PICES, Iron Fertilization Experiment Panel (IFEP)
and N. Pacific SOLAS Planning Meeting Minutes

6 Oct 2001, 08:30-17:30

List of people in attendance (i.e., those that signed in on the attendence list):

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IOS, Institute of Ocean Sciences, Canada
NFRI, National Fisheries Research Institute, Japan
UBC, University of British Columbia, Canada
MLI, Maurice-Lamontagne Institue, Mont Joli, Quebec
SFSU, San Fransico State University, USA
NIES, National Institute for Environmental Studies, Japan
NMFS, National Marine Fisheries Service, USA

Agenda for meeting prior to 9:30:

8:30-8:45 Round-table introduction of attendees. Adoption of agenda.
Adoption of first Panel Report of IFEP held in Tsukuba, Japan (ST)
8:45-9:15 Review of relevant background work, e.g. eddy transport of iron.

Whitney: Where is HNLC water? ENSO factor.
Johnson: Iron distribution and possible transport to HNLC waters.
Chierici: CO_2 uptake/Fe enrichment in an eddy.

9:15-9:25 Review of time-table of international Iron Enhancement Experiments in the subarctic Pacific. (ML & PJH)

The following minutes only cover the meeting from my (NDS) arrival time (9:30) onward. Initials used throughout pertain to the names of people listed above.

9:30 PJH: Review of the July Canadian SOLAS iron enrichment planning meeting.

Four key questions:

1. What is the influence of Fe enrichment on trace gas production? This is the central novelty of the SOLAS Fe enrichment project.
2. What is the fate of carbon and carbon export? Also central to SOLAS because of CO_2 flux, and of key general interest because of poorly restrained export in previous iron enrichment experiments.
3. What is the plankton community response to Fe enrichment?
4. What happens with Fe chemistry, ligand production, and fate of Fe?

Later in the meeting we will refine the core measurements, and areas of responsibility will be assigned to appropriate personnel to oversee task groups according to science and technical requirements.
From the July workshop, we estimated 43 scientists on two ships. This will be reassessed as needed when we finalize the second ship and have firm berth counts.

FW: More important than question #1 is tracking the patch!
Everyone agreed.

ST: Summary of Japanese program (SEEDS)

Preliminary experiment Jun – Aug 2001, next experiment in Aug – Sep 2003
Done in western subarctic Gyre at 45-50°N, 160-165°E
Five goals of the overall project:

1. To measure the response of bacteria, phytoplankton, and zooplankton in terms of species, standing stocks and rate processes to the iron addition.
2. To measure the draw-down of CO2 and the flux of carbon export.
3. To study the interaction between biogeochemical processes in the surface water during the phytoplankton bloom and the production of climate gases in the atmosphere.
4. To study the relationship between phytoplankton (diatom) production and the higher trophic level (salmon).
5. To assess the influence of atmospheric iron supply on the characteristics of the plankton ecosystem in the western subarctic Pacific.

1st enrichment was rushed: Funded in Feb, ship allocated in Apr, experiment in Jun. Included only 16 scientists. Provided the most dramatic phytoplankton response of any HNLC Fe addition experiments done to date with > 20 mg chl m^{-3}.

AT: Goals of SEEDS

1. Fe on CO_2
2. Fe on biology

Done at 48.5°N, 165°E in center of western subarctic gyre from 28 Jun – 8 Aug.
Site survey was 28 Jun – 10 Jul (leg #1)
Observations and Injection (leg 2) started 13 Jul:
2.5 – 3 tons Fe tank and 2 ton SF_6 tank.
Iron release track was up and down along a North/South line generating a radiator pattern relative to the central buoy due to surface currents. Area was ~ 80 km^2.
Enrichment concentration was 7.8 nM Fe later measured at 2-6 nM by 1st survey.
Injection was completed on 19 Jul followed by two weeks of observations (more time would have been very useful).
SF6 was ~3X natural background on last day
Patch moved ~ 100 km beginning to end
Drogues followed patch for ~ 24 – 48 h, and were repositioned every two days.
1st observed response was Fv/Fm on day 3 using FRRF
Change in chlorophyll concentration seen on day 6
20 mg m^{-3} Chl on day 10 and stayed high through end of observations

