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Proceedings of the Workshop on the Role of the Continuous Plankton Recorder in Current and Future DFO Monitoring Programmes

12 – 13 December 2006
Bedford Institute of Oceanography
Dartmouth, NS

Erica Head[1] and Michael Chadwick[2]
Meeting Co-Chairs

Compte rendu de l'atelier sur le rôle de l'enregistreur continu de plancton dans les programmes de surveillance actuels et futurs du MPO

Les 12 et 13 décembre 2006
Institut océanographique de Bedford
Dartmouth (N.-É.)

Erica Head et Michael Chadwick
Coprésidents de l'atelier

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Foreword

This workshop was not carried out as a formal Department of Fisheries and Oceans (DFO) Science Advisory process, but was as a result of a report of the DFO Science Monitoring Implementation Team "Aquatic Monitoring in Canada" (CSAS Proceedings 2006/003). The objective was to evaluate the role of Continuous Plankton Recorder sampling in ongoing monitoring activies, with a view to providing advice to Science Managers on the potential for expansion of the programme in future, for example, by starting new routes in undersampled areas (e.g. the Gulf of St. Lawrence, the Arctic, the Great Lakes). Because it is of interest related in the advisory process, this workshop report is being documented in the Canadian Science Advisory Secretariat (CSAS) Proceedings series.

The purpose of these proceedings is to archive the activities and discussions of the workshop, including research recommendations, uncertainties, and to provide a place to formally archive official minority opinions. As such, interpretations and opinions presented in this report may be factually incorrect or misleading, but are included to record as faithfully as possible what transpired at the meeting. No statements are to be taken as reflecting the consensus of the meeting unless they are clearly identified as such. Moreover, additional information and further review may result in a change of decision where tentative agreement had been reached.

Avant-propos

Cet atelier ne s’inscrivait pas officiellement dans le Processus consultatif scientifique du ministère des Pêches et des Océans (MPO), mais il faisait suite au rapport intitulé « Surveillance aquatique au Canada » produit par l’Équipe de mise en œuvre de la surveillance mise sur pied par la Direction des sciences du MPO. Il avait pour objectif d’évaluer le rôle du programme d’échantillonnage au moyen des enregistreurs continus de plancton dans les activités de surveillance continue, dans le but de renseigner les gestionnaires des Sciences sur la possibilité d’étendre ce programme à l’avenir, par exemple en établissant de nouvelles trajectoires d’échantillonnage dans des zones où l’échantillonnage a été insuffisant jusqu’ici (p. ex. le golfe du Saint-Laurent, l’Arctique, les Grands Lacs). Comme il revêt un intérêt pour le processus consultatif, ce rapport scientifique est versé dans la collection des Comptes rendus du Secrétariat canadien de consultation scientifique (SCCS).

Le présent compte rendu fait état des activités et des discussions qui ont eu lieu à la réunion et contient notamment les recommandations de recherche formulées et les incertitudes soulevées; il sert aussi à consigner en bonne et due forme les opinions minoritaires officielles. Les interprétations et opinions qui y sont présentées peuvent être incorrectes sur le plan des faits ou trompeuses, mais elles sont intégrées au document pour que celui-ci reflète le plus fidèlement possible ce qui s'est dit à la réunion. Aucune déclaration ne doit être considérée comme une expression du consensus des participants, sauf s'il est clairement indiqué qu'elle l'est effectivement. De plus, des renseignements supplémentaires et un plus ample examen peuvent avoir pour effet de modifier une décision qui avait fait l'objet d'un accord préliminaire.

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ABSTRACT

Ecosystem monitoring is a mandate of the Department of Fisheries and Oceans (DFO), and monitoring the base of aquatic food chains, the plankton, is important in any monitoring programme. Plankton species distribution and abundance have been monitored in the NE Atlantic and North Sea since the 1930s using Continuous Plankton Recorders (CPRs) and inter-decadal changes have been observed that can be attributed to changes in climatic conditions, which have had repercussions at higher trophic levels. CPRs are towed by ships of opportunity and sample along commercial routes at monthly intervals. Plankton samples are collected at a fixed depth (~7 m) over discrete 18.5 km transects, and are analysed at the Sir Alister Hardy Foundation for Ocean Science (SAHFOS), which operates the CPR surveys in the N Atlantic and N Pacific. Routes between Iceland and Newfoundland and between Newfoundland and the New England Coast have been run since 1959, and this sampling is now part of the Atlantic Zone Monitoring Programme (AZMP). In a recent national review of DFO monitoring activities, the AZMP was held up as an example of how DFO might implement monitoring programmes in other Canadian waters. The purpose of the CPR Workshop, held in December 2006 at the Bedford Institute, was to discuss the reporting of CPR data in AZMP, to compare results of conventional and CPR sampling over the period of operation of the AZMP (1999-2004), and to discuss the efficacy of setting up new CPR routes to expand ecosystem monitoring of Canadian waters.

RÉSUMÉ

La surveillance des écosystèmes fait partie du mandat du ministère des Pêches et des Océans (MPO) et dans toute surveillance de cette nature il importe de suivre de près la base des chaînes trophiques aquatiques, le plancton. La répartition et l'abondance des espèces de plancton font l'objet d'une surveillance au moyen d'enregistreurs continus de plancton (CPR) dans l'Atlantique Nord-Est et la mer du Nord depuis les années 1930. Au fil des décennies, elles ont connu des changements, pouvant être attribués à l'évolution des conditions climatiques, qui ont eu des répercussions sur les niveaux trophiques supérieurs. Les enregistreurs continus de plancton sont remorqués par des navires auxiliaires occasionnels et ils échantillonnent le plancton à intervalles mensuels réguliers le long de trajets commerciaux. Ces échantillons sont prélevés à une profondeur fixe (~7 m) sur des transects séparés s'étendant sur une longueur de 18,5 km et ils sont analysés par la Alister Hardy Foundation for Ocean Science (SAHFOS), qui est chargée des relevés par CPR dans l'Atlantique Nord et dans le Pacifique Nord. On exploite des transects d'échantillonnage entre l'Islande et Terre-Neuve ainsi qu'entre Terre-Neuve et la côte de la Nouvelle-Angleterre depuis 1959 et cette activité d'échantillonnage font maintenant partie du Programme de monitorage de la zone atlantique (PMZA). Dans un récent examen national des opérations de surveillance continue entreprises par le MPO, le PMZA a été présenté comme un exemple que pourrait suivre le Ministère pour mettre en œuvre des programmes de surveillance dans d'autres eaux canadiennes. L'atelier sur les enregistreurs continus de plancton tenu en décembre 2006 à l'Institut océanographique de Bedford avait pour but de discuter de l'intégration des données de ces enregistreurs au PMZA, de comparer les résultats qu'ils ont donnés à ceux de l'échantillonnage classique sur la période d'application du PMZA (1999-2004) et de discuter de l'utilité de la mise en place de nouvelles trajectoires d'échantillonnage par CPR afin d'accroître la surveillance des écosystèmes dans les eaux canadiennes.

EXECUTIVE SUMMARY

Ecosystem monitoring is a mandate of the Department of Fisheries and Oceans, and monitoring the plankton, which are at the base of aquatic food chains, is an important component in any monitoring programme. For example, changes in the distribution and abundance of plankton species in the NE Atlantic, attributable to climate change, have been accompanied by changes at higher trophic levels (*e.g.,* North Sea cod abundance). On the Canadian Atlantic continental shelf, there have also been changes in species distributions, with an increasing abundance of Arctic species attributable to increased Arctic input to the shelf system. These changes have occurred over decadal time scales and have been observed by means of the Continuous Plankton Recorder (CPR) programme.

The CPR is a device towed by ships-of-opportunity on a monthly basis on routes throughout the North Atlantic and, with less regularity, in the North Pacific. The device collects plankton samples at a fixed depth (approximately 7 m) over discrete spatial intervals. The devices are installed and maintained by staff of the Sir Alister Hardy Foundation for Ocean Science (SAHFOS), who also analyse the samples and make the data available to the scientific community. The routes are funded by a variety of partners, one of which is DFO.

In the context of the idea of DFO setting up of monitoring programmes in new areas, it was decided that it would be timely to hold a Workshop to discuss the utility of CPR to such programmes. The main Workshop objectives were:

- To discuss the role of CPR sampling in current monitoring programmes.
- To examine the desirability for establishing new lines (e.g., Gulf of St Lawrence, Great Lakes, Arctic).
- To share information about CPR data use among current users and potential future users.
- To compare CPR data on plankton distribution and abundance to results obtained using other methods.
- To make recommendations about use of CPR in current and future DFO monitoring programmes.

The Workshop included talks that covered the following topics:

- A description of the world-wide CPR survey work, including technical details such as the sample counting methodology.
- A description of the existing DFO-funded east coast CPR programme, including information on the current costing, and cost estimates for additional lines (e.g., in the Gulf of St. Lawrence, the Great Lakes and to the Arctic).
- A description of the west coast CPR programme, including research highlights.
- A description of the Atlantic Zone Monitoring Programme, and the role of CPR within it.
- A comparison of assessments of biodiversity indices from CPR and net data.
- A comparison of trends in phytoplankton abundance using CPR, satellite and extracted chlorophyll data sets.
- Comparisons of zooplankton abundance trends for net data at fixed stations (HL2 and St 27) and on AZMP sections on the Scotian Shelf and CPR data.
- Spatial and temporal scales of variability on the Scotian Shelf in CPR and net samples.
- Seasonality of plankton on the Scotian Shelf and Newfoundland Grand Banks.

The Workshop also included discussions on the following topics:

- Should CPR be expanded to other regions? (e.g., Arctic, Great Lakes).
- What can we do to increase the public awareness of CPR data?

The results of these discussions lead to the following conclusions and recommendations:

- CPR is a robust, relatively inexpensive and consistent method for sampling the pelagic zone of marine ecosystems that is comparable to other conventional and more costly methods. However, these data should be viewed as complimentary of existing monitoring activities and not as a replacement without careful evaluation.

- CPR data are particularly useful for identifying mid- to long-term trends in community structure and for describing large biogeographic regions. In this context, it is strongly recommended that CPR lines be implemented in the Arctic. CPR data could be used to validate the numerous ecoregions that have been proposed for this area.

- Any CPR data to be used for examining long-term trends in abundance or community structure must be corrected for time of sampling (removing day-night effects) and for seasonal variability that may reflect the effects of catchability, behaviour, or ontogeny. The latter requires sophisticated statistical techniques for de-trending data.

- Implementation of CPR lines in small water bodies, such as the Gulf of St. Lawrence and Great Lakes, including Lake Winnipeg, must take into account the above-mentioned sources of variation, which may not be practical when using ships of opportunity.

- Regular reporting of CPR data should be part of the annual state of environment reports.

- A regular forum for the analysis of CPR data should be initiated within the aegis Atlantic Zone Monitoring Programme (AZMP), perhaps with additional reporting to the Fisheries Oceanography Committee.

- CPR does not provide any meaningful information on the abundance and distribution of gelatinous organisms like jellyfish, which appear anecdotally to be an ever-increasing component of the pelagic marine ecosystem.

- The resolution of species identification of decapods needs to be increased.

- A communications programme needs to be developed to explain to the public the value of CPR data in identifying long-term changes in the pelagic marine ecosystem.

INTRODUCTION

The Continuous Plankton Recorder (CPR) has been used since the early 1930s to study the distribution and dynamics of the near-surface plankton community in the North Sea, with the survey expanding west thereafter, reaching the NW Atlantic in 1959. The sampling survey is currently run by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS), located in Plymouth, UK. CPR is a low-cost sampling device that is deployed from ships of opportunity (e.g., ferries, cargo ships) and the goal is to have all routes towed at least once per month for every month of the year. When the ships reach their destinations the CPRs and the biological samples that are preserved within them are shipped back to SAHFOS; the former for maintenance and the latter for taxonomic analysis. Data products are available to the international scientific community. DFO, however, which currently contributes about 40% of the cost of the operation of sampling lines from Reykjavik to St. John's to Halifax to Boston, has a unique agreement with SAHFOS by which it receives the raw data. The data are generally available in December of the year following the sampling year (e.g., 2006 data will be available by December 2007).

In the NE Atlantic long-term changes in plankton community structure and the abundance and/or phenology (seasonality) of a number of individual species have been linked to changes in hydrographic conditions, which are themselves thought to be linked to the phase of the North Atlantic Oscillation (NAO) via it influence on circulation, wind stress and temperature. On the Canadian Atlantic continental shelf, detailed analyses of CPR data have been less numerous, and those that exist suggest that the effects of the NAO are not straightforward. This may be because in recent decades the system has also been influenced by increased influx of arctic water, caused by changes in arctic circulation. Over the same period there have been marked increases in levels of some phytoplankton and arctic zooplankton species, and decreases in levels of some temperate zooplankton species. Changes in seasonal cycles of abundance of individual taxa have also occurred. These changes have been discussed in terms of both environmental influences (e.g., water masses, circulation, stratification) and internal ecosystem processes (e.g., trophic cascade).

In a recent nation-wide review of aquatic monitoring activities in Canada chaired by Dr. Michael Chadwick, it was recommended that the number of CPR routes be expanded. The review suggested new routes in the Gulf of St. Lawrence, the Great Lakes and the Arctic, the latter using the Coast Guard ships that go north each year from either coast. It was within the context of this discussion that the suggestion for a CPR workshop came up. The Workshop would provide an assessment of the utility of CPR sampling and recommendations regarding the setting up of new lines.

A detailed assessment of the role of CPR within the Atlantic Zone Monitoring Programme (AZMP) was recently made as part of the AZMP Review of 1998-2003 (Pepin et al. 2005). The review noted the following advantages and disadvantages of CPR sampling.

On the positive side:

- Existing CPR data sets (and ongoing CPR sampling) provide the longest time series available, and allow assessments of long-term changes in plankton.
- CPR sampling provides monthly sampling over a large area, which would be otherwise prohibitively expensive.
- CPR devices are rugged and reliable, with a proven 90% success rate.
- CPR data are internally consistent and provide information to the species level for many zooplankton.

- Samples have been curated and stored since the 1950s.

On the negative side:

- CPRs are towed at a constant depth of ca. 7 m and some plankton are seldom found near the surface.
- CPRs sample through a small orifice and use a relatively large mesh size, so that large mobile plankton and very small plankton are not sampled efficiently.
- Sampling tracks may change over time, with changes in sampled assemblages.
- Samples are collected by day and night, and some species migrate vertically on a diel basis.
- Samples may be collected at different times of month, so that sampling may not be evenly spaced throughout the year.
- Some CPR taxonomic categories are not unique; for example, the category "Calanus 1-4" includes the young stages of three Calanus species.
- New taxonomic categories have been recognised over time, so that what appear to be new species occurrences may not be.
- The analysis/counting procedures are systematised such that actual counts are not made.

In the AZMP review it was concluded that CPR and conventional (net tow) sampling provide complementary data sets and that both are desirable elements in the programme. When the idea for a CPR workshop was discussed at the annual AZMP meeting in March 2006, it was also suggested that it could provide a forum for discussion as to how CPR data are currently used and reported on a routine basis and it was decided that the time was ripe for a comparison CPR and net sampling in AZMP, since there was now 6 years of data for which comparisons could be made. In particular, a list of topics was made to be addressed by the workshop:

1) If new funding were to be available from a new external source, would AZMP participants choose to establish new CPR lines (e.g., through the Gulf of St. Lawrence), or are there more important priorities within AZMP?
2) Do CPR and other sampling methods (e.g., net hauls for zooplankton, water sampling and satellite imagery for phytoplankton) show similar trends for the months and years for which AZMP data have been collected systematically over a broad scale (since 1999, Newfoundland Shelf; since 1997, Scotian Shelf)?
3) Do CPR and other sampling methods show consistent seasonal cycles in areas near the fixed stations (i.e., Stn. 27, off St. John's; Stn. HL2, off Halifax)?
4) Currently the amount of CPR data reported in the AZMP annual reports is limited to the annual abundance and seasonal cycles of a few species/categories in two regions, one east and one west of 45°W.

    - Is this division of the data appropriate or should spatial divisions take more account of topography and hydrography?
    - Should we include more or different species?
    - Should we include measures of diversity and/or community structure?

The date for the CPR workshop was eventually set for December 12-13th. Because the idea of setting up new routes was to be discussed participation was sought from DFO scientists from other regions. Unfortunately, the dates conflicted with those of an ArcticNet meeting and a PICES meeting, so that some people were unable to come. Nevertheless there were two DFO scientists from the Freshwater Institute, who had both marine and freshwater interests covered, and there was one from the Great Lakes Laboratory for Fisheries and Aquatic Science. From the West Coast there were two scientists from the University of British Columbia, one of whom had experience working with CPRs and CPR data in the Southern Ocean, and there was one member of the SAHFOS staff, who runs the Pacific CPR survey. Aside from these there were scientists from all regions of the Maritimes and Newfoundland. The total number of attendees was 27.

The meeting opened with introductory remarks by Dr. Mike Chadwick, who described the two main questions to be addressed:

1) Should CPR be expanded to other regions? (e.g., Arctic, Great Lakes).
2) Can more be done with CPR data and how to they compare to other conventional methods such as vertical tows made on sections? During the rest of the morning of Dec. 12th, that afternoon and the following morning there were a series of talks. These covered technical details and the history of the SAHFOS organisation, its Joint Project Agreement with DFO, details of the unconventional SAHFOS sample analysis procedure and cost analyses for running proposed new CPR lines. Research highlights of the global, NW Atlantic and Pacific surveys were also given. During the afternoon of Dec. 12th, the first talk initially briefly described the AZMP programme, for the benefit of those not familiar with it, and thereafter this and three other talks focussed on results of CPR and AZMP sampling, with some comparisons between them. During the morning of Dec. 13th, there were two more talks comparing CPR and net data, and then one talk presenting results of CPR sampling in the Southern Ocean, and one on underway continuous sampling in Lake Winnipeg. Throughout the talks there was lively participation by all members of the group, and it was generally agreed that everyone had learnt something valuable by the end.

The afternoon of Dec. 13th was set aside for discussion of the two main questions. A summary of these discussions and recommendations based on them is given below.

Reference:

Pepin, P., B. Petrie, J.C. Therriault, S. Narayanan, W.G. Harrison, K.T. Frank, J. Chassé, E.B. Colbourne, D. Gilbert, D. Gregory, M. Harvey, G.L. Maillet, M. Mitchell, and M. Starr. 2005. The Atlantic Zone Monitoring Programme (AZMP): Review of 1998-2003. Canadian Technical Report of Hydrography and Ocean Science 242, v+87p.

OVERVIEW OF WORKSHOP PRESENTATIONS AND ENSUING DISCUSSIONS

12 Dec. 2006, Morning Session

Rapporteur - Nancy Shackell

09.00 Introduction and Welcome - Mike Chadwick

Dr. Chadwick put forward the two major objectives of the Workshop:
1) Should CPR be expanded to other regions? (e.g., Arctic, Great Lakes, Gulf of St. Lawrence)
2) Can more be done with CPR data and how to they compare to other conventional methods such as vertical tows made on sections?

