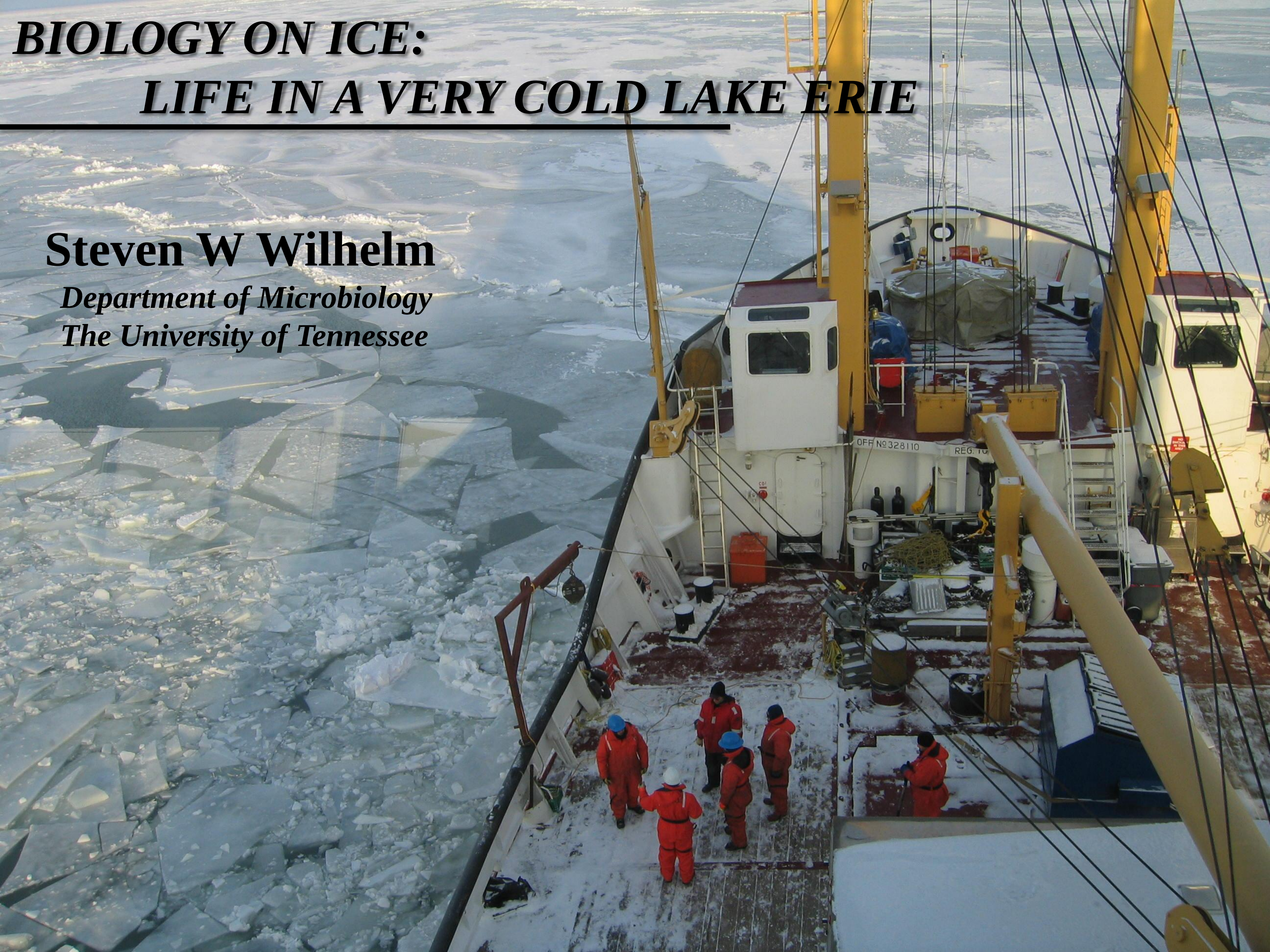
BIOLOGY ON ICE:
LIFE IN A VERY COLD LAKE ERIE

Steven W Wilhelm
Department of Microbiology
The University of Tennessee



WINTER ASSESSMENT OF MICROBIAL BIOMASS AND METABOLISM

The University of Tennessee
Steven W Wilhelm
Matthew A Saxton

Environment Canada
Richard A Bourbonniere
Christopher H Marvin

Bowling Green State University
R Michael McKay
George S Bullerjahn
Nigel D'Souza
Ben Beall

Clarkson University
Michael R Twiss
Derek Smith

University of Waterloo
Ralph EH Smith
Joel Harrison

Penn State
Hunter J Carrick

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Most photos from most Lake Erie cruises look like this one
To develop any forecasting power, we need to look beyond May - October

Life in (on, under) a very cold Lake Erie

A brief history of winter work on Lake Erie
(brief because that is all there is)

Winter AssessMent of Biomass and Metabolism
WAMBaM , 2007 - 2010

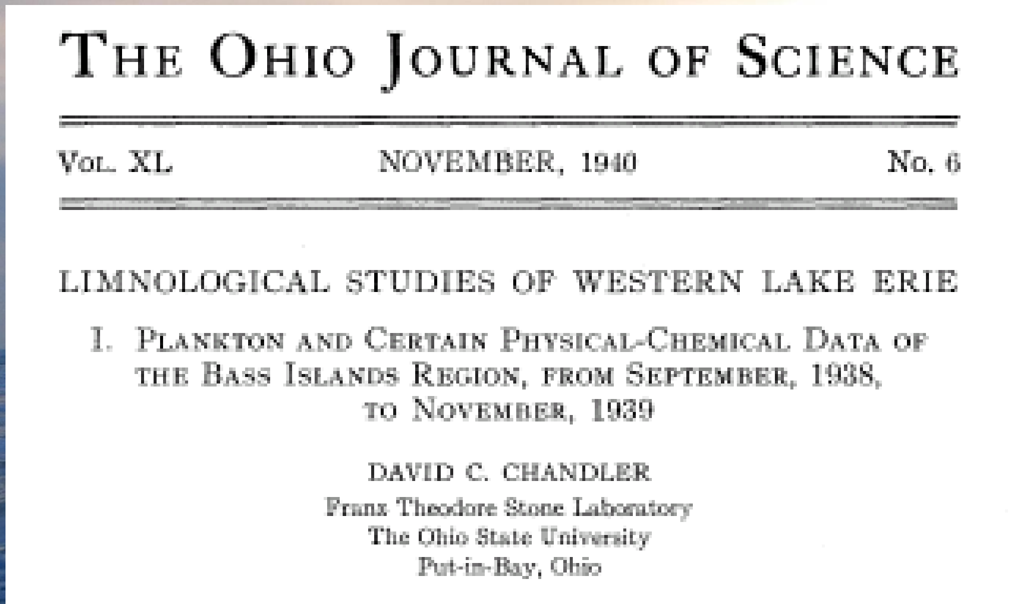
- What have we been doing?

