Seasonal changes in primary production, phytoplankton community composition, and export during the Bering Sea Ecosystem Study

S. Bradley Moran

Graduate School of Oceanography, University of Rhode Island

QuickTime™ and a decompressor are needed to see this picture.

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Changing Arctic sea ice extent

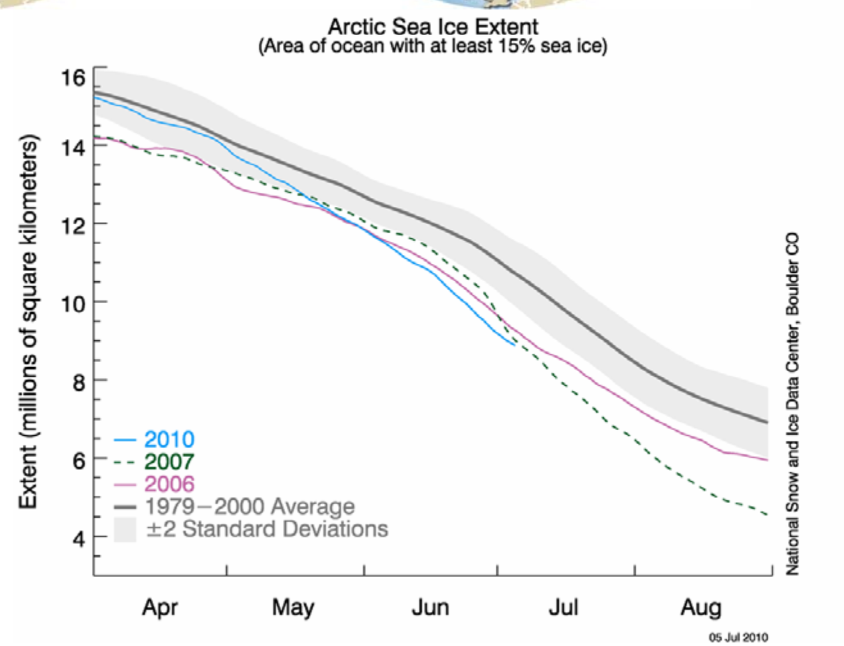
Average scenarios in the Arctic Climate Impact Assessment (ACIA) for the Arctic sea ice extent (permanent ice)

2010 - 2030 **2040 - 2060** **2070 - 2090**

Sea ice extent, M sq km

QuickTime™ and a
decompressor
are needed to see this picture.

1980 1995 2010



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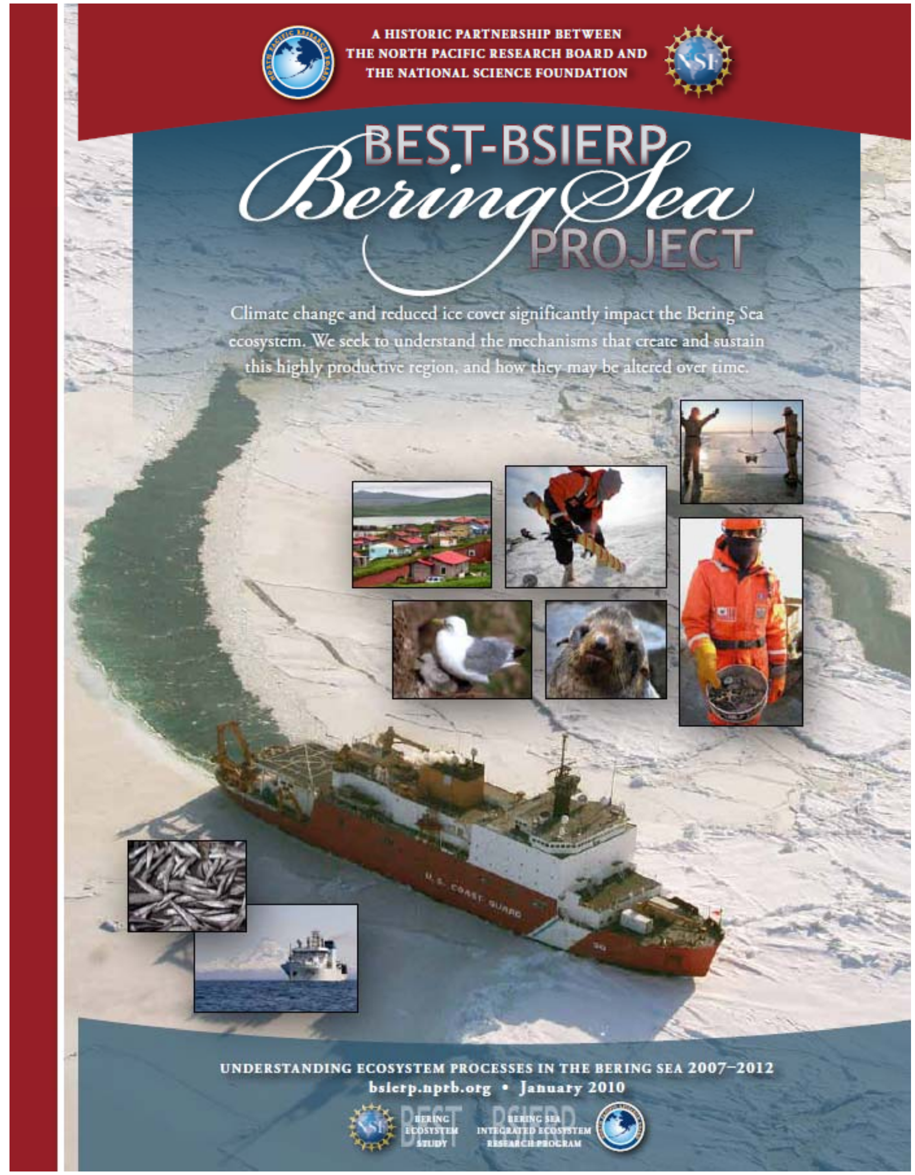
The Earth *is* warming!

Greg Mitchell, SIO

The BEST-BSIERP Bering Sea Project

- Joint NSF-NPRB
- $52 million study
  - 2007-2012
- Multidisciplinary
- >100 scientists
- *‘Seeks to understand impacts of climate change and dynamic sea ice cover on the eastern Bering Sea ecosystem’*



http://bsierp.nprb.org/index.html

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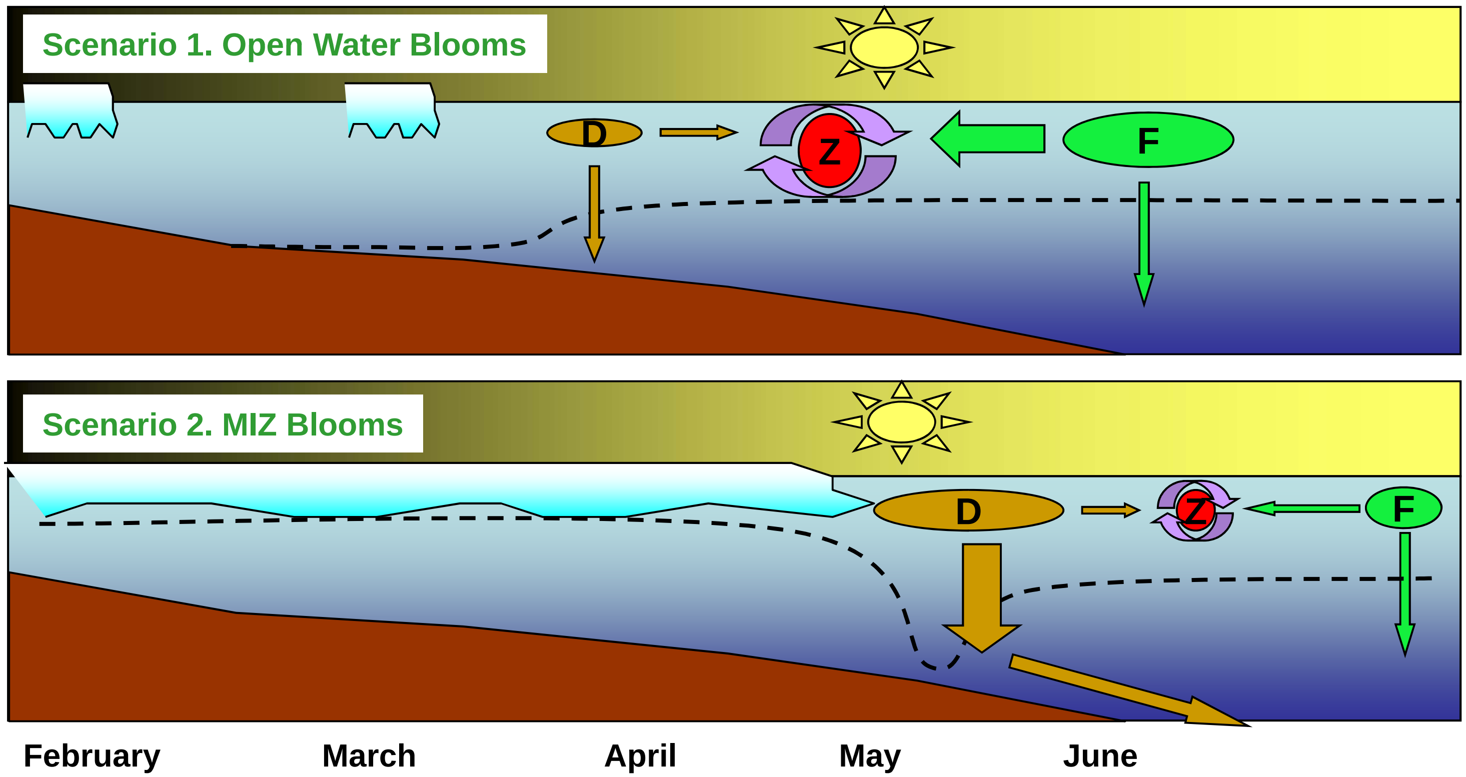
Key Hypotheses



Hypotheses. *Changes in sea-ice extent shifts the autotrophic community between;*

1. ***Open-water blooms*** *characterized by lower biomass, flagellate blooms, low pelagic export, and reduced pelagic-benthic coupling*.
2. ***Marginal ice-zone (MIZ) blooms***, *characterized by high biomass, diatom-dominated blooms, high pelagic export and tighter pelagic-benthic coupling.*

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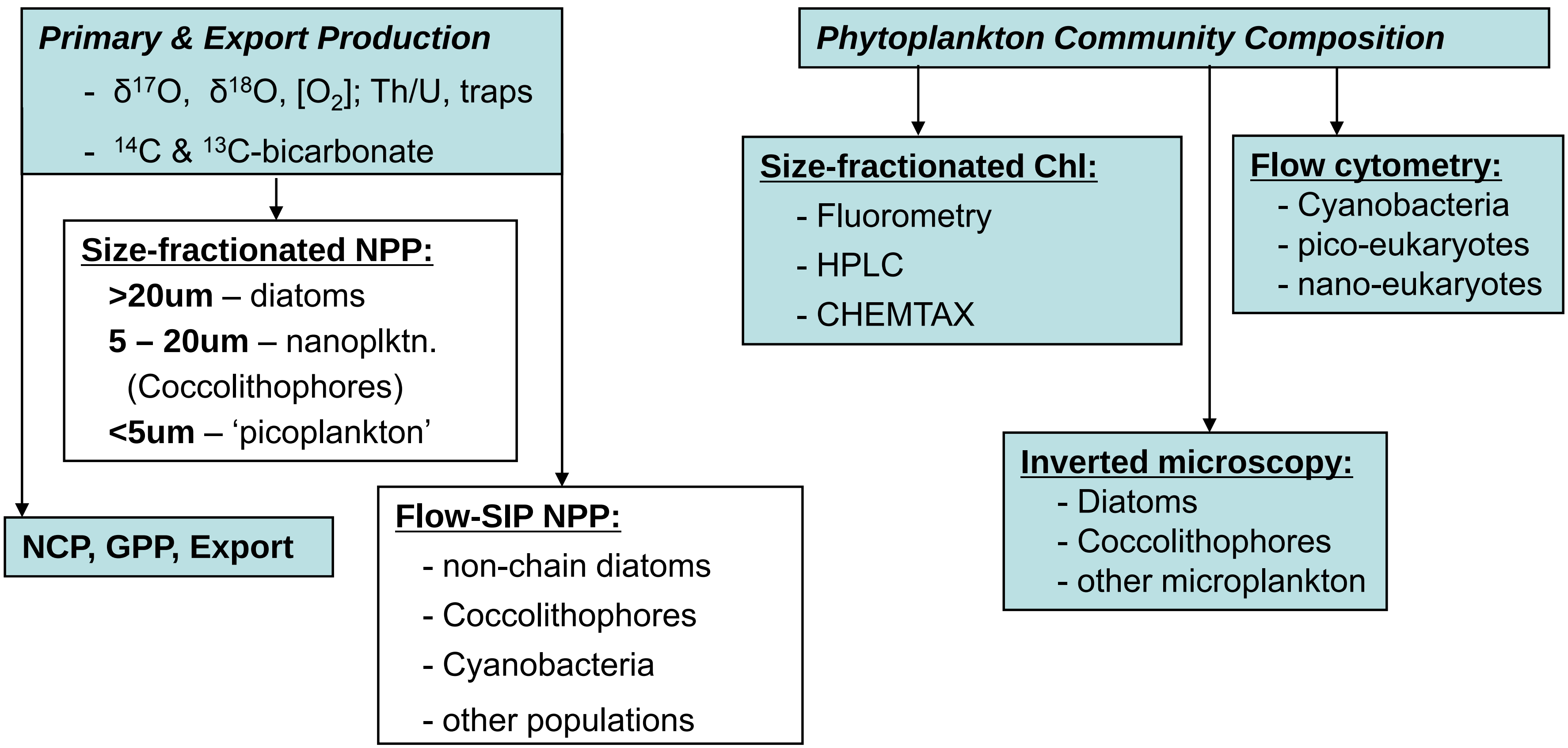
Objectives and Methods

1. Quantify the magnitude and variability of gross PP and NCP in open-water and MIZ blooms.

2. Quantify the 1° floristic patterns & autotrophic cell size distributions in open-water & MIZ blooms.

3. Quantify the export flux of particulate organic carbon in shelf/slope waters.



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HLY-08-02 cruise track

SL

MN

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

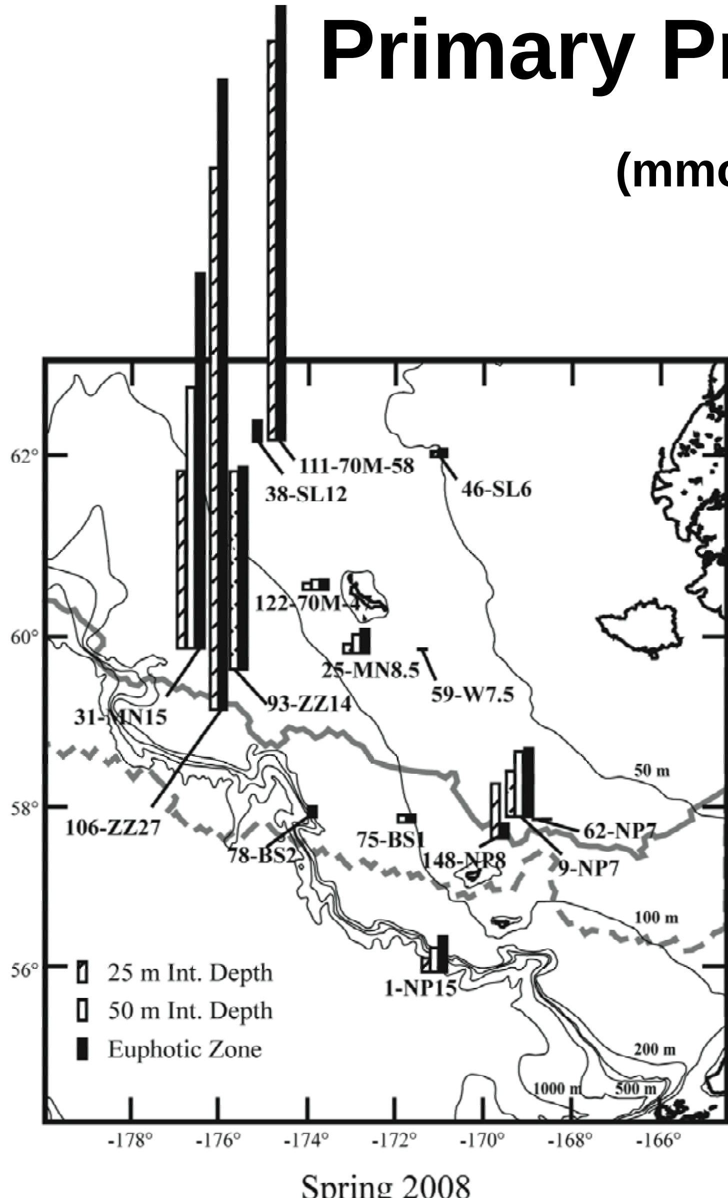
NP

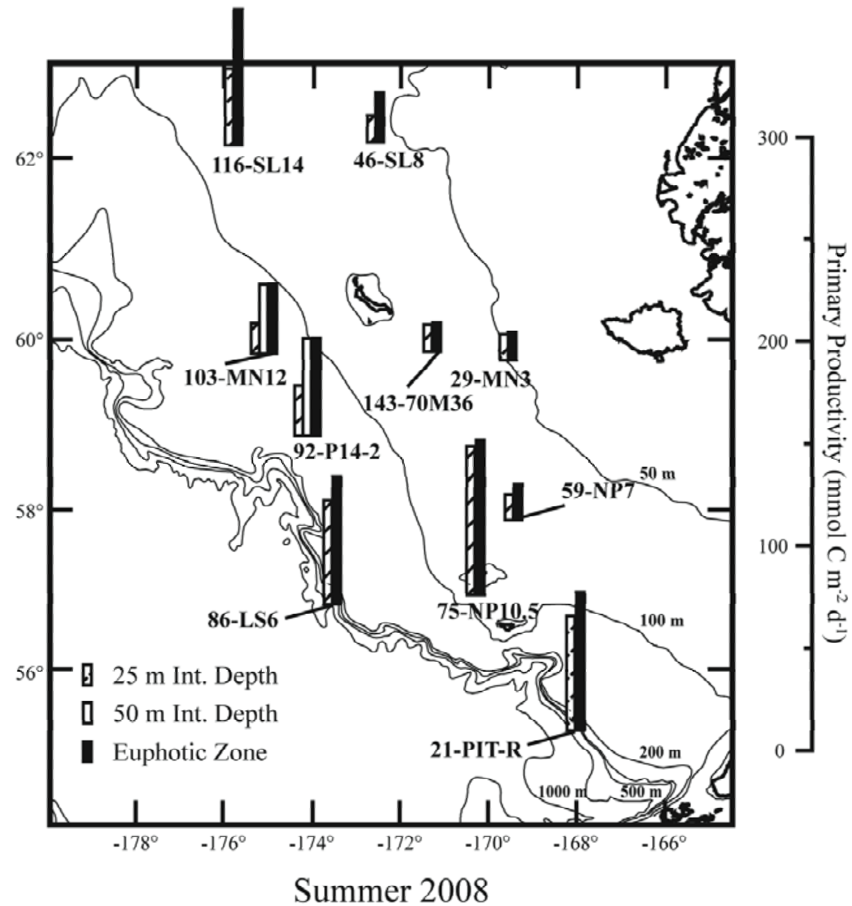
CN

6 cruises (2/yr), 70 d/yr: spring/summer 2008, 2009, 2010
Healy, Knorr, Thompson

Primary Productivity - 2008

(mmol C m^{-2} d^{-1})

