Global change and the future of toxic algal blooms in the North Pacific Ocean

Feixue Fu

Department of Biology, University of Southern California

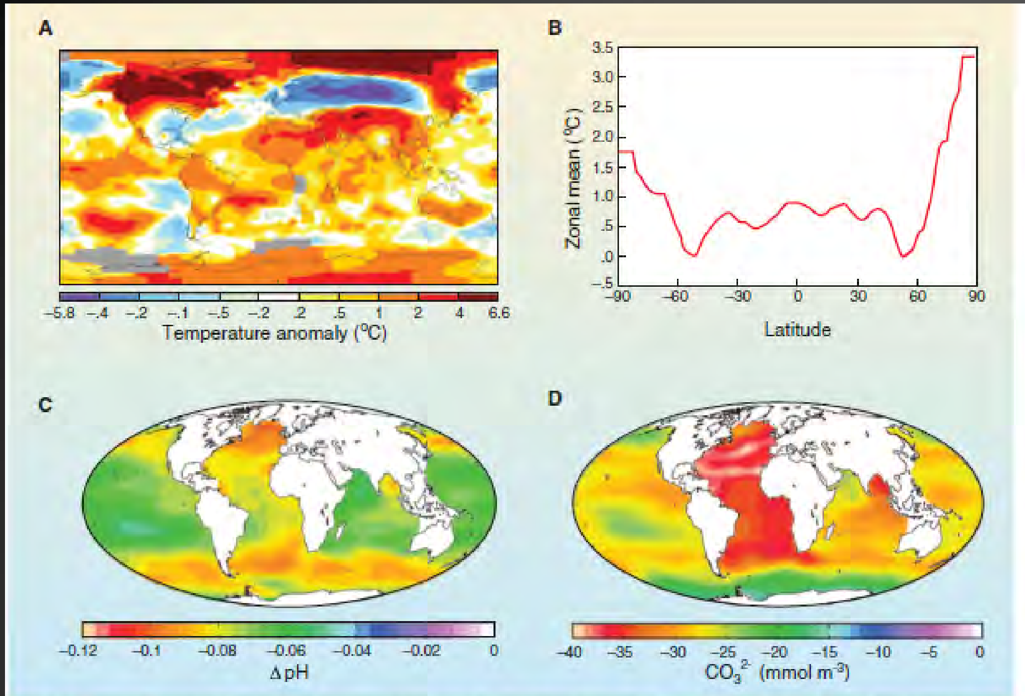


Fig. 1. Recent changes in ocean temperature, acidity, and carbonate ion concentration. **(A)** Surface temperature anomaly for January 2010 relative to the mean for 1951–1980. **(B)** The same data presented in (A) as a function of latitude. **(C)** Estimated change in annual mean sea surface pH between the pre-industrial period (1700s) and the present day (1990s). **(D)** Estimated change in annual mean sea surface carbonate ion concentration between the pre-industrial period (1700s) and the present day (1990s). [Credits: (A) and (B) NASA Goddard Institute for Space Studies; (C) and (D) Global Ocean Data Analysis Project (57)]

Hoegh-Guldberg and Bruno 2010

Global warming

Ocean acidification

Harmful algal blooms and toxin production

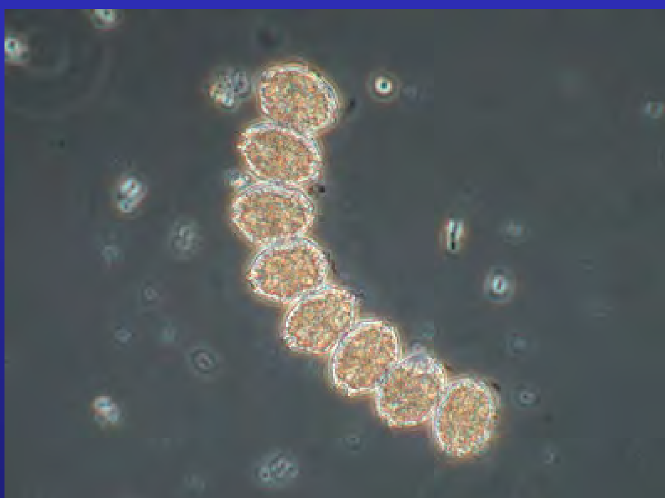
http://www.awi.de/typo3temp/pics/91311ef8a6.jpg

Multiple anthropogenic global change impacts on the surface ocean

By the year 2100:

1. 3-5^{o}C warmer sea surface temperatures.
2. Doubled pCO_2 (~750 ppm), pH decrease of ~0.3.
3. Intensified stratification, shallower mixed layers
   - Reduced vertical fluxes of nutrients
   - Higher mean light intensities
4. Changes in ocean biogeochemistry
   - Nitrogen cycle shifts
   - Iron chemical speciation
5. Major changes in biological communities
   - Competition
   - Grazing

