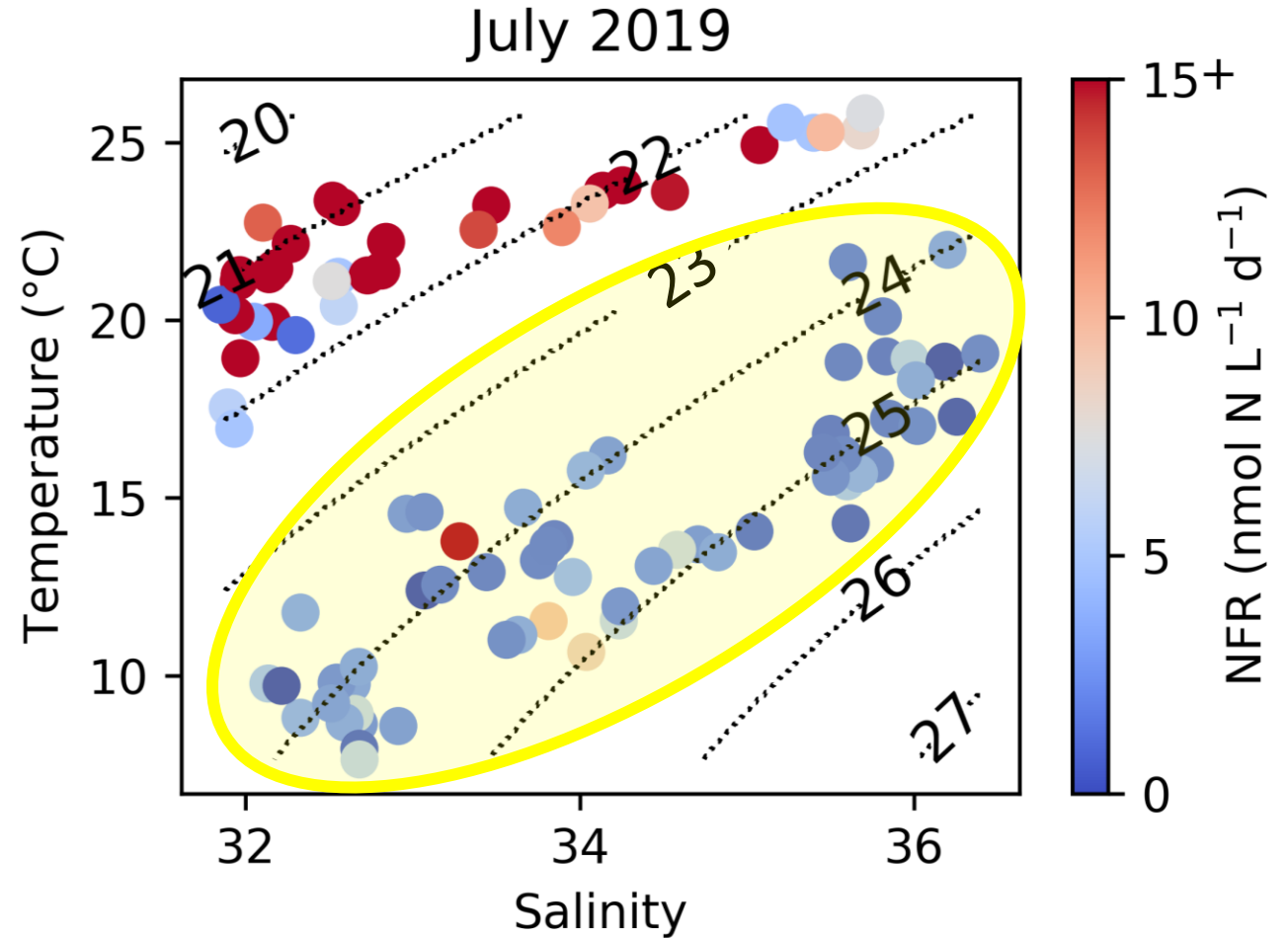
- Specific uptake rate **enhanced at front** in stratified upper layer where particularly high NFR/activity detected

N₂ FIXATION ACROSS SHELF-BREAK FRONT



Overall mean = **2.8 nmol N L⁻¹ d⁻¹**

Range = 0.9 – 5.3 nmol N L⁻¹ d⁻¹



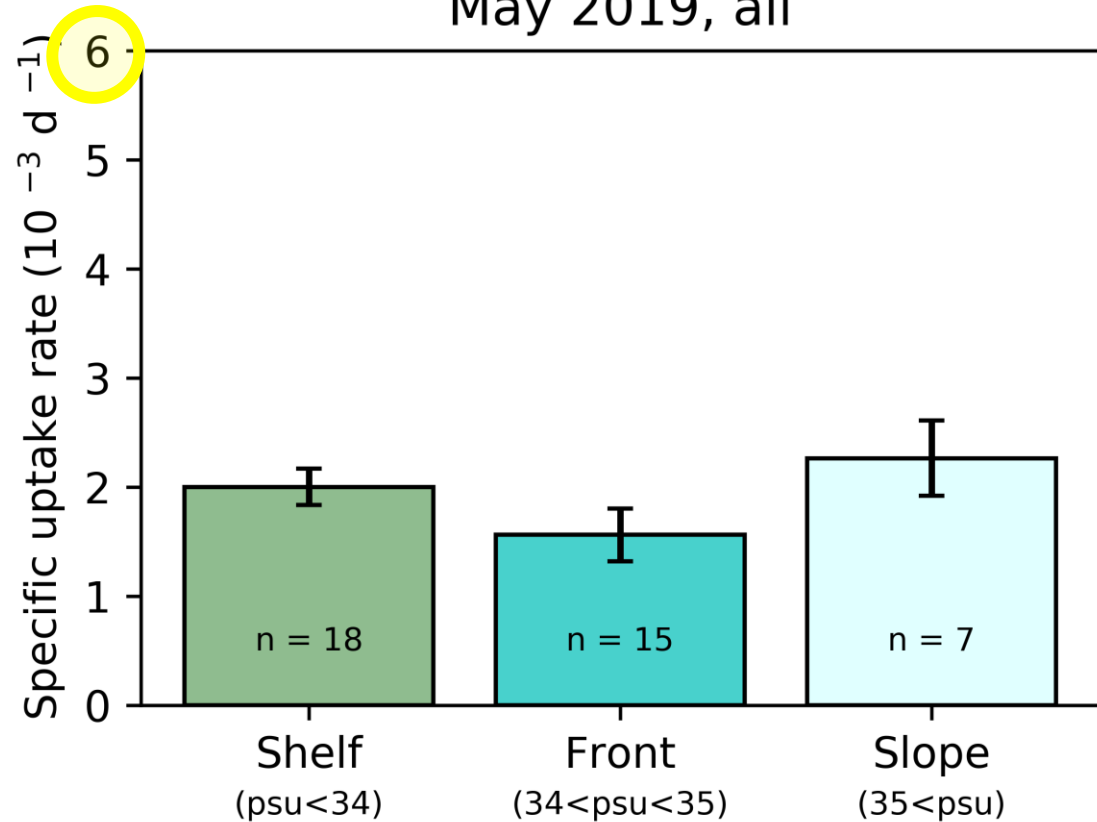
Mean ($\sigma_t > 23$) = **5.2 nmol N L⁻¹ d⁻¹**