09:20 The Sir Alister Hardy Foundation for Ocean Science (SAHFOS) and the Global CPR Programme - Sonia Batten

Dr. Batten gave a brief account of the history of the CPR programme, including a description of the organisation that is currently running the North Atlantic and Pacific surveys, namely the Sir Alister Hardy Foundation for Oceans Science (SAHFOS). She then described the sample analysis protocol used at SAHFOS to process plankton samples, which is semi-quantitative and involves binning abundances into a number of categories. Dr. Batten then gave some examples of important scientific findings of the survey (e.g., long-term changes (1) linked to fisheries yields, (2) in plankton geographic distributions (3) timing of seasonal cycles) thought to be linked to climate change.

Discussion
Q: (Glen Harrison, GH) What is the distribution of people identifying/processing samples? Are they experts in particular taxa?
A: (Sonia Batten, SB) The analysts are given a broad-based training.

Q: (Erica Head, EH) Do you count all the small zooplankton, as you do for the large ones?
A: (SB) We sub-sample for small zooplankton

Q: (Alex Salki, AS) How are you actually recording numbers?
A: (SB) In notebooks.

Q: (EH) How long does it take to process a sample?
A: (SB) Generally approximately 1 hour but much longer in spring, when phytoplankton abundance is high.

Q: (GH) We have same problem. Is there sometimes so much phytoplankton that it may influence your identification of zooplankton groups?
A: (SB) I’m sure there is.

Q: (Alan Longhurst, AL) Is there any effect of flow rate?
A: (SB) I’ll get to that.

Q: What is turn around for sample collection to data provision?
A: (SB) About 9 months to 1 year.

Q: (EH) Does the pigment (i.e., phytoplankton colour index) deteriorate?
A: (SB) Color is done straight away.

Q: (GH) How do the CPRs get back to SAHFOS?
A: (SB) By road courier, if a UK port is involved. If ships sample on the outward leg, in the North Atlantic NA, we wait until they return to the UK (1-2 weeks)

Q: Do these shipping companies get paid?
A: (SB) Some money as a gratuity; they get something. They like to do it (sampling) because otherwise the time at sea is boring.

Q: Do you give any feedback to the companies about what you find?
A: (SB) Yes, we give them a copy of the annual report. Our logistics officer is an ex-ships' captain, which means that the crew don't think scientists are telling them what to do; if a captain tells them it can be done, it can.

Q: Is the sampler towed off the back of the ship, if so does the ship upset actual plankton patterns?
A: (SB) Behind a fast moving ship there is mixing, but it's a good thing because we want a depth-integrated pattern. The turbulence also may reduce the avoidance of larger animals, so it's a good thing.

Q: Is there a minimum speed?
A (SB): 8-10 knots is the probable minimum though some ships tow at over 20 knots, but the volume taken through the sampler should be similar. We have tried to quantify the effect of ship's speed but clogging is an additional factor.

Q: What about flow meters?
A: (SB) Mechanical flow meters may cause a back-up and reduce flow/filtration and bias the time. Electronmagnetic flow meters showed us there is high variability in the flow - so we tried to calibrate ship's speed with flow meter data. A regression is used to calibrate. We think that at large spatial and temporal scales the bias is minimal.

Q: (EH) Do you think lots of phytoplankton and more clogging would impact the flow and therefore the avoidance by larger organisms?
A: (SB) If you look at seasonal cycle, it is likely that winter has less clogging and spring more so that at times when phytoplankton are dense you're underestimating, and in winter you're overestimating, because flow rates are higher. It's a useful question and should be looked at.

Q: Your physical archiving is a good thing: is there a schedule for experts to check archives?
A: (SB) Old samples have been looked at. For example, one interested group used archived samples in the Irish Sea to look for *Nephrops* larvae.

Q: Would it be easier to have SAFOS re-identify because they're all flat (on the gauze and hard to identify)?
A: (SB) Some people like to do it themselves

Q: Can you scan samples?
A: (SB) Zooplankton have to be physically handled to identify them so scanning is no substitute for archiving. Also, new techniques will come about (e.g., recently DNA has been extracted from CPR archived samples).

Q: What is the sampling/analysis capacity of SAHFOS?
A: (SB) With existing staff and facilities at SAFHOS they are at capacity, but there is variability in contracts, and we do often start new projects as others finish.

Q: But you do hire (expand)?
A: (SB) Yes, but we have long-term people, and we encourage people to stay; we invest in their training.

Q: Is the relationship between SeaWiFS Chl-a and SAHFOS phytoplankton systematic enough to make correction between Chl-a SeaWiFS and CPR sampling?
A: (SB) More work should be done. The trends are probably more reliable than absolute values.
Comment: (SB) *C. hyperboreus* has increased in NW Atlantic.
Comment: (Brian Petrie, BP) But, the properties of Labrador Current (i.e., a warming) should be favouring warmer species in recent years.

Q: Does increased salinity indicate a larger proportion of Labrador Sea water in the Labrador Current?
A: (BP) Not really.

Q: (BP) Do you ever put temperature recorders on your CPRs?
A: (SB) Yes, but not for all, but we're making progress with CTDs.

Q: The flow is 0.5 m/s through the mesh. Does this squeeze (extrude) things through it?
A: (SB) The tunnel widens behind the mouth so speed is reduced. Empirically we don't get the impression that body parts are left behind. They're flat but not dismembered.

Q: When the ships stop what happens?
A: (SB) We bring the CPR in and reset it, before the ship carries on, when it is re-deployed.

Q: Have you ever deployed more than one instrument from the same ship?
A: (SB) Yes, we were testing different meshes on CPRs bolted together but and the comparison didn't work, so we abandoned it. We have compared instruments, but not really samples from 2 of the same instrument simultaneously. The ships' captains are not very keen.

Q: Are CPR data available to everyone?
A: (SB) Data are available to the scientific community, but scientists must sign/abide by a licensing agreement.

10:30 Current CPR Activities in the NW Atlantic and a Look to the Future - Erica Head

Dr. Head briefly described the current Canadian involvement with the running of the CPR lines between Iceland and the coast of New England. The route runs over the Newfoundland and Scotian shelves, where organisms display characteristic biogeographic distributions, as well as intra-regional variations in abundance and inter-decadal changes in seasonal cycles. Dr. Head explained the contractual arrangement with SAHFOS, including the costing of the current routes, and estimated costs for running new routes in the Gulf of St. Lawrence and the Great Lakes. She also outlined an IPY proposal to run CPR routes up to the Arctic from either coast.

Discussion

Q: (BP) There has been a change in basic route in CPR line in early (1960s) vs. more recent years (since 1992) on Scotian shelf, could some of the variability that you see in seasonal cycles be related to onshore offshore gradients.?
A: (EH) I don't think so personally.

Q: (BP) I think the earlier bloom that we see on the color is due to a change in lines.
A: (EH) We could tease out these patterns more.

Q: Have you (SB) ever considered a power support for your instrument, for a moored instrument to draw in plankton.
A: (SB) You'd need a power supply. The instrument would not look like a CPR.

Q: (Pierre Pepin, PP) We have an electronic version that is comparable to the CPR instrument moored in Bonne Bay. It draws power through a cable attached to the land.
Comment: (SB) EH remarked that DFO gets the raw data, unlike other institutions. If other people were to ask for it, we could provide raw data if we amended the licensing agreement. Certainly, the US funded Pacific data has to be available to the public.

Q: (Brian Hunt, BH) (With reference to comments about the IPY project). The SAHFOS CPR instrument doesn't handle ice, so we had to re-design the TATTOO mark IV CPR (to have a stronger body). Even little bits of ice can do damage.

Q: If your IPY project is not funded, will a CPR Arctic Monitoring programme go ahead?

Q: (Mike Chadwick, MC) There will be a variety of activities.
A: (EH) There may be other forms of routine monitoring, whether it includes CPR will depend on decisions made here (i.e., our recommendations) and elsewhere.
Comment: (GH) The IPY project is a pilot project – a feasibility study.

Q: (MC to SB): How big/small a boat can deploy CPR, e.g., In IPY the communities might be able to help with transects, using smaller crafts.
A: (SB): Relatively small boats have been used. They need enough speed to tow and the ability to winch CPRs on board and enough room to handle them.
A: (EH) An average fishing boat could do it.
Comment: (GH) But not a Boston whaler.

Q: What is line planned for the Gulf of St. Lawrence (GSL)?
A: (EH) I don't have a line drawn, the GSL people should draw it.
Comment: Would it be the Laurentian Channel?
Comment: (SB) If there is ice around and the CPRs are being brought in and re-deployed, you'll get through more mesh than you might expect, and you would be missing part of the transect.
Comment: (EH) But I would only suggest towing through the ice-free months (May-December) and maybe not into the Lower Estuary.

11:15 CPR Sampling in the Pacific - Sonia Batten

Dr. Batten described the history of the CPR programme in the Pacific, which currently consists of an East-West transect from the Juan de Fuca Strait to Japan (via the great circle route) and a north-south route from Alaska to California. The sampling is seasonal rather than monthly and some sample analysis occurs at IOS, so that data are available quickly for contractors.

Highlights include observations of changes in the timing of the seasonal cycle of the dominant copepod *Neocalanus plumchrus*, and biogeographic associations of plankton and birds (taken by observers on the EW route) with water masses. Funding is not very secure for the long-term.

Discussion

Comment: (GH) Some of the summary interactive data on SAHFOS website, has fixed (spatial) blocks, and we also use fixed blocks on the Scotian and Newfoundland shelves. Your analysis shows that we may have to be careful about fixed blocks because of the biogeographic changes that you've demonstrated. That is, we should try to get a handle on the associations of biogeographic assemblages with currents, etc.

Q: (Ken Frank, KF) You showed biomass differences among years based on species counts, but no data or information about how you converted counts to biomass. Is this done at SAHFOS?
A: (SB) I have done some measurements myself, and there is literature available on length-weight relationships for different species.

Q: (MC) Information reporting to DFO managers and our ability to engage, to interest the public – these are problems (selling/highlighting CPR). Biogeography might be one area of interest public, e.g., comparing large spatial patterns (inter-ocean); toxic diatoms is another. How do we profile what has been found?
A: (SB) Anything that relates to salmon is of immediate interest to the public on the west coast, also with birds, people are interested in birds (e.g., the tufted puffin).

Q: (MC) Have you identified exceptional events, or peculiarities - any details that might interest the public?
A: (SB) There is a Pacific diatom (*Neodenticula* spp.) that is now being found in NW Atlantic. Its transport there might relate to humans *vis a vis* global warming or introductions by ships.
Comment: (EH) Changes in Arctic circulation have been suggested as a mechanism for the transport of Pacific species to the NW Atlantic. Bering Strait water may be entrained ("banked") in a gyre in the Canada Basin, and then released to flow through the Canadian Arctic archipelago. This idea is quite topical and could be discussed further.

Q: (AL) Could this phytoplankton introduction result from ballast water?
Comment: (EH) *Neodenticula* was found simultaneously over a wide area on the Z line (Iceland to Newfoundland), perhaps inconsistent with a local (ship) discharge.
A: (Patrick Ouellet, PO) *Neodenticula* has been found in GSL, but for years it was rare.
Comment: (BP) The arrival in different regions of the GSL followed circulation patterns that were consistent with it having come from the Arctic.
Comment (GH): Because of the nature of counting, SAHFOS it wouldn't detect rare species.
A: (SB) Not really, but presence/absence data would pick up rarer species which would not show up in abundance data.

12 Dec. 2006, Afternoon Session

Rapporteur – Patrick Ouellet

13.00 The Atlantic Zone Monitoring Programme (AZMP) and the Role of CPR Sampling - Pierre Pepin

Dr. Pepin described the elements of the AZMP program, which has been operating since 1999. The sampling area includes the Newfoundland and South Labrador Shelf, the Scotian Shelf and Bay of Fundy and the Gulf of St. Lawrence. The activities include sections occupied twice or three times per year, fixed stations occupied monthly or bi-monthly, opportunistic sampling on groundfish (ecosystem) survey cruises, satellite monitoring of chlorophyll and SST and CPR sampling. AZMP has a focus on Seasonal patterns and annual inter-variability, and the samples collections include: CTD sampling, dissolved oxygen, chlorophyll, nutrients, water column integrated zooplankton abundance with special attention to *Calanus* spp. Dr. Pepin remarked on the difficulties that there have been at fixed stations to cover the seasonal cycle. Dr. Pepin then described the results of applying a general linear model to look at zooplankton abundance variability at Stn. 27 and on transects on the Newfoundland Shelf. *Calanus* and euphausiids levels have decreased over the AZMP period at Stn. 27, whereas farther north *Calanus*, *Metridia*, *Oithona* and *Pseudocalanus* have all increased.

Discussion

Comment: (GH?) The initial rationale in AZMP was to look at dominant species, but now biodiversity has been identified as a big issue.
Comment: (PP) Frequency of occurrence in CPR sampling shows trends that won't be picked up by our AZMP counting protocol. CPR/AZMP provides a balance between imprecise and precise sampling. Both techniques have advantages. The AZMP protocol does not track rare species.
Comment: (MC) The sampling is from top to bottom in AZMP. The CPR samples the surface, I wouldn't expect close correlations in abundance levels.
A: (PP) I would expect abundance to be correlated, and this has been shown before in other tests. The community element does come into play, but we have not done a good job of reconciling the two databases.

Q: (GH) It seems that there should be a redundancy in sampling with both CPR and AZMP, but this workshop should help to show that the two surveys are complementary.
A: (PP) There is a wealth of information for population and life history models that you can get from AZMP sampling that you cannot get from the CPR data. For example, one of the differences is that AZMP differentiate stage distributions of the different *Calanus* spp. By contrast, the large spatial coverage of CPR data may be used to help us identify water masses.

Q: (AL) Do you compare fixed station or transect data with what you can see in satellite information (e.g., chlorophyll and sea-surface height, SSH)? If you find anomalies they may be related to mesoscale features.
A: (PP) Certainly there is patchiness.
Comment: (AL) It is easy to make these comparisons. You can get the data from a University of Colorado website, specifying the points to make a box and you can download a map of satellite images. The website has recently been modified and improved.
Comment: (EH) Often there is cloud off Newfoundland (no good for chlorophyll images).
A: (AL) But there is still SSH (Sea surface height).

Q: What mesh size do you use in AZMP?
A: (PP) The mesh size is 202 μm.
Comment: (EH) We also sample with smaller nets (70-76 μm mesh).

13.30 Recent Uses and Possible Future Applications for East Coast CPR Data - Ken Frank

Dr. Frank first talked about the issues of scale: CPR sampling plankton with a small orifice versus trawl nets sampling fish with a large net. He concluded that the sampling effort on the Scotian Shelf was similar (more-or-less). Dr. Frank then showed how CPR data had been incorporated into a time-series "score card" of ecosystem status of the Eastern Scotian Shelf (ESS) and used data from net tows and CPR to compare species accumulation curves. He examined how species diversity had changed over the decades and included a comparison of decapod abundance and shrimp and snow crabs landings, lagged by appropriate periods, which suggested CPR data could be used to predict invertebrate fishery landings.

Discussion

Comment: There are some questions about the categories that were used in the species richness and accumulation curves.
A: (SB) There is a recent species list in an article by Richardson et al. 2006. Changes since 1996 in the level of identification and in the number of taxa actually counted/reported. Hence the increase in the number of taxa recorded in the 1990s should be viewed with caution. There has been an increase in the level of precision in the identification. Something may have been 'identified' since 1996, but it does not mean that it was not present before. Also, something that was a taxonomic category previously may now have been split, and will now be recorded in duplicate, since the original taxonomic category will be preserved (for continuity). For example, Radiolaria = Thecate radiolarians + athecate radiolarians + "Other" radiolarians. Previously, there was only a category "Radiolaria", now all 4 categories are reported.

Q: (Mary Kennedy, MK) You have not shown net data prior to 1976. Is there any zooplankton data prior to 1976? (e.g., for the Scotian Shelf)
A: (Doug Sameoto, DS): The short answer is "No". Most are probably irretrievable paper records, i.e., lost!

15.00 Seasonality of Plankton on the Newfoundland Grand Bank – Gary Maillet

Gary showed how when he used the method of looking at seasonality used by Edwards et al. (at SAHFOS), he found virtually no differences in seasonality among the years of sampling on the Newfoundland Shelf (unlike the situation in the North Sea). When he tried using another method of analysis (cumulations of species/stage with time throughout the year, rather than the month of maximum abundance), he could find differences in seasonal cycles. In particular there was a shift to later occurrence in the seasonality of plankton (especially copepods) during the 1961-1977 period and the opposite trend during the 1991-2004 period.

Discussion

Comment: (Colin Minto: CM) About the cumulative distribution index: maybe you should plot in 3 dimensions to the day of year in one (x-axis) and year in the second (y-axis) and abundance in the third (z-axis) This would show the changes in seasonal patterns.

Do AZMP and CPR Sampling Identify Similar Spatial and Temporal Variability Patterns in the Zooplankton Community of the Scotian Shelf? – Catherine Johnson

Dr. Johnson compared results of CPR and AZMP sampling along and across the Scotian Shelf in April since AZMP, or AZMP-like sectional sampling, started (1997). She pointed out that the transit time for the CPR over the shelf was ca. 24 h, which might be mainly at night, or during the day, or during day and night, depending on the year. She compared results from AZMP stations and CPR samples that were within 1^o (long/lat) boxes. Total copepod abundances were well correlated for night-time samples, but when particular species were used, correlations were poor. Also, the 10 most abundant species (taxa) were mostly the same.

Discussion

Comment: AZMP samples sorted at three levels: small sub-samples where everything is counted and where there is high diversity. A medium sized sub-sample is analysed for abundance of mesoplankton (mainly *Calanus*) and the whole sample for large species.
Comment: (SB) AZMP uses vertical net hauls throughout the water column. We would expect some taxa would not be sampled by the surface sampling CPR.
Comment: There should be higher discrimination of taxa in the AZMP protocol, i.e., better precision counts, better identification.
Comment: (PP) But the frequency of rare species is higher (better assessed) in CPR because everything is assessed *vis a vis* presence/absence.
Comment (BH): There is also the possibility of difference in taxonomic composition between day and night samples. There is a need to be cautious.
Comment (EH): This does not apply to some of our major taxa, e.g., *Calanus.*

Q: (MC) There is an issue about the coherence between AZMP vs. CPR lines: one set are across the shelf, the other along the shelf? How should you compare CPR lines with AZMP "points".
A: (CJ) By including the CPR samples within the 1^o (lat/long) boxes that correspond to the AZMP samples.

Q: If you had the money to start a new line (in the GSL, for example), what will you do?
A: (GH) Asking the same scientific question, but using different methods will give different answers. At the broad scale, the patterns will be the same or similar but more subtle analysis (may) run into problems. The question should not be AZMP or CPR, these are complementary approaches. Methods also depend on the 'question' to be asked. For monitoring there may be no '*a priori*' question, i.e., the aims are more 'general' – increased insight will accrue as the length of the time series increase (e.g., see Brander et al. 2003). In addition, AZMP was also aimed at giving answers about dynamical aspect of the ecosystems.

