Three Oceans of Biodiversity

Development of a Science Plan for Marine Biodiversity in Canada

Proceedings of the Census of Marine Life and Department of Fisheries and Oceans Workshop

February 25 – March 1, 2002

White Point Beach Lodge, Nova Scotia

Centre for Marine Biodiversity
Department of Fisheries and Oceans
Maritimes Region
Bedford Institute of Oceanography
PO Box 1006
Dartmouth, Nova Scotia
B2Y 4A2

Census of Marine Life
Consortium for Oceanographic Research and Education
1755 Massachusetts Avenue
NW, Suite 800
Washington, DC 20036-2102
USA

2003

K.C.T. Zwanenburg, K. Querbach, E. Kenchington, and K. Frank
[Editors]

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FOREWORD

These proceedings record the presentations and discussions of the Workshop on Canadian Marine Biodiversity, held February 25 to March 1, 2002. The objective of the meeting was to identify present knowledge and knowledge gaps in our understanding of biodiversity in Canada's three oceans. The overall objectives were to develop a 5-10 years science plan outlining research directions for Canada to address these gaps. To position Canada as a contributor to the overall Census of Marine Life, we also laid the groundwork for establishing a national committee on marine biodiversity to oversee the implementation of the plan. The current report gives an overview of the workshop objectives, context, and introduction and then presents a short precis of each of the presentations given during the workshop. The presentations were abstracts of papers, of research programs, or in some cases entire papers. The detailed presentations (where provided by the authors) are available on the CMB website. These proceedings contain the relatively "raw" results of the deliberations of the workshop break-out groups. These are also presented in more distilled and assembled format following each section to give direction to the national committee and as such represents the biodiversity plan.

The organizers, conveners, and participants are grateful for the financial support of this initiative by both the Census of Marine Life and Canada's Department of Fisheries and Oceans

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ABSTRACT

Zwanenburg, K.C.T., K. Querbach, E. Kenchington, and K. Frank. [Eds.] 2003. Centre for Marine Biodiversity, Department of Fisheries and Oceans, Maritimes Region, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, NS, B2Y 4A2 and Census of Marine Life, Consortium for Oceanographic Research and Education, 1755 Massachusetts Avenue, NW, Suite 800, Washington, DC 20036-2012, USA. 2002. Development of a Science Plan for Marine Biodiversity in Canada, Proceedings of the CoML / DFO workshop held White Point Beach Lodge, Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 2432: viii + 72 p.

By signing the International Convention on Biodiversity, Canada has an obligation to lead research and address gaps in the area of marine biodiversity. Specifically, Canada has agreed to (1) make inventories of biodiversity, (2) monitor changes in biodiversity, and (3) make plans to conserve biodiversity. The Centre for Marine Biodiversity proposed the current workshop (in collaboration with the Census of Marine Life) in recognition of the many projects relating to biodiversity that are being carried out in all of Canada's ocean territories (Pacific, Arctic, and Atlantic) and the need to consolidate and review this knowledge at a national scale. Specifically the workshop was convened to achieve the following objectives: (1) To identify the present knowledge and knowledge gaps about marine biodiversity in Canada's three oceans; (2) to identify the present state of knowledge on major processes affecting biodiversity; (3) to develop a 5-10 years plan outlining data collection and research directions to address gaps, and (4) to establish a national committee on marine biodiversity to implement and adapt the plan. This report compiles the results of the workshop.

RÉSUMÉ

Zwanenburg, K.C.T., K. Querbach, E. Kenchington, and K. Frank. [Eds.] 2003. Centre for Marine Biodiversity, Department of Fisheries and Oceans, Maritimes Region, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, NS, B2Y 4A2 and Census of Marine Life, Consortium for Oceanographic Research and Education, 1755 Massachusetts Avenue, NW, Suite 800, Washington, DC 20036-2012, USA. 2002. Development of a Science Plan for Marine Biodiversity in Canada, Proceedings of the CoML / DFO workshop held White Point Beach Lodge, Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 2432: viii + 72 p.

En signant la *Convention internationale sur la biodiversité*, le Canada s'est engagé à effectuer des recherches et combler les lacunes dans le domaine de la biodiversité du milieu marin. Il a convenu, en particulier, 1) d'inventorier la biodiversité, 2) de surveiller les changements dans la biodiversité et 3) d'établir des plans pour conserver la biodiversité. Le Centre de biodiversité marine à proposé de tenir l'atelier dont il est question ici (en collaboration avec le Recensement de la vie marine), eu égard aux nombreux projets concernant la biodiversité qui ont été entrepris dans toutes les régions océaniques du Canada (Pacifique, Arctique et Atlantique) et à la nécessité de réunir et d'examiner les connaissances dont on dispose dans ce domaine à l'échelle nationale. Plus précisément, l'atelier a été mis sur pied dans les buts suivants : 1) Cerner les connaissances actuelles au sujet de la biodiversité marine dans les trois océans du Canada et les lacunes qu'elles comportent; 2) déterminer quel est actuellement l'état des connaissances sur les principaux phénomènes influant sur la biodiversité; 3) élaborer un plan sur 5 à 10 ans décrivant les orientations à prendre en matière de collecte de données et de recherches pour combler les lacunes et 4) créer un comité national sur la biodiversité marine qui serait chargé de mettre en œuvre et d'adapter le plan. Le présent rapport rend compte des résultats de cet atelier.

SUMMARY

The experts recognized the existence of a significant amount of data and samples, which describe aspects of recent patterns of marine biodiversity for each of Canada's oceans. Data registries based on the DFO National Science Data Inventory were developed for each of the Pacific, Arctic, and Atlantic oceans and reviewed at the workshop. These registries list the characteristics of the data sets available for each ocean and provide the meta-data. Additional data sets and sample collections presently not listed in the registries also exist. These additional sources of information range from data collected by individual scientists to institutional data sets and from small-scale sample collections in restricted geographic areas and taxa to more comprehensive collections covering broad geographic areas and phylogenetic scope.

The workshop recommended that a national working group to oversee the completion and integration of the three regional data registries be struck. The work of this group would take place during 2002-2003 and be closely integrated with the on-going development of national and international data management systems (e.g. VDC, OBIS, etc). The workshop developed a set of guiding principles to direct the activities of this group.

The workshop recognized that there are existing biological sampling and survey activities that provide invaluable information on marine biodiversity in each of our three oceans. These range from single site observations where information on biological diversity are collected sporadically to large-scale and long-term surveys that provide comprehensive views of the diversity and abundance of organisms over a wide geographic area. None of these surveys presently provide a comprehensive view of marine biological diversity in Canada.

The workshop recommended that a national working group be struck to examine existing sampling and survey activities in the Pacific, Arctic, and Atlantic oceans in order to determine to what extent these existing activities can be augmented to broaden the taxonomic or geographic scope of the information they collect. The workshop developed a set of guiding principles for this group and distinguished between the requirement for establishment of biodiversity inventories and the need to monitor marine biodiversity. The workshop recommended that consideration be given to the design and implementation of pilot studies, which are intermediate between the network of observatories as outlined below and the existing sampling and survey activities. Such pilots would broaden the taxonomic scope of surveys and make use of best practices, including technologies, to develop protocols and requisite institutional evolution.

The workshop recognized that Canada requires a long-term vision with regard to understanding and conserving marine biodiversity in its three oceans. This vision is encapsulated in the development and implementation of a network of *Marine Biodiversity Observatories* located in each of the Pacific, Arctic, and Atlantic oceans. The nature and location of these observatories will be based on the analysis and exploration of available marine biodiversity information as described in the completed regional registries. Their establishment will also be based on the analysis of existing sampling and survey data and the extent to which these allow for the *a priori* classification of marine habitats in our three oceans. Such classification will greatly increase the efficacy of future sampling and survey activities by directing efforts to areas that either are representative of larger areas or are in some manner unique. The Marine Biodiversity Observatories would be designed to provide detailed estimates of biodiversity across all taxa and to allow for studies of the processes affecting or maintaining biodiversity.

The workshop recommended that a national working group be struck to facilitate the analyses of existing data on the distribution and abundance of marine biota in relation to physical and environmental characteristics to determine processes underlying new or established patterns in species diversity. The findings of this working group would aid in the location of the *Marine Biodiversity Observatories*. The workshop developed a set of guiding principles for the working group and distinguished between processes maintaining community, species, and population levels of diversity.

INTRODUCTION

The world demand for food from the oceans is expected to outstrip availability within the next few decades. As well, the increased use of the oceans for extraction of non-renewable resources and the accelerating growth of coastal population is putting additional pressures on these systems. In Canada, this is reflected by increasing pressures on wild fish and invertebrate stocks, some to the point of fishery closure, increases in offshore oil and gas exploration, and increases in non-consumptive and other ocean use activities. At the same time there is an increasing demand for conservation of marine habitats and biodiversity reflecting a growing recognition that the welfare of mankind is inextricably linked to the welfare of the oceans. Rational management of man's use of the oceans requires reliable information and sound understanding of biodiversity and the processes controlling it to make effective decisions.

In response to the 1993 international Convention on Biological Diversity (CBD), the Census of Marine Life (COML) program was initiated in 1997. The motivations for the COML are that it provides opportunities to make exciting discoveries about our world, that it supports and operationalizes the CBD, and that this improved knowledge will lead to an improved ability to manage marine resources. Specifically the objectives of the COML are to describe: 1) What did live in the Oceans? 2) What does live in the Oceans? and 3) What will live in the Oceans? The global objectives of the Census are not only about classifying and counting the number of organisms in the sea; they are about understanding the complexities of biological-physical-chemical coupling in dynamic marine environments. The COML is one of the grand challenges of marine science whose execution has the potential to unify all its disciplines (biology, chemistry, and physics).

By signing the international Convention on Biodiversity, Canada has agreed to: make inventories of biodiversity, monitor changes in biodiversity, and make plans to conserve biodiversity. Although Canada ranks among the world leaders in marine research and has been carrying out biophysical monitoring since at least the 1950s, knowledge of its vast ocean territories is still rudimentary for many areas, especially for many groups of organisms inhabiting them. A pre-requisite to developing effective programs to protect habitats and biodiversity is to determine the extent to which information on biodiversity is available for Canada's Pacific, Arctic and Atlantic Ocean territories. Identifying the shortcomings in this information will allow us to improve existing biophysical monitoring activities to ensure that these information gaps are filled. In addition, improved understanding of the processes that govern biodiversity would allow us to make informed predictions on the factors that control biodiversity within marine systems and therefore, on mitigative procedures that might be effective for its maintenance.

The Centre for Marine Biodiversity (CMB) proposed this workshop as Canada's commitment to the international COML initiative in recognition of the many projects relating to biodiversity that are being carried out in all of Canada's ocean territories (Pacific, Arctic, and Atlantic) and the need to consolidate and review this knowledge at a national scale. The workshop is timely, given the activity and caliber of Canada's marine science community, the long tradition of monitoring of its marine systems, and the implementation of ecosystem level research in many of its marine institutions. At present a number of pilot projects, exploring various aspects of marine biodiversity are being carried out. The development of a national plan to address marine biodiversity in Canada therefore also represents a logical next step in the evolution of the census from pilot projects through national initiatives to the global census.

This workshop was convened to achieve the following objectives:

- To identify the present knowledge and knowledge gaps about marine biodiversity in Canada’s three oceans;
- To identify the present state of knowledge on major processes affecting biodiversity;
- To develop a 5-10 years plan outlining data collection and research directions to address gaps, and
- To establish a national committee on marine biodiversity to implement and adapt the plan.

OVERVIEW

The workshop was attended by invited experts and others from the Pacific, Arctic and Atlantic regions of Canada and by international experts (Appendix A). The workshop was structured under four thematic areas 1) Background, 2) Patterns, 3) Mechanisms and 4) Visualization, metrics, monitoring and implementation (Appendix B). These sessions were followed by break-out groups and plenary presentations.

The workshop was co-funded by the Canadian Department of Fisheries and Oceans and the Census of Marine Life and held under the auspices of the Centre for Marine Biodiversity at White Point Beach Lodge from February 25th to March 1st 2002.
Development of the workshop was guided by a steering committee consisting of the following experts: John Anderson, Mark Costello, Ken Frank, Louis Fortier, Dick Haedrich, Paul Hebert, Ellen Kenchington, Colin Levings, Clyde Murray, Ken Minns, Ron O'Dor, Howard Powles, Verena Tunnicliffe, Mike Sinclair, and Kees Zwanenburg.

All workshop arrangements were made by Victoria Clayton.

The workshop was co-convened by Kees Zwanenburg and Ken Frank.

STRUCTURE OF THE REPORT

This document serves a number of purposes in that it represents a record of the proceedings and discussions of the workshop, provides summaries of deliberations that took place and provides recommendations for next steps. The report is therefore structured into distinct sections corresponding to each of the 4 sessions of the workshop. The first substantive section following the opening remarks, which try to encapsulate the present state of knowledge and thereby put the workshop into its proper context, is the background session. The background session provides an overview of the status and future of Canada's marine biodiversity inventories and Canada's obligations regarding marine biodiversity from both a governmental and non-governmental perspective. A summary of each presentation is provided. Each of the following three sessions on Patterns, Processes, and Monitoring start with the summaries of each presentation. A relatively unedited record of the discussion groups that followed the session follows this. The last section provides a summary or compilation of those discussions that attempted to draw out the most important points or common elements from the discussion. This format was chose both to preserve the flavor and detail of the original deliberations and to provide a more structured version of them.

OPENING REMARKS

Marine Biodiversity in Canada - Context of the workshop and opening Presentation

Kees Zwanenburg, Department of Fisheries and Oceans, Bedford Institute of Oceanography

"All told there are somewhere between 2 and 30 million species of animals and plants alive on the planet today. Something like a thousand times that many species- about 2 billion – by the most conservative guess- have evolved, struggled, flourished, and gone extinct since the first shelly fossils were laid down in the Cambrian explosion, about 540 million years ago. And the great question for the evolutionist is Why?" (Weiner, 1995). The present estimate of the number of marine animals is on the order of 200,000; however, estimates of potential number of species range from 600,000 on coral reefs alone to between 0.6 and 100,000,000 on the continental slopes and abyssal plains if nematodes are included (Grassle, 2001). Because of a longer history preceding colonization of the land, 13 of 30 free-living phyla of organisms are endemic to marine systems. Paradoxically, only 15% of all described species are described from marine systems, reflecting relatively poor sampling of the marine environment rather than the actual distribution of species (Grassle, 2001).

As an example, the Scotian Shelf has been systematically surveyed for fishes every year since 1970 by the DFO groundfish trawl survey (Halliday and Koeller, 1981). A total of about 4500 trawl hauls (sets) have been made; however, the cumulative area sampled amounts to only 0.09% of the bottom area of the Scotian Shelf (depths < 360 m). This indicates that even for what would be considered a relatively intensively sampled area, the actual amount of bottom areas surveyed is low. In addition to low sampling intensity, the survey protocols have only recently been augmented to include the enumeration and identification of all macro-invertebrates caught by the trawl. There have been no synoptic surveys of the benthic invertebrates of the Scotian Shelf. Canada is not unique in this regard. It is rather symptomatic of the manner in which most marine ecosystems have been sampled for biodiversity. If we define species richness by sampling until a number of species versus area sampled curve reaches an asymptote, then for many species-rich taxa such as benthic invertebrates on coral reefs, or deep-sea benthos, this has not yet been achieved (Grassle, 2001).