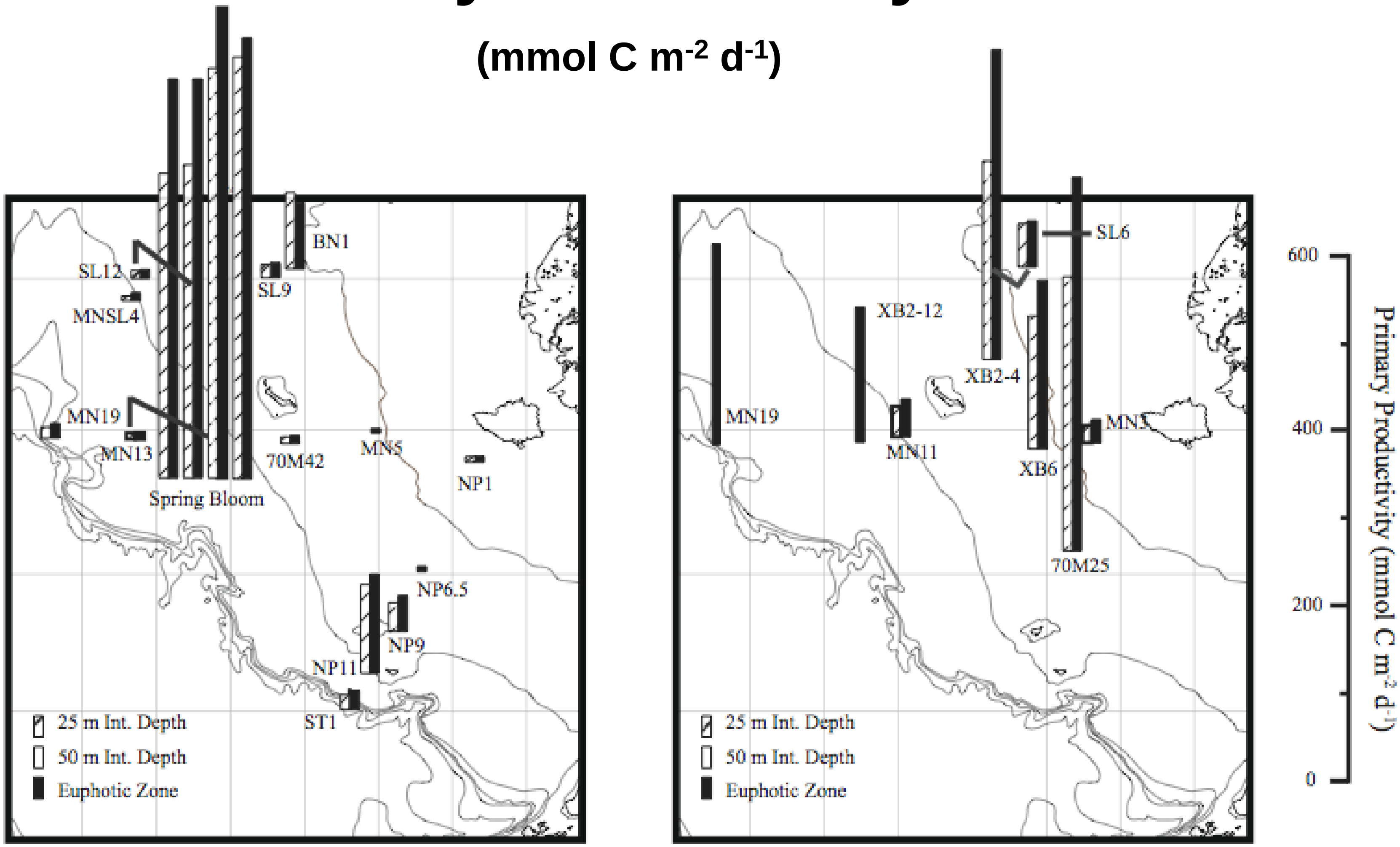




Under-ice	*MIZ*	
45 ± 74	62 ± 114	43 ± 24
n = 9	n = 7	n = 11

Primary Productivity - 2009

(mmol C m^{-2} d^{-1})



Spring 2009

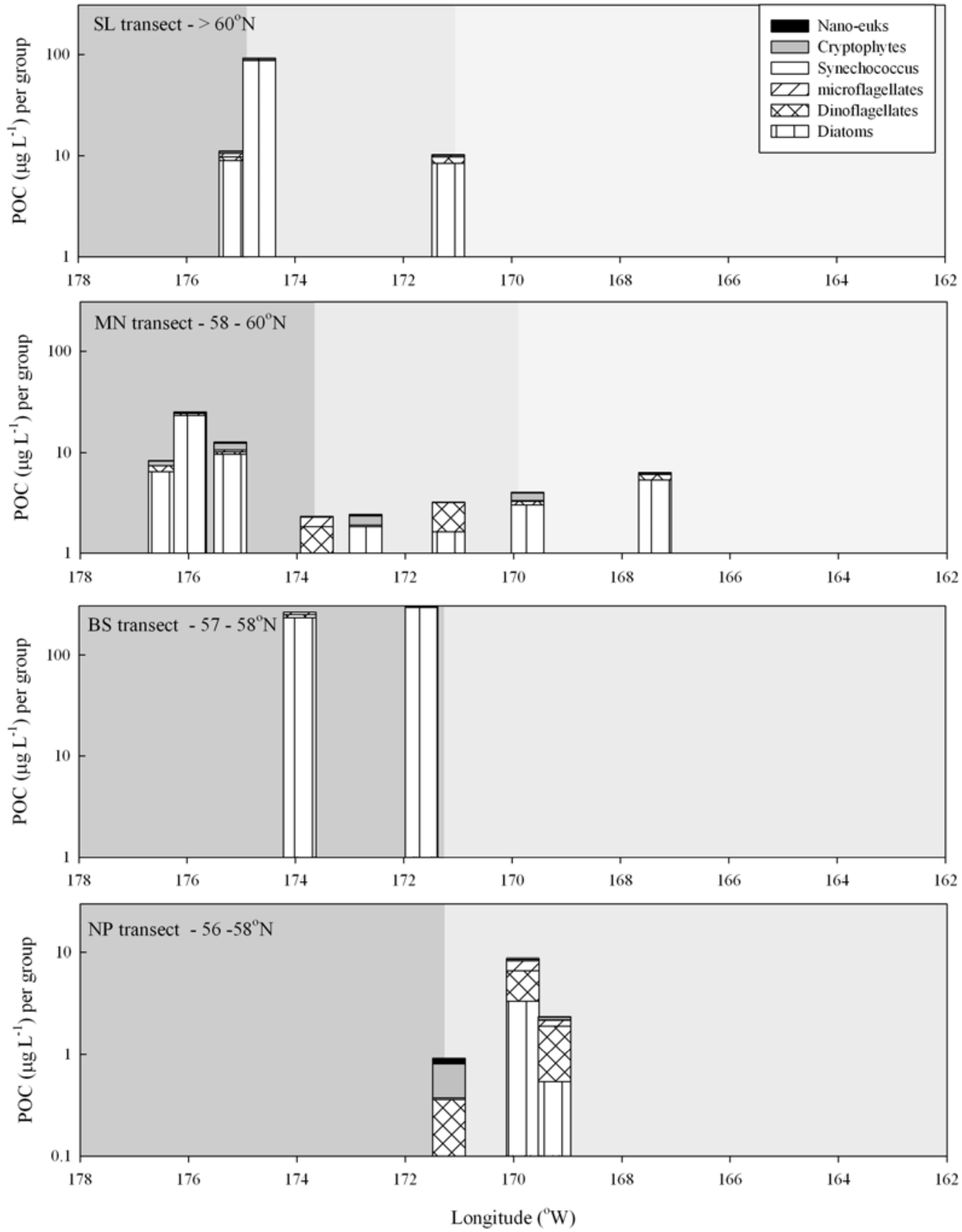
Summer 2009

Under-ice
19 ± 22
n = 10

MIZ
394 ± 214
n = 5

150 ± 146
n = 9

Phytoplankton Community Composition - Spring 2008



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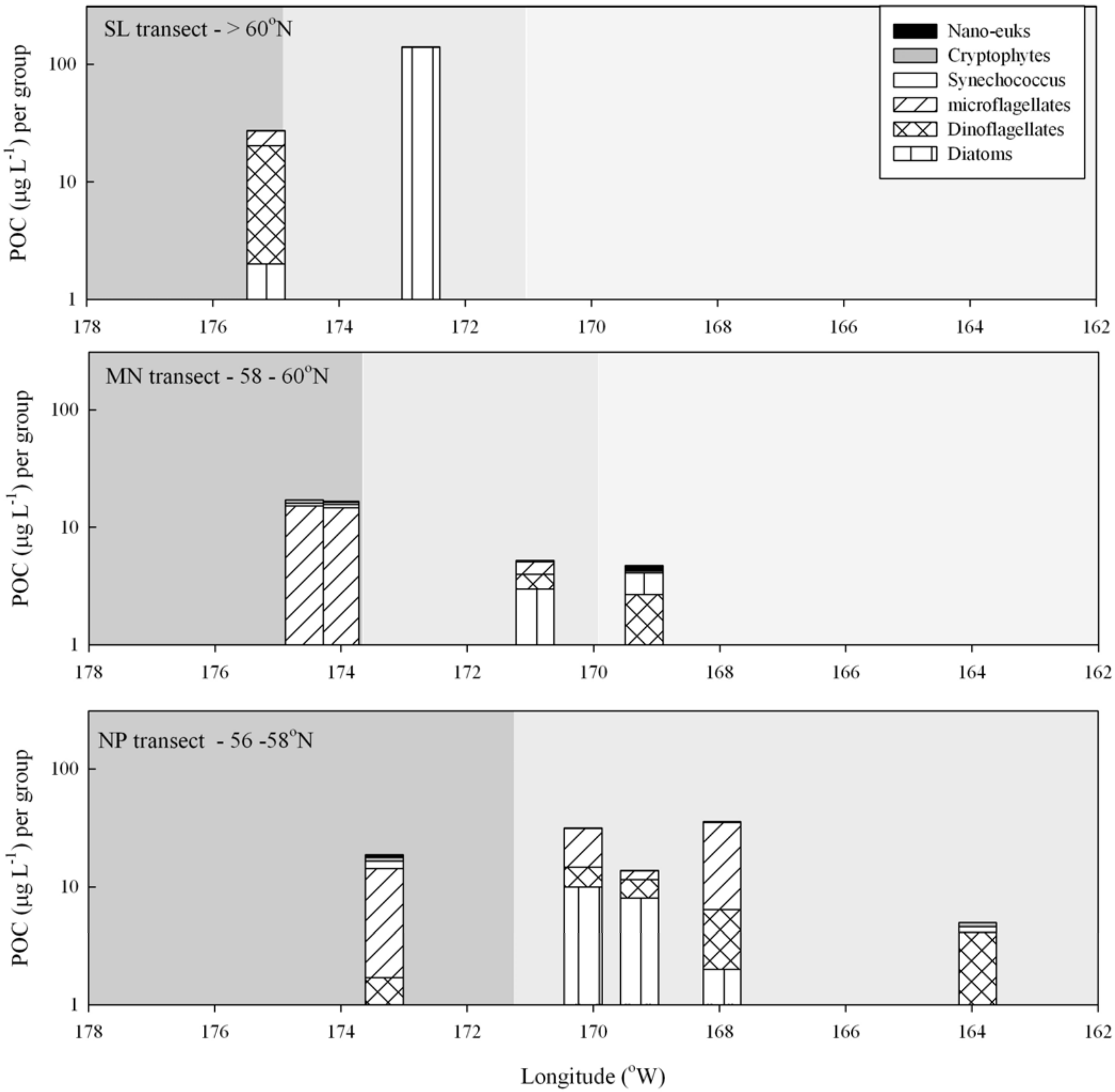
Phytoplankton Community Composition - Summer 2009



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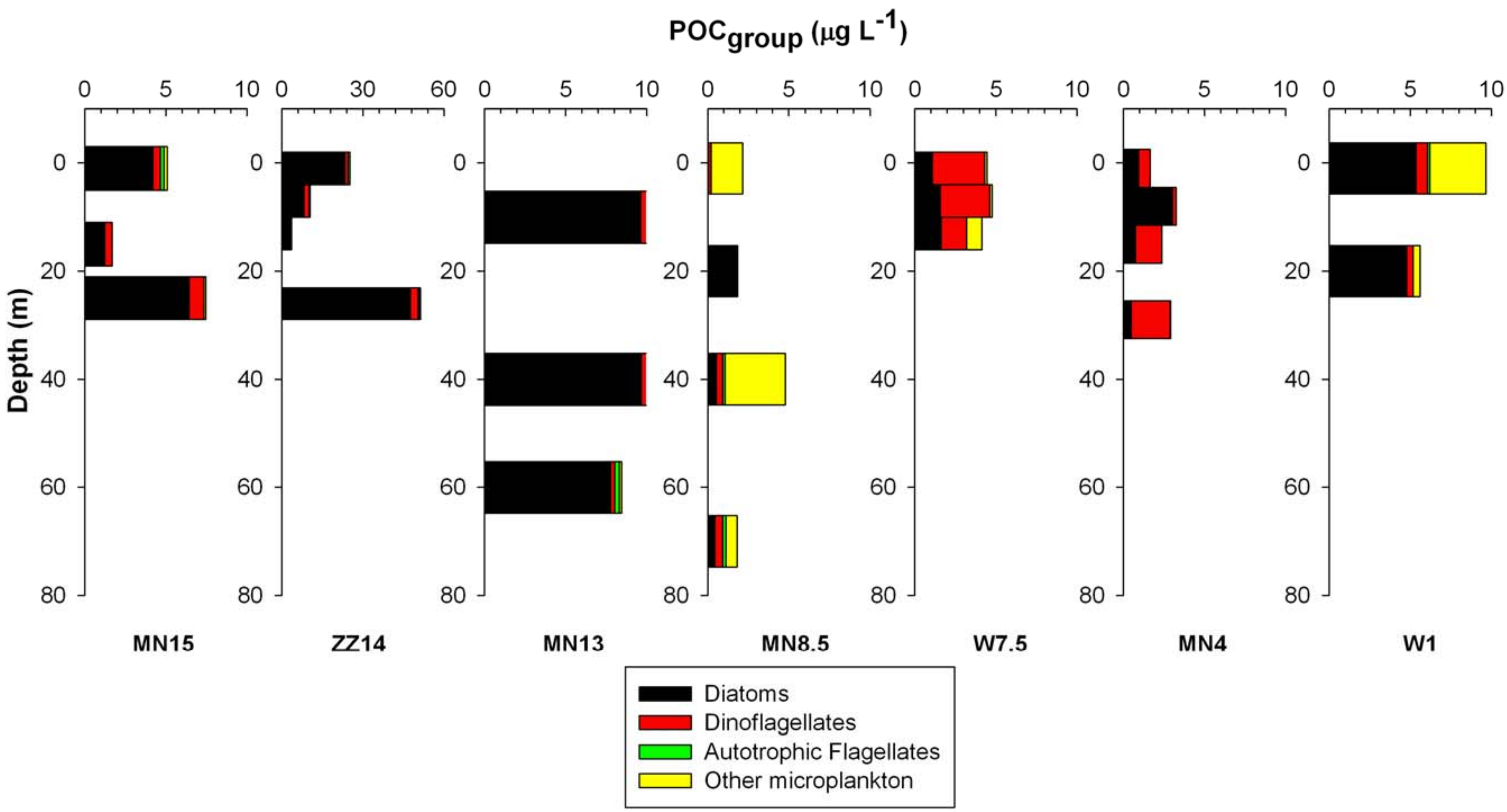
POC_{group} distribution on MN line - Spring 2008



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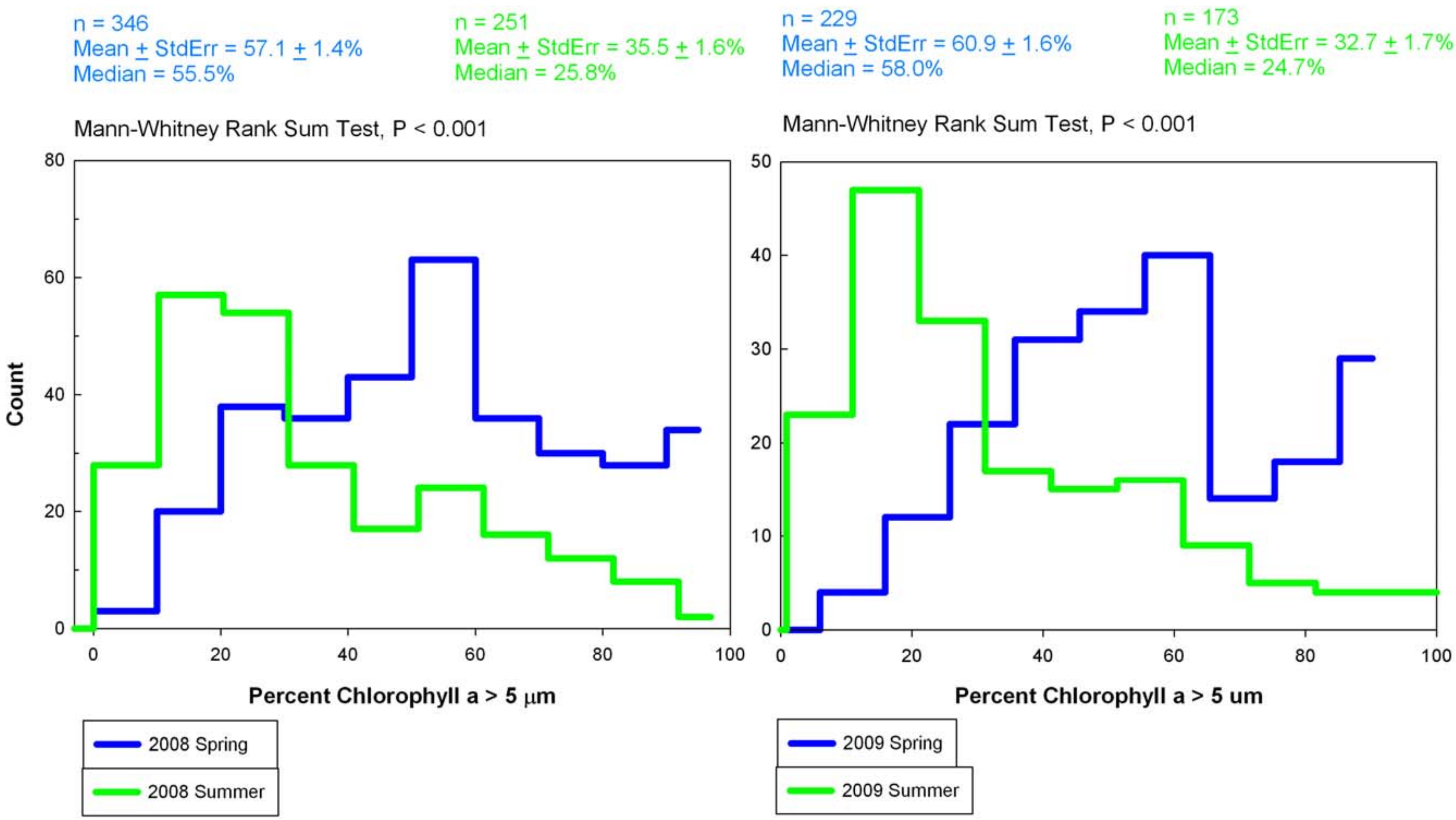
Chlorophyll-*a* in >5 μm - 2008, 2009

