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Regional Science Advisory Process on the Review of Assessment Protocols on Benthic Habitat in the Northeast Pacific

March 16-17, 2010
Sidney, British Columbia

Meeting Chairpersons:
James Boutillier
Elizabeth Clarke
Steve Brown

Rapporteur:
Jessica Finney

Processus de consultation scientifique régional pour l'examen des protocoles d'évaluation de l'habitat benthique dans le Pacifique Nord-Est

Les 16 et 17 mars 2010
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Présidents de la réunion
James Boutillier
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Fisheries and Oceans Canada / Pêches et Océans Canada
Pacific Biological Station / Station biologique du Pacifique
Nanaimo, BC / C.-B. V9T 6N7

September 2011 | **Septembre 2011**

Canada

Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings include research recommendations, uncertainties, and the rationale for decisions made by the meeting. Proceedings also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

Avant-propos

Le présent compte rendu a pour but de documenter les principales activités et discussions qui ont eu lieu au cours de la réunion. Il contient des recommandations sur les recherches à effectuer, traite des incertitudes et expose les motifs ayant mené à la prise de décisions pendant la réunion. En outre, il fait état de données, d'analyses ou d'interprétations passées en revue et rejetées pour des raisons scientifiques, en donnant la raison du rejet. Bien que les interprétations et les opinions contenus dans le présent rapport puissent être inexacts ou propres à induire en erreur, ils sont quand même reproduits aussi fidèlement que possible afin de refléter les échanges tenus au cours de la réunion. Ainsi, aucune partie de ce rapport ne doit être considéré en tant que reflet des conclusions de la réunion, à moins d'indication précise en ce sens. De plus, un examen ultérieur de la question pourrait entraîner des changements aux conclusions, notamment si l'information supplémentaire pertinente, non disponible au moment de la réunion, est fournie par la suite. Finalement, dans les rares cas où des opinions divergentes sont exprimées officiellement, celles-ci sont également consignées dans les annexes du compte rendu.

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SUMMARY

The pressure to provide scientific advice on the nature and extent of anthropogenic impacts on the benthic environment and the management measures required to address these potential impacts (e.g. aquaculture, fishing, oil and gas, etc.) are ever-increasing. Science advice should be provided within an ecosystem-based framework which takes into account not only the direct impacts on specific species and populations, but also addresses the indirect impacts on the health and nature of the ecosystem. To date, both the USA and Canada have experienced challenges in providing science advice on the aforementioned issues as the appropriate data are not always available. Researchers in both countries have utilized a variety of techniques to collect appropriate data such as qualitative and quantitative photographic data on the conditions of benthic habitats to enhance their ability to provide advice. However, developing the appropriate tools, expertise, and infrastructure is a lengthy process and can be difficult in a financially limited environment. A Canadian Science Advisory Secretariat (CSAS) Regional Workshop was convened on 16-17 March 2010 in Sidney, British Columbia to: share experiences related to benthic habitat assessments in the Northeast Pacific; review the present state of knowledge and/or technology; identify gaps; and provide an opportunity to further collaborations between technical experts in the USA and Canada whose work may contribute to the provision of relevant science advice.

The workshop was broken into two sessions: the first session had workshop participants provide presentations on their experiences with respect to data collection technologies, applications used in analyzing the data, and data management. The second session followed a structured discussion format which had participants each respond to questions related to four themes: next steps; improving collaboration; moving interoperability of data, quality assurance/quality control (QA/QC) and annotation forward; and modelling and other applications required to estimate benthic habitat quality, suitability and changes over time.

This report summarizes the key results of the two sessions, and provides a road-map for potential next steps.

OBJECTIVES

The workshop was convened and structured around three linked objectives:

1. Review experiences on current and potential technologies, applications, and data management related to benthic habitat assessments in the Northeast Pacific;
2. Identify gaps and synthesize recommendations for “best practices” for each of the three themes mentioned in 1);
3. Identify opportunities for potential collaborations that would improve the provision of science advice related to benthic habitat assessments in the Northeast Pacific.

SOMMAIRE

La demande est de plus en plus grande pour que des avis scientifiques soient formulés concernant la nature et l'ampleur des impacts anthropiques sur l'environnement benthique ainsi que les mesures de gestion qui doivent être prises si l'on veut limiter ces impacts (p. ex. aquaculture, pêche, exploitation pétrolière et gazière). Les avis scientifiques doivent être produits selon un cadre fondé sur l'écosystème qui tient compte non seulement des impacts directs sur certaines espèces et populations, mais également des impacts indirects sur la santé et la nature de l'écosystème. À ce jour, les États-Unis et le Canada ont éprouvé des difficultés à formuler des avis scientifiques sur les sujets susmentionnés en raison du manque de données appropriées. Les scientifiques des deux pays ont eu recours à un ensemble de techniques pour recueillir les données requises (données photographiques qualitatives et quantitatives sur les conditions des habitats benthiques) afin d'améliorer leur capacité à formuler un plus grand nombre d'avis. Cependant, l'élaboration des outils, de l'expertise et de l'infrastructure nécessaires est un processus qui exige du temps et qui peut être difficile dans un contexte de contraintes budgétaires. Les 16 et 17 mars 2010, le Secrétariat canadien de consultation scientifique (SCCS) a tenu un atelier régional à Sidney, en Colombie-Britannique, afin de partager l'expérience liée aux évaluations de l'habitat benthique dans le Pacifique Nord-Est, de passer en revue l'état actuel des connaissances ou de la technologie, de relever les lacunes et de profiter d'occasions de collaboration entre les experts techniques des États-Unis et du Canada dont le travail peut contribuer à la formulation d'avis scientifiques pertinents.

L'atelier a été divisé en deux séances : au cours de la première, les participants ont fait des présentations sur leur expérience liée aux technologies de collecte de données, aux applications utilisées pour l'analyse des données et à la gestion des données. La deuxième séance a été suivie d'une discussion structurée pendant laquelle les participants devaient répondre à des questions liées aux quatre thèmes suivants : prochaines étapes; amélioration de la collaboration; interopérabilité des données, assurance de la qualité/contrôle de la qualité (AQ/CQ) et acheminement des annotations; modélisation et autres applications nécessaires pour estimer la qualité de l'habitat, son adéquation et les changements au fil du temps.

Le présent rapport résume les résultats clés tirés des deux séances et fournit un plan pour les prochaines étapes potentielles.