Current global patterns of marine biodiversity are determined by historical events tempered by modern conditions. The rates of origination of new families of marine organisms have varied over time with the present having the highest number of marine families since the Cambrian explosion. Extinction of marine families was highest in the Cambrian and now appears to be relatively low (Newman and Elbe, 2001). Sepkoski (1999) also indicated that speciation, measured as the percent of new species arising proportional to the number of species present at any given time, can be divided into two major historical stanzas. The first is the rapid origination of the Cambrian explosion that ends with the great Permian extinction when approximately 90% of all species became extinct. This was followed by an origination 'outburst' starting in the Triassic that has declined slowly since. The results of these historical events remain visible in the patterns of modern marine biodiversity in that marine systems have a greater variety of major taxonomic divisions resulting from a longer evolutionary history prior to the invasion of terrestrial habitats. The results of more recent glacial processes also remain visible in that biological diversity is higher on continental slopes than on continental shelves because glacial scouring affected the latter.

A recent analysis by Kirchner (2002) indicates that the origination rate of marine organisms is much less variable than the extinction rate. This was interpreted to mean that the re-establishment of marine biological diversity is rate-limited relative to extinction. The proximal explanation for this discrepancy is that is takes more time to build something than to destroy it. For example the trophic relationships disrupted by extinction would take a long time to be re-established or re-directed. The seminal conclusion from this work is that a widespread depletion of marine biodiversity would be permanent on a multi-million year time-scale. This is a sufficient incentive to stimulate improved understanding of modern marine biodiversity.

The processes that control and alter modern-day patterns of biological diversity continue to be debated in the scientific literature. Knowledge of these processes are pre-requisite to the development and implementation of effective management measures aimed at ensuring the long-term conservation of marine biodiversity. Huston (1994) provides an eloquent development of the “dynamic equilibrium model of biodiversity”, which states that species diversity is an expression of the dynamic equilibrium between different rates of competitive displacement (correlated with growth and productivity) and different frequencies of mortality causing disturbances. He uses this theory to explain a variety of global patterns of biological diversity including those in marine systems. More recently Hubbell (2001) provides the unified neutral theory of biodiversity and biogeography that builds on MacArthur and Wilson’s equilibrium theory of island biogeography by including speciation and by moving the neutrality assumption from species to individuals. Hubbell’s theory is based on a “zero-sum game” assumption in which the maximum number of individuals in a community has a distinct limit and where increases in numbers in one species must be balanced by decreases in another. His theory is successful in predicting the non-canonical log-normal distributions of species abundance commonly observed with large sample sizes (in that they have long tails of rare species) but is presently restricted to communities composed of species relatively close in trophic level (especially tree communities and sessile marine invertebrates).

The elucidation and interpretation of these theoretical frameworks into applicable management actions is a key to future directions in marine biodiversity conservation. It is essential to addressing such questions as whether or not fragmentation of habitats leads to decay of dependent communities (e.g. Quammen, 1997) or the nature and efficacy of marine protected areas.

Fishing is one of the most significant activities that humans carry out in marine ecosystems. At present approximately 15 x 10^6 km^2 of the world’s continental shelves are trawled annually (Watling and Norse, 1998), and the total removals of fish and invertebrates amount to some 100 million tonnes per annum. Between 17 and 40 million tonnes of this total is discarded. It consists of a diverse array of vertebrates and invertebrates, most of which remain unidentified and the great majority of which are dead. Even with such seemingly large impacts, it remains difficult to document marine extinctions relative to terrestrial extinctions (Carlton *et al*, 1999). Although extinctions are difficult to document, the impacts on fish communities are readily documented and include changes in community dominance, and size spectra (e.g. Haedrich and Barnes, 1997; Bianchi *et al*., 2000; Zwanenburg, 2000). Impacts at other trophic levels remain relatively undocumented.

It has been amply demonstrated that fisheries are size selective and have been operating over long time periods. Frank *et al* (2001) present a graphic example of long-term changes in haddock (*Melanogrammus aeglefinus*) length at age and length at maturity. Length at age and size at maturity for this heavily exploited species declined by approximately 30% over a 30-year period of exploitation. Longhurst (1999) considers that for many north-temperate gadoid (cod-like) species, changes in population size structure and maturity at age represent an erosion of adaptive characteristics required to perpetuate these species. They have developed a strategy of living long and being very fecund. Such a strategy requires the presence of large old females in the population to bridge the temporal gaps in recruitment success characteristic of these populations. Weiner (1995) cites a study of *Heliotus sp.* moths in the USA. The results of this study indicated that in May of 1967 only about 6% of *Heliotis* moths survived a fixed dose of [pyrethroid] application, by September, several moth generations later, 61% survived the same dose. Grant and Grant (1998, cited in Weiner 1995) state that “You can’t preserve a species, every species is constantly changing and capable of further change”; a conclusion based at least partly on the results of their long-term studies of Galapagos finches. Given these findings there is a real question regarding the long-term nature of species being harvested by size selective methods or of those indirectly affected by these fisheries. Are these species the same as they were 500 years ago before substantial industrial fisheries were developed?

In addition to the impacts of fishing, there are other anthropogenic threats to marine biodiversity. At present it is estimated that half of the world’s population lives within 60 km of the coast, and 13 of the world’s 20 largest cities are in the coastal zone. By 2030 this is expected to rise to 70%. This will increase anthropogenic impacts by direct habitat alteration, increased nutrient inputs (eutrophication), and increased outflows of toxic wastes, all of which will alter marine biodiversity.

Globally, marine habitats provide a tremendous range of physical conditions. Canada has the world’s longest coastline (244,000 km) and a total of 6.5×10^6 km^2 of marine habitats. These include: rocky, sandy, and muddy intertidal habitats, vast continental shelves with shallow offshore banks and deep holes, all with an array of bottom types from rocky to muddy and including coral reefs, continental slopes, and abyssal plains. These habitats occur within a range of climatic zones from temperate through boreal to ice-covered arctic. Within this vast expanse of marine habitats that span three oceans (Pacific, Arctic, and Atlantic) Canada has conducted significant numbers of studies to elucidate their biological diversity. These activities range from short-term sampling of limited areas for specific taxonomic groups, to long-term surveys which monitor biological diversity over relatively large areas; however, over relatively limited taxonomic scope. A synopsis of these activities in the form of biological diversity data registers has been prepared for and will be reviewed at this workshop to give an overview of the overall state of our knowledge.

Canada has also established an organization to perform a ‘watch dog’ function over biological diversity, including marine biodiversity. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) currently lists 387 species ranging from extinct or extirpated to those of special concern. The latter category indicates either that there is evidence of a significant decline in abundance of distribution or that there is little evidence but that other sources of information indicate the need for special consideration. This list currently contains 114 species of marine fishes and 1 marine mammal. The list also includes 46 macro-invertebrates (both fresh-water and marine). The fact that the list contains no mention of micro-invertebrates, phytoplankton, bacteria, viruses, etc, is probably a good indicator that these groups represent the “limits” of our current knowledge about marine biodiversity. We just don’t have a lot of information on the diversity of these taxa in any of our oceans.

It is important to define the limits of our knowledge about marine biodiversity especially in view of the recent initiatives aimed at defining ecosystem objectives for the management of human activities in marine ecosystems. Jamieson and O’Boyle (2001) present the most recent work on this initiative in which they identify *inter alia* the following objectives related to biological diversity, namely to conserve or enhance genetic, species, and community diversity, maintain ecosystem functioning, and maintain or enhance physical environmental quality. Their approach of unpacking or translating each of these major objectives into specific actions such that they can be operationalized has significant merit and should be adopted to set more specific objectives applicable to specific systems.

These objectives, however, beg the question of whether we know enough about the current state of marine biodiversity and the degree of natural variability in diversity to achieve these objectives. This workshop was designed to begin the process of answering that question. In many ways the elucidation of the degree to which we know or do not know the full scope of biological diversity in our three oceans will be a journey of discovery. The principles that should guide us during the workshop (and during the subsequent work arising from the workshop) may have been most clearly stated by one of this century leading scientists

> “Scientific knowledge is a body of statements of varying degrees of certainty – some most uncertain, some nearly sure, none absolutely certain….”
> “Our freedom to doubt was born of a struggle against authority in the early days of science. It was a very deep and strong struggle. Permit us to question – to doubt, that’s all – not to be sure.”

"If we want to solve a problem that we have never solved before, we must leave the door to the unknown ajar."

Richard P. Feynman
On the value of science

This workshop could have been organized and approached in any number of ways; we have chosen this one and hope that it will help in achieving our goals. The overall structure of the workshop will be to intersperse a series of invited presentations with a series of break-out or discussion groups. The presentations have been prepared by invited experts and cover a broad range of topics relevant to marine biodiversity. The objective of the presentations is both to give the current state of knowledge of the particular topic addressed and to guide and stimulate the discussion groups. Given the broad range of topic areas that have relevance to the question of marine biodiversity, it was imperative to adopt a conceptual framework to define the ambit of our objectives. The conceptual framework, which has guided the development of the workshop and therefore the choice of speakers and subjects, is encapsulated in the following matrix:

	Inventory	Monitor	Conserve
Ecosystem			
Species			
Population			

This matrix presents both a summary of Canada's obligations under the Convention for Biological Diversity (to inventory, monitor, and make plans to conserve biological diversity) and the three levels of biological organization (communities or ecosystems, species, or populations). The intersection of these topics, represented by the elements of this matrix, defines the ambit of our activities. The elements under the inventory heading will be addressed by the review of the marine biodiversity data registries prepared for each ocean. They will provide information on the degree to which we know and do not know the scope of biological diversity in our three oceans. Knowing what we don't know is a first and important step toward defining geographic and taxonomic areas for which information is presently lacking and for which additional data collection is required. If we do not have a reasonable estimate of how many species are present, we will have no base against which to measure the losses (Briggs, 1994). In a very real sense the complete inventory of biological diversity, at all levels of biological organization, would provide the universe within which all our subsequent activities take place. It is desirable that we work toward this complete inventory both to comply with our responsibilities under the CBD and to satisfy our human nature to more fully understand the full beauty and complexity of the living world. It is one of the remaining grand challenges of biology.

It is essential to realize that this inventory includes critical habitats and seascapes since the other levels of biological organization depend on these. However, it is not necessary to make the complete inventory a pre-requisite to further actions. The elements under the "monitor" heading will define a subset of this inventory with which we will assess the performance of conservation measures that are urgently needed. Note that it is not necessary to have a complete inventory of marine biodiversity from which to choose the subset of monitored species. The set of monitored populations, species, or communities will be based on our current knowledge and abilities and may include species with high economic value, species with high ecological value, and species which we know to be rare or endangered. The scope of the set of biological entities monitored should be augmented or changed as our understanding of both the processes that control biodiversity, and of the human impacts upon those processes, improves. Similarly the conservation of biological diversity will be based on the application of principles from evolutionary, population, community, and ecosystem ecology. Again the scope of what we conserve now will be based on our current knowledge and abilities but will be tempered and influenced by a significant societal input. The set of conserved communities, species, or populations should again be augmented or changed as our understanding of the controlling processes improves.

The workshop started with an overview of global issues related to marine biodiversity. This was followed by a number of presentations that gave a more Canadian perspective on marine biodiversity from a biological, governmental, and NGO perspective. These were followed by three presentations relating to our understanding of "patterns" in marine biodiversity. The first looked at the contribution that the longer term history has had on present day patterns, while the other two discussed patterns of biodiversity in pelagic and benthic marine ecosystems respectively. This set the stage for a set of presentations that described and reviewed the marine biodiversity registries that were prepared for the Pacific, Arctic, Atlantic oceans. This first set of presentations was followed by a set of break-out groups in which a number of pre-defined questions relating to the scope of our knowledge about marine biodiversity, our ability to identify gaps, and the need to fill these gaps, were debated.

The next session featured a number of presentations related to the "processes" that control marine biodiversity at a number of levels of biological organization. These included a discussion of oceanographic influences on protist diversity, the impacts of fishing, some of the general principles underlying marine biodiversity (species-area relationships and species-habitat associations) and several views of diversity at the sub-species or population level including both a discussion of evolutionarily significant units and innovative methods of rapid taxonomic classification. This session was again be followed by break-out group discussions.

The final session of the workshop dealt with a variety of issues from data management and visualization, to the kinds of products that are required for marine biodiversity information, the design of marine biodiversity monitoring programs, and finally a discussion of how to implement the findings of the workshop.

Notes

PowerPoint presentation is available at the Census of Marine Life Marine Biodiversity

Workshop website (http://www.marinebiodiversity.ca/mbw/index.html).

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SESSION I: BACKGROUND

Marine Biodiversity: Four Steps to Knowledge

Pierre Brunel, Département de Sciences biologiques, Université de Montréal

My fifty years of experience with marine biodiversity molded me first as an ecologist (fisheries research station: 14 years), secondly as a taxonomist and biogeographer. University teaching since 1966 later brought me to Invertebrate Zoology and Macroevolution, based largely on high-level classification and paleobiology. My short talk is an outgrowth of a "Marine Biodiversity" chapter in a forthcoming UNESCO "Encyclopedia of Life Support Systems" (EOLSS Publishers Ltd, Paris), providing a welcomed opportunity to expound strong opinions for debate.

Biodiversity, which is not equivalent to almost all of ecology, must be based on comparisons of many, or at least several, operational units. Four well-known kinds of biodiversity are distinguished in that EOLSS chapter: species, high-level, ecological and genetic biodiversity. The most practical, nodal and widely used units now available are **species**, around which subunits (e.g. fish stocks, genetic units) and larger ecological assemblages are organized. In the oceans, benthic species of invertebrates, algae and protists are overwhelmingly dominant: they account for 98% of species biodiversity. High-level world biodiversity is also predominantly marine: new data in the EOLSS chapter show that 96% of the 76 classes of animals occur in the sea, 72 of which are invertebrates. From that chapter, emphasis is placed below on the four main steps to good knowledge on marine biodiversity.

STEP 1 to good knowledge involves **good sampling at sea** which, depending on the sampling objectives and the habitats to sample, entails very small to very large samples, or collections. Five kinds of objectives may be pursued. (1) Good **taxonomic sampling** can be satisfied with qualitative sampling of few undamaged specimens of both sexes and juveniles, to be either named or used as references for identification. (2) Good **biogeographic sampling** can also be qualitative and opportunistic ("flower-picking") but needs coverage of large spatial scales: many more specimens end up in much larger territorial collections. (3) Good **synecological sampling** requires numerous quantitative or at least comparable samples, but must be restricted to smaller spatial scales at the community level; such sampling often means slicing blindly the whole community (planktonic, benthic or parasitic), ideally for an assessment of the whole community structure, but more often for a few target species (e.g. cod larvae); ever-improved high-tech instrumentation is needed, but extreme or difficult habitats are extremely costly to sample (e.g. by "Alvin"); plankton communities are easier to sample quantitatively than benthos since sampling and filtering are simultaneous and damage is rarer; soft-bottom communities are easier to sample quantitatively than hard grounds, but sieving is extremely long and tedious, yet benthic biodiversity **must** be assessed... Suprabenthic sampling with plankton nets on sleds is a good compromise (it's mine...), and so are emergence traps. (4) Good **autecological sampling** calls for long time series (twice a month recommended) for life history studies, but it must be restricted to selected and representative communities: mountains of samples again must be collected, but with fewer of the same species. (5) Finally, good sampling **of community succession** and **disturbance** also calls for high-tech apparatus used in long time series: these can be the same as those aimed at life histories, but few ecosystems can be monitored, and whole-community samples must be stored for later study.

One should note here that the last three kinds of ecological samples always retain significant taxonomic and biogeographic values. They are thus likely to become ever **more valuable** in the uncertain future of biodiversity.