Effects of a warming-induced extended growing season on *Alexandrium catenella*



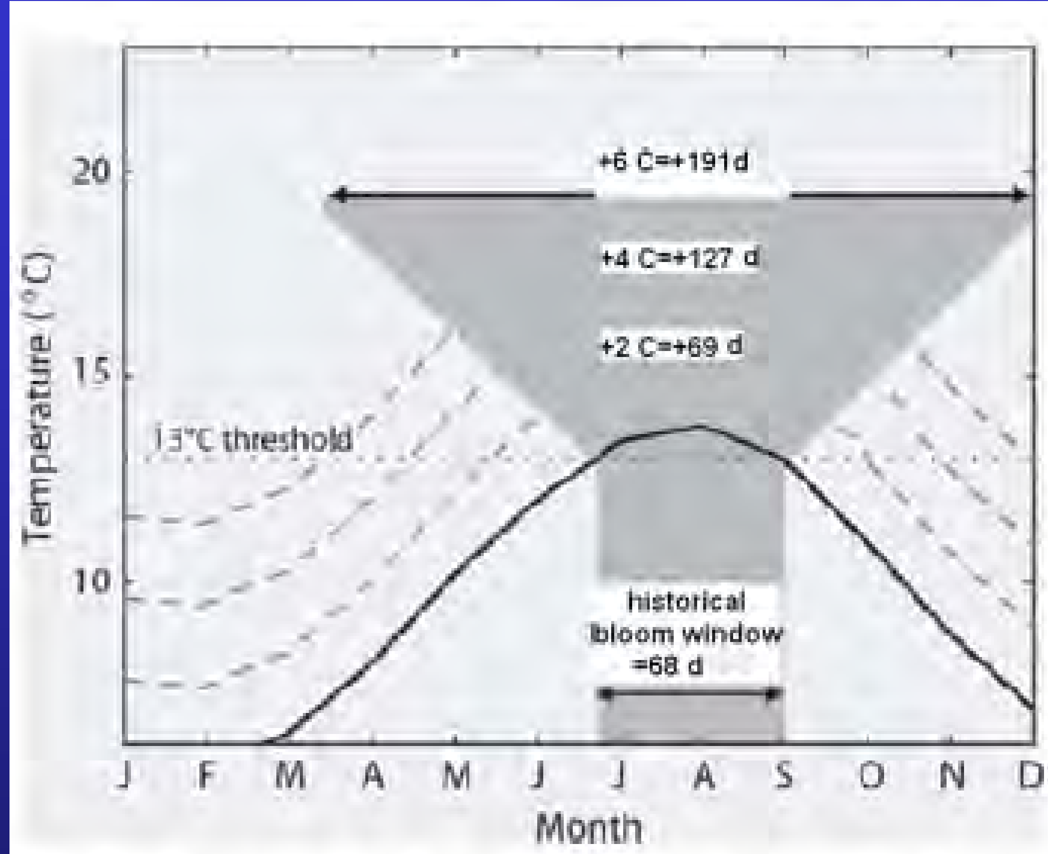
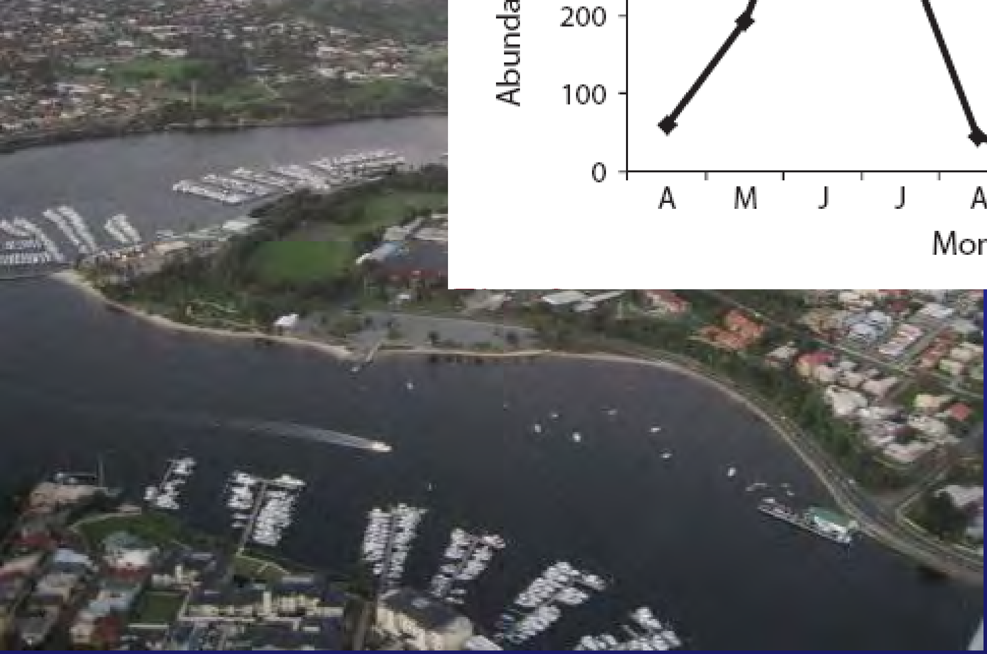
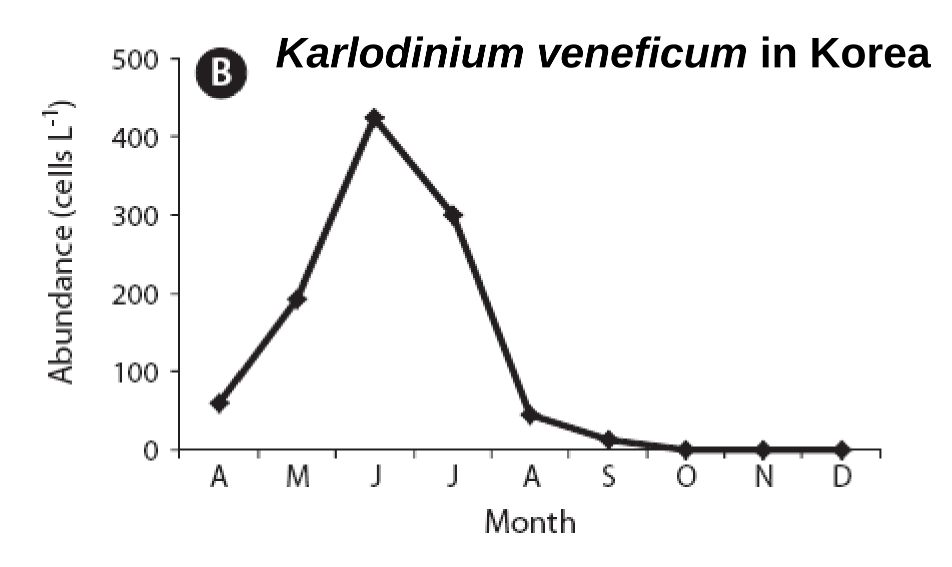


FIG. 7. Scenarios for warmer sea surface temperature conditions in Puget Sound by 2, 4, and 6°C would widen the >13°C window (in gray) of accelerated growth for the PSP dinoflagellate *Alexandrium catenella*. After Moore et al. (2008b). PSP, paralytic shellfish poisoning.

Moore et al. 2008, Environmental Health 7

Karlodinium veneficum blooms





Karlodinium veneficum

Massive Australian *K. veneficum* bloom,
Swan River estuary
(Alice Gedaria, UWA)