16.00 Annual Anomalies of Scotian Shelf Phytoplankton: AZMP Cruises, BIOCHEM Archives, CPR Tows and SeaWiFS Images - Bill Li

Dr. Li described a methodology to apply to the data form these 3 sources. Essentially he created a weekly climatology for each and then looked at annual anomalies. For the periods for which each type of data were available he found that the remote proxies of chlorophyll (PCI and ocean colour) generally over-estimated chlorophyll concentration (determined by AZMP). All three time series indicated a weak annual average decline since 1999, coincident with decreasing annual anomalies in SST and water-column stratification. Annual anomalies did not follow seasonal trends, however, since chlorophyll has been increasing in the spring, and decreasing in the autumn.

Discussion

Q: (GH) The results that chlorophyll is down (annually) in paper of Behrenfeld et al. (2006) - is it consistent with results from SeaWiFS? Do changes in the spring bloom (trend) dominate the annual pattern?
A: (Bill Li, BL) No.
A: (SB) Chlorophyll records instead of taxonomic abundance are more correlated with (CPR) color index. Given the similarity for the recent series, did it tell you that the differences between the two periods (60 vs. 90) are real?
Comment: (GH) From earlier satellite data (CZCS, 1978-81), the nature of spring bloom is different, the amplitude is lower. There seem to be real changes that are more significant in the winter.
Comment: (Jeff Runge, JR): Decadal changes in zooplankton abundance (Gulf of Maine) are associated with salinity changes. One result is that higher chlorophyll in the fall may result in higher chlorophyll in the (following) winter.

13 Dec. 2006, Morning Session

Rapporteur – Catherine Johnson

09.00 Zooplankton Abundance Trends and Inter-decadal Changes in Seasonal Cycles in CPR and Net Data from AZMP Time Series Stations - Erica Head

Dr. Head compared the climatological seasonal cycles of abundance of zooplankton species for the central Scotian Shelf (CSS, determined by CPR) with those determined at St. HL2 (AZMP fixed station off Halifax) and for the Newfoundland Shelf (NSH) with those at Stn. 27 (AZMP station off St. John's). She pointed out that the CPR category *Calanus* I-IV includes a mixture of the young stages of 3 *Calanus* species (*C. finmarchicus*, *C. glacialis* and *C. hyperboreus*). For the CSS, this was mainly *C. finmarchicus*, but at Stn. 27, *C. glacialis* was as abundant as *C. finmarchicus* in spring. She found differences in seasonal cycles that could generally be explained in terms of seasonal changes in vertical depth distribution. On the NSH and at Stn. 27, however, *Calanus* I-IV showed an expected summer peak in the AZMP sampling that was absent from the CPR data. Dr. Head also showed the CPR climatological seasonal cycle for the 1960s, where the summer peak was present, however.

Discussion

Q: (GH) Are *Calanus* mostly in the upper 50 m, so that their concentrations are underestimated in the AZMP?
A: This should not occur.

Q: (BP) Don't *C. glacialis* and *C. hyperboreus* come from the GSL, so they should be higher in the NSC (*i.e.,* at Stn. HL2 versus in the CPR track, which is now generally farther offshore)?
A: (EH) Maybe, but CPR has never shown high levels of these, even when the tracks were inshore; the depth distribution is probably more important.
Comment: (EH) I'm not sure that CPR catches big euphausiids very well.
Comment: (BH) We catch big ones in the CPR in the Southern Ocean.
Comment: (SB) Day/night differences are important for euphausiids and *M. lucens*

Q: (EH) Anyone know why *Calanus* I-IVs are not in the surface layers in summer, whereas they were in the 1960s?
A: (BP) I had thought it might be related to the strength of the inshore Labrador Current, but I looked and I don't think so any more.

Q: (EH) Any ideas about predators?
A: (PP) There has been a loss of much of the pelagic biomass since early 90s, e.g., there are no capelin, but there are now jellies (e.g., ctenophores?), which are not sampled by CPR

Q: (KF) How do you know there are no capelin? There are no estimates.
A: (PP) There are contemporary acoustic estimates.
Comment: (KF) They don't mean anything.
A: (PP) Yes, they do.

Q: (PP) Could the change be due to changes in the tracks?
A: (EH) They weren't hugely different between 60s and 90s. I think this observation warrants further investigation.
Comment: (GH) Is vertical distribution driven by physical or biological features? Is there evidence of changes in the physical structure?
Comment: (DS) Jellies would clean everything out near the surface.
Comment: (EH) But you can't look at jellies with CPR.
Comment (SB) Maybe presence/absence, not abundance, the CPR only captures a small fraction of nematocysts. Historical observations might be more useful.
Comment: (BL) The lag in the *Calanus* I-IV peak is only by about a month.

Q: (CJ) Which species have the largest inter-annual changes?
A: (EH) *Centropages typicus*, *Oithona* and "total copepods" on the CSS.

Q: (GH) Is there evidence that vertical distributions have changed?
A: (DS) There is no evidence that anything changed back in the 70s. Graham Hays attributed day/night CPR difference to changes in the abundance of herring larvae, but this was discredited as being an incorrect analysis (the times of day were not rigorously interpreted).
Comment: (SB, EH) The difference must be due to either physical or biological changes.
Comment: (KF) You should still look at day/night differences, before making too much of this.
Comment: (SB) Trying to correct for day/night effects in the Pacific, could give differences of maybe a factor of 2. Even a change of 5 m in the depth distribution could make a difference to the sampling by CPR.
Comment: (EH) It could be driven by something like a change in the depth of the deep chlorophyll maximum.
Comment: (DS) Changes in ship speed could cause changes in sampling depth.

10.15 Zooplankton Abundance Trends from CPR and Net Data on AZMP Transects – Doug Sameoto

Dr. Sameoto compared data for the CPR "E" line along the Scotian Shelf, with data collected in net tows from the bottom to the surface on transects across the Scotian Shelf. He found that trends for some species (*Calanus finmarchicus*, *Pseudocalanus* spp.) were well correlated over time, whereas others, especially for the small copepods, were not. He also showed that the annual abundances of some CPR taxa were positively correlated with the 10 m temperature in Emerald Basin, others were negatively correlated with temperature, and some showed no relationship.

Discussion

Q: (GH) Would you generalize that the species with a relationship with temperature are the smaller ones, and is there a difference between the response of large and small species?
A: (DS) *Centropages* shows a relationship, and it isn't all that small. Generally one would expect to see a proliferation of small species if the temperature is warmer.
Comment: (GH) You see that in the phytoplankton – a shift in the size spectrum.
Comment: (BL) Sonia, you said the color index is dominated by taxa that aren't dinoflagellate or diatoms.
A: (SB) Cells that are too small to be identified dominate the color index. Smaller (zooplankton) species might be more sensitive to temperature (having a shorter generation time).

Q: (BP/AL) Are you sure these temperature responses are physiological and not an index of changes in the physical environment?
Comment: (BP) You could explore relationships with stratification indices that exist for the Scotian Shelf.

10.45 Establishment and Insights Gained from the Southern Ocean CPR Survey – Brian Hunt

Dr. Hunt described the history and operation of the Southern Ocean CPR survey. This is carried out on research vessels, which have co-incident flow-through sampling of T, S and fluorescence, so that they do not try to measure "phytoplankton colour", which might anyway be influenced by the long duration of their trips. Dr. Hunt described the results of a vertical net tow/CPR comparison along a transect covering a number of biogeographical regions. Species richness was lower in the CPR, but the regions were similarly defined by both techniques. He also described some tests looking at flow, finding that clogging in areas of high phytoplankton could reduce flow by 60%, and that a reduction in ship's speed also caused reduced flow. On the other hand, the flow meter itself may have altered the towing angle slightly. Dr. Hunt also showed data that suggested that even a simple higher order taxonomic identification scheme could delineate his biogeographical regions.

Discussion

Q: (CJ) Could you predict the number of species you would find in the CPR from the vertical net hauls?
A: (BH) There were more individuals collected by the CPR.

Q: (Evgeny Pakhamov, EP) What were the relative volumes?
A: (BH) The volume was about 20 times greater in the vertical net hauls.
Comment: (EH) You need to set bounds of acceptable values resulting from clogging and volume differences.
Comment: (SB) Spatial and seasonal differences probably outweigh clogging and flow variability, but the seasonal abundance cycles may be "squashed".

Q: (EH) Don't you have *Phaeocyctis* causing clogging?
A: (BH) You see changes in the phytoplankton community that influence clogging (e.g., big diatoms in blooms are really bad).

Q: (GH) Could you use the phytoplankton colour index (PCI) as an index of clogging?
Comment: (DS) Could you change the speed of your gauze (e.g., high rate in clogging conditions)?

A: (BH) We don't have this problem this all the time. We know we underestimate zooplankton abundance as their abundance increases.

Q: (KF) Didn't you say that the water was pretty "clean" in the Southern Ocean?
A: (BH) Yes, the problem occurs only when there is an intense bloom.
BH then showed a plot of ship speed vs. sampling depth.
Comment: (KF,SB) No large changes at higher (commercial ship-like) speeds.
Comment: (PO) This suggests there are limitations on the kind of ship that can run CPR lines.
Comment: (SB) Adjustments of wire-out considers the range of speeds on the particular ships, i.e., you put less wire out if towing at slow speeds.

Q: (AL) Is there room in the body to add equivalent buoyant material to compensate for the tail drag caused by mounting a flow meter?
A: (BH) There are now smaller flow meters for which this might be an option.
Comment: (SB) Also, you can only do this if you're sure it's not going to change what's sampled.
Comment: (BH) The flow meter has to be very accurate, because flow rates are much reduced.

Q: (MC) Are there other meridional transects showing biogeographic zones?
A: The EW transect across the Pacific did, but the Newfoundland Shelf/Scotian Shelf regions may be more similar. If we were to include the Newfoundland Shelf to Iceland part of the Z line, we would see strong regional differences.

11.30 Continuous Underway Sampling of Environmental Variables in Lake Winnipeg – Alex Salki

Dr. Salki described a sampling programme that is carried out on a seasonal basis in Lake Winnipeg. Lake Winnipeg has fisheries of great commercial value and has a large surrounding watershed. Recent years have seen large increases in the abundance of cyanobacteria in the near surface layers and a diminution in the number of surface living zooplankton. Numbers of the zooplankton living in the lower layers have not shown such changes. The cyanobacteria increase is probably linked to the fact that Lake Winnipeg is one of the most eutrophic lakes in the world. There are also issues with introduced species (e.g., smelt and microzooplankton). Dr. Salki wondered whether CPR sampling would provide a suitable way of monitoring changes in the plankton in Lake Winnipeg.

Discussion

Q: (GH) Are they mostly filamentous cyanobacteria?
A: (AS) Yes.

Q: (BL) Do you get hypoxia?
A: (AS) It has been observed, but the whole water column is generally well mixed; it's only 13 m deep.

Q: (EH) Are toxins produced?
A: (AS) Levels can be very high.

Q: (GH) When do blooms start and end?
A: (AS) They start mid to late July and last until September, but nowadays they can go to October.

Q: (AS) We see up to 64 mg/L suspended particles. Would this cause clogging? Also, they are filamentous cyanobacteria in the very surface – maybe we could tow underneath the layer
Comment: (BH) A ship's propeller might mix that layer down.
Comment: (Gary Maillet, GM) You could tow from the side of the ship to avoid the wake.

Q: (PP) Do you need to tow as deep as in the ocean?
A: Maybe not.

Q : (EH) Among the zooplankton, are the bugs going to be well sampled or are they generally very small?
A: (AS) Some are up to 2 mm in length.
Comment: (PP) Nutrients concentrations are 2 orders of magnitude higher than in the ocean!

Q: Is the CPR appropriate for L. Winnipeg, given the high chlorophyll, the filamentous algae and your low budget?
A: Maybe not.

Q: (KF) Why was there a 30 year hiatus in (lack of) sampling?
A: (AS) There was no interest. The recent Red River flood increased interest.

Q: (KF) Are you hoping for a zebra mussel problem (to clean out the cyanobacteria)?
A: (SA) There's no sign of one.

Q: (GH) What's the duration of the period when chlorophyll is >10 mg m^{-3}?
A: (AS) The background is about 20, with peaks in the summer.

Q: (GH): Is most chlorophyll in the surface layer?
A: (AS) No answer recorded.
Comment: (Patricia Ramlal, PR) There are also under-ice blooms

Q: (GH) Is open water period expanding?
A (AS) Yes, but only in the South.
Comment: (PR) Because it's a reservoir, for hydroelectric power generation, the lake levels are regulated.
Comment: (AS) This is mainly influenced by regulation of the outflow, and this may be what's driving the phosphate build-up.
Comment: The occurrence of cyanobacteria implies that the lake runs out of nitrogen.
Comment: (SB) The CPR is most efficiently used as a ship-of-opportunity sampler, when ship time is free. It's expensive to use it as a dedicated programme. It's good for linking less frequent net samples.
Comment: (JR) I'm not seeing that the CPR is what you need. AZMP-type sampling is more what you need, since you get more information for the same or less personnel-time. You can sample several times per year in this way. You get spatial patterns from seasonal sampling and seasonal patterns from fixed near shore stations.
Comment: (AL) You could pump and sample sequentially in the continuous inflow (without the need for a CPR).
Comment: (PP) You might be interested in something like a continuous "fish egg sampler" type of apparatus. Carl Boyd had such a system on a ferry (Yarmouth to Bar Harbor). He used small nets to concentrate samples.

Q: (AL) You mentioned that species will likely expand north as temperatures warm. How?
A: (AS) Avian transport, encysted forms, caught on fur and feathers and in guts.

Q: (AL) Do you have data?
A: (AS) *Eubosmina* (rotifers) arrived in the invading smelt.

Q: (GH) How did the smelt get there?
A: (AS) Human transport in bait buckets. Smelt are a food for the walleye population, but could destroy it (by preying on juveniles) if fishing gets out of control.

13 Dec. 2006, Afternoon Session

Rapporteur: Glen Harrison

Two discussion sessions hade been scheduled for the afternoon, but as events transpired, they were merged into one, with both designated Discussion leaders leading the discussion as the different aspects of the two topics came up. The gist of the discussion is provided for both together in the Rapporteur's notes.

13.00 - Discussions on the Future of CPR in Monitoring Programmes in Canadian Waters (Discussion Leader - Mike Chadwick) and Ideas as to how CPR Data Should Be Routinely Analysed and Reported for AZMP (Discussion Leader – Pierre Pepin)

The question regarding the future of CPR in monitoring was as follows:

Monitoring of the ocean is part of the mandate of DFO, and the AZMP has been suggested as a model for future monitoring programmes in other regions. Do we recommend that CPR sampling should be expanded in Canadian waters as part of such monitoring programmes? What can we do with CPR data (to give it a higher profile)?

The questions regarding the analysis and reporting of CPR data in AZMP were as follows:

Currently the amount of CPR data reported in the AZMP annual reports is limited to the annual abundance and seasonal cycles of a few species/categories in two regions, one east and one west of 45^{o}W.

- Is this division of the data appropriate or should spatial divisions take more account of topography and hydrography?
- Should we include more or different species?
- Should we include measures of diversity and/or community structure?
- Do we need to undertake further data analysis to answer these questions (e.g., of the samples east of 45^{o}W)?

Erica Head opened the session with a request that the PowerPoint presentations from the meeting be made available to the workshop participants. There was an agreement with proviso that the presentations would not be distributed outside the group since some of the presentations included preliminary data or data that would require corrections before distribution to the wider community.

The floor was then passed to Mike Chadwick to summarize the last day and a half of presentations and to direct the final discussion towards answering the two questions he posed in his introductory comments at the beginning of the workshop. His goal was to derive a few useful "bullets" in the form of conclusions/recommendations.

The first issue to address was how CPR data compare with other more traditional methods. Mike indicated that lots of analyses using varied approaches were presented and some provided convincing results while others were equivocal and less convincing. As a result of this he suggested that we try to come to a consensus on further research/analysis with a view of attaining better inter-comparability of results and thus more meaningful results.

There was then a considerable amount of discussion on how these comparisons can be made when there are fundamental regional differences in, for example, day-night effects, seasonality, etc. Pierre Pepin suggested a more systematic approach comprised of a number of steps:

1. Region characterization and identification
2. Corridor identification, i.e., characterization of variations in CPR ship routes
3. Analysis of day-night distribution of stations (with a view of having proper representation within identified region
4. Develop data "climatology" (using complete time series) for each category, species, etc.
5. Investigate deviations from climatological patterns
6. Develop appropriate ecological "indices" from above analysis

Discussion then ensued on details of this approach, e.g., day-night discrimination may not be an important consideration for some regions - were vertical migrators are not an important component of the zooplankton community. There was also the suggestion of further breakdown of the climatologies into day versus night, etc.

There was considerable additional discussion on the importance of defining regional boundaries. Should the regional boundaries be determined by the data distribution (what methods should be used, e.g., MDS)? Testing the delineation of the six biogeographic regions of the Arctic (MC) based on CPR data was proposed. It was emphasized again, however, that the CPR was developed and is best applied to relatively large geographic regions. The entire Scotian Shelf, for example, is typically sampled over during one 24h period and would produce a minimum amount of day-night data for analysis. Areas on the scale of LMEs was suggested. It was noted, however, than many of the LME's do not properly align with the biogeography.

Out of this discussion a couple of recommendations were made:

- R1: It is essential in the analysis of CPR data that spatial, seasonal and day-night variations are taken into consideration,
- R2: With special reference to the NW Atlantic "Z" and "E" CPR lines, an objective analysis should be done to delineate biogeographic boundaries and those new regions should be "validated" by comparison with more conventional plankton observations.

It was also recounted that a similar objective analysis of CPR data run in the Arctic (perhaps as part of Canadian IPY) would be one indicator of ecosystem complexity.

Discussion then shifted from "what to do with CPR data" to "if and where new CPR lines should be run?" From the previous discussion, there was general consensus that adding lines in the Arctic was a good idea.

- R3: DFO is encouraged to implement a pilot CPR line in the eastern and western Arctic. IPY appears to be the best funding option for this at present.

The question of adding a CPR to the Gulf of St. Lawrence was not as simple to answer. Patrick Ouellet provided a well thought-out discussion of some of the pros and cons of a GSL CPR line.

He indicated that one first thing that should be considered would be a spatial analysis of the areas of most ecological interest in the Gulf. He cited a number of previous studies and one more recent rather comprehensive analysis carried on for identification of the Ecologically-Biologically Significant Areas (EBSAs) of the GSL, that partition the Gulf (CSAS publications available in early 2007). He suggested that the next step would be to map the commercial shipping routes onto this information to determine if there are routes that would maximize ecological information. A prevalence of commercial routes follow the Laurentian Channel but this area has not been identified as one of the most important ecologically whereas the Magdalen Shallows would be more important ecologically, for example. Another consideration would be the two-layer estuarine nature of the Gulf and that CPR tows are limited to the surface layer; seasonal changes in surface layer depth and the strong stratification in the summer months for example may be sources of additional variability and render difficulty the interpretation of the CPR data (e.g., may not capture some of the more important "biology" of the sub-surface waters). The point was also made that identification of the seasonal production cycle is limited by the current AZMP sampling in the GSL but an investment in the AZMP fixed-stations may be a more sound investment than subsidizing a CPR line with data that may be difficult to interpret. There was also discussion of other possible CPR routes, e.g., north shore supply ships. The issue of fast transit of these commercial vessels was raised again and if sufficient day and night data would be collected. Finally, the more general question of DFO's commitment to sustain a CPR line was raised since the investment starts to pay big dividends only after at least a decade of data have been collected, as the existing "Z" and "E" lines have demonstrated. In the end, no consensus was reached about recommending a CPR line for the GSL.