OBJECTIFS

L'atelier a été structuré en fonction de trois objectifs reliés.

1. Passer en revue l'expérience associée aux technologies actuelles ou potentielles, aux applications et à la gestion des données liées aux évaluations de l'habitat benthique dans le Pacifique Nord-Est.
2. Relever les lacunes et résumer les recommandations en matière de « pratiques optimales » pour chacun des trois thèmes mentionnés au point 1.
3. Relever les possibilités de collaboration qui amélioreraient la formulation d'avis scientifiques liés aux évaluations de l'habitat benthique dans le Pacifique Nord-Est.

INTRODUCTION

A Canadian Science Advisory Secretariat (CSAS) Regional Workshop was convened on 16-17 March 2010 in Sidney, British Columbia, to review experiences related to benthic habitat assessments in the Northeast Pacific, identify knowledge and/or technology gaps, and provide an opportunity to further collaborations between technical experts in the USA and Canada whose work may contribute to the provision of relevant science advice.

The workshop was broken into two sessions: the first session had workshop participants provide presentations of their experiences with respect to data collection technologies, applications used in analyzing the data, and data management. The second session was a structured discussion format which had participants each respond to questions related to four themes: next steps; improving collaboration; moving interoperability of data, quality assurance/quality control (QA/QC) and annotation forward; and modelling and applications required to estimate benthic habitat quality, suitability and changes over time.

WELCOME

The co-chairs James Boutillier, Elizabeth Clarke, and Steve Brown welcomed the workshop participants and invited them to collaborate over the next two days to share experiences, explore opportunities to work together, and discuss ideas for solutions to identified common problems. There was a round of introductions. In total there were 25 participants from across Canada and the United States of America (USA) (17 Canadians and 8 Americans). J. Finney participated as a rapporteur for the meeting.

CONTEXT FOR MEETING

The pressure to provide scientific advice on the nature and extent of anthropogenic impacts on the benthic environment and the management measures required to address these potential impacts (e.g. aquaculture, fishing, oil and gas, etc.) are ever-increasing. Science advice should be provided within an ecosystem-based framework which takes into account not only the direct impacts on specific species and populations, but also addresses the indirect impacts on the health and nature of the ecosystem. Both the USA and Canada have committed to conserving and protecting ocean biodiversity and resources in a variety of domestic and international forums. This is coming at a time when there is a growing need to understand the biological implications of major ecosystem drivers such as climate change, ocean acidification, intrusion of oxygen-depleted water, etc. To be able to tease out the complex relationships between large-scale ecosystem drivers, and effects of anthropogenic stressors, there is need to develop comprehensive benthic ecosystem sampling approaches that can be used for both quantitative assessment of specific impacts, and for monitoring purposes to understand longer-term change.

To date, both the USA and Canada have experienced challenges in providing science advice on the aforementioned issues as the appropriate data is not always available. Researchers in both countries have utilized a variety of techniques to collect qualitative and quantitative data to enhance their ability to provide advice. However, developing the appropriate tools, expertise, and infrastructure is a lengthy process and can be difficult in a financially limited environment. Relevant Departments and organizations in both the USA and Canada have endeavored to assemble a coherent program from which meaningful information can be collected.

OBJECTIVES

The workshop participants were asked to:

1. Review experiences on current and potential **technologies**, **applications**, and **data management** related to benthic habitat assessments in the Northeast Pacific;
2. Identify gaps and synthesize recommendations for "best practices" for each of the three themes mentioned in 1);
3. Identify opportunities for potential collaborations that would improve the provision of science advice related to benthic habitat assessments in the Northeast Pacific.

OVERVIEW OF PRESENTATIONS

Peter Lawton is a research scientist with Fisheries and Oceans Canada (DFO) at the St. Andrew's Biological Station, Saint Andrews, New Brunswick. P. Lawton described some aspects of the research programs he leads, and provided an overview of what a few international bodies are doing related to benthic habitat research.

Much of the research P. Lawton works on deals with the multi-dimensionality in marine habitat mapping programs; from species to communities, spatial patterns to ecological processes, observation to predictive capacity, micro-habitats to mega-habitats. His group has written several technical reports on relational database development for benthic video analysis. P. Lawton emphasised the importance of developing benthic video analysis approaches. This is important even in the present absence of a single, broadly-adopted classification approach, as the longer-term utility of specific analyses is better-preserved. For example, bottom roughness can be classified into both physical and biogenic elements; both sets of habitat features contributing to ecosystem functions.

On a larger scale, P. Lawton's group is working with US and Australian researchers on developing and applying multivariate statistical methodology (Random Forests) to evaluate the potential for using physical surrogates to predict benthic diversity distribution patterns.

P. Lawton also provided an overview of two annual international forums that have a significant focus on benthic systems evaluation. The first is convened through the International Council for the Exploration of the Seas (ICES), and the second is a conference series held by Marine Geological and Biological Habitat Mapping (GeoHab).

There is an ICES working group on Marine Habitat Mapping chaired by Jacques Populus, French Institute for Exploration of the Sea (IFERMER), France. This working group reports on progress in international mapping programs, and reviews national habitat mapping activity by ICES member countries. They have recently established discussions with the ICES Benthic Ecology working group around jointly focusing on current approaches and potential advances in benthic habitat suitability modeling; there is a strong likelihood for a joint meeting of the two working groups. This may be of particular interest to researchers working on similar topics in the Northeast Pacific, as these two working groups entrain a fairly large group of European and Northwest Atlantic benthic researchers.

P. Lawton also mentioned an ICES Study Group on Fisheries Optical Technologies. This group was convened to review state-of-the-art optical imaging and analysis technologies and to produce a literature review of optical technology. They are currently working on a research report.

At their last annual meeting (Norway, May 2009), GeoHab held a benthic video workshop. A report from that workshop is forthcoming. Participants of the workshop recognized the need for an international web-based application so that people can share their experiences. They also emphasised the need to have data that can be transferable between studies.

DISCUSSION

Discussion following the presentation focused on international groups and their role in bringing people together. It was noted that participation in ICES is difficult for Pacific coast-based individuals, and that often researchers on the coast are left working in isolation. On the Atlantic coast there is a national marine biodiversity academic research network (Canadian Healthy Oceans Network, CHONe), which has a significant benthic research component. The CHONe network is trying to get involved with ICES. It was noted that perhaps it would be more beneficial to bring some of the ideas ICES is working on to North America. Participants agreed that the ICES working group processes tend to be very Euro-centric. However, in view of the research investment in Europe in support of marine spatial planning, participants considered that it would be worthwhile for Pacific coast researchers to investigate potential links with one or more of the above noted working groups.

