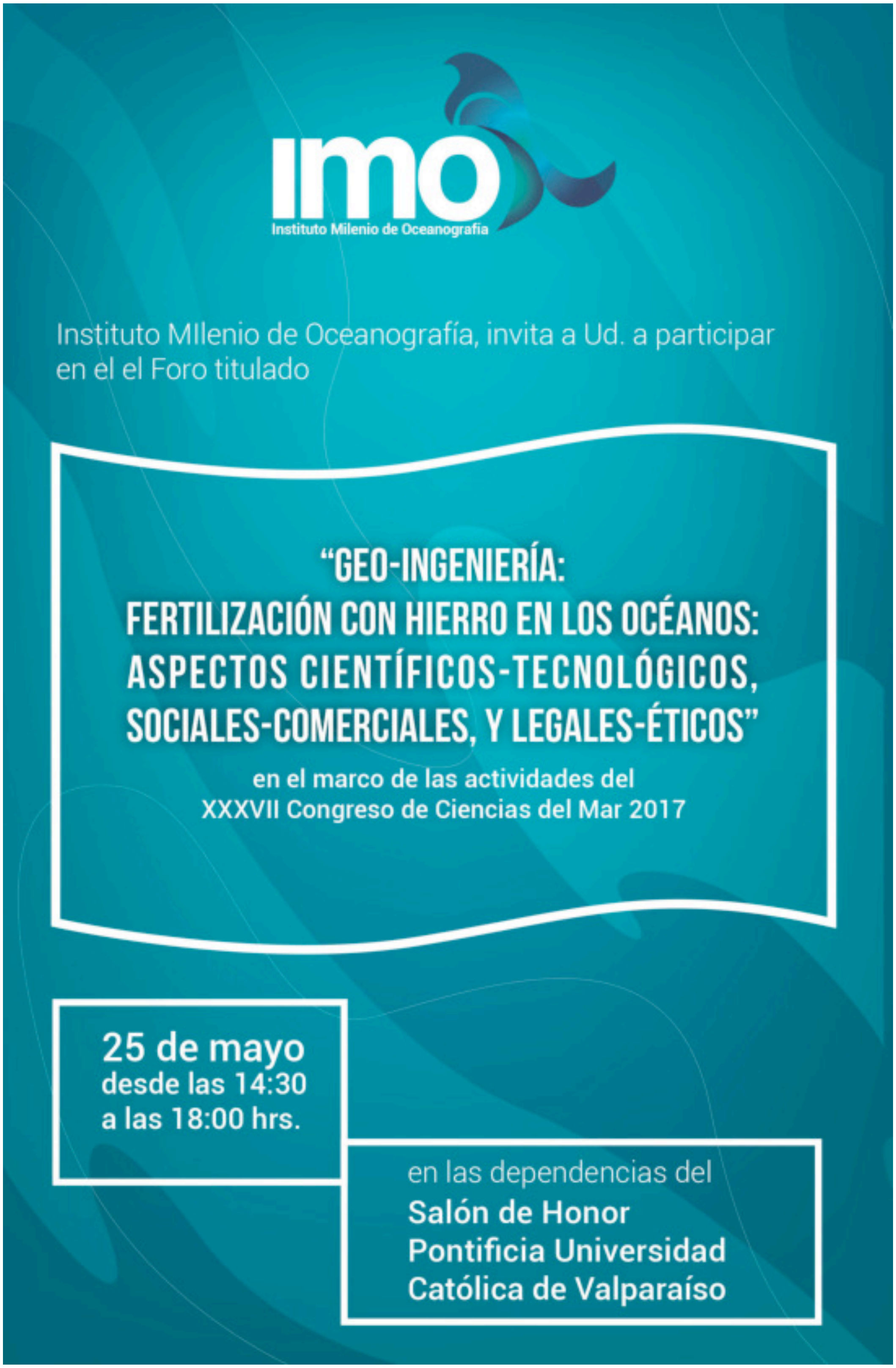
3.1. Instituto Milenio de Oceanografía (IMO): Introducción



PROGRAMA

MODERADORES Dra. Camila Fernandez - CNRS-LIA MORFUN - DOCE Universidad de Concepcion.

Dr. Bernando Broitmann (CEAZA).

14:30 - 14:50 Representante de IMO - Apertura y presentación del Foro: ¿Por qué este Foro y qué objetivos tiene?

14:55 – 17:00 Philip Boyd, Ph.D. (Institute of Marine and Antarctic Studies-University of Tasmania) Title: Fertilization of the ocean with iron in Chile?

Adrian Marchetti, Ph.D. (University of North Carolina - Chapel Hill) Title: Phytoplankton response to Iron fertilization: Ecological consequences and risks

Coffee break

Humberto González, PhD. (Director del Centro de Investigación Dinámica de Ecosistemas Marinos de Altas) Title: Iron fertilisation experiment: the Lohafex vexperience.

17:00 - 18:00 Ronda de preguntas y comentarios

"Transmitido vía streaming en www.imo-chile.cl"

Universidad de Concepción

IMO Instituto Milenio de Oceanografía

Iniciativa Científica Milenio

GEO-INGENIERÍA: FERTILIZACIÓN CON HIERRO EN LOS OCÉANOS

ASPECTOS CIENTÍFICOS-TECNOLÓGICOS, SOCIALES-ECONOMICOS Y LEGALES-ÉTICOS

PONTIFICIA UNIVERSIDAD CATOLICA DE VALPARAISO

GEO-INGENIERÍA

Acciones deliberadas sobre el sistema climático de la Tierra que potencialmente pueden moderar el aumento del calentamiento global, asociado a cambios climáticos antropogénicos:

- Remoción de CO_2 en la atmósfera por medios químicos o biológicos (reducir el forzamiento del cambio climático global)
- Reflejar parte de la energía solar fuera de la Tierra (contrarrestar el forzamiento del cambio climático alterando el balance radiativo de la Tierra)

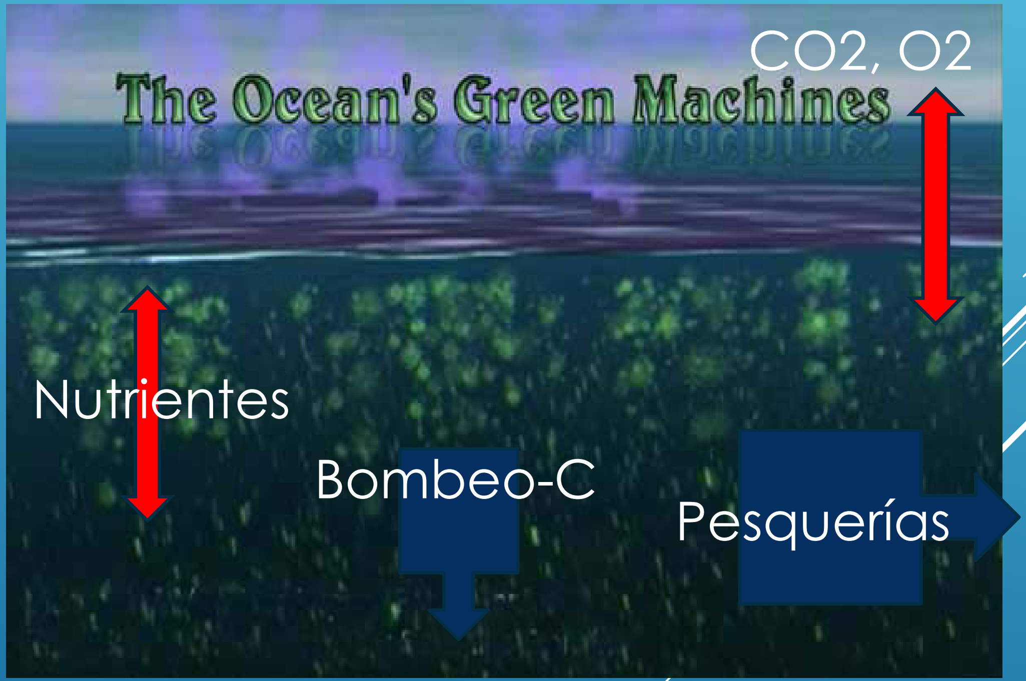
GEO-INGENIERÍA MARINA

SEGÚN PROTOCOLO DE LONDRES:

INCREMENTAR LA PRODUCCIÓN PRIMARIA Y SU EVENTUAL EXPORTACIÓN A TRAVÉS DE:

- → BOMBEO BIOLÓGICO
- → PESQUERÍAS
- → OTROS

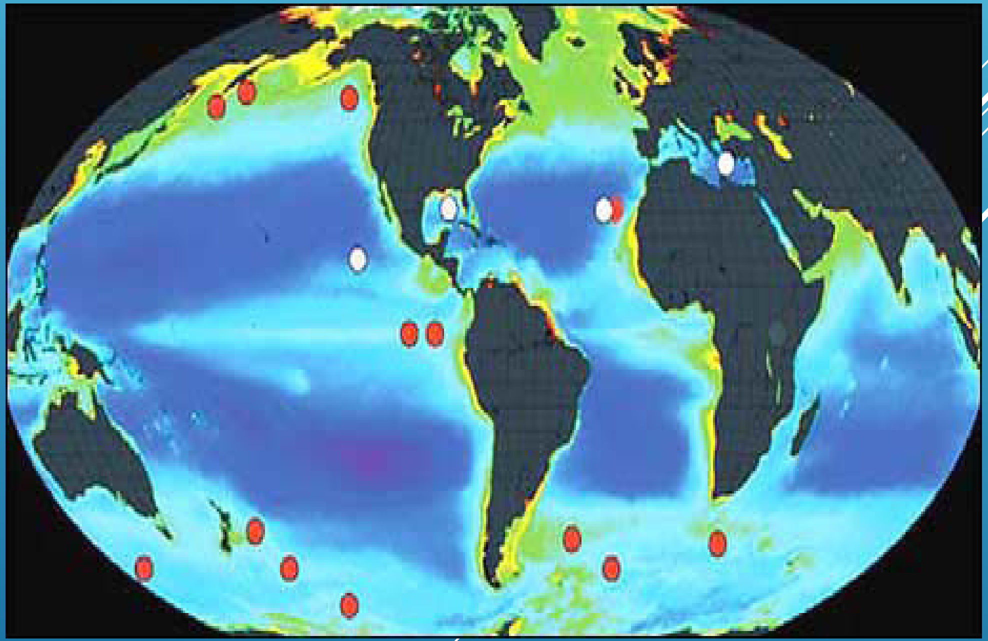
ACCIÓN: ADICIÓN DE NUTRIENTES PARA ESTIMULAR LA PRODUCCIÓN PRIMARIA POR FITOPLANCTON EN CAPAS SUPERFICIALES



FERTILIZACIÓN DE LOS OCÉANOS

Acción deliberada para aumentar la producción primaria en los océanos, a cualquier escala y propósito, que involucre la adición directa o indirecta de nutrientes u otros medios potenciales (IOC-UNESCO, Wallace et al., 2010)

- Técnica de remoción de CO2 más analizada: Fertilización con hierro (Fe) en grandes zonas de los océanos donde este elemento es limitante para la producción primaria
- VARIOS EXPERIMENTOS CIENTIFICOS
- DIVERSOS RESULTADOS ECOLÓGICOS
- DIVERSOS PROBLEMAS/RIESGOS ASOCIADOS
- GENERACION DE INTERESES COMERCIALES
- SURGIMIENTO DE NECESIDADES INTERNACIONALES DE REGULACIÓN
  - CONVENIO DE BIODIVERSIDAD
  - PROTOCOLO DE LONDRES-ENMIENDAS 2006- 2013

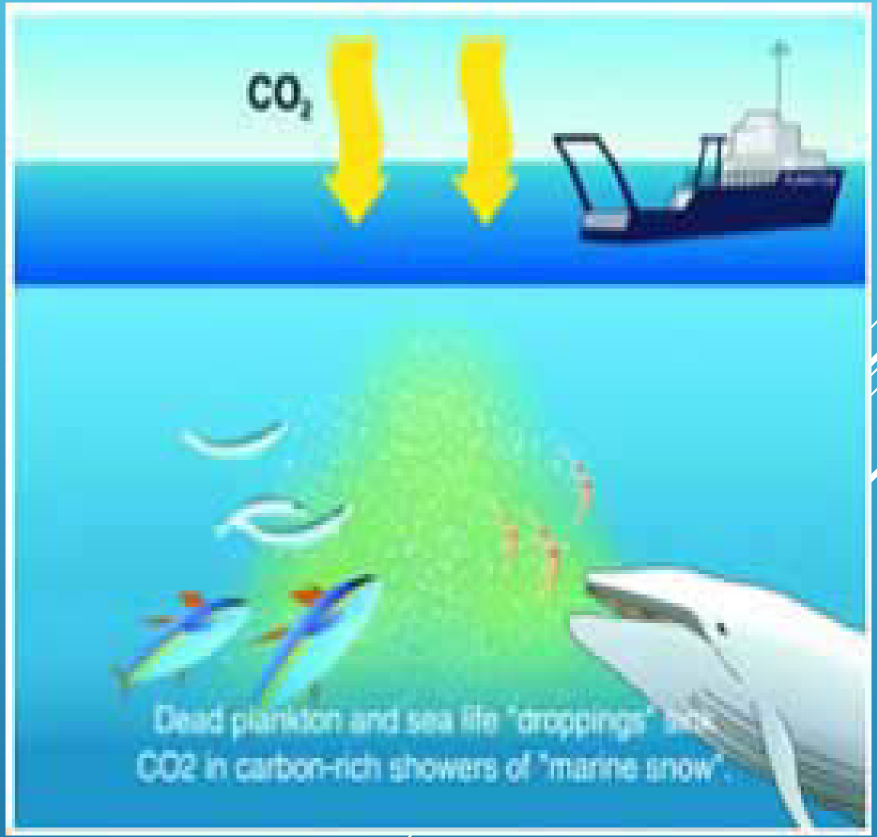


FERTILIZACIÓN DE LOS OCÉANOS

Aspectos científico-tecnológicos:
Incertezas sobre los resultados de la acción dada la dependencia de éstos en el tipo de fitoplancton presente, dinámica trófica, dinámica oceanográfica, ecología de las especies de peces-foco.

Aspectos sociales-economicos:
Intereses sociales y comerciales por aumentar la producción primaria y con ello la pesquera y/o disminuir los aumentos de CO2.

Aspectos legales-éticos:
Regulaciones nacionales/internacionales por contaminación; alcances de los resultados positivos/negativos de la acción.



PROYECTO FERTILIZACIÓN CON HIERRO EN CHILE

EMPRESA/FUNDACIÓN CANADIENSE: OCEANEOS

→ **INCREMENTAR PRODUCCIÓN PRIMARIA Y EVENTUAL AUMENTO DE PECES** (EG ANCHOVETA, JUREL)
→ **ADICIÓN DE HIERRO** PARA ESTIMULAR LA PRODUCCIÓN PRIMARIA POR FITOPLANCTON EN CAPAS SUPERFICIALES – "SEMBRAR EL MAR"
→ **LUGAR: ZONA FRENTE A COQUIMBO** (30°S), ALREDEDOR DE 100 KM DE LA COSTA
→ **PROMOCIÓN DEL "EXPERIMENTO/IDEA", CORFO (START-UP)** Y SOCIALIZACIÓN CON PESCADORES, AUTORIDADES Y EMPRESARIOS
→ **DISEÑO Y PROTOCOLOS: DESCONOCIDOS**
→ **METODOS UTILIZADOS EN EVALUACIÓN DE RESULTADOS: DESCONOCIDOS**
→ **DECLARACION DE IMPACTOS ECOLOGICOS ASOCIADOS: NINGUNO**

NO EXISTEN ANTECEDENTES CIENTÍFICOS PUBLICADOS QUE VINCULEN DIRECTAMENTE EL INCREMENTO ARTIFICIAL DE LA PRODUCCIÓN PRIMARIA Y EL AUMENTO EN LA PRODUCCIÓN DE PECES.

CHILE BAJO LA MIRADA INTERNACIONAL

NATURE | NEWS

Iron-dumping ocean experiment sparks controversy

Canadian foundation says its field research could boost fisheries in Chile, but researchers doubt its motives.

Jeff Tollefson

23 May 2017

OBJETIVOS DEL FORO

Informar sobre iniciativas de geo-ingeniería marina en Chile: autoridades, políticos, ONGs, y comunidad científica en general

Conocer en detalle la propuesta de OCEANEOS E.S. sobre fertilización con hierro frente a Coquimbo

Discutir las alcances de un experimento de esta naturaleza: científico-tecnológicos, sociales-comerciales y legales-éticos

ACCIONES: FORO 1

PROGRAMA

MODERADORES	Dra. Camila Fernández (CNRS-LIA MORFUN - DOCE Universidad de Concepción). Dr. Bernando Broitmann (CEAZA).
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14:55 – 17:00	Philip Boyd, Ph.D. (Institute of Marine and Antarctic Studies- University of Tasmania) Title: Ocean iron enrichments – principles, benefits and challenges. Adrian Marchetti, Ph.D. (University of North Carolina - Chapel Hill) Title: Phytoplankton response to Iron fertilization: Ecological consequences and risks Coffee break Humberto González, PhD. (Director del Centro de Investigación Dinámica de Ecosistemas Marinos de Altas) Title: Iron fertilization experiment: the Lohafex experience.
17:00 - 18:00	Ronda de preguntas y comentarios

"Transmitido via streaming en www.imo-chile.cl"

ORGANIZACIÓN DE FORO:

SCHCM COMO SENO DE DISCUSIONES RELEVANTES AL PAÍS

INVITACIÓN A EMPRESA/FUNDACION OCEANEOS – PROPUESTA DE PROYECTO DE GEO-INGENIERÍA EN CHILE: DECLINADO CON AMENAZA LEGAL

INVITACIÓN A 3 CIENTIFICOS EXPERTOS EN EL TEMA – ESTADOD EL ARTE: DRS P. BOYD, A. MARCHETTI, H. GONZALEZ

INVITACION A SECTORES PÚBLICOS Y ONGs RELEVANTES AL TEMA

RESULTADOS ESPERADOS DEL FORO

Pronunciamiento de la comunidad científica sobre experimentos de esta naturaleza

Solicitud formal de instituciones/organizaciones del área al Estado de Chile para que ratifique el Protocolo de Londres en su enmienda de 2013

Promover una adecuada coordinación entre instituciones públicas y las instituciones de investigación sobre acciones de geo-ingeniería marina y otras intervenciones en los ecosistemas.

3.2. Dr. Phil Boyd : Ocean Iron enrichments- principles, benefits and challenges

Ocean iron enrichments – principles, benefits and challenges

Philip Boyd

IMAS INSTITUTE FOR MARINE AND ANTARCTIC STUDIES

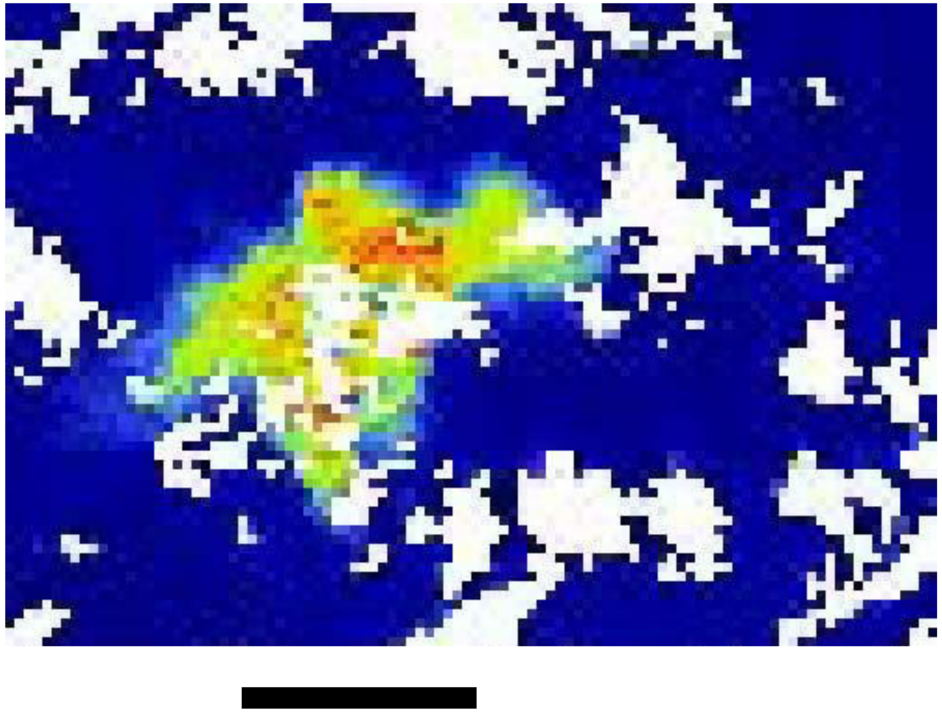
UTAS

translating**nature**into**knowledge**

May 2017

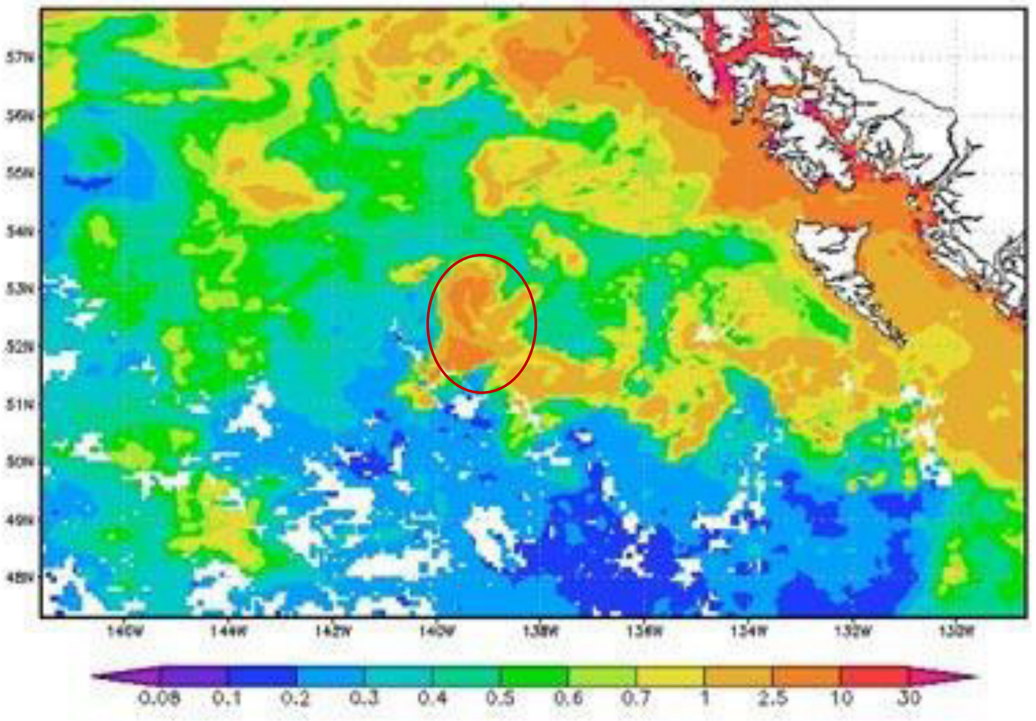
Two large scale ocean iron-enrichments in the Gulf of Alaska

July 2002



100 km

August 2012



WHY ARE THEY DIFFERENT?

