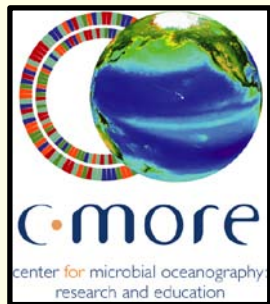




Potential Environmental Consequences of Enhanced Ocean Upwelling

**Dave Karl, Daniela Böttjer, Tara Clemente,
Steve Poulos, Sam Wilson, Karin Björkman and
Sarah Searson**



**UH Manoa
C-MORE/SOEST**



ENHANCED OCEAN UPWELLING: Science, Engineering and Potential Applications



The Center for Microbial Oceanography: Research and Education (C-MORE), a NSF-supported Science and Technology Center at the University of Hawai'i, and the EarthFree Institute, a charitable organization formed to support research into and education about the health of the world's oceans, cordially invite you to participate in a workshop on the science and potential applications of enhanced ocean upwelling. This workshop coincides with C-MORE's deployment, on 1 December 2011, of a novel mesocosm-based open ocean field experiment in collaboration with colleagues from Germany (IFM-GEOMAR).

The first day of this two-day workshop will include several background talks on key science, engineering and economic issues relevant to enhanced upwelling, and reports of representative field projects that have been conducted or are being planned, including modeling studies. Day two will focus mostly on the future. A report summarizing the workshop's recommendations for the next generation of field experiments and for the development of observation networks that will be necessary to detect any unintended consequences of enhanced ocean upwelling will be prepared. There will be ample time for questions, discussion and debate. It should be an enjoyable and thrilling event; we hope you can attend.

Space is limited so please RSVP (sharons@soest.hawaii.edu) by Tuesday 22 November. Workshop updates and agenda available at cmore.soest.hawaii.edu



Tuesday 29 November

East-West Center
Asia Room

8 am coffee; 8:30 am–5 pm (lunch provided);
5–7 pm reception



Wednesday 30 November

C-MORE Hale
Gordon and Betty Moore Conference Center

8 am coffee; 8:30 am–4 pm



A NEW SUBDISCIPLINE?

- Ocean science and society
- Coupled natural-human systems
- Economics and sustainability
- Education and public outreach

November 2011

Agenda and presentations available at:

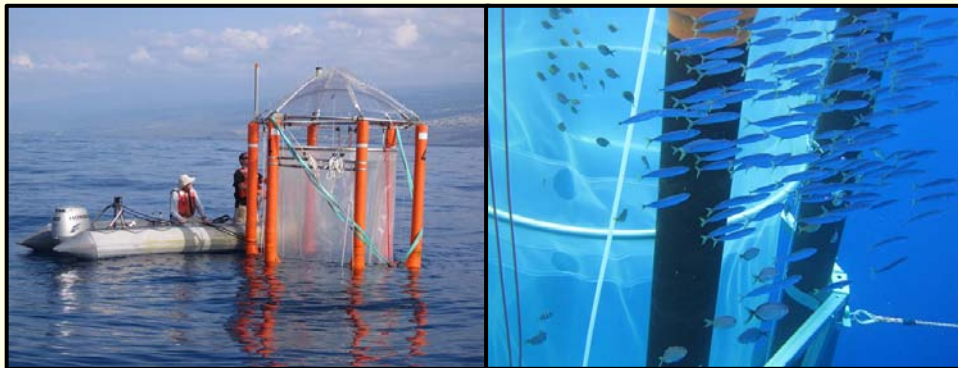
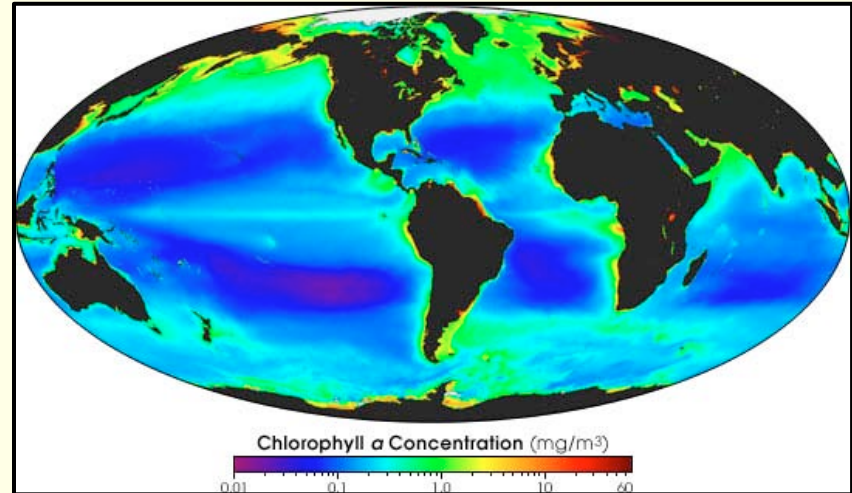
http://cmore.soest.hawaii.edu/events/enhanced_upwelling_nov_2011_video1.htm