Range = BDL – 45 nmol N L⁻¹ d⁻¹

N₂ FIXATION BELOW THE STRATIFIED SURFACE LAYER

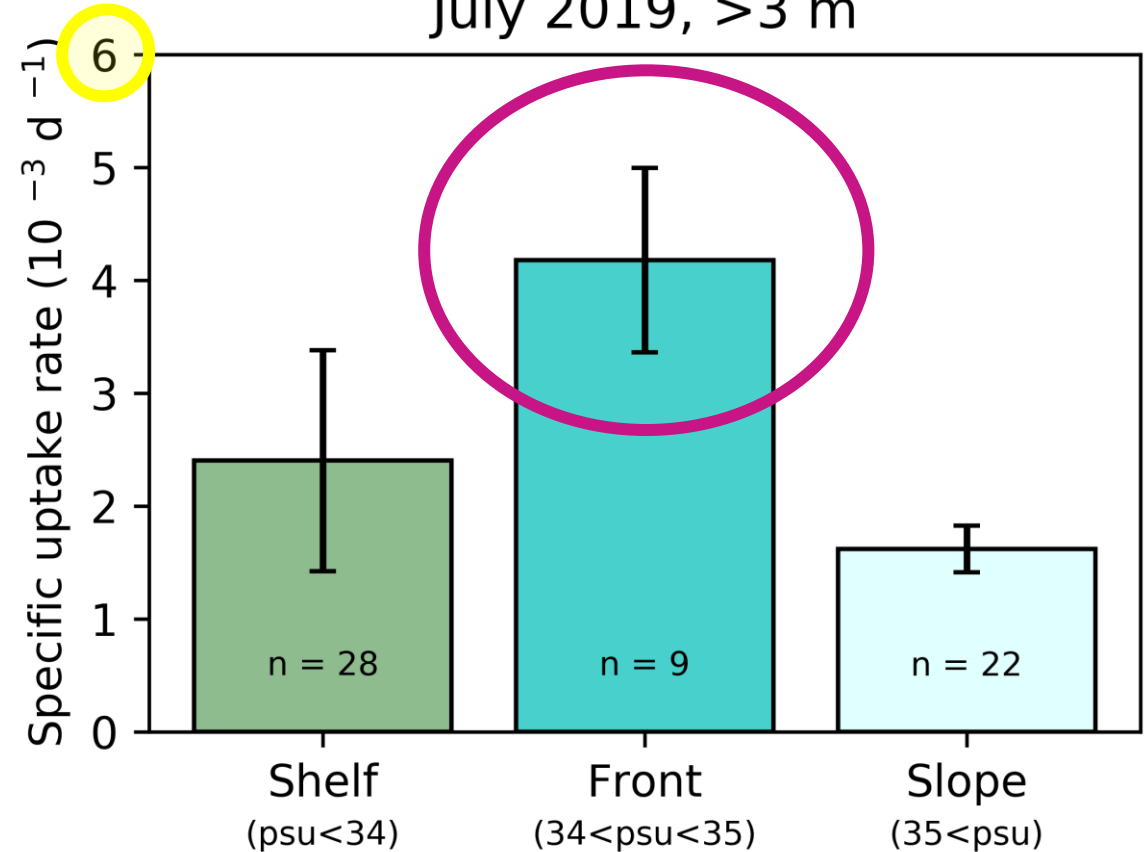
Specific uptake rate

May 2019, all



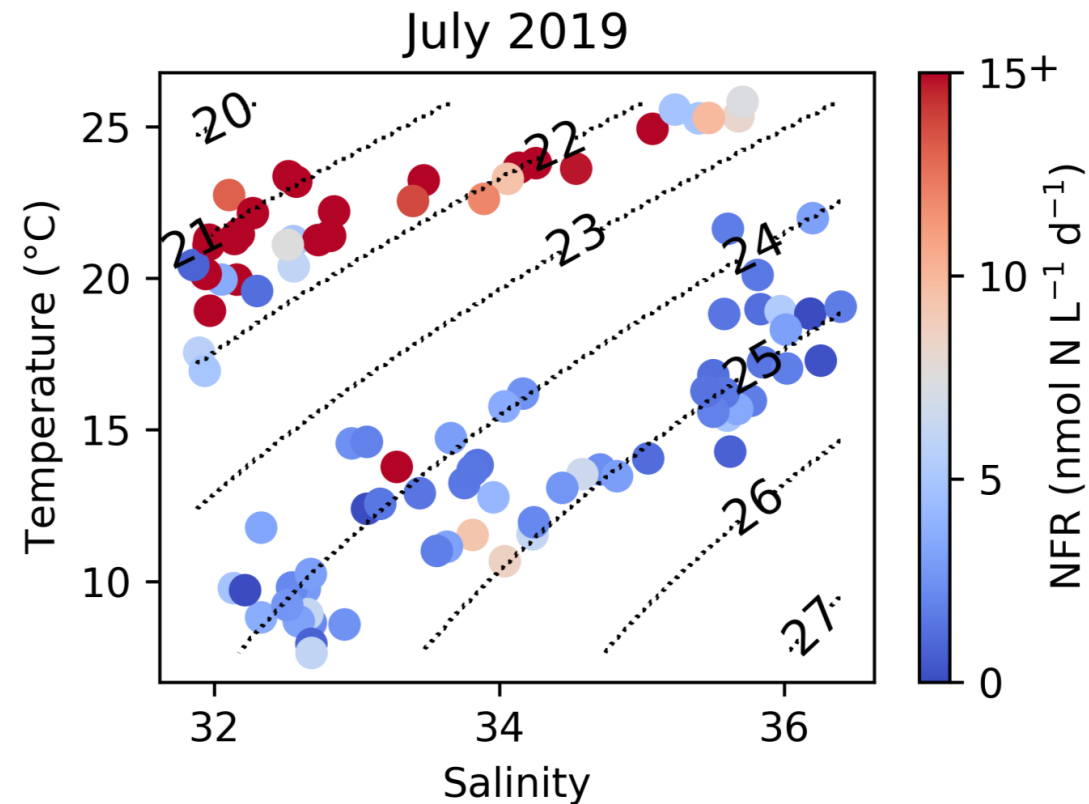
Specific uptake rate

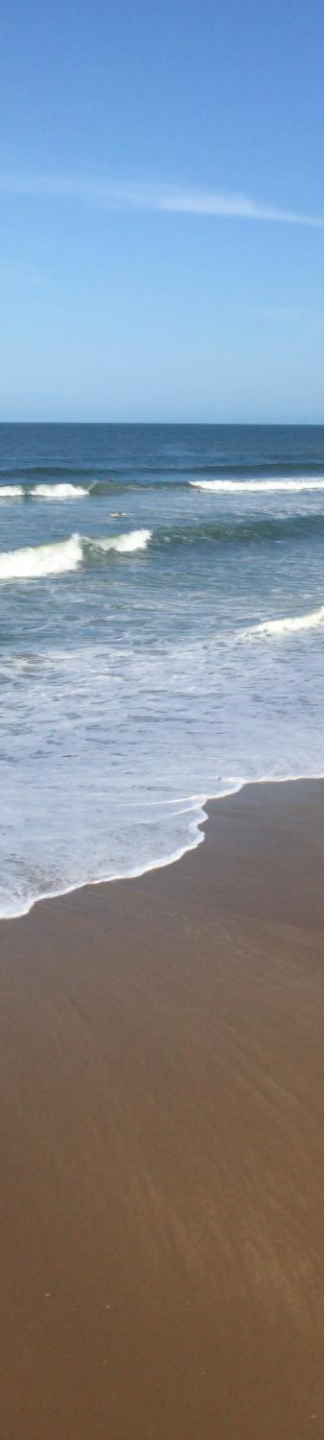
July 2019, >3 m



- N₂ fixation consistently detectable across front, but low in May
- Specific uptake **enhanced at front** in July *below* the upper stratified layer

- What physical factors drive the high N_2 fixation rates (NFR) observed in this region?
 - Development of summer stratification



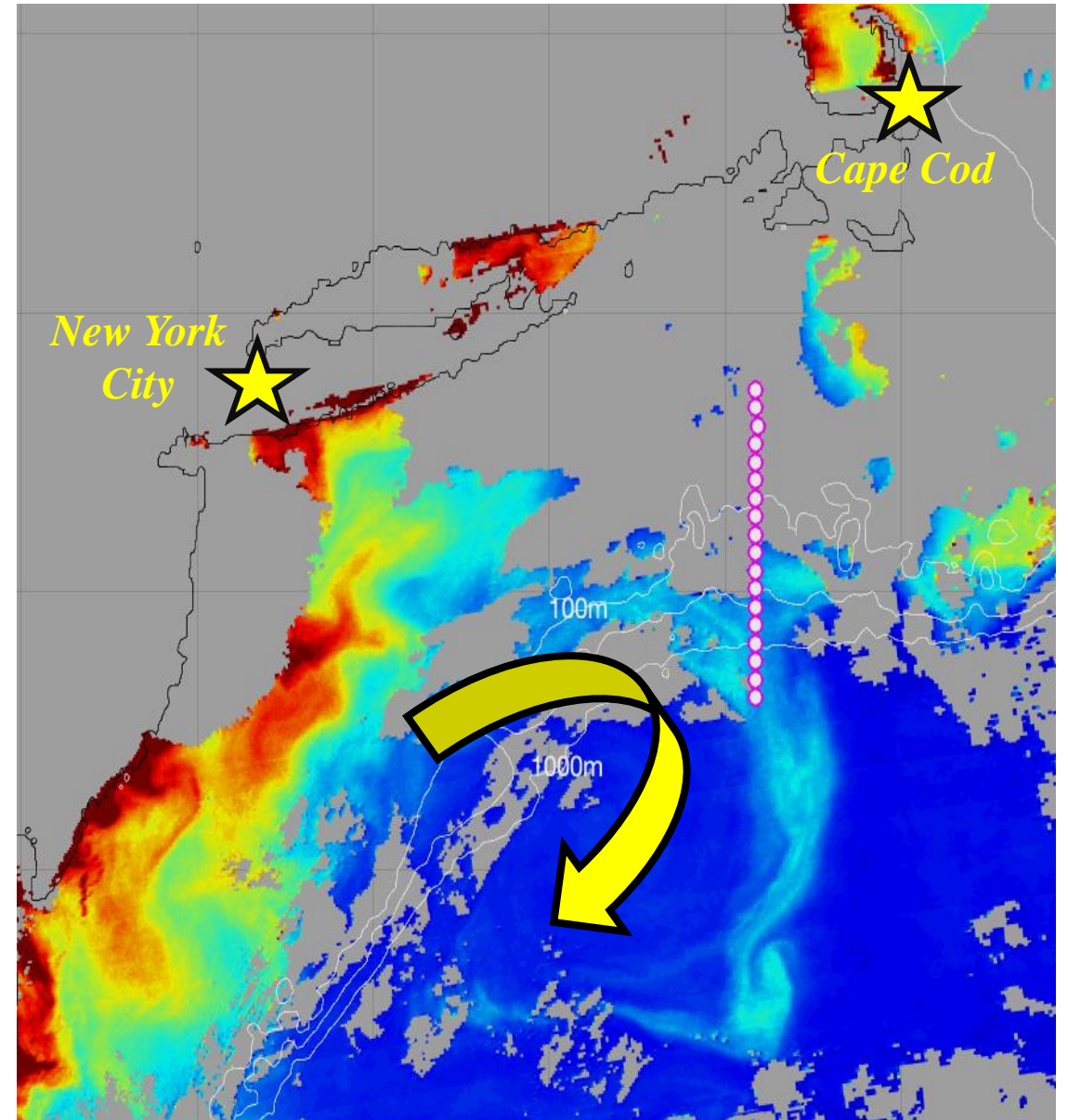


- What physical factors drive the high N_2 fixation rates (NFR) observed in this region?
 - Development of summer stratification
 - (Sub)mesoscale transport/mixing dynamics