OUTLINE

Principles

<u>The Science </u>- Why iron?
Low chlorophyll in high nutrient waters?
A little goes a long way

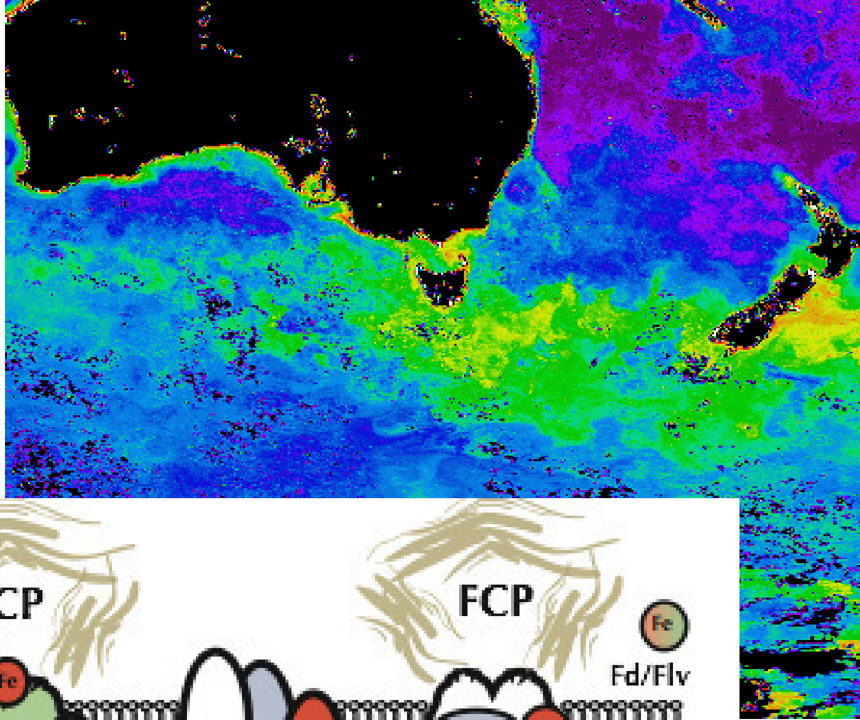
<u>The Research </u>
Gradualism – lab pilot studies to open ocean studies
Public Record – the scientific literature
Transparency - Interpretation & synthesis

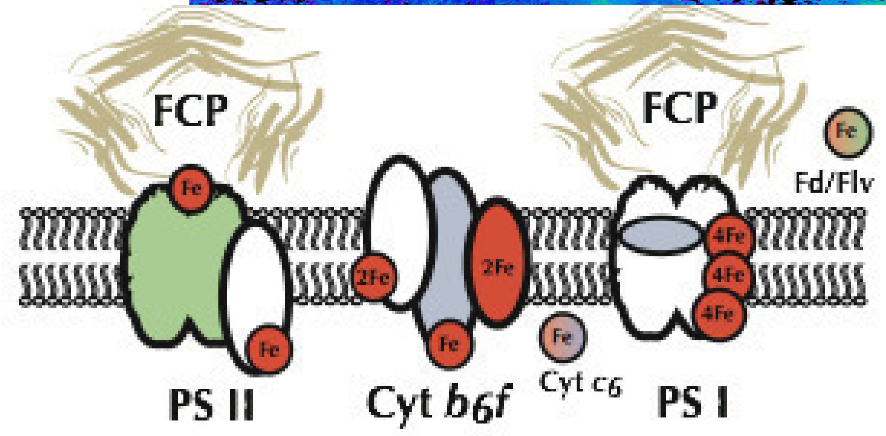
Benefits

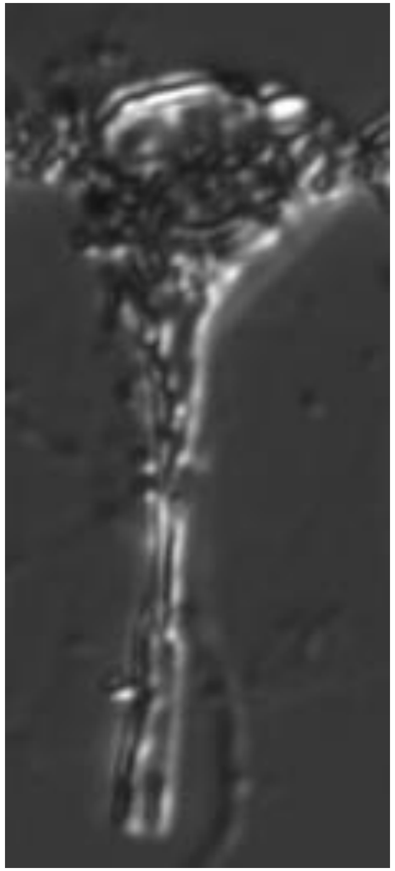
Understanding how iron regulates many ocean processes
Detecting surprises – risk evaluation

Challenges

Using iron-enrichment commercially to modify the ocean
Demonstrating ‘additionality’
Making sense of complexity
Transparency and the public record





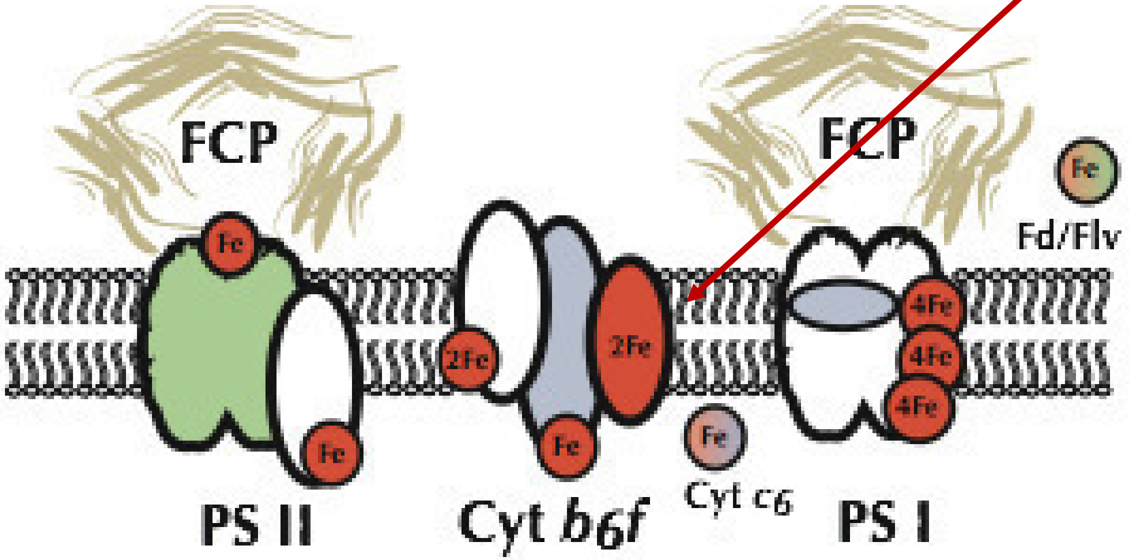


10 microns

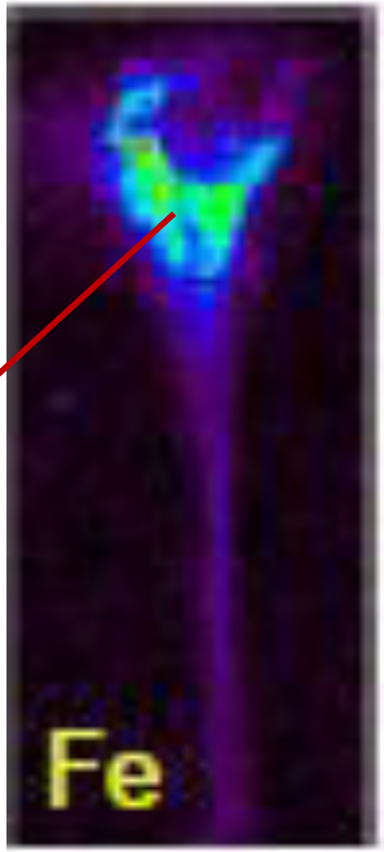
Diatom cell

WHY IRON (Fe) ?

A trace element of
pivotal importance
for phytoplankton
growth and productivity



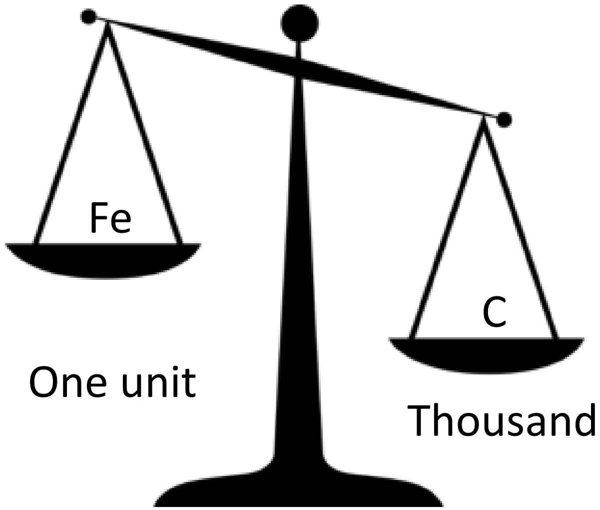
The photosynthetic apparatus – the cell's engine room



Elemental map
of the diatom cell
revealing iron in the
p/s apparatus

Images courtesy B Twining (Bigelow)

Low chlorophyll in high nutrient waters?



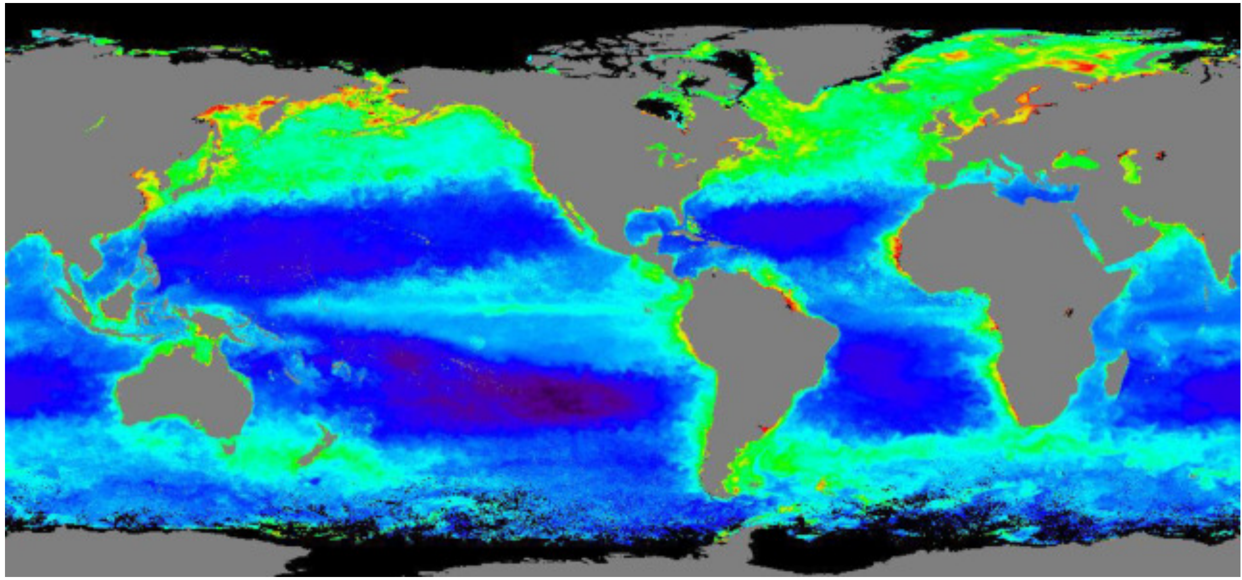
One unit

Thousands

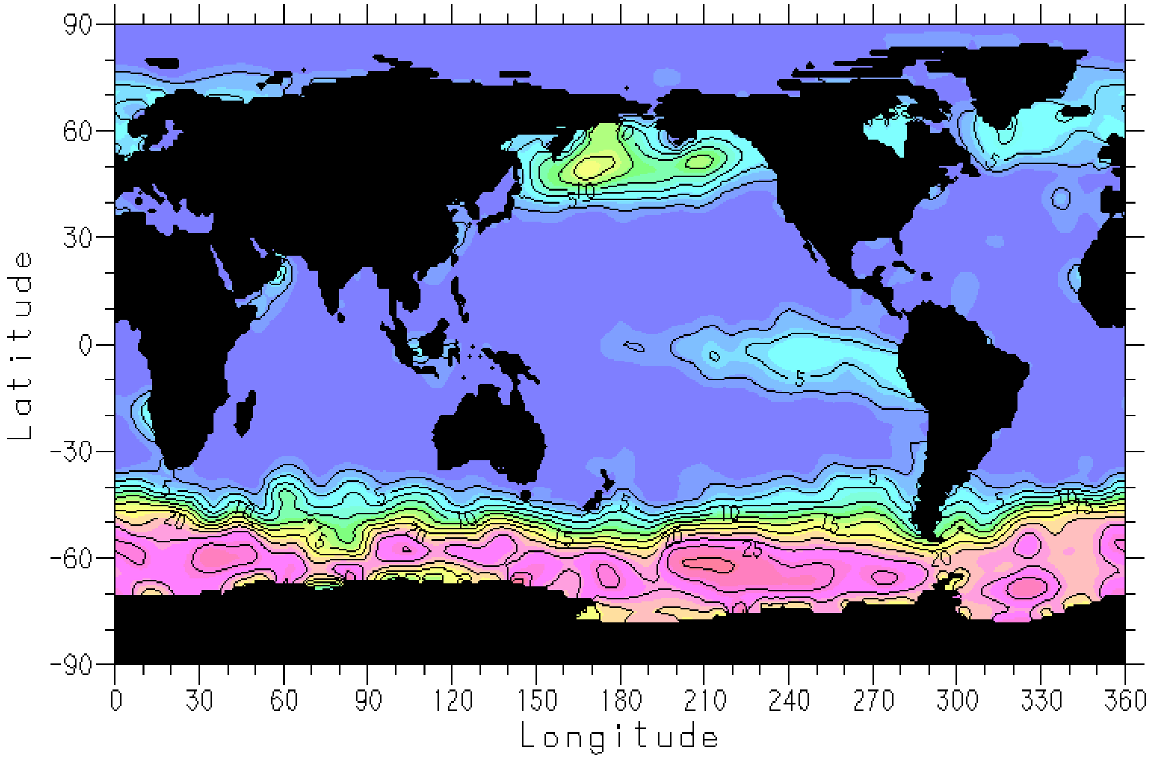
As it is a trace element
a little goes a long way

Very efficient at boosting
Primary productivity

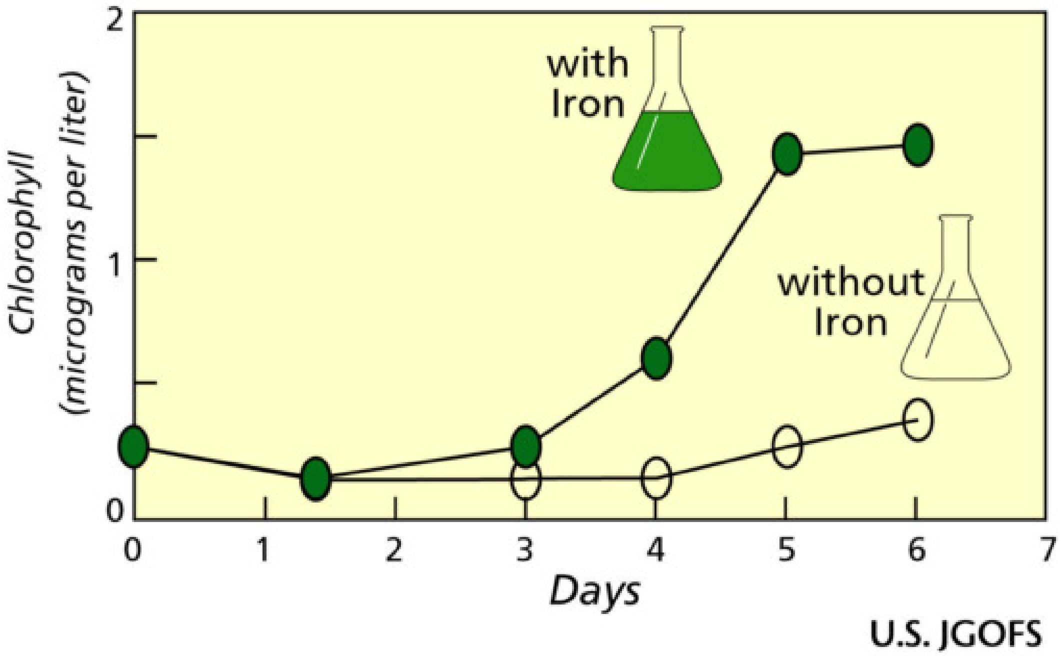
Chlorophyll

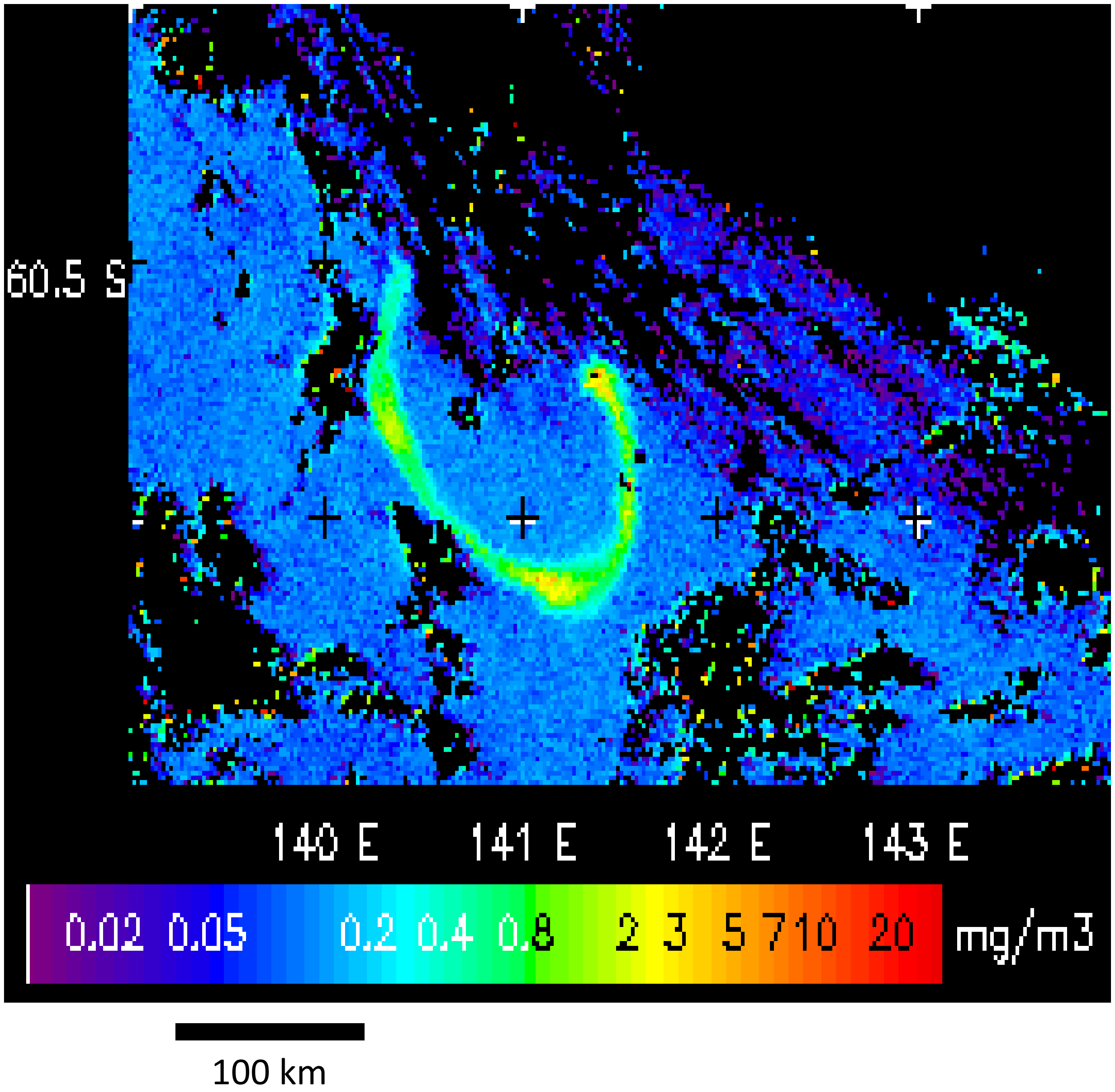


Nitrate



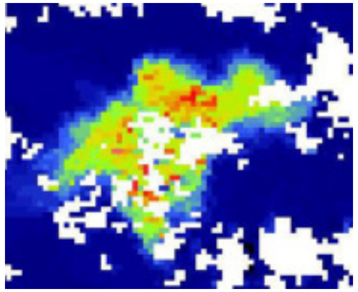
WE NOW KNOW THAT ADDING IRON TO ANAEMIC PHYTOPLANKTON BOOSTS THEIR GROWTH AND THEY BLOOM





BUT IT TOOK YEARS OF CAREFUL INTERNATIONAL RESEARCH TO CONFIRM THIS!!!

A Gradualist approach to iron enrichment research

Lab – contained	Field - contained	Field - uncontained
		

Iron deficiency limits phytoplankton growth in the north-east Pacific subarctic

John H. Martin & Steve E. Fitzwater

Moss Landing Marine Laboratories, Moss Landing, California 95039, USA

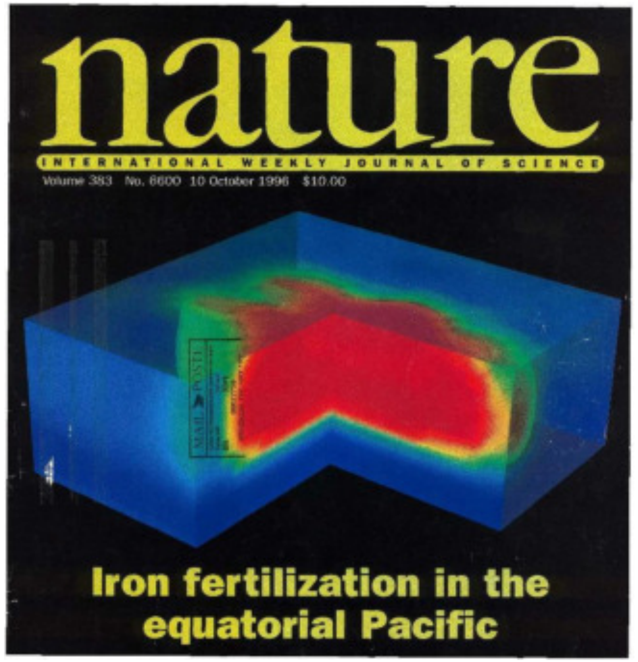
An interesting oceanographic problem concerns the excess major plant nutrients (PO_4, NO_3, SiO_3) occurring in offshore surface waters of the Antarctic[1–3] and north-east Pacific subarctic Oceans[4]. In a previous study[5], we presented indirect evidence suggesting that inadequate Fe input was responsible for this limitation of growth; recently we had the opportunity to seek direct evidence for this hypothesis in the north-east Pacific subarctic. We report here that the addition of nmol amounts of dissolved iron resulted in the nearly complete utilization of excess NO_3, whereas in the controls—without added Fe—only 25% of the available NO_3 was used. We also observed that the amounts of chlorophyll in the phytoplankton increased in proportion to the Fe added. We conclude that Fe deficiency is limiting phytoplankton growth in these major-nutrient-rich waters.