http://cmore.soest.hawaii.edu/events/enhanced_upwelling_nov_2011_video2.htm

Take Home Message

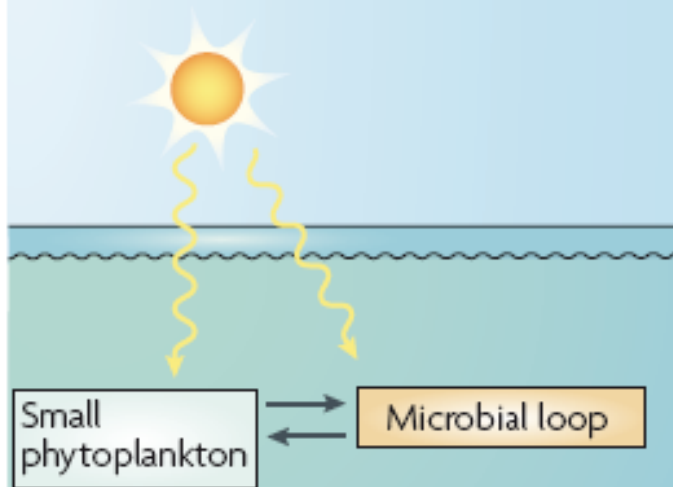


NUTRIENTS + LIGHT
= PHYTOPLANKTON



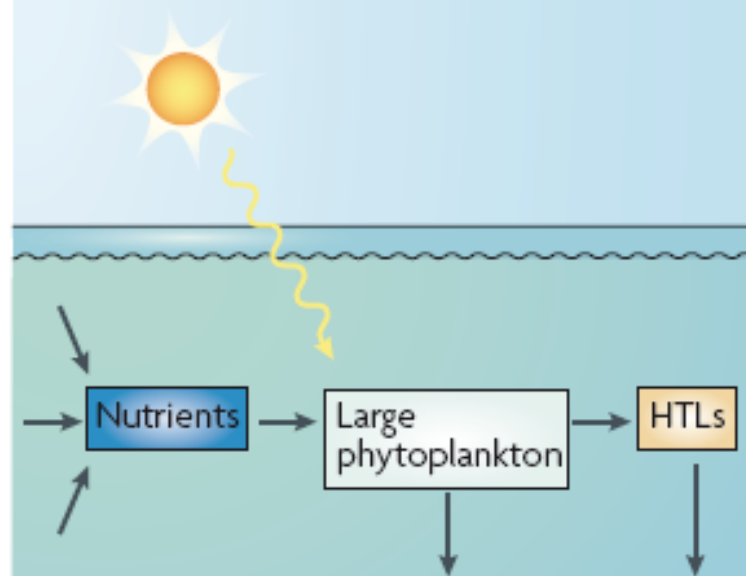
- Oceanographic theory and prediction
- Results from field experiments

a Background state



- Small phytoplankton cells
- Regeneration intensive
- Net heterotrophic ($GPP < R$)
- Low carbon export/sequestration
- Most frequent state

b Nutrient-excited state



- Large phytoplankton cells
- Production intensive
- Net autotrophic ($GPP > R$)
- High carbon export/sequestration
- Rare and stochastic