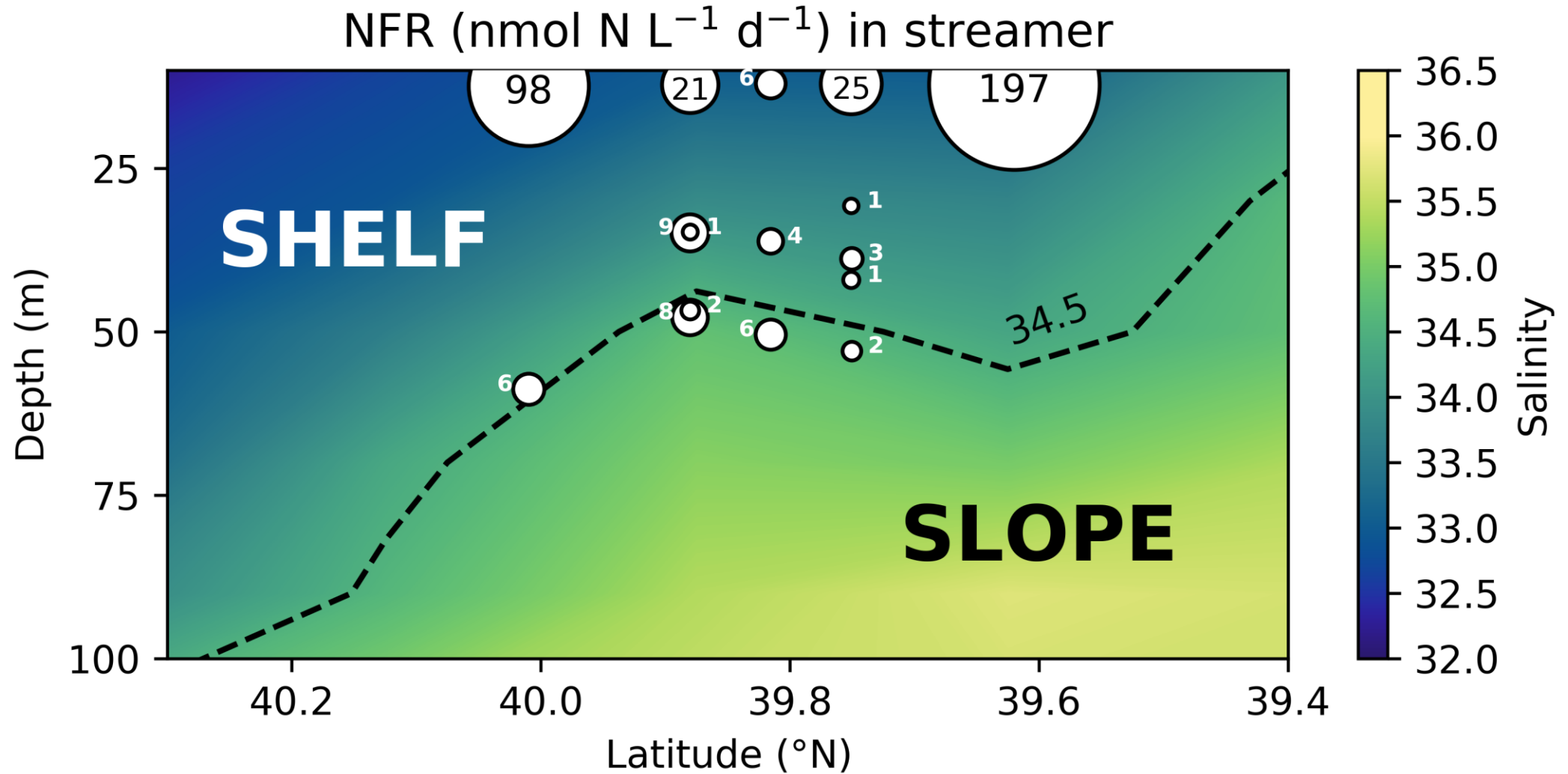
(SUB)MESOSCALE TRANSPORT DYNAMICS

- Encountered shelf water **streamer** in July
 - Eddy pushing onto continental shelf transported shelf water offshore