AM: What was the background Chl
AT: 0.5 – 1.0 mg m^{-3}
PCO_2 draw-down measurable, from day 5-6, made for good and rapid patch tracking during daylight.
Fe decreased continuously from 1st day to last.
Inside to outside comparisons:

Chl (mg m^{-3}), 0.5 outside and 20 inside on days 9 – 14
PCO2 (ppm), ~400 outside and 250 inside (~170 ppm draw-down)
NO3 (µM), 17 outside and 3 inside (11.7 draw-down)

PJH: So NO3 not drawn down to 0?
AT: only to between 3 and 5 µM
PJH: Was there some other limiting nutrient?
AT: Depth of mixed-layer was 10-20 m
1% light ~45 m in beginning and 10-15 m in end. Maybe cells were light limited.
Large phytoplankton increased dramatically. Nano and pico plankton also increased, but less.
Diatoms dominated the response, primarily *Chaetoceros debile* with 2 d^{-1} growth rate. *Pseudonitschia pungens* was dominant before the Fe addition, but with 0.6 d^{-1} max growth, *C. debile* become dominant (almost exclusive) in the patch.

Mass flux into sediment traps increased inside the patch only slightly during days 10-14.
AT: The major flux event would probably occur later.
Fish – salmon were similar inside and outside the patch but small fish (only observed one time) were observed only in the patch.

Tentative conclusion of SEEDS:
1. Fe is limiting phytoplankton growth!
2. Western subarctic is more Fe sensitive than other HNLC regions
3. The presence of a seed population of a fast-growing diatom was key

BB: SiO_4 during the experiment?
HS : SiO_4:NO3 ratio increased over the experiment. Final SiO_4 concentration was ~5 µM.

HS: Fv/Fm response was only seen in mixed-layer peaking at day 9 then decreasing again.
The remaining NO_3 at the end of the experiment may be due to the return of Fe stress or light limitation from self-shading.
FW: Why the shallow mixed-layer depth? Temperature?
ST: Yes, temperature
HS: The area is usually stormy, but not this time.
Fv/Fm shows day/night oscillation.
Microzooplankton response from dilution assays:

growth ~ 0.57 d^{-1} on day 0
~ 0.73 d^{-1} on day 4
Day 7 showed gross phytoplankton growth at 0.86 and net growth at 0.7 d^{-1} so this suggests that the grazing increase is primarily on smaller cells not feeding on diatoms.

It was foggy during most of the experiment, so no good satellite data.
ST: Will there be an airplane for 2002 eastern gyre Fe experiment? [to fly under clouds for ocean color]
PJH: No. That was cut from the budget.

10:52 YN: Mass flux of SEEDS 2001

Things measured included PCO_2, water color & chemistry, DMS, and hydrocarbons
Samples currently being processed include PSi, POC, and PIC
Used Knauer type 8-cup sediment traps for each depth on three different strings

1. reference, outside patch used 20, 40, 60, & 100 m traps
2. Inside patch used 40, 60, 100, and 200 m traps.
3. Center buoy had just a 20 m trap.

Inside trap was recovered every two days. Outside recovered every 4 days.
The inside traps followed patch most of the time, but some variability in data is likely associated with time spent out of the patch.

200 m trap contained 1/2 to 1/3 the material of the shallower traps.
Max flux was on days 11-12
Traps inside patch showed ~ 2X the flux of the reference traps, although both reference and inside traps show an increased flux over the duration of the experiment. Most of the material in all the traps was fecal pellets, not flocks of ungrazed phytoplankton.

FW: Was peak flux at day 11-12 indicative of diatom sinking?
AT: flux at different depths followed zooplankton distribution more than different phytoplankton sinking rates.
Compared to station KNOT (typically 1000 mg m^{-2} d^{-1}) SEEDS was similar later in the experiment although SEEDS had higher percentage of zooplankton.
CSW: Why the smaller traps?
YN: That was what was already available.
AM: Copepod numbers?
AT: Measured wet weight which increased in surface but decreased at depth.

11:10 IK: On-board iron incubation.