On the west coast of North America there is access to the North Pacific Marine Science Organization (PICES), the Pacific equivalent of ICES. PICES, however, does not have a benthic mapping working group. One option would be to develop such a group after looking at the terms of reference for the ICES working groups, and their linkages into provision of scientific advice. It was noted that it would be beneficial to have a parallel session for computer scientists who do not know the biology, but have the interest and expertise in the more technical aspects of benthic mapping. Such interdisciplinary collaborations are beginning to develop in groups like CHONe (e.g. robot vision for automated analysis) and GeoHab (e.g. last year there were some neuroscientists present).

James Barry is a senior scientist at the Monterey Bay Aquarium Research Institute (MBARI) and provided an overview of some of the tools they use in their research at the Institute.

MBARI employs a variety of tools to characterize benthic habitats, using a hierarchy defined by the spatial resolution possible with various technologies. At a large scale, MBARI has contracted vendors using hull-mounted mapping systems to provide moderate resolution bathymetric maps and backscatter intensity. These have allowed resolution as fine as 15 m grid spacing for several locations along the eastern North Pacific margin as well as Hawaii. Within these, they have variously used remotely operated vehicle (ROV) video to provide visual information, or more recently, a mapping automated underwater vehicle (AUV). The mapping AUV is capable of flying 50 m above the seabed, and using a multibeam system coupled with side scan sonar can image the seabed at very high resolution. Gridded maps are on the order of 1 x 1 m or less, with bathymetric depth accuracy of ~0.15 m. These maps have allowed the identification of previously unknown features. Coupled with backscatter information and ROV groundtruthing, these maps enable benthic habitat characterization at very high spatial resolution.

In addition to these tools, MBARI is also working on an automated visual event detection (AVED) system to identify objects recorded on video. Currently the system can detect events, but is unable to identify objects and thus is still about a decade away from being very useful. They are also using a video annotation and reference system (VARS) to analyse video that is

gathered through various research projects. They have a team of annotators that can review video at either fast speeds, providing a coarse description of the contents, or who review it very slowly and provide very detailed descriptions. This process streamlines how information is keyed into a database, and links entries by time and date. There are over 3,000,000 annotations for things such as animals, features, samples and instruments. Key words and concepts can be queried, and results can be downloaded with links to video images. Some of the data can be linked to Google Earth. VARS has been used in hundreds of papers, and is readily available on the web (http://www.mbari.org/vars/), though there is a two year embargo on data.

The Monterey Accelerated Research System (MARS) is a cabled undersea observatory located about 60km offshore from MBARI in 900 m of water. MARS serves as a cabled observatory and as a platform for various instruments. It can have autonomous moorings and benthic systems that communicate with the surface and satellites.

DISCUSSION

Discussion following the presentation focused on some limits and extensions of the work being done at MBARI. MBARI has done some work with sub-bottom profiling; for example, on the Davidson Seamount they are trying to link backscatter with video images to get acoustic signatures of coral and sponges. The AVED software is really designed for homogenous environments, and may not be able to detect objects that don't fit on the screen, and may not be able to be used with mosaic images. Other researchers (e.g., taxonomists) cannot currently contribute to the VARS system, though that would be an excellent addition.

Mairi Best is the associate director of science with North-East Pacific Time-Series Underwater Networked Experiments (NEPTUNE) at the University of Victoria and provided an overview of the NEPTUNE project.

NEPTUNE is a regional-scale underwater ocean observatory based off the west coast of Vancouver Island. It is a circular system that ranges from 17 m depth to the mid-ocean ridge and provides real-time return of information across a range of environments. The system has five nodes from which there are several extension cords, the longest of which is 12 km. Currently, four of the five nodes are instrumented; the Endeavour Ridge node will be instrumented this summer. Collaborators are able to attach a range of instruments to NEPTUNE. Instruments can be very complex (e.g., custom developed programs) or very simple (e.g., conductivity, temperature, depth (CTD) sensors. NEPTUNE currently has networks on seismic activity, tsunamis, chemical systems, fluid dynamics, and audio and visual data.

The NEPTUNE network receives approximately 60 TB of data per year. In order to deal with this, the data management system was developed early on, and involves data acquisition, interactive control of instruments, data archiving, real-time data subscription, and event detection. Data are immediately made freely available on the web.

Leslie Barton is the Shellfish Data Coordinator for the Shellfish Section of Fisheries and Oceans Canada in the Pacific Region. L. Barton identified four areas of challenge for the efficient data management of imagery acquired through their new ROV program: (1) balancing support for the specific question with questions that may be asked in the future; (2) shifting away from a single species assessment mindset to a holistic, ecosystem approach; (3) supporting the complexity of the instrumentation deployed on the ROV; and (4) coping within an infrastructure that lags

behind the requirements of imagery-driven data. Data managers must work closely with researchers to balance the immediate needs of the investigation with the potential requirements of future work, and to advise researchers on the collection of data. Ecosystem approaches will require new tools to support a cultural shift away from the single species assessment model. New data management frameworks must be flexible to accommodate rapid changes in technology. Existing infrastructure has been quickly outpaced and is insufficient to support the imagery-based programs. There is a need to keep an open dialogue with IT so they know what data management needs are now and in the future.

DISCUSSION

The discussion following the presentation revolved around other people's difficulties with data management. There was general consensus that storing and managing data in a way that makes it accessible is one of their greatest challenges. In the USA there is a large national program called the Integrated Ocean Observation System, whose goal is to integrate data. All the protocols for collecting and doing basic analysis have been codified for oceanography, though other research areas lag behind. Consequently, when amalgamating several databases, only the physical oceanographic data can be used. There is a need to standardize data collection and reporting so that data from different research groups can be combined and accessed. There is also a need for a centralized archive of metadata, particularly for video data, so that researchers can easily identify what work has been done where.

Adequately collecting, storing and archiving data is very expensive. Unfortunately, there is a lack of understanding of these problems amongst managers and potential funding sources, which makes it very difficult to obtain funding to improve data management and storage.