- What do we know?

- What does it all mean?

Previous winter limnology on Lake Erie Last major study was seventy (70) years ago.

Chandler 1940, Chandler 1942a, Chandler 1942b, Chandler & Weeks 1945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LIMNOLOGICAL STUDIES OF WESTERN LAKE ERIE

I. PLANKTON AND CERTAIN PHYSICAL-CHEMICAL DATA OF THE BASS ISLANDS REGION, FROM SEPTEMBER, 1938, TO NOVEMBER, 1939

DAVID C. CHANDLER

Franz Theodore Stone Laboratory
The Ohio State University
Put-in-Bay, Ohio

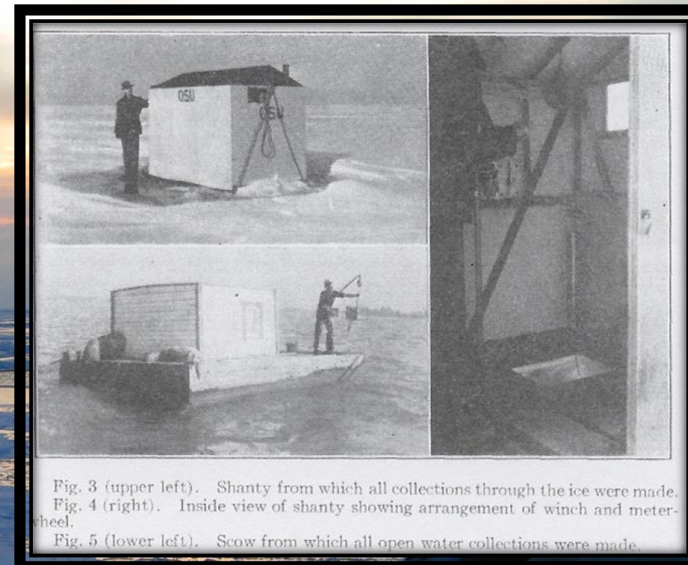


Fig. 3 (upper left). Shanty from which all collections through the ice were made.
Fig. 4 (right). Inside view of shanty showing arrangement of winch and meter-wheel.
Fig. 5 (lower left). Scow from which all open water collections were made.

Chandler observed "pulses" (blooms) of diatoms in mid-winter (mid February to late March) under the ice, low zooplankton populations, and a variable light environment.

A number of "snap shots" taken since then –

Rockwell, D.C., Salisbury, D.K., and Lesht, B.M. 1989.

few process measurements -

e.g., on Lake Michigan - Scavia and Laird 1987; Scavia et al. 1986

__TIMELINE (What have we been doing). Assessment of biological limnology during the "winter"__

2007 – first WAMBaM survey (Wilhelm, McKay, Twiss, Bullerjahn – 2 day "ride along")
- noted significant biomass in the lake

2008 – WAMBaM II. Measured significant rates of primary production. Repeated observations on biomass. Collected samples for thorough community characterization and bacterial production estimates.

2009 - WAMBaM IIIa and IIIb. Measured significant rates of primary production. Repeated observations on biomass. Collected samples for thorough community characterization and bacterial production estimates. Surveys shortened due to logistics.

2010 - WAMBaM IV. Survey shortened due to logistics. Most data still processing.

Research complimented by US Coast Guard (Neah Bay) and EPA (e.g., Lake Guardian) cruises

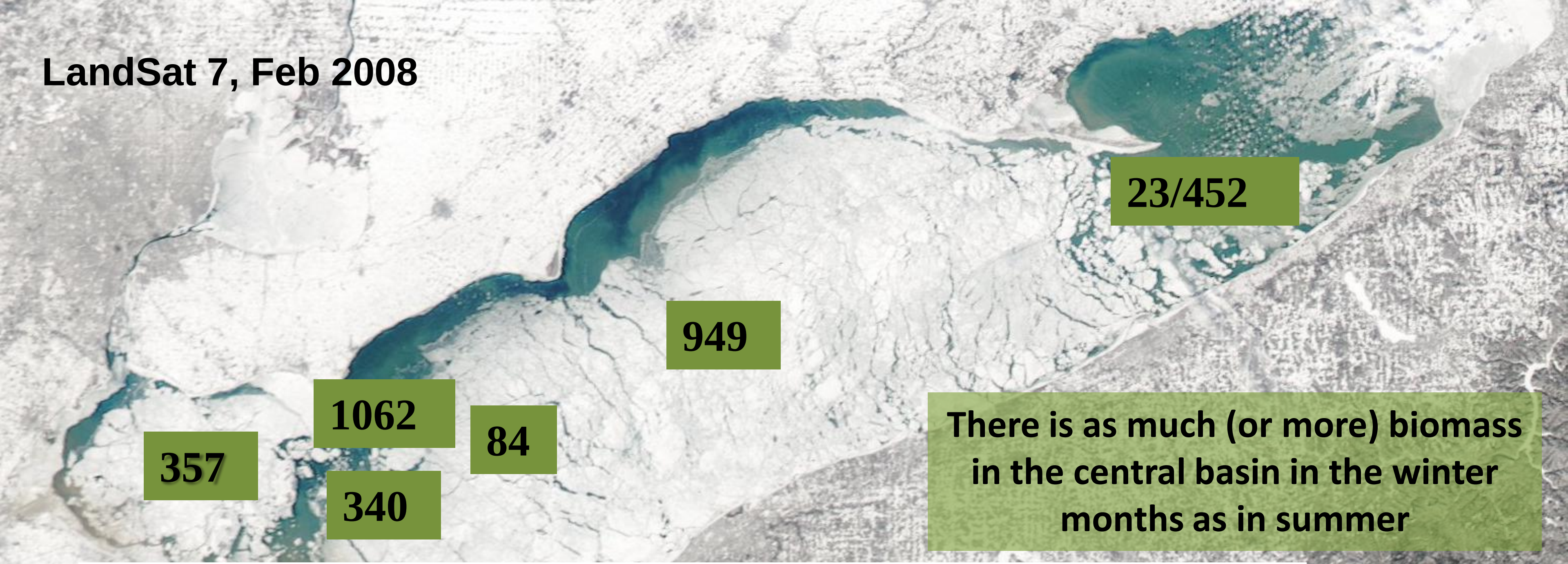
Is biomass in ice, under ice and/or in open water?

