Report of the Eighth Annual Line P Workshop, Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, March 3 2015

Chaired by **Marie Robert**, Line P program manager, Institute of Ocean Sciences, Fisheries and Oceans Canada (IOS/DFO).

Introduction

Fifty ocean scientists and technicians met in March 2015 to share recent observations along Line P, as well as to present their current research interests and proposed future sampling plans. "Line P" is a 1400-km-long set of ocean stations off Canada's West Coast, monitored for over 50 years by weatherships and research vessels. It began with sampling from weatherships during their transits to and from Ocean Station Papa (OSP) at 50N, 145W, from the 1950s until 1981. Fisheries and Oceans Canada has financed ship time and core scientific programs since 1981. With more international and academic partners joining the program, leading to more diverse studies, it became useful to meet annually to compare insights and plan future programs. At the 1st workshop in February 2008 scientists met to discuss future experiments and techniques. The 2nd workshop in March 2009 focused more on scientific results, as well as on promoting collaborations and optimizing ship time and space. Since then the workshop has been very beneficial every year in allowing scientists to share their observations of conditions along Line P as well as in introducing new partners into the Program. This year the workshop is only held on one day since many usual participants will be part of an important Arctic cruise in the summer of 2015, greatly reducing the participation to the two Line P cruises of June and August. Therefore there are less "research plans" to present and no major cruise planning to do.

Marie Robert (DFO/IOS): *Overview of the Line P Program.*

Since quite a few new Line P Program or workshop participants were present this year, the full version of the "overview of the Line P Program" talk was presented, detailing the work that DFO employees perform on Line P cruises and giving important details for those who sail on a Line P cruise. The main points of interest were:

- Requests for security clearance and radioisotope use have to be started preferably three months prior to the cruise. Please contact **Marie Robert** if you want to participate in a cruise. Do NOT contact the DFO security clearance officer directly. Regarding radioisotope use please contact Michael Arychuk (Michael.Arychuk@dfo-mpo.gc.ca) or Kyle Simpson (Kyle.Simpson@dfo-mpo.gc.ca).
- Try not to send untrained people on a cruise on their own. But if you have to, at least give them as much information about the cruise as possible. Tell them about the cruise report expected of them, and let them know that demands like "dry ice" need to be addressed well before the end of the cruise.
- A reminder was given to the supervisors that new students or technicians need to be informed on how to behave at sea.
- There is a new milli-Q water maker on board the Tully with a 30 ℓ tank. We had some problems with it during the first cruise it was used so please come prepared.

- If you are going to be a regular Line P participant, please invest in your own raingear.
- Please respect the deadlines for the cruises and mainly for the workshop. Every year it's a problem.
- The 2015-2016 Line P cruises will be as follow:
    - 2015-09 will go from 7 June to 23 June 2015.
    - 2015-10 will go from 18 August to 3 September 2015.
    - 2016-01 will go from 8 to 22 February 2016.
- Regarding the Line P Website; the data from the August 2014 cruise (2014-19) are finally processed and the Webpage should be available soon.

Finally two slides were presented showing the conditions of "the Blob" – the patch of anomalous warm water present in the NE Pacific since about October 2013 – along Line P from February 2014 to February 2015.

Meghan Cronin (NOAA/PMEL), Jim Thompson, and Holger Klinck**:** *NOAA and UW/APL Station Papa Moorings.*

In January 2015, the UW Applied Physics Laboratory (APL) waverider mooring was turned around aboard the R/V Thompson. These modern day, high-quality wave observations continue the long record begun by the Ocean Weather Ships at station Papa. To be able to use the historical data in analyses with the modern day observations, the historical data were quality controlled by Belka et al. (2014). These OWS data can be accessed from the UW APL data archive: http://hdl.handle.net/1773/25570 . During this same January 2015 cruise, the NOAA Noise Reference Station (NRS) subsurface mooring was also deployed at Station Papa. The NRS Papa mooring is part of a network of NRS to monitor current levels and trends over the next several decades in ocean ambient noise and the abundance and distribution of marine mammals. On the upcoming June 2015 Line P cruise, we plan to deploy the 9th NOAA surface mooring and recover the 8th. The long time series from the NOAA surface mooring contributes to numerous studies, including analysis of the extreme warm anomaly of 2014, referred to as "the Blob", as well as analysis of the diffusivity at the base of the mixed layer, and analyses of the marine carbon cycle (see presentation by Fassbender).