In situ chlorophyll increased on day 6
In vitro chlorophyll also increased on day 6, but decreased again on day 8
10 µm diatoms dominated the bottles
NDS: were the bottles screened or in full sunlight?
IK: no screens. NO_3 was gone after day 7 in bottles.
Both Fe and temperature were important for growth

- Phytoplankton growth was highest in 9 & 13°C incubations.
- Phytoplankton growth was lower in 5 and 18°C incubations.
- 5, 9, & 13°C showed 1:1 NO_3:SiO_4 uptake.
- 18°C incubation showed only NO_3 uptake.
- Cells > 10 µm showed max growth at 9 and 13°C
- Cells 0.7 – 10 µm showed growth increase all the way to 18°C
- Summer temperature max is generally ~ 15°C

FW: Small cells used only NO_3 and not SiO_4?
IK: Yes, they used NO_3 and PO_4, not SiO_4.
PJH: The small cells were??
IK: We haven't looked yet.

ST: The Fe patch

0.03 – 0.1 nM background Fe with subsurface max ~ 600 m showing ~ 1.3 nM
SEEDS 2001 used 1740 kg of food grade $FeSO_4 \bullet H_2O$ (350 kg Fe)
Three types of analysis during experiment:

1. underway with Fe fish and Teflon pumps, 1.5 – 3 m depth
2. vertical profiling using Teflon Niskin on Kevlar (inside and outside the patch)
3. sections through the patch

Dissolved Fe < 0.22 µM outside and stayed low
Particulate < 0.1 – 0.4 at surface outside patch and increased over experiment (maybe aeolean Fe input occurred during the experiment)
Only used one injection of Fe. Prepared for two, but the second infusion was too much work and maybe not needed. 2/3 of Fe was used for first infusion and 1/3 saved for second and not used.
Fe decreased exponentially over time from the initial injection of ~7.5 nM. Had planned for 4 nM injection, but shallow and variable mixed-layer depth changed outcome.
Compared to SOIREE, Fe decreased more slowly (similar to IronEx I)
Fe increased primarily in colloidal (200 kDa – 0.2 µm) size fraction which was used up over time
Fe remained in the mixed layer. Fe in sediment traps not yet measured.
Particulate Fe increased and did not decrease over 13 days
By day 13 the patch was not apparent in dissolved Fe values but was apparent in acid-labile particulate Fe.
% of iron in each fraction:

day 2, 9% soluble, 43% colloidal, 48% particulate
day 10, 10% soluble, 2% colloidal, 88% particulate

Used food grade Fe to cut cost ($1 kg^{-1}) and because it would be non-toxic
Industrial grade was cheaper, but not as safe
Reagent grade was very expensive
KJ: Was size of initial iron addition the reason only one was needed?
PJH: What about a vertical chlorophyll profile to see if the Chl was sinking?
AT: Chlorophyll profile was similar to Fe, no observed sinking of chl.
FW: How did you time your work?
AT: 8-10 h for propeller survey
3-4 h for trap turn-around, moving center buoy, etc.
18-20 h total
PJH: Were buoys helpful?
ST/AT: Not exact, but helpful for identifying the general area.
We needed surface data every day, but couldn't always do it.
Maybe night surface monitoring with day experiments and measurements would be better.
A physicist might help predict patch drift, the center buoy was very helpful.
FRRF was helpful at night for tracking the patch. Photoquenching limited FRRF use for tracking during the day.
SF6 was important in the early phase, then FRRF and PCO2 in middle and end.
In the end, just looking at the water was best way to track the patch, but then, there were no storms to complicate matters.

PJH: Zooplankton grazing was heavy at the end?
AT: Zooplankton data was not comprehensive. Maybe 2X more, but not enough to reduce phytoplankton bloom. Not a big zooplankton grazing change. Biomass of zooplankton was stable.
PJH: What would you have changed?

AT: We would have stayed out longer!!!!!
BB: Was thorium measured?
IK: Yes. I do not have the details yet.
PJH: Would you reinfuse Fe (multiple additions) for a longer experiment?
ST: maybe not. But we would add more SF6
YN: SF6 was sparged into the water at the coast because of tank size limitations.
ML: Bacterial measurements?
AT: Abundance and size were measured.
BB: DOC measurements?
ST: They have not arrived yet.

CSW: Preparations at IOS

For SF6 a few things are done.
- bought 2 GCs for measurement
- building steel tank (at least 1)
- will visit Cliff Law in Nov.

For Fe, we are already measuring it.
- planning large tanks
- planning the pump/delivery system

Were planning on 100, 200, and 300 m traps. Maybe we will change depths now.
Droguing building and mapping software will be done before the test cruse [Feb 2002]

12:06 MW: 5 investigators on NSF proposal that is in review.