- R4: The question of whether a CPR line should be implemented in the GSL could not be decided at this workshop; however, it was recommended that a more detailed case (with pros and cons) be made at the spring AZMP meeting for a wider debate among the zonal science community.

Discussion then shifted to the question of CPR lines in the Great Lakes. They would (exception Lake Michigan) meet the criteria of size (approximately 300-400 km in length) and the commercial shipping traffic frequency and routes would be compatible. The question was raised regarding who would do the sample analyses (since not the typical marine communities SAHFOS has the expertise to identify). Sonia Batten indicated that SAHFOS staff could do the counting and would be able to "tool up" for the freshwater species quite easily. One big advantage, funding-wise, would be exploring a partnership with the Americans to pay for the lines. Heather Niblock indicated that there is a joint Great Lakes Conference (IAGLR) to be held in Ohio in March, 2007 and that would be the time to network to see if there would be interest from the US side for starting CPR lines in the Lakes.

- R5: *[Heather Niblock is going to talk to US colleagues about the possibility of joint funding for implementing a CPR line through the Great Lakes]*

The discussion on additional CPR lines ended with some mention of a line along the coast of Labrador aligned with the increased activity in the region associated with nickel mining and one from Halifax to Nuuk aboard supply ships with service nearly year-round. The discussion did not go beyond mentioning those possibilities.

The session wrapped up with some discussion on the most effective way to communicate results from CPR. This included an overview of the reporting structure of AZMP which includes CSAS Research Documents (Res Docs) and Science Advisory Reports (SARs) as well as an annual Bulletin that targets a much wider audience than DFO scientists to include departmental managers as well as public institutions (e.g., universities and other NGOs). It was also noted that CPR has been reported in Ecosystem Overview and Status reports and NAFO Scientific Council Research (SCR) documents. Mike Chadwick suggested that some sort of more publicly accessible (interactive) web-based site that would promote the CPR data as an indicator of ecosystem status and forecast.

- R6: Ways in which the CPR data can be better communicated (to show value for investment) to DFO management and the public needs to be explored; a web-based tool may be the most effective approach.

14.30 Emerging Issues/General Discussion - Discussion Leader – Erica Head

Workshop participants were invited to bring forth topics for discussion that had not been addressed.

Erica took the floor again to lead the final discussion on emerging issues:

1. Jennifer Martin noted that most of the discussion focussed around CPR and AZMP but other monitoring programmes that could be linked to CPR were not touched on, e.g., the HABs monitoring programme in the SW Bay of Fundy region that has been running since 1988. She also brought up the issue of the need for counting the smaller phytoplankton – absent in both CPR and the AZMP protocols.
2. Doug Sameoto brought up the issue of our numerous unsuccessful attempts to get access to the data from the U.S. CPR programme in the Gulf of Maine. This dataset would be of particular value to us since it would fill in part (1980s) of the major gap in our Line "E" data record between 1975 and 1990.
3. Ken Frank suggested that in addition to considering adding new lines as an enhancement of our CPR programme we should consider putting resources into SAHFOS to enhance the taxonomic resolution of the samples we already collect, e.g., to better resolve the various benthic invertebrate species that are captured in the silks. This enhanced count may not be needed for every year's data; perhaps every 2-5 years?

The session discussion ended with Mike Chadwick summarizing what was covered and briefly outlining what happens next:

1. A report will be produced from the workshop very shortly.
2. A discussion of the workshop will be placed on the agenda for the March AZMP meeting. The case for a CPR line in the GSL will be discussed as part of this agenda item.
3. The concept of "pilot" CPR lines (Arctic, GSL, Great Lakes, etc.) of 2-3 years duration will be further developed. There was strong support for Erica's proposal to be supported by IPY.

Overall, Mike felt that the workshop was very successful - it brought in a broad spectrum of scientists with common interests from across Canada and beyond and represented the first detailed comparative analysis of CPR and standard net data. More importantly, the presentations and discussions help in the formulation of a more systematic approach for analysis of CPR data that provides for better regional inter-comparability.

APPENDIX I. LIST OF PARTICIPANTS

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APPENDIX II. WORKSHOP AGENDA

Tuesday -- Dec. 12, 2006

Rapporteur	Morning session – Nancy Shackell
09.00-09.20	Introduction and welcome – Erica Head and Mike Chadwick
09.20-10.00	SAHFOS and the “global” CPR programme – Sonia Batten
10.00-10.30	Coffee break
10.30-11.00	Current CPR sampling in the Western Atlantic and a look to the future – Erica Head
11.00-11.30	CPR sampling in the Pacific – Sonia Batten
11.30-12.00	The AZMP and the role of CPR sampling – Pierre Pepin
12.00-13.30	Lunch
Rapporteur	Afternoon session – Patrick Ouellet
13.30-14.15	Recent uses and possible future applications for east coast CPR data - Ken Frank
14.15-14.30	General Discussion
14.30-15.00	Coffee break
15.00-15.30	Seasonality of plankton on the Newfoundland Grand Bank – Gary Maillet
15.30-16.00	Do AZMP and CPR sampling identify similar spatial and temporal variability patterns in the zooplankton community of the Scotian Shelf? – Catherine Johnson
16.00-16.30	Annual anomalies of Scotian Shelf phytoplankton: AZMP cruises, BIOCHEM archives, CPR tows and SeaWiFS images – Bill Li
16.30-17.00	General Discussion

Wednesday –Dec. 13, 2006

Rapporteur	Morning session – Catherine Johnson
09.00-09.30	Zooplankton abundance trends and inter-decadal changes in seasonal cycles in CPR and net data from AZMP time series stations – Erica Head
09.30-10.00	Zooplankton abundance trends from CPR and net data on AZMP transects – Doug Sameoto
10.00-10.30	Coffee break
10.30-11.00	Establishment and insights gained from the Southern Ocean CPR survey – Brian Hunt
11.00-11.15	Continuous underway sampling of environmental variables in Lake Winnipeg – Alex Salki
11.15-12.00	Discussion (Leader – Pierre Pepin) – Currently the amount of CPR data reported in the AZMP annual reports is limited to the annual abundance and seasonal cycles of a few species/categories in two regions, one east and one west of 45oW. • Is this division of the data appropriate or should spatial divisions take more account of topography and hydrography? • Should we include more or different species? • Should we include measures of diversity and/or community structure? • Do we need to undertake further data analysis to answer these questions (e.g., of the samples east of 45°W)?
12.00-13.30	Lunch
Rapporteur	Afternoon session – Glen Harrison
13.30-14.30	Discussion (Leader – Mike Chadwick) – Monitoring of the ocean is part of the mandate of DFO, and the AZMP has been suggested as a model for future monitoring programmes in other regions. Do we recommend that CPR sampling should be expanded in Canadian waters as part of such monitoring programmes?
14.30-15.00	Coffee break
15.00-15.30	Emerging issues/General discussion (Leader – Erica Head)
15.30-15.45	Wrap-up and good-byes

APPENDIX III. WORKSHOP CONCLUSIONS AND RECOMMENDATIONS

The discussions at the CPR workshop lead to the following conclusions and recommendations:

- CPR is a robust, relatively inexpensive and consistent method for sampling the pelagic zone of marine ecosystems that is comparable to other conventional and more costly methods. However, these data should be viewed as complimentary of existing monitoring activities and not as a replacement without careful evaluation.

- CPR data are particularly useful for identifying mid- to long-term trends in community structure and for describing large biogeographic regions. In this context, it is strongly recommended that CPR lines be implemented in the Arctic. CPR data could be used to validate the numerous ecoregions that have been proposed for this area.

- Any CPR data to be used for examining long-term trends in abundance or community structure must be corrected for time of sampling (removing day-night effects) and for seasonal variability that may reflect the effects of catchability, behaviour, or ontogeny. The latter requires sophisticated statistical techniques for de-trending data.

- Implementation of CPR lines in small water bodies, such as the Gulf of St. Lawrence and Great Lakes, including Lake Winnipeg, must take into account the above-mentioned sources of variation, which may not be practical when using ships of opportunity.

- Regular reporting of CPR data should be part of the annual state of environment reports.

- A regular forum for the analysis of CPR data should be initiated within the aegis Atlantic Zone Monitoring Programme (AZMP), perhaps with additional reporting to the Fisheries Oceanography Committee.

- CPR does not provide any meaningful information on the abundance and distribution of gelatinous organisms like jellyfish, which appear anecdotally to be an ever-increasing component of the pelagic marine ecosystem.

- The resolution of species identification of decapods needs to be increased.

- A communications programme needs to be developed to explain to the public the value of CPR data in identifying long-term changes in the pelagic marine ecosystem.

APPENDIX IV. PRESENTATION ABSTRACTS

SAHFOS and the Global CPR Programme

Sonia Batten - SAHFOS, Plymouth Marine Laboratory, Plymouth, UK

The Sir Alister Hardy Foundation for Ocean Science (SAHFOS) took over the running of the north Atlantic CPR programme in 1990 when the CPR unit was closed down within the UK government research facility it inhabited. It is now entirely contract-funded and has a Governing Council, a Director and about 30 full or part-time staff and students, most of whom are dedicated to continuing to collect, process and archive the north Atlantic CPR samples. SAHFOS is the world authority on CPR sampling, it maintains the sample archive and also provides training and quality control to related or new surveys. A standard set of procedures has been developed for sample processing and data have been consistently obtained for over five decades.

The length of filtering mesh is cut into discrete samples, each 18.5 km long, which are viewed under a microscope with a special-purpose stage allowing the plankton to be identified and counted against the mesh of the sample. Counting is a compromise between speed and accuracy and a category system of counting is used (Batten et al. 2003). For phytoplankton, 20 fields of view across the sample are examined and a taxon's presence in each field of view recorded. Maximum abundance is indicated by presence in 20 fields, a less abundant organism would be found in say 5 fields. For zooplankton, categories are semi-logarithmic with 1, 2, and 3 organisms having the same category, 4-11 organisms having category 4 abundance, 12-25 having category 5 and so on up to category 12 which has between 2001 and 4000 individuals. Small zooplankton (less than 2mm) are counted in a sub-sample which involves a step-wise traverse of the sample with the microscope objective, counting everything within a 2mm field of view. This is 1/50 of the sample. Larger zooplankton are counted into categories with no sub-sampling.

Actual Abundance	Category	Accepted Value
1	1	1
2	2	2
3	3	3
4-11	4	6
12-25	5	17
26-50	6	35
51-125	7	75
126-250	8	160
251-500	9	310
501-1000	10	640
1001-2000	11	1300
2001-4000	12	2690

Table 1. The category system of counting for zooplankton – a compromise between speed and accuracy. Values for small zooplankton must be multiplied by 50.

The north Atlantic survey currently comprises about 20 routes that are sampled every month, year-round. There are also sister-surveys in the north-west Atlantic (operated by the NOAA Naragansett lab.) and a Southern Ocean survey (operated by the Australian Antarctic Division). In addition, SAHFOS operates a restricted survey in the north Pacific and has conducted short-term or trial surveys in the Mediterranean, Gulf of Guinea, Indian Ocean and the Benguela Current off South Africa.

A selection of results from the north Atlantic survey are presented that illustrate the value of the time series. Sampling and analysis methodology has been unchanged since 1948 so that almost 60 years of continuous data are available. The Phytoplankton Colour Index (PCI) is an assessment of the green coloration of the samples, a proxy for phytoplankton abundance, and has shown a step-wise increase in the North Sea, and other regions of the north Atlantic, from the late 1980s (Reid et al. 1998). This index has been correlated with SeaWiFS data (Raitsos, et al., 2005) and used to extend the SeaWiFS chlorophyll *a* time series back in time. Annual means again show an increase after 1987. Reid et al. 2003 present two time series of sibling *Calanus* species *C. finmarchicus* and *C. helgolandicus* from the North Sea. The two species show generally opposing trends with *C. helolandicus* (a southern species) increasing since 1987 and *C. finmarchicus* (a northern species) decreasing. As well as the changes in the timing and abundance of these two species of *Calanus*, the size and numbers of all copepods in the North Sea markedly reduced after 1987 (Beaugrand *et al*. 2003) and was highly correlated with the observed decline in cod stocks, especially their biomass and recruitment. These signals are all indicative of a regime shift, plankton changes being correlated with higher temperatures in the North Sea. There have also been changes in the western north Atlantic; *C. hyperboreus* increased in abundance after 1990, as did the dinoflagellate *Ceratium arcticum* as well as the PCI (a gap in sampling between 1979 and 1990 means that we cannot determine if this was a gradual or sudden change (Johns *et al*. 2003). Freshening and cooling of the region is thought to be responsible.

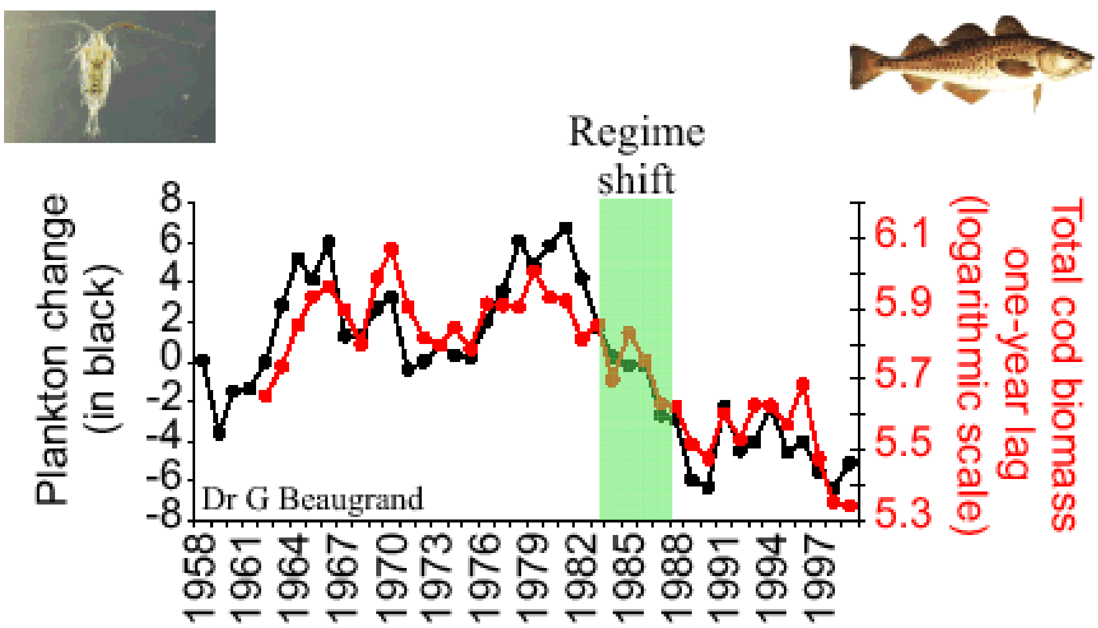

Figure 1. Time series plots for plankton and total cold biomass in the North Sea (after Beaugrand et al. 2003).

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Current CPR Activities in the NW Atlantic and a Look to the Future

Erica Head – Ocean Research and Monitoring Section, Ecosystem Research Division, Bedford Institute of Oceanography, Dartmouth, Nova Scotia

The Sir Alister Hardy Foundation for Ocean Science (SAHFOS) has been running sampling lines between Reykjavik and St. John's (the Z line) and between St. John's and the New England coast (the E line) as part of the CPR North Atlantic Survey since 1961, with a break in sampling between 1976 and 1990. In many of the years during the 1961-1976 period only a few months were sampled, whereas since 1992 coverage has been excellent.

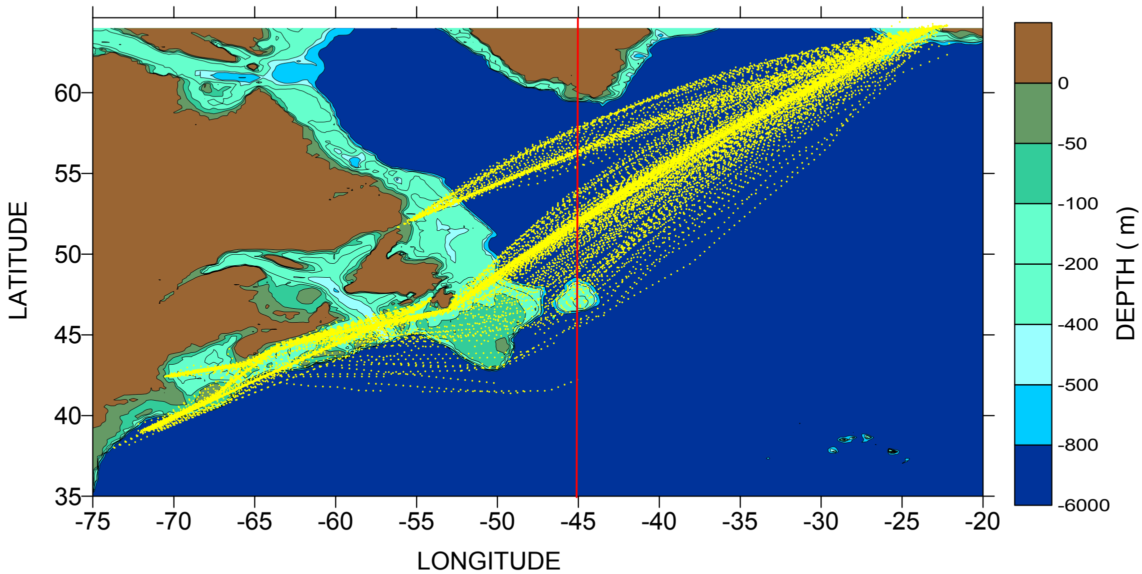

Figure 1. E and Z CPR lines that are currently supported by DFO funding. Each dot represents a 10 mile stretch which represents a sample that has been collected and analysed.

Data analysis over all sampling years on the Canadian continental shelf reveals geographic differences in zooplankton species abundance, with cold-water species exhibiting a gradient from high to low from the cold Newfoundland Shelf to the warm western Scotian Shelf, and warm-water species, the reverse. Further analysis reveals differences in annual abundances and seasonal cycles of abundance for three different time periods (1962-1971, 1992-2000, 200-2004). These may be linked to changes in environmental conditions (*e.g.,* circulation, food, temperature) related to climate change.

The Department of Fisheries and Oceans (DFO) contributes to the cost of operating the E and Z under a joint project agreement with SAHFOS. A new agreement was negotiated earlier this year, which set the contribution of DFO at 40% of the cost of operation of the routes. The USA contributes most of the remainder. Because of increasing costs to SAHFOS the price of the new agreement was substantially higher than the previous one, £65K, in the first year, versus £50K, and includes a 4% increase per year to cover inflation. SAHFOS have also requested that DFO provide additional funding for infrastructure support, including the purchase of a new CPR ($30K) and a microscope ($18K). It is hoped that this will be obtained by an International Polar Year (IPY) proposal that has been submitted by E. Head and D. Mackas.