Hanu Singh is an associate scientist at the Woods Hole Oceanographic Institution (WHOI). He presented an overview of his work on underwater robotics and imaging.
H. Singh's group has developed an AUV, SeaBED, which has been used all over the world. The AUV is relatively inexpensive, and can support many high quality sensors. The AUV was specifically designed so that it is simple enough for anyone to use, and can be dismantled and easily shipped via courier.

Another area of research in H. Singh's lab is image analysis. His research group has developed software that can automatically mosaic images together. Image mosaicing is much easier on flat bottoms than it is in rough areas. They have also developed an online application that facilitates access to multi-sensor and multi-discipline data (http://4dgeo.whoi.edu). Another application, Fish_Rock, is in development. This application will scan through images searching for user-defined objects, and stores the output. Fish_Rock will be manual, computer assisted, or automated. The lab is also working on developing an automated system to calculate coral cover based on texture recognition, and on reconstructing 3D images when there is more than 50% overlap between images. This currently requires a great deal of user input.

DISCUSSION

The discussion following the presentation focused on the development of new technology and methods, as well as the need to give credit to developers of technology and collectors of data.

It is important to develop and build on relationships between biologists and computer scientists and engineers so that new tools can be developed. Specialized tools for data acquisition and processing can streamline research, but also run the risk of providing data that is too specific.

It's important to keep a wider audience in mind when gathering data so that many people can benefit from a research project.

Participants discussed issues of identifying fish when images from ROVs or AUVs are taken from overhead rather than the side. Work is currently being done to address this problem. For example, multiple cameras can be mounted to provide both overhead and side views of the fish. Alternatively, an identification key could be developed for top-down images. Work is also being done so that fish hiding in rugose terrain can be detected.
Having new software and technology be freely available is very valuable, but it is important that developers get proper acknowledgement. There is a similar problem with data that are collected. There is a need to develop standards of using open data in terms of recording metadata and citing sources.

Mairi Best gave a second presentation that included a demonstration of NEPTUNE's website.

As mentioned previously, all of the data collected by NEPTUNE are openly available on the web, so an interface that is useable is essential. The website is modular and has a lot of information to help people navigate it easily. The data explorer allows you to search by instrument type, location, network topology and project. You can obtain images of instruments, their metadata, maps of instrument locations, and information on the testing and calibration of instruments. If you have operator status, you can even pan and tilt cameras from the internet interface.

A social network for users is currently being integrated into the NEPTUNE website. A project environment is being developed that will allow users to upload code and run it through a grid of computers, as well as network and share work projects with other collaborators. Users can work within their own defined group, or search for people with similar interests. Users can save products (e.g., code, output, word documents) in their workspace, and have version control so that all members can work together.

Chris Goldfinger is an associate professor with the College of Oceanic and Atmospheric Studies at Oregon State University. He provided an overview of seafloor mapping initiatives on the west coast of the USA.

In 2006 the Governors of California, Oregon and Washington signed the West Coast Governors' Agreement on Ocean Health to achieve regional collaboration in order to protect and manage ocean and coastal resources. In 2009, a stimulus package provided approximately $6.3 million in funding. Initially, priority areas, which were defined in collaboration with stakeholders, have been the focus. These areas include marine reserve sites, other rocky reef areas, wave energy sites, and tsunami-vulnerable areas. By the end of 2011 about 45% of these sites will be mapped. The multibeam data is being supplemented with grain size analysis and limited ROV work. Once all of the data have been processed, habitat maps will be developed.

The resulting habitat maps and datasets will be stored in a variety of places. The Pacific Coast Ocean Observing System (PaCOOS) habitat server, which was developed by OSU and the NWFSC (http://pacoos.coas.oregonstate.edu/), is a web-based system that acts as a data server. The system can be queried and provides reports on habitat types, species associations, and grain size. The Geospatial Server Interface provides context specific tools and links to metadata. There is also the Habitat Use Database (HUD) which includes records of over 400 species including fish and invertebrates.

DISCUSSION

Discussion following the presentation focused on the difficulties associated with sharing data with a wider audience, and the need for more comprehensive mapping of national waters.

Having data publicly available is very important, but leads to many issues with quality control and ensuring that proper credit is given to the source of the data. When people download data from repositories, it can be difficult to ensure they report the version they are using. Different versions may have been collected in different ways, making it inappropriate to compare them. It is also difficult to communicate any uncertainties, caveats, or errors in databases. Even if you warn people, they may not listen. There are no simple solutions to these issues.

Several participants expressed the need to have greater coverage of multibeam data. Where this is not possible, there are some alternative approaches that might provide coarser resolution, but potentially broad-scale bathymetric coverage. One solution that was suggested involves enlisting the support of the commercial fishing community. In some areas fishers are suspicious of mapping efforts, though in other areas they have been excellent sources of data. For example, commercial fishing fleets in Nova Scotia have invested quite heavily into a bathymetric charting package provided by a Norwegian company called Olex. The company installs computers and software on the vessels that connects to the boats' echosounders. As the boats move around on their regular commercial operations they collect and record depth soundings, which are subsequently transmitted to Olex for integration with soundings from other boats that have the Olex system. The company processes the submitted soundings data and then provides composite bathymetric maps to customers. There are several Olex systems in operation in Atlantic Canada within Natural Resources Canada, Canadian Hydrographic Service, and Science Branch, Fisheries and Oceans Canada. While there are some problems with the compiled data (e.g., unknown data density, possibility of artefacts, potentially "blocky" interpolation where the vessel coverage is lower), Olex-based bathymetric data has proven useful. It has been used to identify bottom features in sufficient detail to permit calculation of bottom complexity measures and bathymetric profiles adequate enough to develop benthic survey plans in regions lacking multibeam survey coverage.

Alison Proctor is a researcher with the Ocean Technology Lab at the University of Victoria. She gave a presentation on the Ocean Technology Test Bed (OTTB) facility run by her group.

The OTTB is located off the coast of Vancouver Island and resides in 80 m of water and covers 2 km^2 of the seafloor. A seafloor cable provides power and communication to a recoverable platform. The integrated acoustic system (IAS) enables precision tracking and acoustic communication throughout the area, and can be used with underwater vehicles. The facility has the tools researchers require to develop new underwater technologies, such as: autonomous underwater vehicles; underwater AUV docking systems; guidance, navigation and control algorithms; multiple vehicle cooperation; acoustic communication; and autonomous remote sensors. The OTTB infrastructure can nominally supply 1.5kW of power and high bandwidth Internet connectivity right to the sea floor. The power is buffered through a battery bank which allows short term, increased power supply to equipment such as the resident SeaEye Falcon ROV.