Karl 2007

Nature Reviews | **Microbiology**

Vol. 332: 63–75, 2007

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published March 5

OPEN
ACCESS

Metabolic response of oligotrophic plankton communities to deep water nutrient enrichment

Patricia M. McAndrew^{1,*}, Karin M. Björkman¹, Matthew J. Church¹, Paul J. Morris^{1,3},
Nicholas Jachowski^{1,4}, Peter J. le B. Williams², David M. Karl¹

¹Department of Oceanography, University of Hawaii, 1000 Pope Road, Honolulu, Hawaii 96822, USA

²School of Ocean Sciences, University of Wales, Bangor, Menai Bridge, Anglesey LL59 5EY, UK

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MARINE ECOLOGY PROGRESS SERIES
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Published July 24

OPEN
ACCESS

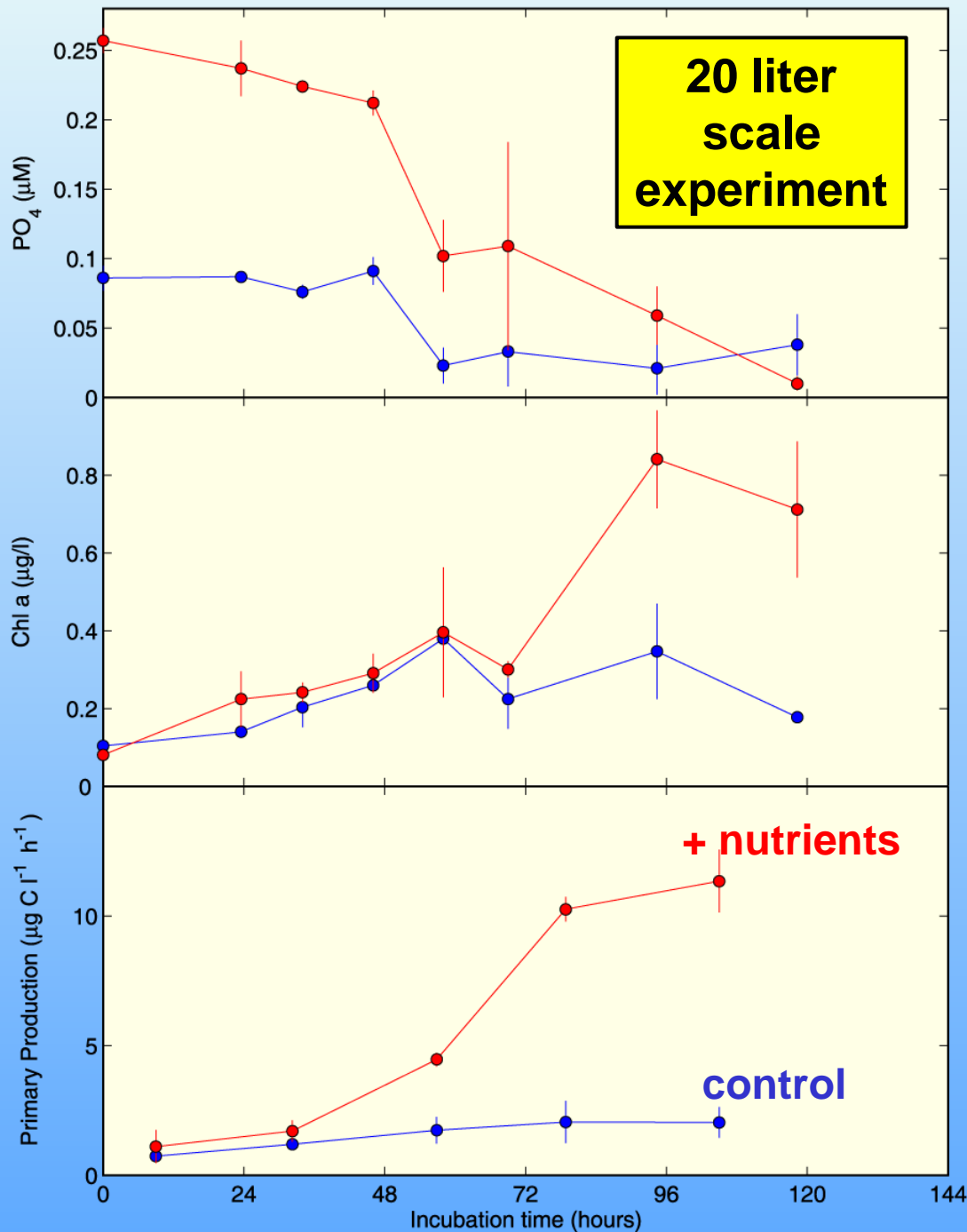
Phytoplankton response to deep seawater nutrient addition in the North Pacific Subtropical Gyre