1988

Change in the concentrations of iron in different size fractions during a phytoplankton bloom in controlled ecosystem enclosures

Jun Nishioka[a,*], Shigenobu Takeda[a], C.S. Wong[b]

1996



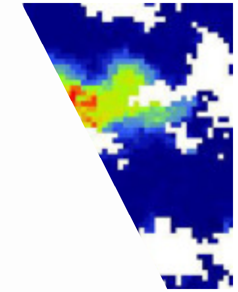
1996 to 2008

The power of the public record – the scientific literature on iron enrichments

Lab – contained

Field - contained

uncontained



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Mesoscale Iron Enrichment Experiments 1993–2005: Synthesis and Future Directions

P. W. Boyd,[1*] T. Jickells,[2] C. S. Law,[3] S. Blain,[4] E. A. Boyle,[5] K. O. Buesseler,[6] K. H. Coale,[7] J. J. Cullen,[8] H. J. W. de Baar,[9] M. Follows,[5] M. Harvey,[3] C. Lancelot,[10] M. Levasseur,[11] N. P. J. Owens,[12] R. Pollard,[13] R. B. Rivkin,[14] J. Sarmiento,[15] V. Schoemann,[10] V. Smetacek,[16] S. Takeda,[17] A. Tsuda,[18] S. Turner,[2] A. J. Watson[2]

2 FEBRUARY 2007 VOL 315 SCIENCE www.sciencemag.org

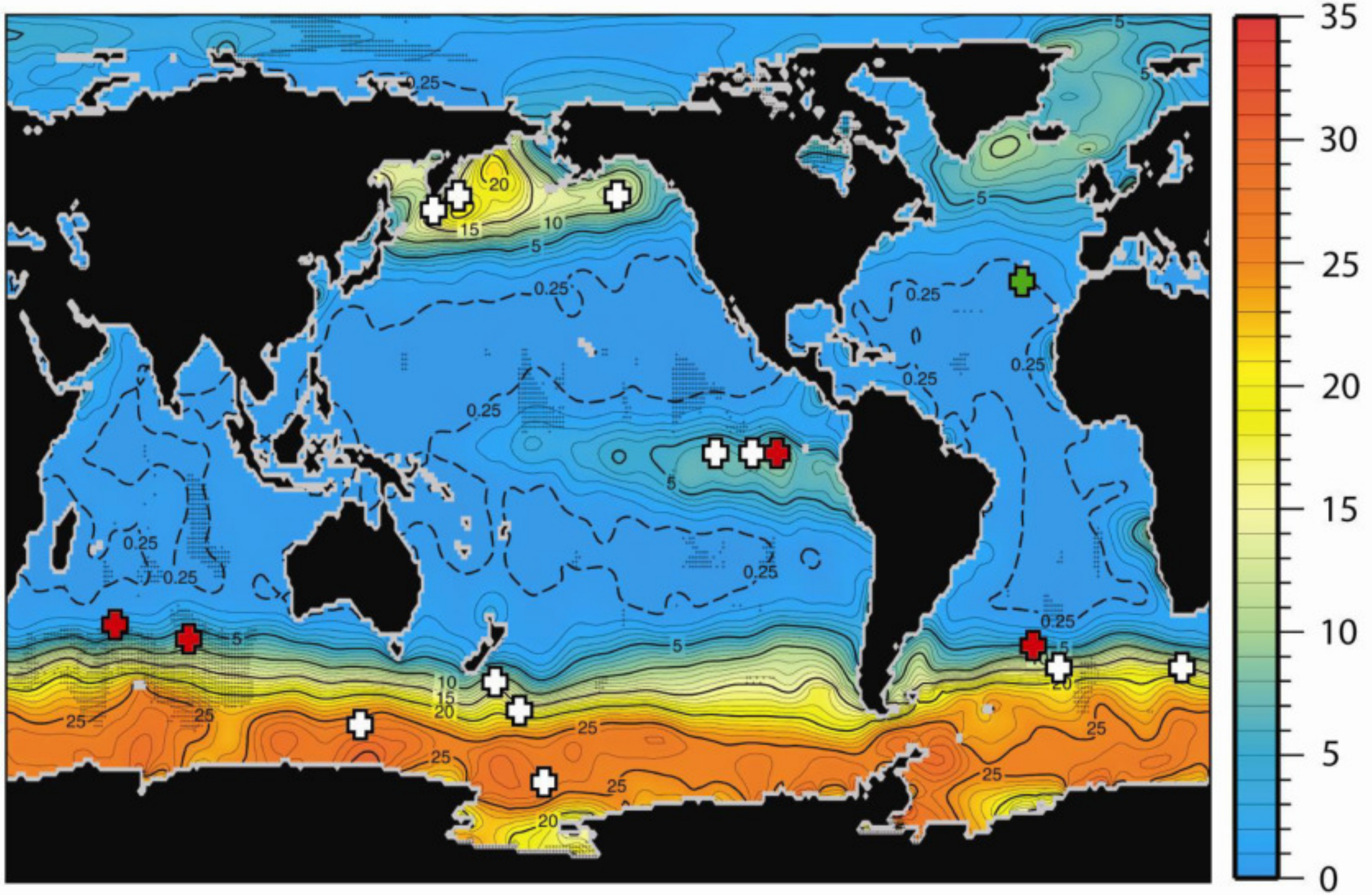
1988 | 1996 | 1996 to 2008

Mesoscale Iron Enrichment Experiments 1993–2005: Synthesis and Future Directions

A transparent debate permitted synthesis of 12 years of scientific literature – learning from both successes and failures

P. W. Boyd,[1*] T. Jickells,[2] C. S. Law,[3] S. Blain,[4] E. A. Boyle,[5] K. O. Buesseler,[6] K. H. Coale,[7] J. J. Cullen,[8] H. J. W. de Baar,[9] M. Follows,[5] M. Harvey,[3] C. Lancelot,[10] M. Levasseur,[11] N. P. J. Owens,[12] R. Pollard,[13] R. B. Rivkin,[14] J. Sarmiento,[15] V. Schoemann,[10] V. Smetacek,[16] S. Takeda,[17] A. Tsuda,[18] S. Turner,[2] A. J. Watson[2]

2 FEBRUARY 2007 VOL 315 SCIENCE www.sciencemag.org

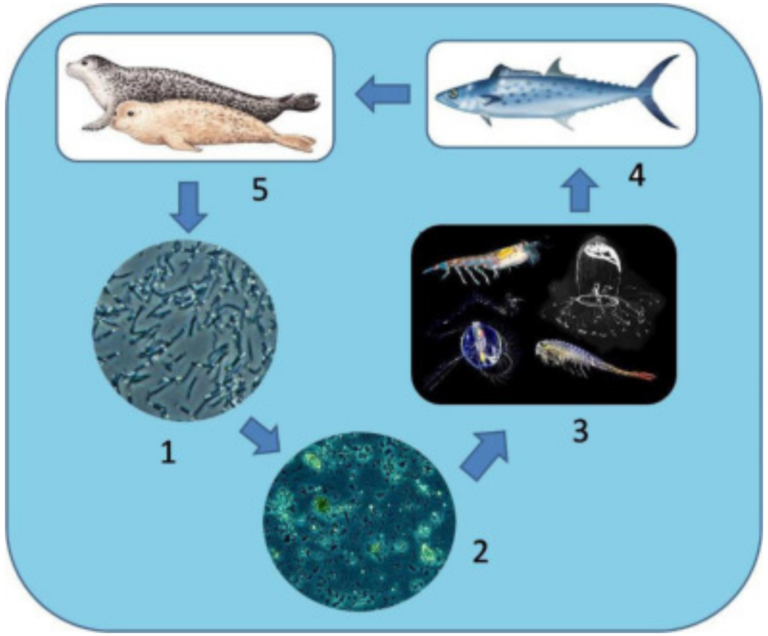


Benefits

Understanding how iron regulates many ocean processes

- **DIRECT**
- **Photosynthesis**
- **Growth rate, productivity**
- **Nutrient uptake ratios (Si:N)**
- **Altered species composition**
- **DOC release**
- **Bacterial processes**
- **Biogenic gas production**
- **Grazer physiology**

- ***INDIRECT***
- ***C, N, Si, & S biogeochemistry***
- ***Particle export flux***
- ***Foodweb structure***
- ***Zooplankton growth & reproduction***
- ***Altered micro-grazer communities***



http://www.seos-project.eu

Such in-depth understanding is essential to discover surprises

Are mesoscale perturbation experiments in polar waters prone to physical artefacts? Evidence from algal aggregation modelling studies

Philip W. Boyd,[1] George A. Jackson,[2] and Anya M. Waite[3]

Iron enrichment stimulates toxic diatom production in high-nitrate, low-chlorophyll areas

Charles G. Trick[a,1], Brian D. Bill[b,c], William P. Cochlan[b], Mark L. Wells[d], Vera L. Trainer[c], and Lisa D. Pickell[d]

Efficiency of carbon removal per added iron in ocean iron fertilization

Hein J. W. de Baar[1,2,*], Loes J. A. Gerringa[2], Patrick Laan[2], Klaas R. Timmermans[2]

Predicting and monitoring the effects of large-scale ocean iron fertilization on marine trace gas emissions

C. S. Law*

Predicting and verifying the intended and unintended consequences of large-scale ocean iron fertilization

John J. Cullen[1,*], Philip W. Boyd[2]

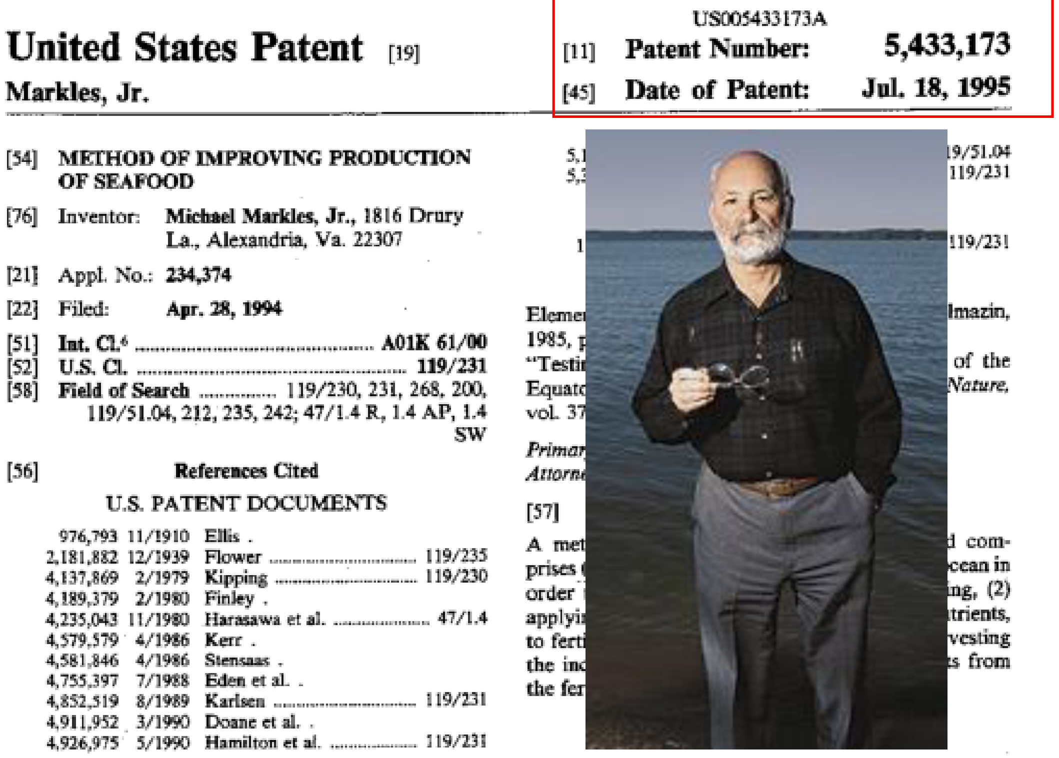
Challenges

Using iron-enrichment commercially to modify the ocean

Plans for commercial fertilization of the ocean were quickly developed

- Patent for fertilization with iron chelate

- May include seeding surface layers with other nutrients, microorganisms, and fish



US005433173A

United States Patent [19]

Markles, Jr.

[11] **Patent Number: 5,433,173**

[45] **Date of Patent: Jul. 18, 1995**

[54] METHOD OF IMPROVING PRODUCTION OF SEAFOOD

[76] Inventor: Michael Markles, Jr., 1816 Drury La., Alexandria, Va. 22307

[21] Appl. No.: 234,374

[22] Filed: Apr. 28, 1994

[51] Int. Cl.[6] A01K 61/00

[52] U.S. Cl. 119/231

[58] Field of Search .... 119/230, 231, 268, 200, 119/51.04, 212, 235, 242; 47/1.4 R, 1.4 AP, 1.4 SW

[56] References Cited

U.S. PATENT DOCUMENTS

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4,579,579	4/1986	Kerr .	
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4,755,397	7/1988	Eden et al. .	
4,852,519	8/1989	Karlsen	119/231
4,911,952	3/1990	Doane et al. .	
4,926,975	5/1990	Hamilton et al.	119/231

Michael Markels, Jr.

Slide courtesy John Cullen

CLIMOS

BRIEFING ON OCEAN IRON FERTILISATION AS A CLIMATE CHANGE MITIGATION TECHNIQUE AND THE POTENTIAL ROLE OF NEW ZEALAND

Thursday, 17 July, 2008, 12:00-2:00 PM

at the Institute of Policy Studies (IPS)
Victoria University of Wellington

There has recently been an increase in interest in large-scale ocean iron fertilisation (OIF) as a tool for sequestering significant amounts of carbon dioxide from the atmosphere. Climos will be hosting a lunch and informational session on this technique and their investigation for its potential use.

Climos is a company (www.climos.com) dedicated to removing carbon from the atmosphere. Founded by entrepreneurs Dan Whaley and Richard Whilden, Climos scientific research is overseen by Dr Margaret Leinen, former Director of Geosciences at the US National Science Foundation (NSF). Climos is guided by a Scientific Advisory Board that includes some of the world's experts in ocean, earth and climate science.

The briefing will provide a factual overview of the history, rationale and scientific background of OIF. The session will feature a presentation from Climos representatives on their proposal to carry out a larger scale scientific OIF programme in international waters.

Dr Philip Boyd, scientist of NIWA, who is not affiliated with Climos, will share his experience as one of the most well known scientists involved in the research and development of this technique in New Zealand, including as the Principal Investigator of the Southern Ocean Iron Release Experiment Expedition (SOIREE) in 1999 which was funded by NIWA and included an international team of ocean and atmostpheric scientists.

Murray Ward, Principal, Global Climate Change Consultancy and Senior Associate at IPS, will open the discussion with a short context-setting presentation on the climate change mitigation challenge facing the global community.

Moving beyond the science

Vol. 364: 213–218, 2008
doi: 10.3354/meps07541

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published July 29

THEME SECTION

OPEN ACCESS

Implications of large-scale iron fertilization of the oceans

Idea: Howard Browman, Philip W. Boyd
Coordination: Philip W. Boyd

CONTENTS

DEVELOPMENT OF LEGISLATION AND OF SCIENTIFIC CONSENSUS

editorial

NATURE 2008

The Law of the Sea

In 2008 ocean iron fertilization was regulated under two sets of international legislation. However, unclear definitions have led to the suspension of legitimate research.

POLICYFORUM

ENVIRONMENT

11 JANUARY 2008 VOL 319 SCIENCE

Ocean Iron Fertilization—Moving Forward in a Sea of Uncertainty

Ken O. Buesseler,[1*] Scott C. Doney,[1] David M. Karl,[2] Philip W. Boyd,[3] Ken Caldeira,[4] Fei Chai,[5] Kenneth H. Coale,[6] Hein J. W. de Baar,[7] Paul G. Falkowski,[8] Kenneth S. Johnson,[9] Richard S. Lampitt,[10] Anthony F. Michaels,[11] S. W. A. Naqvi,[12] Victor Smetacek,[13] Shigenobu Takeda,[14] Andrew J. Watson[15]

THE CONSENSUS VIEW IS

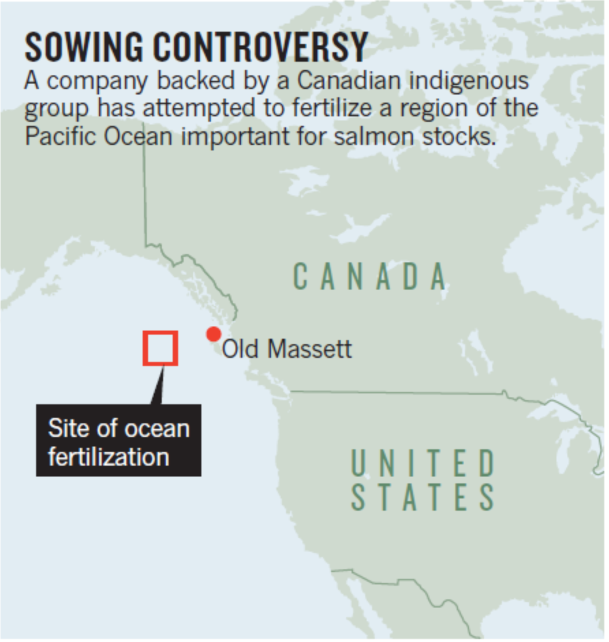
‘It is premature to sell C offsets from ocean iron fertilization

unless research provides the scientific foundation to evaluate

risks & benefits’

2012

Workers on a Haida Salmon Restoration Corporation boat release iron sulphate into the Pacific Ocean.



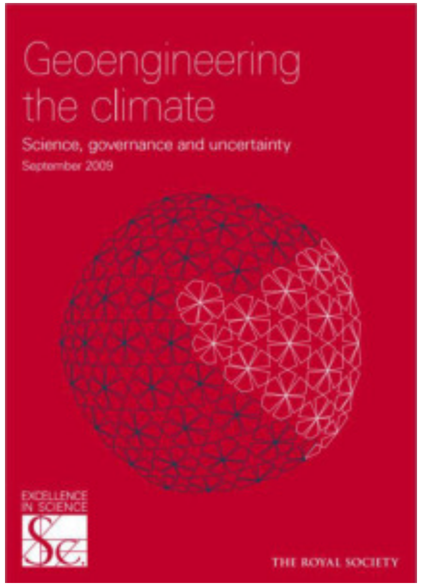
GEOENGINEERING

Ocean-fertilization project off Canada sparks furore

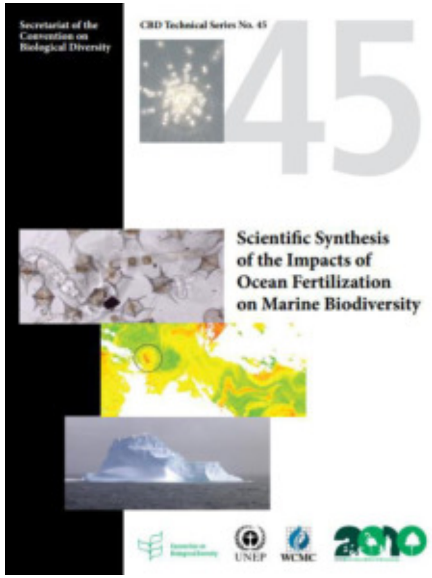
Bid to boost salmon stocks relied on hotly debated science and dubious carbon credits.

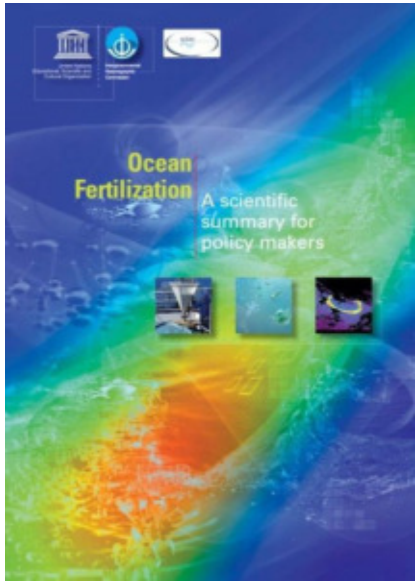
National and international synthesis of benefits and risks of geoengineering

<u>A rich freely-available resource for companies to learn from</u>

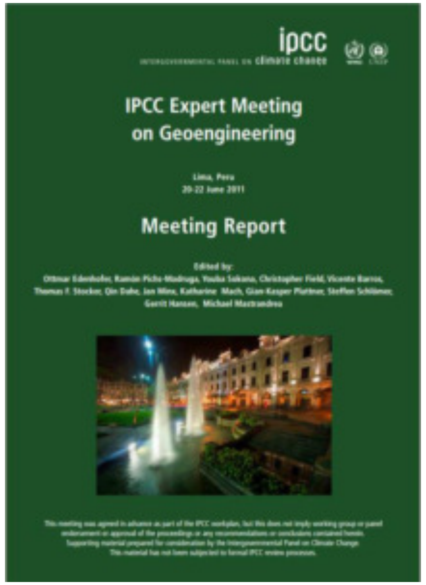


2009

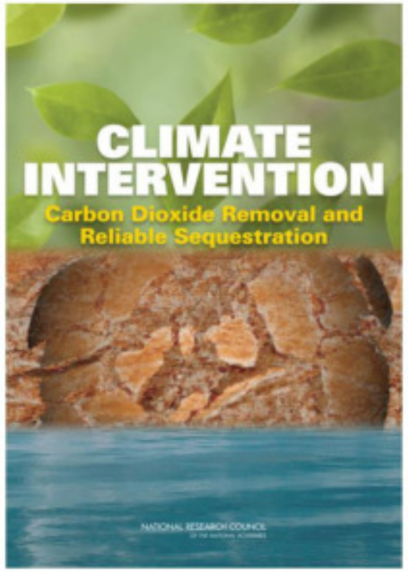




2010



2012



2015

The need for research governance

A charter for geoengineering

A controversial field trial of technology to mitigate climate change has been cancelled, but research continues. A robust governance framework is sorely needed to prevent further setbacks.

Nature editorial 2012

"Problems will persist until geoengineers grasp the nettle of regulation and oversight."

IMO INTERNATIONAL MARITIME ORGANIZATION

E

THIRTY-FIFTH CONSULTATIVE MEETING OF CONTRACTING PARTIES TO THE LONDON CONVENTION
&
EIGHTH MEETING OF CONTRACTING PARTIES TO THE LONDON PROTOCOL
14 – 18 October 2013
Agenda item 4

LC 35/WP.3
17 October 2013
Original: ENGLISH

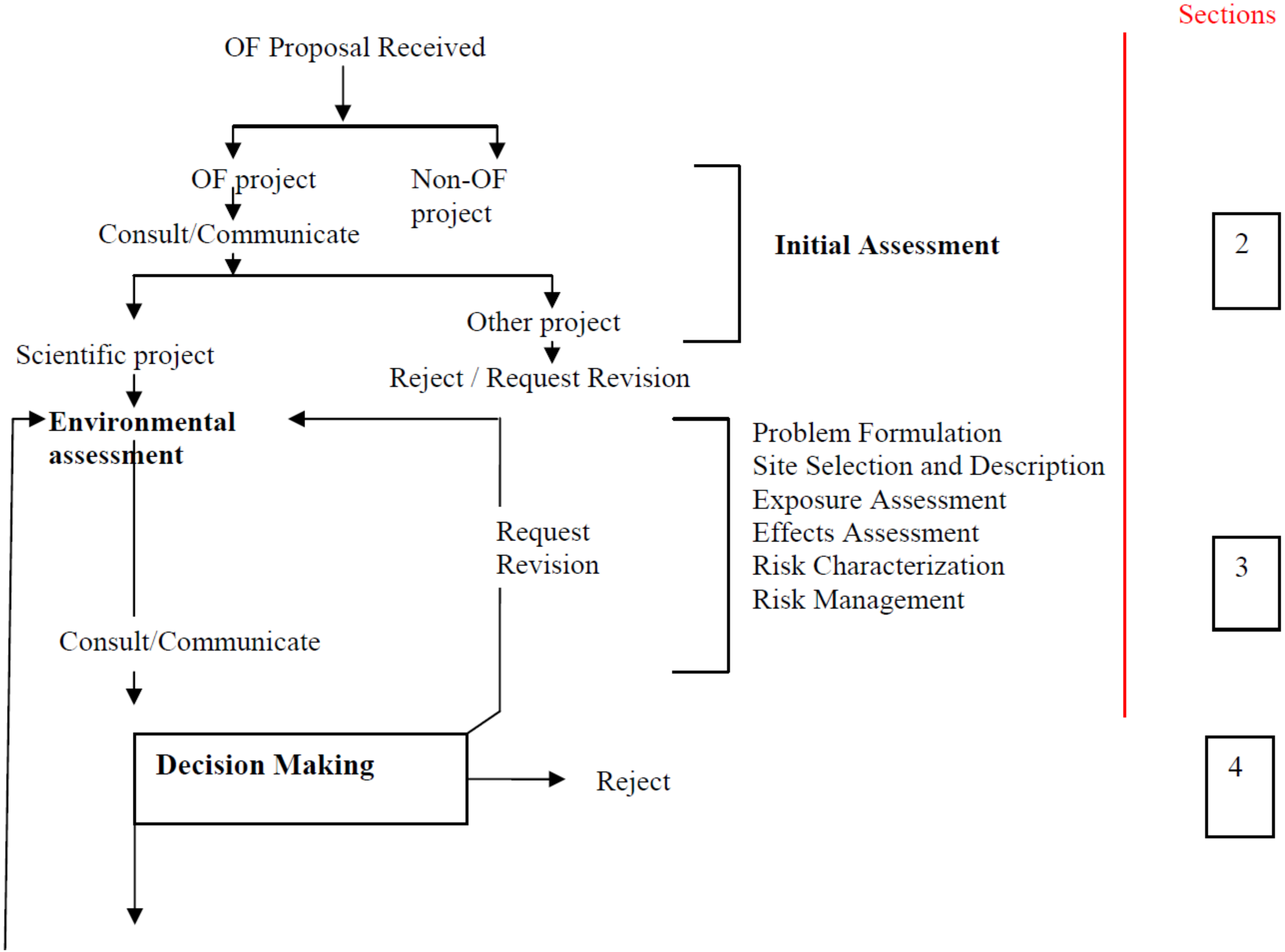
DISCLAIMER
As at its date of issue, this document, in whole or in part, is subject to consideration by the IMO organ to which it has been submitted. Accordingly, its contents are subject to approval and amendment of a substantive and drafting nature, which may be agreed after that date.