For information and data from the NOAA surface mooring and the subsurface ADCP mooring, see: http://www.pmel.noaa.gov/ocs/Papa/.
For information and data from the biogeochemical sensors on the NOAA surface mooring see:
http://www.pmel.noaa.gov/co2/story/Papa
For information and data from the UW/APL waverider mooring, see:
http://www.apl.washington.edu/projects/station_papa/summary.html
For information and data on the NOAA Ocean Noise Reference Stations, see:
http://bioacoustics.oregonstate.edu/project/noaa-ocean-noise-reference-station-network

All data from OceanSITES time series reference station moorings are publicly available. For more information on the global network of OceanSITES reference stations, see: http://www.oceansites.org/.

Ken Johnson (MBARI), Josh Plant, Luke Coletti, Hans Jannasch, Carole Sakamoto, Steve Riser, and Dana Swift**:** *Observations at (near) Station P with profiling floats and chemical sensors.*

Six APEX profiling floats with biogeochemical sensors were deployed at Ocean Station Papa (OSP) between August of 2008 and June of 2013. The standard Sea-Bird Electronics SBE 41 CTD payload on these Teledyne Webb floats was augmented to include optical nitrate and oxygen sensors (Körtzinger, 2005). In addition, floats 6400 and 7601 were equipped with WetLabs FLBB optical chlorophyll fluorescence and backscatter sensors. The floats profile from 1000 m to the surface every 5 days and make chemical measurements at 60 depths. The latest generation of floats can make ~280 profiles = 4 year life. Here, we briefly review the application of this data set to compute Net Community Production in the vicinity of OSP. The array of floats allows us to examine interannual variability, the seasonal cycle, and variability between floats operating simultaneously.

John Smith (DFO/BIO), Robin Brown, Bill Williams, Marie Robert, Richard Nelson, and Bradley Moran**:** *Arrival of the Fukushima radioactivity plume in North American continental waters (presented by Bill Williams).*

The large discharge of radioactivity into the northwest Pacific Ocean from the 2011 Fukushima Dai-ichi nuclear reactor accident has generated considerable concern about the spread of this material across the ocean to North America and its transport to the eastern North Pacific. Time series measurements of ^{134}Cs and ^{137}Cs in seawater revealed the initial arrival of the Fukushima signal by ocean current transport at a location 1500 km west of British Columbia, Canada in June, 2012, about 1.3 years after the accident. By June, 2013, the Fukushima signal had spread onto the Canadian continental shelf and by February, 2014 had increased to a value of 2 Bq/m^3 throughout the upper 150 m of the water column resulting in an overall doubling of the fallout background from atmospheric nuclear weapons tests. Adjusted circulation model estimates that match our measured values indicate that future levels of Fukushima ^{137}Cs off the North American coast will likely attain maximum values of 3-5 Bq/m^3 by 2015-2016, before declining to levels closer to the fallout background of about 1 Bq/m^3 by 2021. The increase in ^{137}Cs levels in the eastern North Pacific from Fukushima inputs will likely return eastern North Pacific concentrations to the fallout levels that prevailed during the 1980s, but does not represent a significant threat to human health or the environment.

Lisa Miller (DFO/IOS): *Acting locally and thinking globally: inorganic carbon on Line P in relation to other ocean time series.*

With 40 years' worth of data, the inorganic carbon time series at Station P is now long enough to confidently identify a climate change signal. Dissolved inorganic carbon concentrations are clearly increasing while pH is decreasing. A recent compilation of data from ocean time series stations around the world found that the trends in pH and pCO_2 in the eastern North Pacific are similar to those in the rest of global ocean.