*July 6 MODIS Chl
courtesy of W. Zhang (WHOI)*

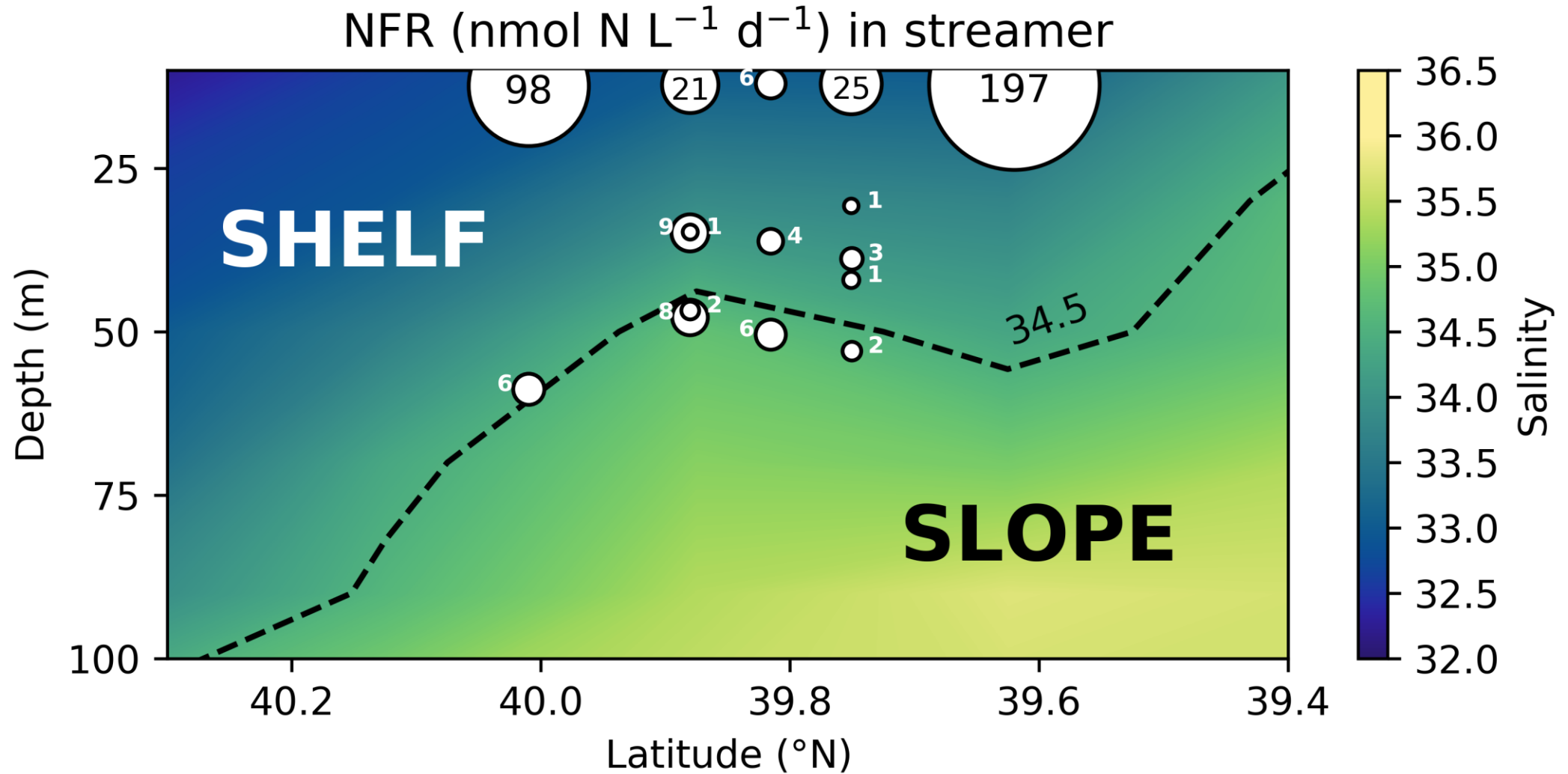


(SUB)MESOSCALE TRANSPORT DYNAMICS



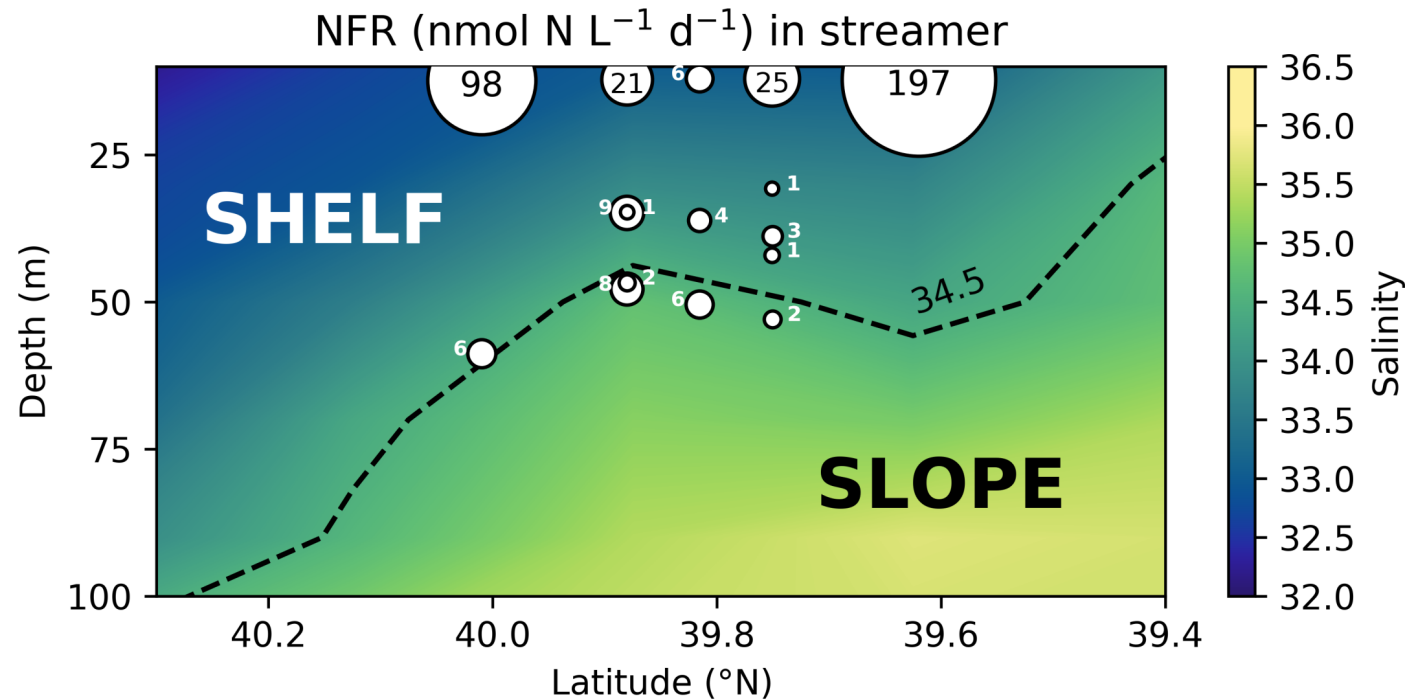
- Highest N₂ fixation rates observed in leading edge of streamer

(SUB)MESOSCALE TRANSPORT DYNAMICS

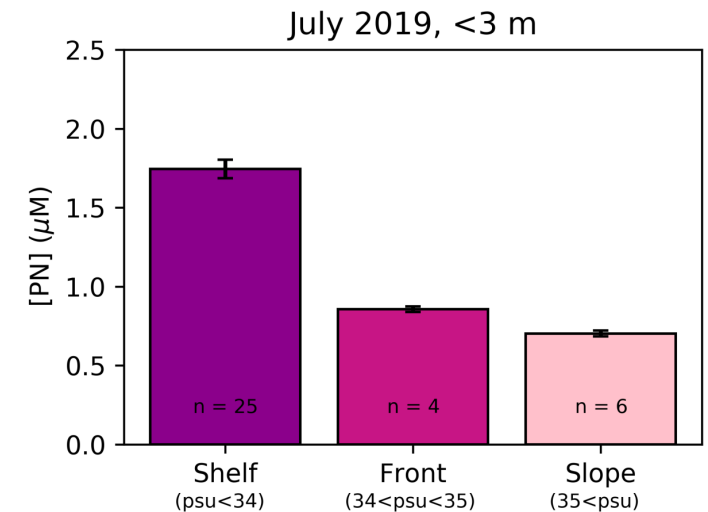


- (Sub)mesoscale transport dynamics may fuel episodic N₂ fixation events

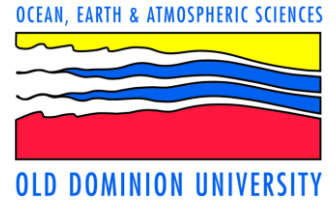
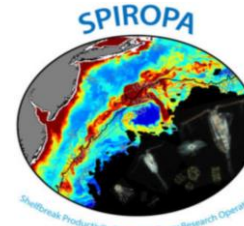
- What physical factors drive the high N_2 fixation rates (NFR) observed in this region?
 - Development of summer stratification
 - (Sub)mesoscale transport/mixing dynamics



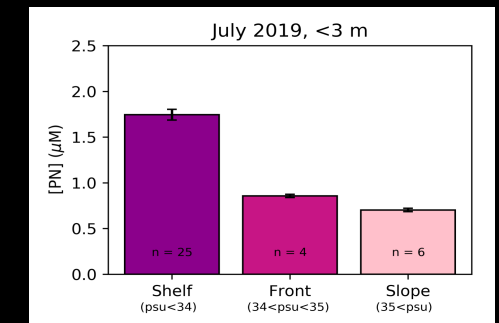
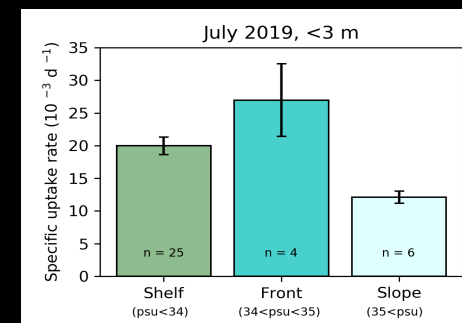
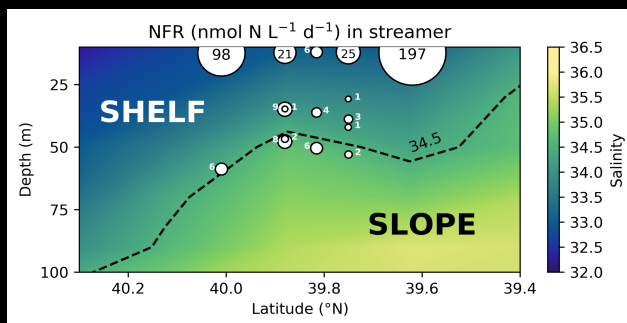
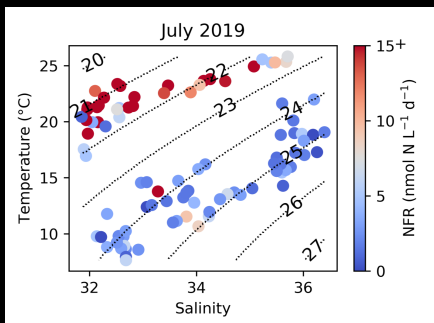
- What physical factors drive the high N_2 fixation rates (NFR) observed in this region?
 - Development of summer stratification
 - (Sub)mesoscale transport/mixing dynamics
- Does water mass mixing enhance diazotroph activity at the shelf-break front?
 - Specific uptake rates enhanced in July
 - NFR generally enhanced along shelf due to high [PN]



ACKNOWLEDGMENTS

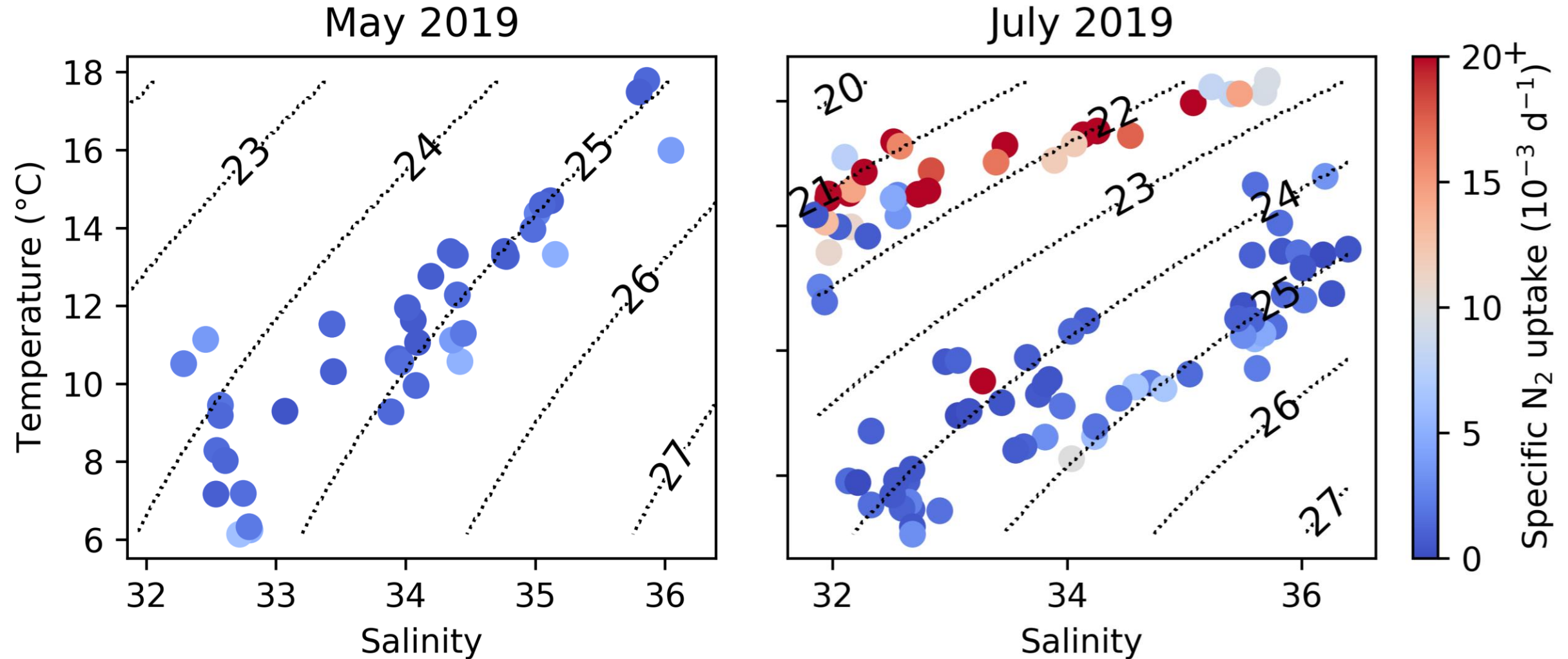


- NSF for funding the ship-time
- Dennis McGillicuddy, Heidi Sosik and Gordon Zhang for inviting us aboard and sharing their nutrient data
- ODU Dept. OEAS for supporting sample collection and analysis
- Gordon Zhang for offering his figures and expertise in Mid-Atlantic Bight (sub)mesoscale physical dynamics