Claire Mahaffey^{1,2,*}, Karin M. Björkman¹, David M. Karl¹

¹Department of Oceanography, SOEST, University of Hawaii, Honolulu, Hawaii 96822, USA

²Present address: School of Environmental Sciences, University of Liverpool, Liverpool L69 3GP, UK

**20 liter scale
field
experiments**



RESULTS

- Add N + P + Si + Fe + vitamins → bloom

No surprises there!

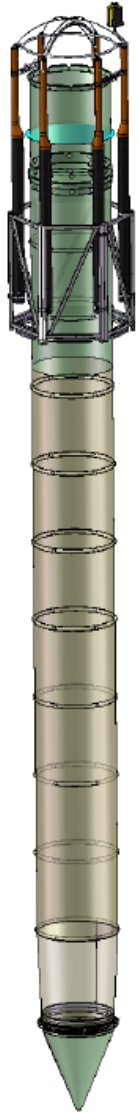
- Chl a and c increase, divinyl chl a/b do not

A “diatom” bloom!

- Eukaryotic algae outgrow their predators

Can we control the bloom?

BAG-I (Biogeochemistry And Genomes)



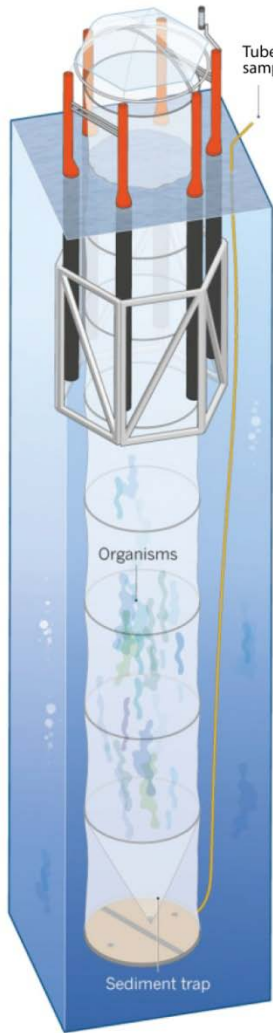
IFM-GEOMAR

Dec 2011

- 60,000 liter scale
- Experimental manipulation of nutrients
- C-MORE/BEACH-IFM collaboration

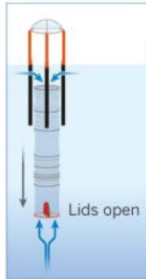


SEALAB



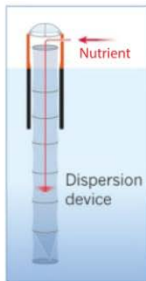
Tube used to sample sediment

Treatments



1 Filling the mesocosm.

The tube is left open at the top and bottom for two days, allowing organisms to fill the space — about the volume of a double-decker bus.