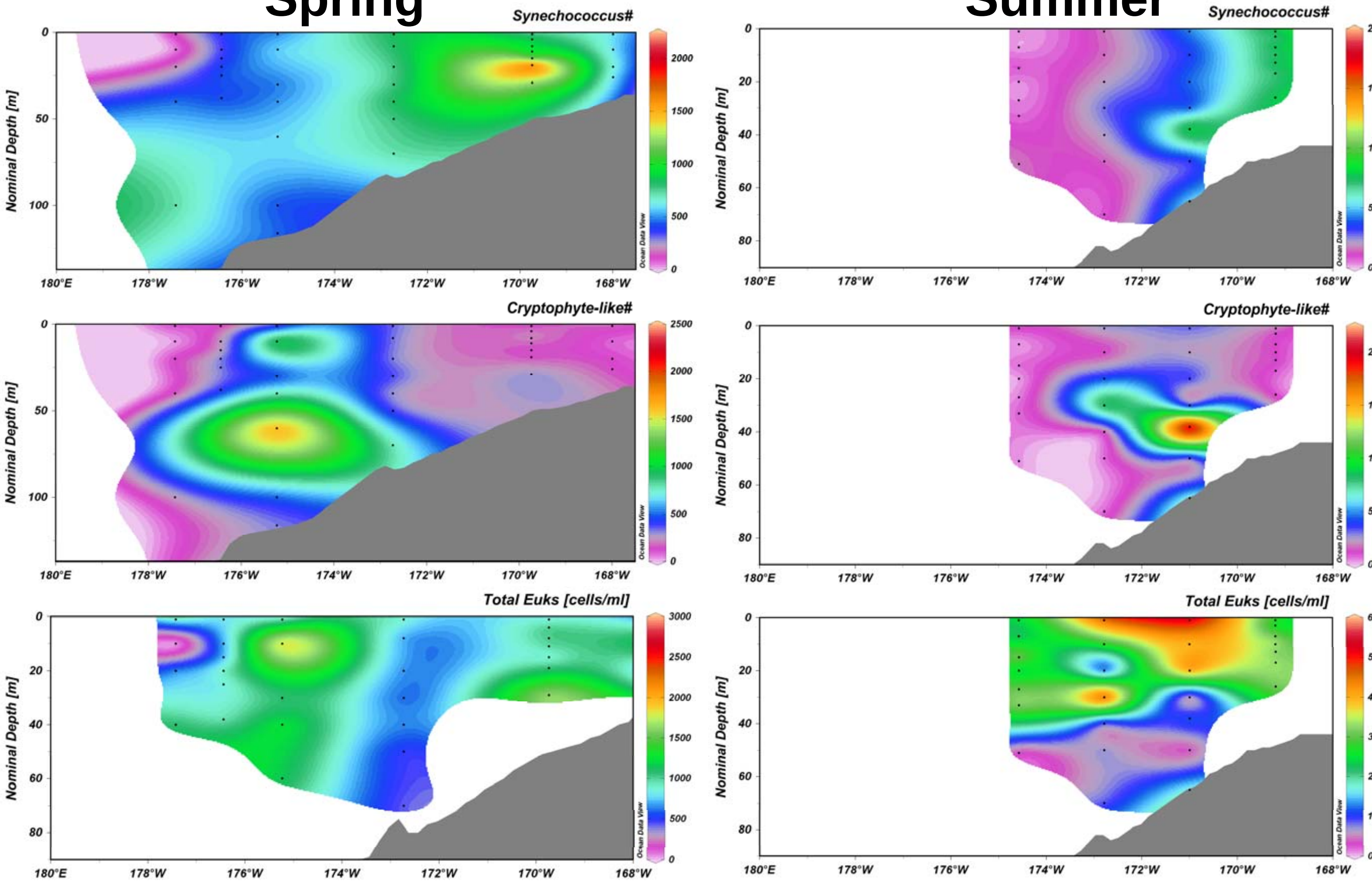


- Reduction in mean size of Chl.-a containing particles from spring to summer

Cell abundances (cell mL^{-1}), MN Line - 2008

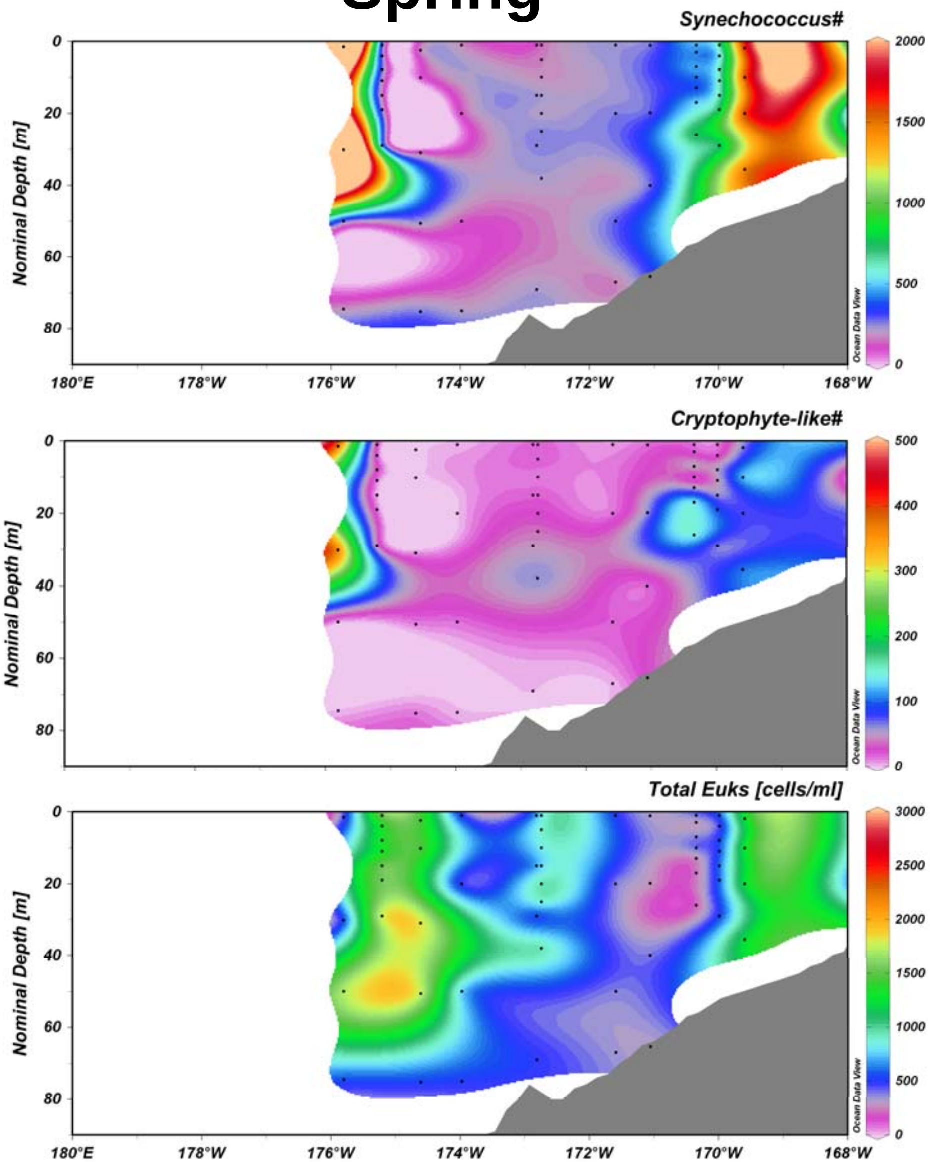
Spring

Summer



Cell abundances (cell mL^{-1}), MN Line - 2009

Spring



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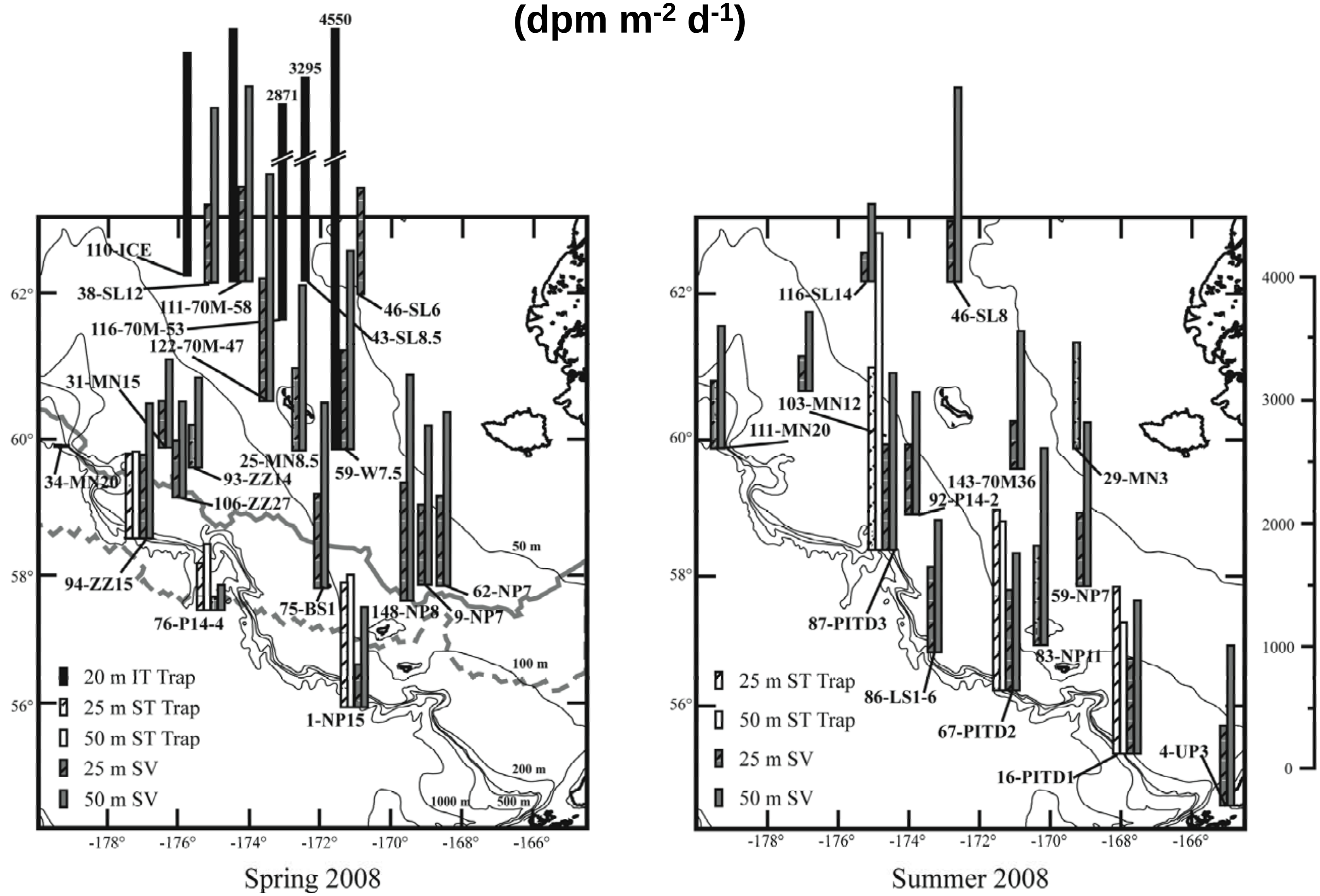
Particle ^{234}Th Export - 2008

(dpm m^{-2} d^{-1})



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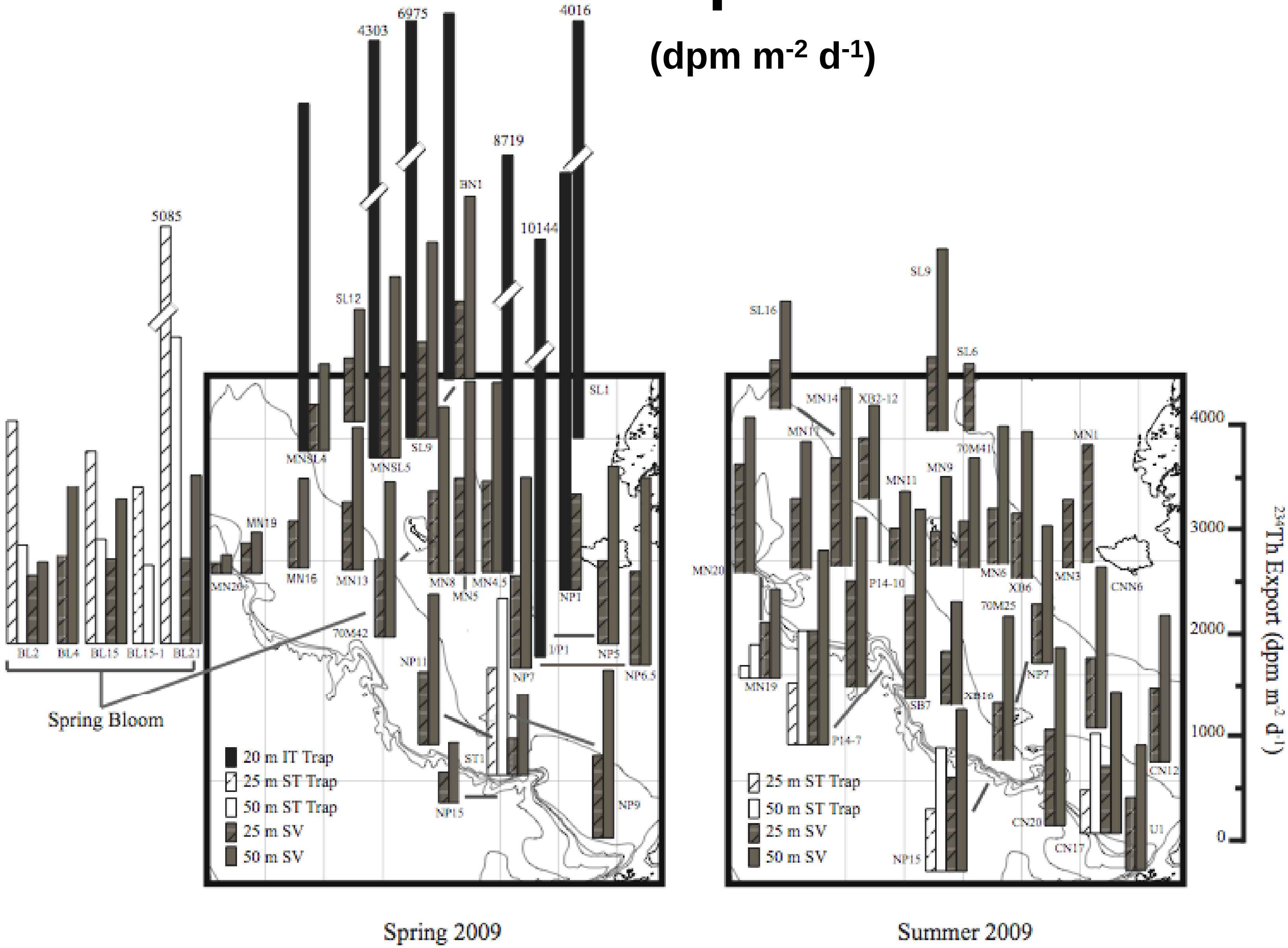
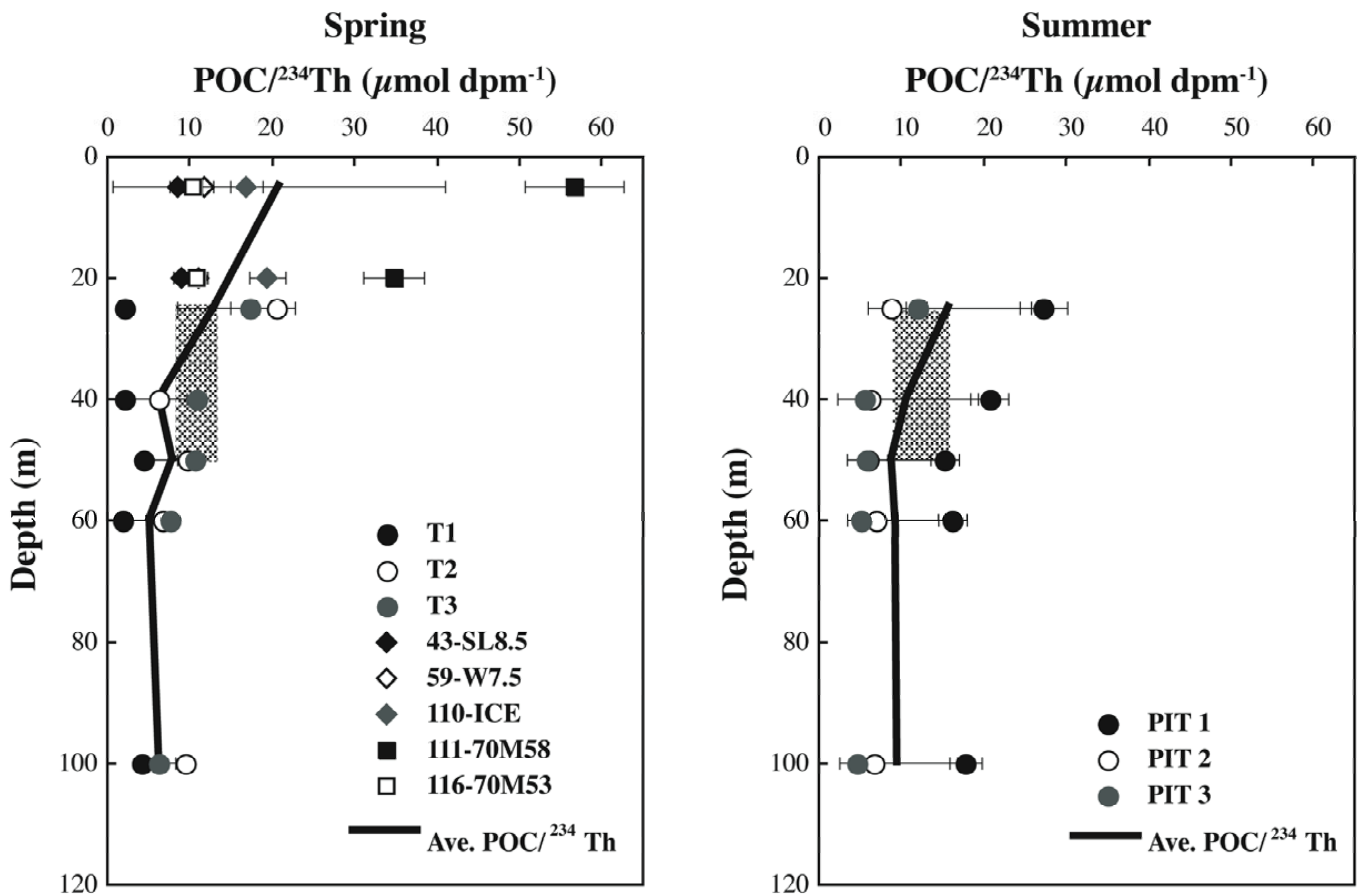
Particle ^{234}Th Export - 2009

(dpm m^{-2} d^{-1})



POC/^{234}Th Ratios - 2008



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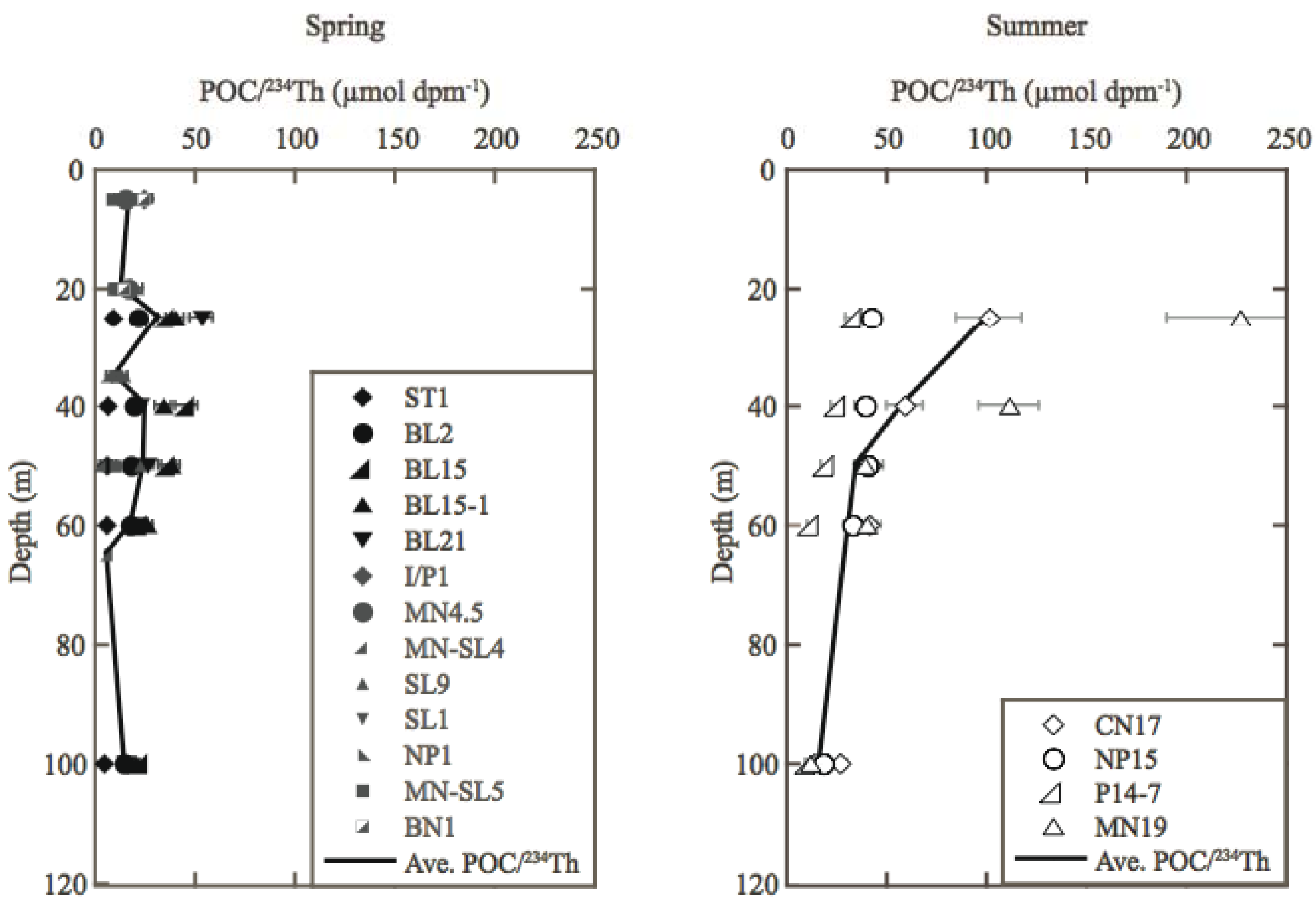
POC/^{234}Th Ratios - 2009