REGULATION OF OCEAN FERTILIZATION AND OTHER ACTIVITIES

Report of the Working Group on the Proposed Amendment to the London Protocol to Regulate Placement of Matter for Ocean Fertilization and Other Marine Geoengineering Activities

PEER-REVIEWED ASSESSMENTS SUCH AS THE LONDON CONVENTION ARE INVALUABLE

Figure 1: Assessment Framework for Scientific Research Involving Ocean Fertilization

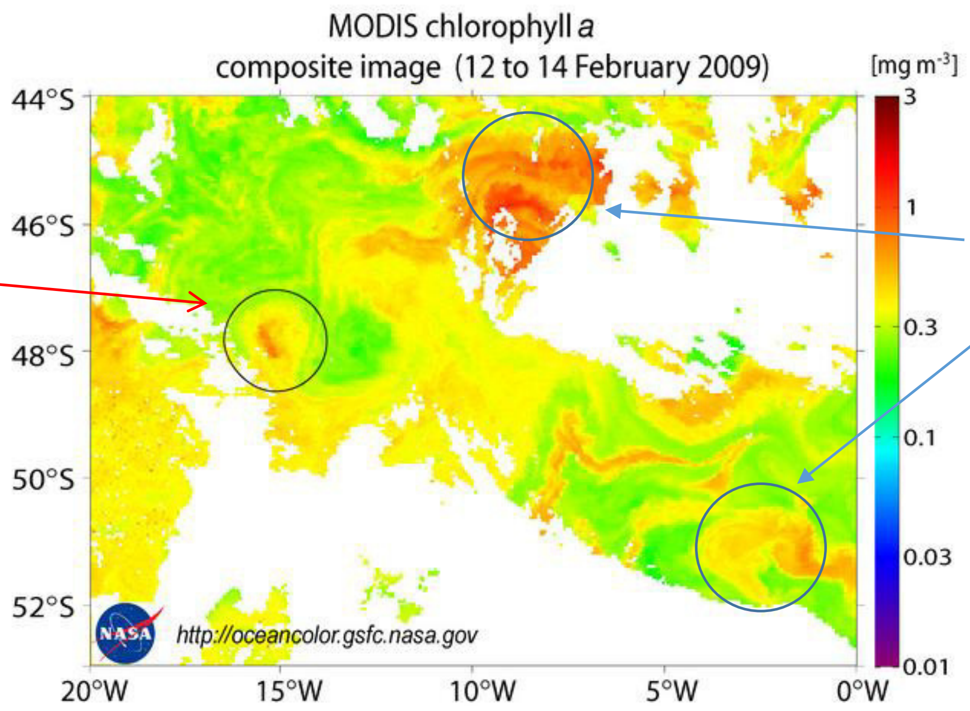


Detection - the concept of Additionality

LOHAFEX study

Purposeful
Iron enrichment
in an eddy

Additional???
No Control
Treatment!!



Natural iron enrichments

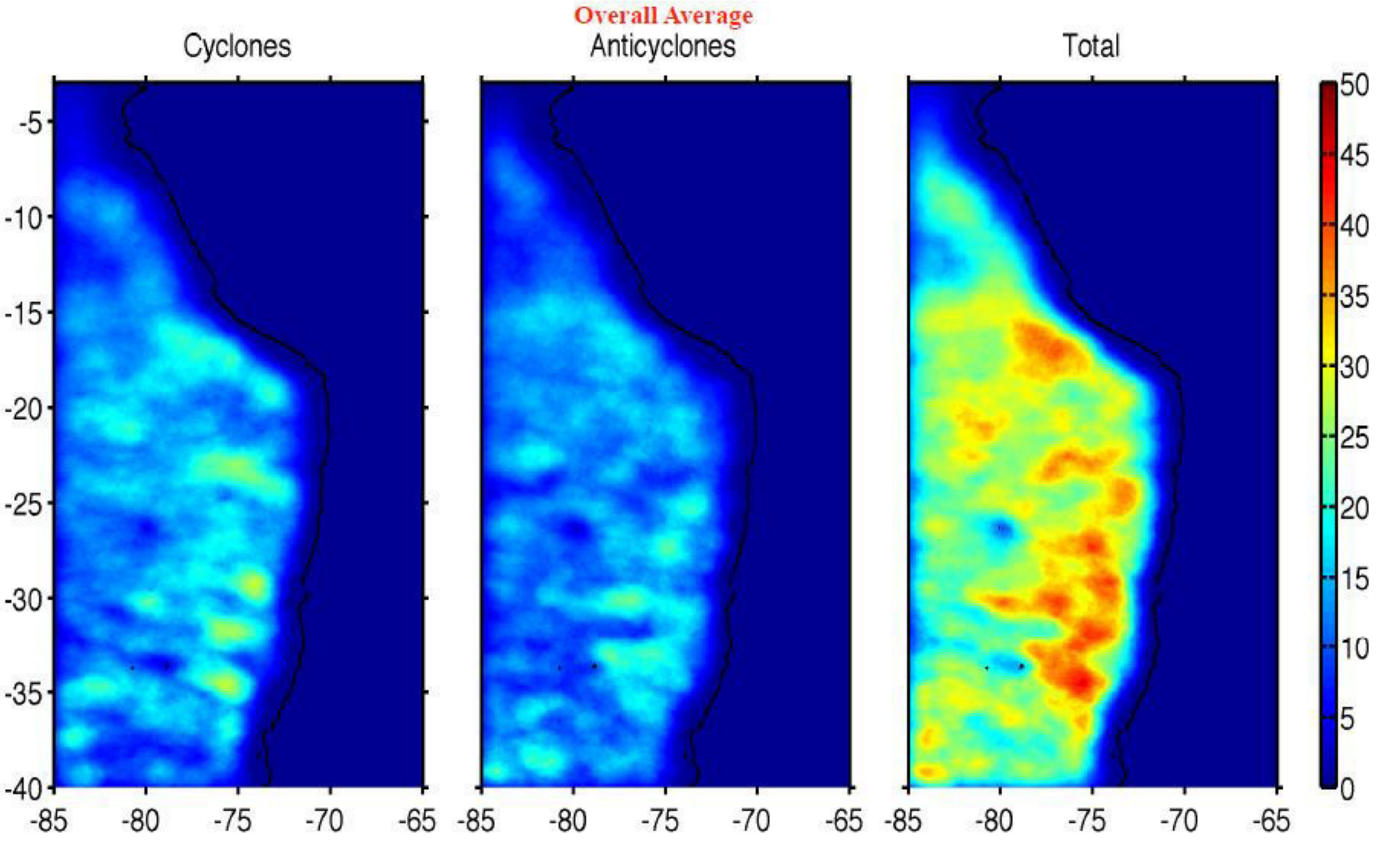
Under the Kyoto Protocol

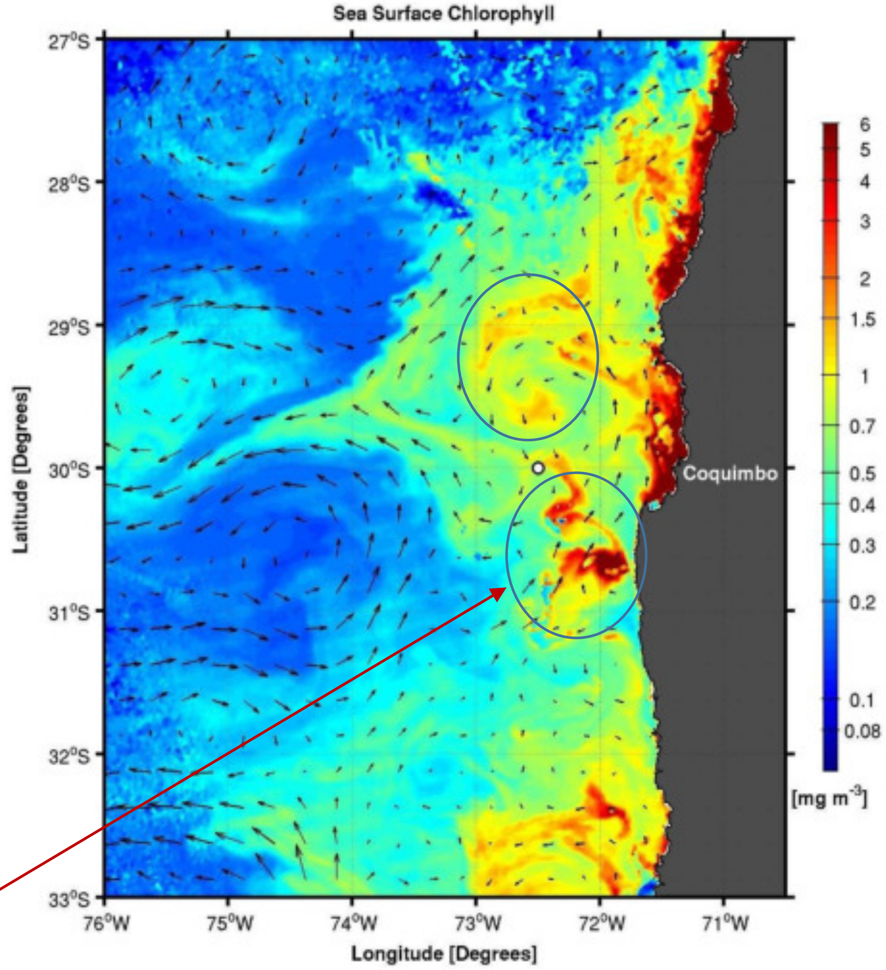
Additionality is defined as follows:

A project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered project activity

Additionality off Chile in the 'iron mosaic'

Humboldt Current showing frequency of cyclonic and anticyclonic eddies

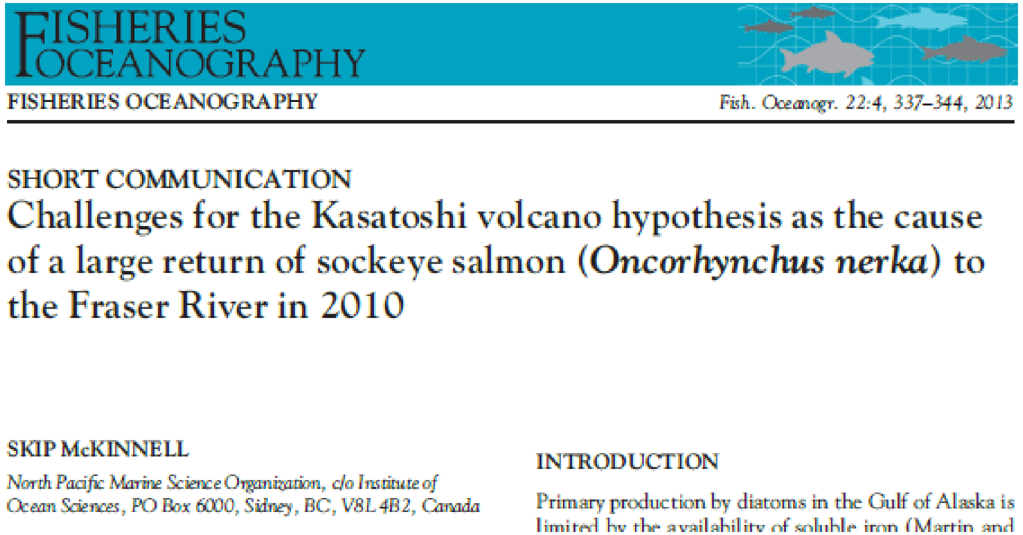




Naturally enriched waters

(Data courtesy of Fei Chai)

Detection - the concept of Additionality for fish stocks REQUIRES that we make sense of complexity


FISHERIES OCEANOGRAPHY

FISHERIES OCEANOGRAPHY Fish. Oceanogr. 22:4, 337–344, 2013

SHORT COMMUNICATION

Challenges for the Kasatoshi volcano hypothesis as the cause of a large return of sockeye salmon (*Oncorhynchus nerka*) to the Fraser River in 2010

SKIP McKINNELL

North Pacific Marine Science Organization, c/o Institute of Ocean Sciences, PO Box 6000, Sidney, BC, V8L 4B2, Canada

INTRODUCTION

Primary production by diatoms in the Gulf of Alaska is limited by the availability of soluble iron (Martin and

This complex puzzle includes:

Fast swimming migratory fish

Naturally enriched waters (volcanic ash)
Other naturally enriched waters (many sources)

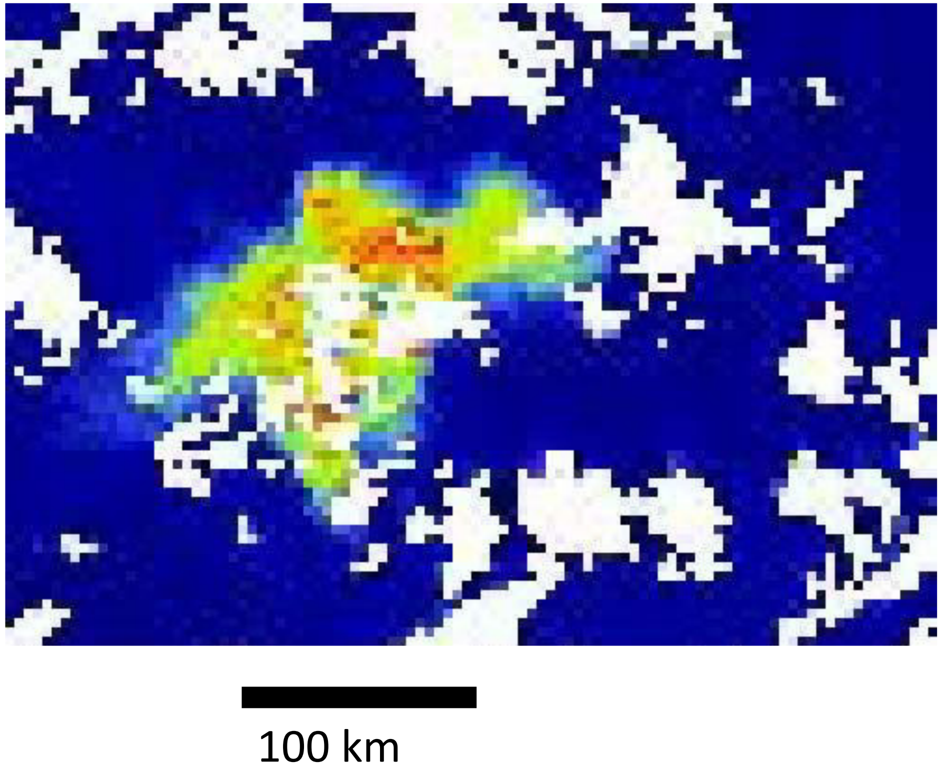
Year-to-year variability in survival rates
Life histories and different cohorts

Life history and occupation of distinct regions (onshore, offshore)
Knowledge of trophic pathways linking diatoms to salmon

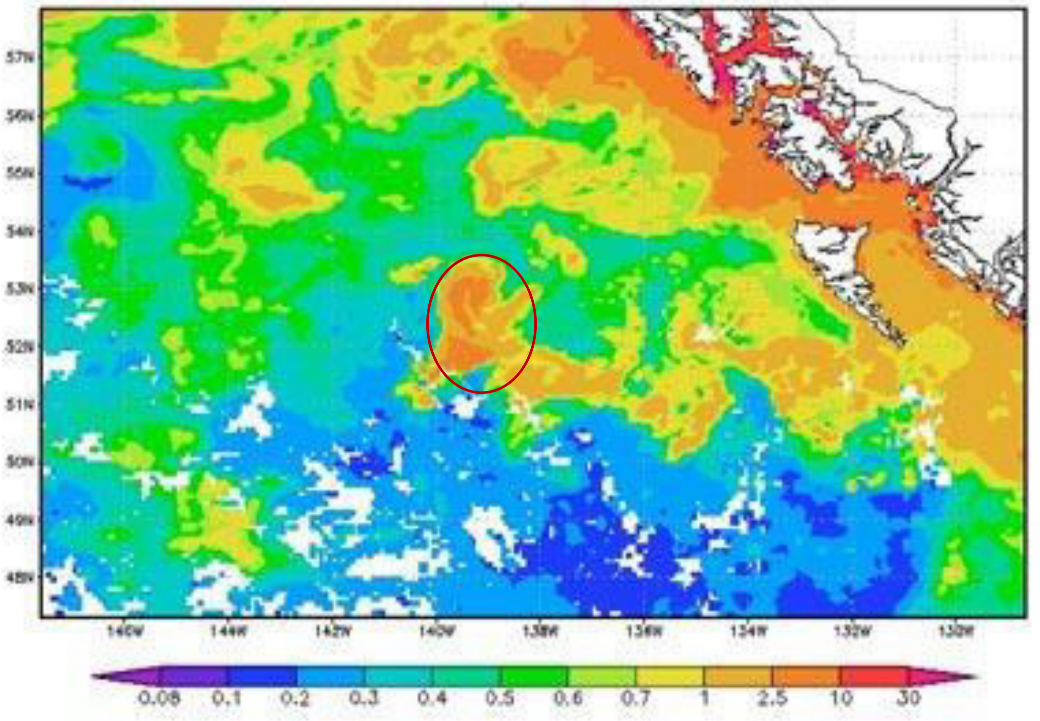
Year-to-year variability in ocean properties (nutrient supply; absence/presence of predators on zooplankton)

Two large scale ocean iron-enrichments in the Gulf of Alaska

July 2002



August 2012



WHY ARE THEY DIFFERENT?

From the Oceaneos website
23 May 2017

Peer-reviewed research is featured alongside a commercial project

"First proposed in 1988, there have since been thirteen demonstrations of Ocean Seeding by research and academic institutions. The largest $200 million dollar Ocean Seeding experiment, conducted by Dr. Victor Smetacek at the Alfred Wegener Institute in Germany, investigated how Ocean Seeding would not just stimulate plankton blooms but sequester carbon dioxide from the atmosphere."

"In 2012, the Haida Salmon Restoration Corporation (HSRC) conducted an Ocean Seeding experiment funded entirely by the Old Massett Band of the Haida First Nation community. The goal of the project was to restore the steadily declining salmon populations, which the Haida depend on for both food and employment. Over the two-month course of the project, the research team observed increased zooplankton, pelagic birds, large whales, tuna, and salmon. Read more about this project and the impacts here."

Read more about this project and the impacts here."

Oceaneos

STATE OF THE OCEANS OCEAN SEEDING ABOUT FAQ E

The page you are looking for does not exist. It may have been moved, or removed altogether. Perhaps you can return back to the site's homepage and see if you can find what for.

PLEASE, RETURN TO OUR HOMEPAGE

"First proposed in 1988, there have since been thirteen demonstrations of Ocean Seeding by research and academic institutions. The largest $200 million dollar Ocean Seeding experiment, conducted by Dr. Victor Smetacek at the Alfred Wegener Institute in Germany, investigated how Ocean Seeding would not just stimulate plankton blooms but sequester carbon dioxide from the atmosphere."

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ARTICLE

doi:10.1038/nature11229

Deep carbon export from a Southern Ocean iron-fertilized diatom bloom

Victor Smetacek[1,2*], Christine Klaas[1*], Volker H. Strass[1], Philipp Assmy[1,3], Marina Montresor[4], Boris Cisewski[1,5], Nicolas Savoye[6,7], Adrian Webb[8], Francesco d'Ovidio[9], Jesús M. Arrieta[10,11], Ulrich Bathmann[1,12], Richard Bellerby[13,14], Gry Mine Berg[15], Peter Croot[16,17], Santiago Gonzalez[10], Joachim Henjes[1,18], Gerhard J. Herndl[10,19], Linn J. Hoffmann[16], Harry Leach[20], Martin Losch[1], Matthew M. Mills[15], Craig Neill[13,21], Ilka Peeken[1,22], Rüdiger Röttgers[23], Oliver Sachs[1,24], Eberhard Sauter[1], Maike M. Schmidt[25], Jill Schwarz[1,26], Anja Terbrüggen[1] & Dieter Wolf-Gladrow[1]

5/23/2017 Oceaneos - restoring ocean life | Page not found

Oceaneos STATE OF THE OCEANS OCEAN SEEDING ABOUT FAQ E

The page you are looking for does not exist. It may have been moved, or removed altogether. Perhaps you can return back to the site's homepage and see if you can find what for.