Since Step 1 involves the outdoors, physical and high-tech activities aboard ships or submarines and with divers, it is visible to the media and the public, and therefore most exciting and attractive to the inexperienced young people, managers and politicians. It has thus been well funded for decades and still is. But it fosters the "quick and easy" gathering of mountains of unprocessed samples, which are dumped on others: "Let George do it!"

STEP 2 is that of **processing** those **mountains of samples** in the laboratory. This generally means a second filtering, hand-sorting, identification, counting, labeling and storage for postponing or checking difficulties. However, since processing is extremely time-consuming, high-tech resistant and labor-intensive, and since all labs are too small for much storage, the outcome of Step 1 is almost always the gathering of **research collections**, which are nothing more than huge backlogs of samples. Most biologists forget that correct identification and naming of specimens still requires also huge backlogs of old and often obscure papers going back to Linnaeus, hence big collections of monographs, reprints or photocopies not yet retrievable online or simply stored out of view and quick use. Step 2 is invisible, tedious and dull and thus lacks mediatic glamour. Despite its requirements for lots of space and permanent jobs (even well supervised undergraduate or amateur "parataxonomists" would do!), Step 2 has been an underfunded drudgery for decades. Yet it is essential for the quality of Steps 3 and 4. And where is

"George" now? In his obscure museum or university lab, with few "customers", yet with several and increasingly important services to render to the environment and even to its shortsighted "users". Space and staff limitations in traditional museums have generally restricted their holdings to taxonomic and biogeographic collections. From the other three kinds of ecological samples, the largest museums at best have kept some so-called "voucher specimens", while government labs with applied mandates and university labs too often funded the same way have either discarded such "useless" samples, after studying only the "useful" or "harmful" species, or simply become cluttered and helpless with such samples. Yet good ecological collections will increasingly become the **only way to sample the biodiversified past** and prepare for our uncertain future.

STEP 3 is that of **data storage, retrieval and dissemination**. Up to recent years, after discarding their collections of specimens, most institutions or scientists ended up with mountains of data, simply because nature is immensely biodiverse as such. The astonishing development of computer technology has recently brought glamour and high-tech visibility to what is now called "bioinformatics". The prospect of "quick and easy" processing of those mountains of data has focused much attention on those magical "solutions" to another former drudgery. But "click-happy" computer proponents tend to treat lightly the dependence of their data on the quality of Step 2. Again the inexperienced young, managers and politicians become excited and attracted to the new magic of step 3, which has therefore been well funded in recent years. How much wrong data will be computerized in the coming years, without the possibility of checking "groundtruth" in collections, is somewhat downplayed.

STEP 4 provides for **data analysis, interpretation and reporting**, preferably in refereed papers. It is essential for good knowledge, "quick" for some who find it fun, slow for others who find it tedious or merely bottlenecked by the poor quality of Steps 2 and 3. It is generally invisible to the media and the public, except through good popularizing of science. Funding is therefore dependent on the "publish or perish" syndrome. Because of unjustified sneering by peers over even good "descriptive biology", many publishing outlets for taxonomy have died, hardly helping the "publish or perish" criteria. Even biodiversity-based ecological papers in good refereed journals rarely provide ways to assess the quality of their taxonomic identifications by biologists unfamiliar with their fauna or flora. Isn't that quality as important as that of statistical tests or numerical methods?

La Biodiversité marine: quatre étapes vers la connaissance

Pierre Brunel, Département de Sciences biologiques, Université de Montréal

Mes cinquante ans d'expérience en biodiversité marine, d'abord dans une station de recherche sur les pêches (14 ans), m'ont formé premièrement comme écologiste et secondairement comme taxonomiste et biogéographe. L'enseignement universitaire depuis 1966 m'a ensuite dirigé vers la Zoologie des Invertébrés et la Macroévolution, fondées surtout sur la classification des taxons supérieurs et la paléobiologie. Mon bref exposé est extrait d'un chapître intitulé "Marine Biodiversity" à paraître dans une

"Encyclopedia of Life Support Systems" de l'UNESCO (EOLSS Publishers Ltd., Paris). L'occasion est bienvenue de lancer pour discussion quelques opinions favorites.

La biodiversité, qui n'équivaut pas à presque toute l'écologie, doit nécessairement comparer un grand nombre, ou au moins plusieurs, unités opérationnelles. Mon chapître EOLSS distingue quatre sortes bien connues de biodiversité: celle des espèces, celle des taxons supérieurs, la biodiversité écologique et la biodiversité génétique. Les unités centrales, les plus pratiques et les plus utilisées dont nous disposons sont les ESPECES, autour desquelles s'organisent les sous-unités (e.g. stocks de poissons, gènes) et les assemblages écologiques plus grands. Dans les océans, les espèces benthiques d'invertébrés, les algues et les protistes dominent massivement: elles comptent pour 98% de la biodiversité des espèces. La biodiversité mondiale des taxons supérieurs est aussi presque entièrement marine: de nouveaux chiffres dans mon chapître EOLSS montrent que 96% des 76 classes d'animaux vivent dans la mer, et que 72 d'entre elles sont des invertébrés. De ce chapître, j'expose seulement ci-dessous les quatre principales étapes d'acquisition de bonnes connaissances sur la biodiversité marine.

L'ÉTAPE 1 vers de bonnes connaissances suppose un BON ÉCHANTILLONNAGE EN MER, qui peut résulter en un très petit ou un très grand nombre d'échantillons, c'est-à-dire des collections. On peut poursuivre cinq types d'objectifs. (1) Un bon ÉCHANTILLONNAGE TAXONOMIQUE se satisfait de prélèvements qualitatifs de quelques spécimens en bon état des deux sexes et des jeunes, qu'on peut décrire et nommer ou simplement utiliser comme références pour l'identification. (2) Un bon ÉCHANTILLONNAGE BIOGÉOGRAPHIQUE peut aussi n'être que qualitatif et opportuniste ("cueillette de fleurs") mais doit couvrir de très grands espaces: on obtient donc des collections territoriales bien plus grandes qui contiennent un très grand nombre de spécimens. (3) Un bon ÉCHANTILLONNAGE SYNÉCOLOGIQUE requiert de nombreux échantillons quantitatifs ou au moins comparables, mais doit se restreindre à des échelles spatiales plus petites, celles des communautés ou biocénoses; de tels échantillonnages se font souvent en prélevant des tranches de communautés entières (planctoniques, benthiques, parasitaires), Iidéalement afin de mesurer leur structure, mais plus souvent pour cibler certaines espèces (e.g. larves de morues); on emploie un appareillage de haut niveau toujours plus précis, mais ces moyens sont toujours plus coûteux dans les habitats extrêmes ou difficiles d'accès (e.g. le sous-marin "Alvin"); les prélèvements quantitatifs sont plus faciles dans les communautés planctoniques que dans le benthos puisqu'on prélève et filtre simultanément des spécimens moins endommagés; il est plus facile de prélever quantitativement dans les fonds meubles que sur fonds durs, mais le tamisage est toujours lent et fastidieux, et pourtant IL FAUT évaluer la biodiversité benthique...Un bon compromis - le mien...- consiste à prélever le suprabenthos nageur avec des filets à plancton montés sur traîneau ou avec des pièges à émergence. (4) Un bon ÉCHANTILLONNAGE AUTÉCOLOGIQUE dépend de longues séries temporelles (on recommande le bimensuel.) pour l'étude des cycles de développement, mais doit se restreindre à quelques communautés représentatives choisies: on obtient encore des montagnes d'échantillons, qui contiennent toutefois moins des mêmes espèces. (5) Enfin, un bon ÉCHANTILLONNAGE DE LA SUCCESSION

ET DES PERTURBATIONS DANS LES COMMUNAUTÉS dépend aussi d'appareils de haut niveau prélevant en longues séries temporelles: celles-ci peuvent être les mêmes que celles qui visent les cycles de développement, mais on ne peut suivre que peu d'écosystèmes, et il faut stocker pour étude ultérieure des échantillons de communautés entières.

On doit noter ici que les trois derniers types d'échantillons écologiques conservent toujours des valeurs taxonomiques et biogéographiques. Ils sont donc susceptibles d'acquérir une PLUS-VALUE croissante dans l'avenir incertain de la biodiversité.

Puisque l'étape 1 survient au grand air et implique des activités physiques avec des appareils de haut niveau à l'aide de navires, de sous-marins et de plongeurs, sa visibilité est grande aux yeux des média et du public, de sorte qu'elle excite et attire beaucoup les jeunes, les gestionnaires et les politiciens inexpérimentés. C'est pourquoi elle a été bien financée depuis des décennies, et l'est encore. Mais elle encourage l'accumulation "rapide et facile" de montagnes d'échantillons non traités, qu'on refile à d'autres: "Que Georges s'en occupe!"

L'étape 2 est celle du TRAITEMENT DE ces MONTAGNES D'ÉCHANTILLONS au laboratoire. Il faut généralement les filtrer encore, les trier à la main, identifier et dénombrer les spécimens, et les étiqueter et les stocker pour en reporter l'étude ou les difficultés à plus tard. Cependant, puisque ce traitement prend énormément de temps, se prête mal à l'automatisation et requiert donc beaucoup de main-d'oeuvre, et puisque tous les laboratoires sont trop petits pour l'entreposage, l'étape 1 aboutit presque toujours à l'accumulation de COLLECTIONS DE RECHERCHE, qui ne sont rien d'autre que d'énormes arriérés d'échantillons. La plupart des biologistes oublient que l'identification et la nomenclature précises des spécimens exigent encore aussi d'énormes collections de publications anciennes et souvent obscures remontant jusqu'à Linné; il faut donc conserver de grosses bibliothèques de monographies, de tirés-à-part ou de photocopies pas encore informatisées ou simplement stockées dans des entrepôts éloignés difficiles d'accès. L'étape 2 est invisible, fastidieuse et ennuyeuse, ce qui la prive de l'attrait médiatique. Malgré ses grands besoins en espaces et en main-d'oeuvre permanente (même des "parataxonomistes" étudiants ou amateurs feraient l'affaire...), l'étape 2 est est perçue comme une corvée sous-financée depuis des décennies...Et pourtant elle est essentielle à la qualité des étapes 3 et 4. Et où trouve-t-on Georges actuellement? Dans son musée obscur et famélique ou dans son laboratoire universitaire, recevant peu de "clients", mais capable de rendre plusieurs services de plus en plus importants à l'environnement et même à ses "utilisateurs" myopes. Les restrictions d'espaces et de main-d'oeuvre dans les musées traditionnels ont généralement limité leurs collections aux fonctions taxonomiques et biogéographiques. Les plus grands musées ont pu, au mieux, conserver des spécimens dits "témoins" des échantillonnages à fonctions écologiques, tandis que les laboratoires d'état à missions appliquées et les laboratoires universitaires subventionnés de façon semblable ont dû, soit détruire ces échantillons "inutiles", soit s'en trouver désespérément encombrés, après avoir étudié seulement les espèces "utiles" ou "nuisibles." Or les bonnes collections écologiques deviendront de plus en plus le

SEUL MOYEN D'ÉCHANTILLONNER LE PASSE BIODIVERSIFIÉ et de se préparer à notre avenir environnemental incertain.

L'étape 3, c'est le STOCKAGE, LA RÉCUPÉRATION ET LA DISSÉMINATION DES DONNÉES. Jusqu'à récemment, après avoir détruit leurs collections de spécimens, la plupart des institutions ou des chercheurs se retrouvaient avec des montagnes de données, simplement parce que la nature telle qu'elle est se trouve immensément diversifiée. Les progrès fulgurants des technologies informatiques ont récemment apporté éclat et visibilité de haut niveau à cette activité maintenant nommée "bioinformatique." Les perspectives de traitement "rapide et facile" de ces montagnes de données ont drainé beaucoup d'attention vers ces "solutions" magiques à une autre de ces anciennes corvées. Mais les protagonistes "cliqueteurs" de l'informatique oublient trop souvent que leurs données dépendent lourdement de la qualité de l'étape 2... Et les jeunes, les gestionnaires et les politiciens inexpérimentés sont de nouveau tout attirés et excités par la nouvelle magie de l'étape 3, qu'on a par conséquent bien financée dans les années récentes. On tend à oublier combien de données fausses seront informatisées dans les prochaines années, sans qu'on puisse valider leur "véracité première" dans les collections.

L'étape 4, c'est l'ANALYSE ET L'INTERPRÉTATION DES DONNEÉS ET LA DIFFUSION DES RESULTATS, de préférence dans des articles arbitrés. Elle est indispensable aux bonnes connaissances, "rapide" pour ceux qui la trouvent amusante, lente pour d'autres qui la trouvent difficile ou simplement bloquée par la piètre qualité des étapes 2 et 3. Elle est généralement invisible aux media et au public, sauf lorsqu'on la simplifie par une bonne vulgarisation scientifique. Les crédits sont donc tributaires du syndrome "publie ou péris". A cause du mépris injustifié des pairs évaluateurs même envers une bonne "biologie descriptive", trop de débouchés imprimés pour la taxonomie ont disparu, n'aidant nullement les critères du "publie ou péris"...Même les articles écologiques fondés sur la biodiversité dans les bonnes revues à jury permettent rarement d'évaluer la qualité de leurs identifications taxonomiques par les biologistes peu familiers avec leur faune et leur flore. Cette qualité n'est-elle pas aussi importante que celle des épreuves statistiques ou des méthodes numériques?

Conservation of Marine Biodiversity in Canada: Instruments and Issues
Howard Powles, Department of Fisheries and Oceans, Ottawa

Aquatic biodiversity in Canada falls under both Federal and Provincial jurisdictions and occurs in three large oceans (Atlantic, Pacific and Arctic). The Convention on Biological Diversity provides a general statement of Canada's commitments. Despite threats from fishing and habitat issues, marine fauna in Canada are not well characterized. Many changes in Canada’s oceans have occurred in recent years including multiple uses and cumulative impacts as well as constant increase in fishing pressure on fishing resources. Management’s focus has moved from fisheries to ocean management, and from single species to entire ecosystems over the last 20 years. Instruments including legislation, regulations, agreements, policy and programs are necessary to protect biodiversity, and Canada has a number of these in place: to protect fish (e.g. Federal Fisheries Act), fish habitats (e.g. Fisheries Act), oceans (e.g. Oceans Act), species at risk (e.g. SARA-in parliament) and marine conservation areas (e.g. Marine Parks Bill). Overall, a federal-provincial Agreement is the major instrument for species at risk, while legislation and regulations are available for fish and fish habitats and legislation is available for oceans. Institutional changes have taken place to support better biodiversity protection, including the Biodiversity Convention office established in Environment Canada, new federal-provincial structures for species at risk, increased interdepartmental activities, and changes within DFO (e.g., Centre for Marine Biodiversity, Biodiversity Science Branch). Some current major issues constraining better biodiversity protection include lack of systematists; incomplete inventories, monitoring and assessments; the need for robust peer review of biodiversity science and information; integrating traditional/local knowledge, and decisions on which metrics best represent "biodiversity". The overall goal should be to build “seamless” protection for biodiversity using the range of instruments available. An ecosystem approach, the new Species At Risk Act (particularly the provisions for Special Concern species) and the formation of biodiversity policies may help to achieve this.

Notes
PowerPoint presentation is available at the Census of Marine Life Marine Biodiversity Workshop website (http://www.marinebiodiversity.ca/mbw/index.html).

Biodiversity: Obligations, Issues and Actions
Robert Rangeley, World Wildlife Fund Canada, Atlantic Regional Office

The mission of the World Wildlife Fund is to conserve biological diversity, ensure the sustainable use of renewable resources and promote the reduction of pollution and wasteful consumption.