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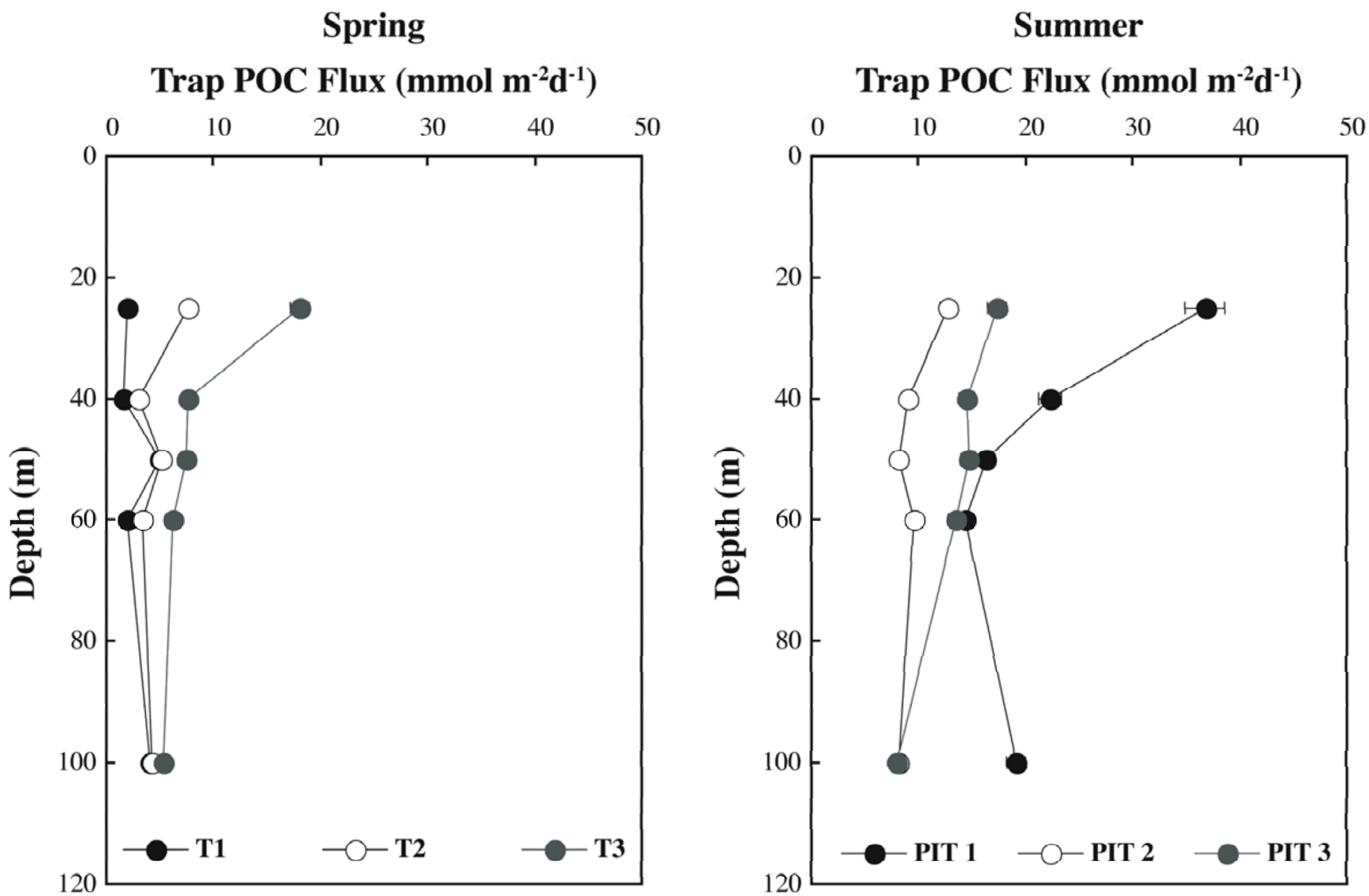
Sediment Trap POC Fluxes - 2008



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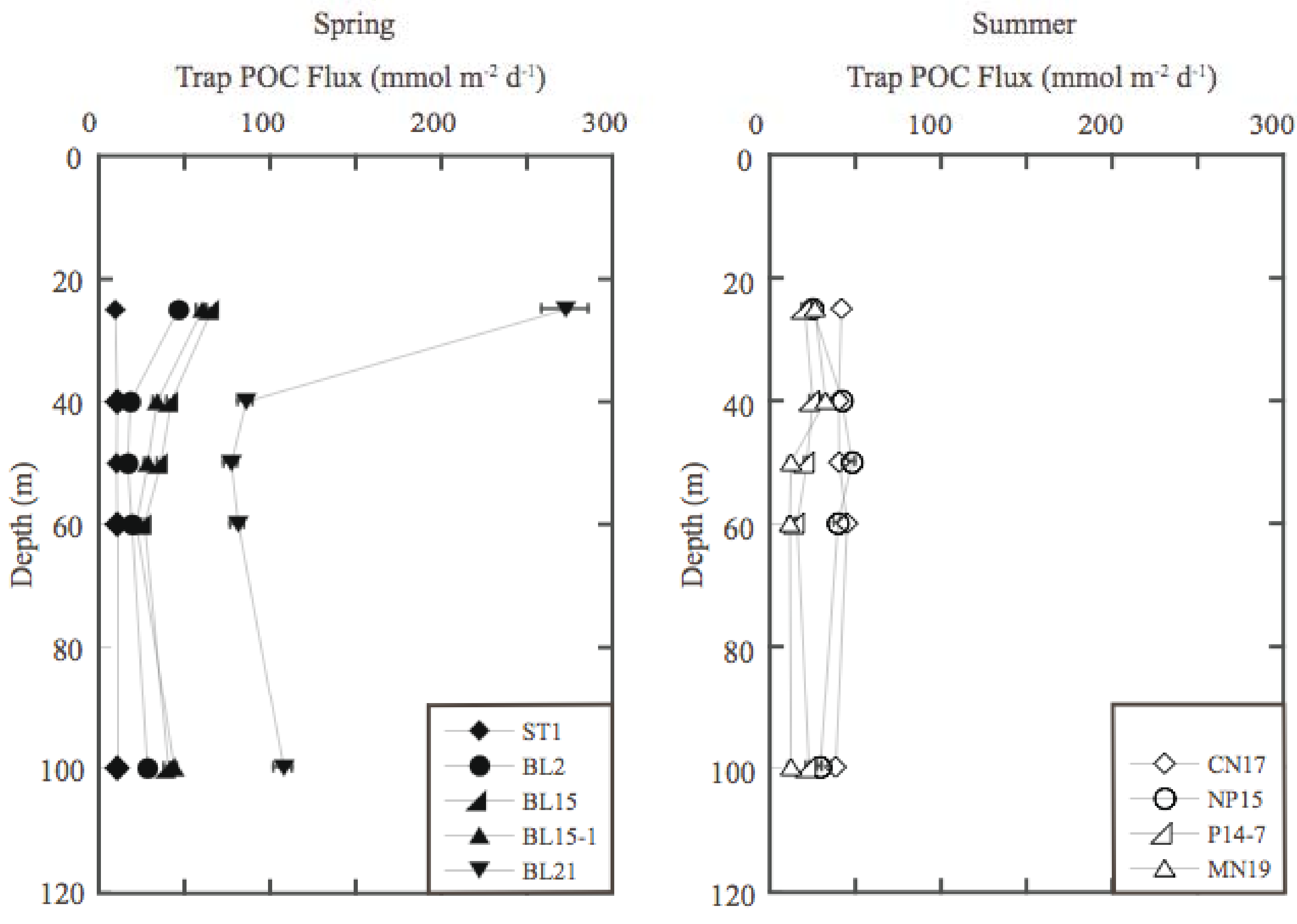
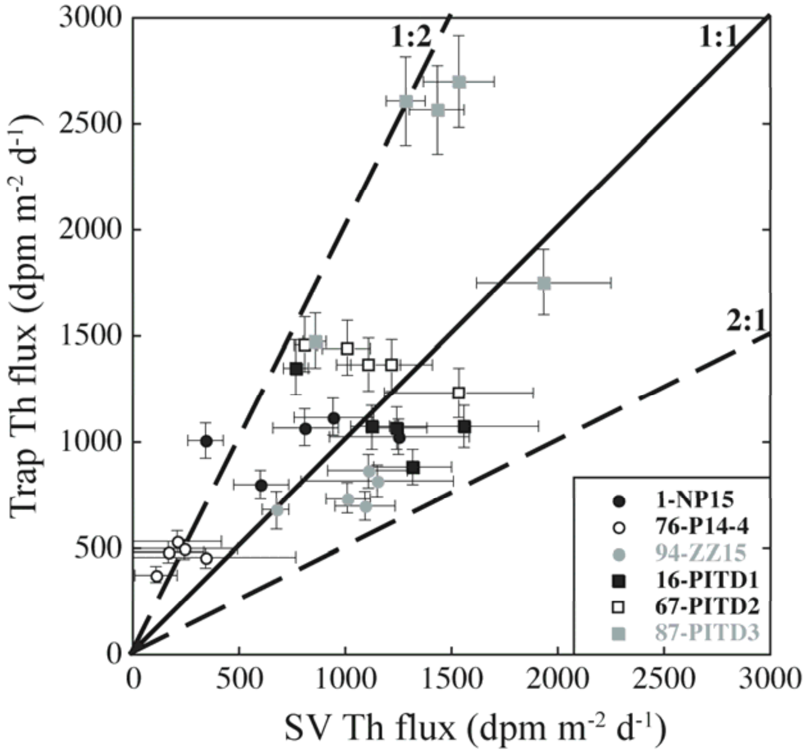
Sediment Trap POC Fluxes - 2009

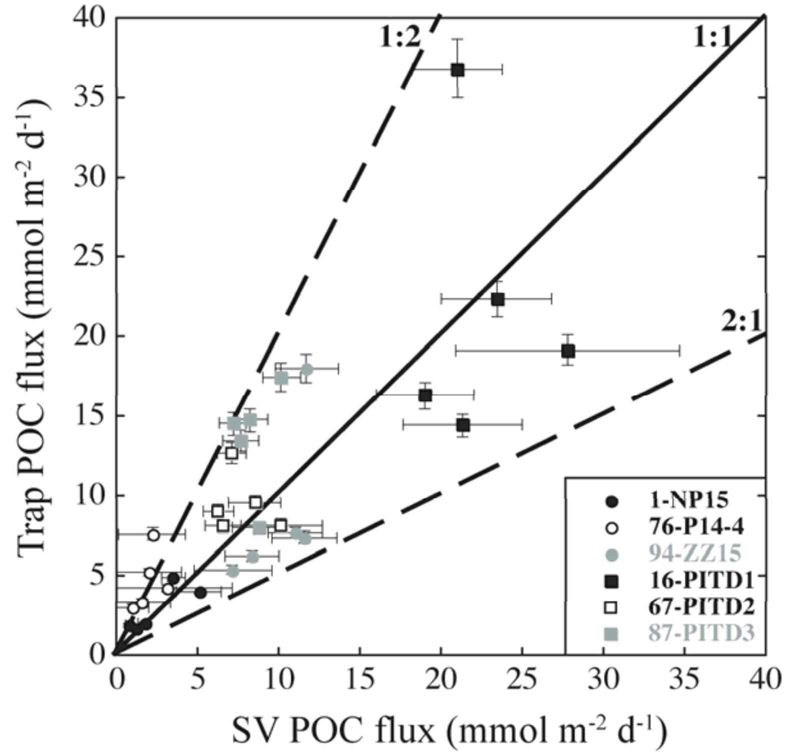


^{234}Th and POC Export Comparison - 2008

^{234}Th - Trap vs. ^{234}Th/^{238}U



POC - Trap vs. ^{234}Th/^{238}U



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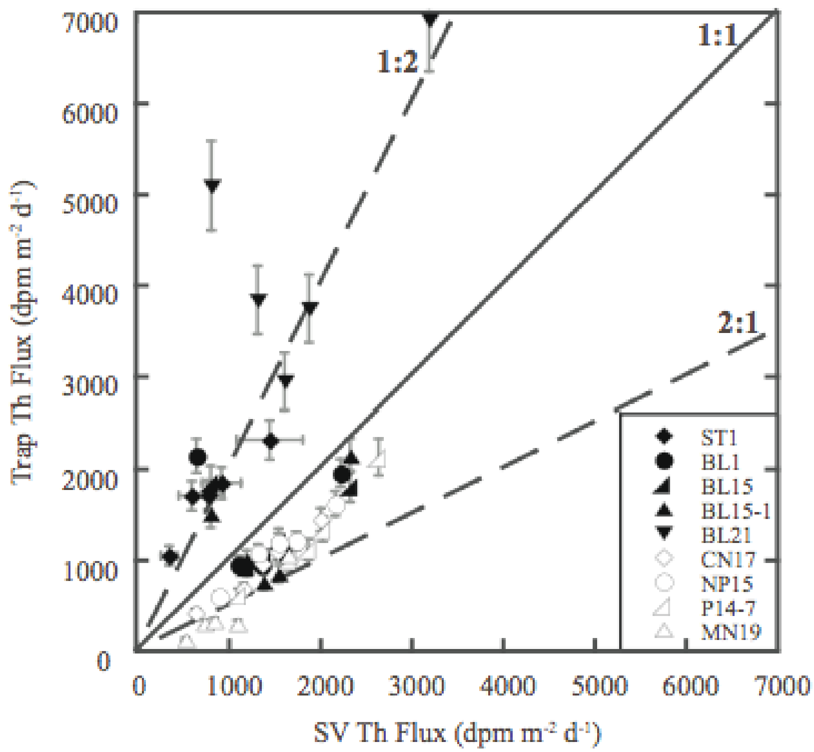
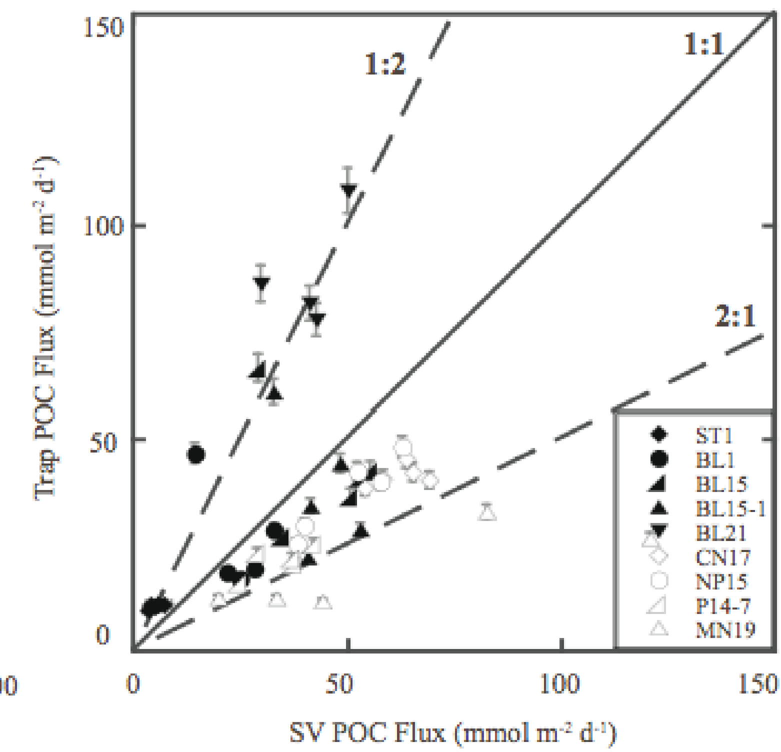
^{234}Th and POC Export Comparison - 2009

^{234}Th - Trap vs. ^{234}Th/^{238}U



POC - Trap vs. ^{234}Th/^{238}U



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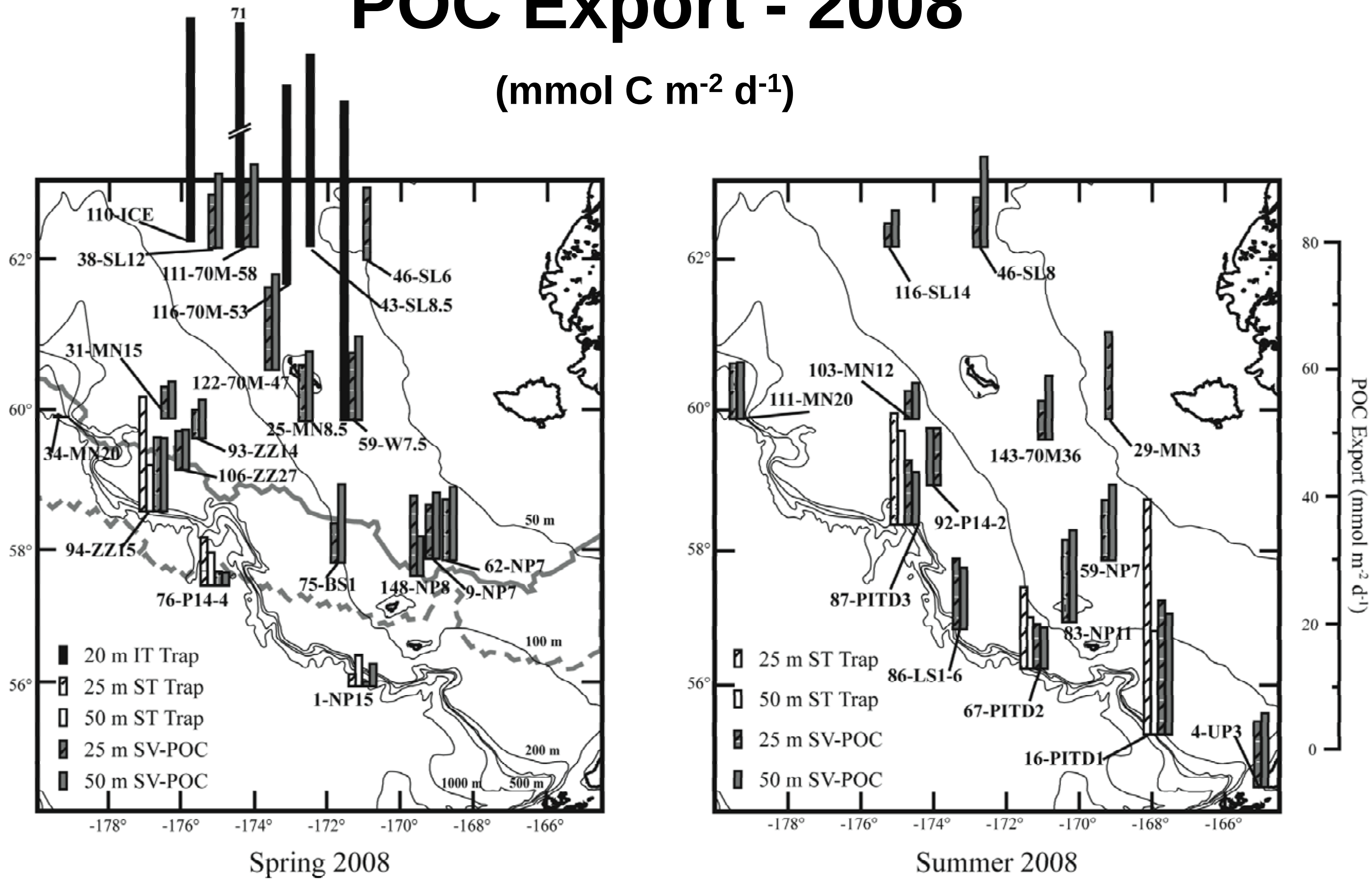
POC Export - 2008

(mmol C m^{-2} d^{-1})



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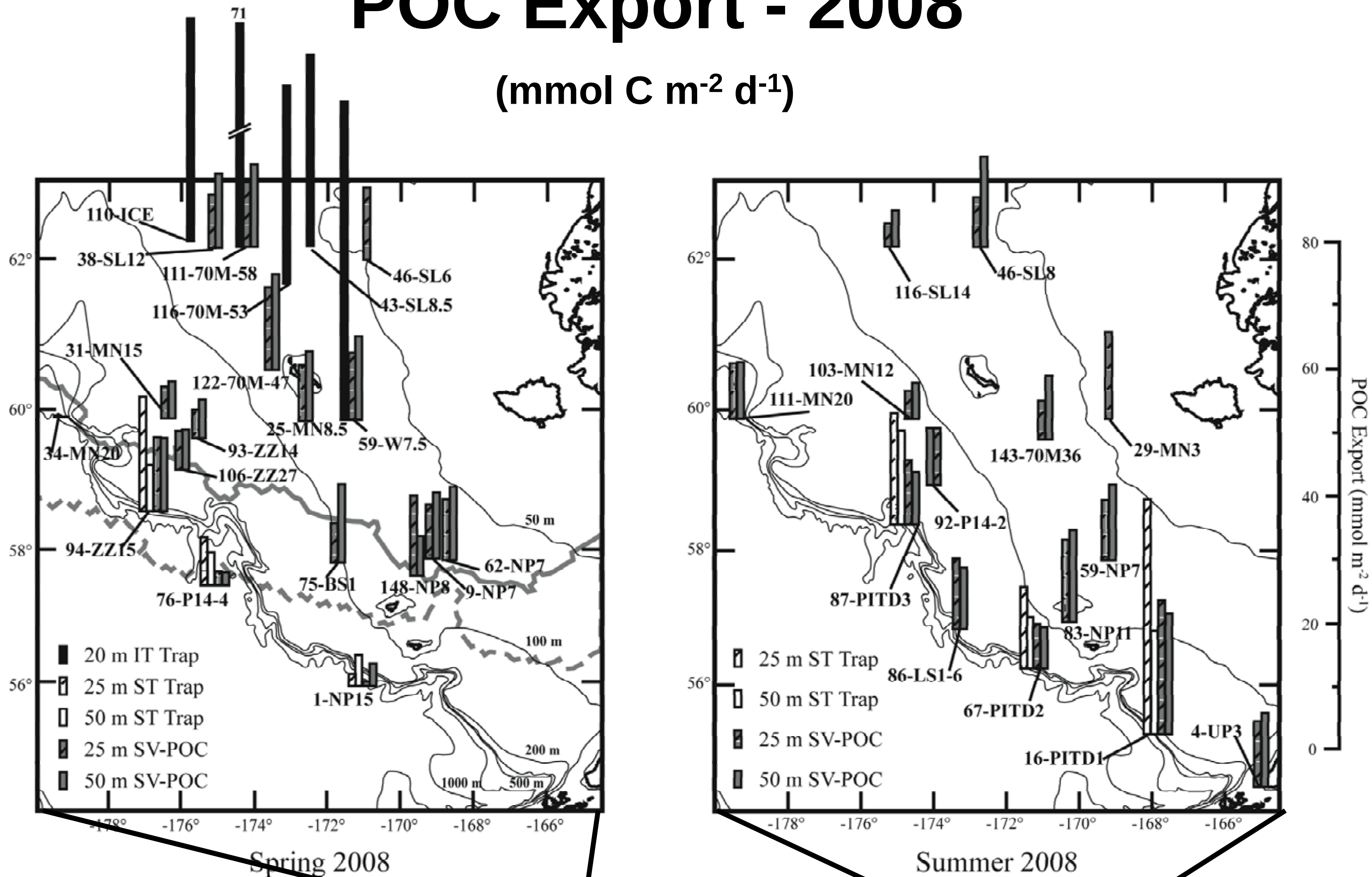
POC Export - 2008