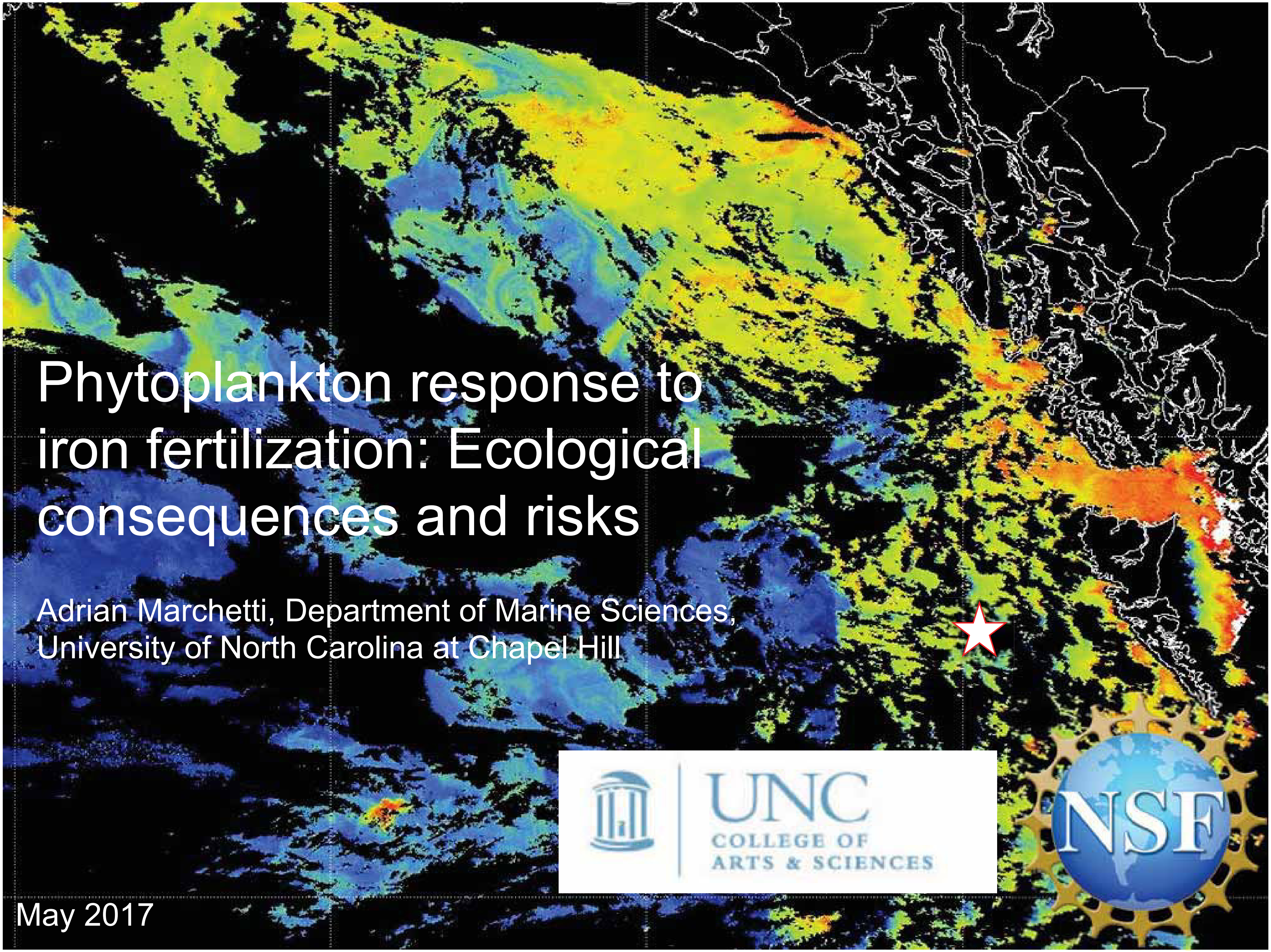
PLEASE, RETURN TO OUR HOMEPAGE

Transparency, peer-review and a place in the public record is why they are different.

3.3 .Dr. Adrian Marchetti : Phytoplankton response to iron fertilization: Ecological consequences and risks

Phytoplankton response to iron fertilization: Ecological consequences and risks

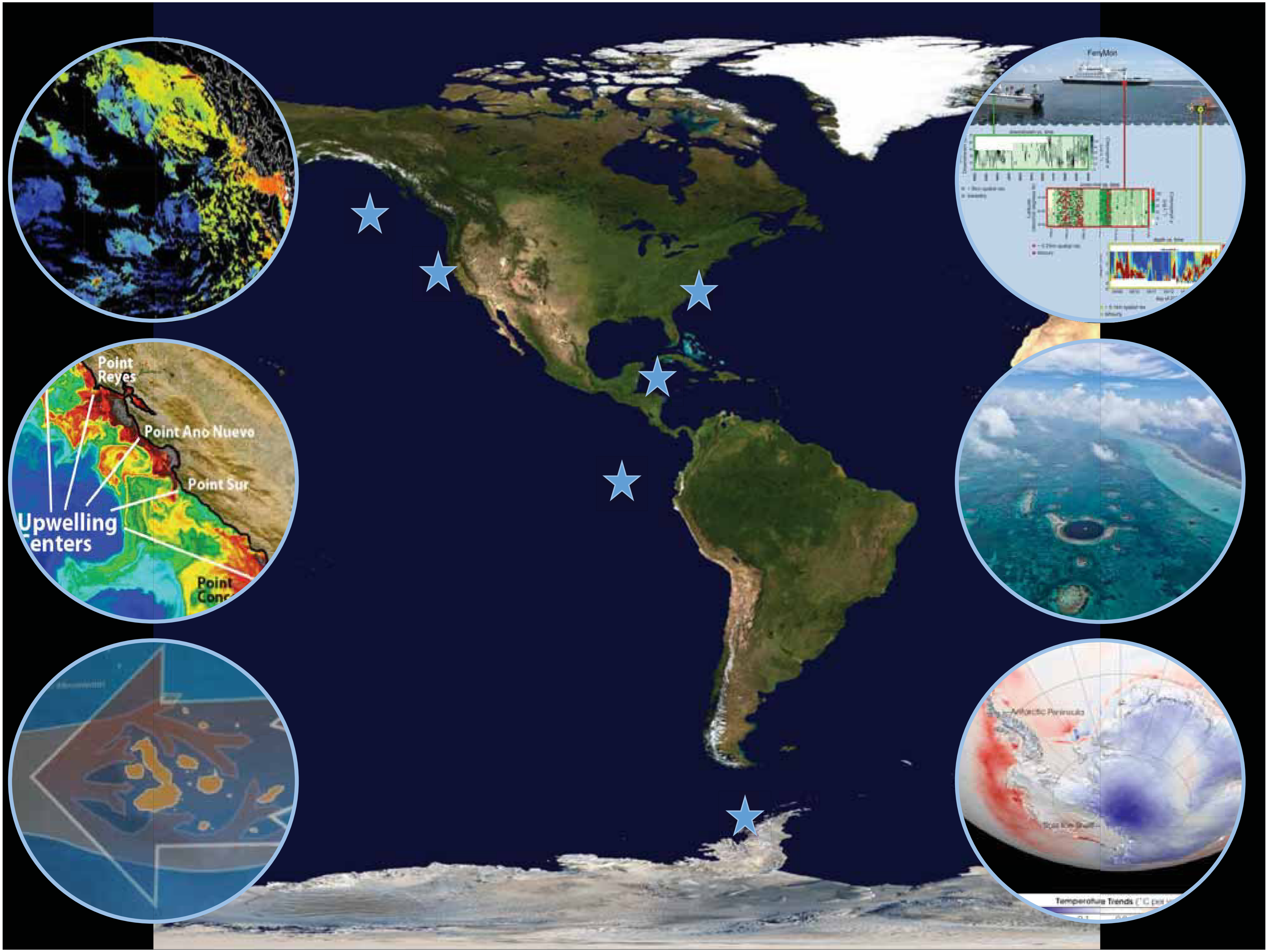
Adrian Marchetti, Department of Marine Sciences,
University of North Carolina at Chapel Hill



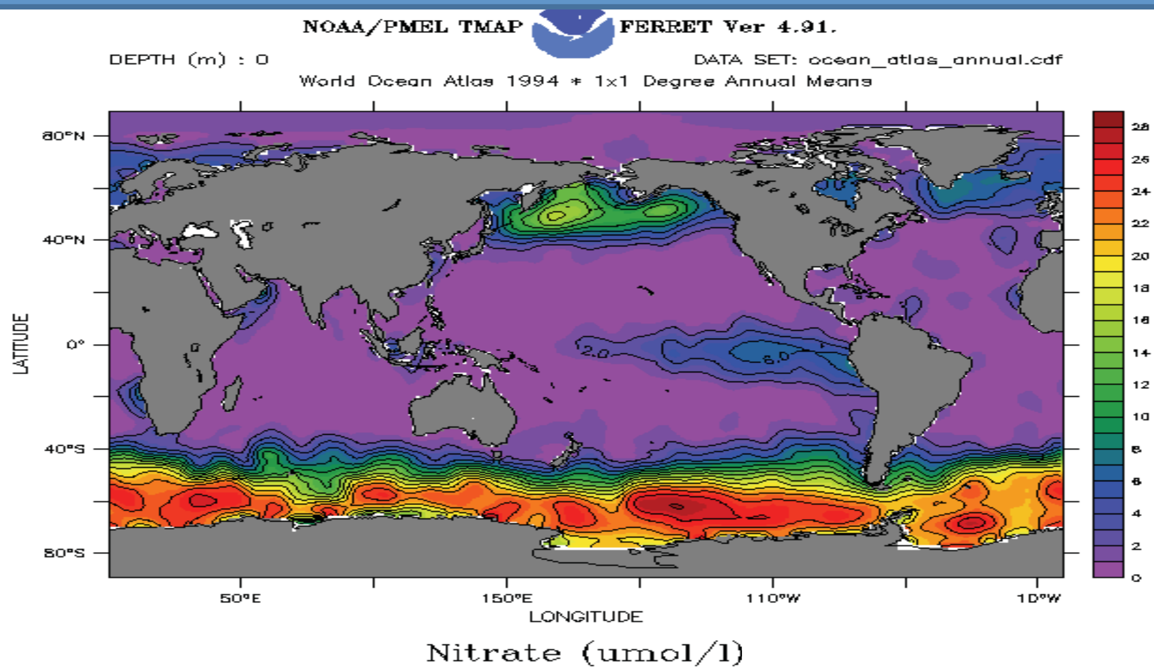
UNC COLLEGE OF ARTS & SCIENCES

NSF

May 2017

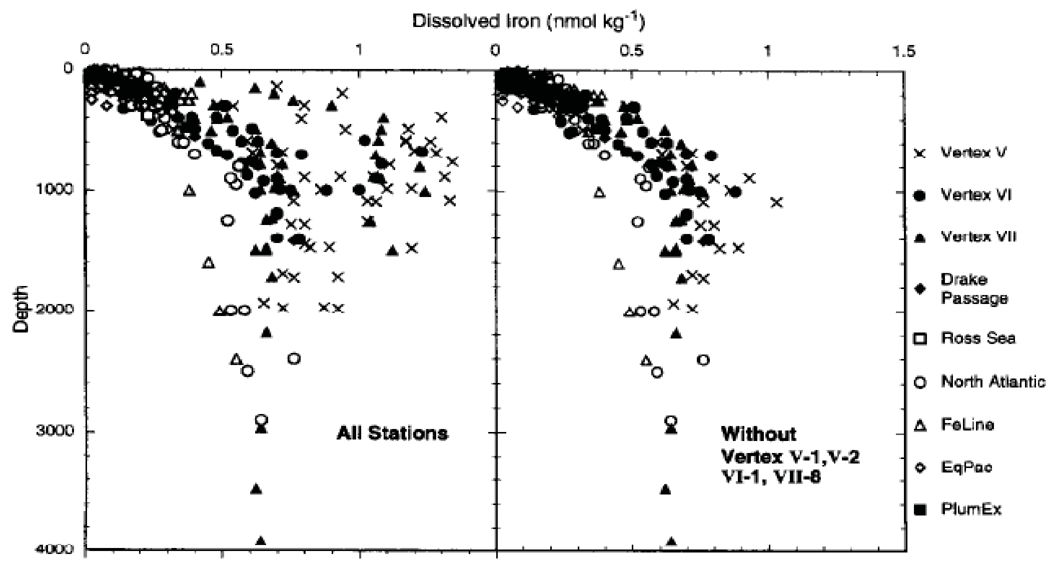

Point Reyes
Point Ano Nuevo
Point Sur
Upwelling
enters
Point
FerryMon
Antarctic Peninsula
Temperature Trends

High-Nitrate, Low Chlorophyll regions (HNLC) and iron-limitation



1) Equatorial Pacific Ocean
2) North Pacific Ocean
3) Southern Ocean

- exhibits a nutrient-like profile
- surface dissolved [Fe] <0.1 nM
- residence time ~ 100-200 years

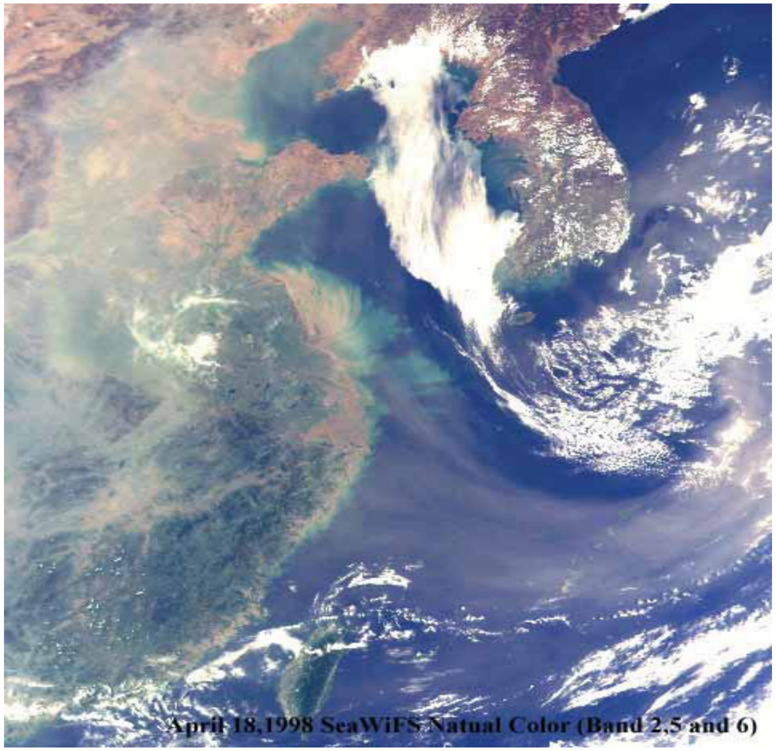


Johnson et al. *Marine Chemistry* 1997

Sources of iron to the oceans

1) Coastal Ecosystems

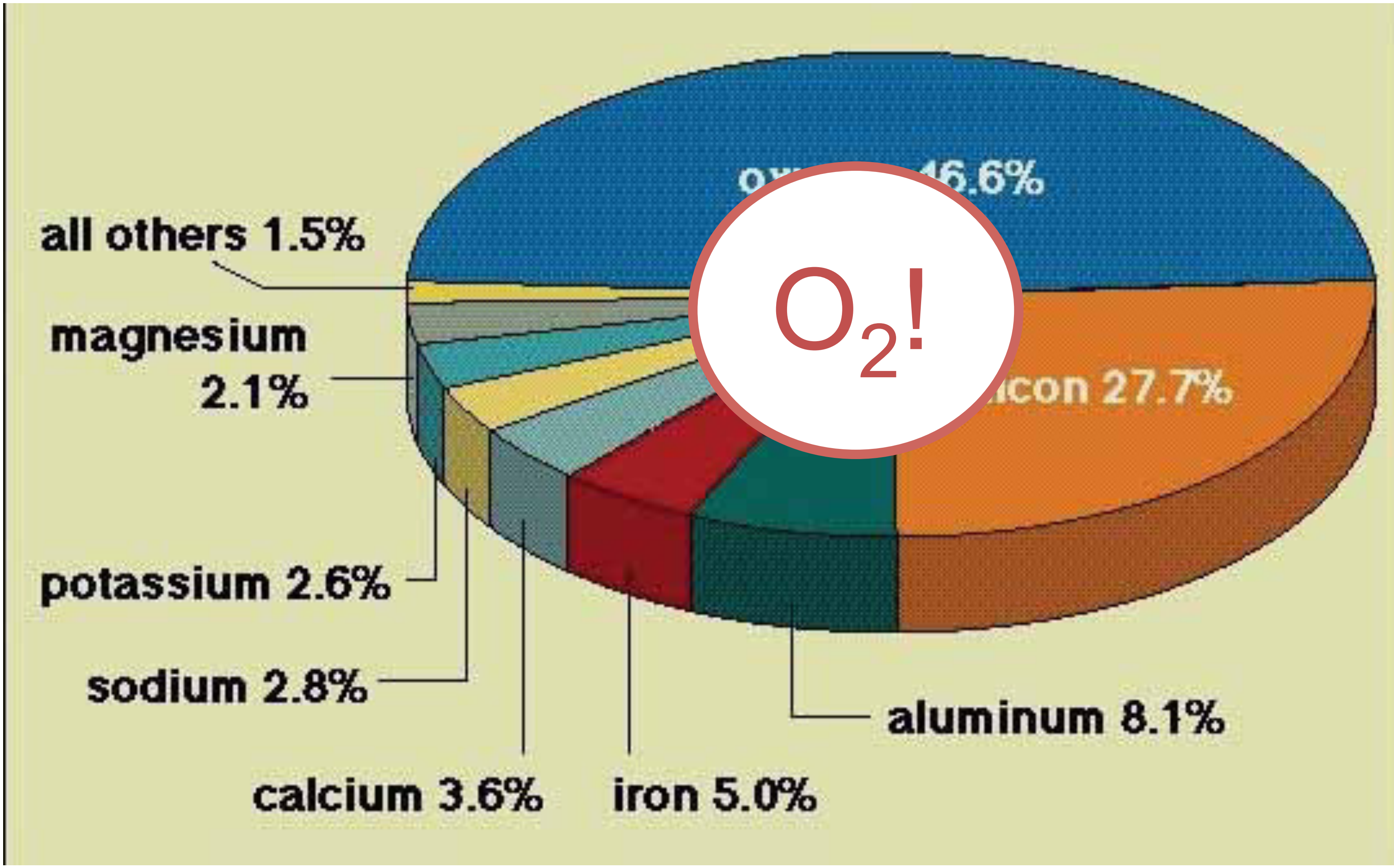
- riverine input
- resuspension of bottom sediments
- vertical mixing of Fe-rich deepwater
- continental dust



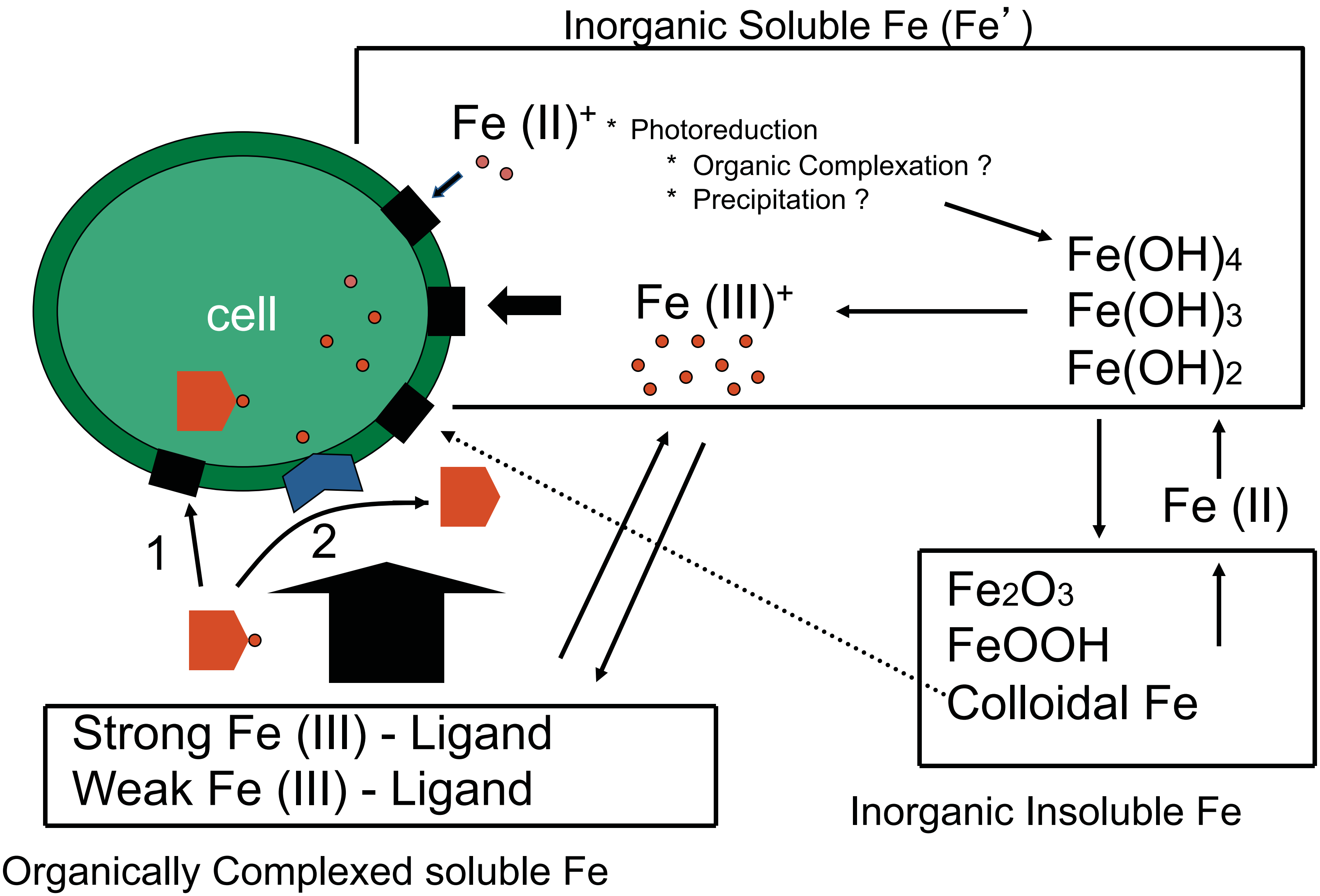
2) Open-ocean Ecosystems

- wind-borne continental dust
- weak upwelling
- coastal eddies
- hydrothermal vents??

Chemical composition of Earth's crust

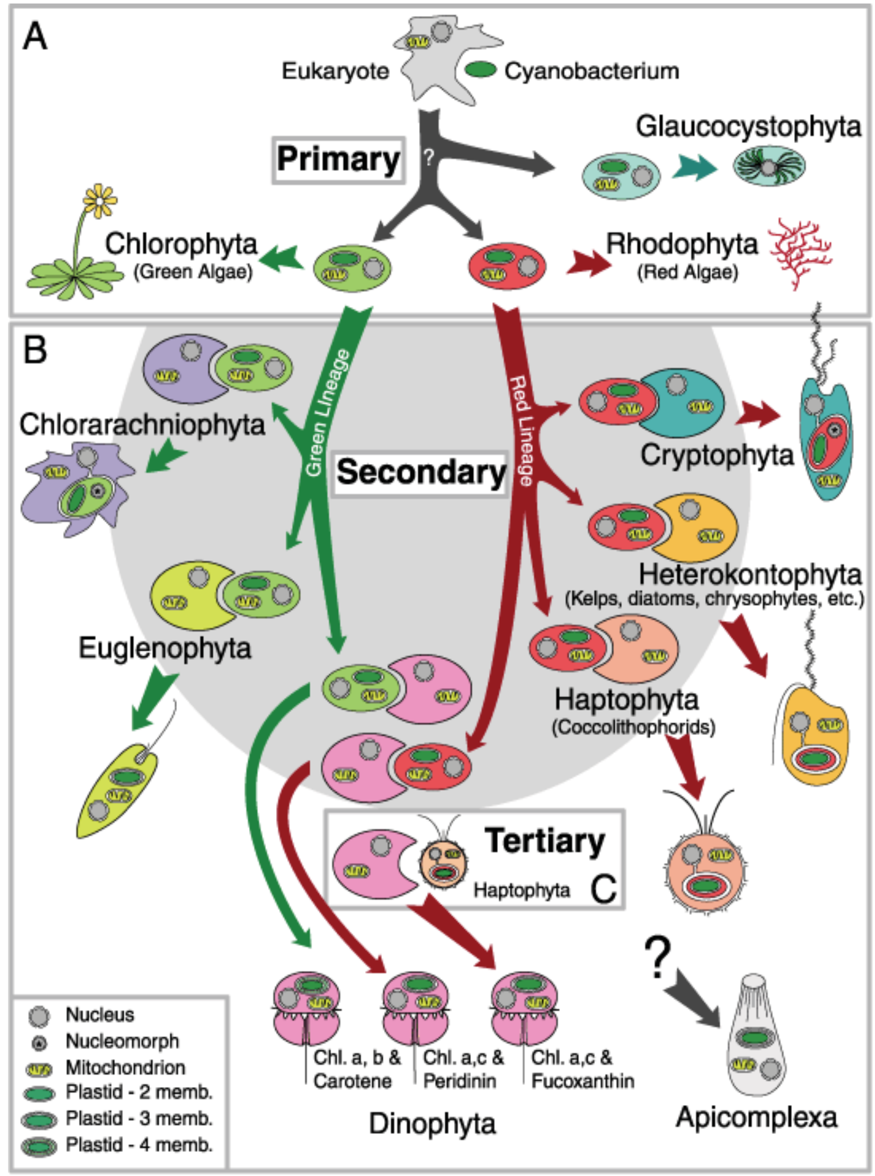


Iron speciation in seawater



Early evolution of life

- Pre-photosynthesis:
  - primordial anoxic ocean [Fe] = mM
  - early cells likely evolved high iron demands due to it's ready availability
- Functions as an effective electron carrier in biological red-ox reactions
- Highest iron-requiring pathways are:
  1) Photosynthetic carbon fixation
  2) Nitrogen assimilation



Modified from Delwiche, C.F. 1999. Tracing the thread of plastid diversity through the tapestry of life. Am. Nat. 154:S164-S177.