WWF Canada is one of 27 in the WWF international network. Our conservation strategies are well-grounded in science, we work to develop cooperative relationships with local communities, industry, government and [other] NGOs and we ensure that our programs have broad public support. WWF has committed to a new marine conservation initiative by opening regional offices on all three of Canada’s Oceans.
WWF promotes a two-pronged approach to conservation: first, a scientifically based system of protected areas that prohibit major industrial disturbance. And second, sustainable management practices on the rest of the landscape, or waters. The main challenge is to balance nature conservation with industrial development.

Systems planning is the common ground between those of us working on protected areas and those of us interested in development: we all want clear goals, consistent criteria for decisions, and a fair but speedy process. This is not a radical environmental position; even the petroleum industry has called for sensitive areas to be identified and placed out of bounds. The bottom line is that we’ve reached the point in Canada where some important conservation steps must be sequenced in advance of development while we still have the option, especially reserving protected areas. This is the essence of WWF’s Conservation First principle.

Effectiveness indicators and biodiversity status reports are required to determine whether conservation targets are met. The Management Effectiveness Initiative (2000-2003) will determine the set of biophysical, socioeconomic and governance indicators that are necessary to ensure MPA goals are met. The "National State of Biodiversity and Ecosystem Health Report" will be launched next year and will report on Canada's success in meeting conservation targets. The commitment by WWF is to establish MPAs in Canada in association with sustainable development initiatives with industry. Biodiversity conservation must take place before further degradation occurs and before future options are lost.

Notes
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SESSION II: PATTERNS

Classification of Pelagic Ecosystems

Alan Longhurst, Carjac, France

The classification of global pelagic ecosystems using physical factors to which ecosystem type shall develop in any region of the ocean or shallow areas is discussed by reference to the terrestrial "Biome 3" model. As in terrestrial systems, phytoplankton biomes appear to be regulated primarily by physical forcing, while interaction between organisms produces only secondary effects. If information on physical forcing is accessible at fine spatial and temporal scales, we ought to be able to predict the global distribution of oceanic biomes, each with a characteristic assemblage of phytoplankton species. With each of these will be associated a characteristic group of herbivorous zooplankton that, in turn, support a characteristic assemblage of predatory zooplankton, larger nekton, fish, mammals and birds. Longhurst argues that the seasonal growth cycle of phytoplankton (both algal and microbial) is determined by only a small number of physical factors, of which the most important are wind mixing and irradiance at the sea surface. These two processes control the stratification of the upper water column and thus the supply of inorganic nutrients; in addition, they largely control the sinking of plant cells. A close approximation to a global classification of the pelagic ecosystem has been proposed. Four biomes are recognized: polar (summer brackish layer), westerlies (seasonal wind stress induces mixing), a trade wind biome between the subtropical convergences, and a coastal biome. It is suggested that each of these biomes can be subdivided into "biogeochemical provinces" to further investigate patterns. Some species' oceanic distributions can be shown to correspond to the proposed provinces. The same logic is expected to apply within the Canadian regional seas at smaller scale; however, increasingly towards smaller the scale, the more difficult it becomes unless you have it captured, as in Bedford Basin. Data such as the regional sea-surface chlorophyll, temperature and mesoscale circulation features produced through "State of the Marine Ecosystem" project of BIO, could be extremely useful in addressing finer spatial discrimination in Canadian coastal seas.

Notes
A detailed text of this presentation is available at the Census of Marine Life Marine Biodiversity Workshop website (http://www.marinebiodiversity.ca/mbw/index.html).

A Systematic Approach to the Conservation of Marine Biodiversity
John Roff, University of Guelph

The current emphasis on marine biodiversity in Canada is on taxonomy and systematics at genetic and species levels of organization. However, this is a never-ending task and updates and inventory are always required. Thus, there is a need for ecological classification to protect components of biodiversity and this "ecodiversity" takes into account the structure and processes in marine ecosystems in an Ecological Hierarchy. Compositional (e.g. genes), structural (e.g. ESUs) and functional (e.g. genetic processes) components make up this framework and it occurs at the species, community and ecosystem level. Integration of single-species, community and ecosystem approaches is paramount, as single-species approaches are unrealistic, and can be achieved using habitat classification. Conservation at the species/population level is achieved by focusing on "focal" species (species at risk, keystone, charismatic species, indicator species, umbrella species, etc). Community and habitat level conservation includes spaces and species seeking to understand patterns in biodiversity as it relates to habitat type. Conservation at habitat/species level can be accomplished through both "representative" and "distinctive" habitats.

Representative habitats are typical of their surroundings at some defined scale and can be classified geophysically (based on structural elements both enduring and recurrent) at the community and ecosystem levels. The geophysical approach to classification and mapping of representative habitat types has many potential uses including: (1) the definition of habitat and community type associations, (2) assessment of habitat suitability for defined purposes (e.g. fisheries enhancement), (3) examining patterns of biodiversity distribution, (4) judging potential impacts of invasive species, (5) as a guide to environmental monitoring programs, (6) evaluation of candidate MPAs…etc. A mapped area could be based on heterogeneity or species-area curves, for example, where the area captures the asymptote. Within habitats, environmental variability relates to species diversity, particularly with salinity, temperature, fetch, and number of predators (i.e. physical stability and disturbance, and natural disturbance events). Distinctive habitats are atypical of their surroundings at some defined scale and to analyse them, we must consider structures and processes across the entire ecological hierarchy including focal species and physical anomalies such as upwelling, high chlorophyll or ocean gyres. Some examples include the Saguenay Fjord (estuarine circulation, islands (isolation) and the Minas Basin mudflats (tidal re-suspension).

The components of biodiversity captured in this strategy include structures and processes; however, meta-population, genetic variation and fine scale habitat variability are not represented.

Notes
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Community Assembly and Possible Generalities in the Histories of Northwest Atlantic Benthic Invertebrates
John Wares, Cliff Cunningham, Cynthia Riginos, Duke University, Durham, North Carolina

The biogeography of Northwest Atlantic benthic marine invertebrates is complex, considering the opening of Bering Strait 3.5 million years ago. This "trans-Arctic interchange" permitted species from the Pacific to cross over to the North Atlantic. Up to 80% of New England rocky shore fauna have a Pacific origin, which makes this trans-Atlantic biota exchange perfect for studying comparative ecology or also called the 'Grand Natural Experiment'. It is possible to distinguish between recent colonists (those who did not survive glaciation) following glaciation and long-term remnant species using genetic divergence to test the hypothesis that all NW Atlantic obligate rocky shore taxa experienced an extinction and then a recolonization. Those taxa that did not survive glaciation will have a genetic structure characteristic of the Pacific and Europe. Unique alleles and genetic divergence suggest the long-term resident species hypothesis. *Mytilus edulis*, for example, has been on both coasts for ~1MYA, and *Semibalanus balanoides* has also survived the glaciation. But in *Littorina obtusata* and *Nucella lapillus*, the lack of genetic diversity suggests a recent colonization event. This may be due to non-dispersing larvae. There is also genetic evidence of a glacial refugium in the Canadian Maritimes.

Notes
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Pacific Marine Biodiversity
Clyde Murray, Department of Fisheries and Oceans, Pacific Biological Station

British Columbia's coast is one of the most biologically productive marine and coastal environments of any temperate region in the world. Conserving biological diversity poses dramatic new problems for comprehensive inventory and monitoring. It is important to collate known information and then to assess what additional information is required. An essential step in ensuring marine biodiversity conservation in the Pacific Region is the assessment of its current status, and regular updates thereafter so that problem areas are identified and addressed. We have started an evaluation of the current knowledge of marine biodiversity in the Pacific Region using the development of a comprehensive data registry as the first step. The data registry identifies current knowledge and in doing so it also gives insight into the areas where data gaps exist and where human capacity and expertise need to be developed. It provides an important benchmark for future status assessments, but is in itself a valuable reference document since it covers the range of marine biodiversity levels (genetic, species, ecosystems). An existing database, the

Pacific Science Data Inventory, proved to be very useful in developing the Pacific Marine Data Registry. The Pacific Science Data Inventory was part of a national initiative to document DFO Science databases. A draft copy of the Pacific Science Data Inventory was modified into the Pacific Marine Biodiversity Data Registry. The modifications were then used to remove freshwater data records and to improve the search and query capabilities of the database.

The Pacific Marine Biodiversity Data Registry has information from 1878 to the present and currently contains 471 records, each representing single or multiple databases. Biological data can be found in 346 records, 105 have only physical data, and 81 have combination of physical and biological data. Information on marine species or habitats can be found in 250 records, 88 records contain information on estuaries, and 133 have data on both marine and freshwater species or habitats. Twelve data records contain information on a broad spectrum of species or habitats relating to ecosystems (sea mounts, marine protected areas). The data registry contains information on 140 species (e.g. little neck clam *Protothaca staminea*) or species groups (e.g. Salmon, Groundfish, Invertebrates, Shellfish, etc.). Most of the information in the data registry is from commercial species associated with a number of geographical regions.

Some limitations of the registry include species representation (i.e. mainly commercial), geographical coverage (i.e. parks best sampled) and the variation in methods used to inventory some groups. There is a need to standard species group classification in the data registry (i.e. keywords among the records are highly variable). With the increase in the number of research, management and public programs dealing with marine species, there is also a need for reference lists of marine species names and species codes. Further, although data sharing is improving with the extensive use of web-based data access, there is no national policy among Federal Departments on providing or sharing data.

Notes
PowerPoint presentation is available at the Census of Marine Life Marine Biodiversity Workshop website (http://www.marinebiodiversity.ca/mbw/index.html).

Marine Biodiversity in the Canadian Arctic
Kathleen Martin, Department of Fisheries and Oceans, Arctic Marine Ecosystems Dynamics, Winnipeg

The Central and Arctic Region of Fisheries and Oceans Canada is responsible for Ontario, Alberta, Manitoba, Saskatchewan, Northwest Territories, Yukon North Slope, Nunavut and the Territorial Marine Waters. This is a vast area and includes 64% of Canada, 71% of Canada's coastline, 67% of the country's fresh waters and 65% of Canada's marine waters. Within DFO’s C&A Region there are 13 researchers studying Arctic marine mammals; 11 - Arctic fish; 2 – Arctic invertebrates; and 1- Arctic phytoplankton. Many more researchers across Canada, both within and outside of government, work in the Arctic. They include individuals from DFO’s other Regions, other Departments (Environment Canada, Parks Canada), Universities, Museums and other Countries.

The approach being taken by C&A with the Regional registry is the same as with the other Regions – adoption of the Science Data Inventory. Although, this provided the basis for the biodiversity database, it became clear that modifications were required as it had limited usefulness in its original format. Following the Pacific's lead – Marine, Marine/Freshwater (mixed datasets and anadromous datasets), Freshwater, Estuary and Ecosystem dataset classifications were added. Addition of Biological Data and Physical data as keywords was required to allow sorting of datasets. Redundant datasets need to be removed and missing information added where possible. All changes and additions are being made to a copy of the Science Data Inventory.

Summary of results:
The original Science Data Inventory has 427 records, 148 are non-Arctic, and 247 are Arctic. The earliest start to any dataset is 1910, which is the Arctic Marine Fish Geographical Dataset. Some of the early datasets have come from other organizations. For example, fish and hydrographic data from the Arctic Biological Station 1947 – 1979 are included as one of the records. The majority of the datasets however begin in the late 1960's. The datasets included are either documents (132 records), electronic/digital formats (178 records), or physical specimens (117 records). There should also be a number of datasets included in the other Regional Registries, which pertain to the arctic. Researchers in the Pacific Region have collected oceanographic data in the Western Arctic, some in Quebec and Maritimes Regions have collected data throughout the arctic. Researchers form Newfoundland Region have also collected data particularly on stocks in Baffin Bay and Davis Strait.

Published data:
Some of the data from the inventory is published and the references are included in a field within the database (195 records). There is also a tremendous amount of information in the published literature pertaining to Arctic Marine Biodiversity. Determining which publications relate to biodiversity can be troublesome as standard keywords are often lacking. Species are generally listed if there are only a few of them.

One of the most critical aspects of developing a useful database of Marine Biodiversity is to decide what the products are to be and how they will be used in the end.

Notes
PowerPoint presentation is available at the Census of Marine Life Marine Biodiversity Workshop website (http://www.marinebiodiversity.ca/mbw/index.html).

Overview of Marine Biodiversity Information on the Gulf of St. Lawrence Ecosystem

Richard Bailey, Department of Fisheries and Oceans, Institute Maurice Lamontagne

The St. Lawrence marine ecosystem is a semi-closed oceanographic system, described as either a large estuary or a small ocean. It extends more than 1000 kilometers from the brackish-water Estuary of the St. Lawrence River to the Strait of Belle Isle, near

Labrador. Mixing between the in-flowing marine waters of the North-Atlantic continental shelf and the fresh water input of the St. Lawrence, combined with harsh winter conditions and bathymetric features such as the Laurentian Channel, result in a complex mosaic of diverse habitats. Although not deeply affected, the St. Lawrence is subjected to significant human activities ranging from fisheries to navigation and toxic contamination. Impacts of these activities on the ecosystem must be monitored and managed and thus, scientific information on biodiversity is required.

Anecdotal information on the wildlife of the St. Lawrence can be found as early as in the 16th century but true scientific data collection is essentially from the 20th century. Two recent and major publications have assembled the current knowledge on the diversity of phytoplankton (Bérard-Therriault, L., M. Poulin, and L. Bossé. 1999) and invertebrates (Brunel, P., L. Bossé, and G. Lamarche. 1998) in the St. Lawrence marine ecosystem. These two groups of organisms are the largest in terms of number of species (499 species of phytoplankton, and 2214 species of invertebrates) and biomass. Unicellular or very small organisms have been poorly studied. Very little is known about planktonic and benthic bacteria diversity. Virus and pathogen bacteria have been studied on host species used in aquaculture (salmonids and mollusks essentially) and on marine mammals. Macrophytes such as algae have been well studied but there is no recent update on their species diversity in the St. Lawrence as a whole. Fishes and marine mammals are well documented; however, some rare or exotic species can sometimes be added to the known list of species.

DFO's information on the existence of data sets and associated metadata has been compiled recently under the National Science Data Inventory initiative. This inventory is a good starting point to build a Registry of marine biodiversity in Canada. DFO's research facilities in Mont-Joli and Moncton together report the existence of 472 series of data sets covering the St. Lawrence, 359 sets at Maurice-Lamontagne Institute (MLI) and 113 data sets at the Gulf Fisheries Center (GFC). Out of the 359 data sets in MLI, only 47 could be identified as having biodiversity study as a goal. The others are either multispecific or specific on abundance, distribution, ecology or biology of various species. These data sets are compiled as a metadata bank; the persons identified in the inventory keeping possession of the raw data themselves. Other institutions in Québec and Atlantic Canada also own series of data on marine biodiversity.

At least 51 different projects in Québec resulted in a series of samples still kept in collections of marine fauna from the St. Lawrence ecosystem. One of importance is the reference collection at Maurice-Lamontagne Institute. Other projects on various phyla, other than the reference collection, also contributed samples kept in collections at MLI. Furthermore, Professor Pierre Brunel in Montréal holds another significant collection of marine organisms from the St. Lawrence, mainly invertebrates. Many more specimens have been deposited at the Canadian Museum of Nature, from a large variety of phyla. Finally, marine mammal collections are essentially of tissues such as skin, fat, bones and teeth.

There is a large set of publications about marine biodiversity in the St. Lawrence;

however, an exhaustive review was beyond the scope of this overview. Nevertheless, two sources of information, the MLI publication list and the ASFA (Aquatic Science and Fisheries Abstract) were examined for such documentation.