Some idea on the success of the proposal should be out in mid-December
They would like to take part in both the east and western gyre Fe enrichments.
[MW then gave many details on the NSF proposal which are covered in the minutes from the July planning meeting, available through me (NDS) if you don't have them]
The highlights follow:
Experimental Approaches:

A. Characterize the community and water chemistry within and adjacent to the Fe-enriched patch over a time period of several weeks (20-50 days) after the initial enrichment.
B. Test a series of sub-hypothesis (see below) using on-deck incubation studies.
C. Assess the phenotypic differences of newly-isolated dominant subarctic Pacific diatoms in laboratory culture experiments.
D. Model the planktonic response to changes in Fe concentrations and chemical speciation in the Fe-enriched patch over a time period of several weeks after the initial fertilization.

Specifics – Changing characteristics of the fertilized patch with aging:

1. Is there a floristic shift in the autotrophic community composition as the patch ages beyond 3 weeks, or do diatoms continue to dominate the autotrophic biomass throughout the ecosystem response?

2. What is the chemical speciation of Fe inside vs. outside the patch, and does this differ between the ESG, with very low Fe inputs, and the WSG having small sustained dust inputs from continental sources?
3. What is the net C transfer within the patch as it ages (rate of photosynthesis vs. heterotrophic bacterial activity)?
4. Does Fe enrichment cause a toxic bloom?
5. Has Fe enrichment caused a significant change in the inventories and turnover rates of N substrates (NO3, NO2, NH4, urea), and if so, what are the responsible factors?
6. Does Fe enrichment substantially increase particle transport to the deep, and does this export differ between the ESG and WSG?
7. Do comparatively rare and under-sampled heterotrophic dinoflagellates graze significantly upon diatoms in the patch, facilitating nutrient recycling in surface waters?
8. Is there an increase in virus-like particles in the aged patch?

PJH: Ship time. Notification for your UNOLS ship will be late, but feasible?
MW: Yes, feasible, but WE NEED TO KNOW YOUR DATE!
PJH: Can the ship change be seamless or must there be a gap?
MW: We need SF6 and Fe equipment and personnel of which there may not be duplicates and thus we would have to change over in port.

14:04 CSW: Should we establish a SOLAS component of PICES?

How should we define this component. Should it include Mexico which is not yet a member of PICES? Should we include Hong Kong as part of China?
Can we define a scope consistent with international SOLAS?
[After some discussion it was decided that SOLAS was more of a global issue and still in the start-up phase, neither of which provided strong impetus to establish a PICES working group based on SOLAS. Instead it was decided that an Iron working group made good sense since the iron work was underway and would benefit from a N. Pacific coordinated effort leading to conclusive results in the next three years or so. PJH would present the idea of an iron working group to the science board and if he received positive feedback, he would put together the terms reference later in the week.]
PJH: So what should the focus of the working group be?
CSW: Ecosystem response to iron additions and the downstream effects?
PJH: Look at the dust gradient east to west?
ML: We cannot model the subarctic N. Pacific without iron, so focus on adding Fe to models. Specific additions are not important, but model iron limitation and N_2 fixation etc.

PJH: So, what will we deliver? A symposium and special Deep-Sea research volume?
MW: Maybe two special issues?
ML: Maybe a special session at PICES to wrap it up?

PJH: I will present the idea to the science board. What about getting other nations involved? This is primarily only US, Canada, and Japan right now?
VS: I don't know how Russia could participate because of restrictions on big open ocean projects.
MW: One reason for working groups is to provide opportunities to other nations.