The OTTB has several infrastructure components. These components include a top-side service buoy; an underwater recoverable platform for mounting experiments, sensors, subsea vehicles, docking systems, video cameras and acoustic transducers; a power and control module that supplies 8 ports with conditioned power at any voltage; a high bandwidth internet

connection; and an integrated acoustic system that provides 3D tracking of vehicles. The Ocean Technology Lab also has a MANO Bluefin-12 AUV that is available to test a variety of instruments and software.

A shore station has servers and a communication system that provides an interface between the subsea OTTB and external users who can view streaming video and data in real time. Clients can access their instruments through a secure virtual private network (VPN), so that the device appears as if it is locally connected to their computer. Each client has their own separate virtual LAN (VLAN), thereby ensuring data security. Clients also have access to real-time 3D graphical software rendering the OTTB arena, all subsea vehicles or targets, and surface vessels.

The OTTB is available to all researchers and companies for undertaking basic research or product development. The OTTB can be accessed over the Internet, thereby allowing researchers to conduct tests on their equipment from anywhere in the world. The OTTB is a unique test and development facility that efficiently leverages the Internet for network-enabled collaboration.

DISCUSSION

The discussion following the presentation focused on the capacity of the AUV to explore water deeper than 200 m. It would be possible to obtain a larger AUV that can go into deeper water in the future, though the lab doesn't currently have the capacity to support a larger system.

Herbert Yang is a professor in the Department of Computing Science at the University of Alberta. In his talk, H. Yang gave an overview of his research, which covers both computer graphics and computer vision.

In computer graphics, models are used to synthesize images, while in computer vision images are analyzed to extract the models. There is a very close relationship between computer vision and computer graphics. He presented an example using texture analysis and synthesis where the same mathematical framework can be used to either analyze or synthesize texture.

H. Yang also presented some work on background estimation. His group uses an in-house developed algorithm to recover background images occluded by unwanted foreground objects. Another project that he discussed involved image-based rendering, which is at the intersection of computer graphics and computer vision. Rather than using geometric models to synthesize images, captured images are used to generate novel views, which are views not in the set of captured images. An image-based rendering system typically uses many cameras.

H. Yang's group also has a project with Neptune Canada where they have designed and developed an eight-camera system for undersea observation. The system is scheduled to be deployed in June, 2010, which will allow the world will be able to observe the undersea in 3D.

Mary Yoklavich is a supervisory research biologist and leader of the Habitat Ecology Team in the Fisheries Ecology Division of Southwest Fisheries Science Center. She provided an overview of the methods her group uses to survey and store data on demersal fishes.

Many demersal fishes live in complex habitats making it very difficult to survey them with traditional methods such as trawl surveys. Divers, manned submersibles, towed cameras and ROVs can all be used to conduct surveys. Her team has used the two-person *Delta*

submersible to survey demersal communities for the past 17 years. This survey platform uses three cameras and a human observer. All fish, and occasionally invertebrates and marine debris, are identified and counted during strip and line transects; bottom type is also quantified. Many rockfish are habitat specific, so estimates of abundance can be extrapolated to other areas with similar habitat. All data are stored in a relational Access database and linked by time. Data from these surveys are used to improve stock assessments, to help design and monitor MPAs in deep water off California, to characterize fish habitats, and to evaluate marine debris on the deep sea floor.

As with all surveys, issues of quality assurance and quality control (QA/QC) are very important. Sources of bias or uncertainty in estimating fish abundance include level of detectability, amount of fish movement in response to the vehicle, and ability to identify organisms. Experiments were conducted to understand these issues. Results from forward-looking cameras were compared to those of side cameras on the submersible; fish movement was minimal. Results were also compared between the *Delta* submersible and ROV transects. Ability to identify and count several species of fishes was much lower from surveys using the ROV. Decisions regarding which survey platform is more appropriate depend on specific research objectives.

DISCUSSION

Discussion following the presentation focused on quality control issues. There were questions regarding the reasons behind the difference in fish counts when using the different survey platforms. However, it was noted that there are uncertainties as to why there is a difference between observations made with the *Delta* and with an ROV. The discrepancy may be due to lights, noise, use of a tether, or some other reason. There is a need to look at the biases of both tools and calibrate the differences so that the lower cost ROV can be used more frequently and with confidence. Observers are tested and calibrated to ensure quality control. There was a suggestion to use a keyboard system to record data during transects to cut down on post-processing time. On the east coast of North America they have found this works quite well, and that observers are able to observe constantly while using a keyboard system.

John Harper is the president of Coastal and Ocean Resources. He provided an overview of the Broughton Archipelago Nearshore Planning Project which aims to fill in the “white strip” of no data in shallow water.

Nearshore seabed habitats (< 20 m depths) are not routinely inventoried with multibeam surveys owing to inefficiencies in existing technologies. Also, nearshore habitats pose survey challenges because the vegetation canopy, which contributes significantly to its structural complexity and often covers greater than 75% of the seabed, cannot be inventoried with standard acoustic techniques. For the 40,000 km of shoreline in British Columbia, there are probably only a few tens of kilometers of coastline with nearshore multibeam coverage and probably only a few kilometers with systematic vegetation mapping. As a result, nearshore habitats are poorly inventoried and unlikely to be systematically inventoried in the near future. A nearshore habitat model was developed to provide a first-order estimate of nearshore habitat types. The model uses: (a) the existing *ShoreZone coastal habitat inventory*, which exists for all of British Columbia, Washington and much of Alaska; (b) existing *bathymetric data*, much of which is based on single-beam soundings; (c) a *numerical tidal model*, which predicts maximum bottom tidal velocities and (d) limited substrate samples. Attributes are used to predict and map biophysical habitat types for use in resource management.

DISCUSSION

The questions following the talk focused on how to obtain funding to test out model results. Targeting commercial activities in those areas is one possibility due to the importance of the nearshore environment to various life stages of several important species (e.g., salmon and sand lance). In the Bay of Fundy researchers collaborated with habitat-specific fisheries. There is currently some collaboration with the Shellfish Group at the Pacific Biological Station in Nanaimo and members of the commercial urchin fishery.