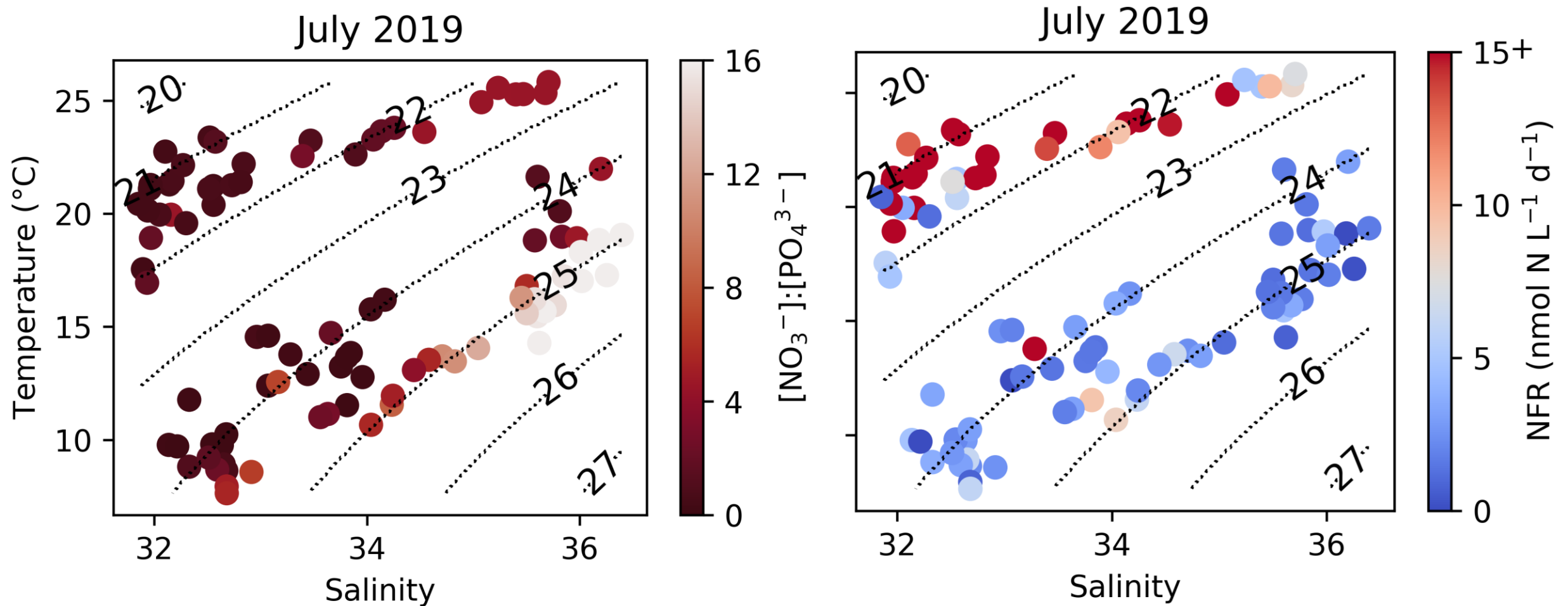


EXTRA SLIDES

TS DIAGRAMS – SPECIFIC UPTAKE

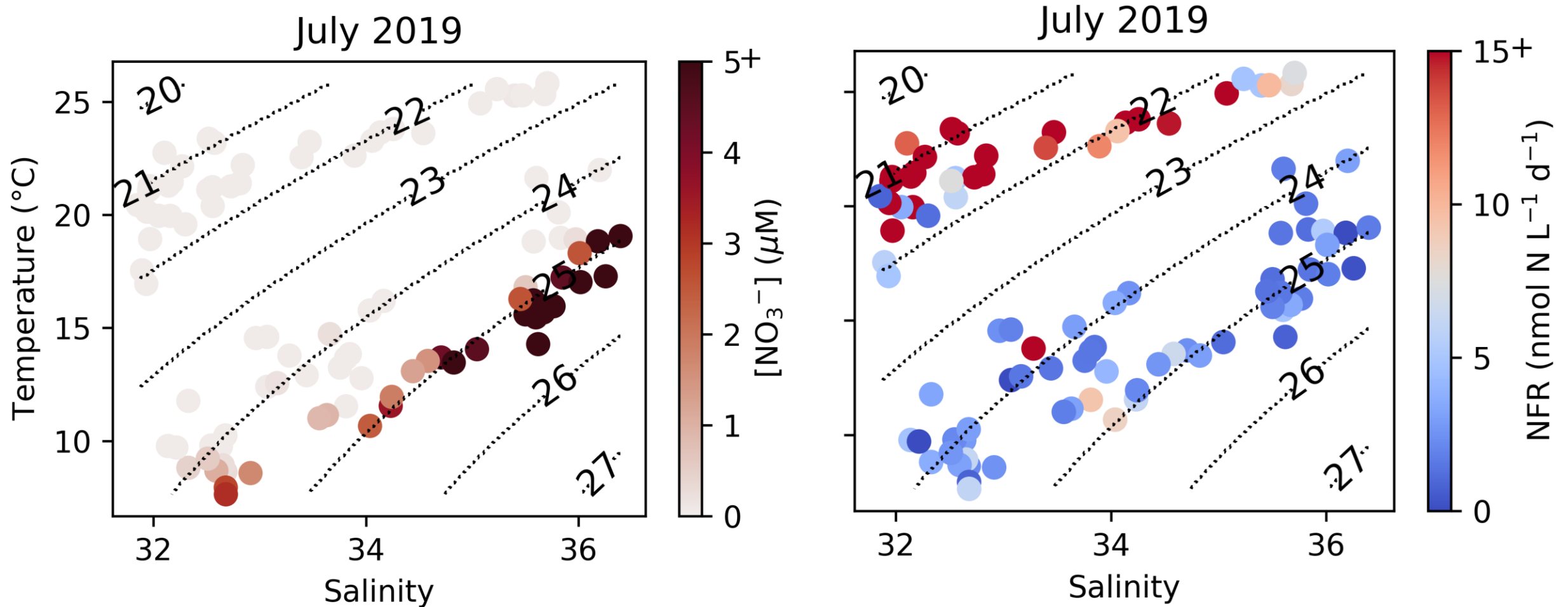


N₂ FIXATION ACROSS SHELF-BREAK FRONT



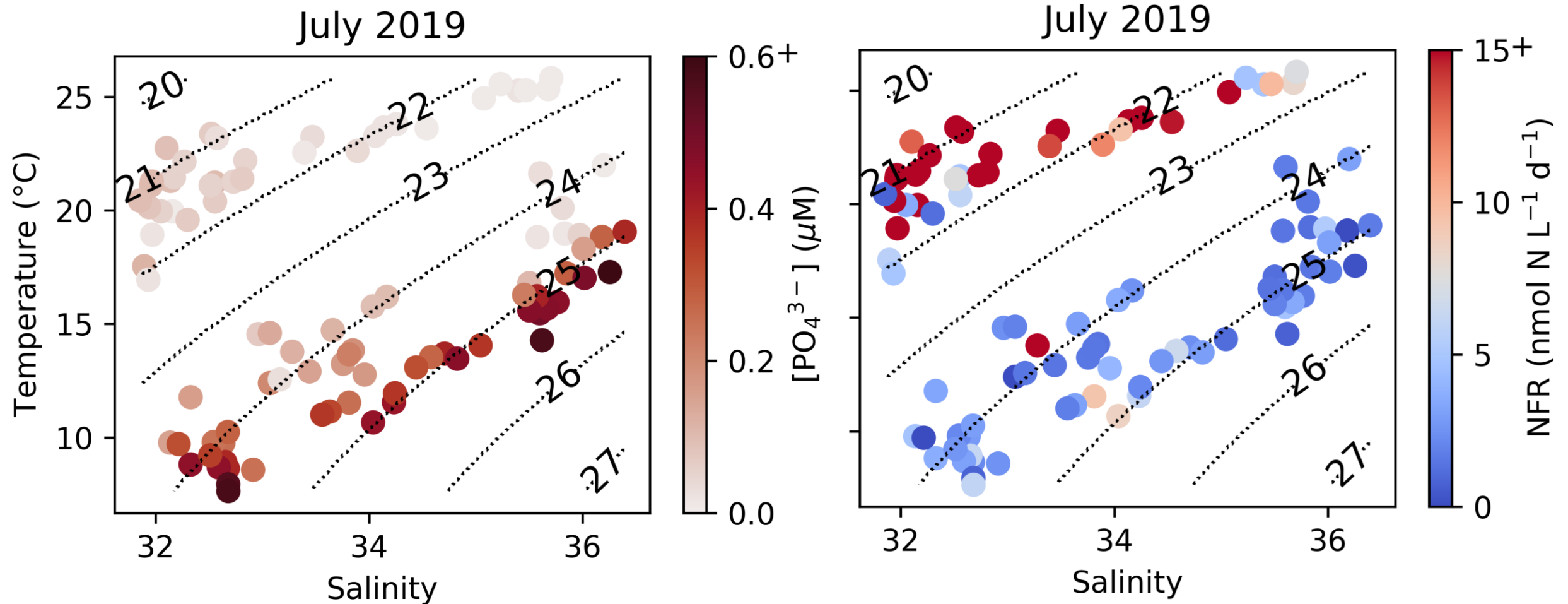
- High NFR primarily occurred in well-lit, stratified surface waters (<3 m), where P is in excess