Andrea Fassbender (NOAA): *New approaches to study the marine carbon cycle: results from seven years of daily observations at Ocean Station Papa and the Kuroshio Extension Observatory.*

The accuracy of climate projections depends heavily on our ability to constrain the impacts of ocean warming and acidification on the marine biogeochemical cycles. In particular, there is significant interest in determining how climate change may influence the efficiency of ocean CO_2 uptake. In order to understand how ocean carbon uptake my change in the future, modern reference points for the marine carbon cycle are needed in which the processes driving air-sea CO_2 exchange are resolved. The goal of this work is to contribute quantitative, modern reference points for carbon cycling in two regions of the North Pacific Ocean using autonomous inorganic carbon sensors. Seven years of *in situ* CO_2 measurements from the Kuroshio Extension Observatory and Ocean Station Papa moorings were used to evaluate the drivers of mixed-layer carbon transformations using a time-dependent mass-balance approach. The complex interplay of biology, physics, and chemistry in these regions determines the annual ocean carbon uptake as well as the potential carbon sink sensitivities to ocean warming and acidification.

Philippe Tortell (UBC), Nina Schuback, and Lindsay Fenwick**:** *Trace gas and primary productivity measurements along Line P. Recent advances and future research goals.*

We continue to develop automated, high through-put methods to trace gas analysis and primary productivity measurements along the Line P transect. We have put significant efforts into an automated laboratory-based GC-MS method for CH_4 and N_2O analysis in discrete seawater samples. This method now enables us to rapidly process hundreds of samples, achieving low detection limits and high accuracy and precision. As a demonstration of the utility of this method, we present depth profiles of CH_4 and N_2O obtained from the 2015 Feb. Line P cruise. Within less than one week of returning from the cruise, we were able to run full CH_4 and N_2O depth profiles (in duplicate) for all of the major Line P station. The results show that surface waters are in equilibrium with the atmosphere, whereas significant production and consumption of N_2O and CH_4 is detected in sub-surface waters. A pronounced CH_4 source from the continental shelf is observed. We have also made significant advances in the deployment of automated methods (fast repetition rate fluorometry; FRRF) to examine phytoplankton photo-physiology, and infer rates of Gross Primary Productivity (GPP) based on calibrations with ^{14}C incubation data. We are now able to predict, with reasonable accuracy, GPP from FRRF data alone. This opens up the possibility of automated productivity estimates along Line P, with very high spatial resolution. Future plans for the UBC productivity and trace gas research program will be briefly presented.

Tereza Jarnikova (UBC): *Reduced Sulphur Compound (DMS/P/O) measurements along Line P – introducing OSSCAR.*

This talk will briefly summarize the motivation for making measurements of dimethylsulfide (DMS) and related compounds in ocean waters in order to examine the potential impact of biogenic sulphur compounds on climate processes. The Line P transect represents one of the longest available timeseries of DMS measurements globally and so provides an opportunity to study spatial and interannual variability in the production of this climate-active gas. A new instrument for measuring biogenic sulphur compounds, constructed by Elizabeth Asher at UBC, is presented. Called the Organic Sulphur Sequential Chemical Analysis Robot (OSSCAR), this

instrument represents an automated sample handling system that extracts seawater from the ship's underway transect and sequentially analyzes it using a pulsed flame photometric detector for three methylated sulphur compounds: DMS, dimethylsulfoxide (DMSO), and dimethylsulfoniopropionate (DMSP). This method represents a substantial reduction in analysis time over traditional methylated sulphur compound analysis methods as well as providing measurements of three related biogenic sulphur compounds simultaneously, which has the potential to give new insights into the oceanic biogenic sulphur web and the processes that lead to the formation of atmospheric DMS. The talk will include measurements made of all three compounds from a recent Line P transect made with the instrument during August 2014, as well as some biological implications of these results. The talk will conclude with a brief proposal of potential uses for the OSSCAR system in the future.

