

REPORT OF WORKING GROUP 22 ON IRON SUPPLY AND ITS IMPACT ON BIOGEOCHEMISTRY AND ECOSYSTEMS IN THE NORTH PACIFIC OCEAN

The final meeting of the Working Group on *Iron Supply and its Impact on Biogeochemistry and Ecosystems in the North Pacific Ocean* (hereafter WG 22) was held from 14:00–18:00 hours on October 24, 2010. The Co-Chairmen, Drs. Fei Chai and Shigenobu Takeda called the meeting to order and welcomed the participants (WG 22 *Endnote 1*). The draft agenda was reviewed and adopted (WG 22 *Endnote 2*). As WG 22 will be disbanded in 2010, the Co-Chairmen expressed appreciation to the WG 22 members and to all scientists who contributed to the workshop and the annual meeting session proposed by the Working Group.

AGENDA ITEM 2

Review of WG 22 activities

Iron biogeochemistry data sets in the North Pacific

Data collected by WG 22 during its term (2007–2010) include dates, position (station, depth), cruise #, iron measurements (size, analytical method). A map of the stations and a list of the data sources will be prepared. Dissolved iron data sets collected from Japanese scientists are being work on. WG 22 members (Drs. Takeda, Mark Wells and William Crawford) will contact other key scientists who have made iron measurements in the North Pacific in order to collect as much available iron data as possible. The database may include cruise/station information in which iron samples were collected and analyzed but have not been published.

Report on BIO Topic Session 2 (S2)

To review the past and ongoing laboratory, field and modeling studies on iron biogeochemistry and its impact on biological productivity and marine ecosystems in the North Pacific Ocean, WG 22 convened the BIO Topic Session co-sponsored by SOLAS (Surface Ocean-Lower Atmosphere Study) on “*Understanding the role of iron in regulating biogeochemical cycles and ecosystem structures in the North Pacific Ocean*” at the PICES-2010 in Portland, U.S.A. Participation included scientists from Canada, China, Germany, Japan, and the United States (WG 22 *Endnote 3*). There were 11 oral presentations focusing on iron biogeochemistry and the impact of iron (dust) on ecosystem dynamics, based on field observations, onboard experiments and numerical models. A summary of the session is included in the Session Summaries section of this Annual Report. Co-convenors (Drs. Angelica Peña, Toshiro Saino and Mark Wells) will ask invited speakers to submit extended abstracts with key figures and tables to be included in the WG 22 final report.

AGENDA ITEM 3

Basic questions and recommendations for the future of iron studies within PICES

The Working Group discussed basic questions regarding the future of iron studies within PICES. It was agreed that the next phase of iron research in the North Pacific will involve:

- ecosystem responses to changes in iron supply rate, amount, and pathway,
- dissolution or biological availability and residence time of suspended particulate Fe (from rivers, resuspended sediments, industrial combustion, and dust),
- mechanisms controlling chemical speciation of Fe in seawater and interaction of Fe binding organic ligands with particulate Fe,
- dynamics of Fe binding organic ligands, and
- interactions of iron with other stressors such as pH, Cu, *etc.*

For improving ecosystem models that include an iron cycle, more information is needed on:

- iron removal and recycling,

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- iron sources,
- physiology of co-limitation by iron and other parameters, and
- grazing on phytoplankton communities.

The Working Group agreed that they needed to have a better understanding of the iron supply before they can get ecosystems right, but they also need to get ecosystems right before they can get the iron concentration right.

WG 22 recommended that PICES should support:

- integration of regional studies on iron biogeochemical cycles and its ecosystem impacts,
- development of a North Pacific database for iron and related parameters,
- symposium/annual meeting sessions on the role of iron in regulating ecosystem responses to natural and anthropogenic forcing in the North Pacific, and
- model inter-comparisons activities.

WG 22 term of reference 5 “*Elucidate the role of iron as a potential regulator of harmful algal bloom (HAB) in coastal ecosystems of the North Pacific*” has not been fully taken up for discussion in WG 22. Therefore, it is suggested that this topic could be incorporated into the activity plans of HAB-S and/or FUTURE.

AGENDA ITEM 4

Publication of the WG 22 final report

A draft of the final report will be prepared for the PICES Scientific Report series in April 2011. The contents and assignment of the WG 22 final report were discussed (*WG 22 Endnote 4*). WG 22 will also prepare a review to be submitted to *Oceanography* that summarizes the key issues on iron sources and cycling in the North Pacific and the Working Group recommendations for future iron studies in the North Pacific.