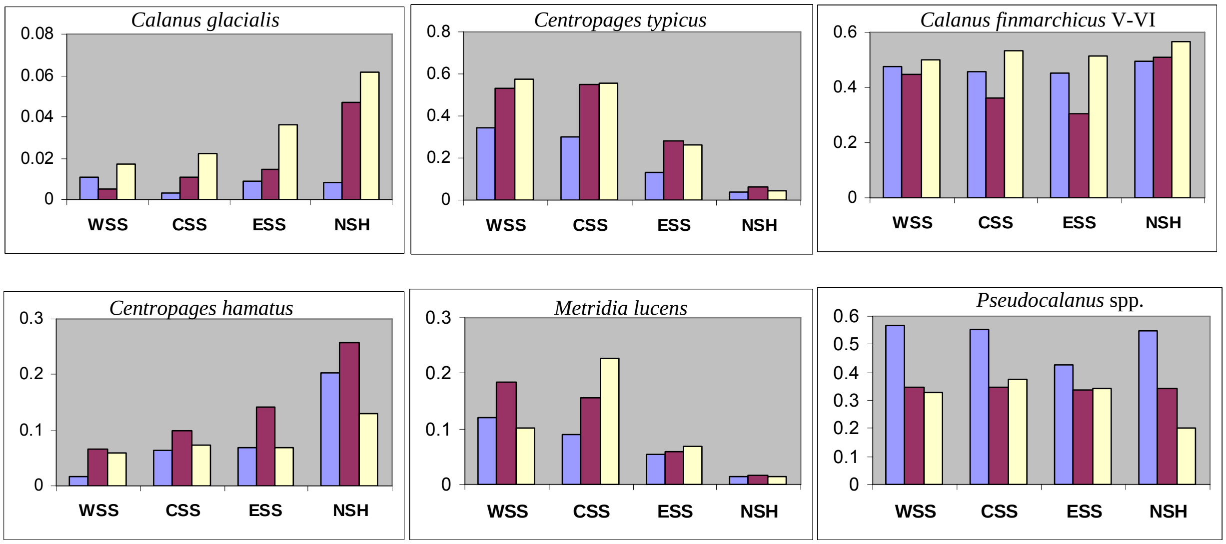

Figure 2. Annual average abundances of six species of copepod on the Western Scotian Shelf (WSS) the Central Scotian Shelf (CSS), the Eastern Scotian Shelf (ESS) and the Newfoundland Shelf (NSH) for three different time periods. The time periods are 1962-1972 (lavender), 1992-2000 (brown) and 2000-2004 (yellow).

The IPY proposal (# 1065) of Head and Mackas entitled "Ecosystem monitoring in Canadian Arctic waters using the Continuous Plankton Recorder – CPR Monitoring" involves mounting CPRs on ships of opportunity that will be going to the Arctic during 2007, 2008 and 2009. SAHFOS will carry out most of the operations (e.g., fitting the ships with davits, training crew members, arranging for the transport of samples and CPRs to and from Plymouth) and the project leaders will be responsible for co-ordinating operations and receiving and analysing the data. This project will be a "proof in concept" for ecosystem monitoring in the Arctic, which may lead to a long-term programme.

CPR Sampling in the Pacific

Sonia Batten - SAHFOS, Plymouth Marine Laboratory, Plymouth, UK

SAHFOS undertook a trial CPR tow in the northeast Pacific in 2007 and were then invited to the annual meeting of the North Pacific Marine Science Organisation (PICES) in 1998. The MONITOR task team wanted to address the lack of regular open ocean plankton sampling and the CPR was a candidate. With PICES endorsement, funding was obtained and the first routine sampling began in 2000. There are currently 2 transects, one north-south between Alaska and the west coast of continental USA and one east-west following a great circle route from the Straits of Juan de Fuca to the coast of Japan. The east-west route is sampled 3 times a year in spring, summer, and fall and the north-south transect is sampled 6 times between March and September, on a monthly basis. Initially, all of the servicing and sample processing was carried out at SAHFOS in the UK, but as the programme became established local technicians were trained by SAHFOS. Since 2003 SAHFOS has had a collaborative agreement with Fisheries and Oceans Canada and the east-west CPR is serviced at the Institute of Ocean Sciences, Sidney. The North-south CPR is serviced by personnel at the Prince William Sound Community College but samples are sent to IOS where sample preparation and analysis of 25% of the analysable samples is undertaken. These samples are analysed within a few months of collection so that some data are available earlier than SAHFOS UK can provide, to fulfil contract reports and attract more funding for this new survey.

Although all SAHFOS protocols are followed there are some differences from the north Atlantic survey. Funding constraints mean a focus on spring and summer sampling, not year round deployments, and only every 4th sample (rather than alternate samples) is analysed. Taxonomic differences between Pacific and Atlantic plankton have also led to some modifications, for example, the copepodite stages 2-5 of the dominant copepod *Neocalanus plumchrus/flemingeri* are counted separately to enable a more accurate determination of its annual cycle in surface waters than would be obtained from just ‘juveniles’ and ‘adults/sub-adults,’ the traditional CPR categories.

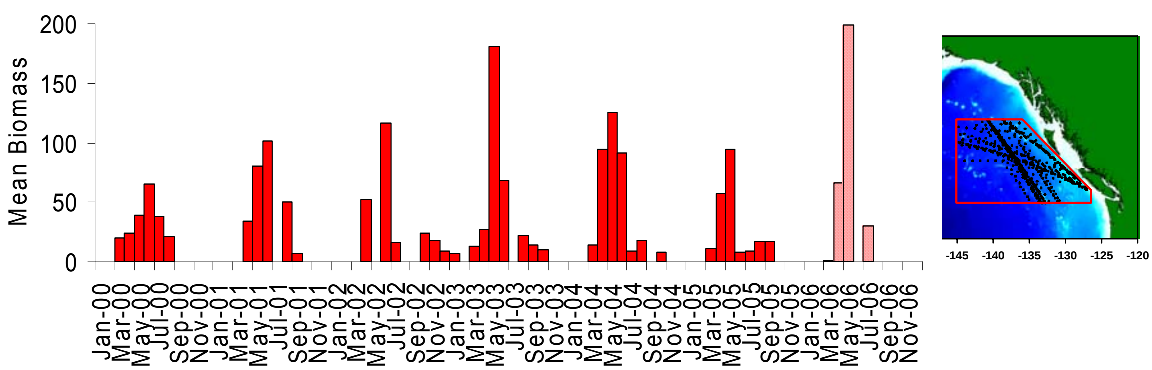

Figure 1. Changes in mesozooplankton biomass in the NE Pacific as determined for CPR tows. The 2006 data are not quality controlled.

Although the time series is short (seven years) climatic variability during the sampling period has led to some interesting results. Time series of mesozooplankton biomass (estimated from abundance data) for the northeast Pacific show an earlier progression of the spring mesozooplankton peak. This appears to correlate with the sea surface temperature which was cool in the first years of sampling (following the 1999 la Niña) and then became anomalously warm, especially in 2004/2005. *N. plumchrus*, which accounts for much of this biomass peak, has shown an earlier development to the sub-adult stage across much of the region.

The east-west transect has had a marine bird and mammal observer on the vessel, and a CTD fitted to the CPR and we used this multi-disciplinary data to characterise the transect. Community composition changes in higher and lower trophic level data coincided and were related to bathymetry or the current systems of the north Pacific (Batten et al., 2006) allowing us to identify 10 regions, or meso-marine ecosystems that seem to persist between years.

The Pacific survey is in its infancy and has no secure funding; contracts are renewed following RFPs on an annual/biannual basis. However, funding shared between at least two organisations seems to help lever continued funding and the fact that results are evident, and published, after just a few years of data encourages further support.

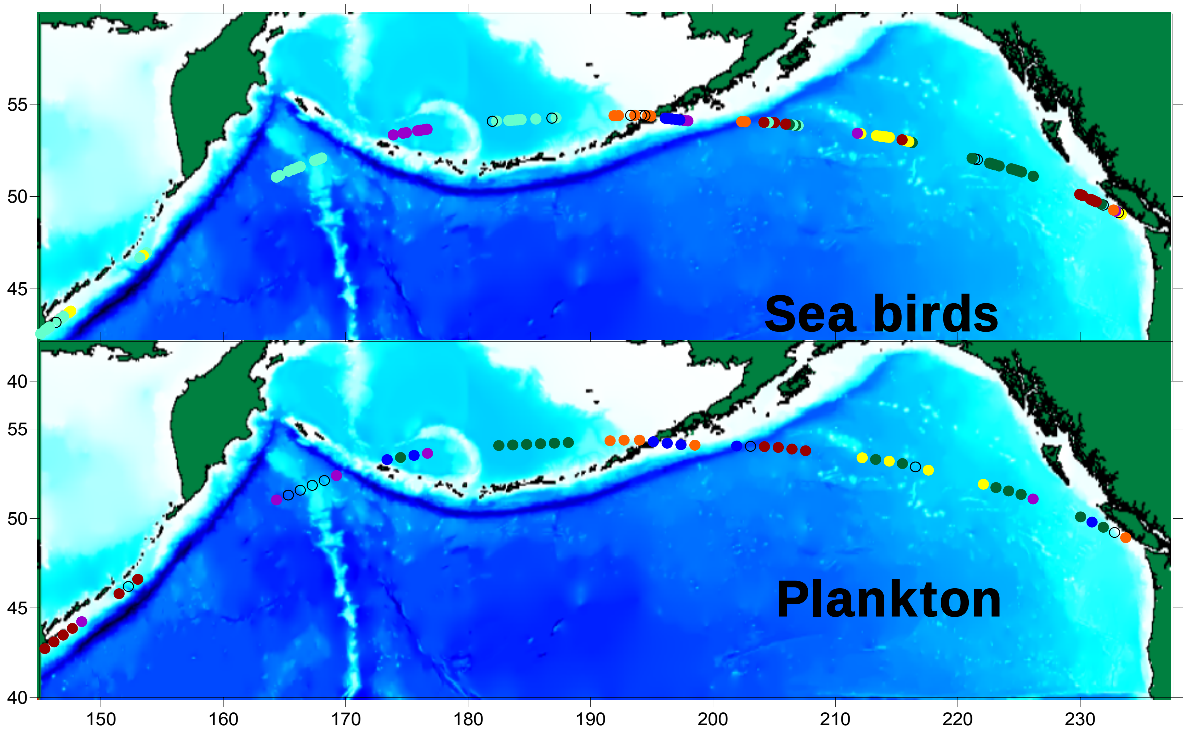

Figure 2. Seabird abundance and plankton community composition show similar patterns of change with different water masses in the N Pacific.

Reference

Batten, S.D, K.D. Hyrenbach, W.J. Sydeman, K.H. Morgan, M.F. Henry, P.P.Y. Yen, and D.W. Welch. 2006. Characterising meso-marine ecosystems of the North Pacific. Deep-Sea Res. II. 53, 270-290.

The Atlantic Zone Monitoring Programme (AZMP) and the Role of CPR Sampling

Pierre Pepin, Northwest Atlantic Fisheries Centre, St. John's, Newfoundland

The AZMP was designed to quantify the changes in the ocean's physical, chemical and biological properties. It derives its information on the state of the marine ecosystem from data collected at a network of sampling locations (fixed point stations, cross-shelf sections, and groundfish surveys) in each region (Quebec, Gulf, Maritimes, Newfoundland) sampled at a frequency of bi-weekly to once annually. A description of the **seasonal** patterns in the distribution of phytoplankton (microscopic plants) and zooplankton (microscopic animals) provides important information about organisms that form the base of the marine foodweb. An understanding of the production cycles of plankton, and their **interannual** variability, is an essential part of an ecosystem approach to fisheries management.

Zooplankton monitoring within the AZMP consists of vertically integrated sample collections from key stations along the thirteen core oceanographic transects and the six fixed stations (Figure 1) along with data collected by the CPR programme along the Z (Iceland – St. John's) and E (St. John's – Portland) lines. In recent years, sampling coverage at some fixed sites has been less than the goals defined by the programme (bi-weekly) because of issues dealing with the availability of appropriate platforms, and there have also been some reductions in the seasonal coverage along the core oceanographic transects. Consequently, I investigated the possibility that the CPR could serve as an additional source of information that could fill in gaps in terms of the seasonal coverage within the zone.

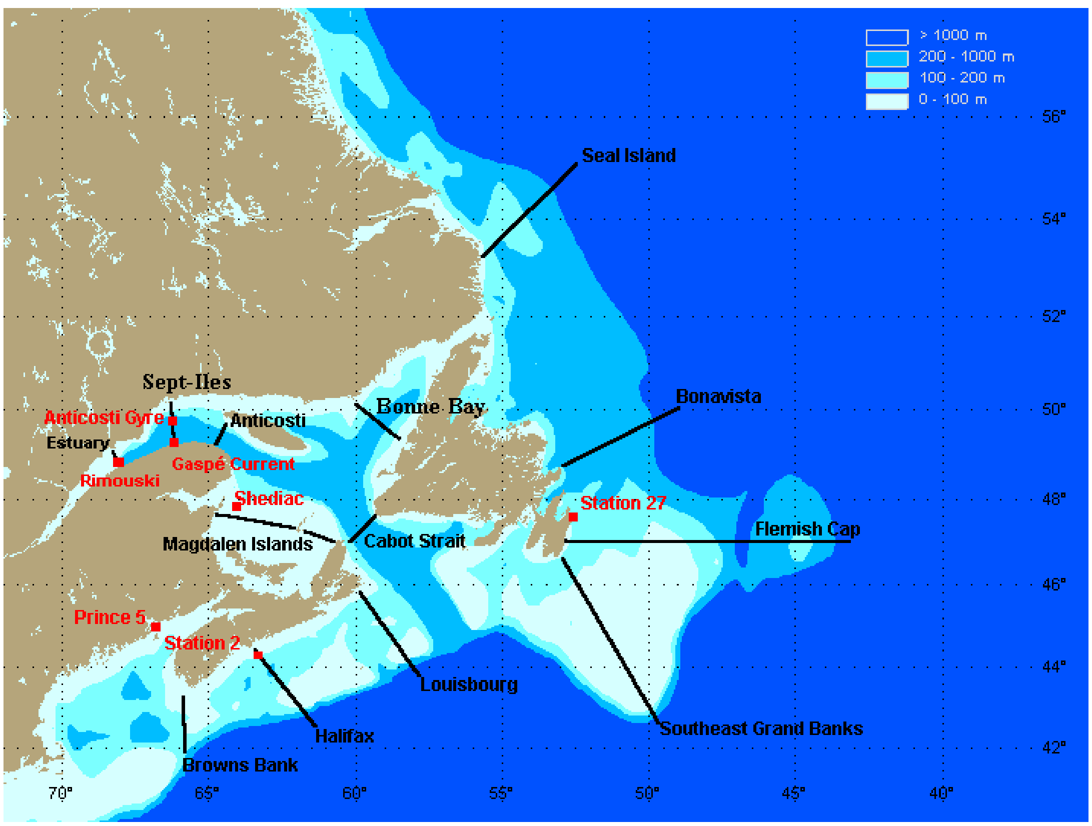

Figure 1. Map of the sections (black lines) and fixed stations (red dots) sampled in the AZMP. Sections are sampled 2-3 times per year, fixed stations (ideally) 2 times per month.

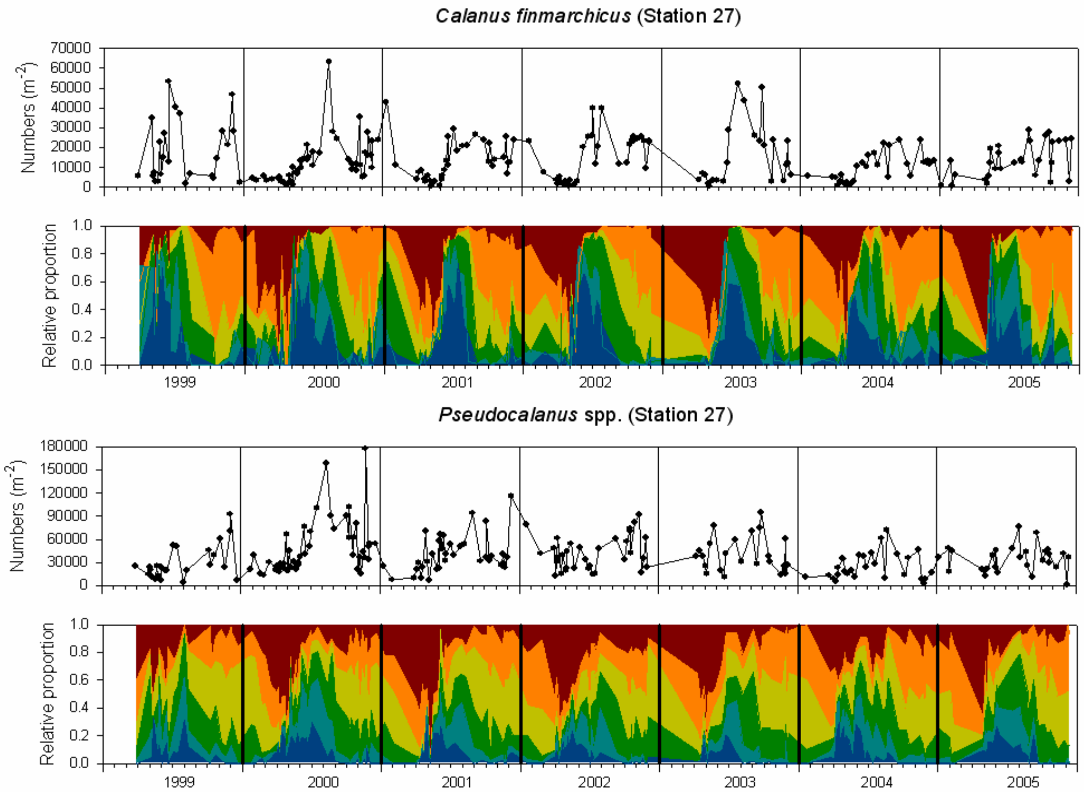

Figure 2. Seasonal stage distribution of Calanus finmarchicus and Pseudocalanus spp. at Stn. 27 over 7 years of sampling.

CPR data from the Z-line were contrasted with seasonal estimates of abundance from the four oceanographic transects on the NL Shelf as well as data from Station 27 for the period from 1999-2004. Monthly CPR data for *Calanus* spp., *C. finmarchicus, C. glacialis and C. hyperboreus* from the continental shelf (NAFO areas 3K and 3L) and from the Labrador Sea (41ºW to 47ºW) were stratified and averaged for the months of overlap with oceanographic surveys in the NL region. The averages were contrasted with GLM-derived estimates of abundance from the oceanographic transects, and the seasonal cycle for each CPR strata was contrasted with the seasonal cycle for *C. finmarchicus* at Station 27 (Figure 2).