N₂ FIXATION ACROSS SHELF-BREAK FRONT



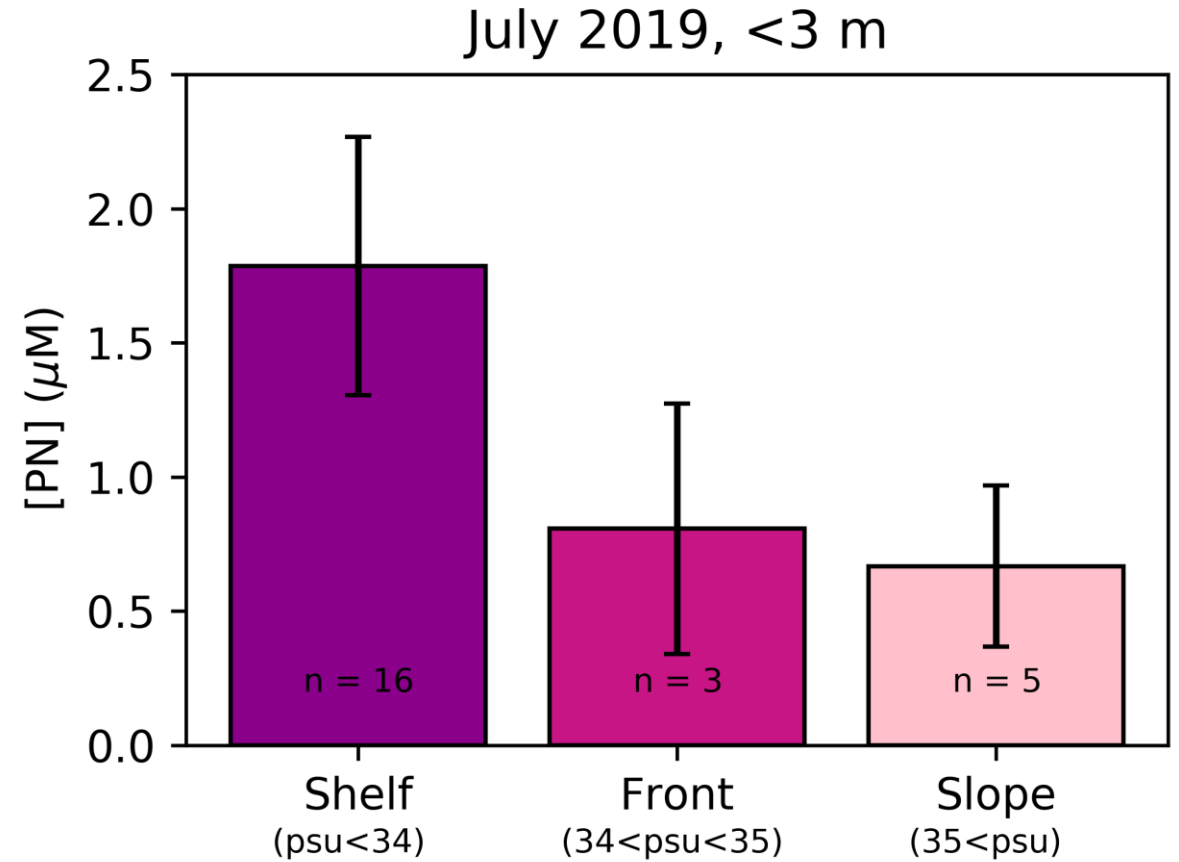
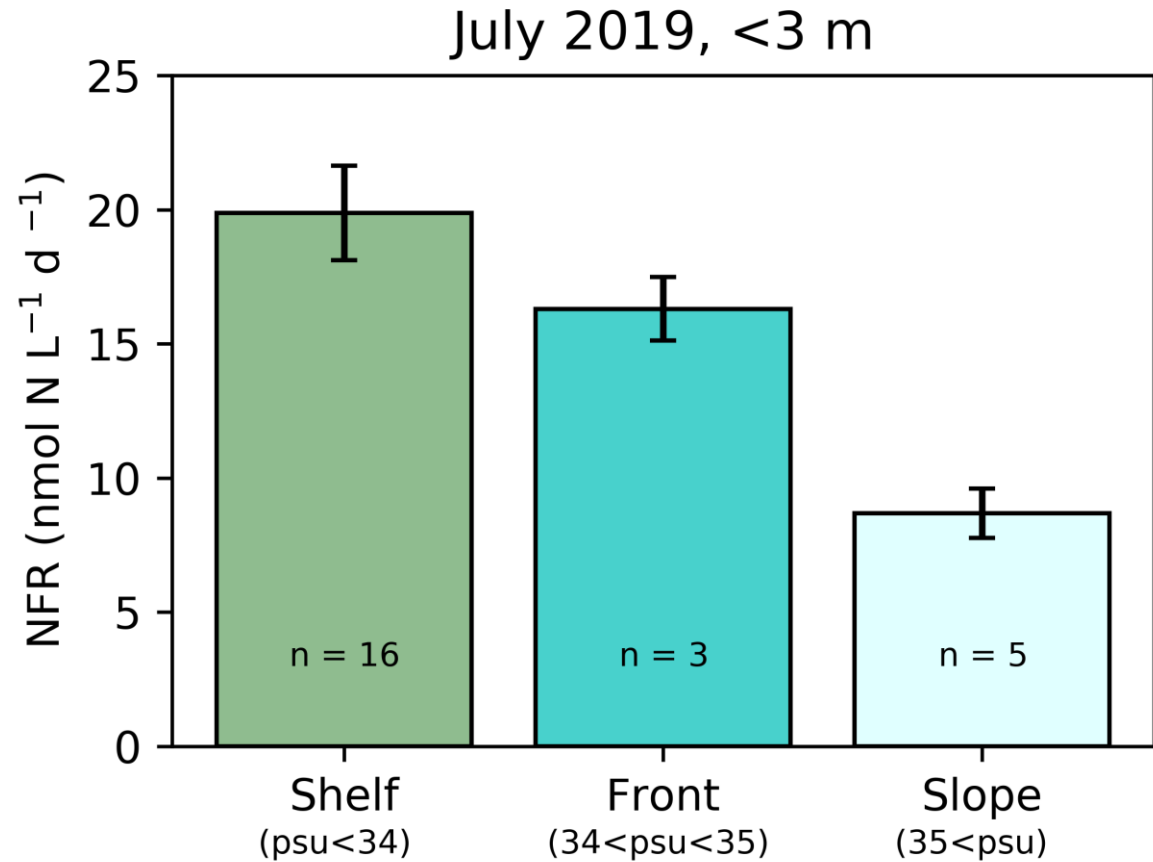
- Not solely driven by absence of NO₃⁻

N₂ FIXATION ACROSS SHELF-BREAK FRONT



- Not solely driven by absence of NO₃⁻

N₂ FIXATION IN STRATIFIED UPPER LAYER – no streamer data

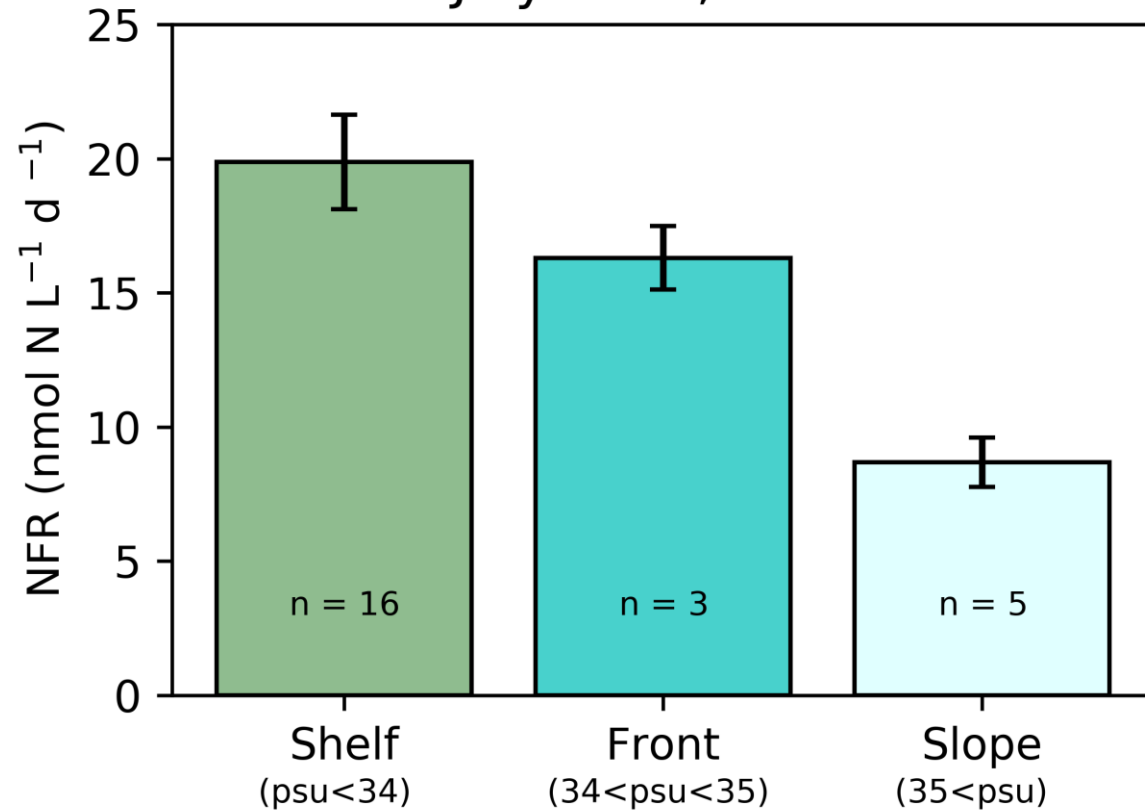


- NFR highest in **shelf waters** where biomass and **particulate N** concentrations were high