Lance Morgan is the vice president for science with the Marine Conservation Biology Institute (MCBI). He was recently involved in the Finding Coral Expedition and provided an overview of the mission.

MCBI and Living Ocean Society are two organizations that have organized and participated in deep-sea research expeditions and have conducted scientific analyses to help establish criteria for identifying, nominating and protecting deep-sea coral sites.

In 2009, Living Oceans Society led and funded a survey to explore the distribution, ecology and possible human impacts on deep ocean coral communities off the Northwest coast of British Columbia. This survey, the “Finding Coral Expedition”, used one-person submersibles (DeepWorkers) to survey sites in Queen Charlotte Sound northward through Hecate Strait to the Alaskan border. The scientific objectives of the survey were to document species richness and abundance of deep-sea corals, provide additional deep-sea coral records for subsequent distribution modeling work, identify fish and invertebrates associated with deep-sea corals, and document and identify habitat perturbations in areas with coral records.

In addition to exploration and at-sea research work to document deep-sea corals, environmental non-governmental organizations (ENGOs) are engaged in many important collaborative research efforts to identify vulnerable marine habitats as part of their conservation goals. These projects include mining deep-sea coral records from published literature, government data and historic archives, as well as predictive modeling efforts to proactively identify probable sensitive benthic habitats based on known occurrences. ENGOs have become key players in many areas of the world by helping to raise awareness of deep-sea ecosystems, undertaking research needed to better document deep sea habitats, analyzing potential human impacts, and partnering in finding conservation and management solutions. In working more cooperatively, ENGO’s and decision-making bodies have begun to build greater trust and understanding of each other’s cultures and concerns.

Kim Conway is a scientist with the Pacific Geoscience Center of Natural Resources Canada. He provided information on the survey methods his group uses, including multibeam and backscatter data, geological approaches, seismic profiling, sidescan sonar, direct sampling, and photography.

Benthic habitat studies at the Pacific Geoscience Centre (GSC-P) are undertaken using a geological approach and take advantage of all available technologies to characterize benthic habitats for a variety of purposes. The approach is founded on the integration of multibeam and backscatter datasets with other high resolution acoustic survey tools, such as sidescan sonar and sub-bottom profiling, and seabed sample analysis, all merged into an ArcInfo GIS framework. These same datasets are also useful for addressing more traditional geological problems such as the distribution of active (neotectonic) faults, seabed sediment transport and other geoscience questions in the region.

Ongoing habitat studies at GSC-P include habitat mapping in the San Juan Islands/Gulf Islands transboundary area, in collaboration with the Moss Landing Marine Laboratories and the SeaDoc Society. The benthic habitat datasets developed will allow the use of GIS to quickly generate potential habitat maps where benthic habitat requirements for species (e.g. Pacific sandlance) are known. An ultimate goal is to make the habitat ArcInfo coverage available to ocean managers to help address emerging habitat questions regarding benthic species or groups of species.

Assessment of new sponge reef areas discovered during multibeam surveys operated by Canadian Hydrographic Service (CHS) is ongoing at GSC-P. As the CHS undertakes multibeam/backscatter surveys in shelf and inshore areas, small reefs (area < 10 km^2) are occasionally identified. The overlaying of a backscatter data, rendered semi-transparent onto multibeam elevation data, makes the reefs readily apparent. In order to confidently map the distribution of sponge reefs, confirmation of these locations (via groundtruthing) is sought when possible. For example, in April 2010 sponge reefs identified by CHS in the Portland Canal were surveyed in cooperation with the National Oceanic and Atmospheric Administration (NOAA), and glass sponge reefs were shown to be present, and in a healthy growing condition. These are the first sponge reefs confirmed to exist in Alaskan waters. Other areas where such ground truth activities would be appropriate include new reefs identified in Queens Sound, adjacent to Queen Charlotte Sound.

DISCUSSION

Discussion following the presentation focused on the limitations of multibeam in shallow water. Currently data can only be gathered in a minimum of 10 m of water due to safety issues with small boats in shallow water. There was also some discussion on the calibration of backscatter data. On the Atlantic coast they have recently commenced some work with the geocoder utility within CARIS hydrographic software to examine calibration issues. That has not yet been tried on the Pacific coast.

The first session concluded with Peter Lawton and Jim Boutillier providing a brief presentation with links to the websites of various companies and organizations that had been discussed throughout the meeting.

Olex http://www.olex.no/index_e.html

- A Norwegian company that installs the software necessary for fishing vessels to collect soundings data to create a moderately dense bathymetry grid
- Approximately $8000 to obtain and install the laptop and software into the ship's system
- In Jordan Basin in the Gulf of Maine they have used available Olex bathymetric data to interpret the local structure of rock pinnacle features that were not well resolved on available Canadian Hydrographic Service digital charts
- There was sufficient resolution to focus new surveys to explore basin-level topographic complexity even in the absence of multibeam survey coverage

MESH www.searchmesh.net

- Mapping European Seabed Habitats
- Recommends operating guidelines to map seabed habitats

Biodata Mining www.biigle.de (can login as "test" for username and password)

- Have web enabled software for labelling and exploring of images

Royal BC Museum Online Taxonomic Key Application
http://taxonomy.royalbcmuseum.bc.ca/taxonomy

- Online taxonomic key used to identify specimens
- A site for people to contribute taxonomic information

BREAKOUT GROUP DISCUSSIONS

During the second session of the workshop participants considered four questions (chosen by the co-chairs based on feedback from what the participants wanted to get from the workshop). Participants were separated into groups of four, and each individual was assigned a question. Individuals were asked to record the responses of the other group members. Participants were then grouped according to question number and compiled the answers. Answers were presented to the group at large, discussed, and agreed upon. The responses are summarized below.

Question 1: What do you think the next steps should be to moving the objectives of this workshop forward?

- Increase communication and collaboration
  - published proceedings of this workshop will be helpful
  - provide a list of contacts of participants in the workshop
  - create an identity for participants in the workshop
  - work with related PICES and ICES working groups
  - have additional meetings, include stakeholders and managers
  - communicate institutional infrastructure issues to senior managers
  - develop an online catalogue of experts, what they're doing, and what resources are available
- Raise the profile and identity of the group (workshop participants)
  - develop a website or wiki to communicate and share
- Facilitate improvements in practices/technologies/data management
  - follow up on specific data management issues
  - initiate a PICES workshop on data management
  - take advantage of PICES and ICES experience
  - communicate to senior managers/decision makers in order to secure funding; issues are not just technical, also financial
- Identify funding opportunities
- Clarify mangers' objectives and needs for benthic habitat mapping

Question 2: What could we do to improve collaboration?