(mmol C m^{-2} d^{-1})

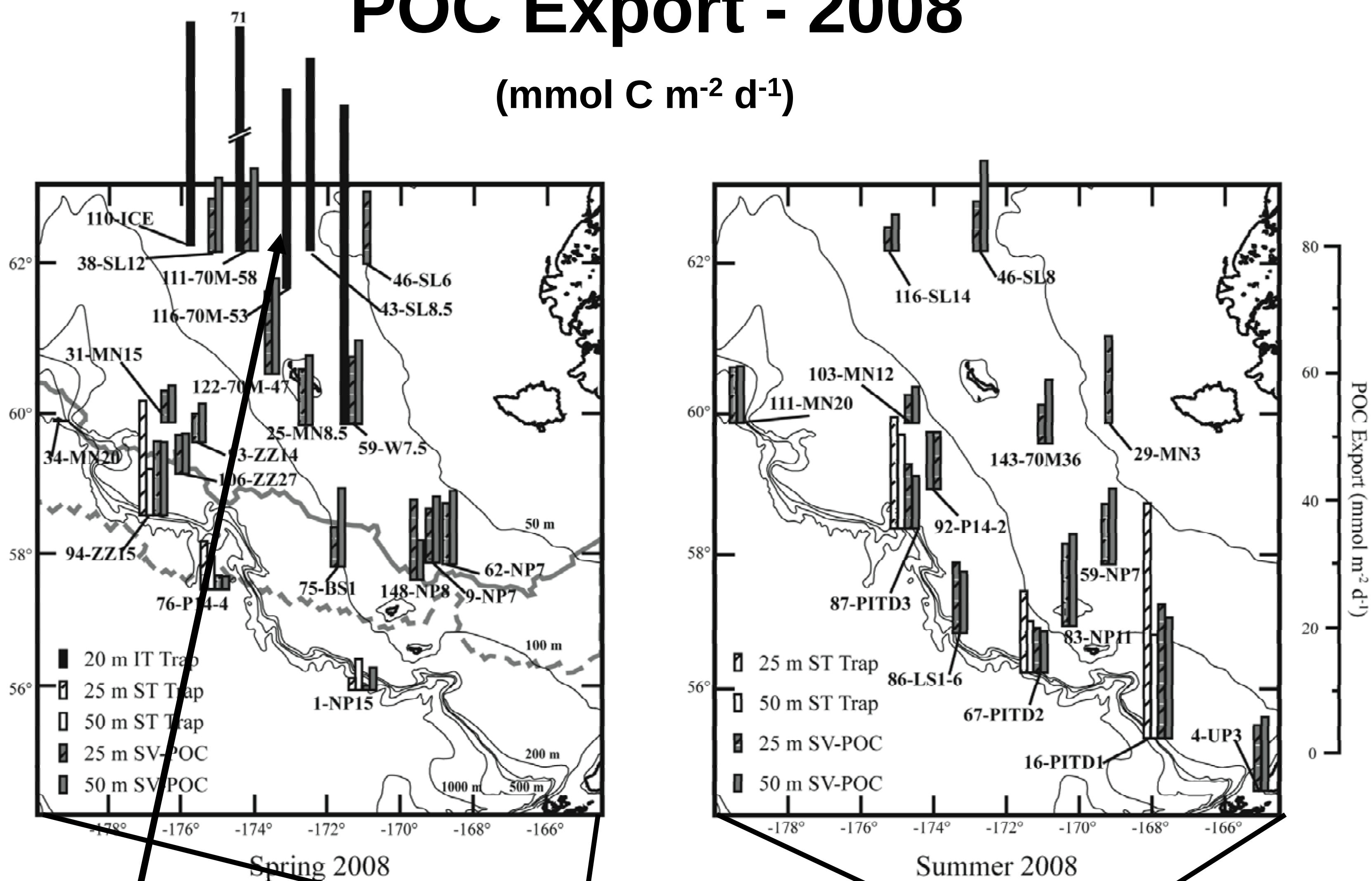


5.8 ± 1.3 n = 3	*50 m Trap*	13 ± 4.4 n = 3

5.7 ± 6.0 n = 3	*50 m SV-POC*	10 ± 3.8 n = 12

POC Export - 2008

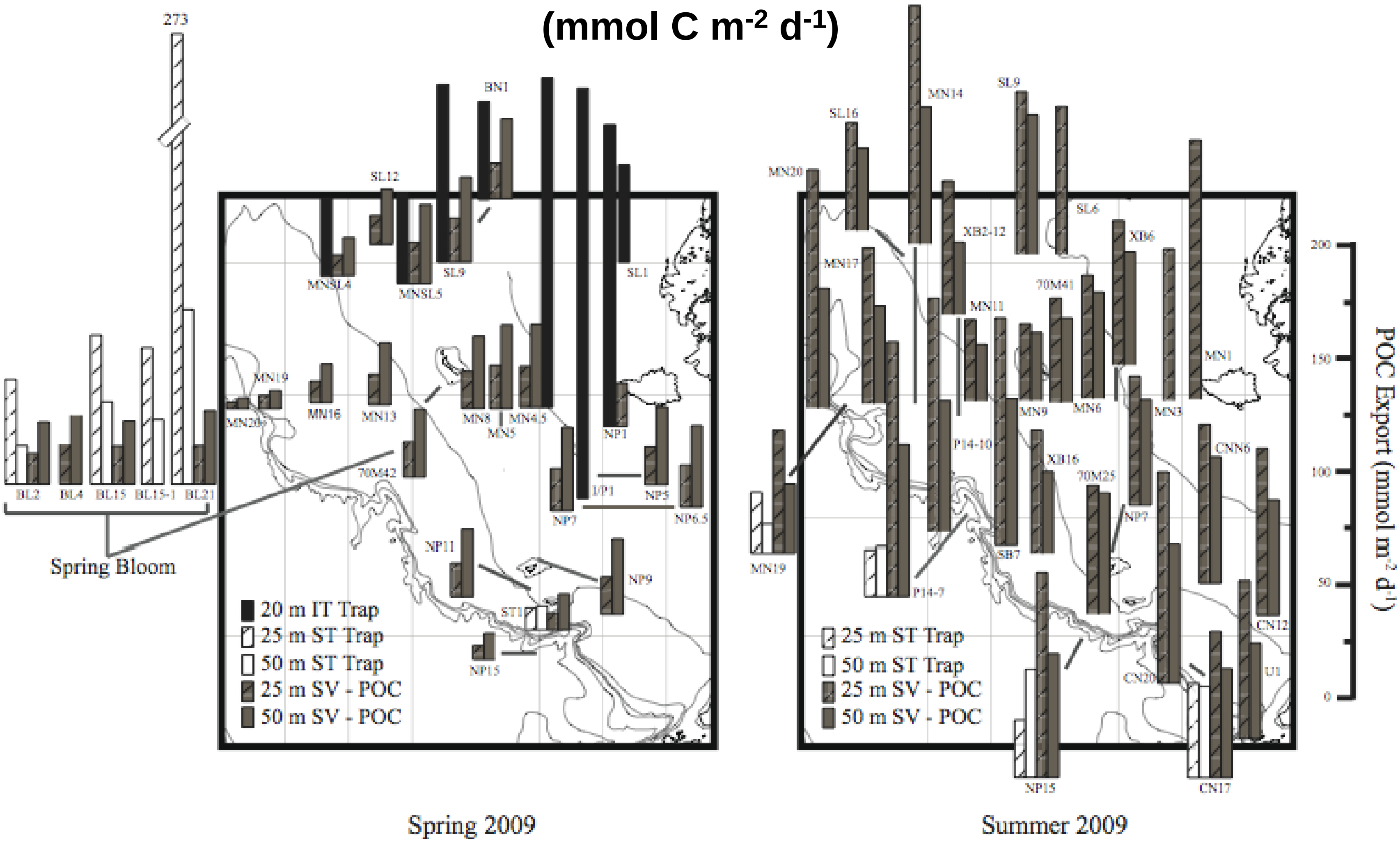
(mmol C m^{-2} d^{-1})



43 ± 17, n = 5	*20 m Ice Trap*	5.8 ± 1.3, n = 3	*50 m Trap*	13 ± 4.4, n = 3
7.9 ± 3.6, n = 15	*25 m SV-POC*	5.7 ± 6.0, n = 3	*50 m SV-POC*	10 ± 3.8, n = 12

POC Export - 2009

(mmol C m^{-2} d^{-1})



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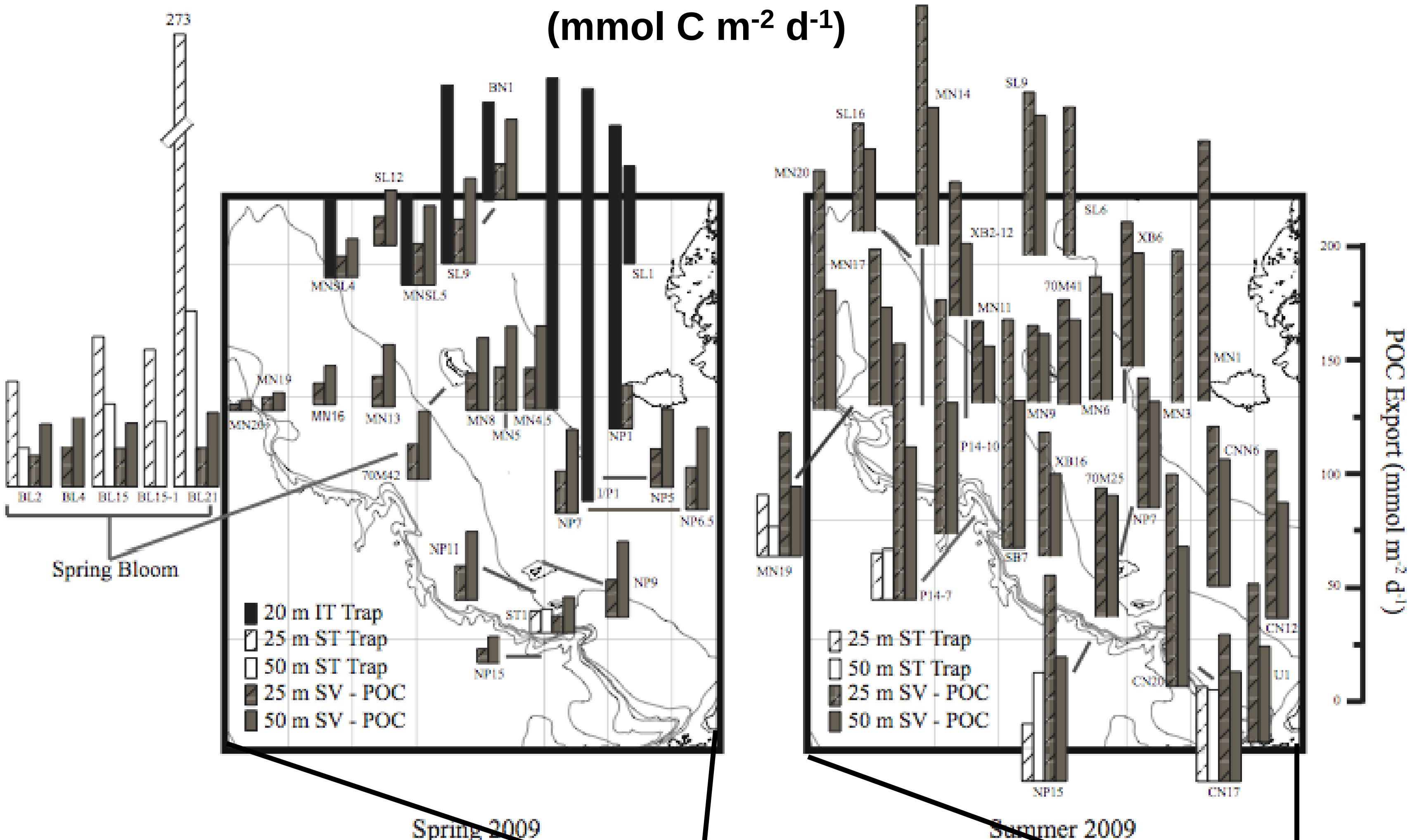
POC Export - 2009

(mmol C m^{-2} d^{-1})



40 ± 26 n = 4	*50 m Trap*	27 ± 17 n = 5
22 ± 12 n = 6	*50 m SV-POC*	45 ± 15 n = 27

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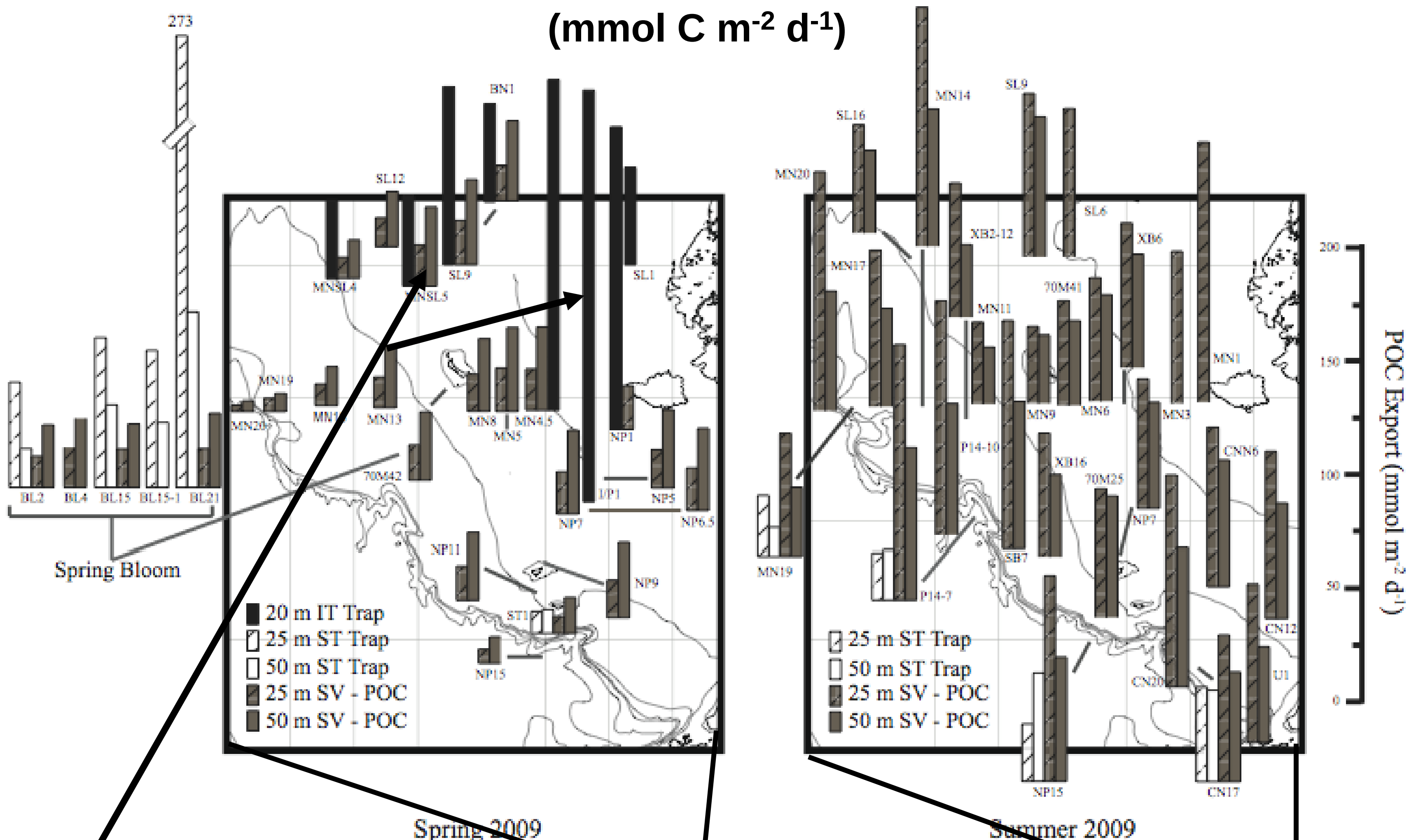
POC Export - 2009

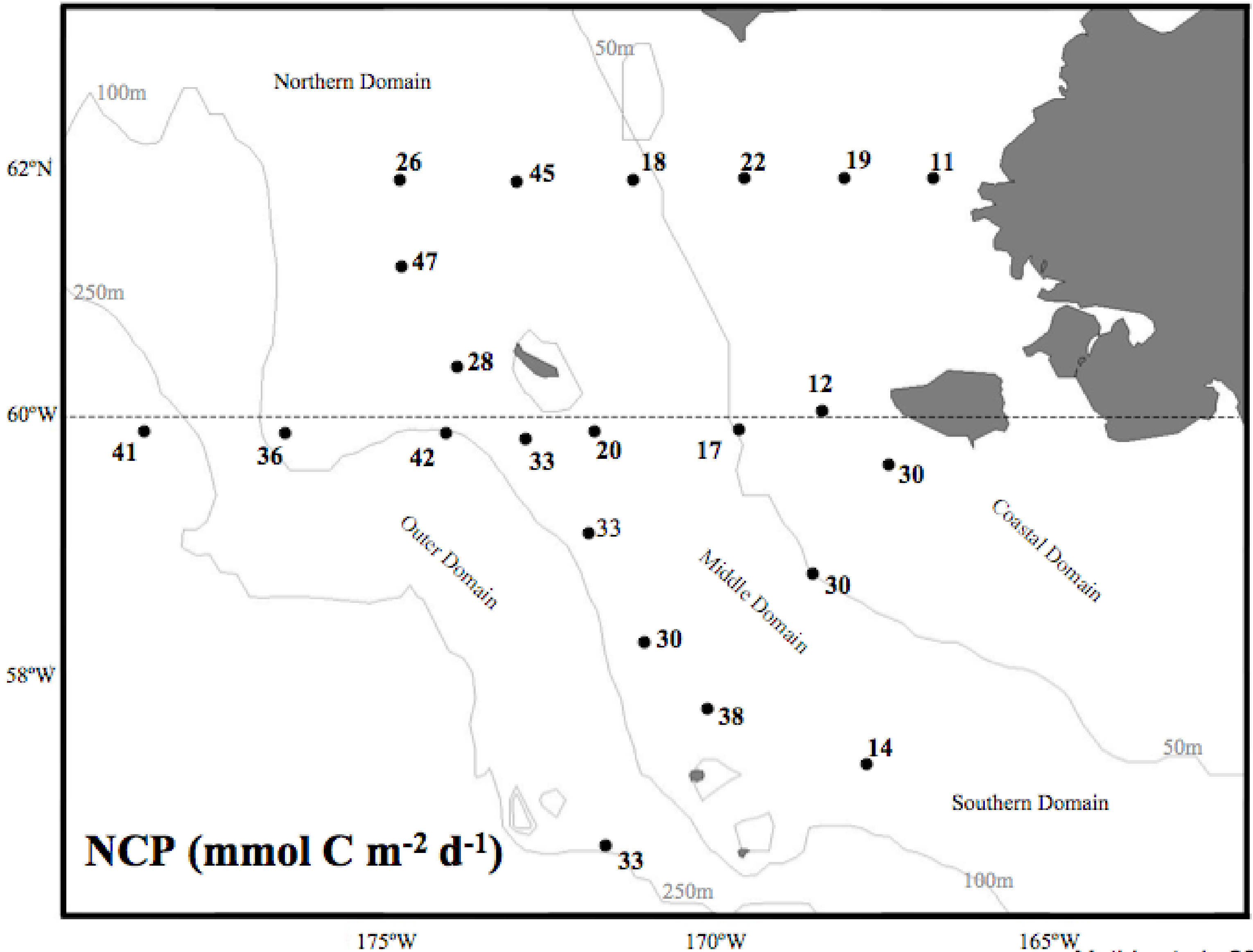
(mmol C m^{-2} d^{-1})