Overall, the correspondence between CPR and AZMP derived estimates of inter-annual variability in seasonal abundance were poor and highly variable, but the limited number of degrees of freedom and short time series may not have registered a sufficiently dramatic change in standing stock to yield a strong correlation. Also, the contrast between CPR and net plankton observations can be influenced by ship track that may limit correspondence between programmes. CPR tracks show considerable variability that may result in the sampler crossing different zooplankton communities on the continental shelf. However, the CPR provides broad view of seasonality, particularly in offshore areas, which is not available from AZMP seasonal surveys and limited by the location of the fixed stations. Data from the Labrador Sea shows an earlier peak in abundance of *C. finmarchicus* relative to Station 27, consistent with the cycle of emergence from diapause and transport across the shelf known to occur throughout the North Atlantic. The integrated samplers used in AZMP provide a fuller measure of all life history stages for the focus species within the programme but CPR provides a more thorough analysis of rare elements than current AZMP protocols, which can be used to identify shifts in community structure and climate change. The overall conclusion is that AZMP and CPR plankton collections provide complimentary information for the NL region. Care needs to be taken in interpreting discrepancies between the data sets and well defined protocols have to be developed to ensure that inter-annual variations in CPR indices provide reliable measure of change that are not influenced by bias in the coverage by ships-of-opportunity given the limited number of observations available each month.

Net Plankton Data: Recent use and Possible Future Applications

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The temporal distribution of zooplankton sampling on the Scotian Shelf has been highly variable over the past 50 years. Prior to 1976, the Continuous Plankton Recorder (CPR), programme which ran from 1961-1976 and 1991-present, provides the only quantitative information for the region. From 1977-82, the Scotian Shelf Icthyoplankton Programme represents the largest contribution to zooplankton observations on the Scotian Shelf, 94% by volume of water sampled. Since 1991, the CPR programme has collected at least 44% by volume of the total dataset for 5 months of the year, providing a strong contribution to the overall sampling. The regular spatial sampling of the CPR programme allows for an estimation of the scales of variability of plankton on the Scotian Shelf; e-folding scales varied from <100 km for dinoflagellates to 240 km for *Calanus finmarchicus* and 580 km for diatoms.

The largest overall contribution to the annual abundance estimates of selected groups of phytoplankton and zooplankton from the CPR programme have been used in the recent evaluation of the eastern Scotian Shelf ecosystem (DFO 2003). Recent trends in the CPR data are consistent with a top-down effect from one trophic level to the next starting with reduced predation on pelagic fish species associated with the collapse of groundfish, and intensive consumption by pelagic fish on zooplankton leading to relatively high levels of phytoplankton.

The success of this recent application of CPR data has led to further examination of their utility to address other questions concerning assessment of changes in the plankton community structure and to quantify biodiversity. We focused our evaluation on zooplankton from two geographic areas along the E-line: the eastern Scotian Shelf (ESS) and southern Newfoundland (SN). Analysis of net plankton from archived collections and recent AZMP observations was also undertaken for the ESS. Briefly, we found 90 (ESS) and 72 (SN) unique categories (mixture of species, genera, family types) from the CPR observations and that distinct changes in community structure had occurred. On the ESS, three distinct community types were evident with the greatest separation occurring before and after 1992. The most recent period was dominated by *Calanus glacialis*, *Centropages typicus*, *Oithona* sp., Decapoda, Coelenterata, Bryozoans and Larvacea. The time series of decapod larvae was found to coincide remarkably well with the commercial landings of snow crab after accounting for an average age of recruitment of 8 years. Community structure in the SN showed two distinct time periods: before and after 1992; however the categories contributing to the differences were not the same as observed on the ESS, particularly with respect to decapod larvae. The net plankton data from the eastern Scotian Shelf collected before and during AZMP using 200-243 micron mesh nets (comparable to CPR mesh), different gear types and deployment methods resulted in identification of close to 400 unique categories. There was generally good agreement between these collections and CPR with AZMP providing much higher taxonomic resolution of the dynamics of the component species. Collectively, the species distributions should be evaluated in association with T-S properties, population dynamics of selected species, indicators of structural/functional changes in continental shelf ecosystems, monitoring and evaluating changes in biodiversity, development of biomass size spectra (from fish to phytoplankton) and for assessing changes in benthic macroinvertebrate abundance.

Reference

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Seasonality of Plankton on the Newfoundland Grand Banks

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The seasonality of plankton production may have important implications for the transfer of energy from primary to secondary and tertiary producers. Recent studies suggest the timing of plankton production in temperate marine systems is a sensitive indicator of climate change. It is hypothesized that the general trend in rising ocean temperatures in the eastern North Atlantic during the later part of the 1990s and into this century will modify trophic interactions among key planktonic taxa, resulting in the alteration of food web structure, and leading to ecosystem level responses. Similar trends in ocean warming have been documented in the western North Atlantic. We examine the seasonality of plankton production for dominant phytoplankton, mesozooplankton, and macrozooplankton on the Newfoundland Grand Banks using data from the CPR surveys during 1961-77, and 1991-2004.

The sampling distribution of the CPR surveys was uneven for both spatial and temporal scales due to the nature of opportunistic sampling with ships of opportunity, variation in shipping routes, and funding. We did not differentiate the data based on bathymetry (e.g., shelf versus slope) and included all the data bounded by the NAFO Divisions 3L and 3Ps (Figure 1). The CPR estimates of plankton abundance are means of transformed raw binned counts in $3m^3$ samples averaged over each available month and year from 1961-77 and 1991-2003. We excluded data from the analysis when more than two consecutive months were missing. We examined the seasonality of plankton on the Grand Banks using the centre of mass of the monthly counts (T_{CM}) based on the entire year's data.

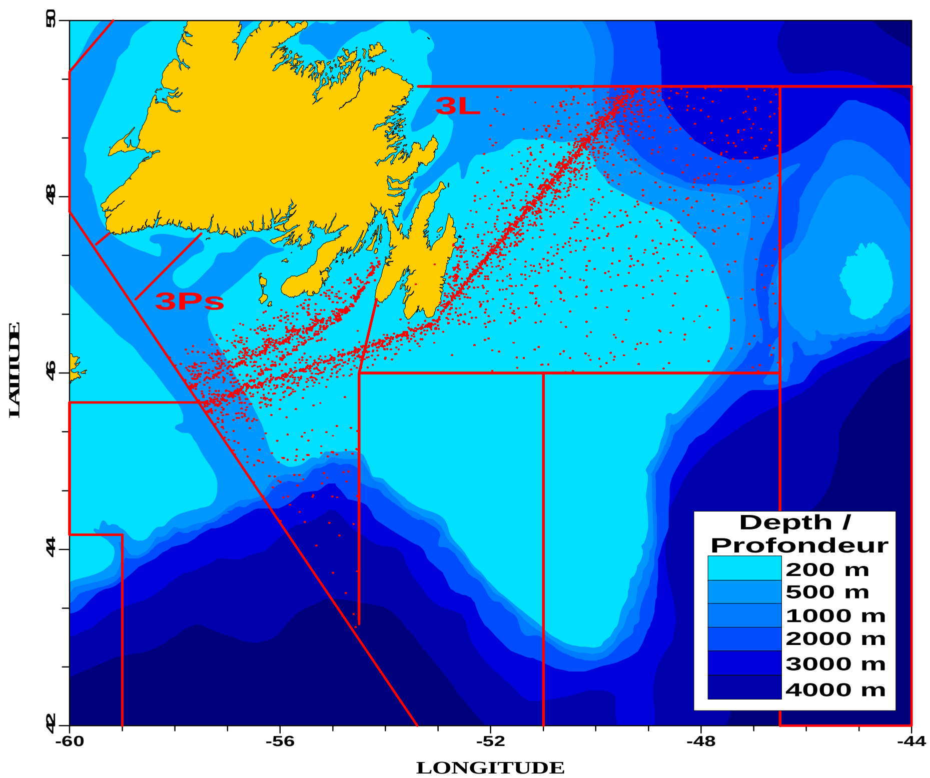

Figure 1. Overlay of the CPR stations within NAFO Divisions 3L and 3Ps (Newfoundland Grand Banks) from 1961 to 2003. Note the concentrations of stations along the main commercial shipping lanes.

The temporal indexes of the major phytoplankton production were relatively stable on the Grand Banks during the entire period (Figure 2a). No significant linear trends were detected during either time period with the exception of *Chaetoceros* spp., which gradually shifted to a later occurrence during the 1960-1970s. The seasonality of dominant CPR mesozooplankton, consisting mainly of copepods, also showed remarkable consistency from year to year on the Grand Banks (Figure 2b). Interannual variability in the T_{CM} of mesozooplankton was particularly high for certain CPR taxa (e.g., *Paracalanus/Pseudocalanus* spp.). The only trends were observed for the early life stages of Calanus spp. (CI-CIV; composed mainly of *Calanus finmarchicus*) which occurred later during the 1960-1970s relative to the 1990-2000s, and vice versa for *Oithona* spp.

The temporal centre of mass of dominant macrozooplankton taxa remained largely unchanged although interannual variability was high (Figure 2c). Interannual variability of Chaetognatha and Euphausiacea revealed abrupt changes from summer to spring during the early to mid-1960s (Figure 2c). These taxa also showed evidence of a systematic and gradual move back to summer production during the later part of the 1970s. The T_{CM} of the Euphausiacea shifted gradually to later in the year during the 1960-1970s, but this pattern changed for both Chaetognatha and Euphausiacea during the 1990-2000s, with a shift back to an earlier occurrence during the year.

The results reported recently from the NE Atlantic indicate that plankton bloom earlier today in the central North Sea compared to past decades. The study attributed changes in seasonality of plankton to the general trend in warming of the ocean. Statistical analyses of the CPR plankton revealed a high degree of correlation between timing in the seasonal peak with sea surface temperature. The magnitude of changes in the timing of peak occurrence of plankton in the North Sea are greater than previously documented in terrestrial systems and suggest that temperate marine systems may be sensitive indicators of climate change. One of the main conclusions of the study suggest that the differential responses of the plankton community to changes in environmental conditions (i.e., warming of the oceans) has led to a "mismatch between successive trophic levels and a change in the synchrony of timing between primary, secondary, and tertiary production." The authors also suggest that combined with the effects of over-fishing, changes in the abundance and seasonality of key planktonic prey have recently been implicated in the lack of recovery of some commercial fish stocks in the North Sea.

Overall, the small changes in the T_{CM} of dominant CPR plankton on the Grand Banks contrasts with observations in the central North Sea where long-term variability of the parameter was driven by an earlier seasonality during the main production cycle. Despite the general trend in ocean warming observed over the whole of the North Atlantic since the late 1990s, the seasonal cycles of most of the dominant CPR plankton taxa on the Grand Banks remained relatively stable. Additional analyses using cumulative distributions of the dominant CPR plankton groups appear to better resolve the timing of production compared to the centre of mass index which averages data to monthly intervals. These more detailed analyses for the time of first arrival indicate a general trend to later occurrence in the seasonality of plankton during 1961-1977, in contrast to the opposite trend during 1991 to 2004 (Figure 3). The mesoplankton (mainly copepods) and macrozooplankton (Larvacea and Chaetognatha) showed the largest changes in the time of first arrival on the Newfoundland Grand Banks during the past several decades. We plan to continue our efforts to further develop these phenological indicators and evaluate their relationship to environmental variability to refine our view of the annual and interannual variability of plankton dynamics in the NW Atlantic.

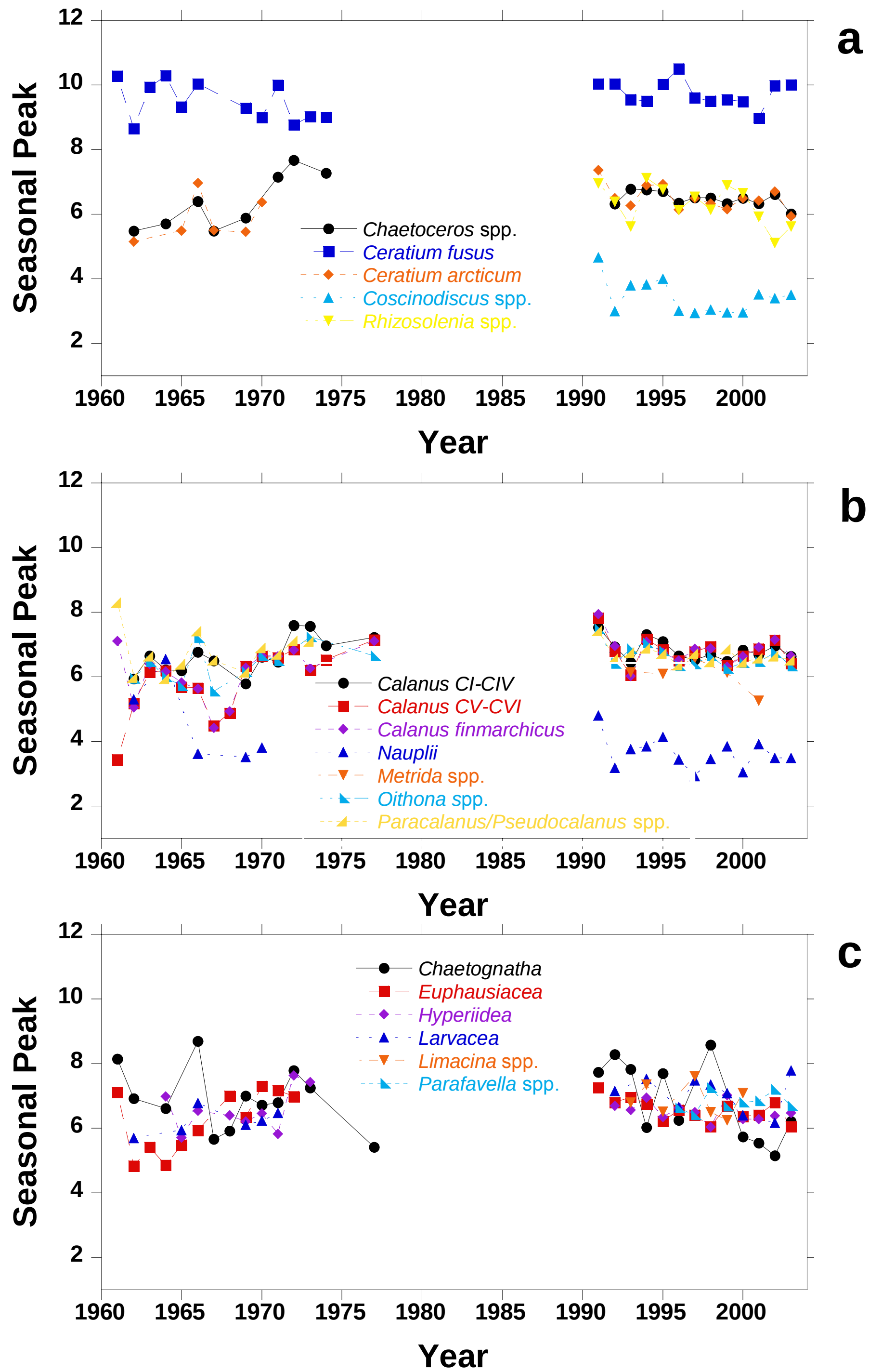

Figure 2. Annual value of the TCM index (annual centre of mass of the monthly plankton counts) for (a) phytoplankton ; (b) mesozooplankton, and (c) macrozooplankton taxa collected during the CPR survey on the Grand Banks during 1961-77 and 1991-03 time periods.

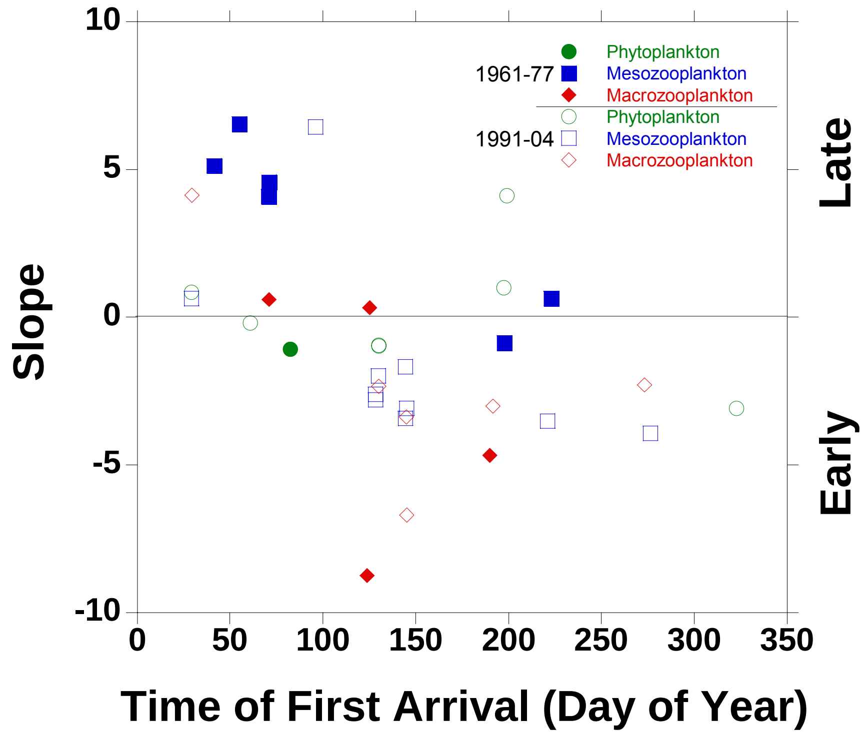

Figure 3. Change in the slope (based on linear regressions) during the time periods 1961-1977 and 1991-2004 and time of first arrival estimated from cumulative distributions at the beginning of each respective period. A negative slope indicates the trend in seasonality is becoming earlier while positive values suggest the reverse trend

Do AZMP and CPR Sampling Identify Similar Trends in Zooplankton Community Composition?

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Although the Continuous Plankton Recorder (CPR) and Atlantic Zone Monitoring Programme (AZMP) estimate zooplankton abundance in different parts of the water column using different sampling gear and a slightly different suite of taxa, both platforms have been assumed to represent reasonable indices of the abundance and community composition of the Scotian Shelf mesozooplankton. Here, broad-scale patterns of zooplankton community composition as well as abundance and dominance structure in intersecting sampling regions were compared for the two platforms in springtime of six years between 1997 and 2004.

On the Scotian Shelf, larger numbers of species were observed in the AZMP ring net tows than at CPR stations, probably due to differences in both the volumes and depths sampled. The largest shifts in community composition in the AZMP transects were observed between the Scotian Shelf and Cabot Strait and between stations on and off the shelf. Similarly, the largest shifts in community composition in the CPR transects were associated with the shelf-slope boundary. The CPR samples the entire Scotian Shelf in approximately a day, and thus diel differences in zooplankton abundance and community composition were difficult to discern in broad-scale spatial plots, due to spatial gradients encountered by the CPR at timescales less than a day.

To compare abundance and community composition in samples collected at close proximity in space and time, zooplankton abundance at stations within one degree boxes surrounding intersection points of AZMP and CPR April or May transects were averaged and transformed (ln[n+1]), and the transformed mean abundances from all intersections and years were correlated. When both daytime and night time CPR stations were included, there was no correlation between total abundance of mesozooplankton sampled by the CPR and AZMP programmes ($r^2 = 0.16$; $p = 0.052$). Total abundance was significantly correlated when only night time CPR samples were included ($r^2 = 0.41$; $p = 0.01$), but not when only daytime CPR samples were included ($r^2 = 0.013$; $p = 0.34$). The difference between daytime and night time relationships likely results from diel vertical migration of many zooplankton taxa.