CACHE: Concentrated Algae Community and Heterotrophic Ecosystem

- **Extremely high chlorophyll**
- **Rapidly growing phytoplankton**
- **Abundant bacteria**

Is biomass in ice, under ice and/or in open water?

Ice is transient. It comes and goes. Commonly moves northwest to southeast (away from the shore) and southwest to northeast (with the wind)



Chlorophyll comparisons (µg L^{-1})

Station	Feb 2007	Feb 2008	Feb 2009	Feb 2010	Jul 2005	Aug 2005	Aug 2006	Aug 2007
23/452	0.6	0.6	0.6	1.4	1.4	1.6	0.6	3.1
84	2.4	2.4	0.7	1.4	1.5	4.4	0.9	3.6
357	1.2	0.6	0.4	*na*	3.3	15.1	5.1	3.7
340/961/341	8.4	2.4	9.66	1.4	2.5	10.4	1.3	na
949/1053	*na*	1.5	2.21	2.1	*na*	*na*	*na*	*na*

ice-free winter samples

na – not available

All samples collected at 1m

CONSTRAINTS ON PRIMARY PRODUCTION

LOTS OF NUTRIENTS

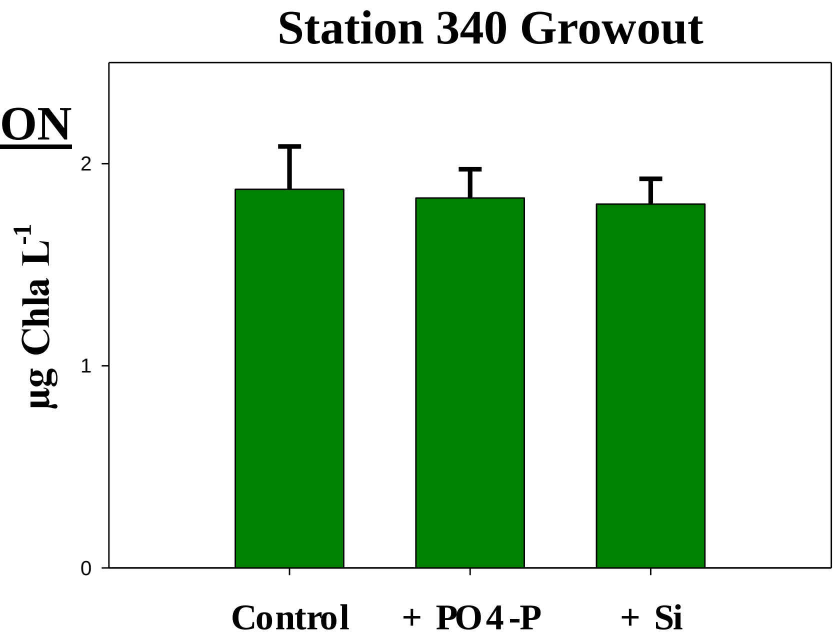
Direct measures of water column chemistry as well as microcosm growth assays suggest the community is nutrient replete.

Alkaline phosphatase extremely low (not shown).

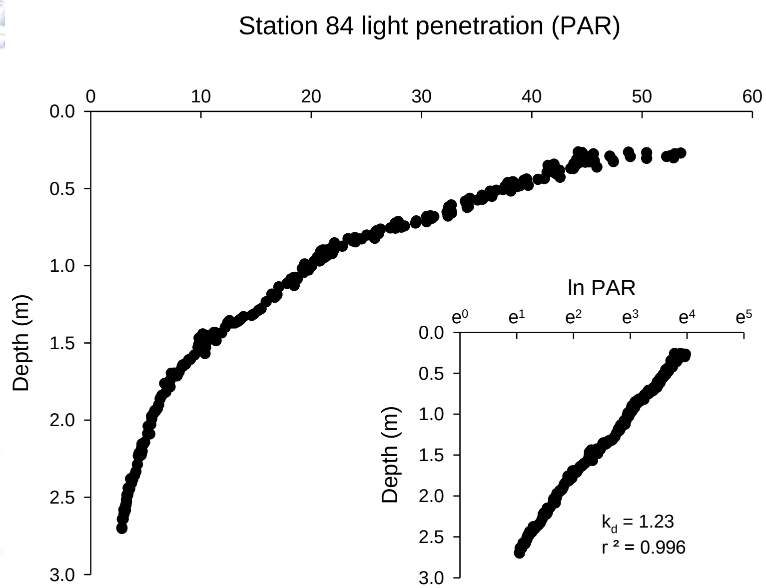
LIGHT

There is significant light penetration to at least 3 m in the water column and the community seems to be able to rapidly respond to levels of high light.

Light limitation seems likely though as the water column is isothermal.



Wilhelm and Saxton 2008



Harrison and Smith 2010

RESULTS - 2008: Total (>0.2 µm) primary production (data from MR Twiss) ranged from 0.7 to 1.7 g C· gChl-a^{-1}·h^{-1}, and are similar to those measured by McKay (^{14}C technique, photosynthetron) and Carrick (light:dark DO technique).

The concentration of picoplankton was too low at Sta 357 (3% total) to accurately measure ^{14}C uptake and accumulation.

Values are *ca* 20-60% of values measured using the same technique during summer 2003 and incubated at 150-300 µmol photons·m^{-2}·s^{-1} (Ostrom et al. 2005). The higher winter biomass in some areas suggests total production is similar.