Amanda Timmerman (UVic): *Productivity comparison on Line P.*

Biological productivity is an important process controlling the export of carbon to the deep sea. By comparing methods, primary production rates can be more constrained. Determining if there are consistent differences between methods and applying them to historical data will increase our ability to compare datasets. My research along Line P is focused on comparing five methods: O_2/Ar ratios, triple oxygen isotope, $^{13}C/^{15}N$ dual incubations and ^{18}O incubations. Based on data that we have for Line P, there are two regimes when comparing new production and O2/Ar (net community production). Two distinct slopes emerge depending on whether the station had low or high new production rates. We want to examine whether these trends continue to hold with larger datasets. In August, we observed lower than average nitrate concentrations through out the euphotic zone along Line P. Production rates from ^{13}C and ^{15}N fall within the ranges from historical datasets. We did see there was increased new production at P16 compared to the other major stations. We hope to continue to have the opportunities to sample on future Line P cruises.

Aram Goodwin (UBC), Chris Holmden, Maureen Soon, and Roger François**:** *Neodynium isotopes in Line P.*

Each of the oceans is characterized by a different $^{143}Nd/^{144}Nd$. Pacific water has eNd values ~ -4, Atlantic ~ -12 and the Southern Ocean, comprising a mixture of Atlantic and Pacific water, is ~ -8.

Paleoceanographers are attempting to use this ratio to infer changes in ocean circulation in the past, as Nd is scavenged by marine particles that sink to the sediments.

Many observations noted that water masses often change their isotopic composition as they flow above continental shelves, without necessarily a net change in concentrations, suggesting that there is an exchange of Nd between seawater and shelf sediments. If this is true for Nd then that would also be true for other elements whose oceanic budget would have to be revised.

We are trying to confirm this mechanism in the Strait of Georgia. We know that the suspended solids of the Fraser River have an isotopic composition of ~-10. Therefore, the Pacific water (-4) has enough of an isotopic contrast so that any modifications to it as it flushes the strait, could be used to quantify these fluxes, and for the first time, *in situ*.

Preliminary measurements we obtained from the Fraser, the strait and Line P, from 2014 surprised us with an additional finding that may be equally important. A clear source of Nd with a very high isotopic value (-1) was evident in surface water in the vicinity of P1. As our

preliminary data is yet scarce, we cannot determine whether this source is associated with California Undercurrent or whether it is from the BC shelf. Regardless, eddies can carry these coastal high values to the Pacific and mix them with Southern Ocean values of -8 to give the Pacific's canonical -4.
The local settings of the Fraser River – Strait of Georgia – Line P provides an ideal setting to meticulously document all the above processes by which the oceans acquire their Nd isotopic composition for the first time, and data acquisition should be finalize before the end of this year.

Dave Janssen (UVic), Jay Cullen, Wafa Abouchami, and Steve Galer**:** *Dissolved Cadmium along Line P highlights water-column trace metal deficits.*

Dissolved cadmium (Cd) shows a nutrient-type distribution and a strong correlation with dissolved phosphate (PO_4^{3-}) throughout the world ocean. Stable cadmium isotope composition ($\varepsilon^{112/110}Cd$) reflects this nutrient-type control of dissolved Cd, with elevated $\varepsilon^{112/110}Cd$ found in surface water with depleted dissolved Cd, and lower $\varepsilon^{112/110}Cd$ found in deep water with elevated dissolved Cd. In contrast to data from other ocean basins, $\varepsilon^{112/110}Cd$ is remarkably uniform in subsurface Line P waters. Dissolved Cd is depleted relative to PO_4^{3-} in the oxygen deficient zone (ODZ) along Line P. Similar depletions of Zn, Cu, and Ag are observed in the subarctic northeast Pacific ODZ. We propose that the observed Cd depletions are driven by the formation of insoluble metal sulfides in the water column. The Line P Time Series presents a unique opportunity to further explore the depletions of trace metals in oxygen-depleted water, this possible removal mechanism, and the feedbacks between ocean oxygen depletion, trace metal removal, and surface ocean productivity.