2009 Maryland *K. veneficum* fish kill
(Maryland DOE)

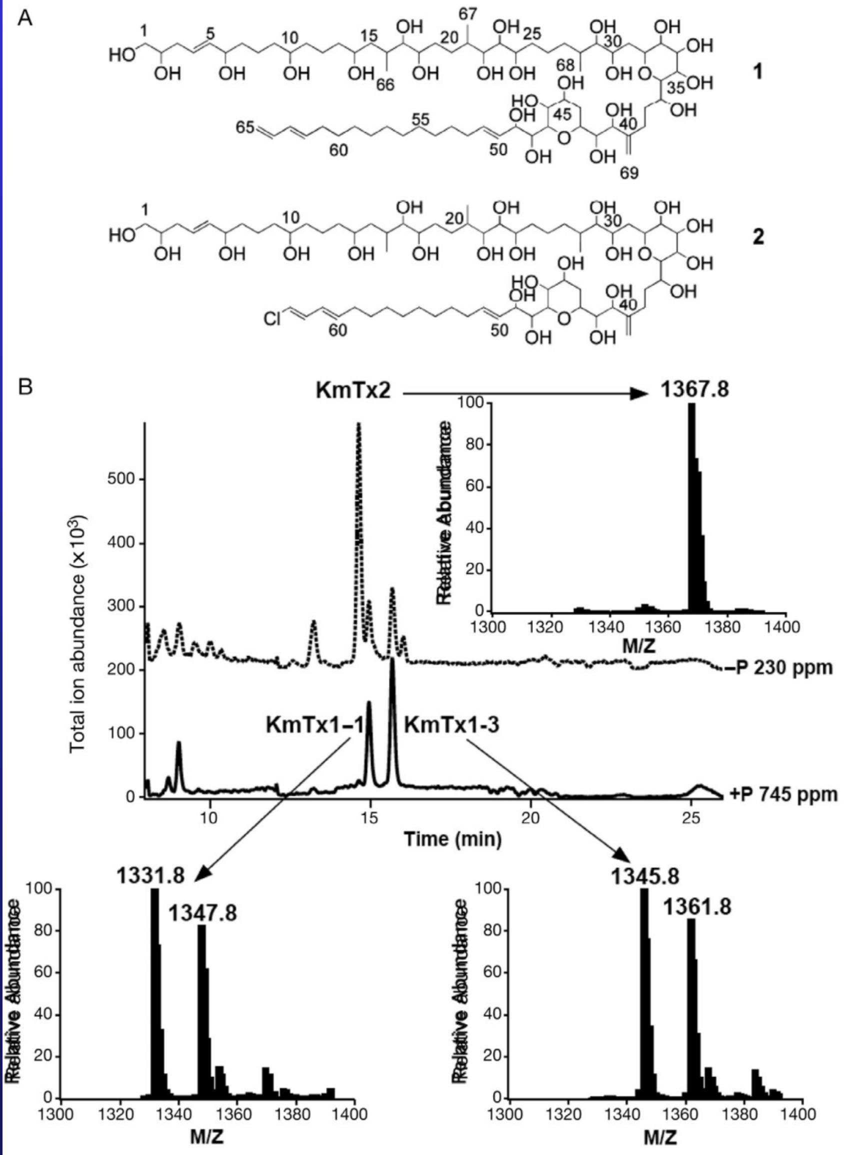
Methods

1. Karlodinium veneficum cultures isolated from the DIB were grown in semi-continuous cultures

2. Treatments: Three pCO_2 levels: 230, 430, and 745 ppm: each under both P-limited and P-replete growth conditions

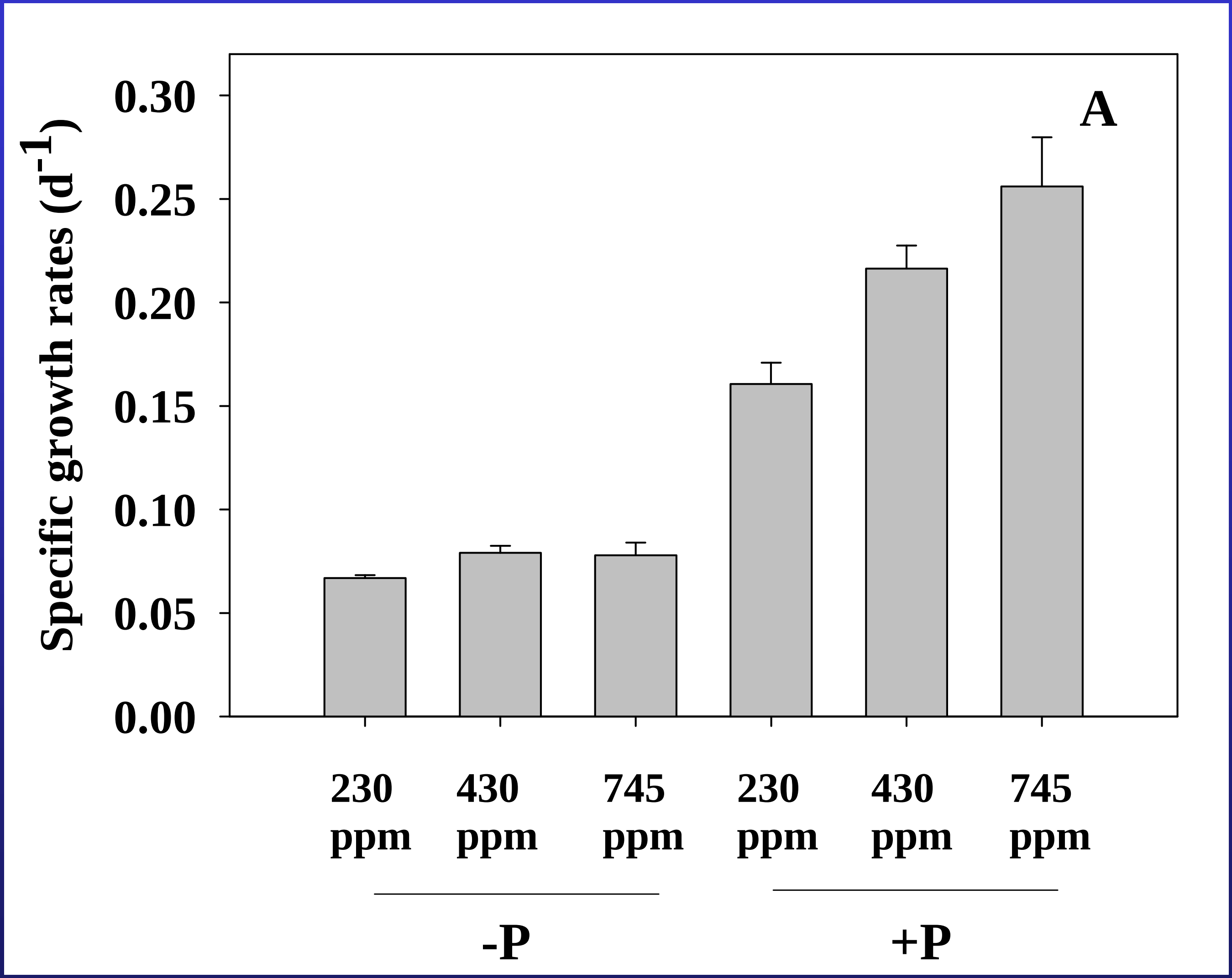
3. Measurements of growth rates, physiological parameters, karlotoxin production

LC-MS measurements of karlotoxin congeners (by Al Place, UM)