Iron limitation hypothesis

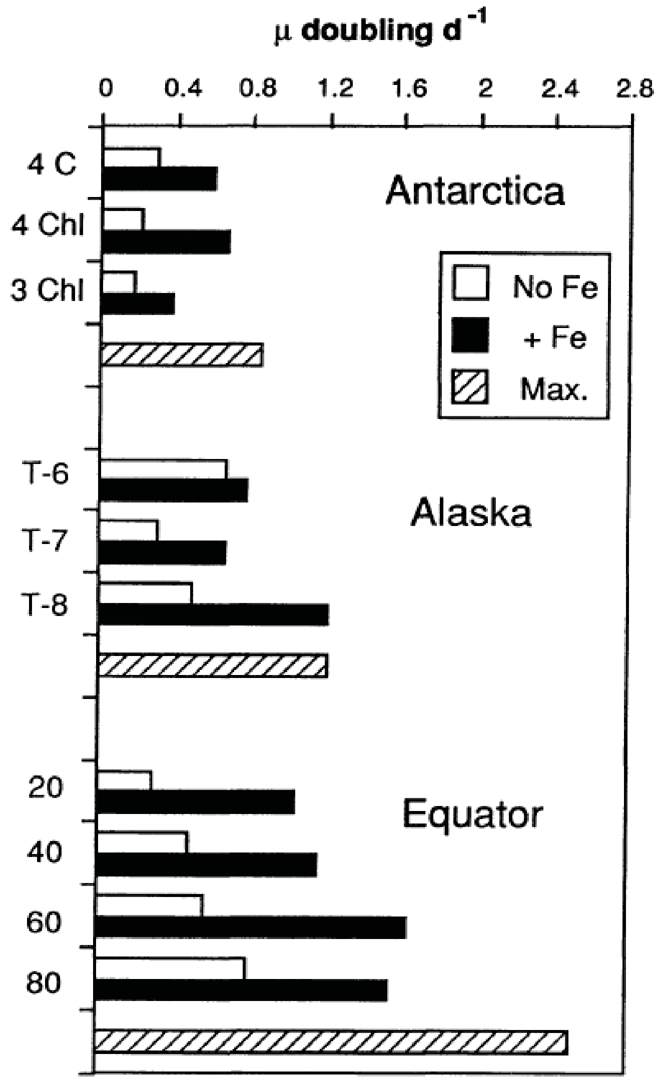


Fig. 7. A comparison of doubling rates from the Antarctic, Gulf of Alaska, and equatorial Pacific with and without added Fe (data from Table 2); theoretical maxima for various temperatures are also shown.

John Martin's iron hypothesis:

"Phytoplankton growth and biomass are limited by low concentrations of available iron in large regions of the world's oceans where other plant nutrients are abundant"

Martin et al. 1991

N limitation versus Fe limitation

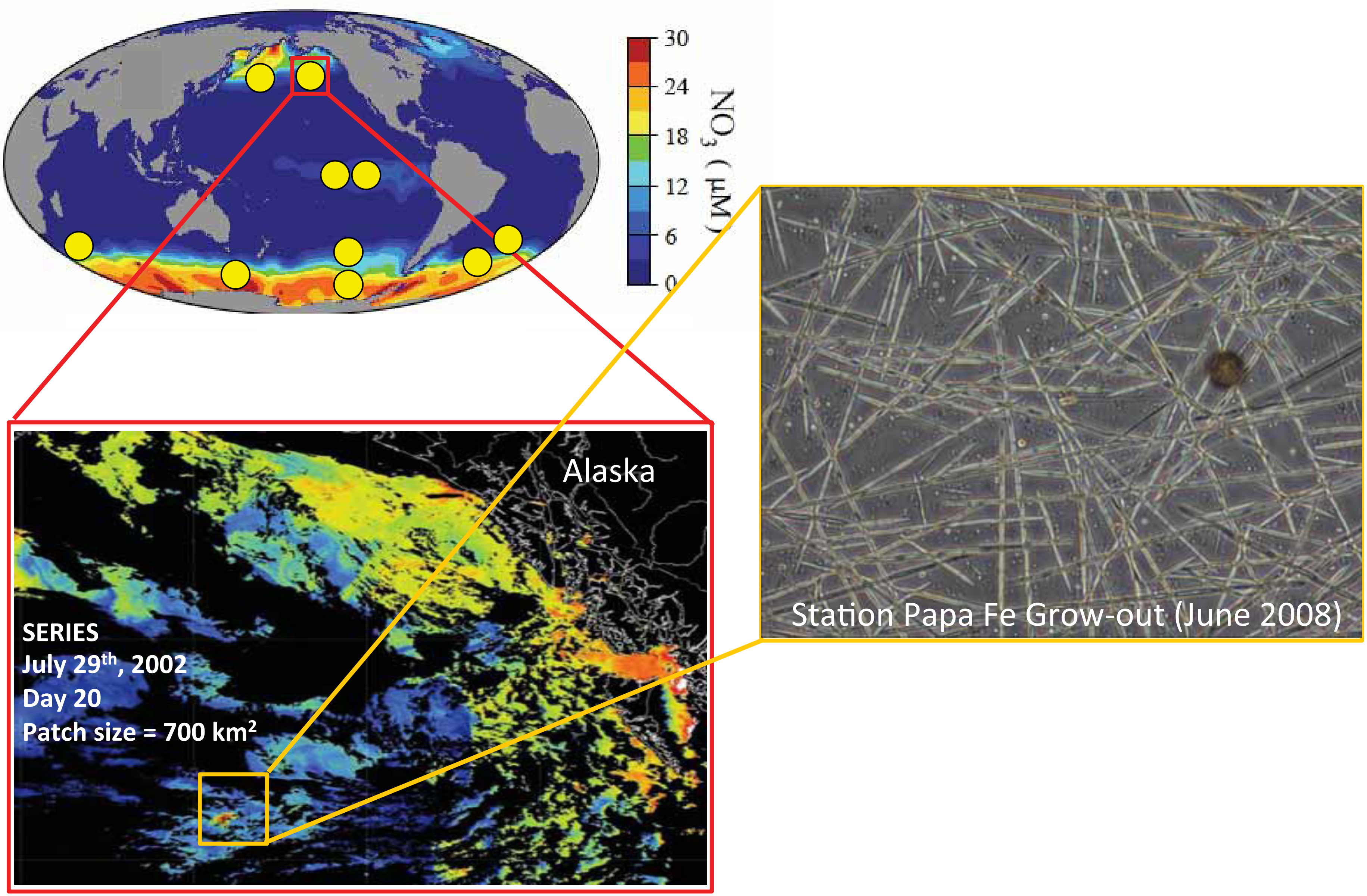
- Phytoplankton C:N requirement ratio is around 7

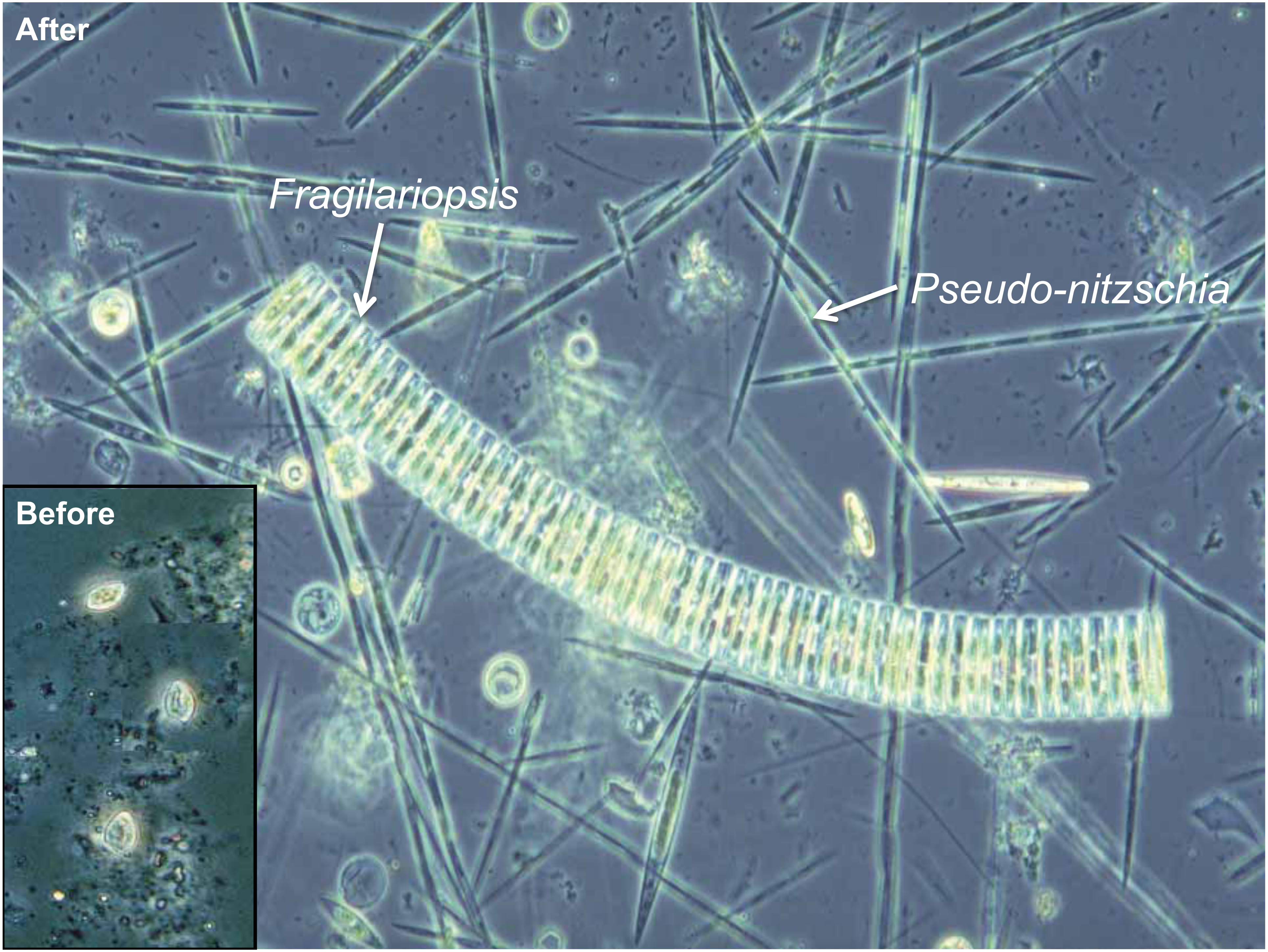
  Therefore, every one mole of N added results in 7 moles of carbon incorporated into organic matter.

- Phytoplankton C:Fe requirement ratio is around 100,000

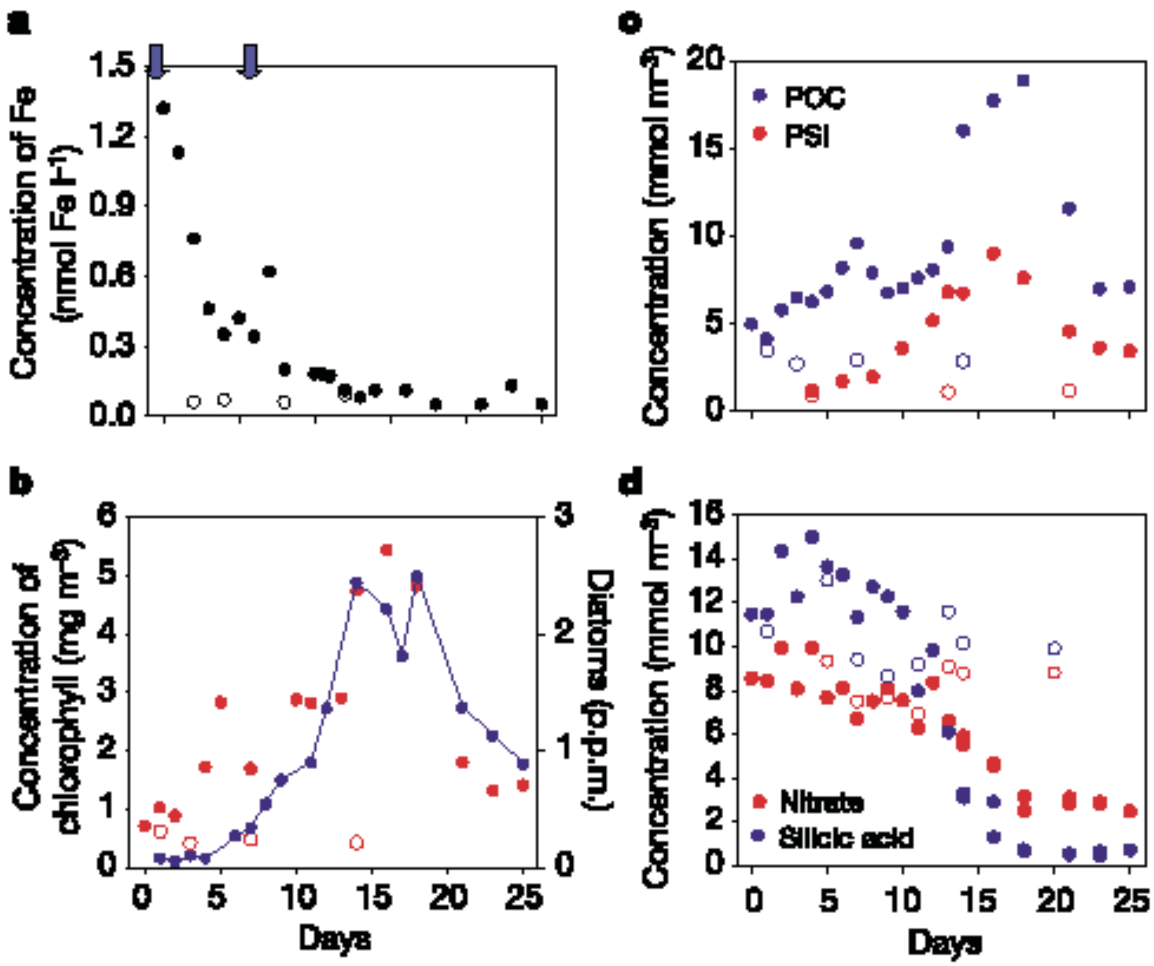
  Therefore, every one mole of Fe added results in 100,000 mole of carbon incorporated into organic matter!!

Iron limitation and iron fertilization




After
Fragilariopsis
Pseudo-nitzschia
Before

SERIES: Phytoplankton response



- Chlorophyll *a* increased >20-fold
- Large diatoms were main respondent to iron enrichment
- Particulate carbon concentrations increased >5-fold
- Silicic acid depletion resulted in bloom termination

Boyd et al. Nature 2004

ENVIRONMENT

Ocean Iron Fertilization—Moving Forward in a Sea of Uncertainty

It is premature to sell carbon offsets from ocean iron fertilization unless research provides the scientific foundation to evaluate risks and benefits.

Ken O. Buesseler,[1*] Scott C. Doney,[1] David M. Karl,[2] Philip W. Boyd,[3] Ken Caldeira,[4] Fei Chai,[5] Kenneth H. Coale,[6] Hein J. W. de Baar,[7] Paul G. Falkowski,[8] Kenneth S. Johnson,[9] Richard S. Lampitt,[10] Anthony F. Michaels,[11] S. W. A. Naqvi,[12] Victor Smetacek,[13] Shigenobu Takeda,[14] Andrew J. Watson[15]

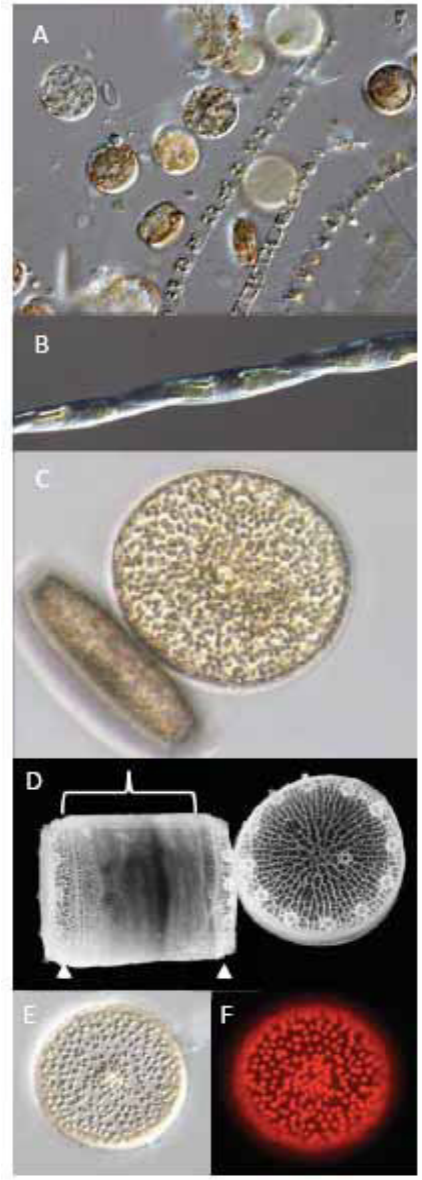
- Field studies on larger spatial and longer time scales, because ecological impacts and CO_2 mitigation are scale-dependent.
- Consideration of OIF in high- and low nutrient regions to understand a wider range of processes that are affected by iron, such as nitrogen fixation and elemental stoichiometry.
- Detailed measurements in the subsurface ocean to verify the fate of fixed carbon, including remineralization length scales of carbon, iron, and associated elements.
- **Broad assessment of ecological impacts from bacteria and biogeochemistry to fish, seabirds, and marine mammals.**
- Long-term monitoring and use of models to assess downstream effects beyond the study area and observation period.
- Characterization of changes to oxygen distributions, biophysical climate feedbacks, and cycling of non-CO_2 greenhouse gases, such as methane, nitrous oxide, and dimethylsulfide.
- Improved modeling studies of the results and consequences of OIF, including higher spatial resolution, better ecosystem parameterization, inclusion of other greenhouse gases, and improved iron biogeochemistry.
- Analysis of the costs, benefits, and impacts of OIF relative to other climate and carbon mitigation schemes and to the impacts of global change if we take no action.

Science 2008

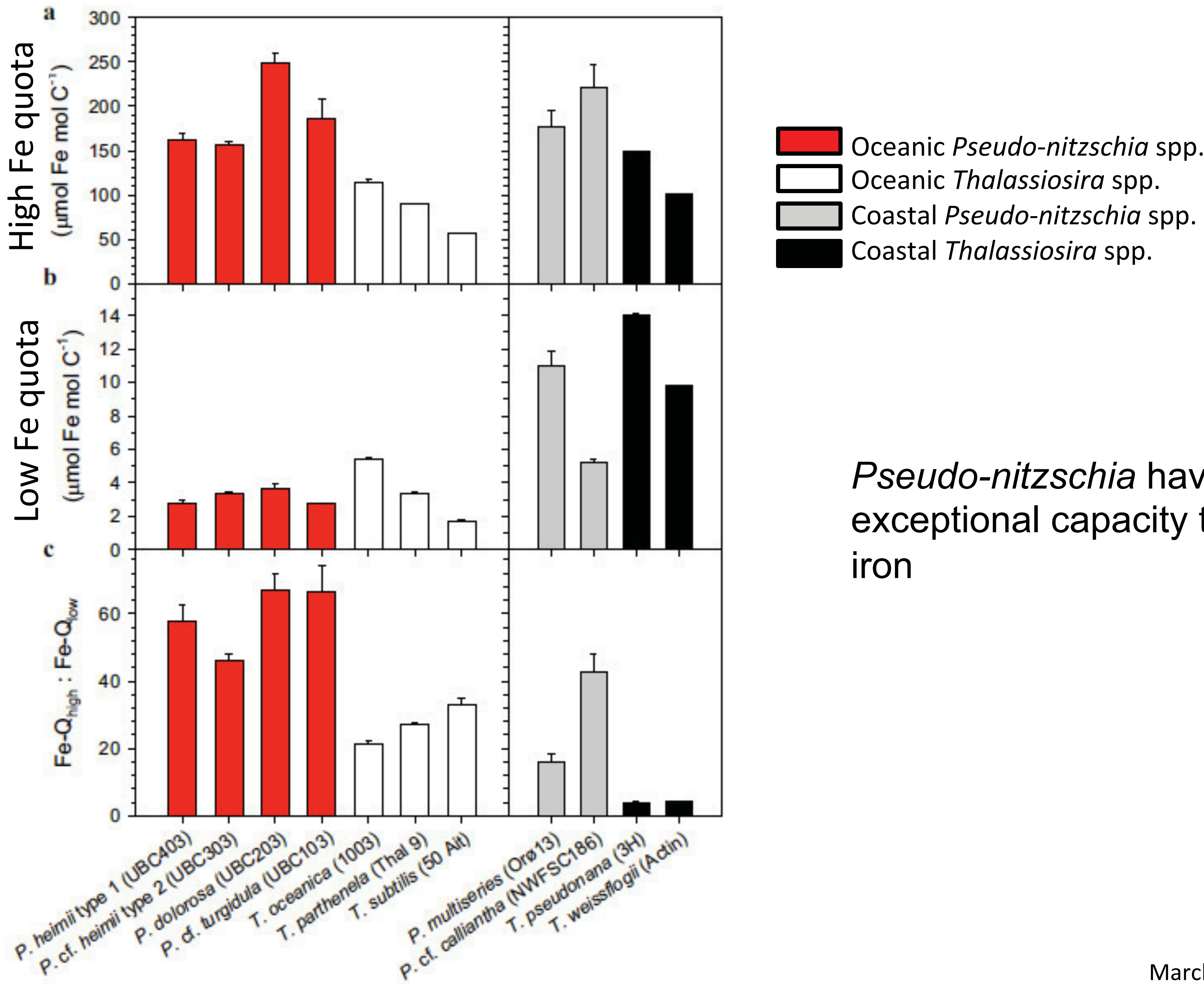
Diatom acclimation to variable iron conditions

When dealing with low iron, diatoms will:

- change their cell morphology
- reduce their iron requirements
- increase their iron uptake affinity
- have an extensive iron storage capacity

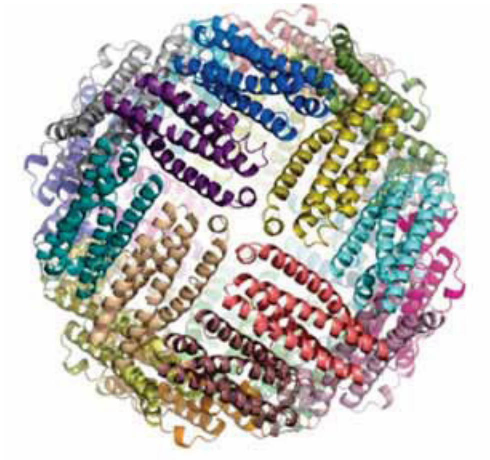


Iron requirements in coastal versus oceanic diatoms



Pseudo-nitzschia have an exceptional capacity to store iron

Marchetti et al. L&O 2006



Vol 457 | 22 January 2009 | doi:10.1038/nature07539 nature

LETTERS

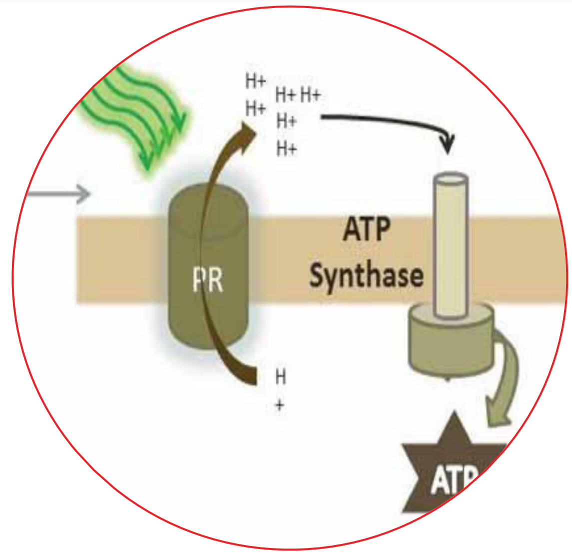
Ferritin is used for iron storage in bloom-forming marine pennate diatoms