Station	Size fraction	Chlorophyll-*a* µg Chl-*a*/L	Chlorophyll-*a* %Total	Primary production gC/g Chl-*a*/hr Mean ± standard deviation (*n* = 3)
357	Micro	2.41	66	0.74 ± 0.20
	Nano	1.10	30	0.85 ± 0.24
	Pico	0.12	3	-1.52 ± 1.73
	Total	3.63	---	0.70 ± 0.05
84	Micro	0.88	58	1.28 ± 0.22
	Nano	0.49	32	1.74 ± 0.28
	Pico	0.16	10	3.66 ± 1.56
	Total	1.53	---	1.68 ± 0.14
23	Micro	0.17	29	1.01 ± 0.46
	Nano	0.27	46	1.12 ± 0.19
	Pico	0.15	25	0.98 ± 0.15
	Total	0.59	---	1.05 ± 0.23
1026	Micro	1.96	59	0.48 ± 0.33
	Nano	0.99	30	1.55 ± 0.003
	Pico	0.39	12	2.00 ± 3.87
	Total	3.33	---	0.97 ± 0.30

Sta. CCB (1290)

Date	P^B_m	I_k	ε_{PAR} (m^{-1})	Areal Prod (mg C m^{-2} d^{-1})
2/24/09	3.2	21	0.7-1	1469/952
4/24/09	3.6	54	0.45	1523
2/10/10	1.8	23	0.66	424

Sta. 341

Date	P^B_m	I_k	ε_{PAR} (m^{-1})	Areal Prod (mg C m^{-2} d^{-1})
2/24/08	3.4	29	1.32	230
2/17/09	2.1	9	0.68	313
2/27/09	3.2	14	0.68?	114

P_m: g C g chl a^{-1} h^{-1}
I_k: µmol photons m^{-2} s^{-1}

SUMMER RATES FOR COMPARISON

- Smith et al. 2005: 800-1200 mg C m^{-2} d^{-1}
- Fahnenstiel et al. 1995:
  - pre-zebra mussel: 738 mg C m^{-2} d^{-1}
  - post zebra mussel: 342 mg C m^{-2} d^{-1}

Data from RML McKay research group

ARE THE DIATOMS ACTUALLY GROWING?

•Incubate samples with PDMPO

•Fluorescent compound incorporated along with newly deposited Si in diatoms frustules

(Leblanc and Hutchins, 2005 L&O:Methods)

• **Quantitative***:* Incorporated at 2800:1 molar ration (Si:PDMPO)

•**Taxonomic:** Can see which cells are growing

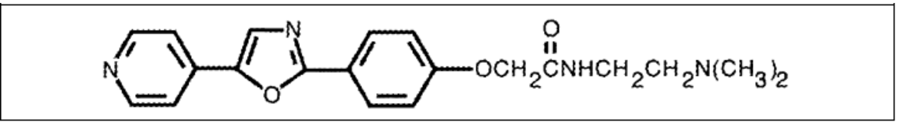
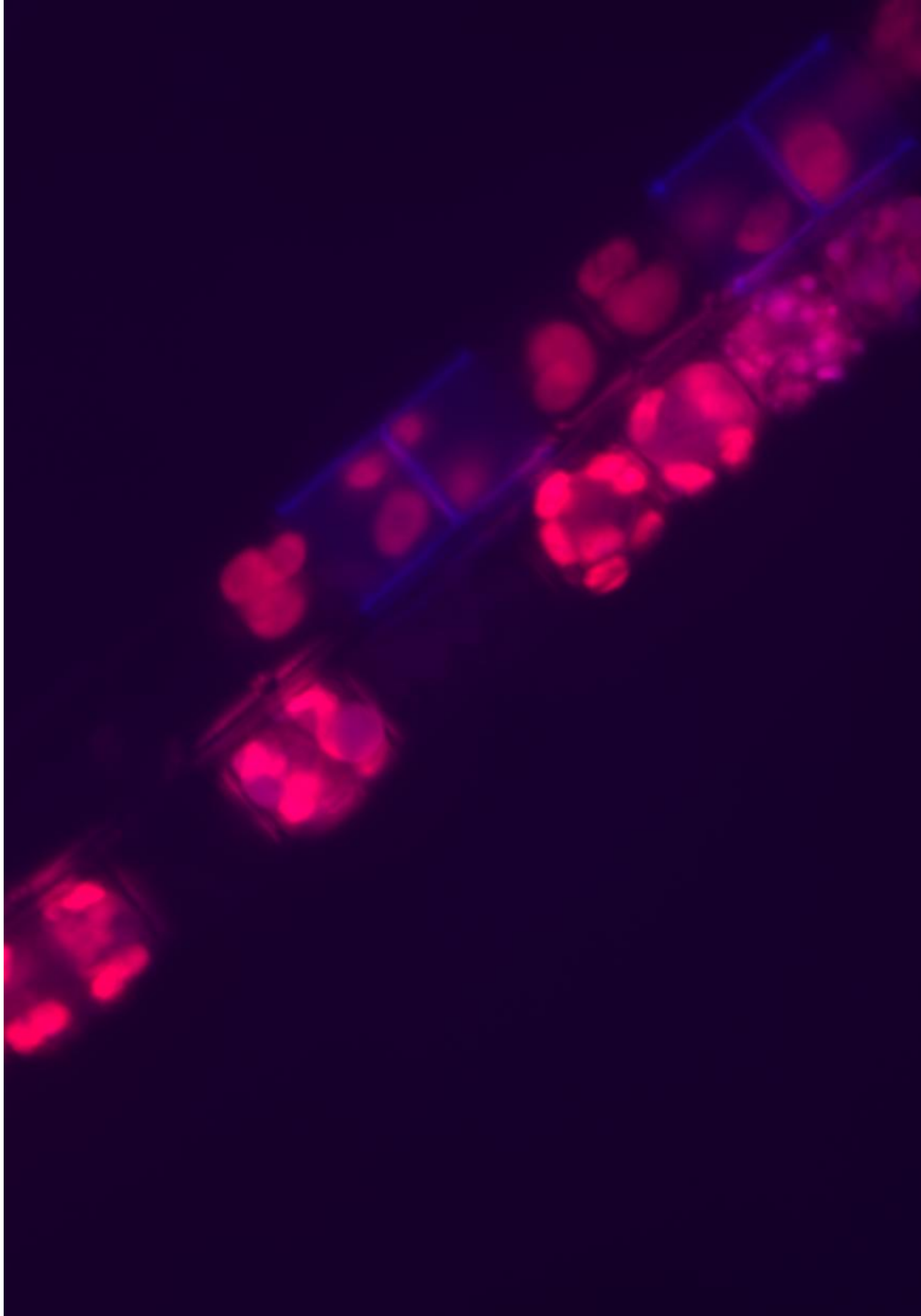
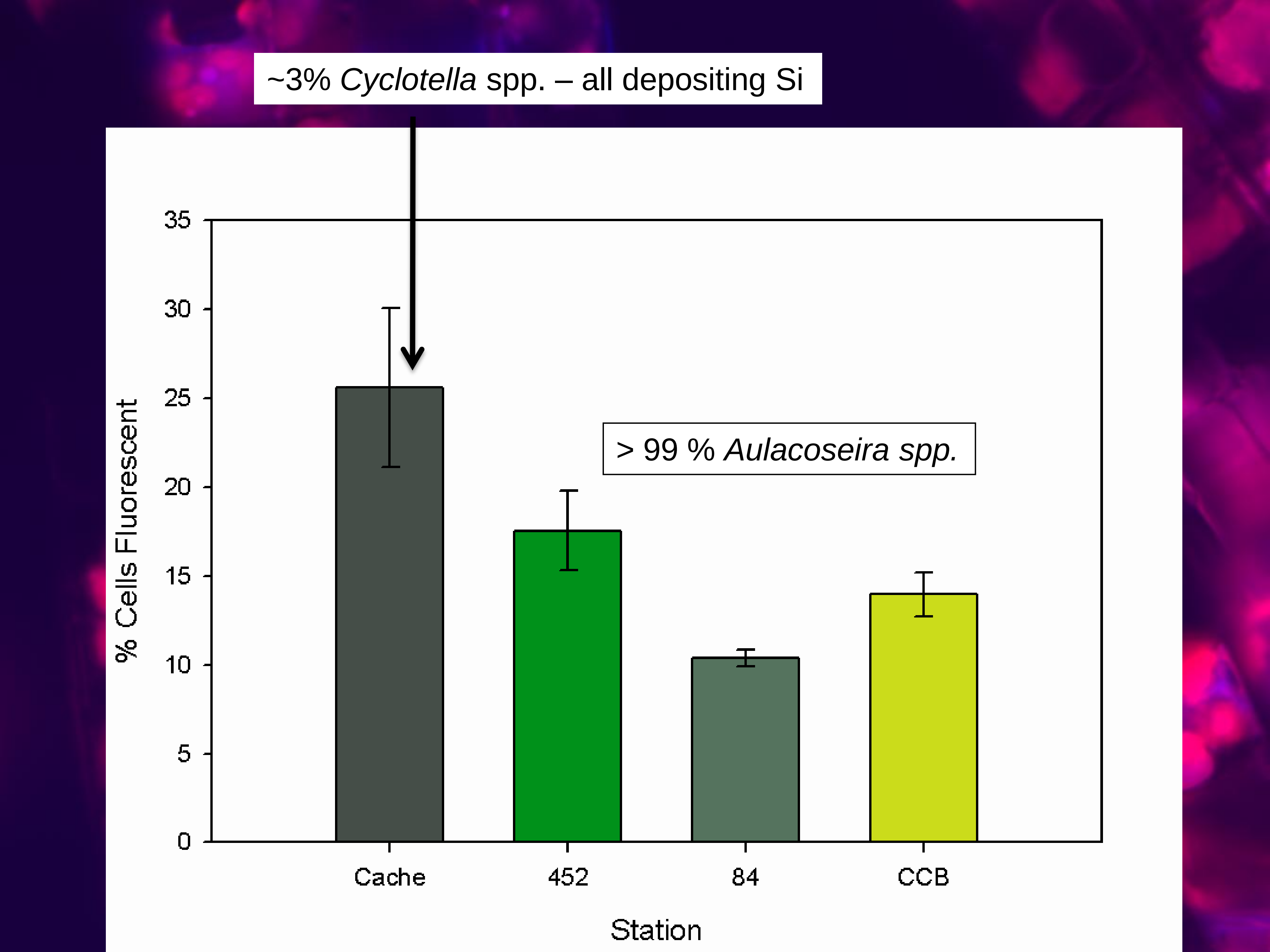