Fu et al. 2010 AME

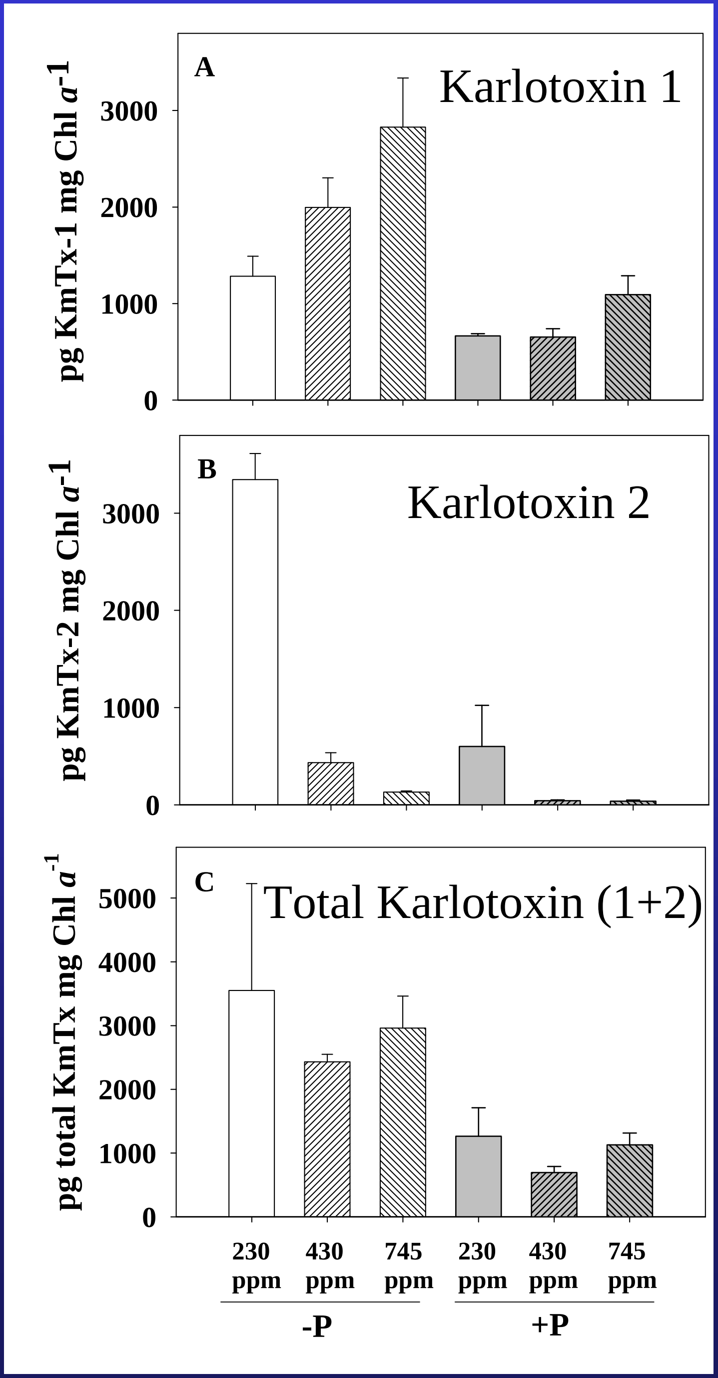
Karlodinium growth rates



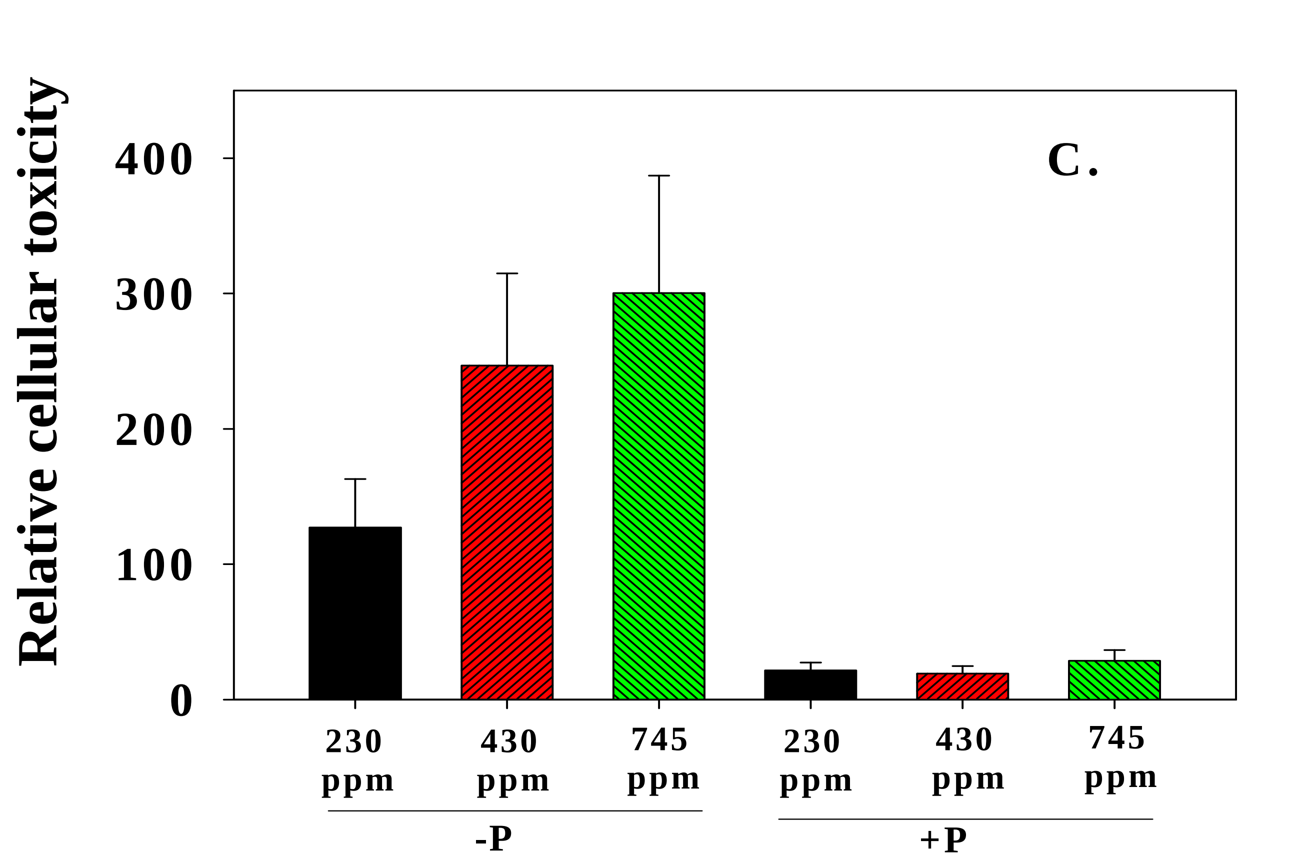
Fu et al. 2010 Aquatic Microbial Ecology

pCO$_2$ and
P availability
together
control
Karlodinium
toxin production
and congener
composition

(Fu et al. 2010 AME)



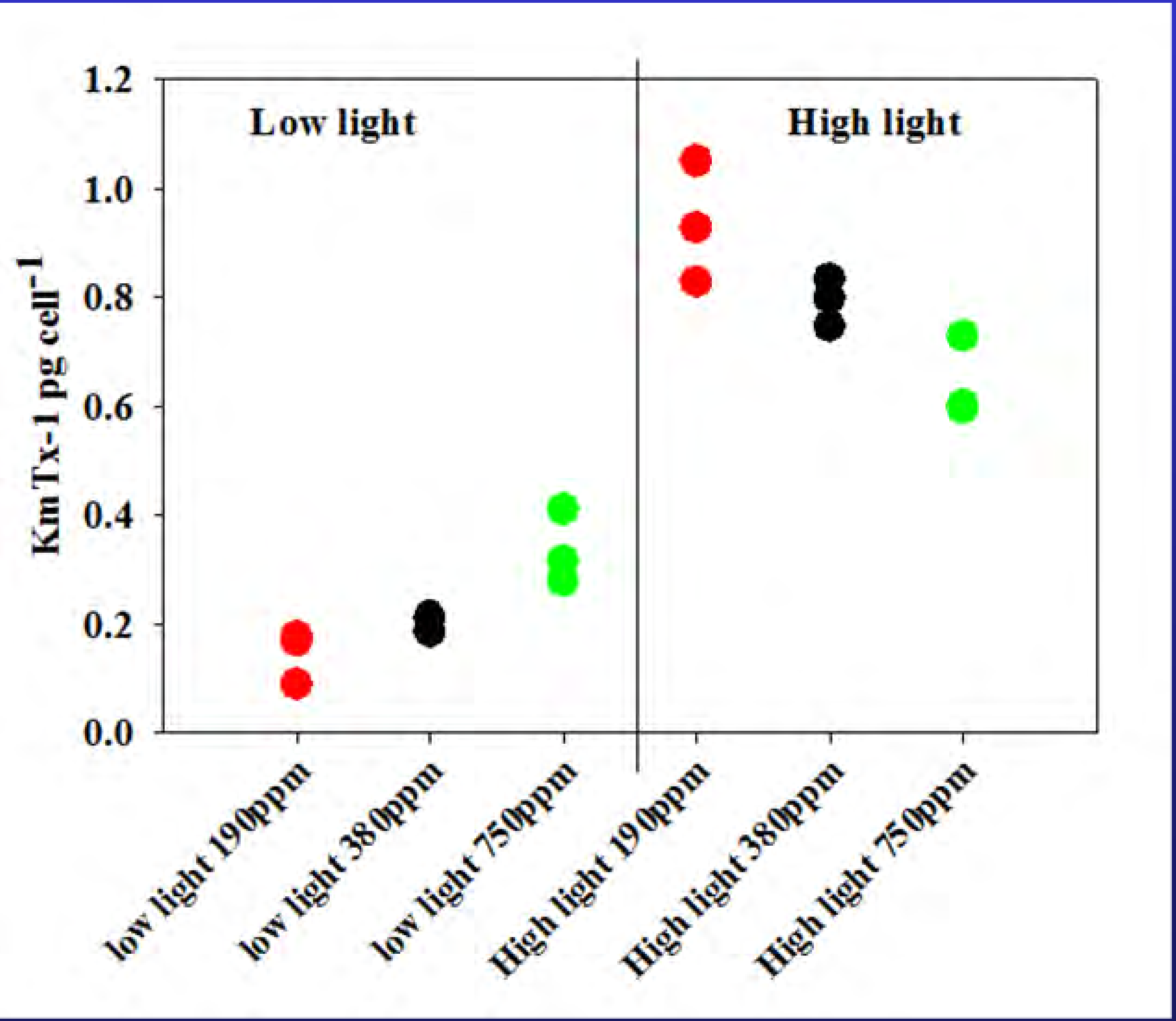
Karlodinium: Cellular potency increases under higher pCO_2 and reduced P availability



(picosaponin equivalents cell^{-1})

Fu et al. 2010 AME

Complex interactions between pCO_2, light and karlotoxin production



Fu, Place and Hutchins, unpubl. data

Conclusions

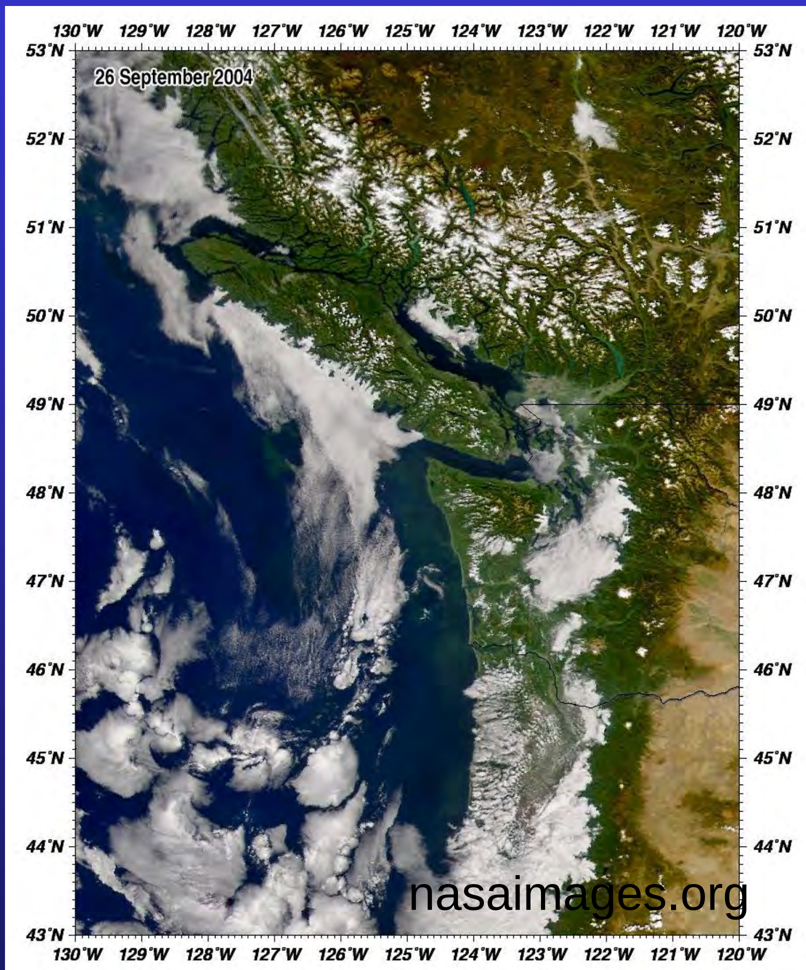
- **Higher pCO_2 could greatly increase the cell-specific toxicity of *Karlodinium* blooms, through changes in the relative production rates of differentially potent karlotoxin congeners**