N₂ FIXATION IN STRATIFIED UPPER LAYER – no streamer data

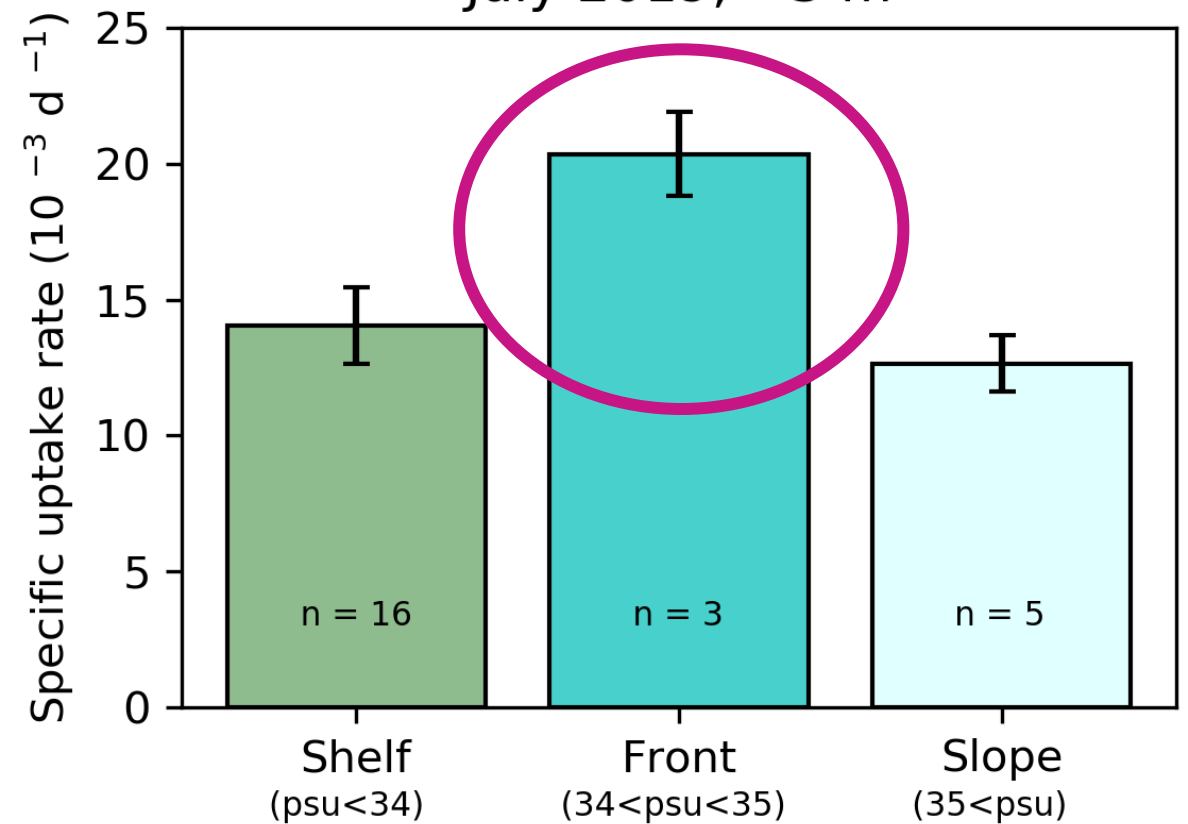
N₂ fixation rate

July 2019, <3 m



Specific uptake rate

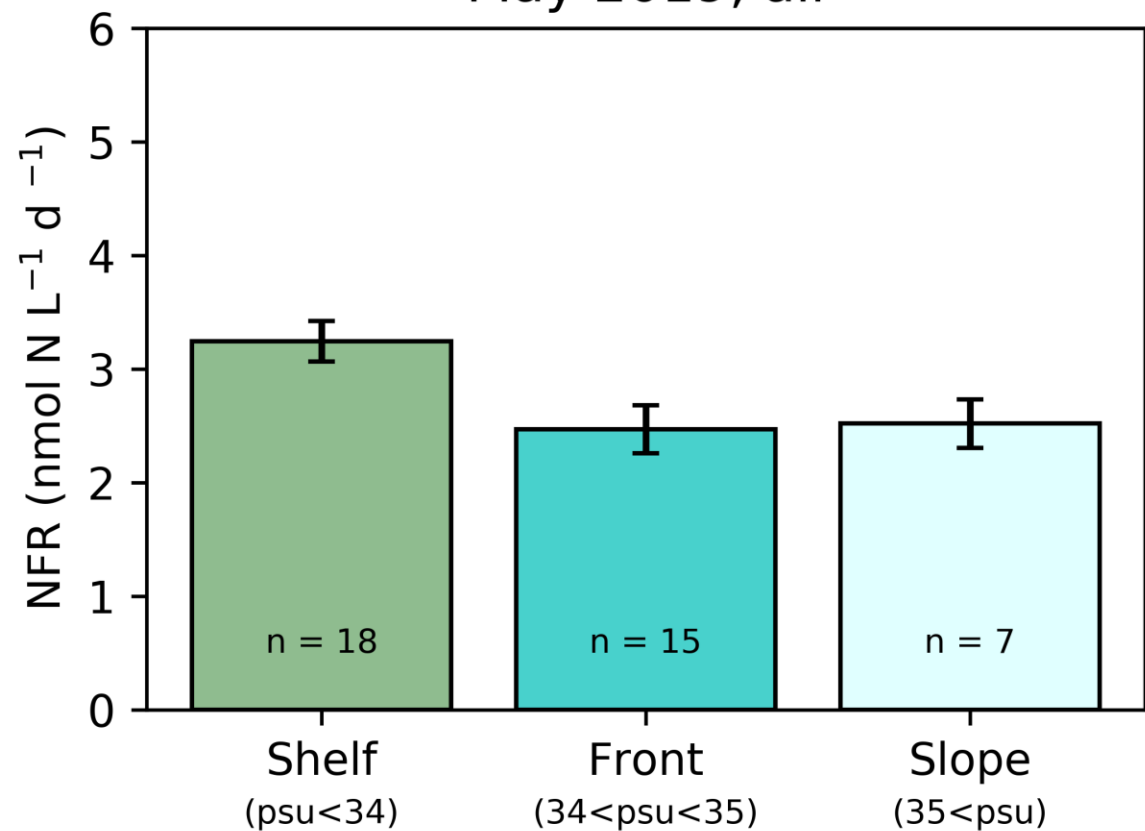
July 2019, <3 m



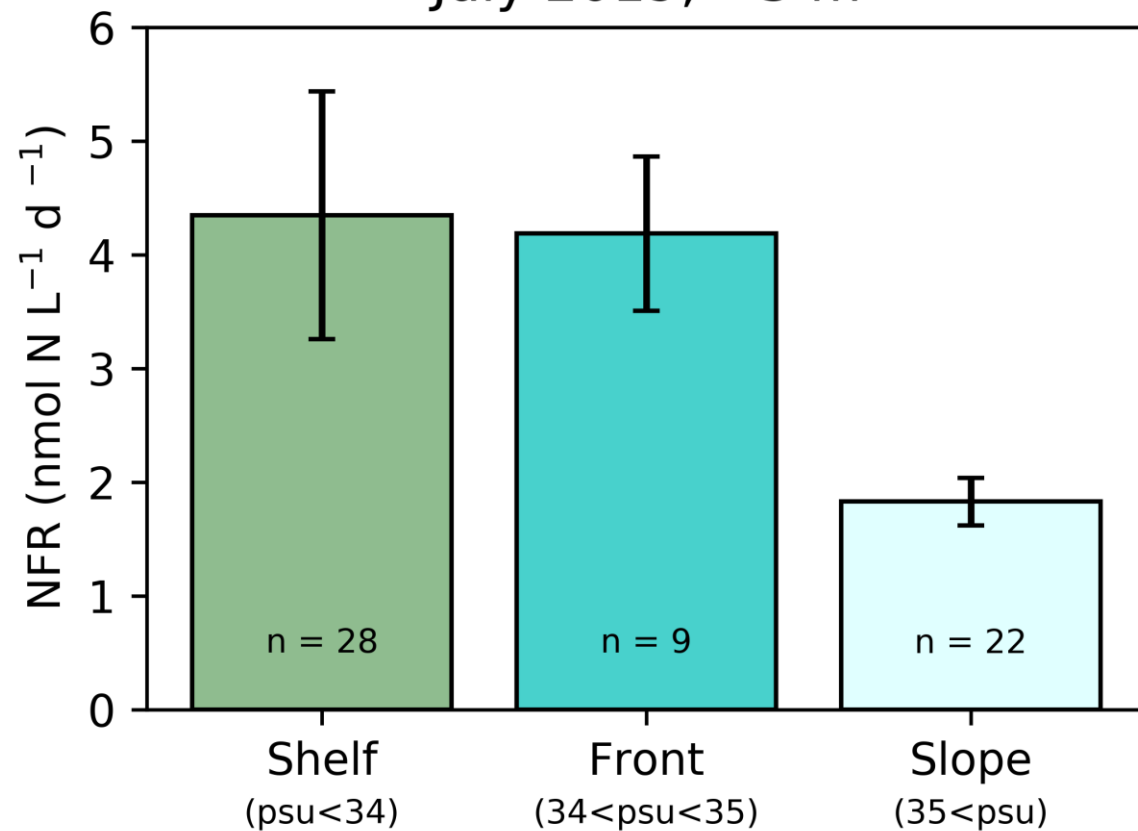
- Specific uptake rate enhanced at front in stratified upper layer where particularly high NFR/activity detected