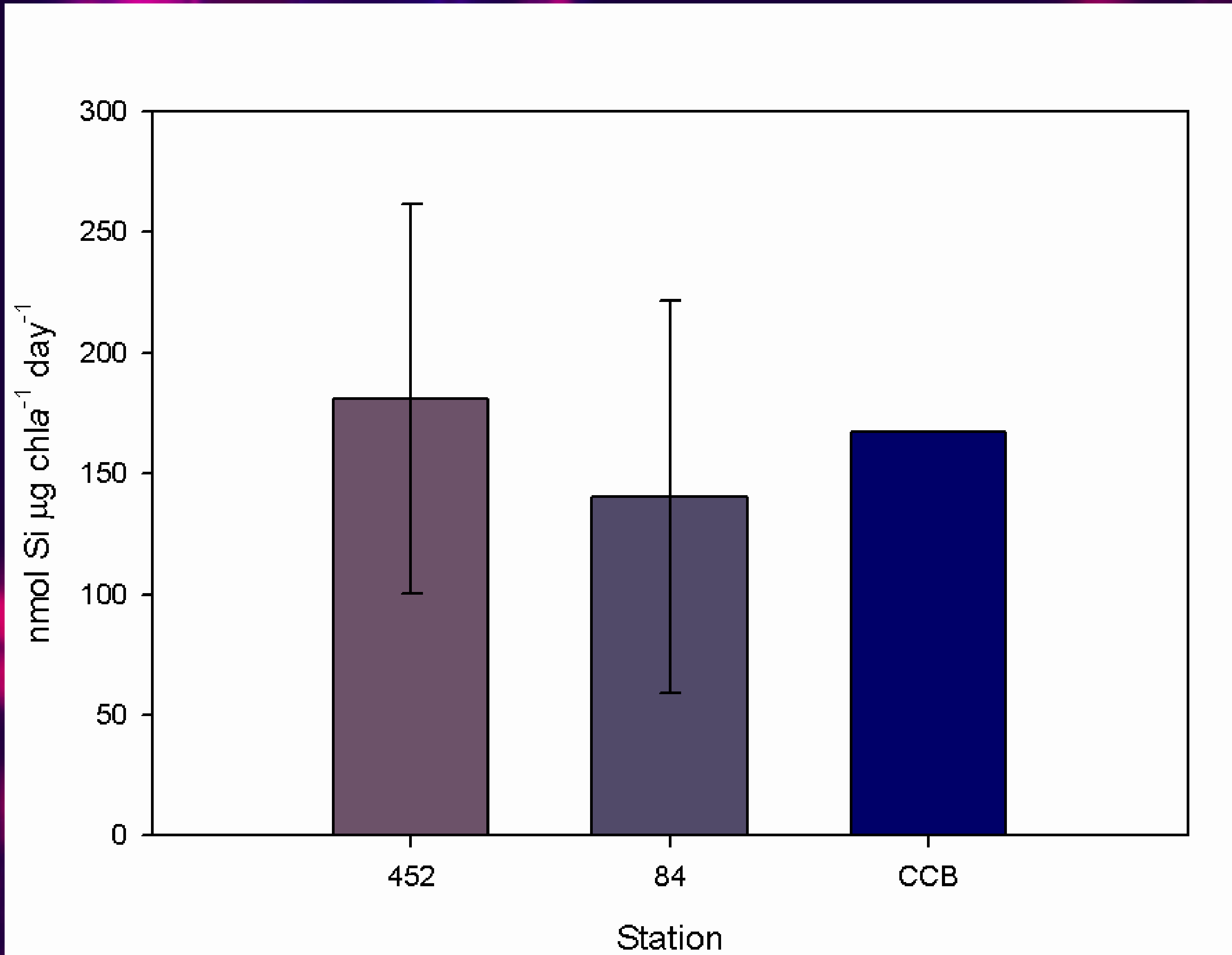
Fig. 1. Chemical structure of PDMPO [41].