88 ± 58 n = 5	*20 m Ice Trap*
16 ± 3.5 n = 15	*25 m SV-POC*

Spring		Summer
40 ± 26 n = 4	*50 m Trap*	27 ± 17 n = 5
22 ± 12 n = 6	*50 m SV-POC*	45 ± 15 n = 27

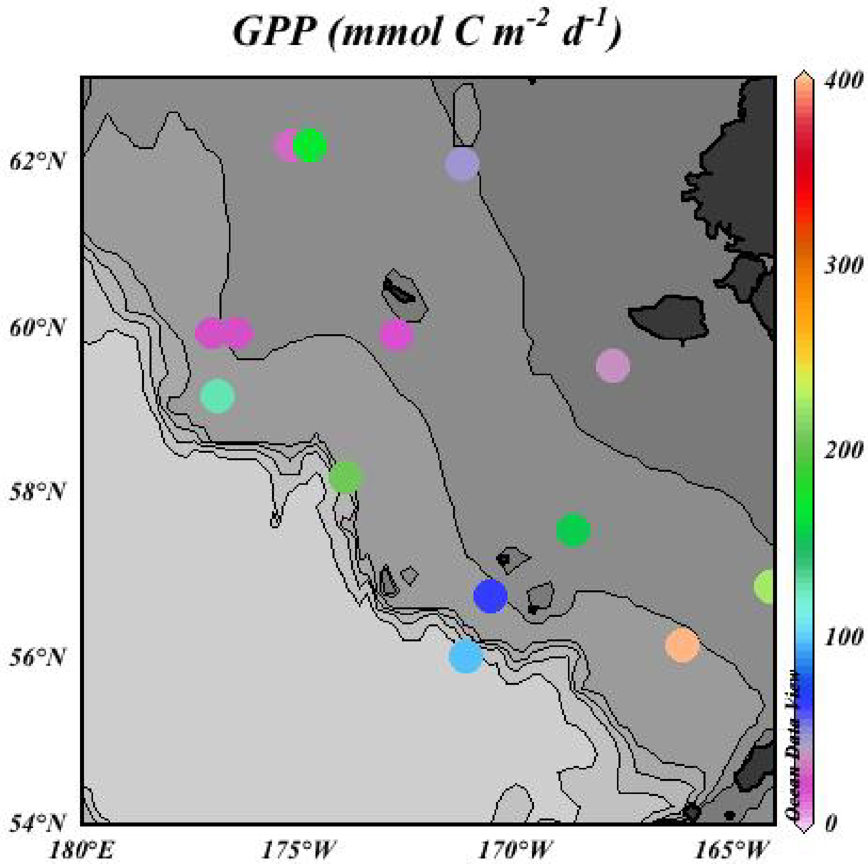
NCP (from seasonal ΔDIC) 2008

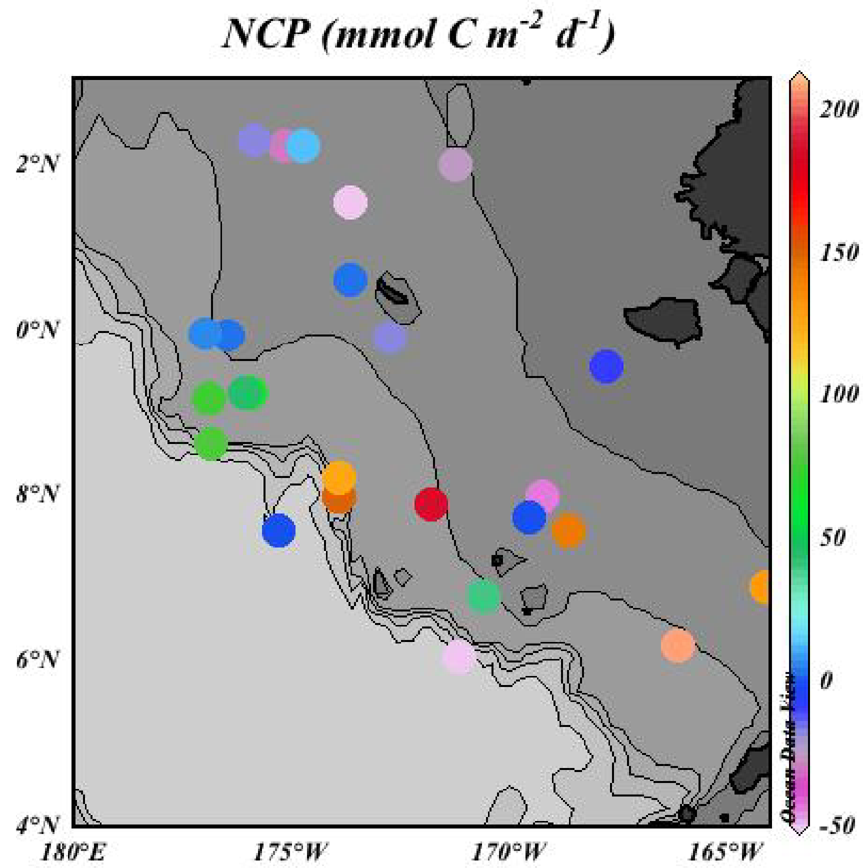


Mathis et al., 2010

Ave. NCP = 28 mmol C m^{-2} d^{-1} on inner, middle and outer shelf.

GPP-Δ^{17}O and NCP-MIMS O_2/AR Spring 2008





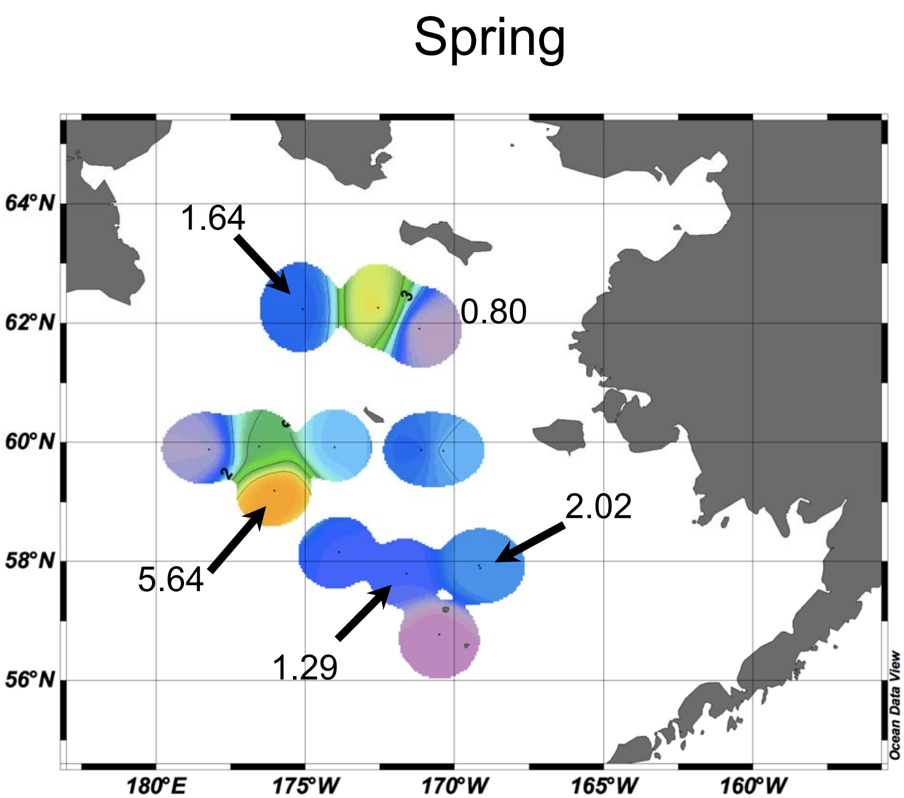
Ave. GPP = 115 mmol C m^{-2} d^{-1}

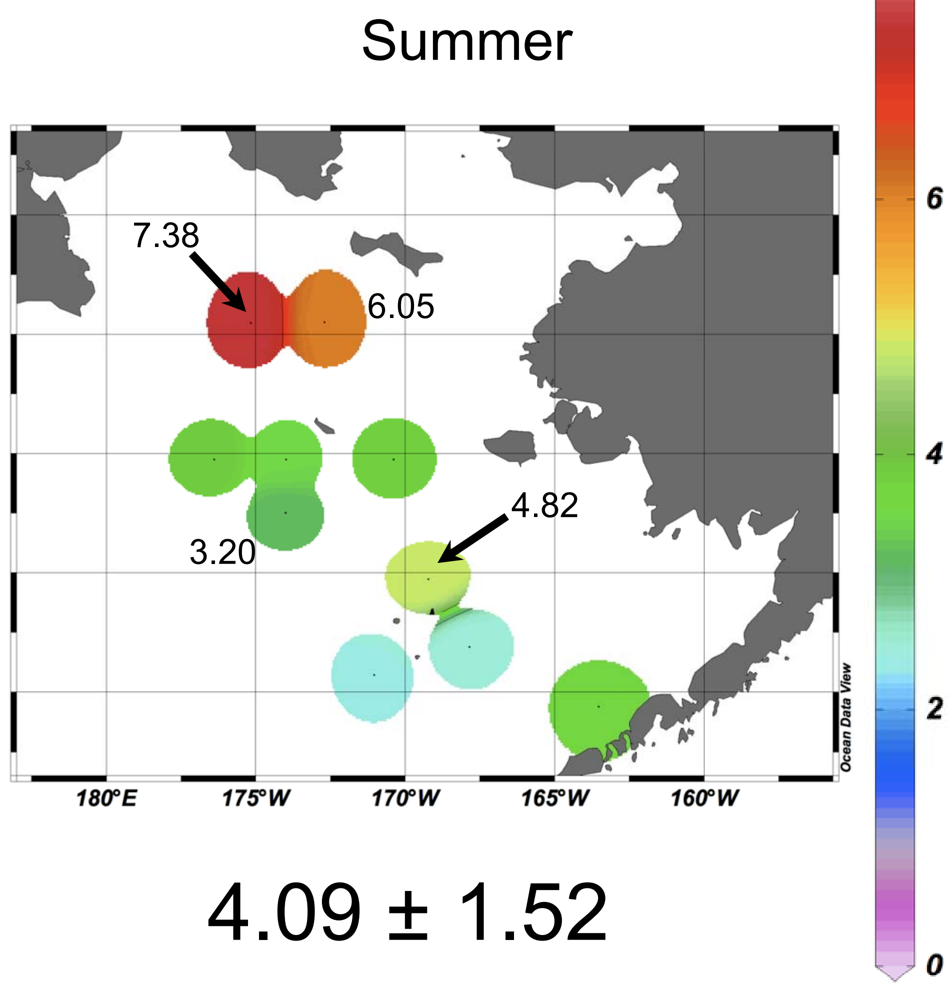
Ave. NCP = 36 mmol C m^{-2} d^{-1}

Prokopenko, Sigman et al., (in prep)

2008 shelf oxygen uptake rates

mmol/m2/d





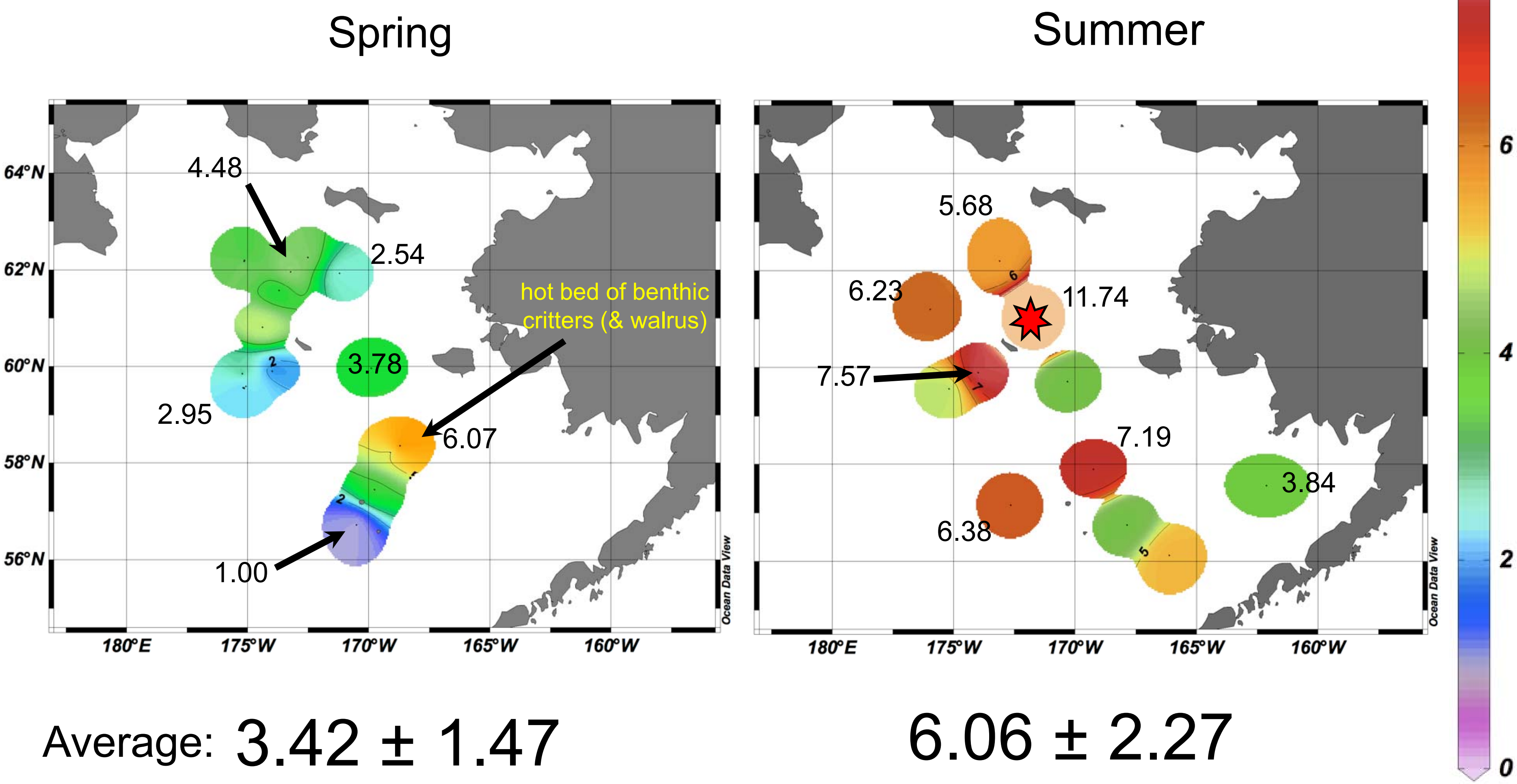
Average: 2.15 ± 1.50 4.09 ± 1.52

***OC_{ave}*: 1.50 ± 1.04** ***OC_{ave}*: 2.85 ± 1.06**

Courtesy of Al Devol

2009 shelf oxygen uptake rates

mmol/m2/d

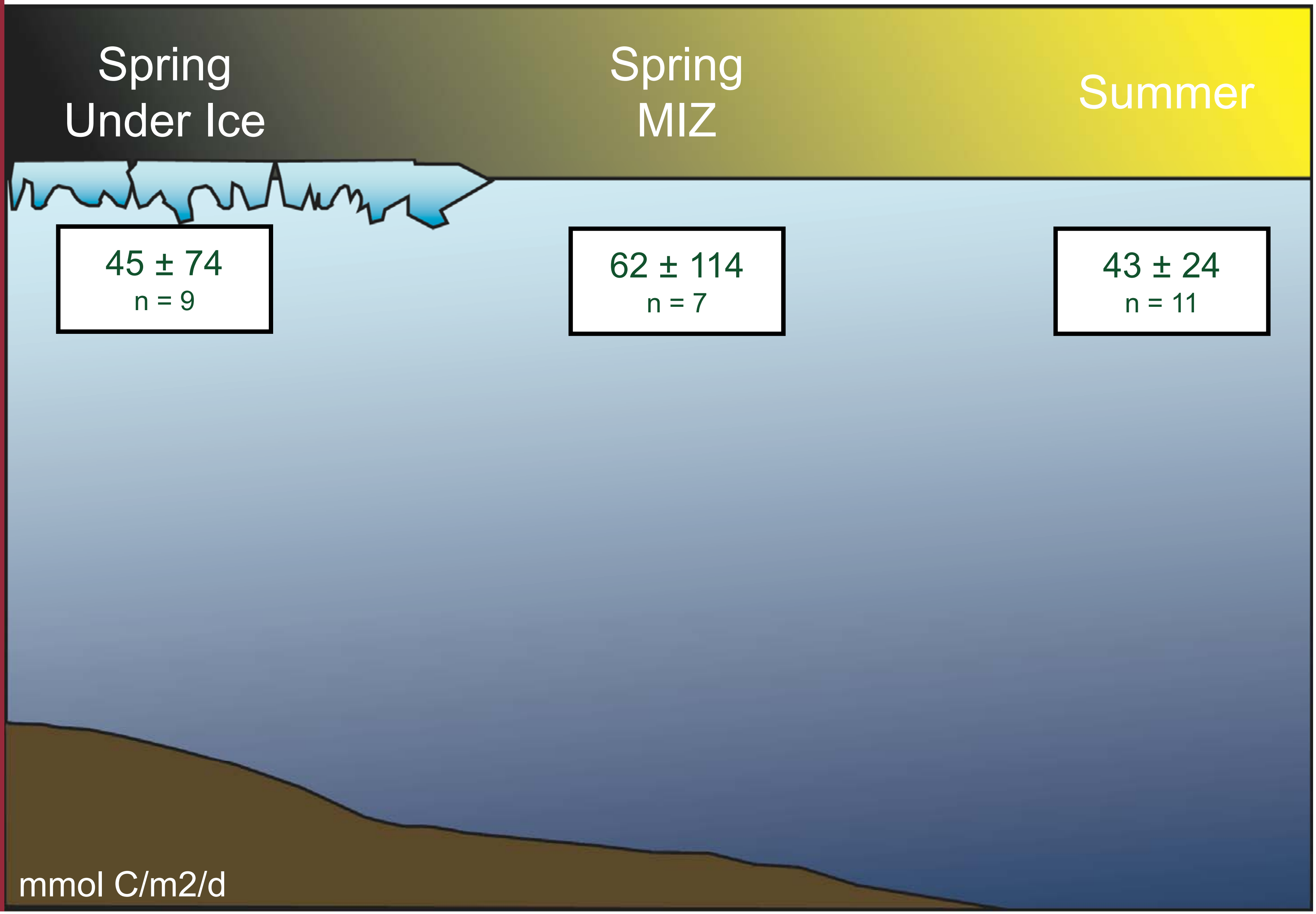


Average: 3.42 ± 1.47 | 6.06 ± 2.27

OC**$_{ave}$**: 2.38 ± 1.02 | ***OC**$_{ave}$**: 4.22 ± 1.58***

Courtesy of Al Devol

Primary Productivity 2008



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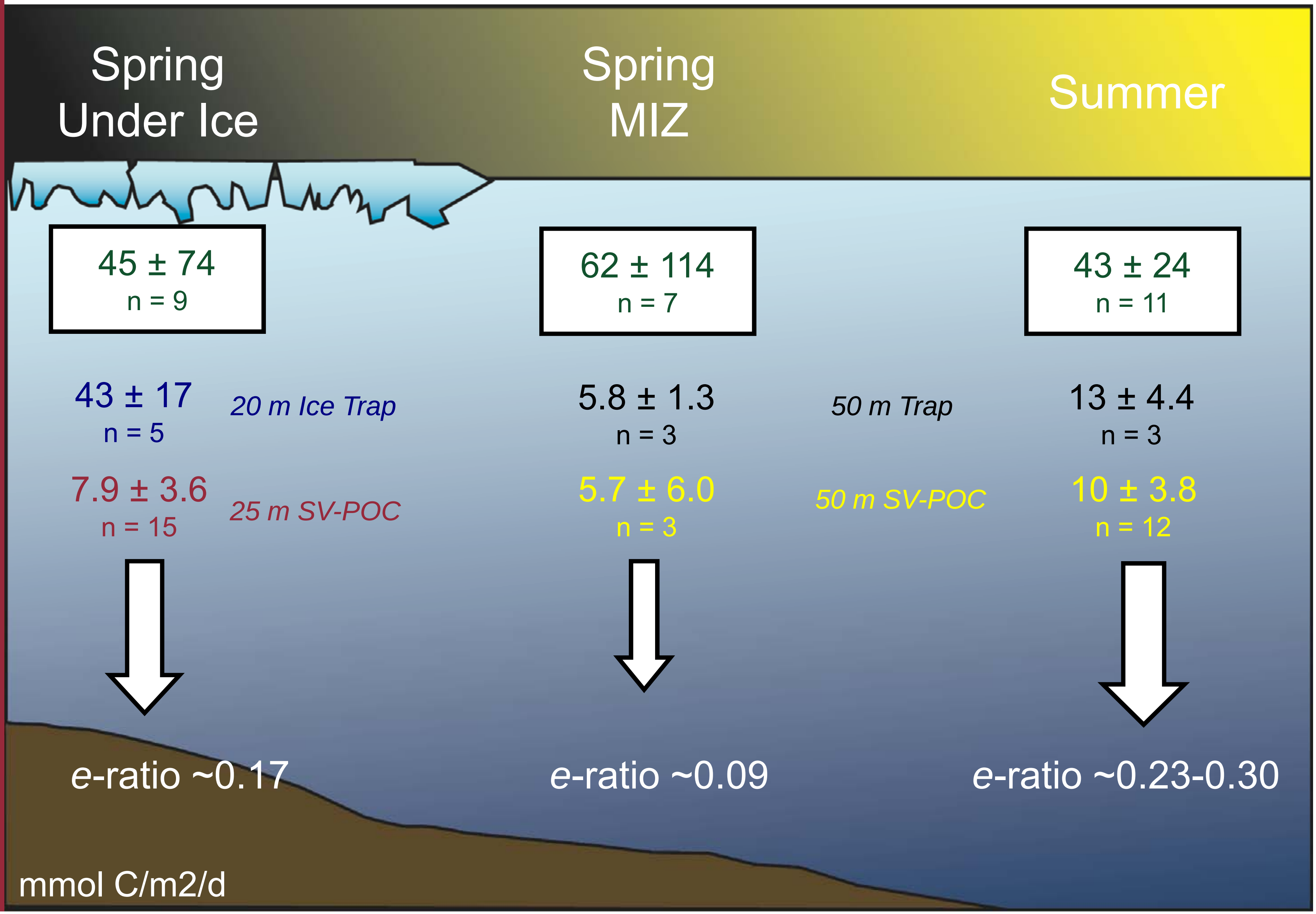
Primary Productivity & POC Export 2008