In general, the information on biodiversity in the St. Lawrence is scattered and essentially available to experts knowing its existence and developing a contact with the owner or custodian of the data. Much of the information is not even compiled and verified in sets of metadata, or registries, neither on paper nor in electronic format. Current internet sites presenting information includes l'Observatoire du Saint-Laurent (DFO), Portrait of biodiversity in the St. Lawrence (Environment Canada) and Centre de données sur le patrimoine naturel du Québec (Nature Serve).

Notes
PowerPoint presentation is available at the Census of Marine Life Marine Biodiversity Workshop website (http://www.marinebiodiversity.ca/mbw/index.html).

REFERENCES

Bérard-Therriault, L., M. Poulin, and L. Bossé. 1999. Guide d'identification du phytoplancton marin de l'estuaire et du golfe du Saint-Laurent (incluant également certains protozoaires). National Research Council of Canada. Canadian Special Publication of Fisheries and Aquatic Sciences 128: 387 p.

Brunel, P., L. Bossé, and G. Lamarche. 1998. Catalogue des invertébrés marins de l'estuaire et du golfe du Saint-Laurent. National Research Council of Canada. Canadian Special Publication of Fisheries and Aquatic Sciences 126: 405 p.

Atlantic Marine Biodiversity Registry

Lou van Guelpen, Gerhard Pohle, Atlantic Reference Centre, Huntsman Marine Science Centre

The Atlantic Marine Biodiversity Registry is based on the Science Data Inventory (SDI), as other co-ordinators followed for their respective regions. Atlantic Reference Center biodiversity datasets were incorporated and blank inventory forms were sent to others who may have relevant biodiversity datasets: federal and provincial government agencies (including Maine Dept. of Marine Resources), museums, and universities. Response included 216 records from DFO Maritimes, one record from the provinces, 10 records from the museums and one record from an NGO. There are currently a total of 228 records and the Atlantic waters that are not included are Newfoundland and the Gulf of St. Lawrence. Data exist for diadromous species (salmon), physical oceanography, algae, benthos, plankton, other invertebrates, groundfish/cod/haddock, birds and mammals. The weaknesses of the registry include incomplete records, respondent non-participation due to time and interest, problems with query capabilities and the magnitude of the project. Its strength includes the registry's usefulness when completed, as it is a good summary of biodiversity datasets and a good indicator of gaps in knowledge. In the future, we hope to have a comprehensive registry that combines all regional registries.

Notes
PowerPoint presentation is available at the Census of Marine Life Marine Biodiversity Workshop website (http://www.marinebiodiversity.ca/mbw/index.html).

SESSION II: BREAK-OUT GROUP DISCUSSIONS

Four break-out groups were pre-determined for each of the three working sessions. For each session a number of questions were posed to each group to deliberate and prepare a report for plenary. Group composition, chairs and rapporteurs for each of the break-out groups is given in Appendix II.

Since the issue of patterns in biodiversity applies to all levels of biological organization, the groups were set up to have one group each discuss the following questions for Ecosystems, and populations, and two groups to discuss these questions at the species level.

- What are the most urgent research questions required to address the gaps in our understanding of patterns in ecosystems, species, and populations?
- From the available data on species do we have enough information to identify threatened species?
- From the available data do we have enough information to track changes in species, ecosystem, and population distribution and abundance in relation to human or environmental impacts

Break-out Group 1 – Jean-Marc Gagnon (Chair), Kirsten Querbach (Rapporteur)
Break-out Group 2 –Norm Sloan (Chair), Arran MacPherson (Rapporteur)
Break-out Group 3 – Paul Snelgrove (Chair), David Kulka (Rapporteur)
Break-out Group 4 – Mark Costello (Chair), Lea-Ann Henry (Rapporteur)

WHAT ARE THE MOST URGENT RESEARCH QUESTIONS REQUIRED TO ADDRESS THE GAPS IN OUR UNDERSTANDING OF PATTERNS IN SPECIES?

Species Level
First, we need to know the gaps
- No knowledge of species and their distributions below 200-300 m and Arctic – no keys and no expertise
- Little knowledge of microfauna
- Lack of trained taxonomists resulting in misidentifications and thus, inconsistency among data sets
- Access to correct and updated taxonomic literature again, resulting in misidentifications and inconsistency
- Problem of ‘science literacy’ – being able to track species over time in the literature; difficult due to inconsistent names
- List of taxonomic authorities

- Lack of good taxonomic keys
- Gaps tend to be in the same groups globally (i.e. the ones that are difficult to identify)
- Information on species distributions
- Time-series data

Research Questions?

- Make an inventory of all taxonomic groups using the most correct literature and put the literature together based on these groups – taxonomic monographs – person with taxonomic background
  - This will allow the most correct identifications and thus, the most confidence in species lists – without proper identifications through correct literature, species lists are less useful
- Basic taxonomy, baseline information on poorly represented groups
  - Need to set criteria (e.g. indicator spp.?)
  - Could have Year of 'Taxa X' as an initiative
- Need good time series
- Taxonomic consensus from many specialists – used in terrestrial realm – use old data and new data – need an organization to do this – experts constantly update it
- Extensive sampling
- Honest assessment of the difficulties of putting into place what the experts in the field believe is necessary in terms of taxonomic groups
- 'reality-check' – we need to understand how difficult it is to persuade people to do taxonomy or to get people interested – cannot be concerned about marine biota without good taxonomy
- Capture present knowledge before it is lost (taxonomic mentoring)
- More structure and communication among interested groups
  - What are species indicators that we can track over time to delineate the relative health of the ecosystem?
  - How well do we understand/know the biogeography of all marine species?
  - Can a new approach (e.g. remote sensing) be used to establish these biogeographic patterns?
  - What is the connection between biogeography and the physical environment that may determine the distribution of species?
  - What is the natural variation in abundance and distribution of all marine species or their representatives?
  - What processes control extinction? Are there reference points that may be used to generalize among species and track probability of extinction?
  - How do we assess the risk of and identify irreversible changes within species? Can reference points be generalized among species?
  - Is the umbrella species concept valid and applicable in marine environments? Can umbrella species be identified?
  - Can common threats to umbrella species be identified?
  - Are there functional similarities if umbrella species?
  - Is there a way to classify families of species and then make generalizations on life history and/or functionality?

- Can vulnerable species be identified and subsequently be used as indicators of ecosystem health?

Community Level

- Concordance
  - Although we are unable to enumerate all important assemblages, we must go about the process of enumeration in a systematic way. In evaluating assemblages, the focus should be on patterns that can be used as predictors.
  - Taxonomic disparities exist. For example, fish communities are easier to evaluate than for example benthic fauna, leaving gaps in our knowledge of certain ecosystems.
  - Determination of properties of the habitat are required in order to enhance our understanding of the associated assemblages. Links between habitat and communities are often deficient.
  - Axes of biodiversity are relatively easy to measure.
  - Bio-geographic boundaries are reasonably well understood, less so at diminishing scale.
  - Analytical tools such as Pattern Analysis Tools are deficient or unavailable

- Sampling
  - Require better scale analysis and habitat mapping tools (to define habitat discontinuities as they relate to assemblages)
  - Thorough enumeration of most marine assemblages is not possible. Access to some ecosystems and assemblages (Arctic and deep-sea for example) is particularly difficult leading to data deficiencies.
  - Defining range boundaries particularly for some groups such as benthos is difficult. However, habitat characteristics can be used to predict ecotones.
  - Geo-referencing in the data is often deficient
  - Taxonomic errors in the data can bias the results, require better taxonomic tools.

- Biodiversity Hot/Cold Spots (distinctive and enduring areas/assemblages as defined by their richness or unique qualities)
  - Poorly defined in the marine environment (where and why they exist)
  - Process of formation and sustainability is poorly understood (why are some habitats persistently richer than others)

- Temporal Variability
  - structure of assemblages can relate to historic events on a geological scale and usually information on the long term processes is deficient
  - genetic variation over time is poorly understood.

Population Level

- Some general comments
  - Populations highly relevant as they take into consideration processes that e.g., permit differentiation/segregation of species. Populations are also the most

suitable management units

Research questions?

- How do you *define* self-sustaining populations? Amount of genetic differentiation, so need more genetic work, particularly on those that regulate phenotypes.
- What are the factors structuring populations? Isolation mechanisms?
  - Are there physical structures/barriers that delimit putative populations? Can geographically explicit hypotheses (e.g. biomes, provinces, and seascapes)?
  - Range of taxa with contrasting life-history strategies.
- How do our activities (e.g., fishing) cause genetic changes i.e., loss of genetic diversity in stocks and subsequent changes in phenotypes and populations?

  - Conversely, how do management plans affect genotypes, phenotypes and populations?
- What are the past changes in populations? This will put the present into a context of longer-term change, and thus aid prediction of future change.
    - These studies will need access to archived specimens in museums and collections.

- Relevance of Archiving
  - Link sampling with archiving specimens to enhance inventories: includes putting more pressure on e.g., museums to use EtOH>>formalin, to store DNA, archive sampling data, and put pressures on e.g., journals to insist on depositing voucher specimens before acceptance of papers for publication.
  - A guide to best practice in specimen collection, preservation, archiving, and data management to provide best options for future specimen analysis, helping biodiversity research.
  - What are the consequences of aquaculture on genetic biodiversity e.g., escapees, benthos mortality, GMO?
  - What are the consequences of pollution on genetic biodiversity?

FROM THE AVAILABLE DATA ON SPECIES DO WE HAVE ENOUGH INFORMATION TO IDENTIFY THREATENED SPECIES?

Species Level

- On some fish, invertebrates, plants but not many others
- May not have the knowledge to say that some species are threatened b/c we do not know their distribution – e.g. corals –still err on the side of caution
- Instead, we might want to take the path of ‘likely threatened’, making inferences about the kinds of groups that would be threatened by certain kinds of anthropogenic practices – make generalizations about this
- A number of traits can make species more susceptible to extinction including slow maturation rate and low fecundity

Community Level

- In order to identify and rank threat one must understand both the source of the threats and the vulnerability of the assemblages.
- Information to predict vulnerability of assemblages (predicting those most at risk) is deficient.
- Geo-referenced definition of the threats (such as trawling) is often missing (usually cannot reconstruct human activities in sufficient detail to understand the nature of the threat). This results in a lack of reference sites (cannot differentiate affected and pristine areas)

Population Level

- NO
- COSEWIC provides framework to do so, but not well examined in marine species.

FROM THE AVAILABLE DATA, DO WE HAVE ENOUGH INFORMATION TO TRACK CHANGES IN SPP. IN RELATION TO HUMAN OR ENVIRONMENTAL IMPACTS?

Species Level

- There is most likely information but it may not be easily accessible – need to inventory it and make it available
- Yes there is available data for some fish species
  - Need more info on non-commercial species
- Need to have good data on natural variability – inventory this consistently as is done in Denmark
  - Do this through time series, as this is greatly lacking
  - However, need to address the 'something is/is not better than nothing' idea, as some believe that this is very difficult due to the variability in the data and the large amount of data required to provide confidence that the changes are captured
  - Could be useful just to get a feeling (e.g. Denmark)
- Train local people to take samples, preserve them and then experts come in and identify and train them to identify thereby setting the standards – establish time series – people own it and feel the commitment to keep it going – First Nations are interested in this
  - Initial investment in training etc.
  - Start with well-known groups for identification
  - Good for coastal settings but offshore is more challenging
  - Could get samples taken in deep water off research vessels and brought back for community members to identify
  - May have a problem with interest in marine invertebrates etc.
- Baseline information required for many species to be able to track human impacts
- Most data series start after human impacts have occurred and thus, we cannot make conclusions on what has changed from the 'pristine' state
- There are some species for which we have enough knowledge to make an attempt at

this including trawl surveys and continuous plankton recorder measurements

Community Level

- Long term data sets required to track changes (alterations in the environment) are deficient.
- Attributing causality to altered environments is difficult (often cannot definitively differentiate natural from human disturbance) because the nature of the human activity is often poorly defined in the marine environment.

Population Level

- NO
- We don’t even know what’s out there.
- Need permanent stations established and high quality taxonomy.
- Links with granting agencies? e.g., NSERC for intensive sampling in particular “observatories” / localities, coupled with habitat classifications e.g., SeaMap.
- Marine “Observatories”
    - An All Taxon Biodiversity Inventory (ATBI), e.g. BioICE in Iceland, BioFAR in Faroes, proposed BIOMARE ‘reference sites’ in Europe.
    - Future sampling and observation stratified by oceanographic features (e.g. seascapes) and make best use of sites with long-term environmental data. Such sites would provide a vertical approach to the study of populations but required a complementary horizontal approach in which many putative populations of a species are sampled over a wide geographic scale.

SUMMARY COMMENTS ON DISCUSSIONS FOR SESSION II

Inventory

Compilation of existing information (Data Registries) – all levels of biological classification.

The experts recognized that there exists a significant volume of data and samples, which describes aspects of biodiversity for each of Canada’s oceans. Data registries based on the DFO National Science Data Inventory (NSDI) were developed for each of the Pacific, Arctic, and Atlantic oceans and reviewed at the workshop. These registries list the characteristics of all the data sets available for each ocean. The registries list information held by government (provincial and federal), universities, NGOs and other stakeholders.

The developers of the regional registries used the NSDI inventories as a starting point and then augmented them with additional regional data not listed in the original. They also modified the structure of the database to improve searchability. The regional data coordinators considered that the registries, as presented at the workshop, were not yet exhaustive listings of all available data but that they captured a significant portion of what is available. They were therefore cautious in using the registries to identify gaps in knowledge. They considered that with dedicated effort the regional inventories could be expanded and improved. In particular they observed that;

1) There are additional data sets and sample collections presently not listed in the registries. These additional sources of information range from data collected by individual scientists to institutional data sets, and from small-scale sample collections from restricted geographic areas and taxa to more comprehensive collections covering broad geographic areas and phylogenetic scope.
2) There are data sets that are not part of the institutional infrastructure, in that they were collected by individuals and have been used by them. Many of these individual researchers are now reaching retirement age and their data sets will cease to be available unless a co-ordinated effort is made to document and rescue them
3) The original format of the National Science Data Inventory data sets required a number of modifications particularly relating to the inclusion of key words (which allows for searching the data base).
4) Data collection, storage, and retrieval methods were not consistent within regions (or between) and this included the taxonomic classification schemes used. It was agreed that for purposes of the present regional registries that we would adopt FISHBASE (http://www.fishbase.org) and SPECIES 2000 (http://www.sp2000.org) as standard taxonomic references.
5) There is presently no national policy on data sharing (both between Federal Departments and between NGO, Universities and governments). It is essential to develop such a policy if marine biodiversity information is to be widely available and accessible to all users.
6) There is a lack of dedicated personnel assigned to the maintenance and development of regional biodiversity data.
7) There is a need to collate the regional data sets into a national data set.
8) It is important to identify the products that are to be derived from the marine biodiversity data sets in that this will influence its scope and design.
9) The marine biodiversity database must be dynamic. Its efficacy in tracking changes in marine biodiversity in addition to providing baseline data, is dependent upon establishing a long-term protocol for maintenance of the data base, including especially, regular updates.

Results of Discussion Groups

For each of the major workshop sessions a number of discussion groups consisting of presenters and gathered experts were asked to deliberate responses to a set of questions relevant to the key elements of the session. In the case of the inventory session the questions were asked for each level of biological organization, that is one group was asked to deliberate the questions relative to the community level of organization, another at the species level, and another at the population level. The questions that each group addressed were as follow;

1. What are the most urgent research questions required to address the gaps in our understanding of patterns in communities, species, and populations?