Sean Crowe (UBC), Céline Michiels, Kate Thompson, Kohen Bauer, Roger François and Steven Hallam**:** *Linking microbial diversity to community metabolism in the North Pacific.*

Earth's biogeochemical cycles are underpinned by microbial metabolisms that catalyze most redox reactions at Earth's surface. The 'blueprints' to run these biogeochemical cycles are thus coded in the genomes of a vast diversity of microorganisms that populate the oceans, soils and the terrestrial subsurface. Rapid advances in DNA sequencing technology have enabled metagenomic studies that are yielding a wealth of information on the metabolic capacity of marine microorganisms. Translating this information into predictive models of biogeochemical cycling, however, remains a grand challenge in the Earth and life sciences. Coupling metagenomic studies with biological process rate measurements provides a means to translate metabolic capacity into rate equations and ultimately predictive numerical models. Our goal then is to conduct such coupled metagenomic and process rate measurements in the North Pacific and to integrate this information into 'gene-centric' predictive models of coupled carbon, oxygen, nitrogen, and sulfur cycling. Our initial measurements suggest the presence of microbial communities poised to catalyze sulfide oxidation or uptake. Previous metagenomic studies revealed the presence of sulfide oxidation capacity in the abundant and apparently ubiquitous Marine Group A bacteria. Together then, our process rate data and metagenomic information implicate microbial sulfur cycling as a cryptic yet key component of the metabolic network that underpins biogeochemical cycles in the North Pacific ocean. Future work will expand on the quantitative significance of these findings and integrate our measurements of dark carbon fixation, bacterial production, and nitrogen transformation pathways into the emerging picture of microbial diversity and metabolism along the Line-P transect.

John Dower (UVic), Akash Sastri, Ian Perry, and Moira Galbraith**:** *Zooplankton research along Line P – what have we learned and where might we go next?*

Zooplankton sampling along Line P extends back to about 1960, making it one of the longest zooplankton time-series in the world. Analysis of data from this time-series has produced a wealth of insights on zooplankton life histories and revealed links between community composition and both medium- (ENSO) and decadal-scale (PDO, NOI) climate forcing. Here we propose some additional lines of research that build on this historical framework while also taking advantage of new directions in the field. Potential lines of inquiry include (i) correlating in situ measurements of primary and secondary production along the offshore Line P gradient, (ii) quantifying interannual variability in the fatty acid profiles of key zooplankton species as a proxy for the food quality available to higher trophic levels, and (iii) exploring the importance of the microbial loop to copepods and larval fish (i.e. for their nutritional requirements) in coastal versus oceanic environments in the NE Pacific.

Sonia Batten (SAFHOS): *Sampling along a "Line P-like" transect with the Continuous Plankton Recorder.*

This presentation provides information on a ship-of-opportunity monitoring program that is analogous to Line P, in an effort to raise awareness of available data that could be used to assist with Line P research. The Continuous Plankton Recorder is towed behind a commercial vessel on a great circle route from the mouth of Juan de Fuca Strait to Japan. The program began in 2000 and three transects are usually sampled each year, normally in April, June and September. This transect is typically a little further north than Line P, and does vary between transects, particularly in spring and fall when significant storms may be avoided by the vessel. Once the instrument is returned to the lab, plankton are identified and counted on every 4th sample collected and all samples are archived. There are several hundred taxa in the database, but summary indices are presented here. The data have also been summarised into shelf samples (equivalent to Line P stations 1-4), central (equivalent to stations P5-12) and outer (equivalent to stations P13-26 and beyond to 150°W). With 15 years of sampling, because of the variability in transect timing between years, seasonal cycles can now be calculated and are presented here. Differences between regions are apparent, such as higher numbers of smaller zooplankton on the shelf, and a lengthier zooplankton biomass peak in the outer region. Time series of data for the summer transect (which consistently follows the great circle route) are also presented. Although the difference in seasonal timing between years confounds the interpretation, it can be seen that warm years favour more diatoms on the shelf and in the central region, while zooplankton biomass may be lower (and/or earlier). The CPR is fitted with a CTD-F instrument, which logs the along-transect, in situ temperature, salinity and chlorophyll-*a* fluorescence at the depth of the CPR (typically ~7m) every 5 minutes. Temperature-salinity plots are presented for the summer transects from 2007 to 2014, showing considerable inter-annual variability. The CTD data are available for download from the PICES website (http://www.pices.int/projects/tcprsotnp/CTD_data/CPR_CTD%20data.aspx), plankton updates are also available there, and data can be obtained from Sonia Batten. Samples from the archive can also be made available for specific studies.