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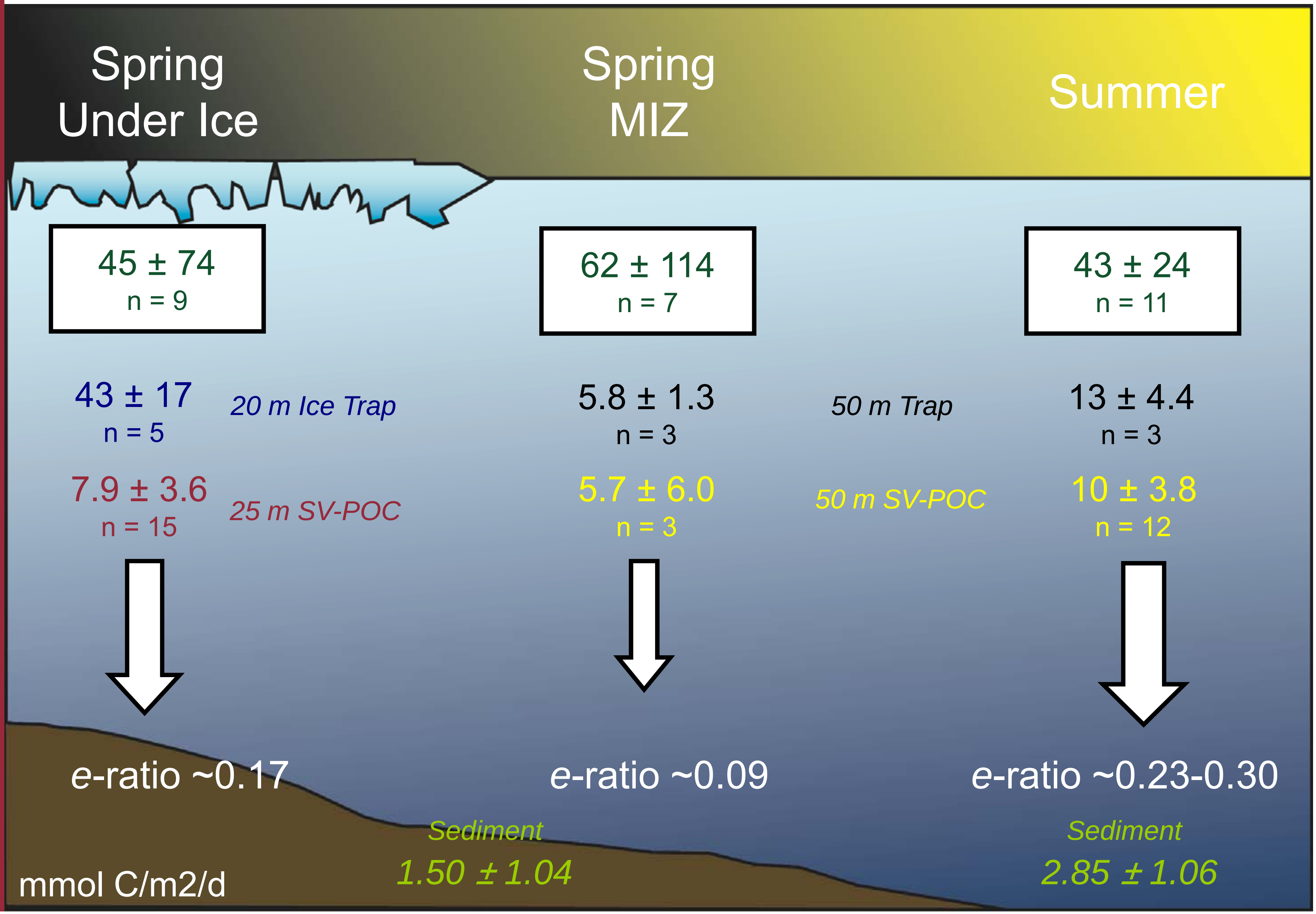
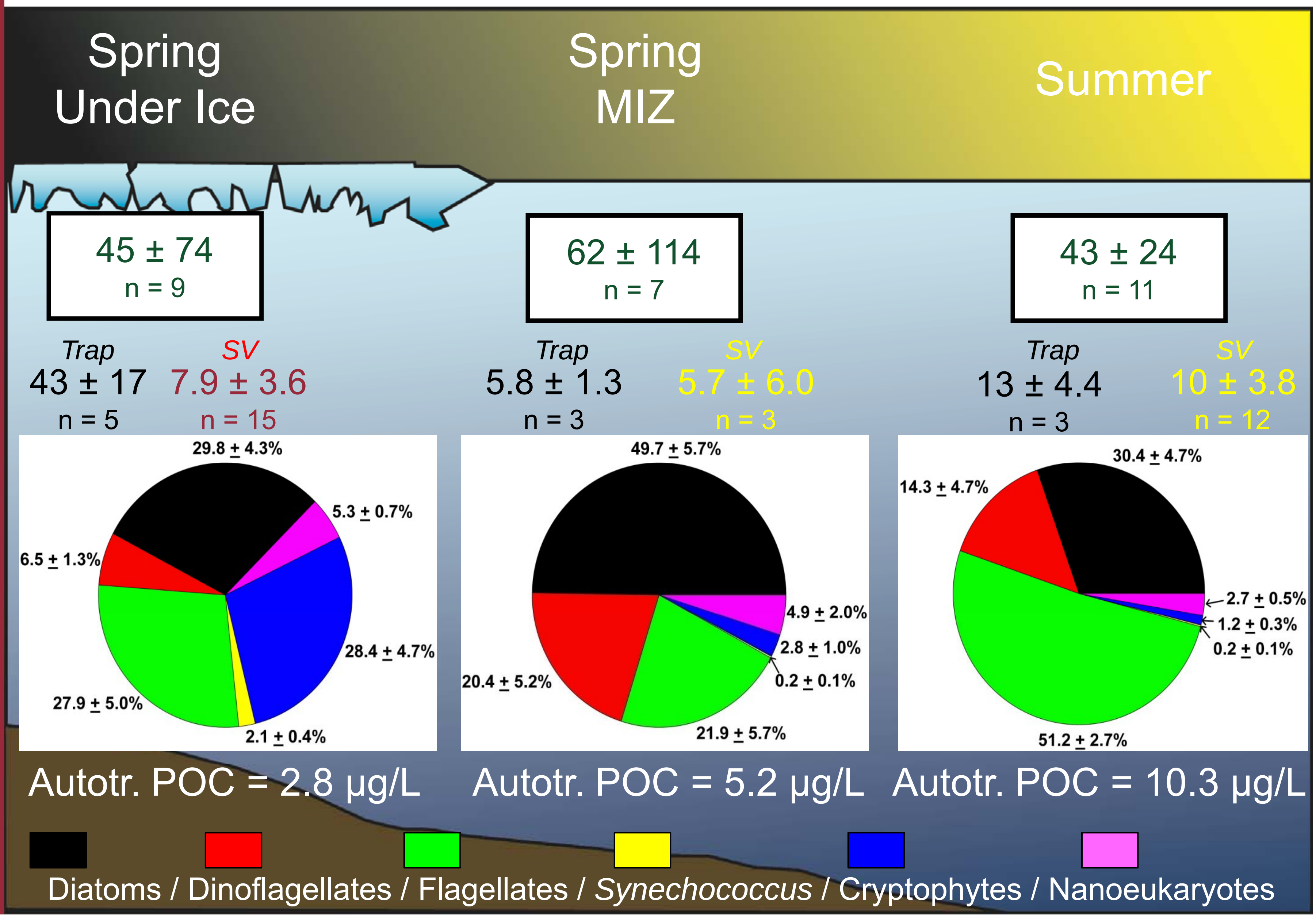
Primary Productivity & POC Export 2008



PP, Export, and Phyt. Comm. Comp. 2008



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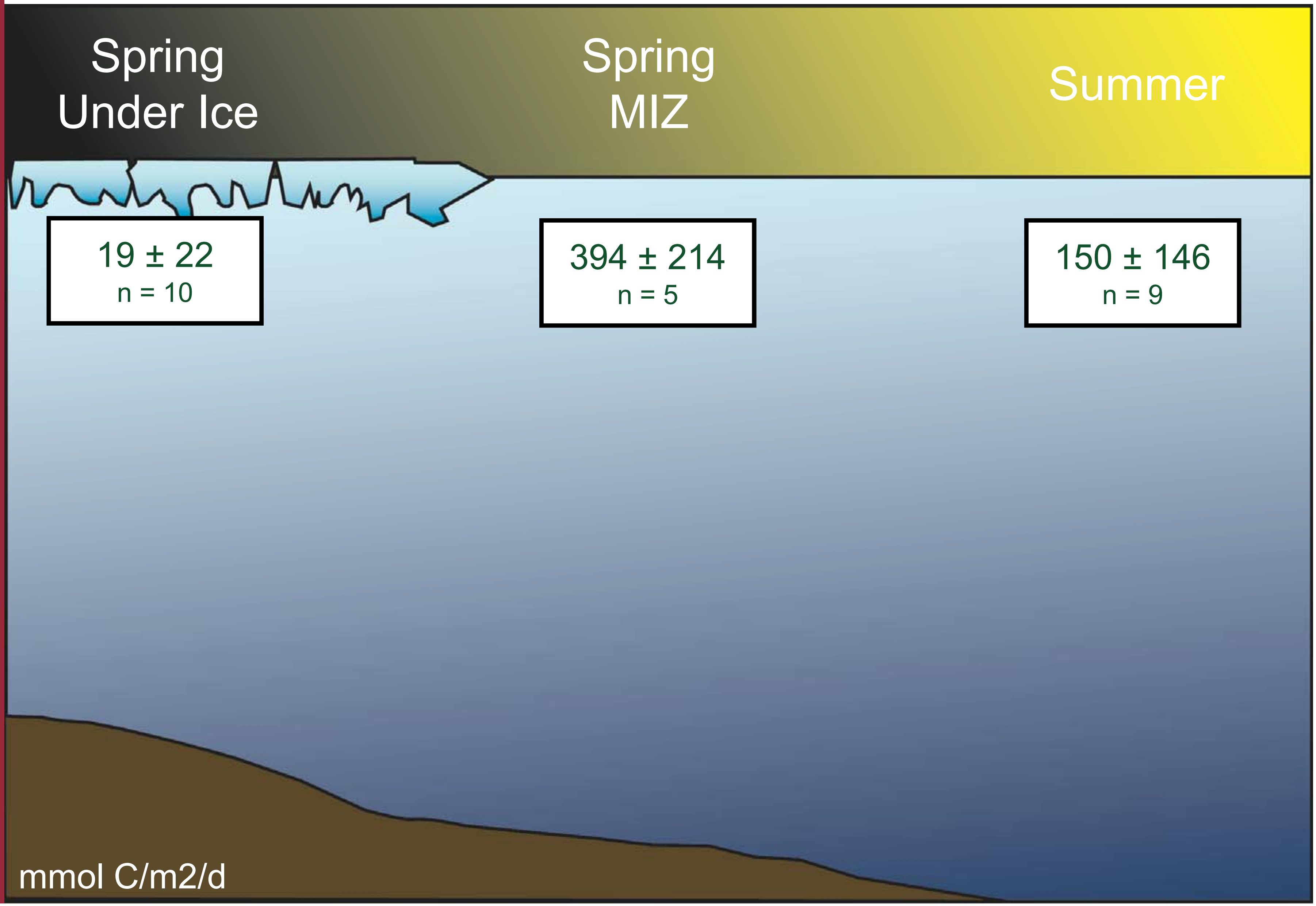
Primary Productivity 2009



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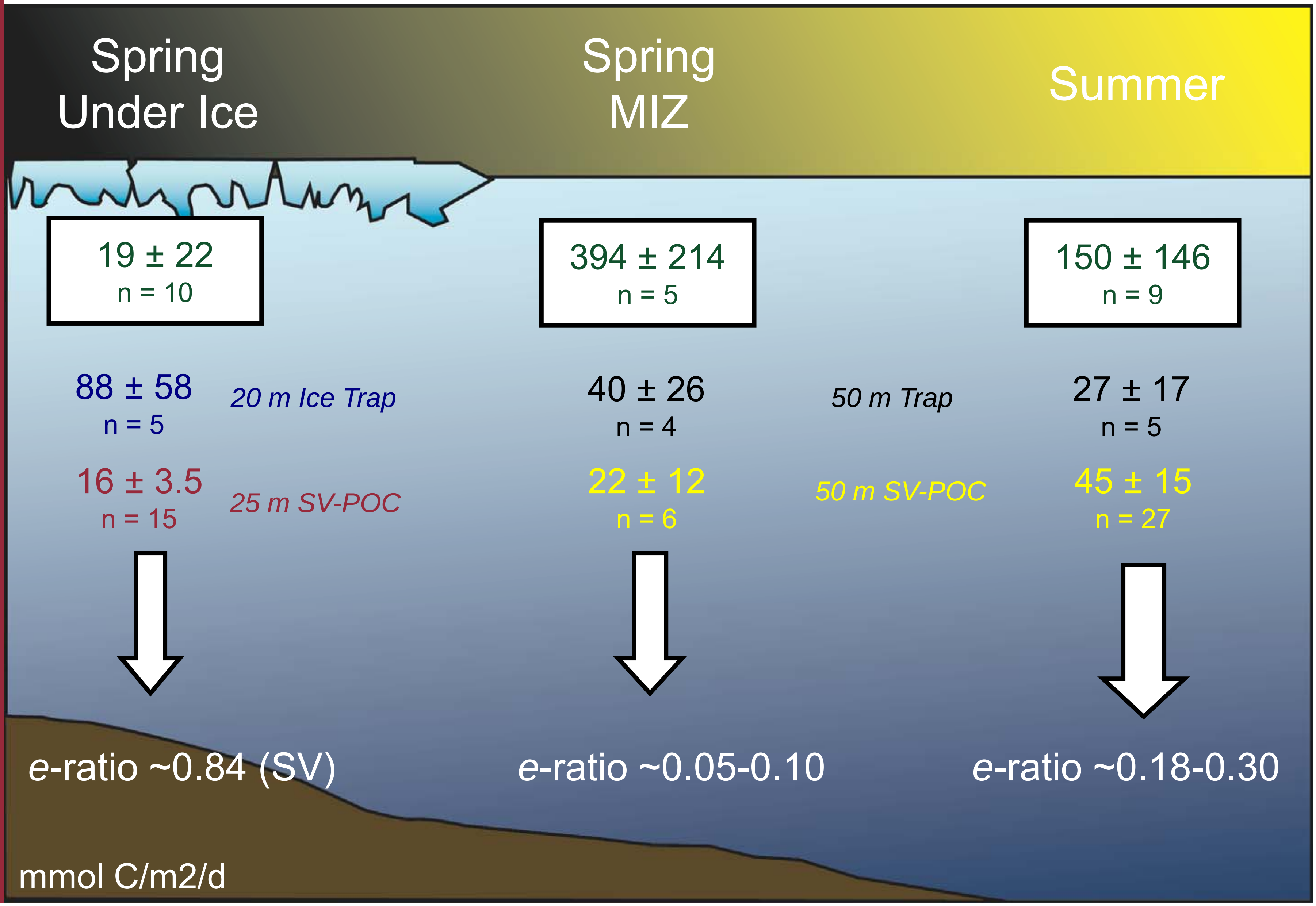
Primary Productivity and POC Export 2009



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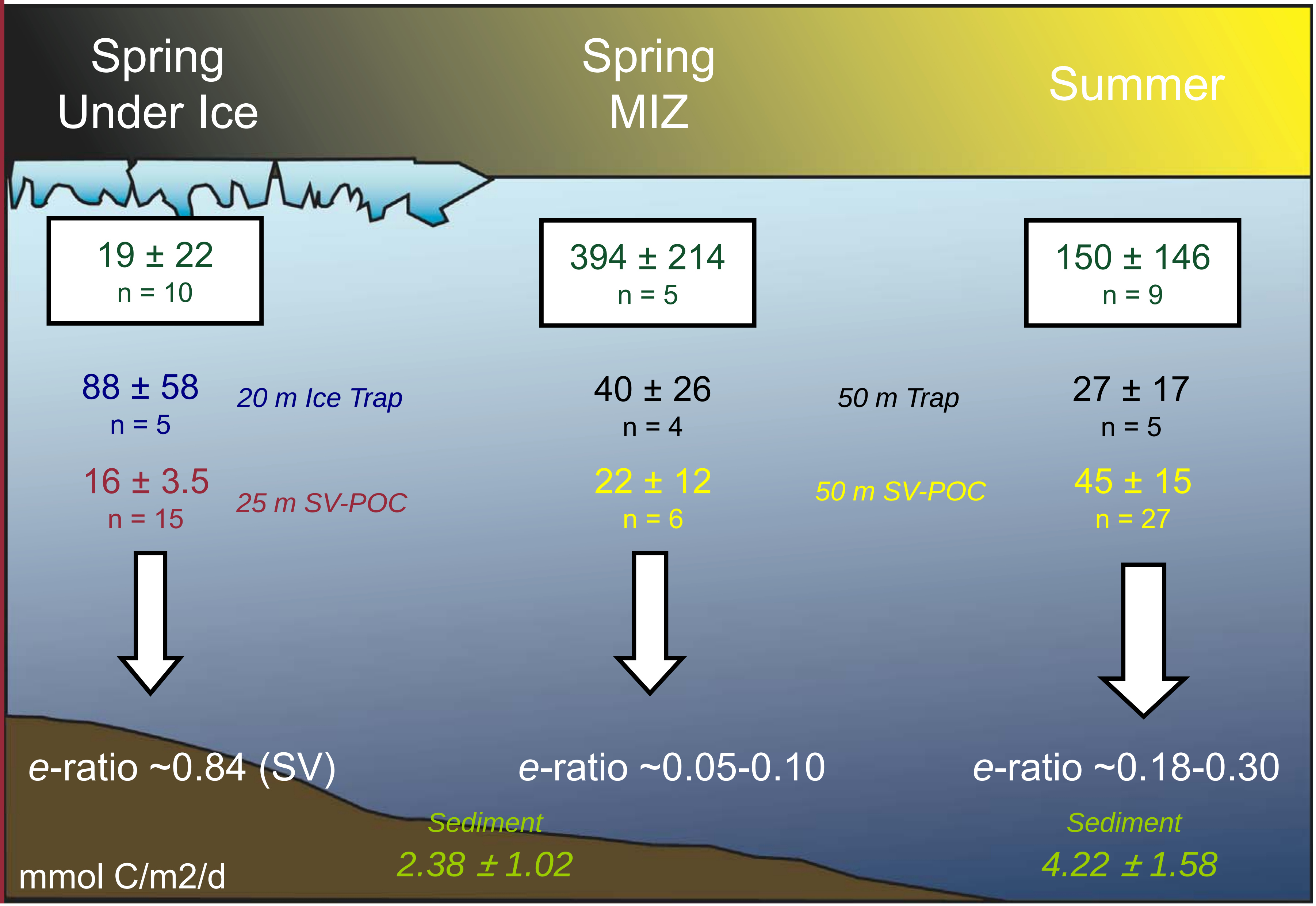
Primary Productivity and POC Export 2009