15:30 PJH: Planning session for Canadian Fe enrichment in 2002

CSW: How about a Japanese communication component?
ST: Copy all the emails to AT
PJH: We will have another planning meeting at the Hawaii Ocean Sciences meeting, tentatively the Sunday before (Feb 10)
PJH: The 2002 iron enrichment . . .
Key issues and questions [see preview at 9:30 above]
There will be 28 days of ship time so 14 days on patch
AT: We (Japanese ship) might have 7-10 days to fill the gap between the Canadian effort and the US effort depending on the timing. We are currently asking for ship time that would put us at Station Papa around the 1st week of August. Would have 16 people that could take over key measurements and follow the patch. Will come to Station Papa regardless of Canadian schedule, but a good match-up would be best.
KJ: Jun 24 – Jul 21 would be first option for Tully
Jul 22- Aug 18 would be second option for Tully.
But, with transit time the Tully would have to leave the patch at least 3 days prior to the end date. [So if Japanese could arrive closer to mid-July this might allow continuous occupation].
KJ: SF6 tank can be filled with Papa water on previous cruise for sparging prior to arrival on station for the iron enrichment.
MW: We will have a clue about our funding success in Dec and know for sure in Jan.
KJ: Ship time will be firm for Tully by Dec.
PJH: On to the details on core measurements
BC and YN: [Discussion on dogues and buoy types use during SEEDS 2001]
Japanese used 3 types of buoys:

1. GPS
2. ORBICON Satellite
3. RADAR reflector (worked best since rapid and constant location confirmation)

BC: not excited about radar buoy because of windage and drifting
AT: Used 2x10 m drogue with top at 3-5 m
YN: Used 4 sediment trap arrays. One to redeploy and the other to recover.
BC: Funding will be left to CSW for drifters, ARGOS cost, etc.
CSW: Will know about funding by Dec.
WC: There were very effective drogues used in IronEx. Their designs should be looked into.

KJ: Underway sampling of Fe and SF6 on one ship with discrete samples collected on the other will not work. No way. (Fe on both ships isn't feasible).
PJH: We will revisit this in detail later.
FW: The Tully will be have come out from its winter refit during which time the underway system will have been cleaned out.
MW: You will need trace-metal clean sampling on the second vessel. This better get figured out. Pumps work better than bottles.
ML: Aerosol people want 24 h uninterrupted gas sampling

Ship Logistics –
UNOLS availability will be know in one month.
Mexican ship is next possibility
Need a mid-ship boom on 2nd ship for underway sampling
BM and technical person to visit ships to verify usability?
Duplication of systems?
ML: DMS and food-web people need to be on the same ship
MW: If you end up with just one ship, you don't need to give up on all the iron chemistry because samples can be collected and processed on shore.

Roles: Who's responsible for what?
CTD Rosette – FW and IOS Water Properties Group
Fe purchase, storage, and setup – KJ (fertilizer grade Fe is \$250 ton^{-1})
SF6 – Mike Arychuck
Fe and SF6 tanks – Tim Soutar
Seawater loop on Tully – FW
Underway data acquisition – Doug Yellend
Fe sampling and analysis – NS
DMS – ML
Sediment traps – CSW
Buoys – BC / Marie Robert

[See the attached list of core measurements for the rest of the measurement task assignments]

Science Categories:
1. Fate of carbon and carbon export – CSW
2. Fe influence on gas – Bill Miller and Ulrike Lohmann
3. Fe ligand production and fate – Bill Miller
4. Biological responses – PJH
5. Baseline physics and Chemistry – Dave Crawford (starting Jan/Feb)

These scientist will need to oversee the details of each of these groups' measurements.

Cliff Law needs to be on the Tully.
PJH: Ship tax will be decided when we get the ship.

PJH, CSW, and ML will try to maintain a regular notification and update of the project status.

Updates of information since the meeting:

PJH: Since the iron enrichment efforts are well underway in the N. Pacific, and international cooperation is being well coordinated among the different nations involved, the Science Board at PICES decided that a formal Working Group was not necessary. The Iron Fertilization Experment Panel (IFEP) will continue (but will be renamed to omit the word “fertilization”) and will report to the BASS Task Team at PICES.

After much debate (among a few people) on an appropriate acronym for the subarctic NE Pacific iron enrichment experiment in 2002, the current consensus is SERIES, Subarctic Ecosystem Response to Iron Enhancement Study. This acronym is both a memorable word and includes the terms “ecosystem response” and “iron enhancement”. These are both important elements for some of us.

Feedback on this acronym is welcome. We should finalize an acronym soo.

Further ship update:

We are looking further into the Mexican ship that was presented as an option some time ago. It may be on the small side, but according to scientists that have sailed on it, it is a good and seaworthy platform, and it is relatively affordable. We are running the ship’s specifications past the Tully’s captain for comment and, if positive, will likely send Frank Whitney south to look it over.

The other ship option that is still presently open is a UNOLS vessel. We are expecting to be notified on availability my mid-November.