Despite differences in the division of taxonomic groups that were enumerated in the two programmes, the shape of rank-abundance curves were similar for zooplankton in the intersecting regions. The most abundant taxon in the AZMP samples, *Oithona*, was less abundant in the CPR samples, perhaps because of its small size and the larger mesh size of the CPR, but *Oithona* spp. ranked fifth among CPR zooplankton. The second, third, and fourth ranked AZMP taxa, *Pseudocalanus, Calanus finmarchicus*, and *Fritillaria* were represented by the highest-ranked CPR taxa, *Calanus* I-IV, *Para-Pseudocalanus,* Larvacea, and *Pseudocalanus* adults. Correlations between log-transformed, night time abundance of individual dominant taxa, including *Oithona*, *Calanus finmarchicus*, *Pseudocalanus-Paracalanus*, *Centropages*, *Temora longicornis*, and *Metridia lucens* were significant only for *Oithona*.

Annual Anomalies of Scotian Shelf Phytoplankton

William K.W. Li - Ecosystem Research Division, Bedford Institute of Oceanography, Dartmouth, Nova Scotia

The Scotian Shelf is a large marine ecosystem in the Northwest Atlantic Shelves Province of the Atlantic Coastal Biome. In this region, the phytoplankton colour index (PCI) from the Continuous Plankton Recorder (CPR) is generally much higher than it was four decades ago. The implied increase in phytoplankton biomass has been alternatively attributed to cascading effects resulting from the removal of top predators, and also to control by bottom up forcing, depending on the shelf subregion. Since the 1990s, we have monitored the chlorophyll a concentration (Chl) on the Scotian Shelf by shipboard measurements of filtered seston (AZMP-BIOCHEM), by remote visible spectral radiometry (SeaWiFS), and by continued use of colorimetry from CPR. Here we compare the weekly climatologies of Chl constructed from the three separate datasets, and compute the average anomaly for each year. Although both CPR and SeaWiFS Chl were strongly correlated with AZMP-BIOCHEM Chl, both types of remote measurements overestimated sea-truth over a large range, and were much less variable through the progression of the 52-week cycle (Figure 1). The inexact match of Chl calculated from remote proxies (PCI and ocean colour) to sea-truth indicates that the record of absolute phytoplankton biomass on the Scotian Shelf cannot be reconstructed into the past; nor can the future record be established without in vitro measurements. Although the annual anomaly has decreased since 1999, a much longer record of observations is needed to discern if this is a reversal of the multi-decade increase.

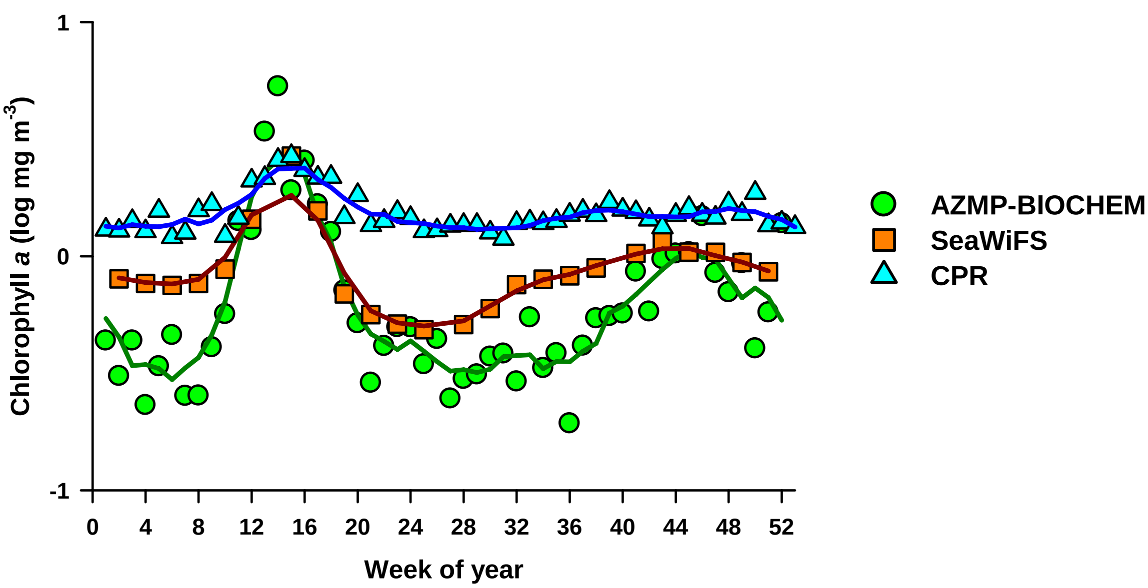

Figure 1. Comparison of the chlorophyll climatologies for extracted chlorophyll (AZMP), satellite derived chlorophyll (SeaWiFS) and phytoplankton colour (CPR)

Zooplankton Abundance Trends and Inter-Decadal Changes in Seasonal Cycles in CPR and Net Data from AZMP Time Series Stations

Erica Head – Ocean Research and Monitoring Section, Ecosystem Research Division, Bedford Institute of Oceanography, Dartmouth, Nova Scotia

There has been sampling of zooplankton in ring vertical net hauls from the bottom to the surface at approximately monthly intervals at time series stations off Halifax (Stn. HL2, 150 m depth) and St. John's (Stn. 27, 175 m depth) since 1999 as part of the Atlantic Zone Monitoring Programme (AZMP). There has been CPR sampling across the Scotian and Newfoundland shelves at a fixed depth of approximately 7 m on an approximately monthly basis since 1992. The techniques use different mesh sizes (200 μm for the AZMP, approximately 300 μm for the CPR) and the sampling mouth areas are different (the ring net has cross-sectional area of 0.44 m^2, the CPR has a cross sectional area of 12 mm^2).

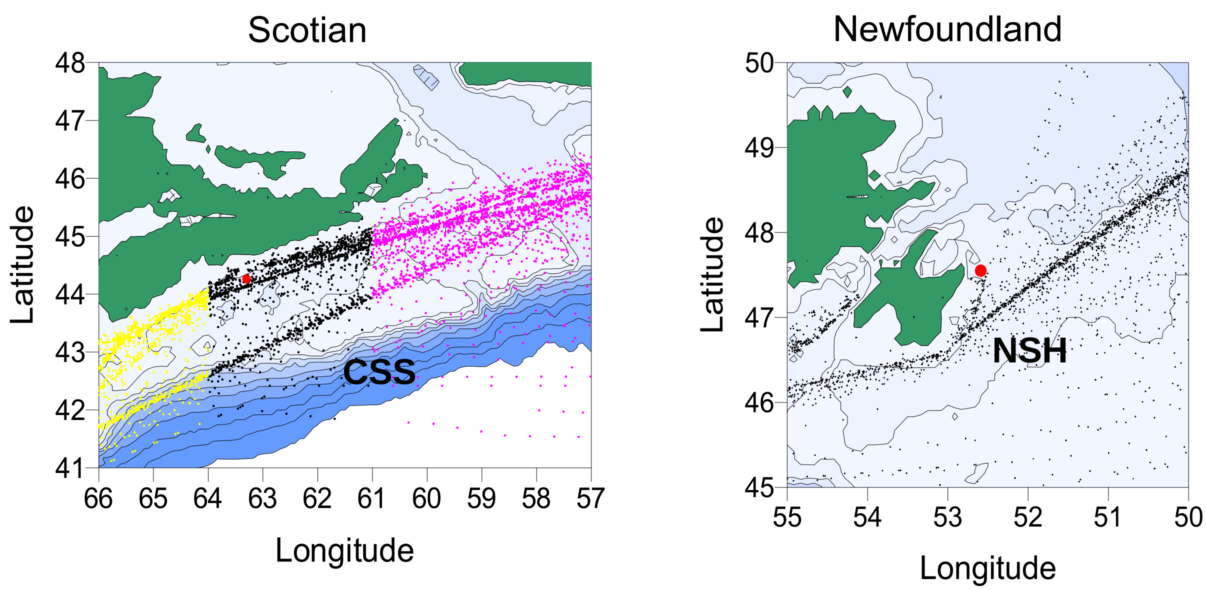

Figure 1. Sections of CPR tracks on the Scotian Shelf (CSS) and Newfoundland Shelf (NSH) for which data were analysed (1999-2004) to compare with the results obtained from AZMP sampling at fixed stations Stn. HL2 (red dot) on the CSS Shelf and Stn. 27 (red dot) on the NSH.

In order to compare results from the two sampling techniques, CPR abundance data (# m^{-3}) were Log (N+1) transformed and averaged for each month of each year for restricted areas of the Central Scotian Shelf (CSS) and the Newfoundland Shelf (NSH). The number of samples in each area was >6 for 70% of the sampled months. The AZMP abundances (# m^{-3}) were also averaged for each month of each year (there were seldom >2 samples per month) and Log (N+1) transformed for the comparison.

The CPR category *Calanus* I-IV, which is one of the most important groups in terms of abundance and biomass on the Scotian and Newfoundland shelves, includes *C. finmarchicus* stages I-IV, *C. glacialis* stages I-IV and *C. hyperboreus* stages I-II. The *Calanus* species are enumerated to stage and species in the AZMP, and for this comparison the appropriate stages were summed to give a comparable AZMP *Calanus* I-IV group.

On the CSS CPR and AZMP seasonal cycles of abundance were similar for *Calanus* I-IV, which were mostly *C. finmarchicus*. The differences in the seasonal cycles for the late stages for the *Calanus* species could be explained by seasonal changes in depth distribution, since the CPR only samples the surface layer and AZMP, the entire water column. The same was true for 2 *Metridia* species and *Centropages typicus. Oithona* and euphausiids were probably undersampled by CPR the former species due to their small size, the latter due to their large size and high mobility. Annual trends over the 6 year period were in the same direction for 6 of the 10 categories examined and in opposite directions for 2.

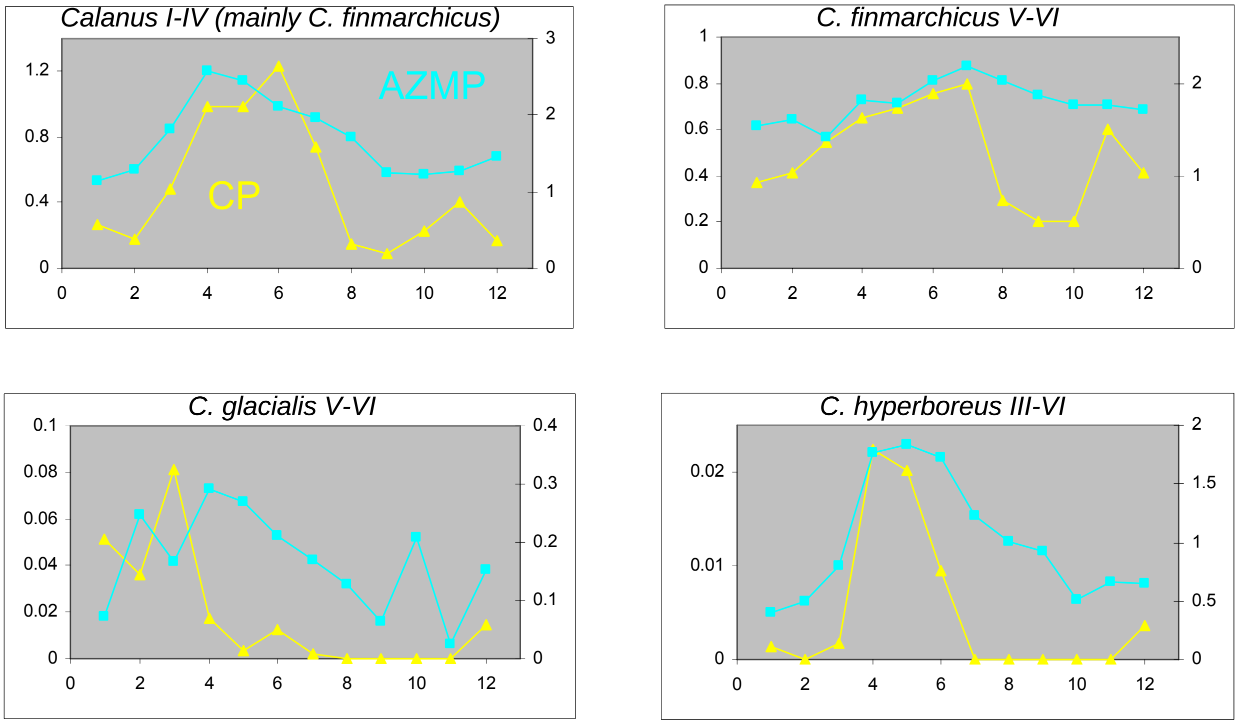

Figure 2. Seasonal cycles (monthly averages 1999-2004) of 4 categories of Calanus species on the Central Scotian Shelf (CPR) and at Stn. HL2 (AZMP). Left y-axis is Log (N+1) CPR abundance, right Y-axis is Log (N+1) AZMP abundance.

On the NSH only the data for the 4 *Calanus* categories are shown. The annual trends in abundance were upward for the late stage Arctic *Calanus* species (*C. glacialis* and *C. hyperboreus*) and downward for *C. finmarchicus* V-VI in both datasets. *Calanus* I-IV showed an upward trend in AZMP and a downward trend in CPR sampling, which was precisely the opposite of what was seen on the CSS and at Stn. HL2. Seasonal cycles for late stage Arctic Calanus species showed higher maximal abundances than of the CSS and CPR/AZMP differences indicated that they spent longer in the surface layer on the NSH than on the CSS. The seasonal cycles for *C. finmarchicus* V-VI were similar in both datasets, but those for *Calanus* I-IV were quite different. The AZMP data showed a peak in June/July and the CPR data a peak in October and trough in April-July. *C. glacialis* I-IV made a substantial contribution of the *Calanus* I-IV group in April-June in the AZMP data, but not later. Interestingly the peak in CPR *Calanus* I-IV abundance on the NSH in the 1960s used to be between May and September. The inter-decadal change in seasonal cycle does not seem to be an artefact related to changes in sampling tracks. Since *Calanus* I-IV is a dominant and ecologically significant group, this difference merits further investigation.

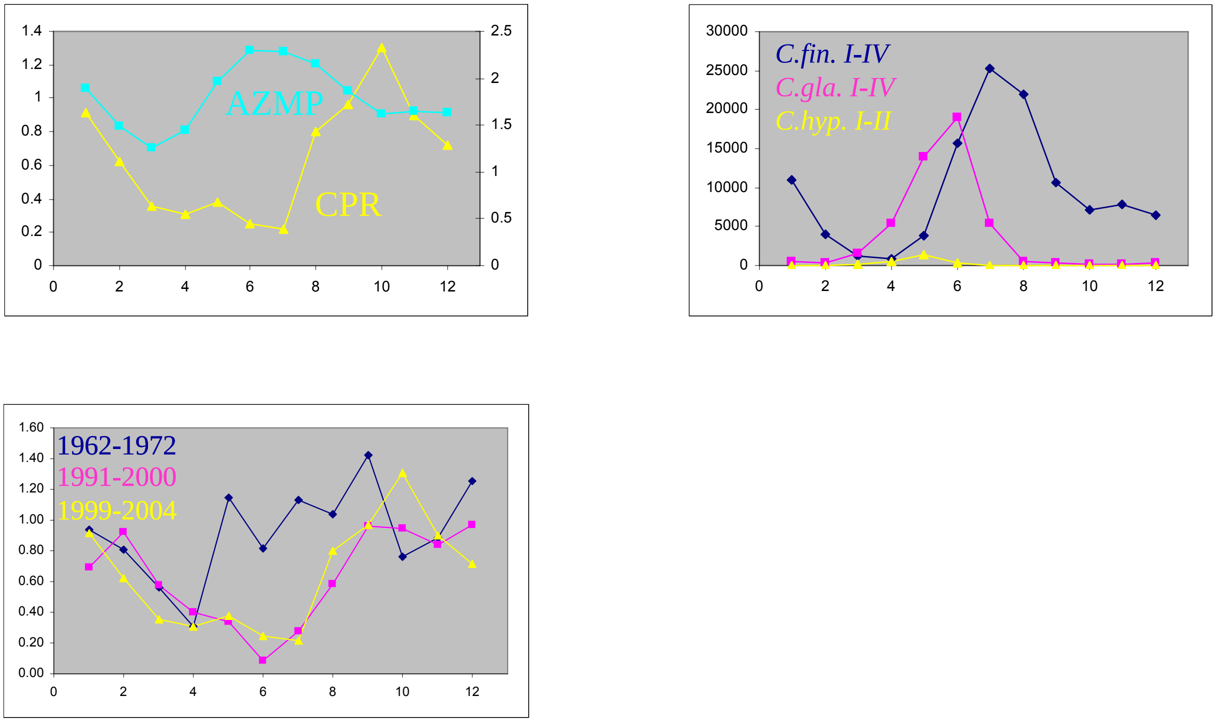

Figure 3. Seasonal cycles of abundance of Calanus I-IV on the Newfoundland Shelf. Comparison of CPR (left y-axis) and AZMP (right y-axis) abundance values Log (N+1) transformed (upper left); contributions of the 3 Calanus species to the AZMP Calanus I-IV group abundance (# m-2) (upper right); seasonal cycles of CPR abundance Log (N+1) transformed for 3 time periods (lower left).

CPR and Zooplankton Net Data Trends from the Scotian Shelf and the Influence of Temperature on CPR Taxa Numbers

Doug Sameoto – Ecosystem Research Division, Bedford Institute of Oceanography, Dartmouth, Nova Scotia

Patterns of abundance for selected species of zooplankton collected with CPR and vertical and BIONESS net tows collected on the Scotian shelf were compared for years 1991 to 2002. The CPR data were from the Scotian shelf section of the E line and the net data were taken from stations sampled during the Atlantic Zonal Monitoring Programme (AZMP). The CPR sampled at a depth of approximately 6 m for a distance of 10 nautical miles and represented approximately 3 m^3 of filtered water. The net data were taken from vertically towed 200µm mesh nets that sampled the entire water column and represented the numbers of animals per m^2. The comparisons of the two different sampling methods looked at trends in the data rather than changes in absolute abundances of the animals.

Abundances of *C. finmarchicus, Pseudocalanus spp., Temora spp., Oithona spp*., total copepods and total euphausiids were compared. Various least squares smoothers were calculated for these data to detect trends in the data. The two data sets showed good agreement for *C. finmarchicus* and *Pseudocalanus spp*. but did not agree well for smaller species of copepods, total copepods or total euphausiids.

A number of CPR taxa showed positive significant correlations with increasing water temperature at 10 m depth, whereas some taxa showed no relationship or a negative correlation with temperature at this depth.