- Samples collected from water column
- Incubated for 24 hours
- Subsamples collected every 6 hours

- Microscopic determinations for taxonomy
- PDMPO extracted and measured for rates

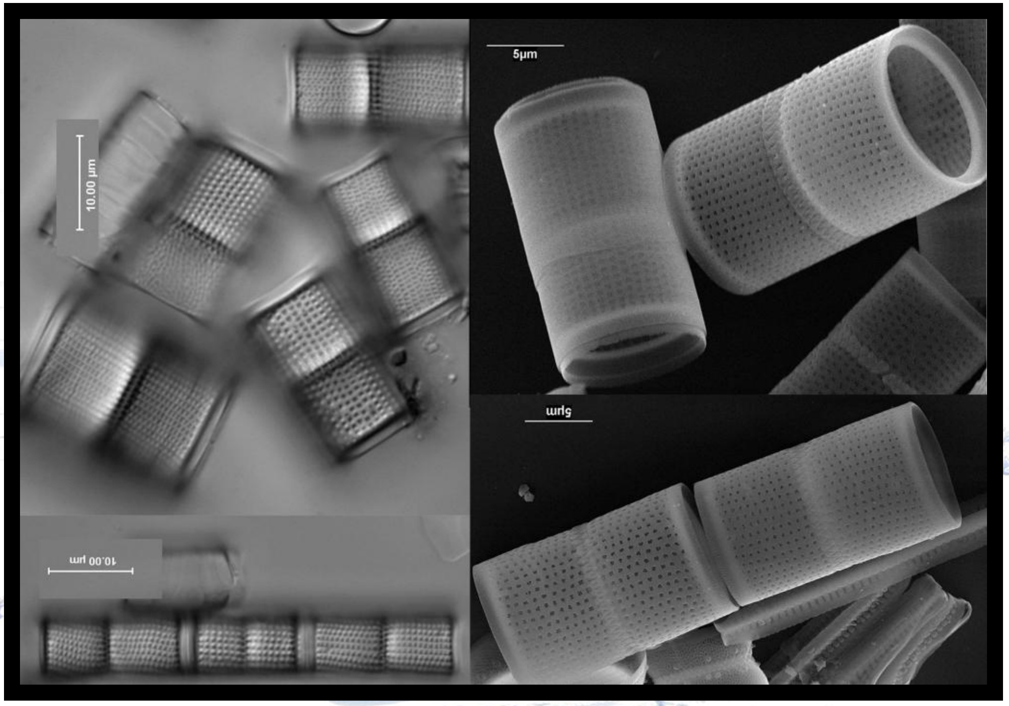

~3% *Cyclotella* spp. – all depositing Si
> 99 % *Aulacoseira spp.*
% Cells Fluorescent
0
5
10
15
20
25
30
35
Cache
452
84
CCB
Station



300
250
200
150
100
50
0
nmol Si µg chla-1 day-1
452
84
CCB
Station

Aulacoseira islandica (O. Müller) Simonsen

Samples from Lake Erie 2007



Photos by Furey and McKay, unpublished

Nutrient assimilation (molar)