2. From the available data on species do we have enough information to identify threatened species, communities, populations?

3. From the available data do we have enough information to track changes in species, ecosystem, and population distribution and abundance in relation to human or environmental impacts

Communities

Most urgent research question to fill knowledge gaps

1. Because there are gaps in the inventories of marine organisms and some groups are better understood than others (e.g. fish communities are easier to evaluate than benthic fauna) our knowledge of most ecosystems will be incomplete. It was also identified that the Arctic Ocean is particularly poorly understood in terms of its marine assemblages. Filling these knowledge gaps requires completion of the overall marine biodiversity inventory at a species level and in particular improvement of the inventory of the Arctic Ocean.
2. Focus on the elucidation of patterns that can be used as predictors of communities or assemblages. This requires knowledge of the properties of habitats and of the links between habitat and communities. Although this is also dependent on completion of the inventory phase, these habitat community associations can be developed for at least the known communities
3. The development of pattern analysis tools is essential to progress on 1 and 2 above
4. It is important to develop habitat-mapping tools that can be used to define habitat discontinuities especially as these relate to benthic assemblages (e.g. multi-beam mapping). Such mapping should also be accompanied by faunal sampling to determine biotic boundaries and association. This sampling must use strict geo-referencing and standard taxonomy.
5. Identification of marine biodiversity cold and hot spots. These are poorly defined in the marine environment (where) and the processes of formation and maintenance (why) are poorly understood. Why are some habitats persistently richer than others?

Ability to identify threatened assemblages

1. Our knowledge on the vulnerability of assemblages to threats, and the distribution (spatial and temporal) of these threats are both deficient. Although we have some knowledge of the vulnerability of particular communities to certain threats (e.g. corals and trawling) we do not have a general knowledge.
2. We require marine biodiversity reference sites to determine the impacts of human activities on non-reference sites.

Ability to track changes in assemblages in relation to human and environmental impacts

1. Although some long-term data sets are available from a number of monitoring initiatives (e.g. east coast trawl surveys) these focus only on a subset of marine biodiversity.
2. Separating the effects of human impacts from natural variability or from long-term environmental changes is difficult.
3. Reference sites that are protected from human impacts are required to differentiate human from natural impacts in non-discovery corridors

Species

Most urgent research question to fill knowledge gaps

1. It is essential to make an inventory of all known taxonomic groups using the most up to date taxonomic literature for each group. Such a "verified" species list will then serve as a standard for further marine biodiversity sampling initiatives.
2. The baseline taxonomic descriptions of poorly understood groups must be improved – perhaps by encouraging the "year of taxa X" approach. It is equally important to get an informed opinion from current experts as to time and resources that would be required to generate an acceptable level of taxonomic description for the currently poorly understood groups
3. There is a general lack of skilled marine taxonomists, up to date taxonomic literature (it is no longer in vogue), and taxonomic keys. This is resulting in misidentifications, inconsistent naming, and an inability to track species over time through the literature.
4. There is a general lack of information on species distribution and time series data to track species abundance. The limits of natural variability in these parameters are not well known for most species. It is therefore essential to start new time series and continue (and build on) the ones that are already in place.
5. There is a need to improve our understanding of the relationship between species distribution and the distribution of physical habitats, as the latter, which is generally easier to measure and more amenable to remote or automated sensing, may become useful in predicting species distributions.
6. We do not have a good understanding of the processes that control extinction. Are there indicators and reference points for these indicators that may allow us to generalize about the "extinction probability" of one species relative to another? Can we classify groups of organisms on the basis of life-history etc. to make generalizations about their vulnerability?
7. Is the concept of umbrella species applicable in marine environments?
8. Knowledge of marine biodiversity in waters deeper than 200-300 m is poor.
9. Knowledge of Arctic marine biodiversity is particularly poor. There are few if any taxonomic experts and few if any taxonomic keys
10. Knowledge on the diversity of marine microfauna (including protists) is particularly and generally lacking.
11. There is a need for increased structure and communication between groups carrying out taxonomic work on marine biodiversity.

Ability to identify threatened species

1. It was considered that we have adequate information for some fish, a few macroinvertebrates, and some plants but that in general we lack the information to identify threatened species. This is the result of having little or no information on their present or historical distribution, abundance, or natural variability in these parameters. We are usually unable to describe the "pristine state" of an ecosystem because time series began after humans began using of affecting the systems. There is a need to establish discovery corridors where human impacts have been considered minimal, to allow for comparisons to more heavily used areas and to give guidance to rebuilding strategies.
2. We are in a position to make inferences about the kinds of marine groups that would "likely be threatened" by particular human activities. This kind of forecasting would be consistent with the overall precautionary approach.
3. We are in a position to identify species traits that may make them more vulnerable (slow maturation, low fecundity etc).

Ability to track changes in species in relation to human and environmental impacts

1. Although there is information to judge changes in species abundance and distribution for some groups (most notably fishes and then mainly for commercially harvested species) this is lacking for many other groups. There is a need to broaden the monitoring to non-commercial groups and species
2. There is a need to develop a better understanding of the natural variability of distribution and abundance of species. This generally requires long time-series and drawing conclusions from short time series can be misleading
3. Time series may be initiated using local people to collect samples on a regular schedule. This requires initial investment in training and setting standards but can result in time-series that are maintained because of "local ownership". These are generally only useful in coastal environments and are not as applicable to deep sea or open ocean systems

Populations

Most urgent research question to fill knowledge gaps

1. There is no comprehensive estimate of the amount of genetic variation in current populations of marine organisms, although there is some information for a limited number of groups (mainly commercially exploited)
2. There is currently no agreed upon definition of a self-sustaining population at the genetic level. The degree of genetic variation between population, especially of functional genetic difference remains an open and relevant question
3. The factors that structure meta-populations are not well understood (relative importance of physical barriers versus life-history traits).

4. We have little understanding how activities such as fishing cause genetic changes (i.e. loss of genetic diversity) resulting in phenotypic changes in harvested or impacted species.
5. We have little understanding of historical genetic changes in populations against which to judge current changes. Some indication of these changes may be gained from the examination of archived specimens
6. There is a need to link current sampling for genetic diversity with archiving to enhance inventories and to provide reference points. In particular, museums should be encouraged to store DNA containing samples in ethanol as opposed to formalin and journals should be encouraged to link publications with the requirement to archive specimens.
7. A guide to best practices in specimen collection, preservation, archiving and data management is needed to provide the best options for future analysis, and the ability to track changes in genetic diversity.
8. What are the consequences of aquaculture on genetic biodiversity, especially where this may involve genetically modified organisms.
9. What are the consequences of pollution on genetic biodiversity?

Ability to identify threatened populations

1. We are currently not in a position to identify threatened populations on the basis of their genetic make-up.
2. We should encourage the concept of focal or discovery corridors ("observatories") that would be designated for intensive sampling and classification of biota, genetic diversity, and coupled with habitat classification. These observatories or marine biodiversity discovery corridors should be areas with long-term environmental data. They would be ideal for vertical studies of population genetics (over time) but would require a complementary horizontal approach in which many putative populations of a species are sampled over a wide geographic scale.

Ability to track changes in populations in relation to human and environmental impacts

1. We are currently not in a position to track changes in genetic biodiversity.

SESSION III: PROCESSES

Biodiversity and Complex Hydrography

Connie Lovejoy, Departement de Biologie et Centre d'etudes Nordiques, Laval University

Hutchinson 1961 first stated the paradox of the plankton as the co-existence of numerous species in a homogenous appearing environment. This diversity of plankton is contrary to the Hardin (1960) competitive exclusion principle which would predict that the number of coexisting species cannot be larger than the number *k* of limiting resources.

The shear numbers of species or taxa that are typically found in any litre of water, attest to biodiversity of plankton. The North Water Polynya (NOW) is biologically diverse with >270 identifiable protist taxa seen from April through July 1998. There were phototrophic, mixotrophic and heterotrophic protists present, with representatives from most phylogenetic groups. In the 1960s when Hutchinson postulated the paradox of the plankton, deep phylogenetic and trophic diversity of pelagic eukaryotes was under appreciated, and it follows that the number *k* of limiting resources was also underestimated. In addition, the homogeneity of aquatic habitats may also be overestimated. The NOW polynya is extremely advective with two main "water assemblies" interleaving. The interleaving in the upper water column was evident from temperature-salinity diagrams but not from depth-density diagrams. Total water column protist biomass and production was greater over interleaved regions and would have provided available food to upper trophic levels and ultimately the rich megafauna in the NOW. Complex hydrographic structures are common in many marine regions and may be responsible for greater biodiversity and community production in these areas.

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How does Fishing change Marine Biodiversity?

Jake Rice, Department of Fisheries and Oceans, Newfoundland Region

Fisheries have many effects on marine biodiversity. Some are direct; fisheries affect relative abundance of species in the ecosystem through their removals, whether species targeted directly by harvesting or species killed incidentally by harvesting other species. Mobile bottom gears also affect relative abundance of bottom-dwelling species directly, again through mortality inflicted by impacts of the gears. The scale of these direct impacts depends on the fishing mortality inflicted on the target species, the selectivity of the gears, the intensity and spatial distribution of effort, and many biological characteristics of the species impacted. Even if the only impacts of fisheries were these direct ones, fisheries would be a major cause of change in biodiversity. Fisheries commonly remove 20-25% of the target species mature biomass annually, and exploitation rates have often exceeded the 20-25% rate. The percent biomass of species taken as bycatch has rarely been estimated accurately, but for vulnerable species is sometimes high.

Fisheries have many indirect effects on biodiversity as well. Selective harvesting (by species and by size) necessarily means fisheries change the relative species and size composition of communities. Modelers have great fun simulating how trophic responses (both predation and competition) to the direct removals by fisheries could cause possible lasting changes to biodiversity of exploited ecosystems. As mobile (and some static) gears affect benthic species directly through physical impacts, they also alter substrate and habitat features. Because rocks don't heal, and species create biogenic structures slowly, these changes can be much closer to permanent than changes to relative species composition due to direct mortality.

Other higher order effects can arise through discards and offal, which become a new food supply that favours some types of consumers over others. Sediment mixing by gears can change the nutrient dynamics at the bottom of the food chain, and again modelers can predict many possible consequences of different patterns of nutrient availability on biodiversity.

The ICES Working Group on Ecosystem Effects of Fishing has addressed all these factors in detail, in response to requests for advice from the EU and OSPAR. Those analyses summarized the magnitudes of various ways that fisheries affect biodiversity, and the strength of documentation that the effects really do occur at scales large enough to justify management actions to mitigate. Although ecologists remain interested in higher-order effects of fishing such as changes to competition regimes, WGECO concluded that weight of scientific evidence indicated that if first order effects of fishing (catches, bycatches, and habitat impacts) were kept sustainable, then higher-order effects were unlike to be at serious risk from fishing. Mitigating recommendations included reduced fishing, preventing expansion of gear use/licenses, enhanced partnerships with conservation groups, and improved impact detection.

Notes
PowerPoint presentation is available at the Census of Marine Life Marine Biodiversity Workshop website (http://www.marinebiodiversity.ca/mbw/index.html)

Species area relationships or does size really matter?

Kenneth T. Frank and Nancy L. Shackell, Department of Fisheries and Oceans, Bedford Institute of Oceanography

Biodiversity theories have largely been developed and applied in relation to terrestrial systems. Such theory may not apply to marine systems because the scales of oceanic systems are too large, ecological theory may not be applicable to marine ecosystems and the belief that marine systems lack the necessary data to test biogeograhic theory. It has been known empirically for over a century that species diversity is predictably related to the area of the habitat – i.e. the species-area relationship or SAR. This relationship holds for many species groups in both island fauna and insular habitats on mainlands. It was once a widely held view the SAR was an outcome of the equilibrium theory of island biogeography, however now it is realized that habitat diversity, resource concentration and sampling phenomena are also important. SAR has also been used in conservation planning and to predict species losses from habitat reduction. We evaluated the SAR for finfish resident on the offshore banks on the Scotian Shelf, arguing that offshore banks can be consider as "islands" or insular habitats. A significant relationship was found between bank area and species richness supporting one of the most common observations in terrestrial and freshwater ecology. The slope of the SAR was low implying high connectivity, suggesting the complex of banks may conform to a meta-population structure. In addition, population sizes were, on average, higher on larger banks for both common and uncommon species, with the expectation that the probability of extinction is lower on larger banks. We also examined some potential applications of SAR to marine conservation, notably the prediction of species loss due to habitat reduction and the single large/several small (SLOSS) debate. Species richness on a few larger banks was similar to that on a collection of smaller banks with comparable combined area. If the conservation objective were to maintain high species richness then larger banks should be protected as sources for maintaining extinction prone populations on smaller banks. What have we learned from this insular biographic approach to marine fish communities? Size does matter – larger banks have higher resources, lower extinction rates, a higher complement of rare species that may act as multi-species sources areas that represent key areas for system stability.

What is the basic unit of Conservation?

Paul Bentzen, DFO Chair, Fisheries Resource Conservation genetics, Department of Biology, Dalhousie University

The term 'Evolutionarily Significant Unit' (ESU) was coined by Ryder in 1986 to denote important units of evolutionary diversity within officially recognized species. Since then there has been widespread support for the concept of ESUs, but much controversy about how to define them, or what criteria to use to recognize them. Two widely quoted operational definitions of the ESU are those promoted by Waples and the National Marine Fisheries Service (NMFS) and Moritz. NMFS defines an ESU as a group of populations that is (1) substantially reproductively isolated from other populations and (2) represents and important component of the evolutionary legacy of the species. The Moritz criteria for an ESU are that it must exhibit reciprocal monophyly for mitochondrial DNA (mtDNA) relative to another lineage within the species, and must show significant differences in allele frequencies at nuclear loci. Although both views of ESUs rely heavily on molecular genetic data, and both directly or indirectly stipulate reproductive isolation, the NMFS definition also relies on information pertaining to ecology and local adaptation, whereas the Moritz definition is strictly based on molecular data. In general, the Moritz requirement for reciprocal monophyly implies reproductive isolation that is more complete, and of much longer standing than that needed for the NMFS definition. A number of other definitions of ESUs have been proposed, but these all tend to reflect variations on the ecological/adaptive criteria emphasized by NMFS, and phylogenetic criteria as exemplified by Moritz.

I employ a number of examples to argue that definitions of ESUs such as Moritz's that require significant phylogenetic divergence are generally too stringent, and inappropriate for marine and aquatic species in Canadian latitudes, for two general reasons: (1) Because most species occur in formerly glaciated areas and effective population sizes have often been large, there may not have been enough time for even fully isolated and ecologically divergent forms to have achieved reciprocal monophyly with respect to mtDNA. (2) An increasing body of evidence suggests that measures of genetic divergence obtained with neutral genetic markers often under-estimate the genetic divergence among populations in adaptive traits, when neutral genetic divergence is low. Therefore, definitions of ESU such as that used by NMFS that employ both molecular genetic data and information pertaining to local adaptations are in general most appropriate for the identification of important units of diversity within the marine realm. However, since the Moritz definition is generally more stringent, groups of populations that qualify as an ESU *sensu* Moritz will usually also qualify as an ESU according to NMFS. This is important, because in some cases, molecular genetic data may be the only data available; in these cases if the Moritz criteria are met, the biological units in question should be regarded as ESUs and receive protection commensurate with that status.

Notes
PowerPoint presentation is available at the Census of Marine Life Marine Biodiversity Workshop website (http://www.marinebiodiversity.ca/mbw/index.html).