Establishment and Insights Gained from the Southern Ocean CPR Survey

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The Southern Ocean Continuous Plankton Recorder (CPR) Survey was started by Dr. Graham Hosie of the Australian Antarctic Division in 1991. Initial sampling was limited to the seasonal ice zone, but by 1997 had been expanded to include regular seasonal sampling of the permanently open ocean zone south of Australia. In 1999 Japan joined the programme, increasing CPR coverage south of Australia, while the joining of Germany and New Zealand in 2004 and 2006 further extended sampling to the Atlantic and Pacific sectors of the Southern Ocean. To date the Southern Ocean CPR Survey has completed greater than 100,000 nm of CPR tows, providing greater than 20,000 samples at 5nm resolution. As this long term monitoring programme is still relatively early in its development analyses have focused on establishing a baseline against which future change can be measured. The spatial distribution and biogeographic zonation of zooplankton communities has been established, and the seasonal cycle of communities quantified. Species inventories are being added to as an ongoing process and the first analyses of inter-annual variability are in progress. In addition, three methodological studies have been conducted to: 1. calibrate CPRs against vertical nets; 2. quantify CPR volume filtered; and 3. identify the taxonomic resolution required to identify biogeographic zones. These studies are covered in more detail in this abstract.

1. Calibration against vertical nets was completed by direct comparison of CPR samples with those collected by vertically hauled NORPAC nets (45 cm diameter). Both CPR and NORPAC were fitted with 270μm nylon mesh and sampled the same transect line approximately 3 weeks apart. NORPAC hauls were stratified into 4 depths (0-20m, 20-50m, 50-100m, 100-150m), to provide insight into the influence of the shallow CPR sampling depth (approximately 10m) on zooplankton collected. In comparison to NORPAC nets from the same depth zone (0-20m) the CPR underestimated zooplankton species richness, while overall species richness increased with depth indicating that the CPR sampled a distinct surface community (Figure 1). However, despite sampling differences both nets identified the same biogeographic zones.

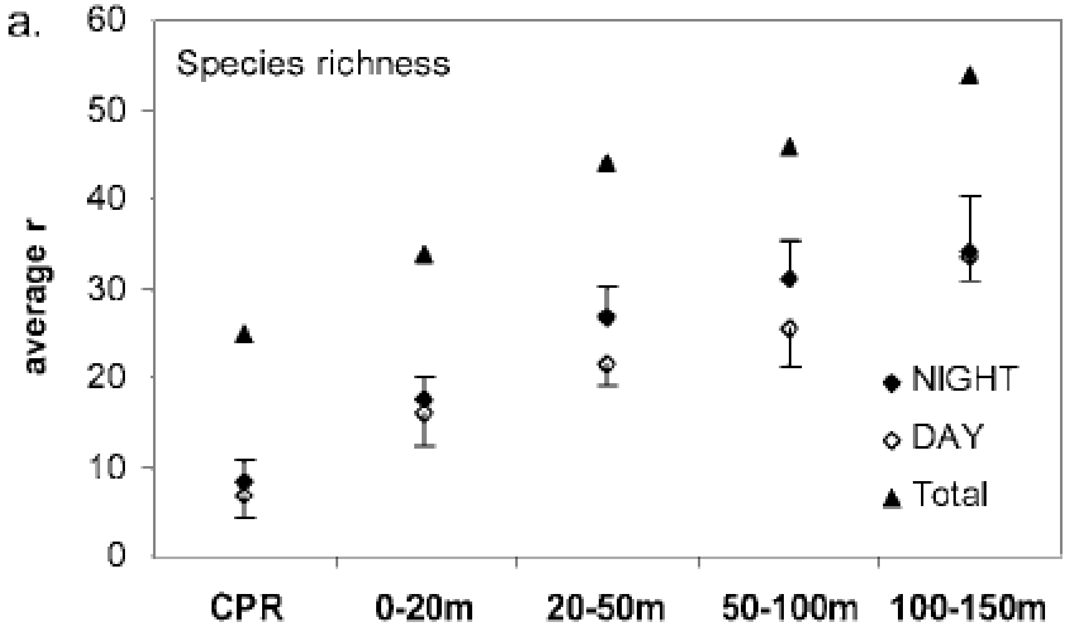

Figure 1. Night, day and total species richness recorded from CPR samples and four NORPAC net depth zones (0-20m, 20-50m, 50-100m, 100-150m). From Hunt and Hosie 2003.

2. An electromagnetic flowmeter (Valeport) was fitted to a Type II Mark III CPR and three tows completed. In addition to recording volume filtered at ~3 second intervals, ship board sensors recorded GPS position, ship speed, fluorescence and photosynthetically active radiation at 1 second intervals. Clogging by high phytoplankton and zooplankton densities caused up to a 60% reduction in measured volume filtered (Figure 2). A negative relationship was observed between measured volume filtered and ship speed, with an ~ 30% reduction associated with a decrease in ship speed from 14 to 9kn. In combination clogging and ship speed resulted in a maximum 78% reduction in volume filtered. We contend that the negative relationship between ship speed and volume filtered was caused by the flowmeter itself, and specifically that the placement of the heavy (17kg) flowmeter battery pack in the tail of the CPR caused an increase in towing pitch at with decreasing ship speed. It has been demonstrated that a 10^{o} change in CPR pitch can result in an ~10% reduction in flow (Reid et al. 2003). The impact of clogging highlights the necessity for routine use of flowmeters on CPRs, however, there is a requirement for the development of smaller and lighter instruments and the continued miniaturization of loggers for attachment to marine vertebrates holds promise in this regard.

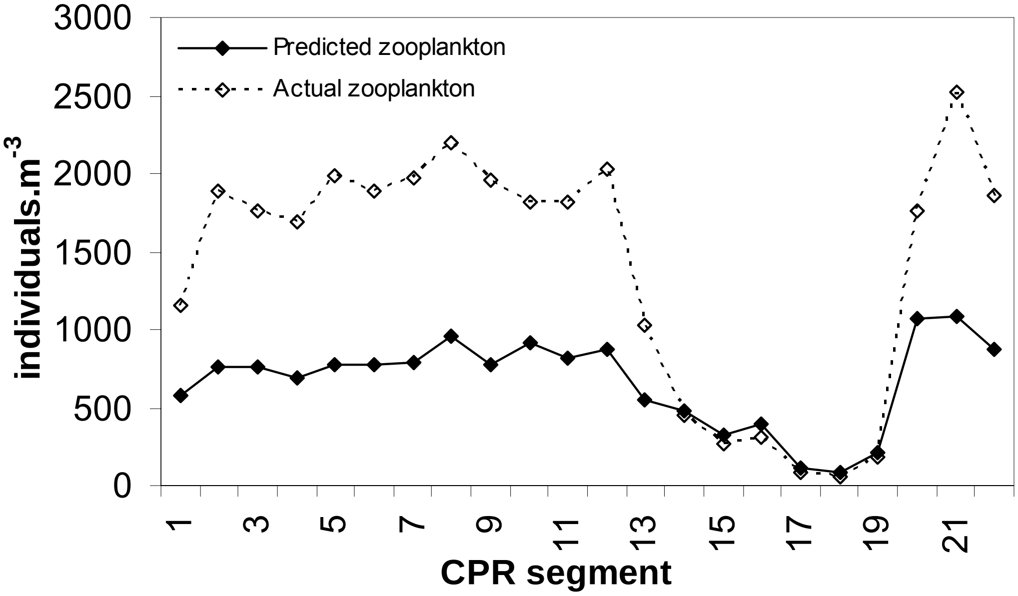

Figure 2. Predicted zooplankton (assuming 1.5m-3 filtered.5nm-1) and actual zooplankton densities (calculated from flow meter measurements), demonstrating how predicted levels underestimated actual densities. From Hunt and Hosie 2006.

3. Six biogeographic zones have been identified in the Southern Ocean south of Australia (Hunt and Hosie 2005, DSR I 52). Using the same data set we investigated the taxonomic resolution required to identify these zones. Post-hoc ANOSIM tests of between zones differences in Bray-Curtis similarity levels were calculated for both abundance ($\log_{10}(x+1)$ transformed) and presence / absence data. The taxonomic levels of species, genus, family, order and class were used. As expected, taxonomic richness within zones decreased with increasing taxonomic level. Similarities within and between zones increased with increasing taxonomic level for both abundance and presence / absence data (Figure 3). However, ANOSIM tests showed that differences between zones were significant at all taxonomic levels when using abundance data. In the case of presence / absence data, loss of information after taxonomic compression reduced the power of the data set to resolve small-scale biogeographic differences. Nonetheless, 92.5% of between zone comparisons were significantly different using these data. Overall, ocean basin scale biogeographic zones were identifiable from species level to class using both transformations. The application of higher taxonomic levels to discerning biogeographic zones provides a means to compare CPR data, where the taxonomic resolution obtainable for some groups is reduced due to e.g., damage to soft bodied taxa, with those collected by other nets. Higher taxonomic levels also open up possibilities for post-hoc generation of long-term data sets for climate studies through effective merger of data collected using different apparatus.

a. within zones (abun)

b. within zones (P/A)

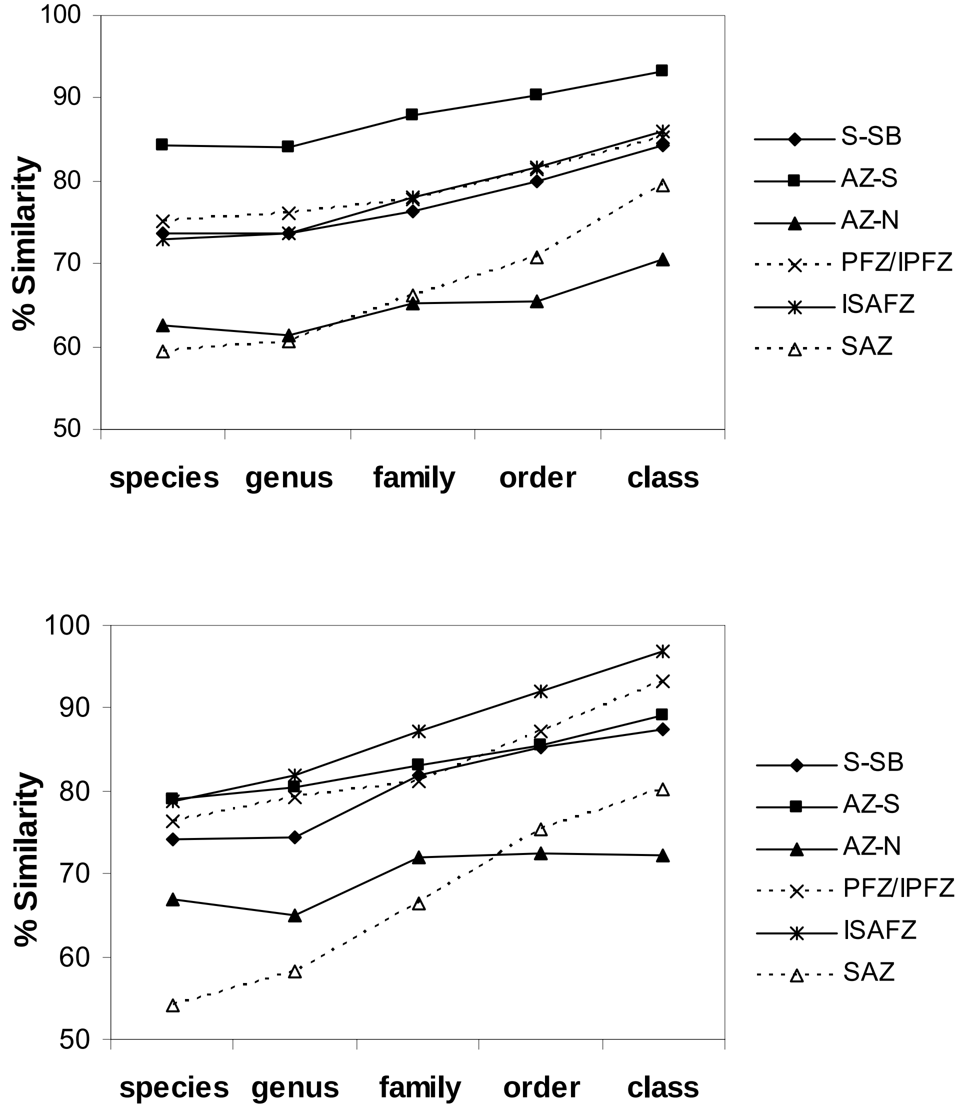

Figure 3. Average sample similarity (Bray-Curtis) within zones for each taxonomic level calculated using: a. log10(x+1) abundance (abun) data, and b. presence / absence (P/A) data. From Hunt and Hosie (in review).

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Resuscitation of Lake Winnipeg Using CPR? - Subtitle: Continuous Underway Monitoring of Environmental Variables in Lake Winnipeg

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The world's tenth largest freshwater ecosystem, Lake Winnipeg, nearly 25,000 km^2 in area, like other fresh, brackish and marine systems is becoming increasingly eutrophic as a result of nutrient loads from multiple human activities. Its immense watershed of approximately 1,000,000 km^2 is drained by sixty streams and rivers with the Saskatchewan, Winnipeg, and Red Rivers flowing from the west, east and south, respectively, supplying most of the water to the lake. The lake, divided into three sub-basins (North, Narrows, and South) and straddling a geologic boundary with Precambrian rocks on the east and sedimentary deposits on the south and west is physically and chemically diverse. With a relatively shallow mean depth, 12m, Lake Winnipeg is flushed every 3 to 4 years by inflows which impart their distinctive qualities to various parts of the lake resulting in a spatially heterogeneous system (Figure 1). During the last three decades, the increasing load of total phosphorus (TP) associated with higher Red River flows and elevated TP concentrations has stimulated biological production resulting in the accumulation of cyanophyte blooms in all regions that threaten the sustainability of environmental services ($25M commercial fishery, $100M recreation, drinking water supplies) provided by the lake.

Figure 1. Satellite Image of Lake Winnipeg August 2005 (G. McCullough, U of Manitoba).

Until recently, little scientific information on Lake Winnipeg was available as a basis for management decisions aimed at ecosystem restoration. In 2001, to facilitate much needed study, the Lake Winnipeg Research Consortium was incorporated and brought together federal, provincial and university scientists to conduct ecosystem studies on the lake. Over the past 5 years, mainly using discretionary (non-funded) time, DFO Freshwater Institute scientists sampled the physical, chemical and biological properties of Lake Winnipeg each spring, summer, and fall from the MV Namao, a 34 m buoy tender transferred to the LWRC by the Canadian Coast Guard in 2005. Discrete physical, chemical and biological samples were collected from a lake-wide network of 65 stations (Figure 2) and selected physical (temperature, spectral surface reflectance), chemical (O_2, pCO_2, TSS) and biological (algal chlorophyll, species biomass, toxin content) properties were monitored continuously underway during which time side-beam trawls were also used to sample the pelagic fish community.

Continuous underway monitoring is used primarily to improve estimates of gas (O_2, pCO_2, CH_4) flux for assessing the Lake Winnipeg carbon budget (Stainton FWI). In addition, continuous in-situ chlorophyll and turbidity monitoring to truth surface reflectance sensed by satellites will enable assessment of the annual primary productivity of Lake Winnipeg. Algorithms to estimate the abundance of algal community groups (cyanophytes, diatoms, chrysophytes) have been developed by Greg McCullough (CEOS U of Manitoba) in collaboration with algal species identifications by Hedy Kling (Algal Taxonomy and Ecology).

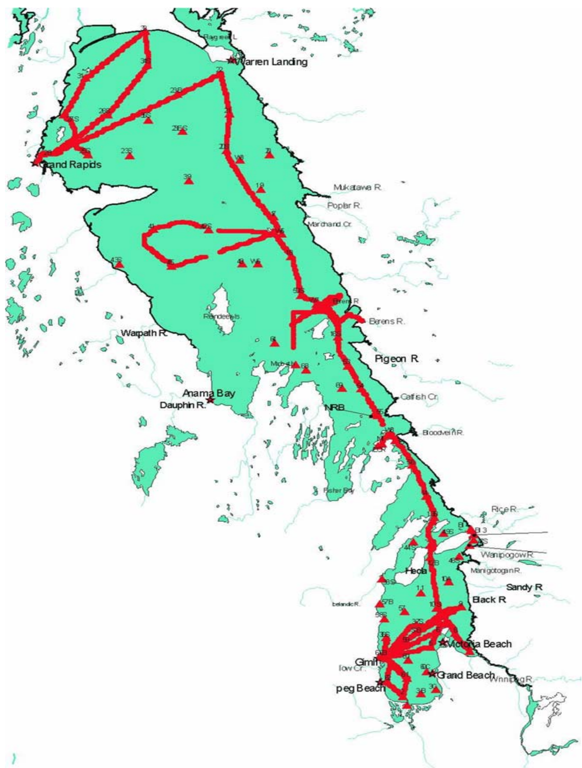

Figure 2. Station network and typical continuous underway sampling pathway.

Continuous plankton recording (CPR) may improve understanding of algae – zooplankton interactions in Lake Winnipeg, a necessary pre-requisite to predict fishery productivity. While the lake is vertically well mixed, its extreme horizontal patchiness may be best sampled by the CPR method. However, high chlorophyll (50 – 100 ug/L) and turbidity levels may reduce filtration efficiency of CPR gear.

BIO researchers familiar with the CPR method recommended that instead of using the CPR technique, Lake Winnipeg researchers should refine the zooplankton net-sampling programme by reducing the number of stations and shortening the sampling interval.

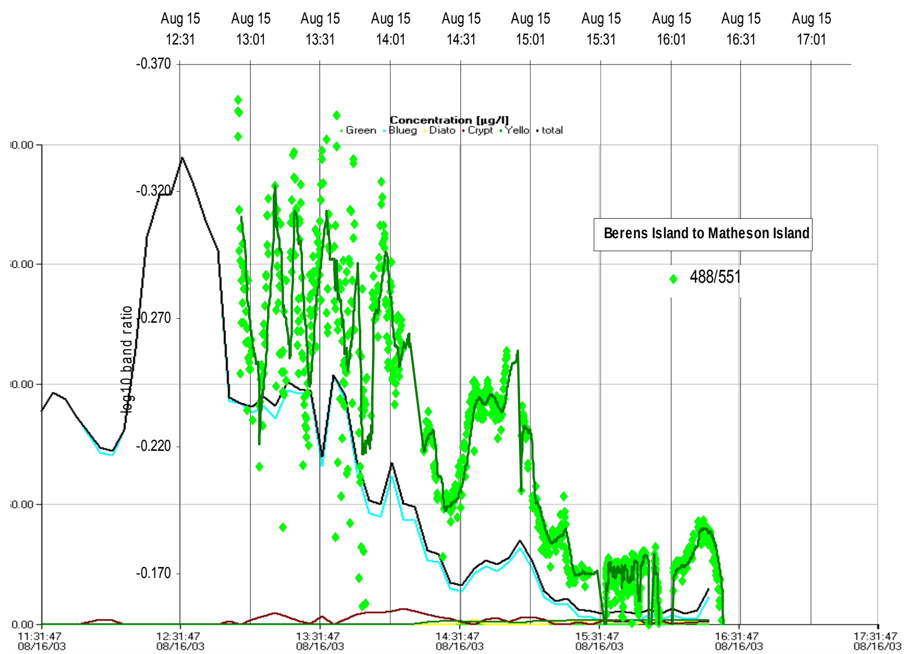

Figure 3. Continuous (5 hour) fluoroprobe monitoring of chlorophyll components associated with major algal groups and coincident spectral reflectance data, Lake Winnipeg, 2006.