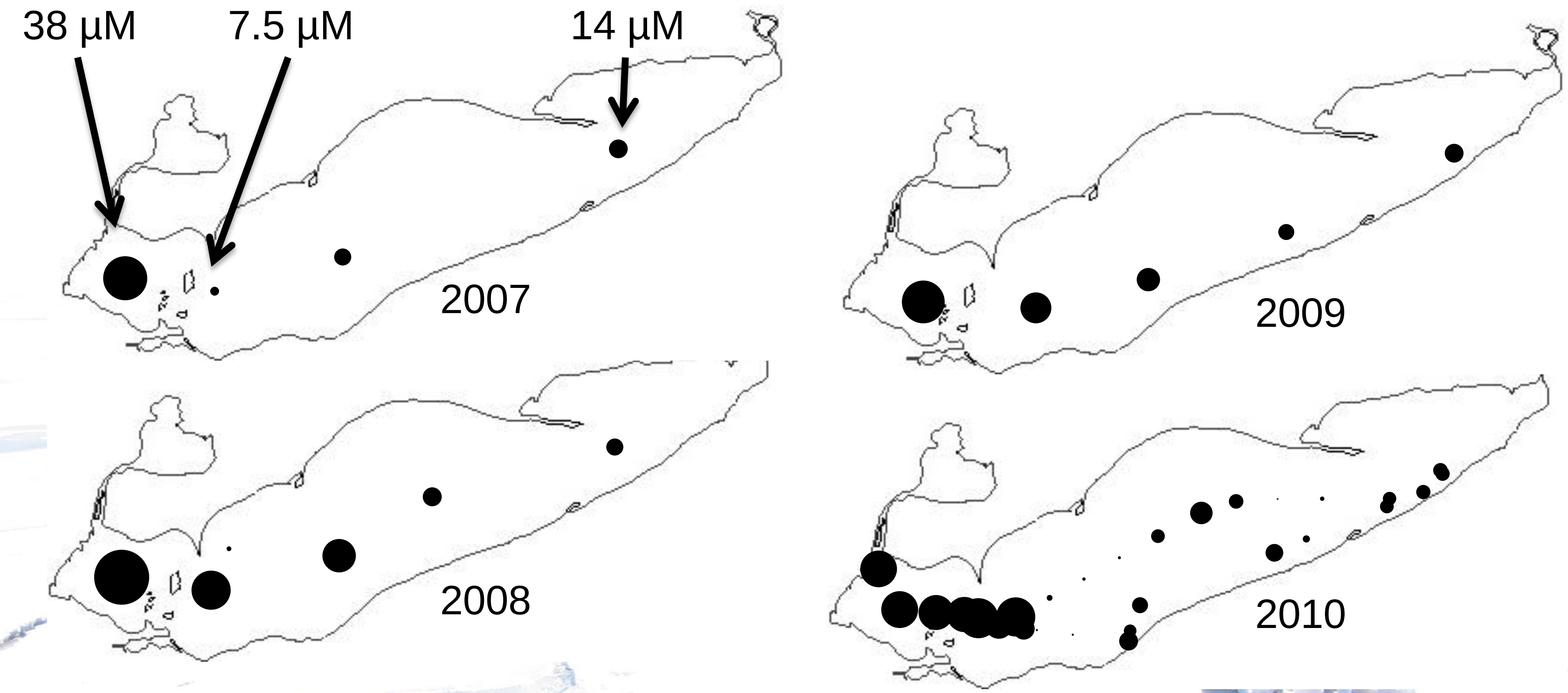
Si:C = 0.03 – 0.04

Luxury C-fixation?

Brzezinski 1985
for 27 marine diatoms

Si:C = 0.13 ± 0 .04
Range (0.04 – 0.36)

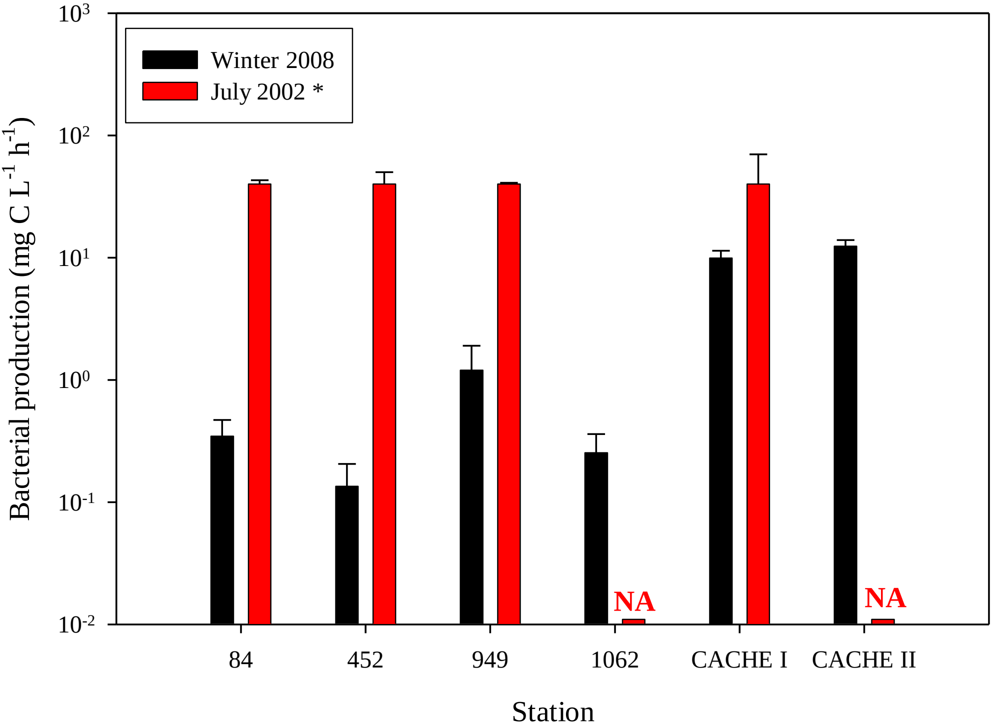
Bubble plot of SiO_2 concentrations in January / February, 2007-2010



SiO_2 is markedly drawn down but never depleted

D Smith, Bourbonniere, Twiss and Wilhelm, unpublished

Surface bacterial production

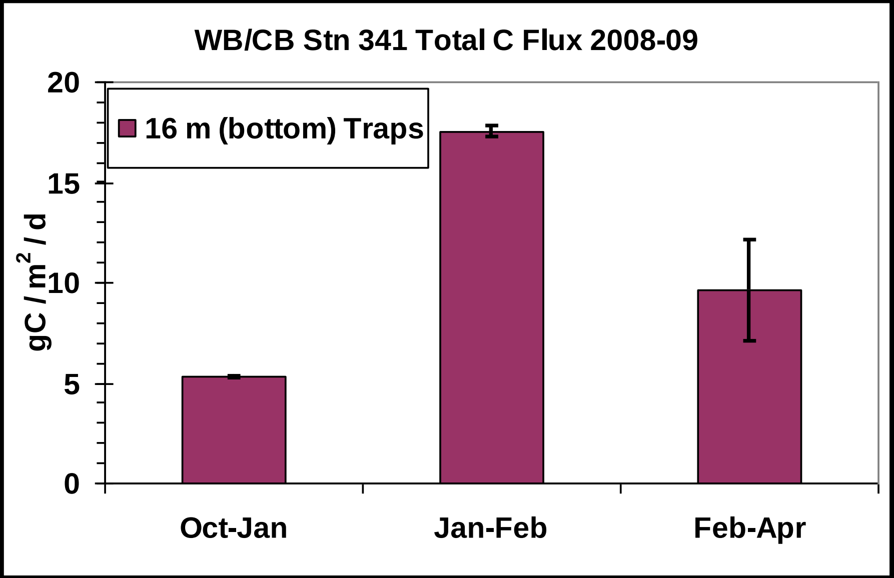


Bacterial (2°) carbon production in the winter is 50 to 100 fold lower than in the summer.