AGENDA ITEM 5

Future activities related to the work of WG 22

- A workshop on Asian Dust and Ocean EcoSystem (ADOES), November 28–December 2, 2010;
- A joint Quebec–Shandong provinces workshop on ocean acidification in Qingdao, December 6–8, 2010;
- American Geophysical Union 2010 Fall Meeting, December 15:
 - B06 Linkages in biogeochemical cycles between the surface ocean and lower atmosphere over the Pacific Ocean (Convenors: Mitsuo Uematsu, William Miller, and Maurice Levasseur);
 - OS27 Biological, chemical and physical controls on the Gulf of Alaska ecosystem (Convenors: John Crusius, Rob Campbell, Yi Chao, and Fei Chai);
- A SCOR Working Group 131 Synthesis and Modelling workshop (Convenors: Philip Boyd and Dorothee Bakker), Summer 2011;
- Dr. Chai introduced a new consortium of In-Situ Iron Studies (ISIS) to resolve the impact of iron fertilization on marine ecosystems, to quantify its potential for removal of atmospheric carbon dioxide, and to improve our collective understanding of the changing ocean.

Proposal for a new working group

Dr. Maurice Levasseur (Canada) prepared a proposal for a new working group on “*Sensitivity of the North Pacific to Atmospheric Iron Deposition in a Low pH Ocean*” (*WG-22 Endnote 5*). This proposal was discussed at the COVE-AP meeting on Friday, October 22, 2010 where they decided to include the topic as part of the mandate of their own Working Group proposal on “*Ecosystem response to multiple stressors.*” COVE-AP felt that the topic of Dr. Levasseur’s proposal was too specialized and should be broadened to comprise other important issues that all PICES countries are interested in. WG 22 recommended that COVE-AP consider nominating a few of WG 22’s current members (*e.g.*, Levasseur, Wells, Chai, or Takeda) as potential members of the new working group to reflect the activities that have been accomplished by WG 22.

WG 22 Endnote 1**WG 22 participation list**Members

Fei Chai (U.S.A., Co-Chairman)
 William Crawford (Canada)
 Jun Nishioka (Japan)
 Hiroaki Saito (Japan)
 Shigenobu Takeda (Japan, Co-Chairman)
 Mark Wells (U.S.A.)

Observers

Emilie Brévière (SOLAS)
 Mike Dagg (U.S.A., BIO)
 Hidefumi Fujioka (Japan)
 Joaquim Goes (U.S.A.)
 Josiane Mélançon (Canada)
 Atsushi Tsuda (Japan)

WG 22 Endnote 2**WG 22 meeting agenda**

1. Adoption of agenda
2. Review of 3 years of WG 22 activities
3. Basic questions and recommendations for the future of iron studies within PICES
4. Publication of the WG 22 final report
5. Future activities related to the work of WG 22
6. Other business

WG 22 Endnote 3

**Participation list for BIO Topic Session (S2) on
 “Understanding the role of iron in regulating biogeochemical cycles and ecosystem structures in
 the North Pacific Ocean” (co-sponsored by SOLAS) at PICES-2010**

Emilie Brévière (Germany, SOLAS)
 Fei Chai (U.S.A.)
 Hong Chen (China)
 William Crawford (Canada)
 Jay Cullen (Canada)
 Huiwang Gao (China)

Josiane Mélançon (Canada)
 Kazuhiro Misumi (Japan)
 Jun Nishioka (Japan)
 Hiroaki Saito (Japan)
 Mark Wells (U.S.A.)
Others

WG 22 Endnote 4**WG 22 final report**

- Table of Contents
- Introduction (Fei, Takeda)
- Natural supplies of iron to the North Pacific
 - Atmospheric depositions, rivers and resuspended sediments (Nishioka, Wells, Crawford, Uematsu)
- Linkages between iron supply and ecosystem responses (Yamanaka, Fei)
 - Model improvements during the past three years
 - New ecosystem models with iron cycle
- Data sets of iron and related parameters in the North Pacific (Takeda, Wells)
 - Dissolved Fe, particulate Fe, total Fe, Fe(II), and organic ligands data
 - Station maps
- Basic questions and Recommendations for future activities of iron studies within PICES and connection with other international programs (Saito, Wells, Maurice, Fei, Takeda)

- References
- Appendices
 - List of iron measurements in the North Pacific,
 - Annual reports,
 - (Extended) abstracts from the workshop/session.