Microgenomics and Life's Diversity
Paul Hebert, Canada Research Chair, Molecular Biodiversity, Department of Zoology, University of Guelph

Biodiversity studies, whether they focus on a community or a species, depend critically upon a detailed understanding of taxon diversity. Yet the inventory of life is far from complete; just 13% of extant species have been described and the task of species diagnosis lies with a dwindling band of taxonomists. These facts make clear the need for new approaches, which will both expedite initial species descriptions and their subsequent recognition. It is now apparent that the answer lies in building DNA-based identification systems. In this presentation, I review recent results which establish the feasibility of a DNA barcoding system for animals-at-large. Once established, this system will enable both the automated diagnosis of new species and the identification of previously encountered taxa. Aside from providing a robust, cost-effective and accessible taxonomic platform, the move to DNA-based identifications promises a newly detailed understanding of the evolutionary affinities of life.

SESSION III – BREAK-OUT GROUP DISCUSSIONS

Contrary to the approach of the first session where each of the groups was asked to deliberate a set of questions at different levels of biological organization, the approach to this session was to have all groups deliberate the following series of questions at all levels of biological organization.

- What are the most urgent research questions required to address the gaps in our understanding of processes that maintain or alter the diversity of marine ecosystems?
- From the available knowledge do we have enough information to define the primary processes that maintain marine biodiversity
- From the available knowledge do we have enough information to define the primary processes that currently alter marine biodiversity

Break-out group 1 – John Roff (Chair), Glen Jamieson (Rapporteur)
Break-out group 2 – Paul Bentzen (Chair), Bob DeWreede (Rapporteur)

Break-out group 3 – Julian Dodson (Chair), Jim Boutillier (Rapporteur)

WHAT ARE THE RESEARCH QUESTIONS REQUIRED TO ADDRESS THE GAPS IN OUR UNDERSTANDING OF THE PROCESSES THAT MAINTAIN OR ALTER BIODIVERSITY?

- Formulation of appropriate Models (relate heterogeneity to biodiversity)
- coastal zone information is missing
- Arctic information is very poor (Ice/water interface adds and additional component)
- We don't understand the atmospheric linkage
- Does heterogeneity of physical environment affect biodiversity?
- What is the benthic-pelagic coupling process in deep water?
- Data integration including oceanographic and biological
- Need an historical record from core sampling
- Understanding human impacts
- Information needed on ice-covered areas
- Basic biological data
- Information on species abundance and distribution
- Need information on ESU for most species
- Need information on trophic interactions
- Are all phytoplankton the same? phytoplankton linkages (utilization) to secondary productivity
- Can we identify areas that are or are near pristine? Baseline areas, areas of probable importance?
- What determines the biodiversity in the pristine environment? We know the pattern, but we don't necessarily understand why it's there.
- What are the criteria to use to define the areas of the ocean that we want to set aside that will become the reference sites that we will use to monitor the state of marine biodiversity?
- What is the natural level of disturbance and variation in a system?
- Effect of climate on biodiversity
- Impact of introduced species.
- Better understanding of natural history of species.
- Reference points – limits and reference points (when does a species enter the potential extinction zone?).
- Test the extent to which genetic tools are useful in understanding and conserving biodiversity.
- Research to identify irreplaceable units below the species level.
- Impact of fishing on biodiversity above and below the species level
- Biogeographic boundaries -do we study the processes or define the bio-geographic processes? Is the pelagic environment more variable then the benthic?
- What happens when you stop fishing? Comparisons between disturbed verses non-disturbed influences. Shallow water structure for some species but not the same structure as in the deep water.

- What causes a species to take off? One mans invasion is another mans colonization.
- Primary production do we have consistent programs to collect the information that would describe the processes.
- Identification of critical habitats at all life stages?
- Are we consistently studying bacterial food webs?
- Need to understand the pattern by which habitat structure affects biodiversity and the processes responsible for the pattern.
- Need for good biodiversity inventories and good pattern identification as precursor to selecting most informative and cost-effective monitoring.
- Collect and preserve Ecological time capsules.
- Building up the Null Hypotheses to be tested with greater care and rigor – good Neutral Model analysis and good formulation of hypotheses in general.
- Explore the Roff conjecture that heterogeneity/diversity of the things which are well measured (groundfish, habitats) will be will be informative surrogates for things much less poorly quantified.
- Conduct focused on research on areas which have comparatively low disturbance regimes (haddock closure areas)
- Evaluate the effectiveness of alternative management approaches intended to conserve and restore biodiversity.
- Evaluate the information content of metrics of biodiversity – to what are they sensitive and to what are they robust.
- Evaluate the degree to which the demersal and pelagic ecosystems are structured by size-based rather than species-based processes.
- Explore and act on how to determine the IMPORTANCE of biodiversity – why care if it is only functional redundancy.
- Explore the potential value of uncommon species as something that can indicate the state and disturbance to biodiversity

FROM THE AVAILABLE KNOWLEDGE, DO WE HAVE ENOUGH INFORMATION TO DEFINE THE PRIMARY PROCESSES AVAILABLE TO MAINTAIN BIODIVERSITY.

- We do know what the shortlist is, and we can make a pretty good set of *a priori* hypotheses about which ones are important where in the world. It will vary with latitude, nearshore to offshore, major oceanographic features, history of human activities, but knowing those large-scale things we can even rank the items on the short-list. Then site-specific research can be focused and efficient, and resolve the factors for that specific site to perhaps the nearest 10%.
- Unless MPAs are established to reestablish the pristine environment (reference sites, control sites, areas of conservation to sustain elements of the natural system) in areas at least of perceived biodiversity and representative importance, there is not too much point in further describing processes, which are basically of a perturbed system.
- Abiotic processes include**:**
    - Gyres

  - Upwelling: nutrient input
  - Tidal exposure
  - Tidal circulation
  - Disturbance
  - Evolution
  - Speciation
  - Global warming
  - Migrations
  - Dispersal/retention
  - Recruitment
  - Invasions
  - Extinctions
  - Heterogeneity of habitat
  - Fragmentation of habitat
  - Substratum stability
  - Advection
  - Hydrography
  - Currents

- Biotic Processes include:
  - Predation
  - Competition
  - Feeding
  - Behaviours
  - Reproductive strategy
  - Growth
  - Survivorship
  - Food web structure
  - Genetic drift and natural selection
  - High level of species interactions
  - Species interactions

Interactions between the two include:
- Benthic – pelagic coupling

FROM THE AVAILABLE INFORMATION, DO WE HAVE ENOUGH INFORMATION TO DEFINE THE PRIMARY PROCESSES THAT ALTER BIODIVERSITY?

- We know what the processes are, we understand them in physical terms, but we don't understand how they influence biodiversity.
  - Fishing: recruitment, community structure.
  - Modified habitat variability: pollution, water and nutrient flows of the land,

pollution inputs (including oil spills).

- Competition for space.
- Fishing effects (gear and species fished); fishing both reduces and alters diversity within a species, and their life history schedules. It also alters these variables in non-target species (injuries; changes in lifeform; changes in food resources and overall food-web changes).
- Habitat degradation.
- Invasive species.
- Eutrophication
- Contaminants.
- Cumulative impacts (e.g. timing of different events).
- Effects of fisheries and culture on habitat structure biodiversity

SUMMARY COMMENTS ON DISCUSSIONS FOR SESSION III

As was the case in the Inventory and Monitoring sections, workshop participants were asked to debate a pre-determined series of questions relating to monitoring of biodiversity. The groups were again asked to deliberate each of the questions for each of the three levels of biological organization. The responses to the first question have been incorporated in the previous section.

1. What are the most urgent research questions required to address the gaps in our understanding of processes that maintain or alter the diversity of marine ecosystems?
2. From the available knowledge do we have enough information to define the primary processes that maintain marine biodiversity
3. From the available knowledge do we have enough information to define the primary processes that currently alter marine biodiversity

Most urgent research question to fill knowledge gaps

1. Unless marine protected areas are established to re-establish the “pristine” environment (marine biodiversity reference sites) in both unique and representative areas (see above) we will only be able to look at processes in more or less disturbed systems. We need to identify areas that are near pristine. The areas established must preserve both the diversity and the landscape and environmental conditions that support the diversity.
2. We need to better articulate the importance of marine biodiversity. Why is it important if all of this diversity merely represents functional redundancy? How do we articulate the inherent value of marine biodiversity? This is a difficult task in the present economic bottom line driven climate. It is essential that we establish clearly the link between the long-term survival and well being of the human species (dependent on clean air and water, nourishment, and) and the survival of a diverse ocean. We need to better articulate that it is the diversity of marine organisms that is responsible for the processes of solar energy capture, the recycling and creation of air, and the purification of water.

3. We need to determine the “natural level” of variation in biodiversity especially in relation to the variation in climatic and ambient environmental conditions. The development of historical reference points (documentation, data mining, core sampling of sediments), and the establishment of discovery corridors are essential to this task.
4. We need to better define the relationships of marine biodiversity and community types to habitat (biogeochemical processes). Basic information such as good models of bottom topography for all areas and the associated fauna that inhabit these seascapes is essential. Although collecting this information begs the question of the underlying processes that result in the observed relationships, determining these patterns will aid in the rational establishments of marine discovery corridors that will then allow for more detailed analyses of underlying processes.
5. We need to develop reference points e.g. when does a particular species, community, or population enter a danger zone for extinction or a potentially irreversible change in trophic status. The precautionary principle should be applied during the development of such reference points
6. We need to develop estimates of the rates of dispersion of species and susceptible life history stages. If species are structured as meta-populations it is essential to know the rates at which the meta-populations exchange individuals or reproductive products. This may be one of the essential variables in determining the distances between marine biodiversity reference sites.
7. We need to better articulate experiments that derive from modern theories of biodiversity control (i.e Hubbell, Huston). The experiments should be designed such that the results become proof of principal and aid in the development and implementation of rational management actions. Some of the tests would be the validity of the species area relationship, the impact of habitat heterogeneity and variability on marine biodiversity, and the contribution of dispersal rates to the maintenance of meta-population structure.
8. We need to better define and be able to identify irreplaceable units at the population level.
9. We need to understand and describe the human impacts on biodiversity in general. Our understanding of these impacts, even in the best-studied examples (impacts of fisheries) remains rudimentary (we have some indications of impacts at the species level but not at the population or higher taxonomic levels). We need to better determine the impacts on marine biodiversity of changes in trophic structure that can results from either direct human activities or through the impact of introduced species.
10. We need to explore more fully the efficacy of indicator species to give us information about the state of marine ecosystems in general and marine biodiversity specifically.

Do we have enough information to define the primary processes that maintain marine biodiversity?

1 Although we recognize that certain conditions are associated with hotspots of marine biodiversity (nutrient sources, and structurally complex habitats), and we recognize a

suite of parameters that are associated with high or low diversity (habitat grain size and bottom rugosity, nutrient transfer – including benthic pelagic coupling, water column physics, disturbance regime – both environmental forcing, and biotic disturbance on a wide array of time scales) we do not understand the processes that govern the patterns in a general sense. Another shortcoming is that most of the information on patterns is derived from observations of more or less impacted systems. Our initial and rudimentary pattern recognition may be useful in locating marine biodiversity discovery corridors. Understanding the processes could take place once these have been established.

Do we have enough information to define the primary processes that currently alter marine biodiversity?

1. As was the case for the primary controllers we have an understanding of the factors that alter biodiversity but no general understanding of the process by which they control it.
2. The best understood human impacts are those of fisheries that have been shown to effect target species, non-target species, and communities. The documentation on the nature and extent of these impacts is often weak. It was also concluded that the biggest effects are initial (i.e. when the fishery is first started) and when there is severe overfishing. We need to improve our ability to detect and measure impacts of and the consequences of remedial measures through improved monitoring programs (see monitoring section)

Modeling and Hypothesis Testing regarding marine biodiversity processes

The experts reviewed evidence that indicates the applicability of some terrestrial based approaches to conservation in marine systems. It was shown that the fundamental characters of pelagic marine ecosystems are determined by a relatively small number of physical factors (irradiance and wind mixing of the upper water column) much as terrestrial biomes are determined by soil types. For benthic marine ecosystems the workshop was presented a review which defined habitat heterogeneity, using principles of landscape ecology, as the basis for community diversity. This concept of ecodiversity integrates single species and meta-population distributions by basing these patterns on the distribution of habitat varieties. It was also shown that species area relationships apply to marine fishes and that the insular biogeographic theory is an appropriate construct for evaluating and interpreting patterns of marine fishes.

Marine biodiversity reference areas (see below) will be essential for testing hypotheses derived from competing theories for the control of biodiversity (e.g. Huston vs Hubbell) in that they represent area where natural (as opposed to anthropogenic) processes dominate the presence or absence of species and the structure and functioning of populations and communities.

Marine Biodiversity Discovery Corridors (Discovery corridors)

A recurrent theme in the discussions during the workshop was that of marine biodiversity observatories or marine biodiversity discovery corridors. The World Wildlife Fund is urging a two pronged approach involving the establishment of a network of marine protected areas, coupled with sustainable management practices elsewhere. The protected areas would prohibit major industrial disturbance of the habitats. DFO itself is developing criteria and locations for the establishment of marine protected areas. The location of MPA and the amount of protection they will be afforded from human activities are the difficult decisions that are now being deliberated. The WWF and other NGOs are urging that this process be sped up and that these areas be protected from industrial use.

During our deliberations the concept of marine biodiversity discovery corridors was discussed as essential to or greatly facilitating the attainment of a number of the objectives identified by the workshop. It should be made clear at the outset that marine biodiversity reference sites were defined as ocean areas protected from human impacts to the greatest possible degree. They would be areas where human activities would be severely restricted or eliminated and would be chosen on the basis of either their representativeness of a seascape or of being a unique seascape. The attributes and benefits of marine biodiversity reference sites are that they;

1. Could be areas where human impacts on habitat or biota are severely restricted or eliminated
2. Could be areas that are either representative of a particular seascape or encompass a unique seascape and will protect and conserve these seascapes.
3. Should be of sufficient size to encompass a significant proportion of the seascape it represents, or all of a unique seascape.
4. Should be established with the realization that they must fulfill the requirements of both resident and migratory species. Although it is not necessary to have a single reference area for both it is essential that both needs are addressed
5. Should be put in place permanently.
6. Should be sampled (for all taxa) at a predetermined frequency to provide longitudinal data on changes in distribution and abundance of biota and environmental conditions. These observations will provide “ecological time-capsules” against which future conditions can be compared.
7. Will be essential as controls for marine biodiversity monitoring programs designed to evaluate impacts of human activities relative to changes resulting from natural variability.
8. Will greatly facilitate the development of a complete inventory of Canada’s marine biodiversity by acting as focal areas for intensive taxonomic evaluations. Since their locations will be chosen as representative or unique their combined taxonomic evaluations should represent a complete inventory of all Canadian seascapes. For greatest efficiency they should be associated with the institutional support required for adequate sampling of all taxa, processing of samples, archiving of samples, data storage, data analysis, and dissemination of analytical products.

9. Will greatly facilitate research to elucidate the processes that control or alter marine biodiversity. These areas can provide living observatories within which we can study process that maintain diversity at all biological levels of organization. By comparing the structure and function inside the discovery corridors to areas affected by human activities it will provide greater insight into the specific mechanisms through which human activities effect marine biodiversity.