CACHE bacterial production is also lower than in summer months

<u>Bacterial production is 0.011 % (n=14) of the average photosynthetic carbon production in winter months. CACHES (n = 2) 2° production is *ca* 0.27%.</u>

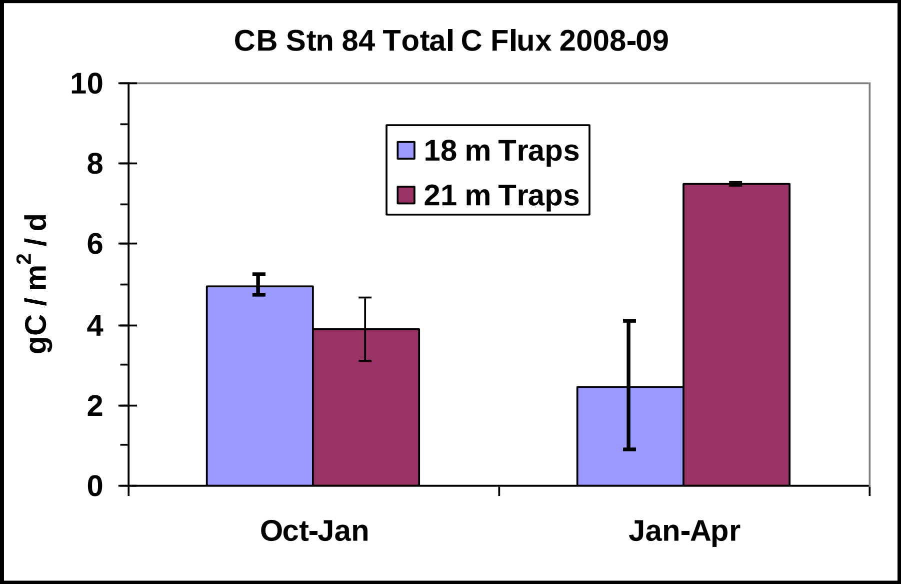
Total C Flux from Oct 2008 – Apr 2009

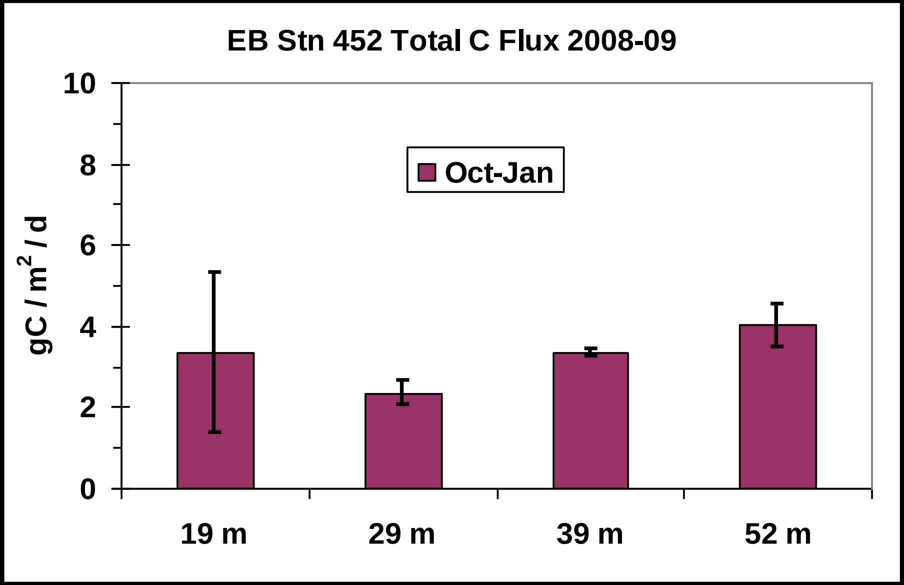


<u>Stn 341</u> ***(note higher scale)***
– evidence that winter C-flux is considerably higher than fall

<u>Stn 84</u> - evidence for sequential settling of C, higher in winter

<u>Stn 452</u> fall only - same range as other stations during fall



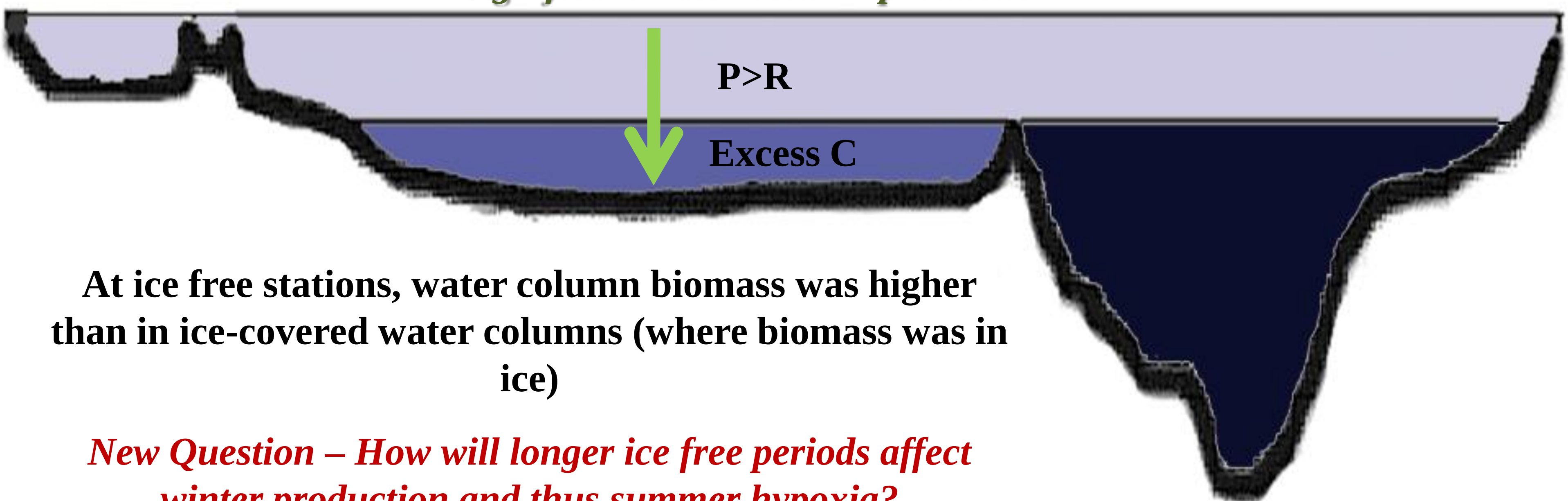


Bourbonniere, Marvin and others, unpublished

Summary

- Abundant photosynthetically "happy" diatoms dominate
- Significant wintertime carbon production and export in the water column
- Slow microbial decomposition rates

Significant water column production



At ice free stations, water column biomass was higher than in ice-covered water columns (where biomass was in ice)

New Question – How will longer ice free periods affect winter production and thus <u>summer hypoxia</u>?


CCM