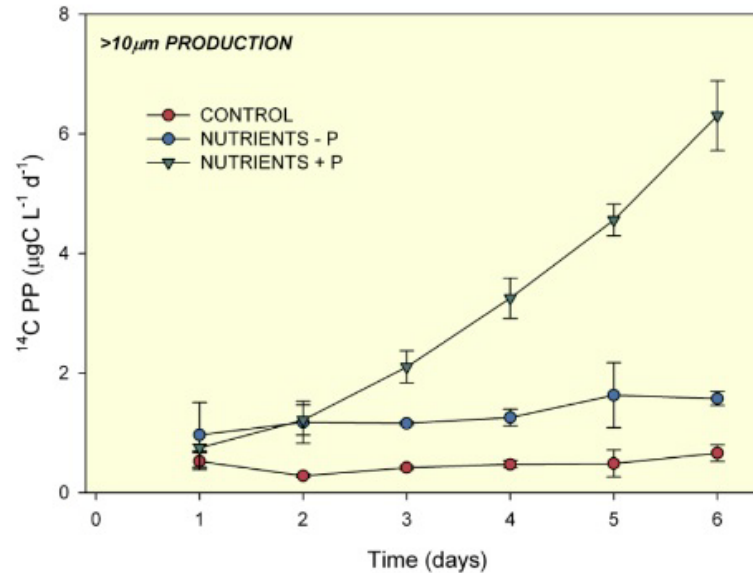
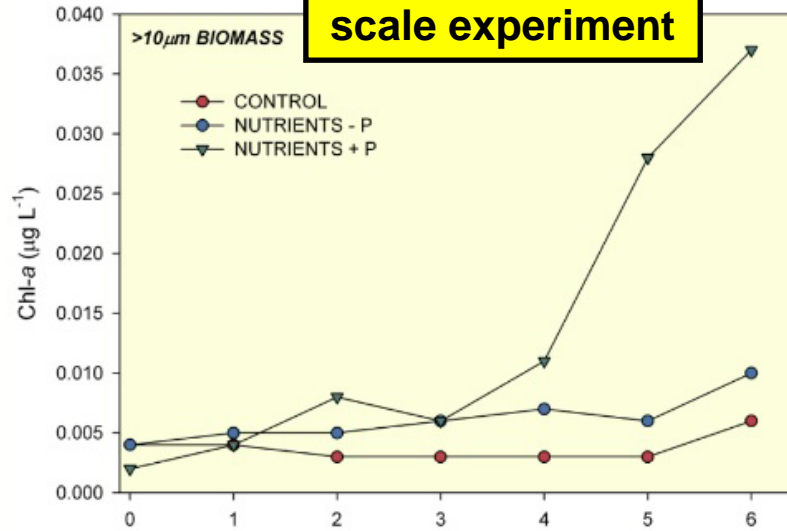


2 Nutrient injection.

The mesocosm is closed and water enriched in nutrients is added.

J. Krzysztofak, Nature 2013

60,000 liter scale experiment



Control
surface seawater only

Deep-sea Nutrients (+P)
nitrate, phosphate,
silicate, trace metals and
vitamins

Deep-sea Nutrients (-P)
nitrate, silicate, trace
metals and vitamins

Duration of experiment:
6 days

PEAK P?

Nature, 6 Oct 2011



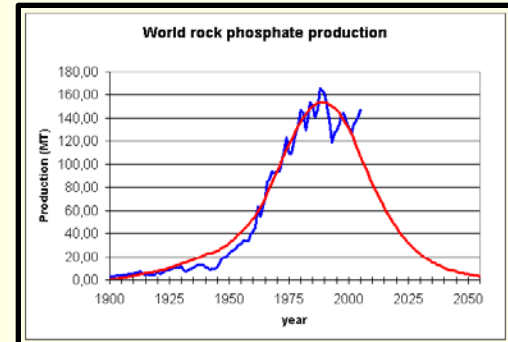
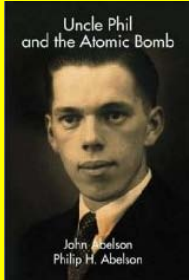
Phosphate is mined to produce fertilizers for crops, but phosphorus leaching into water supplies is an environmental hazard.