WG-22 Endnote 5

A proposal for a new expert group on *Sensitivity of the North Pacific to Atmospheric Iron Deposition in a Low pH Ocean*

Co-Chairs (proposed)

Maurice Levasseur (Laval University, Canada)
Gui-Peng Yang (Ocean University of China, China),
Philippe Tortell (University of British Columbia, Canada)
Shigenobu Takeda (Nagasaki University, Japan)

Proposed members

Martine Lizotte (Laval University, Canada)
Guangyu Shi (Institute of Atmospheric Physics, China)
Hui-Wang Gao (Ocean Institute of China, China)
Nadja Steiner (Fisheries and Oceans Canada, Institute of Ocean Sciences)
Lisa Miller (Fisheries and Oceans Canada, Institute of Ocean Sciences)
Michael Scarratt (Fisheries and Oceans Canada, Maurice Lamontagne Institute)
Takeshi Yoshimura (CRIEPI, Japan)
Mark Wells (University of Maine)
Jay Cullen (University of Victoria, Canada)
Andrew Ross (Fisheries and Oceans Canada, Institute of Ocean Sciences)

Central Objective

To determine how the predicted decrease in ocean pH will impact the response of the HNLC ecosystems to atmospheric iron deposition in the North Pacific.

Rationale

Twelve large-scale iron ocean fertilizations (IOFs) have been conducted so far in order to assess the impact of Fe deposition on primary production, carbon sequestration, climate-relevant trace gas emissions, and global climate (see reviews by de Barr *et al.*, 2005, Boyd *et al.*, 2007). These experiments have shown that Fe-dust can increase, albeit modestly, carbon sequestration, and significantly affect the production and flux of DMS and other trace gases to the atmosphere (see review MEPS 2008). In several of these experiments, the dynamics of DMS were tightly coupled to the growth and decline of prymnesiophytes such as *Emiliana huxleyi* and *Phaeocystis* spp. which tended to respond quickly to iron addition. These early blooms of prymnesiophytes also contributed to carbon production and sequestration by diverting a portion of the nutrients from the diatom blooms. Several prymnesiophytes are calcifying organisms, which are highly sensitive to variations in pH. Thus, the predicted decrease in oceanic pH could affect their response to iron availability. This could significantly alter the impact of atmospheric iron deposition on the North Pacific ecosystems.

The proposed working group would contribute to bring together the following ongoing activities, foster additional collaborations, and help secure funding; 1) In Canada, Nadja Steiner (IOS-DFO) and Maurice Levasseur (Laval University) are already leading a project on the co-effect of Fe and pH on the North-East Pacific Ecosystem, 2) Maurice Levasseur (Laval University) and Gui-Peng Yang (Ocean University of China) received funds from the Government of Quebec (Canada) to conduct a joint Quebec–Shandong workshop on the impact of ocean acidification on marine resources and biogeochemical cycles. The objective of the workshop is to establish a new Quebec–Shandong joint multidisciplinary 3-year research program on the impact of ocean acidification and the functioning of marine ecosystems, coastal resources, and biogeochemical cycles.

General Approaches

This important question should ideally be addressed through large-scale *in situ* experiments (addition of dust, Fe, Fe+CO₂, CO₂, control). But this represents a technical, financial, and logistical challenge probably out of reach. For this reason, we propose to start with the development of onboard and *in situ* mesocosms protocols. Such protocols should allow maintaining a constant pH level for the duration of the experiment (several days). These experiments should be conducted in the different HNLC regions. The target area for the PICES WG 22 could be the North Pacific HNLC waters.

Specific Approaches for WG 22

In Canada, part of this project could be associated with the ongoing Line P cruise program led by the Institute of Ocean Sciences (IOS) of the Department of Fisheries and Oceans (DFO). Additional days devoted to the project could be added to the two Line P summer cruises if we can find extra money (NSERC) to cover these extra days at sea. Chinese colleagues could explore the possibility of obtaining a special research permit to use Chinese dust during PICES experiments. Mesocosms have been developed for ocean pH studies by Dr. Ulf Riebesell. Dr. Lefvasseur contacted him for potential use of the mesocosms at OSP).

Contributions

The proposed working group would contribute to bring together the following ongoing activities, foster additional collaborations, and help secure funding; 1) In Canada, Nadja Steiner (IOS-DFO) and Maurice Lefvasseur (Laval University) are already leading a project on the co-effect of Fe and pH on the North-East Pacific Ecosystem, 2) Maurice Lefvasseur (Laval University) and Gui-Peng Yang (Ocean University of China) received funds from the Government of Quebec (Canada) to conduct a joint Quebec–Shandong workshop on the impact of ocean acidification on marine resources and biogeochemical cycles. The objective of the workshop is to establish a new Quebec–Shandong joint multidisciplinary 3-year research program on the impact of ocean acidification and the functioning of marine ecosystems, coastal resources, and biogeochemical cycles.

Related Article

Lefvasseur, M. 2011. If Gaia could talk. *Nature Geoscience* **4**: 251–252.