- **Interactions between cellular toxicity and pCO_2 are likely to be especially significant in P-limited and high light conditions**

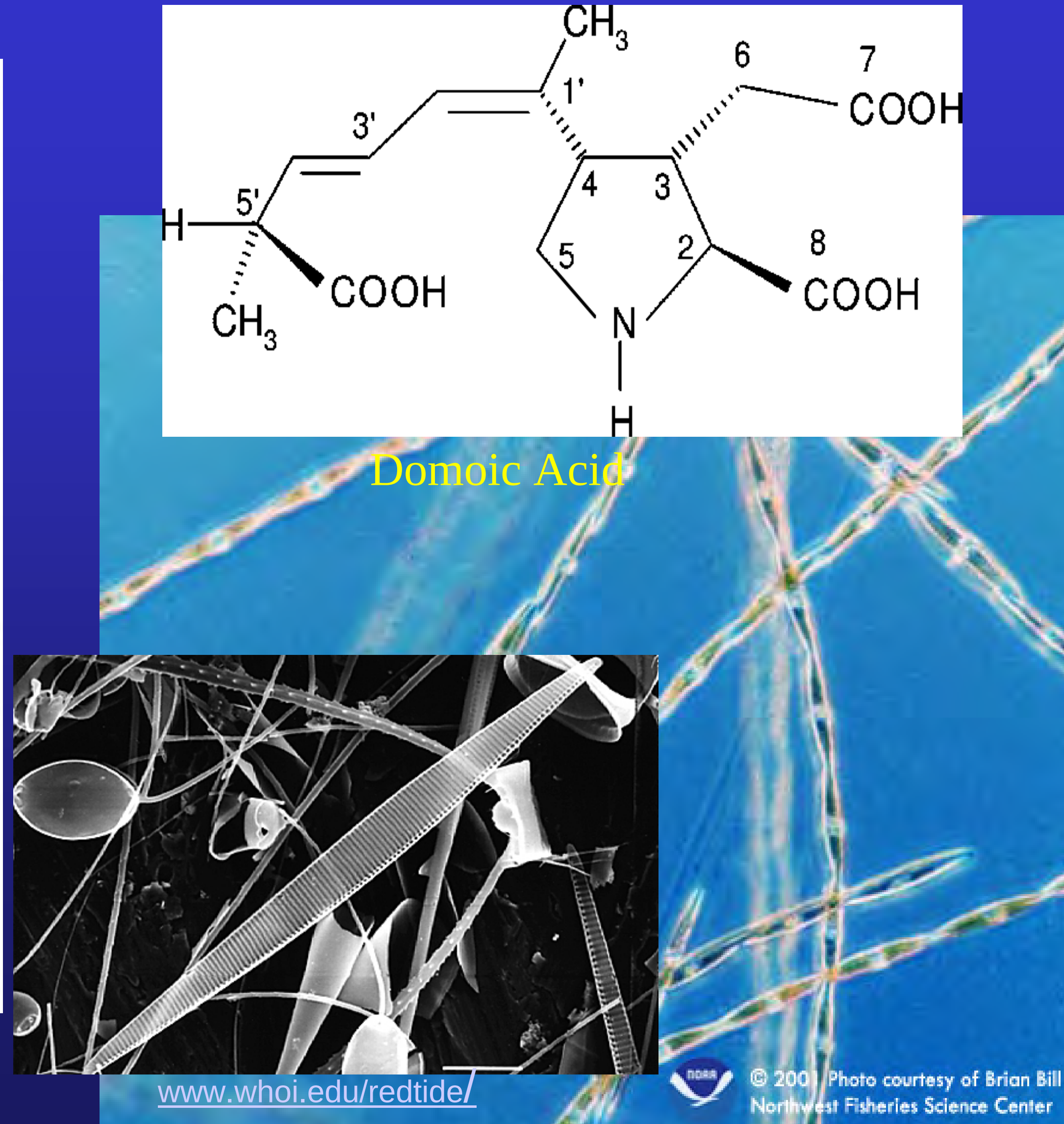
- **The effects of pCO_2 on cellular karlotoxin are also dependent on light intensities**

- **More work is needed to determine the interactions of global change variables with pCO_2 in other toxic dinoflagellates e.g. *Alexandrium, Pyrodinium bahamense,* and *Gymnodinium catenatum* in the Pacific region**

Pseudo-nitzschia blooms



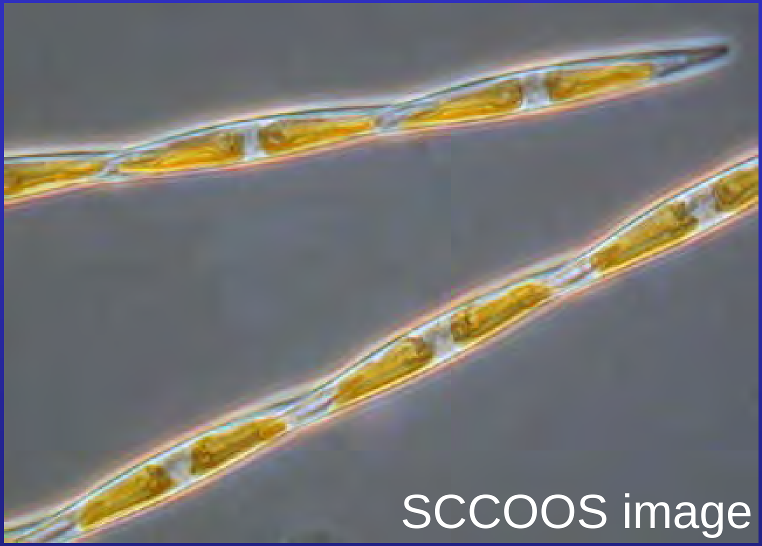
Pseudo-nitzschia bloom,
Juan de Fuca eddy



www.whoi.edu/redtide/

Methods

- Toxic *Pseudo-nitzschia multiseries* culture from eastern Canada
- Grown at three pCO_2 levels (220, 400 and 730 ppm)
- Each pCO_2 treatment under P-limited and P-replete conditions
- Measurements of domoic acid production (ELISA), physiological and biogeochemical parameters