Stephen Page (DFO): *Recent oceanographic drifter comparisons at Station P.*

Over the past year, we have been developing a cost-effective satellite-tracked surface water drifter to aid in understanding surface drift in the Douglas Channel / Kitimat region of British Columbia. These $300 drifters provide positioning data in real-time updated every 5 minutes, thus have the ability to provide high resolution insights into circulation pathways and drift statistics. On the recent February 2015 Line P cruise, 35 of our new style drifters were deployed at various stations along Line P. We also launched 3 other styles of traditional oceanographic drifters for comparison. We will present the 2 weeks of drifter progress since the recent deployment along Line P, as well as detailed behaviour of the other conventional drifters launched at Station P.

General discussion / Strategic planning:

Meghan Cronin opened the general discussion by re-bringing up the idea of a synthesis paper on "the blob" as seen at Station P and along Line P, to be led by Howard Freeland (Howard.Freeland@dfo-mpo.gc.ca) and herself (Meghan.F.Cronin@noaa.gov). If you are interested in contributing to the manuscript please contact them.

Philippe Tortell then presented a series of strategic planning questions which he also emailed to the Line P community the day before the workshop. What he hopes is for people to think about these, hopefully send answers to himself (ptortell@eos.ubc.ca) and to **Marie Robert** (Marie.Robert@dfo-mpo.gc.ca), and discuss answers / further questions during the ninth annual Line P workshop in 2016. One question on **Philippe**'s list was the need for a Line P steering committee / scientific advisory board. **Howard Freeland** gave an example when "screams from academics" helped save a DFO project and strongly encouraged the formation of such a committee, constituted of DFO and non-DFO investigators. On the other hand it was suggested that, since we already meet once a year for the annual workshop, important issues could simply be discussed at the workshop and a separate committee may not be needed. Another point discussed by **Philippe** is the new / emerging technologies which the academics could develop and the Line P Program could deploy and test. He is hoping that a collaborative effort from the Line P community could help keeping **Ken Johnson**'s (MBARI) float program alive in the North Pacific. **Philippe** also mentioned how, from his point of view, the Line P program should not be treated independently from the La Perouse, Strait of Georgia and High Seas Salmon programs. All these programs are essential to oceanographic research in the North Pacific and they can all complete each other. More effort should be made to let the scientific community know about these other programs and have outside scientists gather data on all these cruises.

Howard Freeland brought up the point that, even though it's a good idea to plan for the future, we have to keep in mind that the Line P program could be shut down at any time, just as the Contaminants section of DFO got shut down two years ago. **Ken Johnson** suggested being pro-active and visible BEFORE potential cuts occur.

Throughout this conversation it was pointed out that next year will be the 60th anniversary of Station Papa. This provoked all kinds of ideas for celebratory actions in 2016. **Philippe Tortell** suggested that a special session be held at the next PICES meeting, as well as the Ninth annual

Line P workshop to occur just before/after the PICES meeting so that people attending the meeting (thought to take place in San Diego, California) could then attend the workshop. **Angelica Peña** suggested that a public lecture could be presented all across Canada, in a similar fashion as the "CMOS speaker of the year", but the lecture would be presented at the various venues, not a specific speaker. The lecture could first be presented at the 2016 Line P workshop, and then various Line P collaborators could give the talk in their own hometowns. **Philippe** proposed the Vancouver Public Aquarium as an example. **Meghan Cronin** suggested receiving congratulatory letters from national and international partners and organizations to enhance the importance of the program. **Christina Schallenberg** introduced the idea of having a "Line P panel" at next year's University of Victoria IdeaFest.

Finally a quick note to say that many key players had already left the workshop when we started this general discussion. Hopefully next year the general discussion can take place during the "core hours" of the workshop so that more people can attend. We could hopefully then use a second day if needed. Please accept my apologies if I forgot to mention some key points or if I misinterpreted what was said during the discussion.

Marie Robert.