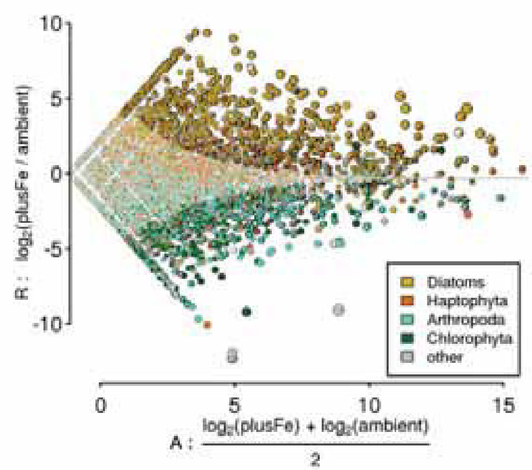
Adrian Marchetti[1]*, Micaela S. Parker[1]*, Lauren P. Moccia[2], Ellen O. Lin[1], Angele L. Arrieta[3], Francois Ribalet[1], Michael E. P. Murphy[3], Maria T. Maldonado[2] & E. Virginia Armbrust[1]

SHORT COMMUNICATION

Marine diatom proteorhodopsins and their potential role in coping with low iron availability

Adrian Marchetti[1], Dylan Catlett[1], Brian M Hopkinson[2], Kelsey Ellis[1] and Nicolas Cassar[3]
[1]*Department of Marine Sciences, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA;*
[2]*Department of Marine Sciences, University of Georgia, Athens, GA, USA and* [3]*Division of Earth and Ocean Sciences, Nicholas School of the Environment, Duke University, Durham, NC, USA*





PNAS

Comparative metatranscriptomics identifies molecular bases for the physiological responses of phytoplankton to varying iron availability

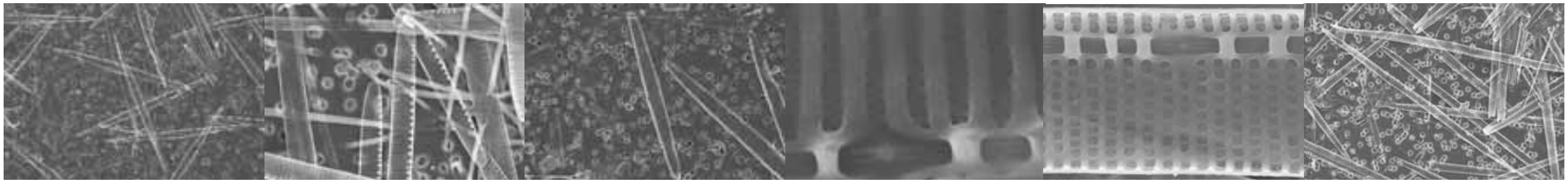
Adrian Marchetti[a,1,2,3], David M. Schruth[a,1], Colleen A. Durkin[a], Micaela S. Parker[a], Robin B. Kodner[a], Chris T. Berthiaume[a], Rhonda Morales[a], Andrew E. Allen[b], and E. Virginia Armbrust[a,2]

[a]School of Oceanography, University of Washington, Seattle, WA 98105; and [b]J. Craig Venter Institute, San Diego, CA 92121

Edited by David M. Karl, University of Hawaii, Honolulu, HI, and approved December 20, 2011 (received for review November 9, 2011)

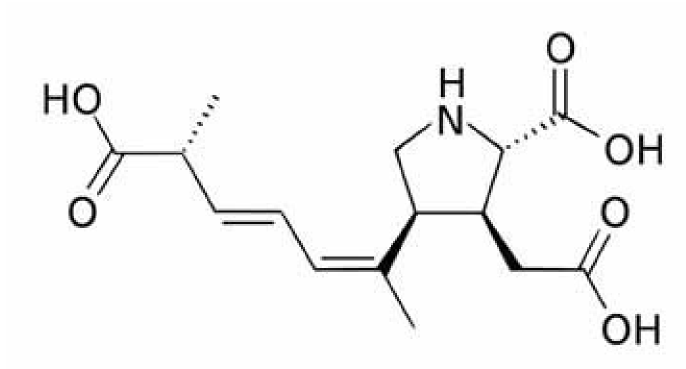
Pseudo-nitzschia

- A widely distributed marine pennate diatom genus
- they are a universal respondent to iron fertilization
- They are fast growers and have high iron storage capacities using ferritin
- Oceanic *Pseudo-nitzschia* contain rhodopsins
- Compared to other diatoms, they are lightly silicified (low Si;N ratios)



Domoic acid (DA)

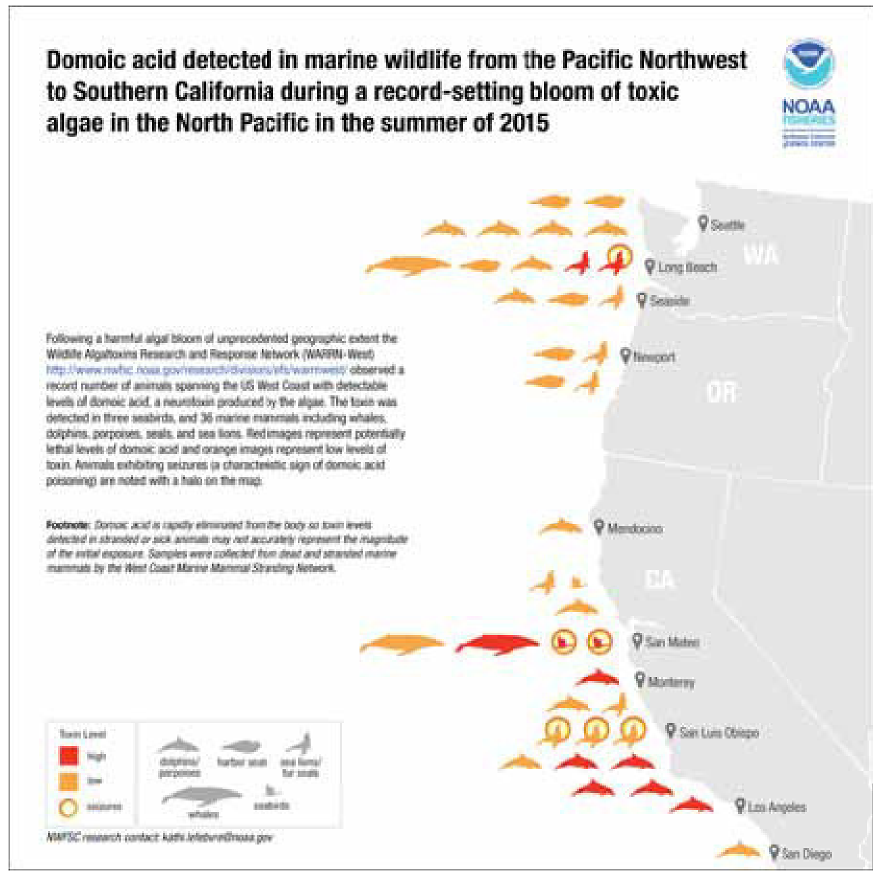
- a neurotoxin produced by *Pseudo-nitzschia*
- Amnesic Shellfish Poisoning (ASP)
- primarily effects marine mammals and birds
- fish not significantly impacted but are vectors for DA (Lefebvre et al. 2012)
- most *Pseudo-nitzschia* species can produce DA in varying amounts
- physiological status of *Pseudo-nitzchia* influences DA production



Energy and Environment

The Pacific blob caused an 'unprecedented' toxic algal bloom — and there's more to come

- Washington Post



Iron limitation in the California upwelling zone (CUZ)

Limnol. Oceanogr., 43(6), 1998, 1037–1054

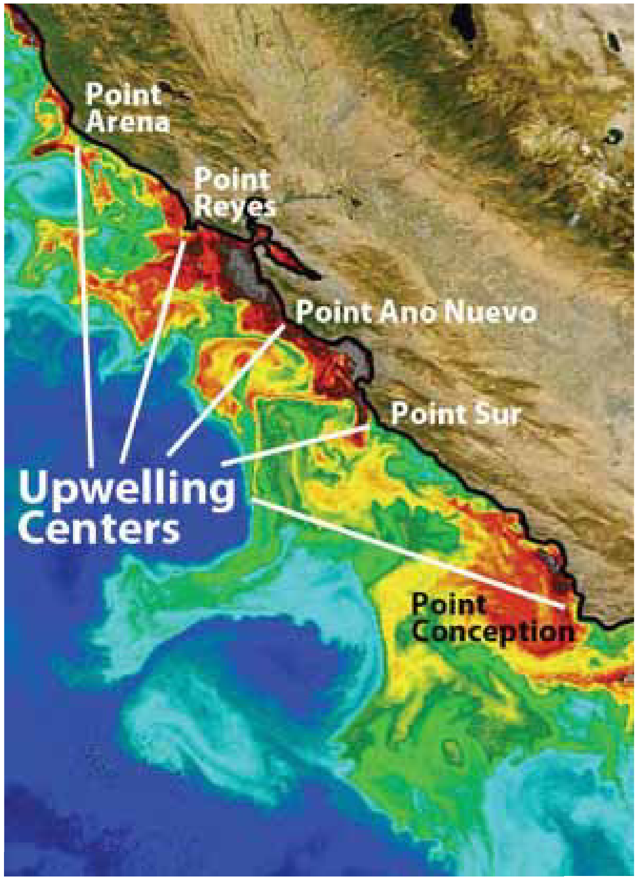
An iron limitation mosaic in the California upwelling regime

D. A. Hutchins
College of Marine Studies, University of Delaware, 700 Pilottown Rd., Lewes, Delaware 19958

G. R. DiTullio
Grice Marine Laboratory, University of Charleston, 205 Fort Johnson, Charleston, South Carolina 29412

Y. Zhang
College of Marine Studies, University of Delaware, 700 Pilottown Rd., Lewes, Delaware 19958

K. W. Bruland
Institute of Marine Sciences, University of California, Santa Cruz, Santa Cruz, California 95064

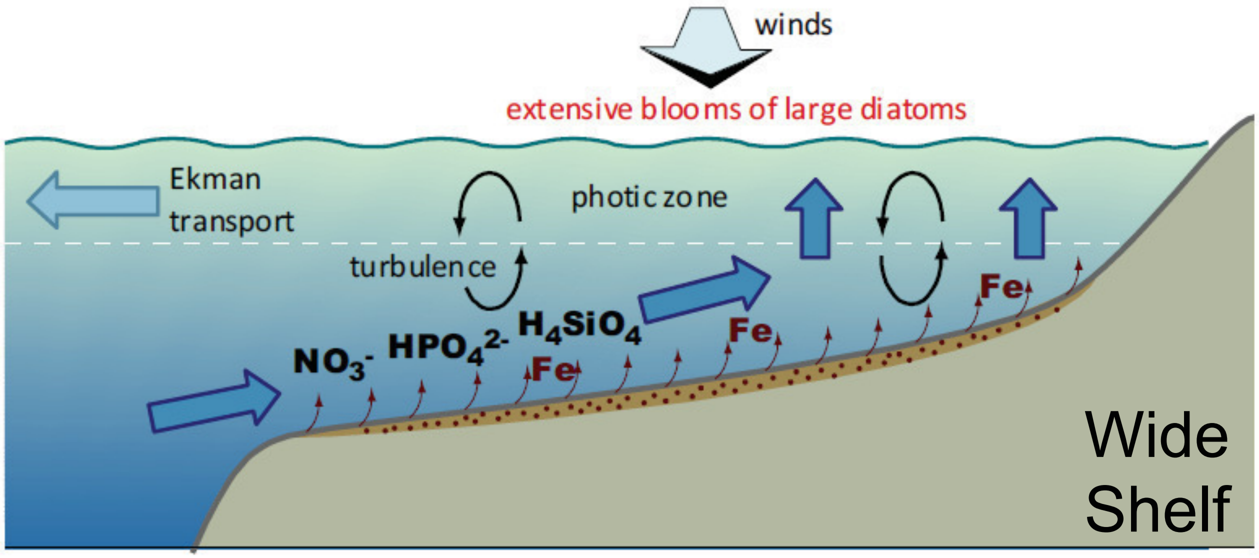


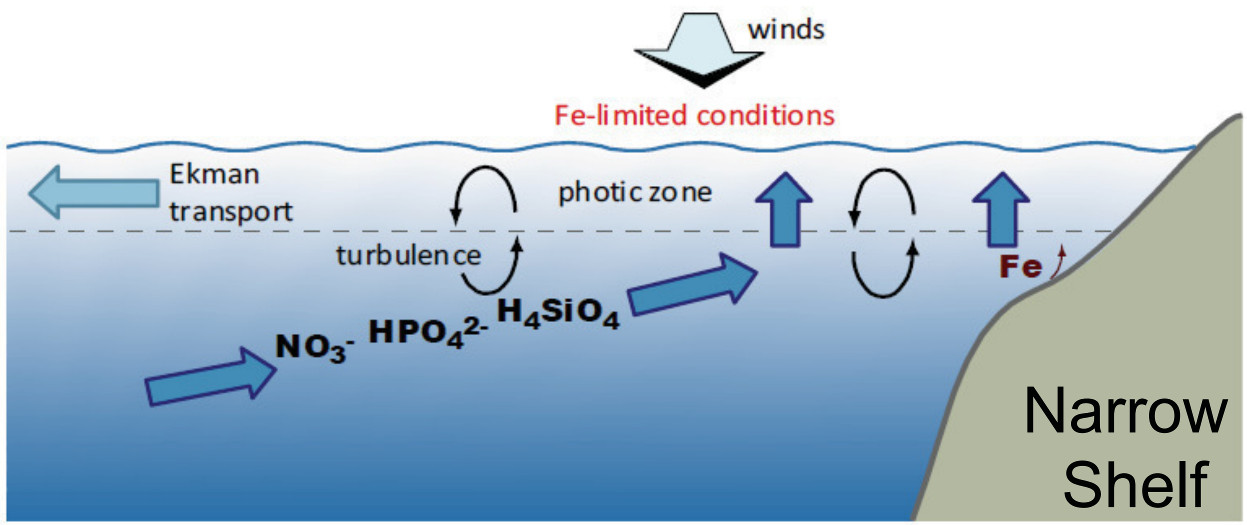
Limnol. Oceanogr., 46(7), 2001, 1661–1674

Iron and macronutrients in California coastal upwelling regimes: Implications for diatom blooms

Kenneth W. Bruland, Eden L. Rue, and Geoffrey J. Smith
Institute of Marine Sciences, University of California at Santa Cruz, Santa Cruz, California 95064

What controls the iron mosaic in the CUZ?



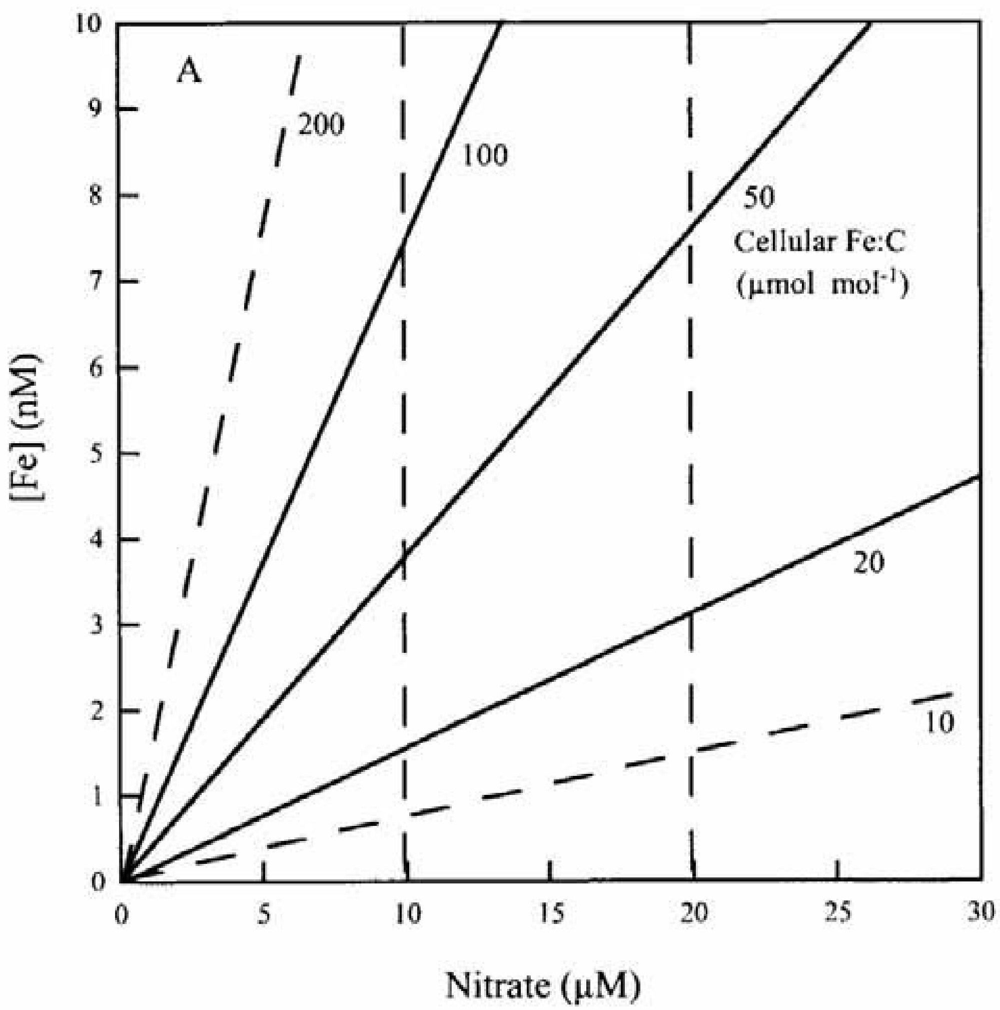


Low iron in areas that have:

1. Narrow shelf width
2. Low riverine input

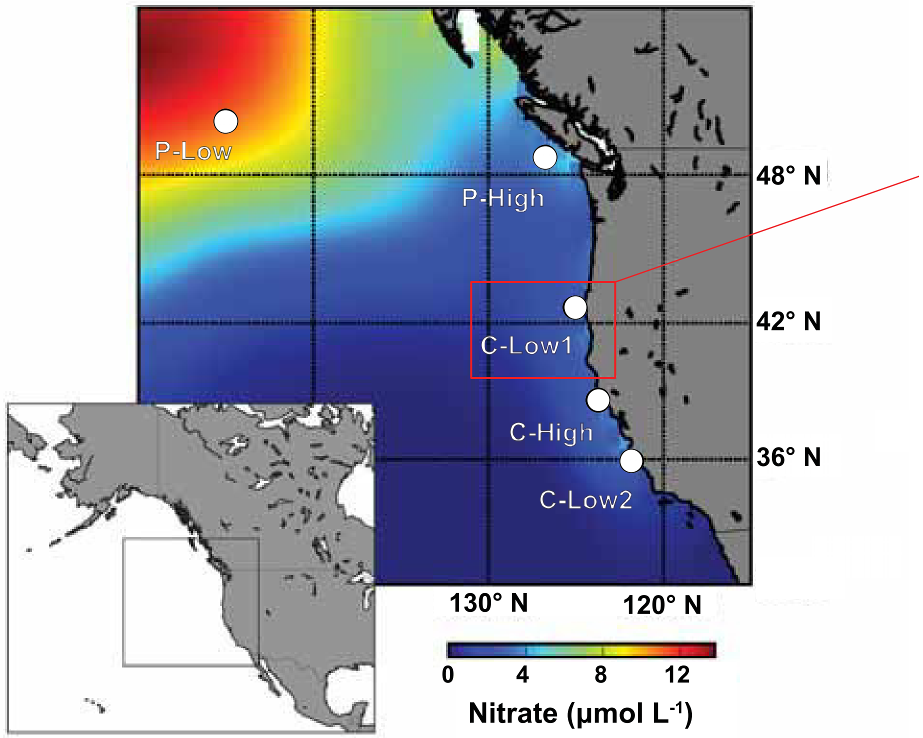
Parker 2016, Biller *et al.* 2013, Bruland *et al.* 2001, Hutchins *et al.* 1998

Iron limitation in coastal upwelling environments



The amount of iron required to fully consume a given amount of macronutrients can be predicted

Brulend et al. 2001

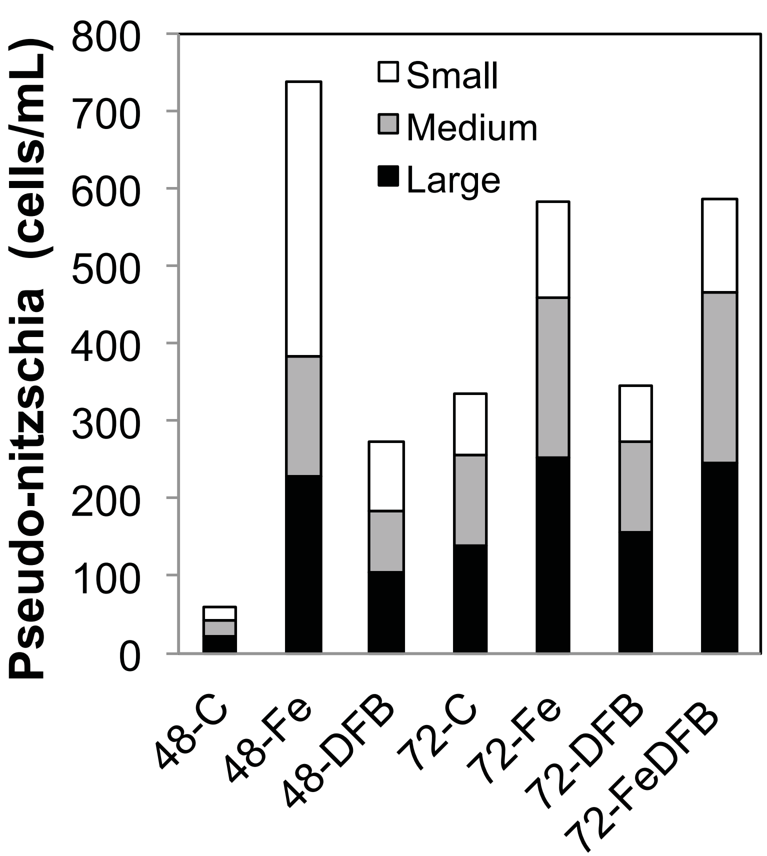


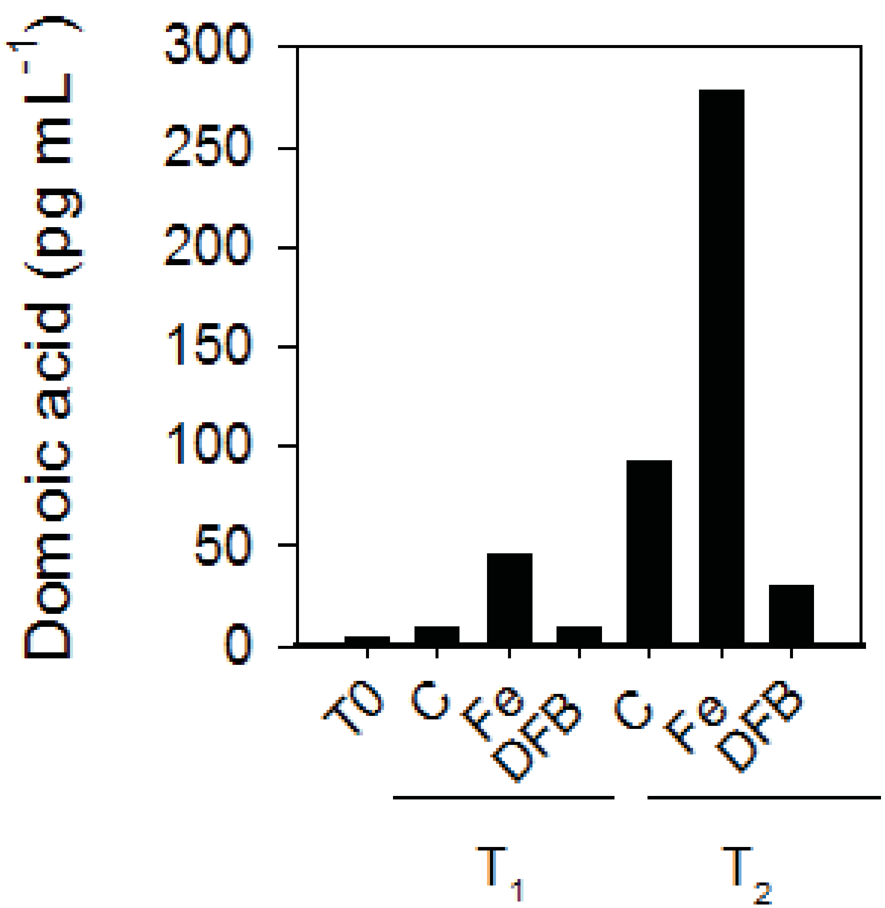
Site	$Fe:NO_3$ (nM:µM)	Description
C-High	5 : 20	Wide shelf, weak upwelling
C-Low1	1.2 : 20	Narrow shelf, strong upwelling
C-Low2	1.2 : 20	Simulated upwelling
P-High	8.4 : 20	NE Pacific coastal
P-Low	0.1 : 20	NE Pacific oceanic