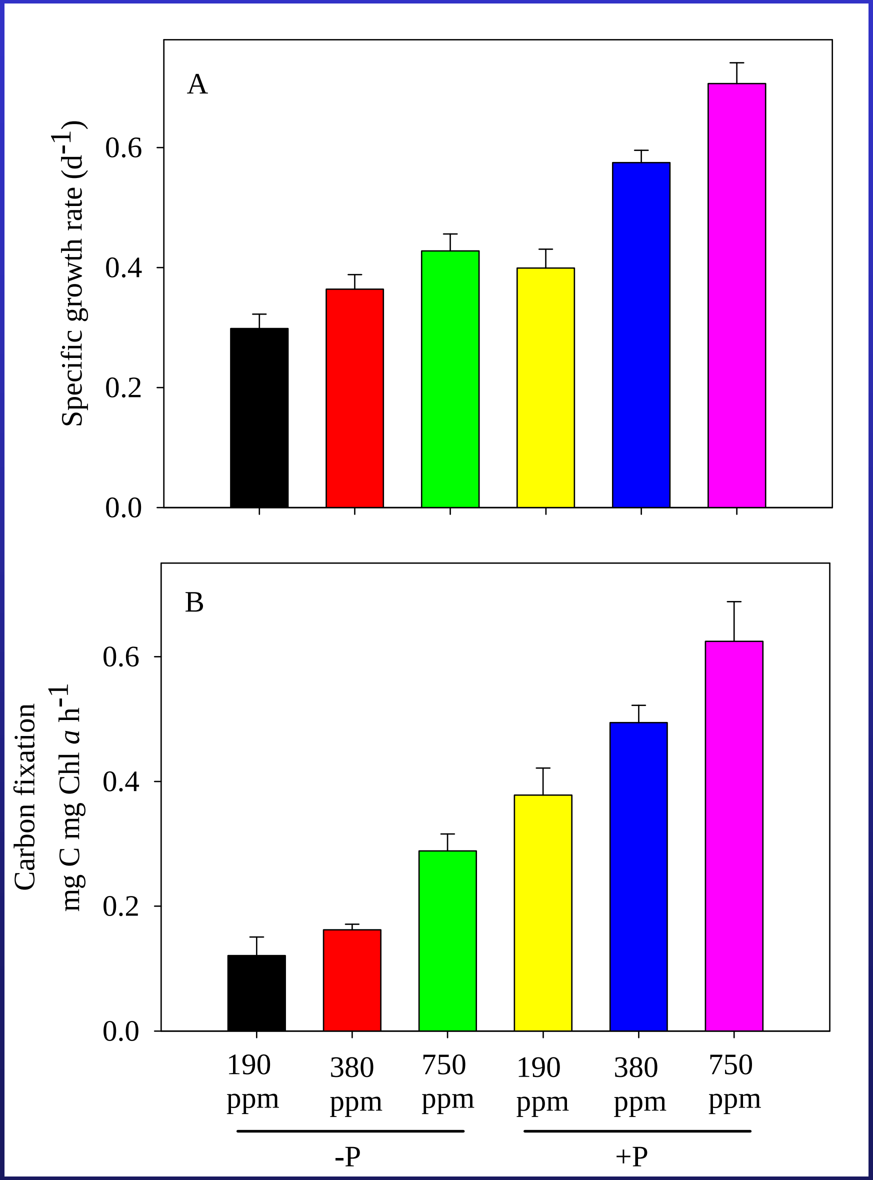


Effects of changing pCO_2 and phosphate availability on domoic acid production and physiology of the marine harmful bloom diatom *Pseudo-nitzschia multiseries*

Jun Sun, David A. Hutchins, Yuanyuan Feng, Erica L. Seubert, David A. Caron, and Fei-Xue Fu

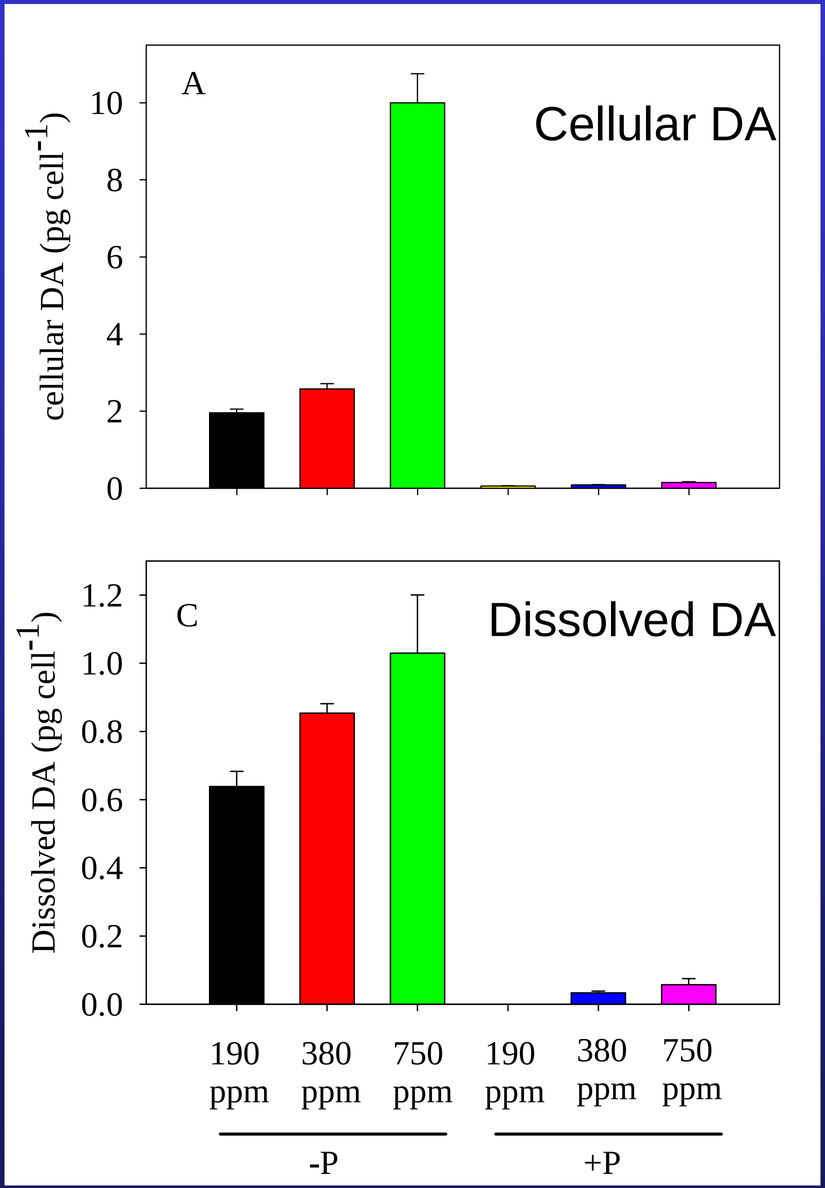
Limnology and Oceanography 56 (2011)

Pseudo-nitzschia multiseries- growth and carbon fixation rates



Sun et al. 2011
L&O 56

Domoic acid production is regulated by both pCO_2 and P availability



Sun et al. 2011

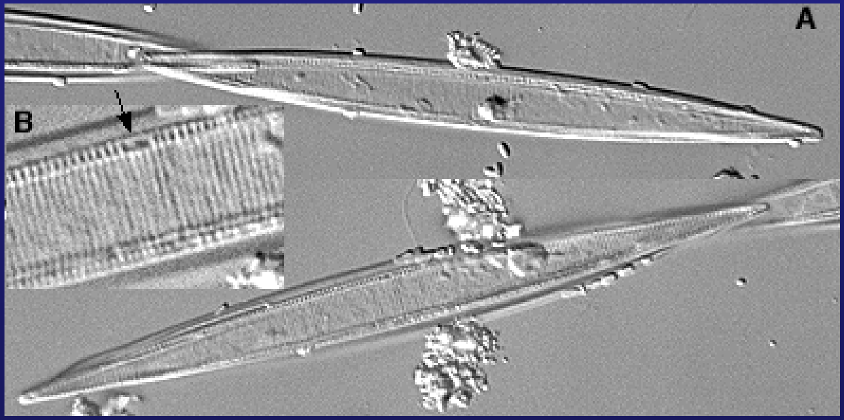
L&O 56

Si and CO_2 effects on a coastal Southern California *Pseudo-nitzschia fraudulenta* isolate

Three CO_2 levels (210 ppm, 380 ppm, 770 ppm)