N₂ FIXATION BELOW THE STRATIFIED SURFACE LAYER

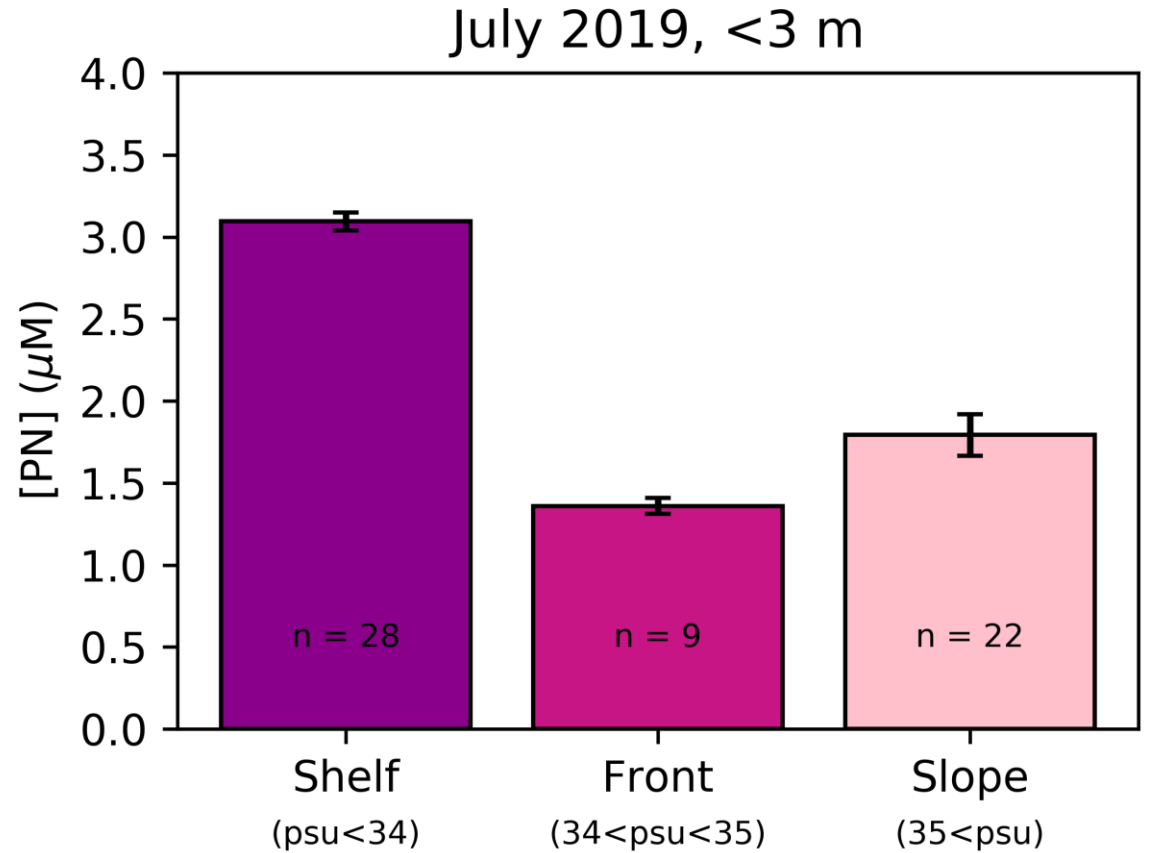
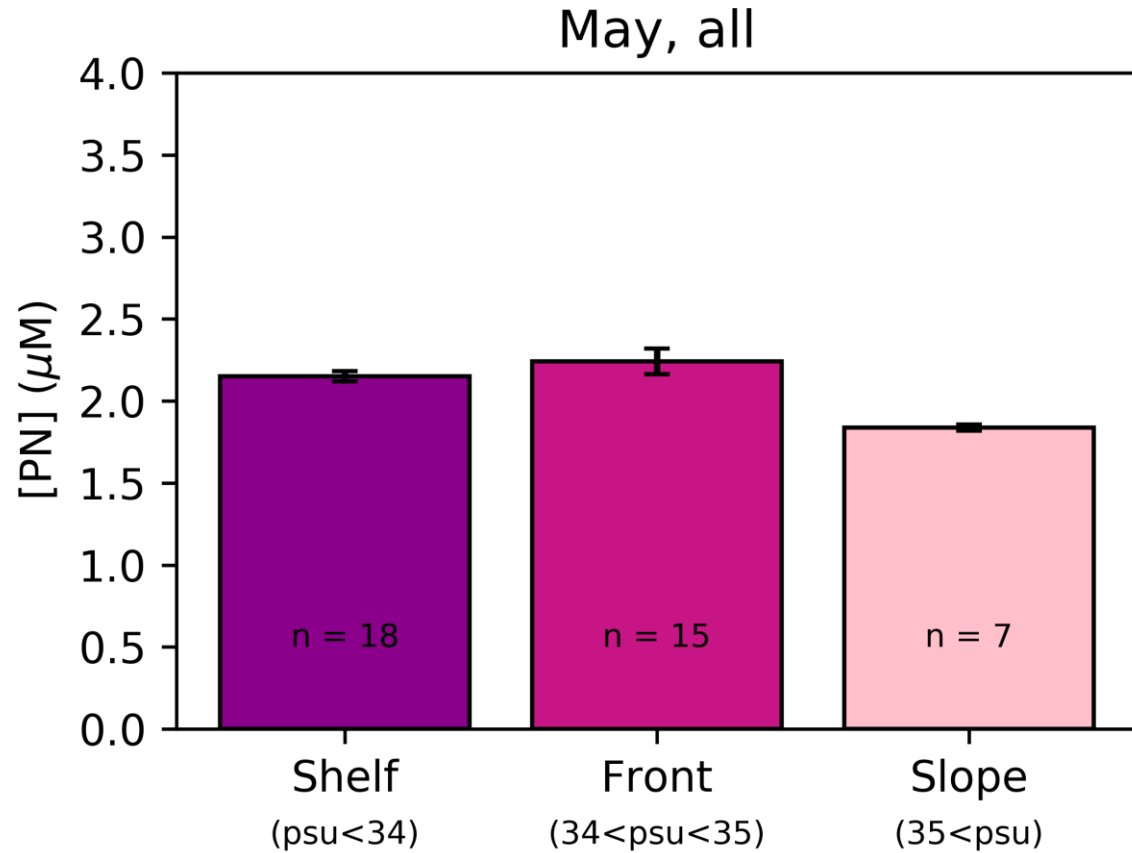
May 2019, all



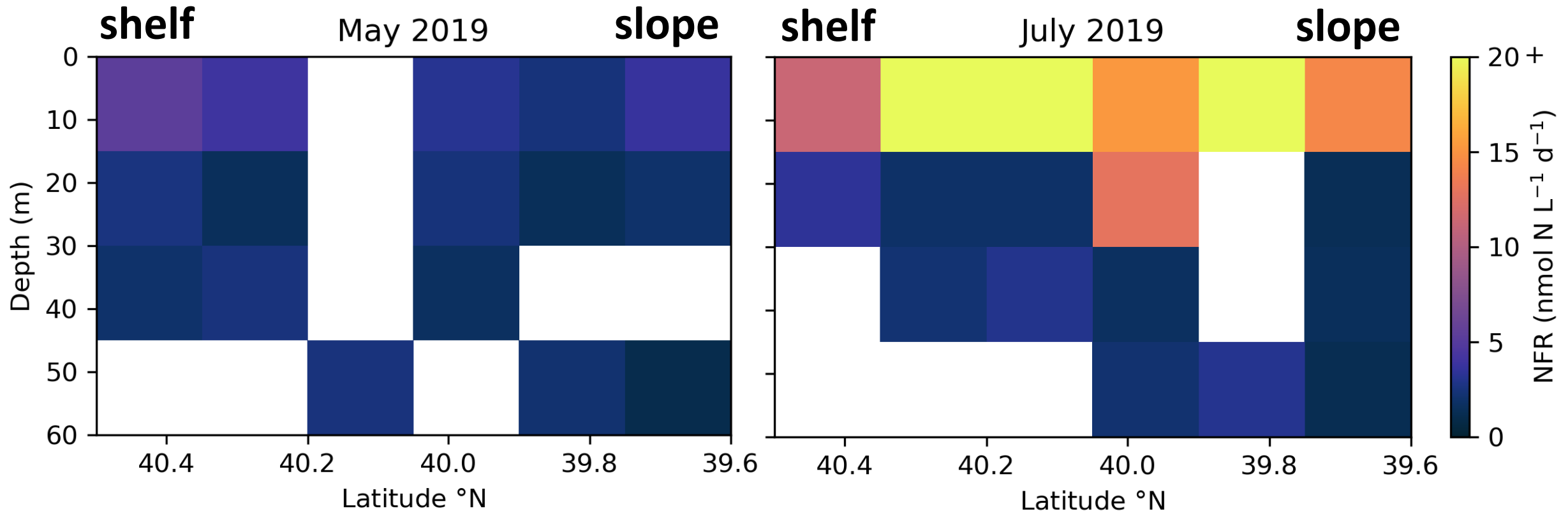
July 2019, >3 m



N₂ FIXATION BELOW THE STRATIFIED SURFACE LAYER



NFR binned by depth and latitude across transect



SUR binned by depth and latitude across transect