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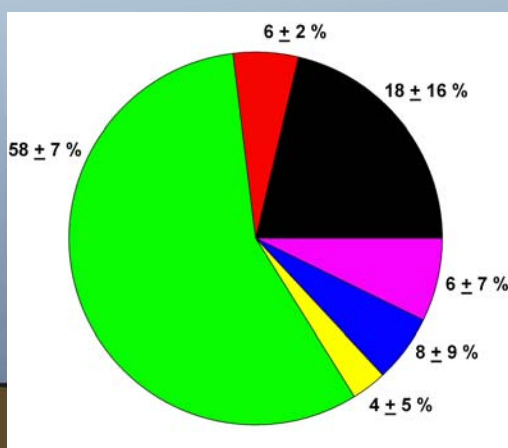
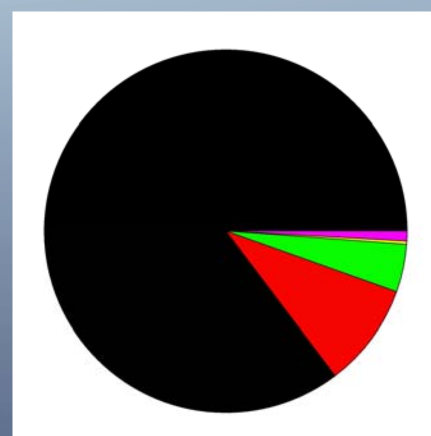
PP, Export, and Phyt. Comm. Comp. 2009

Spring Under Ice	Spring MIZ	Summer
19 ± 22 n = 10	394 ± 214 n = 5	150 ± 146 n = 9
Trap 88 ± 58, n = 5; *SV* 16 ± 3.5, n = 15	*Trap* 40 ± 26, n = 4; *SV* 22 ± 12, n = 6	*Trap* 27 ± 17, n = 5; *SV* 45 ± 15, n = 27



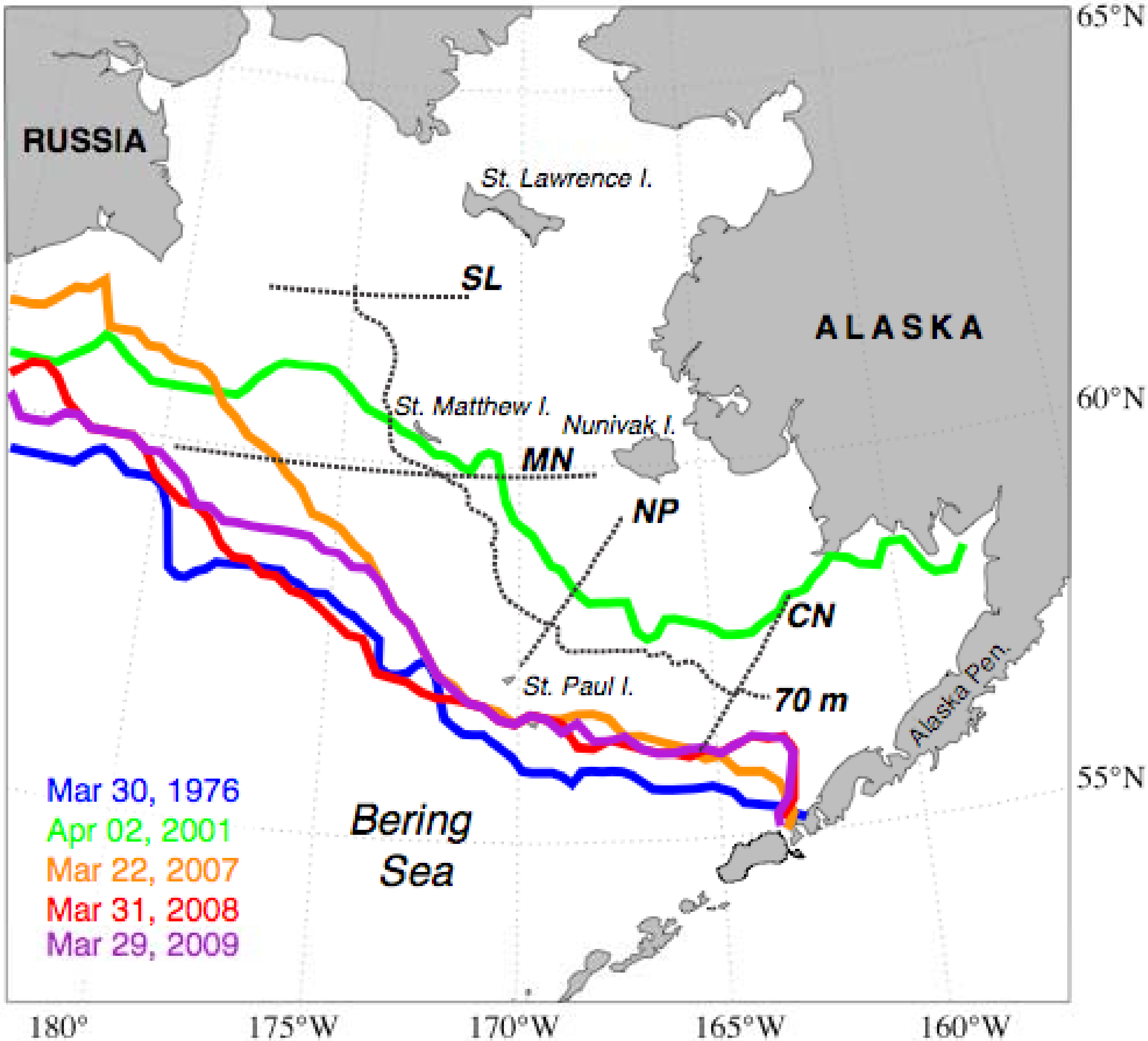
Autotr. POC = 1.14 µg/L



Autotr. POC = 14.1 µg/L

Diatoms / Dinoflagellates / Flagellates / *Synechococcus* / Cryptophytes / Nanoeukaryotes

Bering Sea ice extent 1976-2009



Sigler et al., *Eos*, in review

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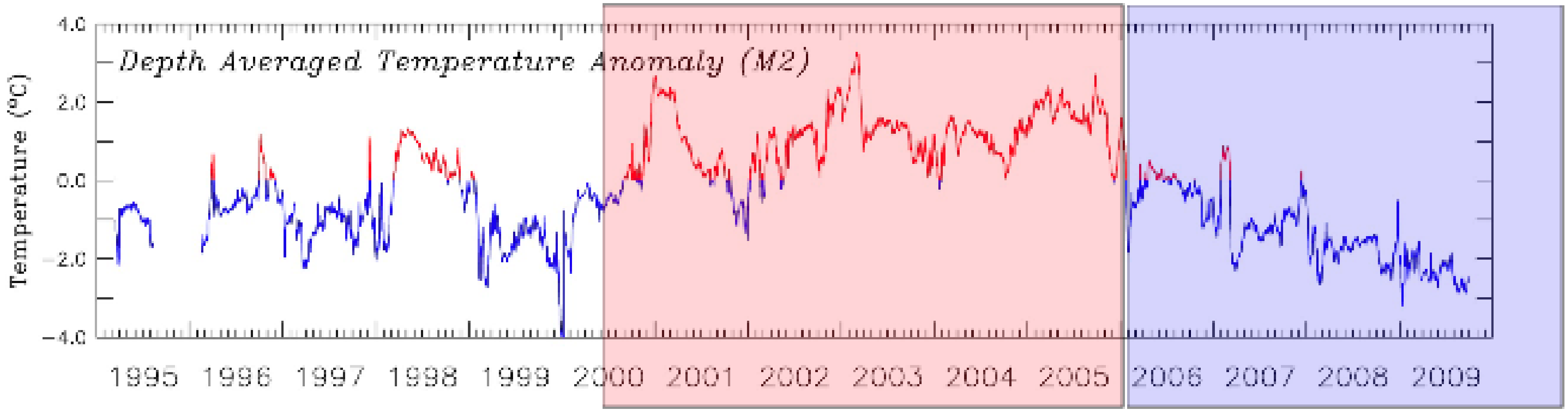
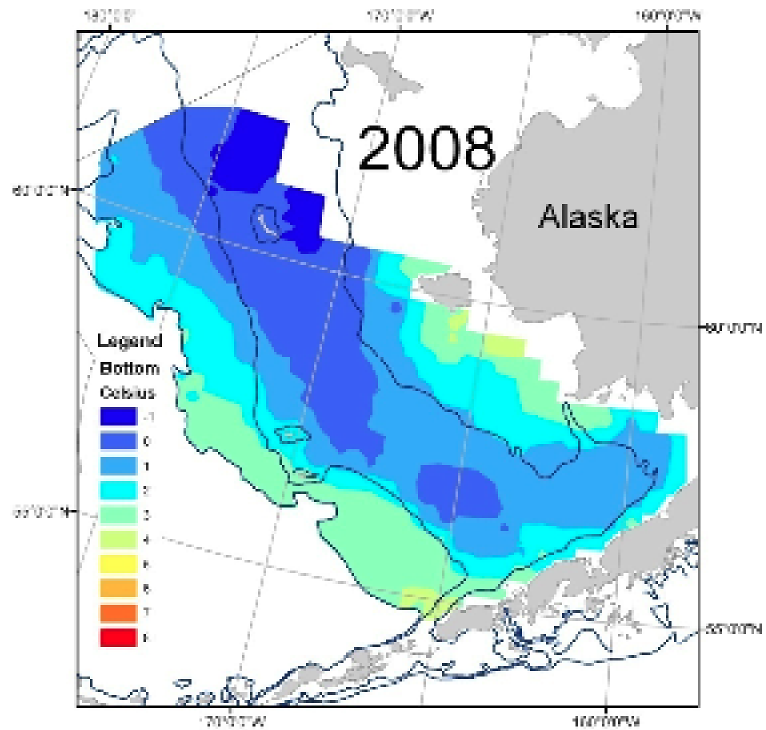
Warm period followed by cooling



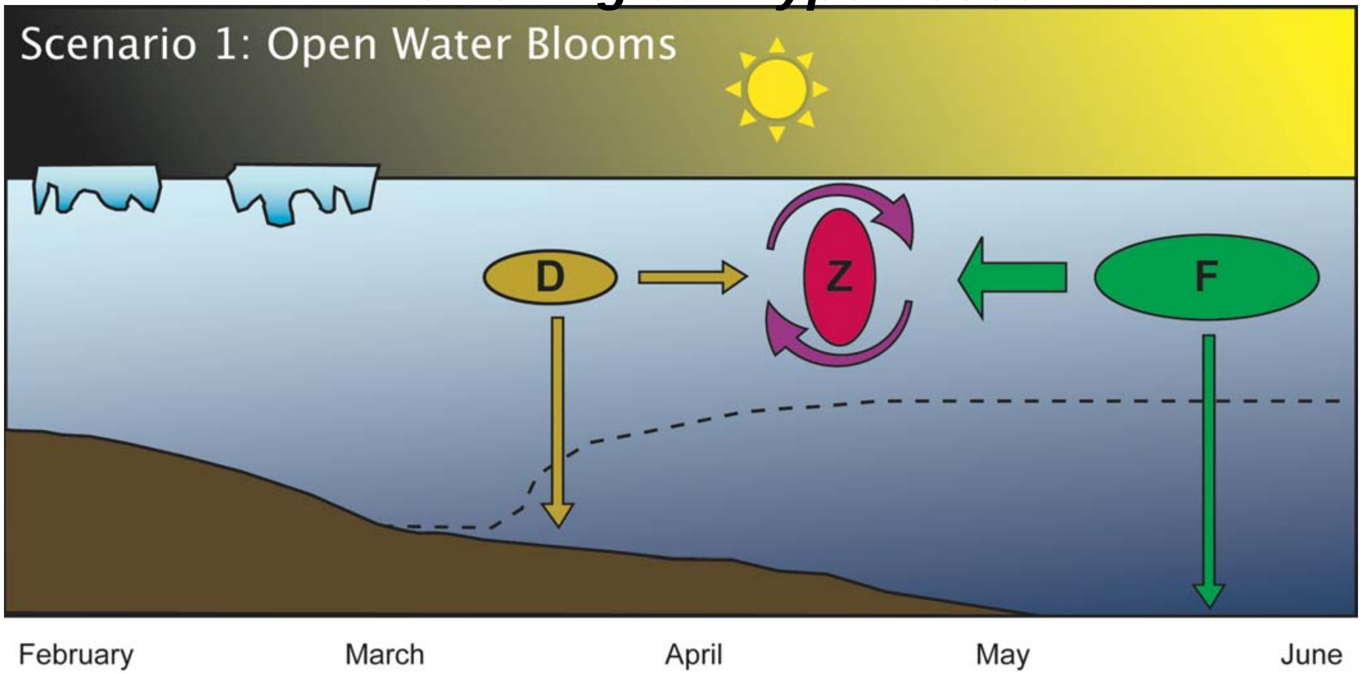
Cold bottom temperatures structure the Bering Sea

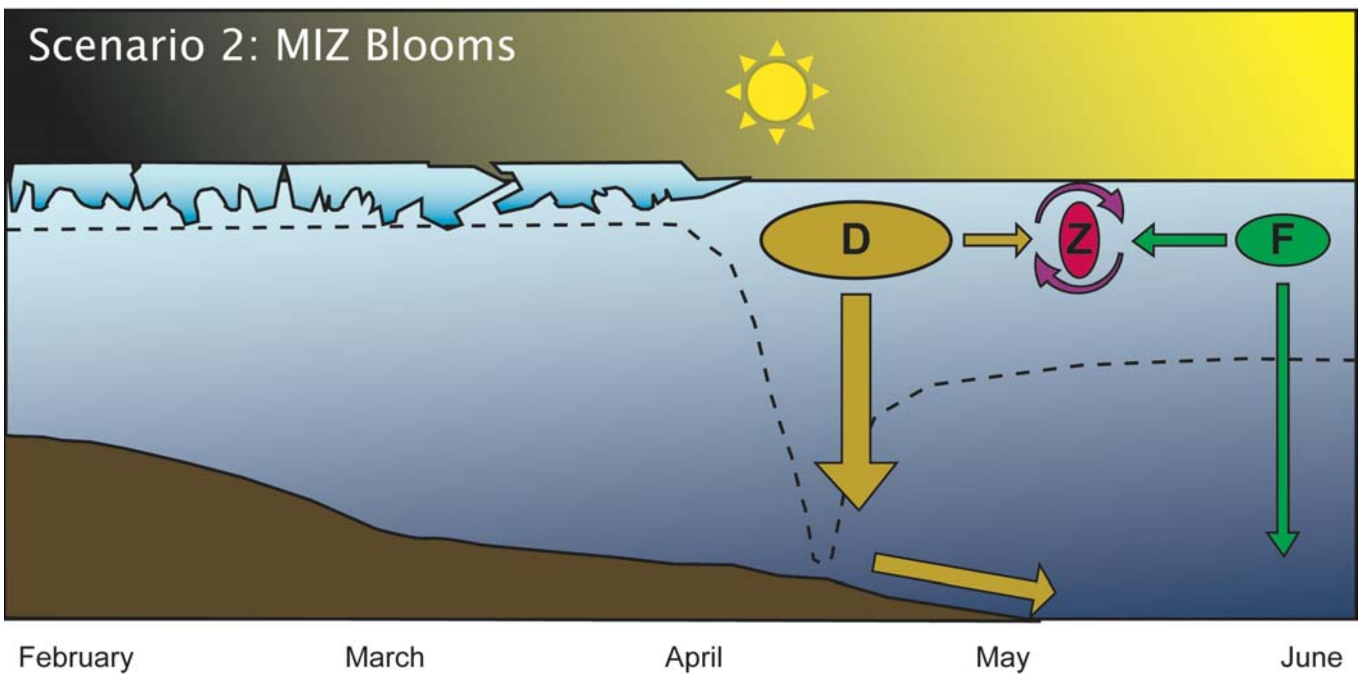


M. Sigler., NOAA

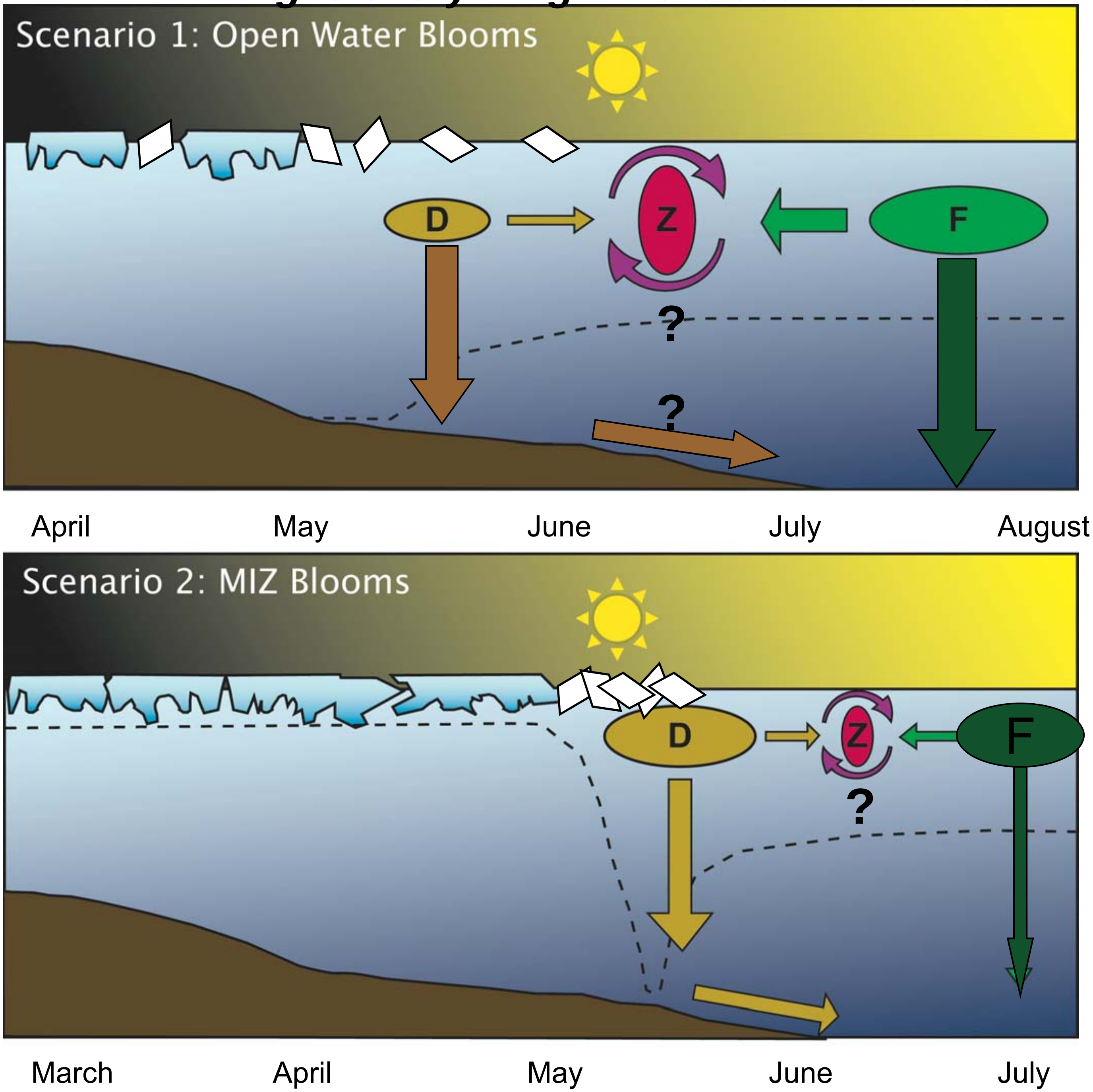
Biophysical moorings: Stabeno, Whitledge, Napp;
Bottom trawl survey: Lauth

Revisiting our hypotheses…





…timing is everything –> late sea-ice retreat



Summary

- ***Consequence of late sea-ice retreat in 2008-2009;***

  - delayed shift in autotrophic community from MIZ (bloom/higher export) to open-water (enhanced recycling) conditions.

  - spring bloom, greater 1° production, export, sed. O_2 utilization in 2009 due either to sample timing and/or thin ice.

- ***Implications for pelagic-benthic coupling;***

  - Scenario 1: increased solar insolation & stratification, lower nutrients and production, leads to more pelagic fish dominated ecosystem.

  - Scenario 2: greater export, increased benthic ecosystem (e.g., crabs), at cost to pelagic fisheries (e.g, pollack).

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Acknowledgements

M.L. Lomas[1], R.P. Kelly[2], M. Baumann[2], K. Iken[3] and R. Gradinger[3], J.T. Mathis[3], M. Prokopenko[4], D. Sigman[4], M. Bender[4], A. Devol[5], D. Schull[6]

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[2]Graduate School of Oceanography, University of Rhode Island

[3]Institute of Marine Science, University of Alaska-Fairbanks

[4]Princeton University

[5]University of Washington

[6]Western Washington University

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