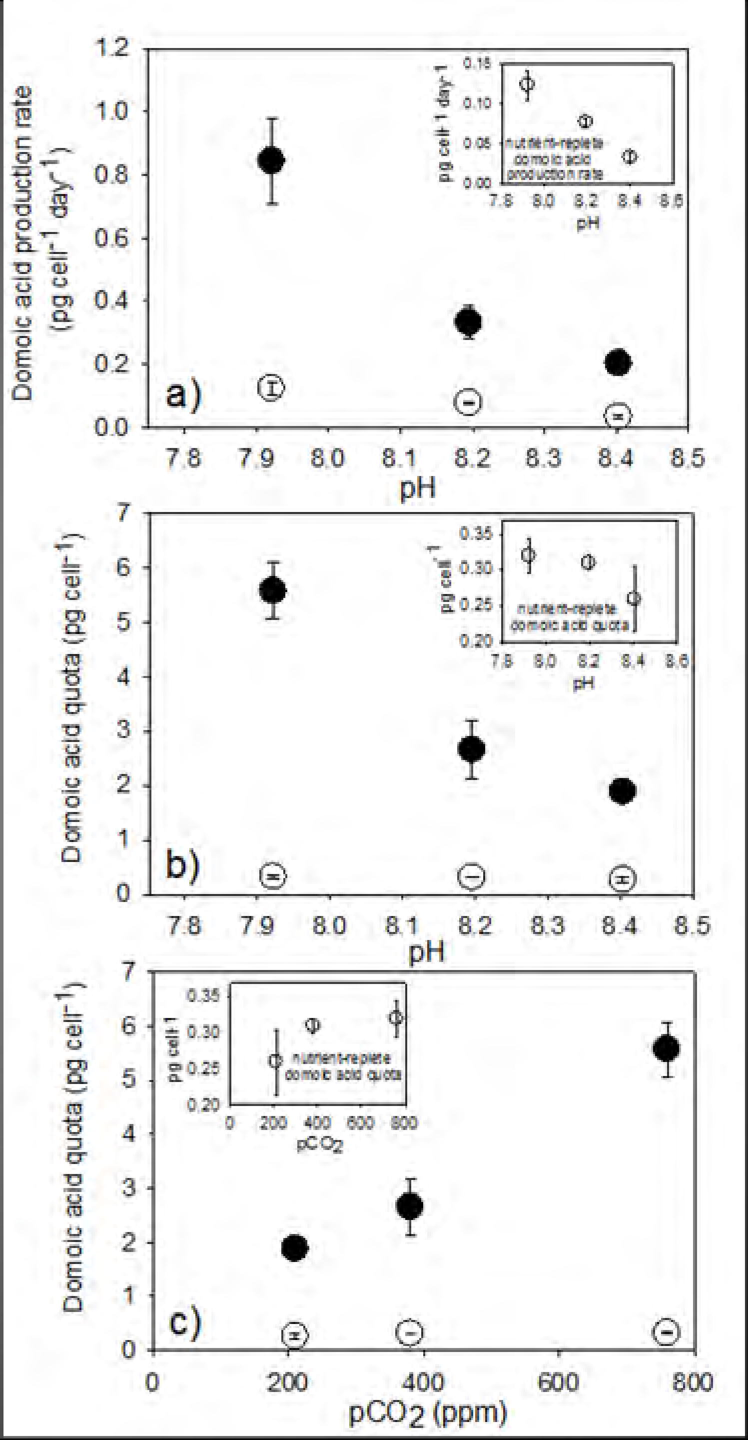
Silicate-limited and Silicate-replete

Measurements of domoic acid production (HPLC), growth rates, elemental ratios



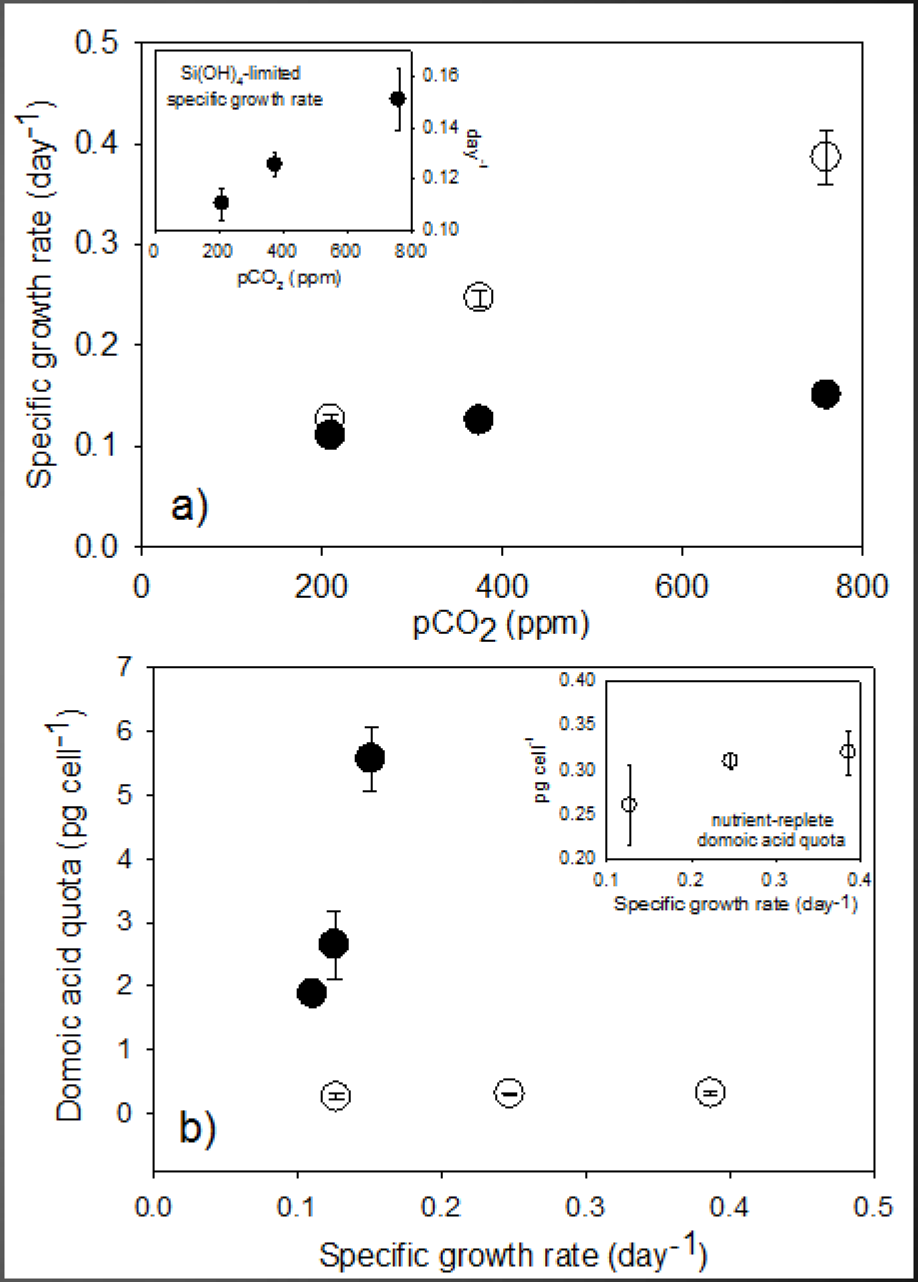
http://www.smhi.se/oceanografi/oce

Domoic acid production increases dramatically at lower pH (higher pCO_2), especially during Si-limited growth



Tatters, Fu and Hutchins in preparation

Growth rate is positively correlated with toxin production in both Si-limited and Si-replete diatom cultures