- Facilitate collaborations
- Have more meetings similar to the present workshop
  - connect with larger meetings (e.g., ICES, GeoHab)
  - efficiency of travel – have meetings at other meetings
  - create specialized groups
- Organize the community of experts
  - develop a wiki or website
  - determine who will organize and fund this

- set up working groups with meetings and publications
- develop a way to connect people with common interests

- Enhance existing groups (e.g., ICES and PICES working groups)
  - webcasts, broadcasts, web stream conferences
- Have staff exchanges between organizations/Departments
- Develop a shared vision among experts and/or organizations/Departments
- Share and establish best practices

Organise and collaborate to secure and share funding

- Develop methods to ensure that effort is not duplicated
  - share data
  - have metadata available and searchable
  - e.g., GeoBase
- Have cruise notifications so that people can share research vessel time
- Establish an advisory and steering committee
- Extend collaboration to clients (including their consultants) and resource managers
- Foster collaboration with outside groups e.g. International governments (DFO and NOAA), universities, NGO, museums etc.

Question 3: How can we move interoperability of data, QA/QC and annotation forward?

- Standardize simple non-controversial things e.g. use of International species codes (ITIS or WORMS)
- Do not force standardization, aim for equivalency and compatibility
  - make sure you can at least understand each other
  - agree on test data sets and establish a benchmark to ensure people processing data meet some basic standard
- Develop specialty working groups
  - have meetings in person (important to make connections)
  - online meetings (efficient)
  - websites
  - important that this is an iterative process
- Develop open-source software
  - have feedback
- Have an accessible metadata list
  - where, when, who has it
- Develop metadata guidelines
  - include resolution, spatial, temporal, taxonomic
- Have joint training

Question 4: What sort of modelling and applications do we need and what additional data do we need to estimate benthic habitat quality, suitability and changes over time?

- Necessary to fill data gaps related to:
  - understanding carbonate chemistry
  - series data
  - spatial accuracy of data and capture uncertainty
  - multibeam data in federal waters.
  - standardized descriptor system, (e.g., set up standardized monitoring sites)
  - data in the 0-10 m “white” strip, possibly with an automated vehicle
- Improve measurements and parameters

- identify standard datasets, both good and bad, to distribute to the community to try to improve techniques
- distribute a test dataset to test models against
- develop a standard suite of modeling tools
- establish a dialog between physical oceanographers geologists, chemists and habitat modelers for a more holistic habitat understanding
- acquire a broader set of descriptors and establish a minimal set of descriptors
- determine/describe the difference between habitat and ecosystem; this influences what the list of descriptors (above) to help transition from habitat understanding to ecosystem understanding.
- automate algorithms for capturing change over time
- create standard tiers for depth ranges or other stratified criteria, data availability, etc.
- plan stratification according to purpose of the study
- automate imagery classification of fish
- make better linkages between habitat initiatives/research and stock assessments
- develop criteria for observations of rocky and other habitats at outcrop scale to understand the use of hiding space and hierarchy, and use this for predictive value of geologically distinct habitats

- Predictive modeling
  - predict presence and absence of coral, sponges, sediment types, other parameters
  - apply point sampling to habitat maps to facilitate their validation and to determine the relationship between predicted probability of presence and actual probability of presence
  - review habitat based on suitability rather than the data analysis point of view.

CONCLUDING REMARKS

The co-chairs thanked attendees for their participation in the meeting. There was general consensus that the meeting had met its objectives as outlined in the TOR.

For the first objective “A review experiences on: current and potential technologies, applications, and data management related to benthic habitat assessments in the Northeast Pacific”:

- The meeting gave participants a chance to compare and contrast various challenges and approaches to all 3 of the central themes for the meeting: technologies, applications and data management.
- Not only were the participants introduced to various options and approaches of doing things but they new contacts that they could follow-up with on specific questions or approaches.

For the second objective “Identify gaps and synthesize recommendations for best practices for each of the three central themes (see above), the results came from the reports from the question break-out session:

Gaps identified included the need:

- to fill critical data gaps – we aren’t collecting much of the data we need to address these issues
- to improve measurements and parameters
- for standardization or at least equivalency
- for metadata guidelines
- to understanding carbonate chemistry
- long time series of data

- to work on the spatial accuracy of data and capture uncertainty
- to collect habitat data in the 0-10 m “white” strip, possibly with an automated vehicle
- for better communications

Best practices included:
- Open source programming
- Shared Metadata
- Shared training
- Standardizing non-controversial items
- Do not force standardization seek equivalency
- Use of predictive modeling

For the third objective: Identify opportunities for potential collaborations that would improve the provision of science advice related to benthic habitat assessments in the Northeast Pacific. The workshop participants pointed to mechanisms like:
- The strongest message that came across from all break-out sessions was the need to build on the success of this workshop which not only provided a forum for becoming more aware of what colleagues in other regions were doing, but also would lead to facilitating communication and potential collaborations. Everyone agreed that the momentum of the meeting should not be lost, and that participants of this workshop should continue to work together to address common issues with benthic data collection, management, and application. There were suggestions that this should be carried out through mechanisms like the joint ICES/PICES working groups or through organizations like GeoHab.

APPENDIX I: Table of Acronyms

AUV	Automated Underwater Vehicle
AVED	Automated Visual Event Detection
CTD	Conductivity, temperature, depth
CHONe	Canadian Healthy Oceans Network
CHS	Canadian Hydrographic Service
DFO	Fisheries and Oceans Canada
GeoHab	Marine Geological and Biological Habitat Mapping
GIS	Geographical Information System
GSC-P	Pacific Geoscience Center
ICES	International Council for the Exploration of the Seas
IFERMER	French Institute for Exploration of the Sea
MARS	Monterey Accelerated Research System
MBARI	Monterey Bay Aquarium Research Institute
MCBI	Marine Conservation Biology Institute
NEPTUNE	North-East Pacific Time-Series Underwater Networked Experiments
NOAA	National Oceanic and Atmospheric Association
OTTB	Ocean Technology Test Bed
PaCOOS	Pacific Coast Ocean Observing System
PICES	North Pacific Marine Science Organization
QA/QC	Quality assurance/quality control
ROV	Remotely Operated Vehicle
VARS	Video Annotation and Reference System
WHOI	Woods Hole Oceanographic Institution