Marchetti et al. JPhyc 2017

Iron addition increases *Pseudo-nitzschia* and DA

Site C-Low1





Cohen et al. in prep

Pseudo-nitzschia and domoic acid in Chilean waters

The occurrence of domoic acid linked to a toxic diatom bloom in a new potential vector: The tunicate *Pyura chilensis* (piure)

Américo López-Rivera[a,*], Maricela Pinto[a], Andrea Insinilla[a], Benjamín Suárez Isla[a], Eduardo Uribe[b], Gonzalo Alvarez[b], Mary Lehane[c], Ambrose Furey[c], Kevin J. James[c]

[a] *Marine Toxins Laboratory, Physiology and Biophysics Program, Biomedical Sciences Institute, Faculty of Medicine, University of Chile, Independencia 1027, Santiago, Chile*
[b] *Department of Aquaculture, Faculty of Marine Science, Northern Catholic University, Coquimbo, Chile*
[c] *PROTEOBIO, Mass Spectrometry Centre for Proteomics and Biotoxin Research, Cork Institute of Technology, Cork, Ireland*

Domoic acid production by *Pseudo-nitzschia australis* and *Pseudo-nitzschia calliantha* isolated from North Chile

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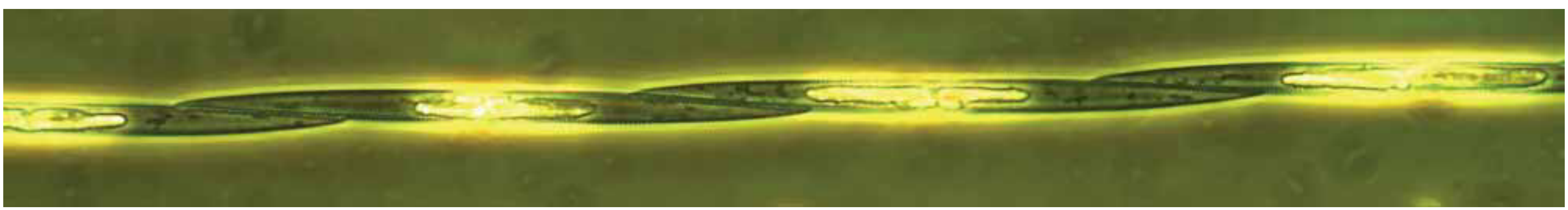
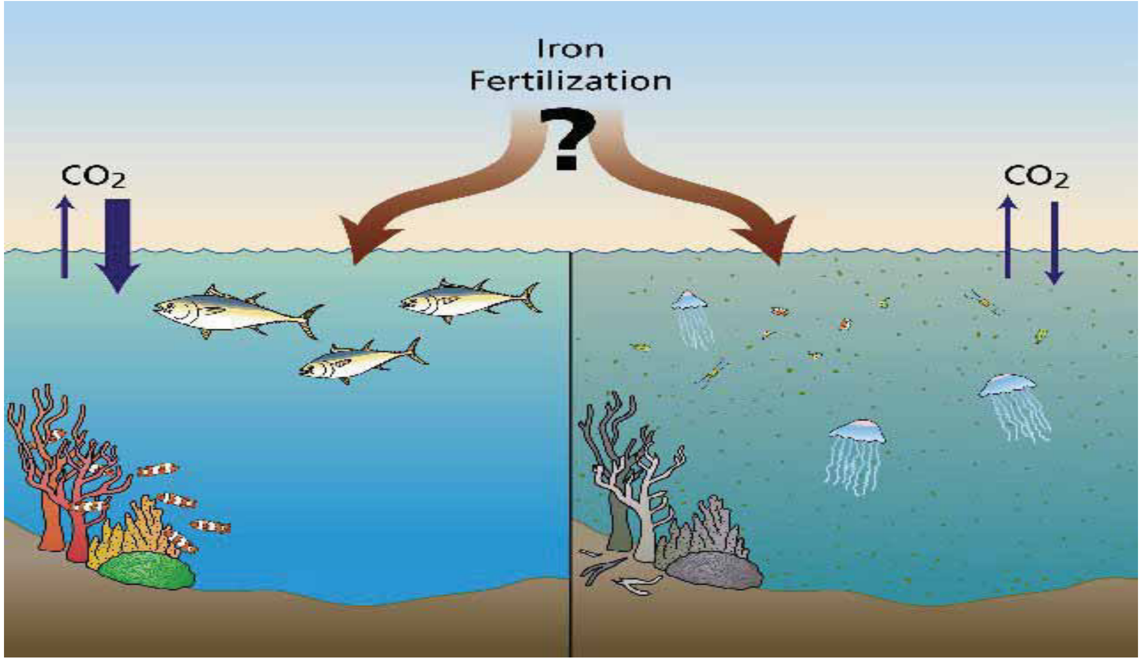
[a] *Centro de Investigacións Mariñas (Xunta de Galicia), Apto. 13, 36620 Vilanova de Arousa, Pontevedra, Spain*
[b] *Facultad de Ciencias del Mar, Departamento de Acuicultura, Universidad Católica del Norte, Larrondo 1281, Coquimbo, Chile*
[c] *Centre Mediterrani d'Investigacions Marines i Ambientals - Passeig Marítim de la Barceloneta, 37-49 E-08003 Barcelona, Spain*
[d] *Centro Universitario de Investigaciones Oceanológicas, Universidad de Colima, Km 20 Carretera Manzanillo-Barra de Navidad, Campus El Naranjo, Manzanillo, Colima, Mexico*
[e] *Laboratorio de Toxinas Marinas, Instituto de Ciencias Biomédicas, Facultad de Medicina, Universidad de Chile, Avenida Independencia 1027, Santiago, Chile*



Pseudo-nitzschia from waters near Coquimbo.
Image by Peter Von Dassow and Francisco Diaz (funded by FONDECYT)

Possible negative impacts of iron fertilization

- disruption of natural ecosystem balance
- decreased production in adjacent coastal regions
- deoxygenating the deep ocean
- generation of greenhouse gases more potent than CO_2
- shifts in phytoplankton composition to toxic species
- ?????



3.4. Dr. Humberto González : The Lohafex Iron-Fertilization Experiment in the S-W Atlantic Ocean (northern- ACC)

Why iron fertilisation experiments?

Historical framework

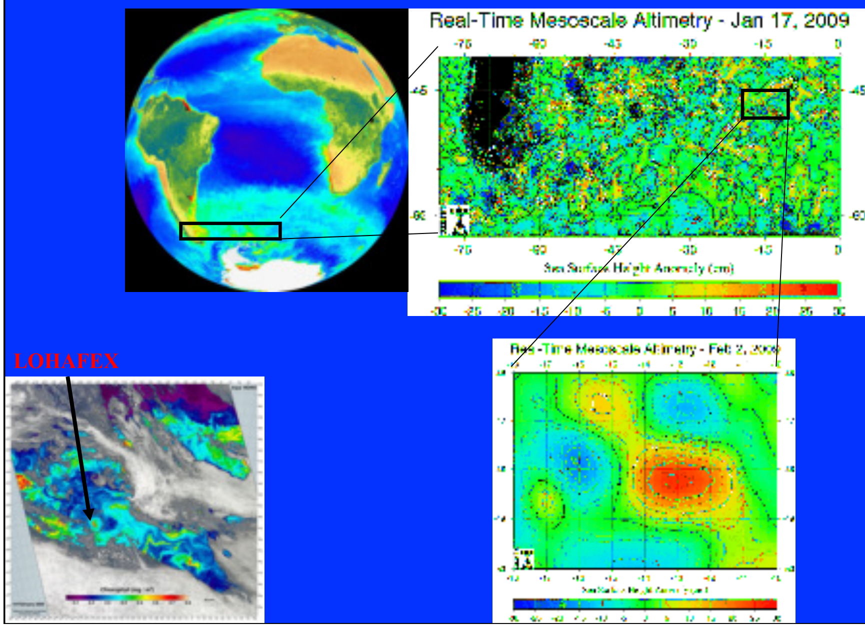
1.- Geo-engineering: CO_2 drawndown from the atmosphere and carbon export to the deep sea.. and…. Radiation Management Climate Engineering: Technology, Modeling, Efficacy, and Risks (Gordon Conference Sunday River, Newry, Maine, July 2017)

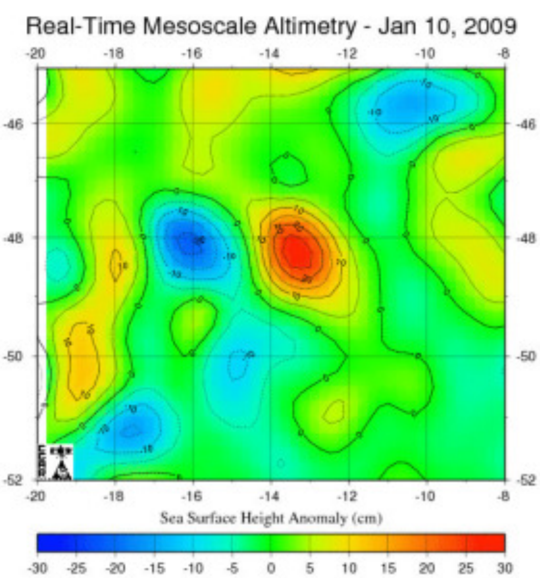
Ironex II, 1995; SOIREE, 1999; EisenEx, 2000; SEEDS, 2001; SOFeX, 2002; SERIES, 2002; SEEDS-II, 2004; EIFEX, 2004; CROZEX, 2005; LOHAFEX, 2009. ; HSRC, 2012. The Haida Salmon Restoration Corporation

Needs
•Quantification of the coupling of oceanic iron and carbon biogeochemistry (Boyd et al. 2007)
•To provide the scientific foundation to evaluate risks and benefits (Buessler et al. 2008) .
•Iron-fertilized diatom blooms may sequester carbon for timescales of centuries (Smetacek et al 2012). But…..Lohafex lesson was that this depends on the location.

LOHAFEX
Major goals were to explore for:
•Carbon export to the deep sea.
•The role of key species and/or functional groups.
•Changes in classical/microbial food webs?

Where?


Real-Time Mesoscale Altimetry - Jan 17, 2009
Sea Surface Height Anomaly (cm)
LOHAFEX


Real-Time Mesoscale Altimetry - Jan 10, 2009
-20
-18
-16
-14
-12
-10
-8
-46
-48
-50
-52
Sea Surface Height Anomaly (cm)
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30

Experiment details

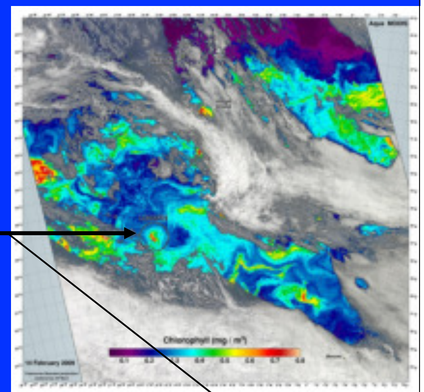
Site: A cyclonic eddy in the Southwest Atlantic (48^{o}S, 16^{o}W)

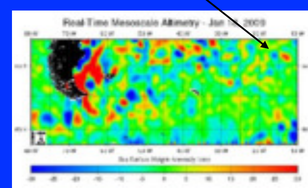
Duration: 27 January (Cape Town) to 6 March, 2009 (Punta Arenas)

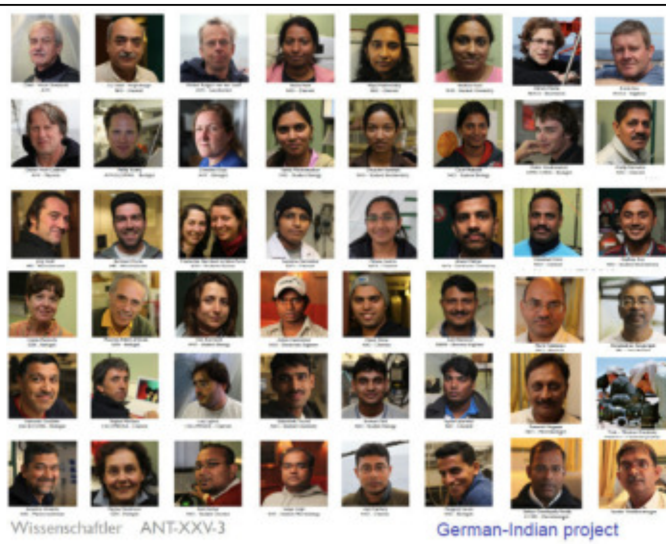
Area fertilized: 300 km^2

Total amount of ferrous sulphate used: 20 tonne (2 applications)

- Largest and longest OIF to date







The whole group

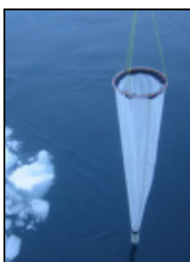
30 Sci from India
08 Sci from Germany
04 Sci from Italy
02 Sci from Spain
02 Sci from England
01 Sci from Chile
01 Sci from Holland
01 Sci from Belgium

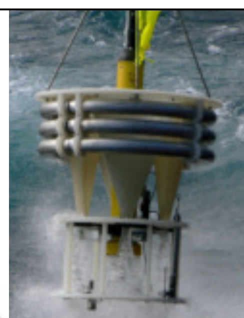
The zooplankton group

Objectives of the zooplankton group

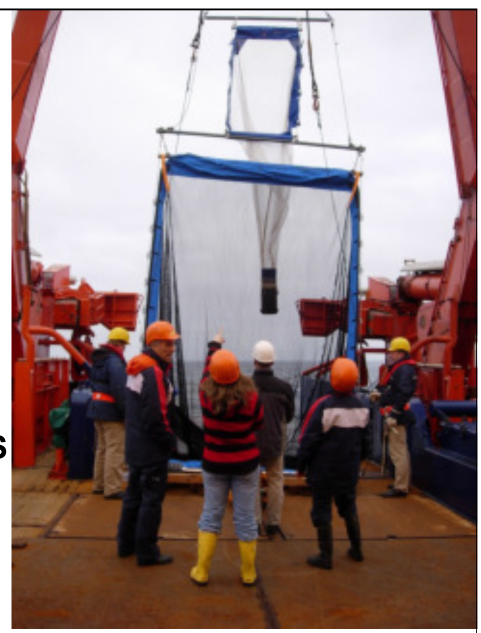
To evaluate:

- the structural and functional responses of consumers (species composition, distribution, faecal pellet production rate and grazing rate)
- The possible impact of zooplankton activity on the carbon flux (i. e. faecal pellet carbon export).





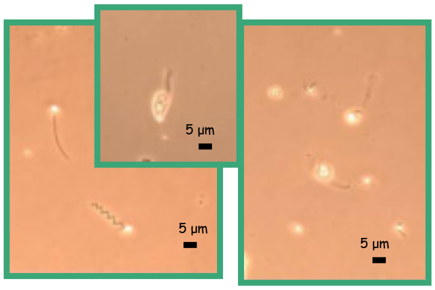
METHODS

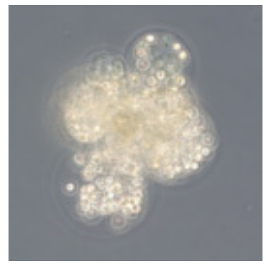


Differents zooplankton nets and “Pelagra” neutrally buoyant (Patrick Martin, Richard Lampitt), free-floating sediment traps

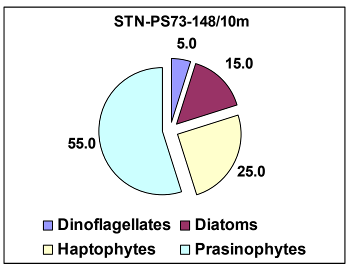
The autotroph component were mainly small flagellates, Phaeocyst colonies and large Ceratium.

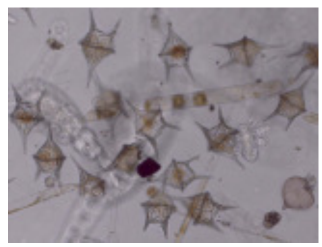
Phytoplanklogist were very disappointed!!!





Phaeocystis showed a highgrowth rate in culture, but was controled by zooplankton grazing

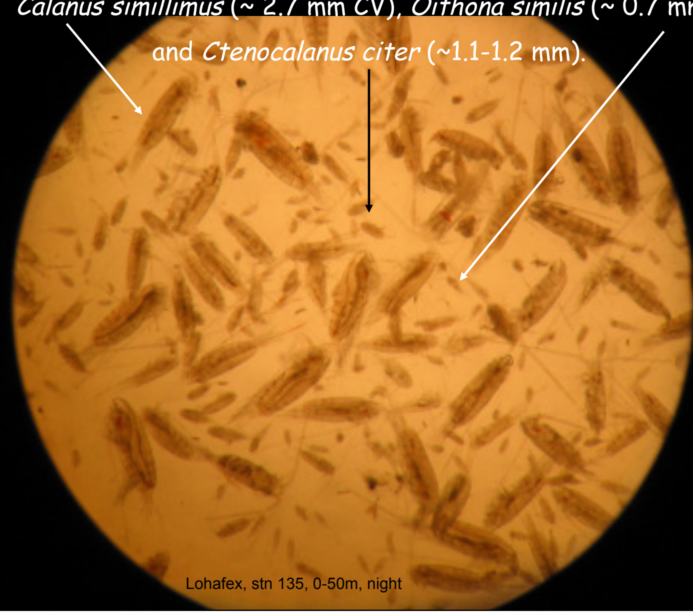




Ceratium was relatively abundant and probably escape from copepod grazing due to their large size

A typical picture of LOHAFEX zooplankton

Calanus simillimus (~ 2.7 mm CV), *Oithona similis* (~ 0.7 mm), and *Ctenocalanus citer* (~1.1-1.2 mm).



REMARKS

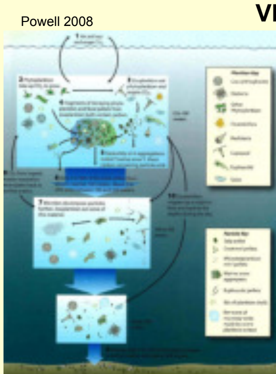
- "Simple" mesozooplankton communities characterized by low diversity and dominated by three copepod species: *Calanus simillimus* (biomass), *Oithona similis* (numbers), and *Ctenocalanus citer,* which are very different for size, behaviour, biological traits and life cycles.

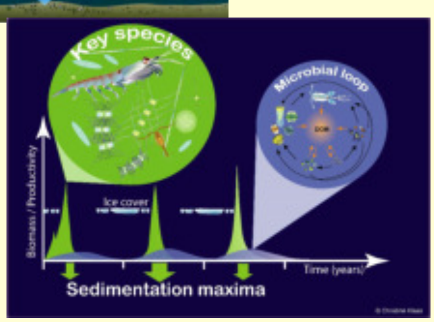
- The responses to iron fertilization appear to be weak and contradictory in total mesozooplankton standing stock.

- All this hints to a complex (interesting !) scenario and prompts investigations on different aspects of these populations/communities.

VERTICAL FLUX OF PARTICULATES : FAECAL PELLETS EXPORT AND THE ROLE OF ZOOPLANKTON IN THE BIOLOGICAL CARBON PUMP

Powell 2008





Pelagra: Neutrally buoyant trap

Three different hypotheses were tested to study the fate of the "surplus" biomass generated by the iron-induced phytoplankton bloom;

1) increased carbon export to deeper layers,
2) efficient recycling by increased microbial activity, and
3) removal by zooplankton grazing.

We only found support for the third hypothesis :

1) Despite a very low concentrations of silicic acid (~1 μM), diatoms showed a relatively high growth rate. However, the Chla-a conc. and phytoplankton biomass were relatively even during the whole expedition.

2) Zooplankton faecal pellets were very abundant in the water column.

3) The faecal pellets were loaded with remains of microzooplankton skeletons (tintinnids, forams shells, etc.) and phytoplankton.

4) Copepod faecal pellets were incubated onboard producing vigorous cultures of diatoms, phaeocystis and other phytoplankton..

5) Chemical analysis of copepod faecal pellets showed that this type of particles recycle Fe and probably contribute to maintain the PP and phytoplankton biomass in stady state within the fertilised patch.

Conclusions of LOHAFEX

Fundamental control mechanisms by the food web on the export fluxes can only be studied under *in situ* conditions. Iron fertilization experiments provide insights on the functioning of ocean ecosystems that cannot be acquired from in vitro observations of natural systems.

It could be shown that a growing phytoplankton bloom can be kept in check by zooplankton. The carbon cycle is hence not only determined by chemical factors. Clear top-down example

Mainly diatoms, which are protected against grazing, are able to transport large amounts of carbon to the deep sea (if there is enough silicid acid concentrations!!!).

LOHAFEX has in addition provided new insights on physical, chemical and biological processes that govern the functioning of planktonic ecosystems.

**For example: Zooplankton faecal pellets: Key particles in the carbon pump? In this case
Yes!!!.**

Closing thought

Some positive aspects

Scientifically handled experiments would provide important basic information on how pelagic ecosystems function……. that cannot be gained from mere in vitro observations.

Adding iron (single specific experiment) will not necessarily cause environmental harm.

Some negative aspects

I don´t agree in the fact that this type of experiments can be runned by companies with profit spirit.

The scientific community (in general terms) are reluctant and afraid on this type of artificial fertilization experiments.

Some unknown aspects:

My impression is that a mismatch between spatial and temporal scale for iron-enhanced primary production (small/medium scale processes) and fisheries recovery (large scale processes) would happen. Thus…. I have the impression that the OIF in Chile will not work to boost fish stock.

Multiple fertilization experiments would potentially cause environmental harm. For example, toxic phytoplankton blooms, oxygen decrease, changes in the nutrient stoichiometry, etc.

LOHAFEX has just confirmed that the carbon sequestration potential depends strongly upon careful choice of location.