A broken biogeochemical cycle

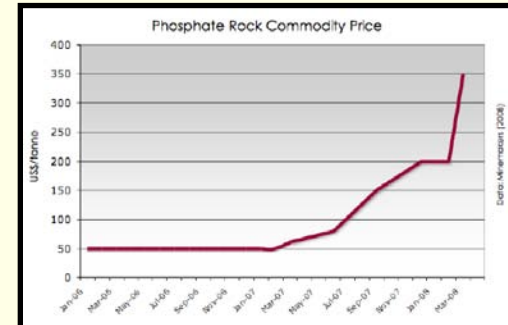
Excess phosphorus is polluting our environment while, ironically, mineable resources of this essential nutrient are limited. James Elser and Elena Bennett argue that recycling programmes are urgently needed.

Science Editorial
26 March 1999
“A Potential Phosphate Crisis”
Philip H. Abelson

Scientist extraordinaire

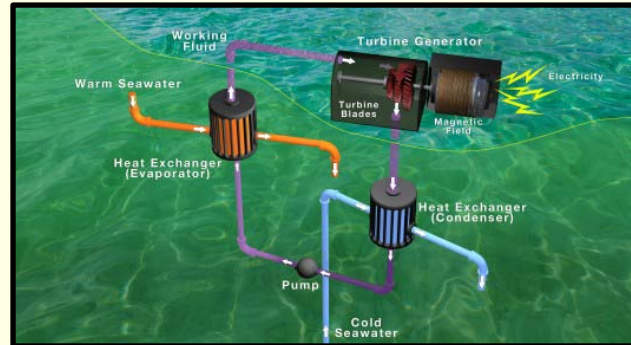
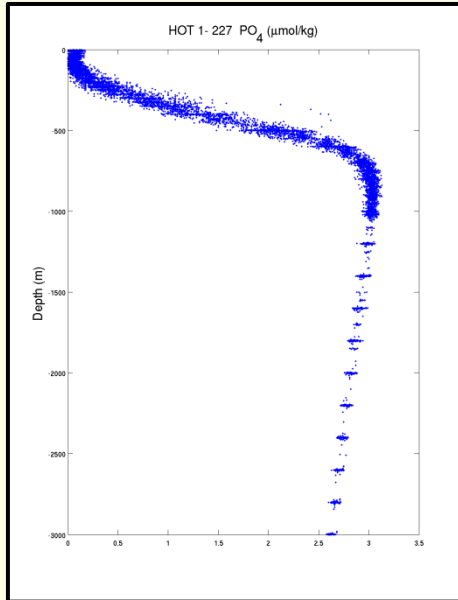


COMMODITY \$\$\$



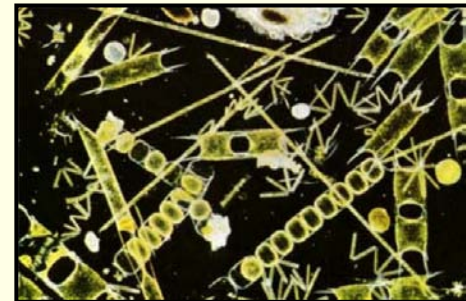
P RECOVERY FROM THE DEEP BLUE SEA?

Patent pending...



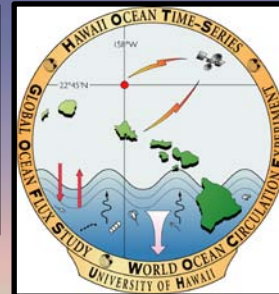
Pump deep sea
water
(SWAC/OTEC)

Remove/Recover
P by "MAGIC"



N/P discharge
leads to
phyto bloom

No P, no bloom,
*AND a possible revenue
stream to support research*



Mahalo

(Photo: Tara Clemente)