APPENDIX II: List of Participants

Proceedings of the workshop to review the assessment protocols on benthic habitat in the Northeast Pacific

March 16-17, 2010
Institute of Ocean Sciences (IOS)
Sidney, British Columbia

Name	Affiliation
Leslie Barton	Fisheries and Oceans Canada, Pacific Biological Station
Jim Barry	Monterey Bay Aquarium Research Institute
Mairi Best	NEPTUNE Canada
Brian Bornhold	NEPTUNE Canada
Jim Boutillier	Fisheries and Oceans Canada, Pacific Biological Station
Steve Brown	ST NOAA Fisheries
Wolfgang Carolsfeld	Fisheries and Oceans Canada, Pacific Biological Station
Xida Chen	Fisheries and Oceans Canada, Pacific Biological Station
Elizabeth Clarke	Northwest Fisheries Science Center
Kim Conway	Natural Resources Canada -Institute of Ocean Sciences
Jessica Finney	Fisheries and Oceans Canada, Pacific Biological Station
Maeva Gauthier	University of Victoria
Chris Goldfinger	Oregon State University
Rob Hare	Canadian Hydrographic Service
John Harper	Coastal and Ocean Resources
Reyna Jenkyns	NEPTUNE Canada
Kim Juniper	University of Victoria
Peter Lawton	Fisheries and Oceans Canada, St. Andrews Biological Station
Lance Morgan	Marine Conservation Biology Institute
James Pegg	Fisheries and Oceans Canada, Pacific Biological Station
Alison Proctor	LACIR UVic Mechanical Engineering
Jennifer Reynolds	West Coast National Undersea Research Program
Hanu Singh	Woods Hole Oceanographic
Herb Yang	Computer Science Department, University of Alberta
Mary Yoklavich	Southwest Fisheries Science Center

APPENDIX III: Terms of Reference

Terms of Reference

National Science Advisory Workshop to Review Assessment Protocols on Benthic Habitat in the Northeast Pacific

March 16-17, 2010
Sidney, British Columbia

Context

The pressure to provide scientific advice on the nature and extent of anthropogenic impacts on the benthic environment and the management measures required to address these impacts (e.g. aquaculture, fishing, oil and gas, etc.) are ever-increasing. The provision of science advice should be provided within an ecosystem-based framework which takes into account not only the direct impacts on specific species and populations, but also addresses the indirect impacts on the health and nature of the ecosystem. Both the United States of America (USA) and Canada have committed to conserving and protecting ocean biodiversity and resources in a variety of domestic and international forums. This is coming at a time when there is a growing need to understand the biological implications of major ecosystem drivers such as climate change, ocean acidification, intrusion of oxygen-depleted water, etc.

To date, both the USA and Canada have experienced challenges in providing science advice on the aforementioned issues as the appropriate data is not always consistently available. Researchers in both countries have utilized a variety of techniques to collect photographic qualitative and quantitative data to enhance their ability to provide advice. However, developing the appropriate tools, expertise, and infrastructure is a lengthy process which often competes with more conventional assessment methods. Relevant Departments and organizations in both the USA and Canada have endeavored to assemble a coherent program from which we can start to collect meaningful information.

A Canadian Science Advisory Secretariat (CSAS) Regional Workshop will convene on 16-17 March 2010 in Sidney, British Columbia to review experiences related to benthic habitat assessments in the Northeast Pacific, identify knowledge and/or technology gaps, and provide an opportunity to further collaborations between technical experts in the USA and Canada whose work may contribute to the provision of relevant science advice.

Objectives

The workshop participants will:
1. Review experiences on current and potential technologies, applications, and data management related to benthic habitat assessments in the Northeast Pacific;
2. Identify gaps and synthesize recommendations for “best practices” for each of the three themes mentioned in 1);
3. Identify opportunities for potential collaborations that would improve the provision of science advice related to benthic habitat assessments in the Northeast Pacific.
Background information for consideration at the workshop may include:

- *ICES working group experience.*
- Report of the CBD Expert Workshop on Ecological Criteria and Biogeographic Classification Systems (Azores, Portugal, October 2-4, 2007);
- DFO, 2004. Identification of Ecologically and Biologically Significant Areas. DFO Can. Sci. Advis. Sec. Ecosystem Status Rep. 2004/006.

Workshop participants are encouraged to contribute presentations which report on how they are approaching technologies, applications, and data management for benthic habitat assessments in the Northeast Pacific. For example, presentations could focus on: i) what technologies, applications, and data management tools are currently available; ii) how have they contributed to developing policy or management measures; iii) what will we need in the future; and iv) how can science advice related to benthic habitat assessments of the Northeast Pacific be more effective?

Outputs

Outputs from the meeting will include CSAS Proceedings to document the discussion of the meeting and to report the results and any recommendations that are brought forward.

Participation

The workshop will be co-chaired by Elizabeth Clarke (NOAA- Northwest Fisheries Science Center) and Jim Boutillier (DFO – Pacific Biological Station) and will include experts from the National Oceanic and Atmospheric Association (NOAA), USA and DFO Science (Pacific Region), as well as appropriate external academic and NGO participants.

APPENDIX IV: Agenda

Tuesday, March 16, 2010

09:00 Introductions and TOR for the meeting, Logistics etc.
09:30 Review of ICES – Peter Lawton
10:00 Health Break
10:30 Data Management
Presentations (~20 min with questions) by NEPTUNE, NOAA, MBARI, DFO and Others
12:30 Lunch
13:30 Discussion on Data Management Issues
14:00 Presentations on Technologies: Hanu Singh, UVic, NOAA, NEPTUNE
15:00 Health Break
15:30 More Technology presentations: MCBI, NRCan, DFO (CHS &MEAD, and Others
16:30 Wrap up for the day

Wednesday, March 17, 2010

08:30 Any further presentations on Technologies and Discussion on Technology Issues
09:30 Applications:
Presentations : University of Alberta, NOAA, NEPTUNE, Others
10:15 Health Break
10:30 Applications: presentations continued: DFO
12:00 Lunch
13:00 Discussion on applications
14:00 Break out groups to get feedback and recommendations on the workshop
Health Break
15:00 Presentations of breakout groups by question
15:30 Recommendations and Wrap-up
16:30 Safe trip home