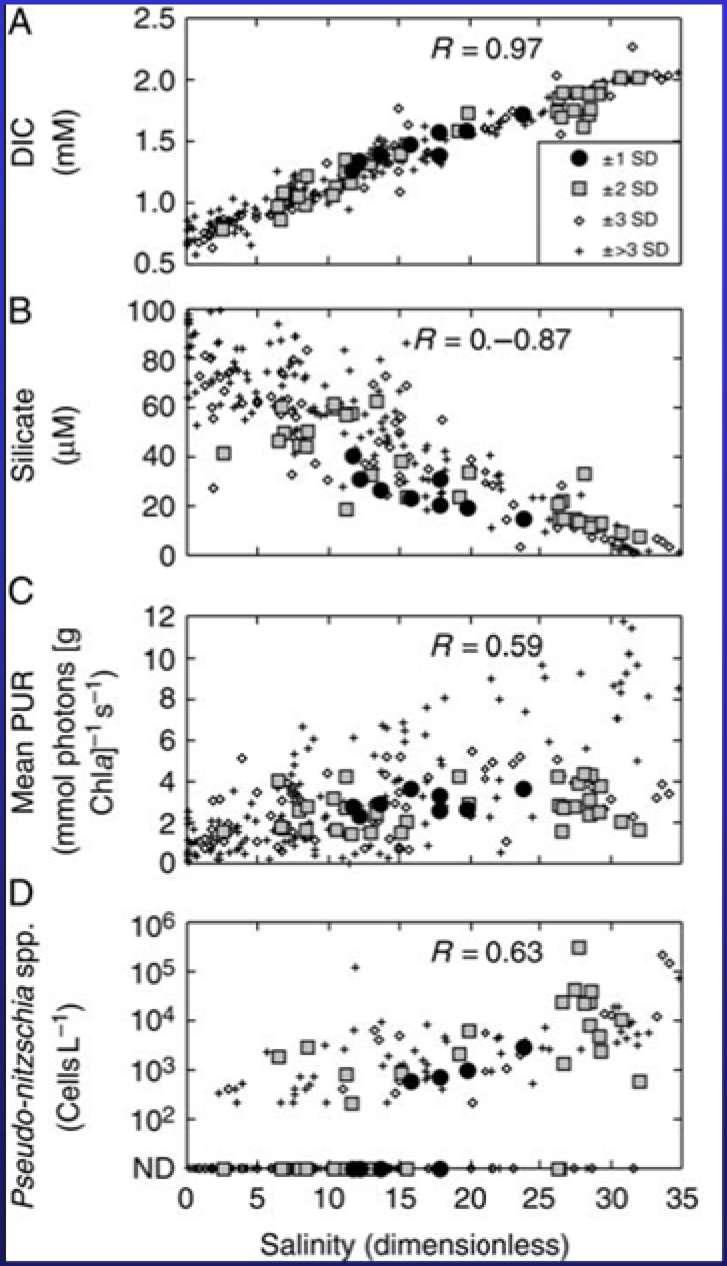
Tatters, Fu and Hutchins

In preparation

Supporting evidence from field studies

MacIntyre et al. 2011.

Environmental correlates of community composition and toxicity during a bloom of *Pseudo-nitzschia* spp. in the northern Gulf of Mexico. *J. Plank. Res.* 33



DIC (pCO_2)

Silicate

Irradiance

Pseudo-nitzschia cell number

Estuary → Open ocean

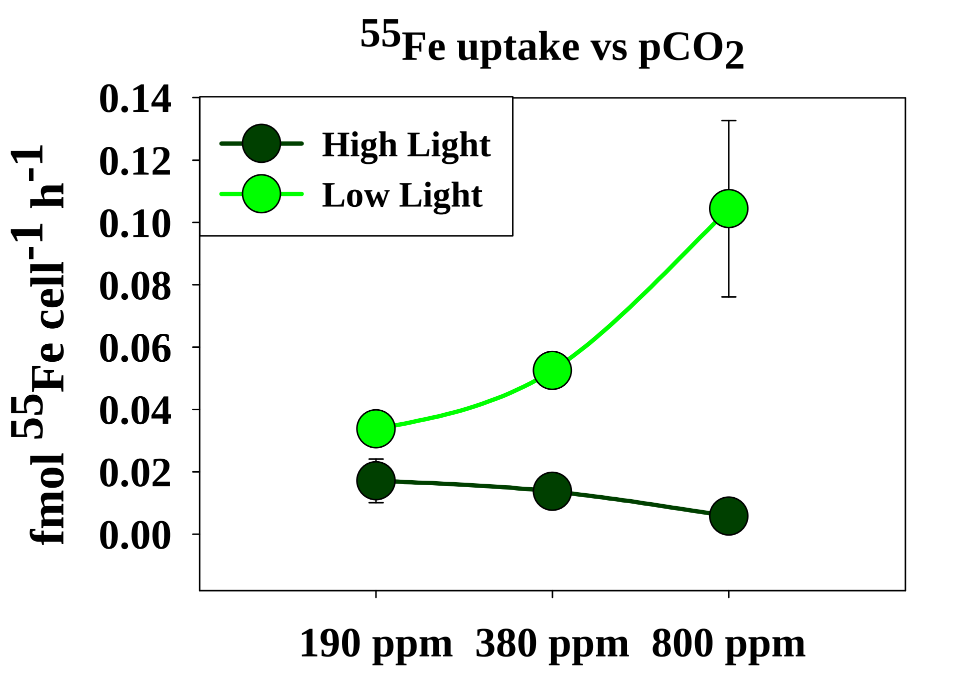
Gene expression and domoic acid/CO_2/Si interactions

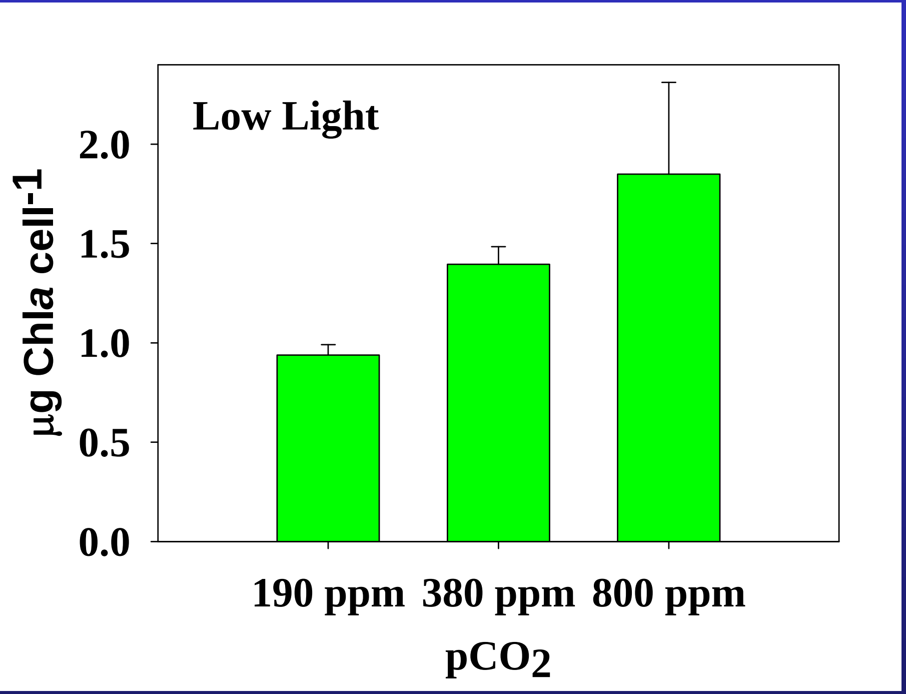
- Transcriptome samples from this *Pseudo-nitzschia fradulenta* CO_2/Si experiment have just been Illumina-sequenced through a small grant from the Moore Foundation Marine Microbial Eukaryote Transcriptome Project, in collaboration with Bethany Jenkins (URI)

- Gene expression patterns are currently being analyzed, with an eye towards identifying CO_2- and toxin-responsive genes for future followup work

GORDON AND BETTY MOORE FOUNDATION

The interactive effects of CO_2 & light on Fe uptake and cellular Chl in *Pseudo-nitzschia fraudulenta*





Conclusions

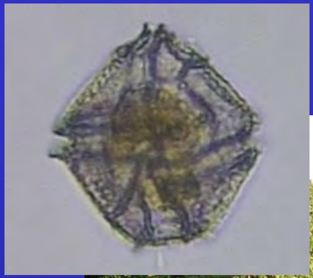
- **Like the dinoflagellate, the toxicity of *Pseudo-nitzschia* spp. diatoms is greatly increased by the combination of nutrient limitation and elevated pCO_2.**
- **Effects on domoic acid production of interactions between pCO_2 and other global change variables, such as temperature, light and iron, are unknown and still need to be determined**
- **There is a potential for greatly increased toxicity of *Pseudo-nitzschia* blooms in the future acidified ocean**

Overall conclusions

In some HAB dinoflagellates and diatoms, cellular toxicity can increase dramatically as pCO_2 goes up

Interactions of global change variables with other key environmental variables like nutrients and light are critical and need to be considered

The potential for adaptation of HAB species to long-term ecosystem changes also needs to be considered



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