Marine biodiversity discovery corridors fulfill a number of needs identified in the workshop both for science and within the broader community. Marine biodiversity discovery corridors would be synonymous with marine protected areas only of the latter afford near complete protection from human impacts. In addition to the characteristics and benefits outlined above a network of well-chosen reference sites could provide an overall framework for marine biodiversity related research presently conducted. By choosing areas that are representative, results of research could be more readily generalized or applied to the areas represented. Focussing research in these areas may also facilitate the development or augmentation of the requisite institutional and financial support required. Funding agencies should look favorable on research that is conducted in areas where it becomes part of an overall goal oriented approach. Institutional support would likewise be facilitated by

SESSION IV: VISUALIZATION, METRICS, MONITORING, AND IMPLEMENTATION

The Virtual Data Centre

Bob Branton and Jerry Black, Department of Fisheries and Oceans, Bedford Institute of Oceanography

The Marine/Invertebrate Fish Divisions Virtual Data Centre (VDC) website is an in-house research tool for fisheries science staff at the Bedford Institute of Oceanography (BIO). Quality controlled data are generally available to end-users via this system within hours of collection. Sources include: catch statistics, logbooks, port samples, at-sea samples, research surveys, tagging and museum specimens. The system facilitates the analysis and exchange of scientific data and information between numerous research projects underway at BIO by providing a suite of tools including: data dictionary, SQL query library, map server and statistics server. Users easily conduct ad-hoc data extractions as well as produce a wide range of publication ready products. Although direct public access to the VDC is not permitted, similarly styled products have been developed for the Gulf of Maine Biogeographic Information System (GMBIS) website. Products from that site include electronic atlases of Canada and United States bottom trawl surveys and the Atlantic Reference Centre specimen collection as well as a facilities for users to create maps from their own data. This site can be viewed at: http://cephbase.biology.dal.ca/gmbis/.

Notes

PowerPoint presentation is available at the Census of Marine Life Marine Biodiversity

Workshop website (http://www.marinebiodiversity.ca/mbw/index.html).

The Gulf of Maine Biogeographical Information System (GMBIS) Project

Dale Kiefer and Vardis Tsontos
University of Southern California

Central to the development of an inventory of marine life and improved conceptual understanding of the mechanisms that dynamically shape species distribution patterns is the implementation of strategies aimed at enhancing assimilation and access to existing biogeographical information. Using the Internet as a medium, the Gulf of Maine Biogeographic Information System (GMBIS) project provides a framework and set of reusable tools for the integration, visualization, analysis and dissemination of diverse types of biogeographical and oceanographic information. End-to-end viability of this approach is demonstrated in the context of a series of scientific storylines and a pilot application for the Gulf of Maine, a well-studied ecosystem that has been subject to large-scale perturbation due to overfishing. Databases at the core of the information system include those of the DFO Bedford Institution of Oceanography and Atlantic Reference Center, which are the product of multidisciplinary research efforts over the last several decades. Development of GMBIS may serve not only as a model for OBIS, but it may also provide a tool supporting new international and Canadian directives for integrated marine resource management. This presentation summarizes the status of the GMBIS project currently in its final phase, and outlines possible future directions in information system development for the CoML.

Marine Biodiversity Metrics

Mark Costello, Huntsman Marine Science Centre

Biodiversity is a quality of nature measurable in different ways. There are many uses for these measures including education, research, environmental assessment, conservation management and resource management. Because there is no single metric or descriptor that encompasses biodiversity, a framework of approaches is required. The best metrics allow for (a) clarity and communication, (b) variety of presentation options, (c) variety of analytical options, (d) variety of statistical analyses, (e) rapid assessment from sampling to reporting, and (f) are low cost. Species lists are the key to these metrics. They provide data on species composition, richness, indicators, phylogenetic diversity, beta diversity, gamma diversity, stability, rarity, dominance and keystone functions.

By its definition in the Convention of Biological Diversity, it is necessary to include variation within and between species, as well as of ecosystems. Biodiversity within a species can be indicated by phenotypic traits, genetic analysis and geographic isolation. Biodiversity between species has been described by many different indices and models, including graphical techniques. Generally, the simpler measures of species richness and dominance are the most useful univariate indices. Graphical techniques that plot relative abundance data (and show species richness) are also recommended. With this information, a variety of multivariate and other analytical techniques can be utilized if required. The biodiversity of ecosystems can be characterized by physical, chemical and biological variation in space and time. In practice, this requires habitat maps of the seabed and water column, and information on nutrient dynamics as a measure of ecosystem function. A standard methodology for mapping is very useful. The 'BioMar' project produced a detailed benthic biotope (= habitat + community of organisms) classification in Europe, and this approach is transferable elsewhere. Considering the different levels of biodiversity that need to be measured, it is recommended that widely obtainable and readily interpretable measures based on species lists, combined with standardized habitat (or biotope) descriptions, are used to measure marine biodiversity. This data will allow for more complex analyses to be conducted and new indices to be tested.

Notes
PowerPoint presentation is available at the Census of Marine Life Marine Biodiversity Workshop website (http://www.marinebiodiversity.ca/mbw/index.html).

How Do We Decide On What To Measure? - Principles For Developing A Marine Biodiversity Monitoring Program
Dr. Ken Minns, Department of Fisheries and Oceans, Great Lakes Laboratory for Fisheries and Aquatic Sciences, Burlington, Ontario

This paper provided an introduction to and a stimulus for the workshop's discussions on designing a marine biodiversity-monitoring program. It was noted that both marine and non-marine experiences and knowledge can be used to design the program. A set of generic guiding principles includes: CDE (cannot do everything), KISS (keep it simple), NIP (nothing is perfect) and TOTB (think outside the box). General cautions are to anticipate and avoid monitoring stagnation, to be wary of feel-good public involvement, and to know that the future will be different from the past. We need a reality check before trying to elaborate complex, expensive programs, as biodiversity is not a firm priority of people and governments yet. Further, since marine biodiversity is largely invisible, it is likely that resources (people, time and money) will always be limited. The rationale for a biodiversity monitoring program includes (i) tracking spatial and temporal trends in elements of biodiversity, (ii) tracking the behaviour/persistence of environmental and ecological processes that sustain biodiversity, (iii) tracking down recurrent ecosystem patterns and behaviours to formulate hypotheses and identify cause-effect links, and (iv) tracking and evaluation of the effectiveness of management actions designed to conserve biodiversity. To ensure the tracking succeeds, the designers must consider practicalities, key elements, and purposes. The practicalities include standardized methodology, sustained funding, and integration of activities nationally and internationally. Key elements include time-series monitoring and multi-dimensional effort covering three oceans and many levels of biotic organization. Maintaining balance and flexibility and measuring the efficacy of management actions are a couple of the purposes required. A few global and Canadian examples were briefly introduced with emphasis on strengths and weaknesses of different approaches. Some of the important specific issues for monitoring were introduced: representativeness, indicator species, mapping associations, and habitat metrics as surrogates for biodiversity measurement. It was concluded that while there are many factors and issues to be considered, a combination of clear goals and existing knowledge and understanding should provide a sound basis for creating a systematic monitoring program. A shortlist of recommendations was given including (i) tracking of ecosystem behaviours rather than checking the species lists, (ii) testing management actions rather than accumulating passive observations, (iii) forecasting and assessing risks rather than periodic reporting, and (iv) reinforcing existing efforts rather than creating new programs.

Notes
PowerPoint presentation is available at the Census of Marine Life Marine Biodiversity Workshop website (http://www.marinebiodiversity.ca/mbw/index.html).

Biodiversity Science: Thoughts on Next Steps
Howard Powles, Department of Fisheries and Oceans, Ottawa

Current challenges in the area of biodiversity include the difficulties in clearly articulating the need for biodiversity research and information, and the fact that "biodiversity" is not well understood by decision-makers. We need to provide clear answers to 'what happens if we don't' questions. Despite this there is wide recognition of the importance of healthy oceans and of the importance of maintaining 'biodiversity', as shown by the desire of federal-provincial-territorial Ministers to have a work plan for furthering national biodiversity agendas. Integrated ocean management is also becoming a focus for the government.

There are a number of options for institutional frameworks for biodiversity science, including Centers of Excellence or networks. Existing institutions like the Centre for Marine Biodiversity (CMB) can be used as a model. A Marine Biodiversity Knowledge Network would seem to be the ideal institutional model: this could set priorities for cooperative work, establish standards for information networks, acquire funding, link partners and share experiences. A network of this nature would need shared goals and objectives, dedicated resources (at a minimum some funding for a secretariat), and communication mechanisms to achieve its goal. Possible goals would be to develop, maintain and disseminate knowledge of all marine life in Canada; to contribute to sustainable exploitation of biological resources and integrated management of oceans; and to increase public awareness of the diversity of life in Canada's oceans.

There is some potential for funding in the federal government although generally obtaining new resources is difficult. 'Biodiversity' departments are working together to develop funding approaches including the Biodiversity Knowledge and Innovation Network (BKIN), the Federal Biosystematics Partnership (FBP), the Federal Innovation Networks of Excellence (FINE), and the Canadian Information System for the Environment (CISE). Potential funding through DFO includes additional funding for species at risk (following the passage of legislation) and funding to support oceans management. Non-governmental sources include the Philanthropic Funding Organizations (e.g. Sloan Foundation), industry (e.g. petroleum) and the World Wild Life Fund (WWF), which currently has the Endangered Species Research Fund (ESRF). In addition to the above sources, the Canada Foundation for Innovation could be an important source with the goal to strengthen the capability of Canadian universities, colleges, research hospitals and other non-profit institutions to carry out world-class research and technology development. A network approach where partners solicit funding for components that fit into an overall whole might be a good approach to increasing funding for biodiversity science.

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PowerPoint presentation is available at the Census of Marine Life Marine Biodiversity Workshop website (http://www.marinebiodiversity.ca/mbw/index.html).

The Census of Marine Life – an overview
Jesse Ausubel (for Ron O'Dor), Sloan Foundation, New York

The Census of Marine Life (CoML) is a research program whose purposes are to assess and explain the diversity, distribution and abundance of marine organisms, an international program that will involve experts in a variety of biological fields from around the globe, and an emerging program that will identify key questions and support observations and research over the next 5-10 years. The CoML initiative was essential given the urgent need for biological information around the world to enable the conservation of living resources in addition to the availability of new techniques and technologies that enable us to better understand the ocean. Further, we are experiencing environmental changes including habitat loss, pollution and perhaps global climate change. We need to work toward alleviating these issues through marine protected areas, sustainable fisheries, data management and communication, technology, and data analysis.

Some initiatives through CoML include the History of Marine Animal Populations and the Ocean Biogeographical Information System (OBIS). The former is an interdisciplinary research program that uses historical and environmental archives to build the picture of life in the oceans before fishing and the recent history of marine communities. The OBIS endeavor is a data assimilation framework for new and historical data amassed by the CoML. Its goal is to enable learners of all ages and users of many kinds to click on areas on maps of the oceans and conveniently bring up information on what has been reported to live there.

The CoML is also fostering international field projects. Those underway so far are based in Japan, USA, Norway, the UK and Canada. These are designed to get the numbers right about everything that lives in the water column both in areas that are studied but controversial and in areas that have yet to be explored. So far about $25 m have been committed around the world to the program.

Ultimately the Census will consist mostly of the sum of national programs, together with the international efforts such as OBIS that provide cohesion. The Census is both a means and an end. It is an end, in that the Census will culminate in 2010 with a report, probably in the form of an on-line dynamic atlas, about what is known, what is unknown, and what is unknowable about the diversity, distribution, and abundance of marine life. The Census is a means toward a much better ongoing observational system for marine life and enhanced support for research and management relating to marine life.

SESSION IV: BREAK-OUT GROUP DISCUSSIONS

For the final break-out session of the workshop the groups were asked to deliberate the following questions.

- What are the principles that should guide the development of a marine biodiversity-monitoring program?
- What are the products that we need from marine biodiversity data?
- What is the state of data storage, visualization, and analysis relative to the products required from marine biodiversity information?
- What are the relative roles of government, NGO's, and academic institutions in marine biodiversity research.

WHAT ARE THE PRINCIPLES THAT SHOULD GUIDE THE DEVELOPMENT OF A MARINE BIODIVERSITY MONITORING PROGRAM?

Two different philosophies: need to know what we have first or recognize absence of knowledge but start monitoring anyway.

Principles

- Principles described by Costello's & Minns' presentations (e.g. KISS, CDE, NIP, TOTP)
- Long-term commitment and stability, including institutional & funding.
- Monitoring linked to clear goals and objectives
- Evaluate the effectiveness of monitoring to meet objectives
- Integrate biodiversity monitoring with other monitoring initiatives, e.g. Atlantic Zone Monitoring Program, groundfish surveys
- Establish marine observatories in each of the oceans – areas strategically chosen (on ecological criteria)– serve monitoring and discovery functions. Detailed studies are required on processes for all levels of biodiversity.
- Don't forget George. Don't just fund the boats; include data management, sampling collection, identification, archiving, analysis.

Key Suggestions

- Broad scale monitoring every 20-25 years during the interim one can sample a small number of sites coupled with remote sensing and modeling. Site selection should be determined by a careful review of habitat diversity to ensure coverage of major habitat types.
- The only monitoring program that were successful are those that have very clear objectives; therefore, we should direct monitoring programs on charismatic species (e.g. Atlantic salmon). These will have the public support. We should add additional

scientific components to make broad biodiversity sites.
- Information should be accessible to all.

Priorities
- Retrospective review & analysis
- Establish criteria and priorities
- Develop designs
- Review and reevaluation
- Actions/implementation

WHAT ARE THE PRODUCTS THAT WE NEED FROM MARINE BIODIVERSITY DATA?

Products
We need products that would apply to all three oceans. Three levels of product: data, information & knowledge. Scientifically defensible at all levels. Useful for managers educators, researchers and the public. Products need to be communicated in ways that are accessible and appealing to the public.

- Indicators – abiotic/biotic-driving factors, comm. Sp. pop.
- Human factors
- Census of Marine Life
- Reference points
- Maps as tools (species distribution, impact, integrated management etc.)
- Observatories
- Accessible online resources
- Taxonomic databases
- Historical data coverage
- Texts on selection design and implementation of monitoring programs.
- Locations with good species list and existing time series should be front and centre for location of monitoring sites.
- Two approaches should occur simultaneously - Document/map and monitor.
- Industry to monitor sites “we” select that would be sites to measure anthropogenic change.
- List of research priorities
- Selection criteria for indicators. There is another international group working on this and should wait until we see what they come up with. US have set out some as a result of 4 yrs work that we could look at.
- Time series of species distribution & abundance linked with environmental & oceanographic data.
- Products to service education, management and for the research community.
- On line resources.
- Improving the management of natural resources (economic).
- Accessibility towards images of life (aesthetic).

Priorities

Technical Issues

- Id info/aids
- Checklists
- Indices
- Standardization

Mapping

- Broad overview first priority
- Species, environments, communities
  Client oriented

WHAT IS THE STATE OF DATA STORAGE, VISUALIZATION, AND ANALYSIS RELATIVE TO THE PRODUCTS REQUIRED FROM MARINE BIODIVERSITY INFORMATION?

Data storage

- The capability to store the data is appropriate.
- Orphan data
- Museums have huge data sets that should be on line
- Observation based program to get data on table.
- Data archeology is needed in all regions. This should be part of Census.
- Need reference collections of specimens, taxonomic issues. Not enough people curating. Collections being lost. Few young people coming in and the government is not interested in funding it.
- Need storage place for samples.
- Need archiving, security, long-term retention
- Foster integration of data systems
- Need to standardize and raise the capacity nationally & internationally
- Needs stable funding and institutional support
- Need to complete data registries, data rescue & put all information, including published studies, on-line
- Capabilities for data storage & management are lacking for genetic data.

Visualization

- The capability is adequate.

Analysis

- Analytical capacity is there.
  - Ecosim and Ecopath and Ecospace. Conflicting scientific opinions on its value. Level of taxonomy in these is functional group. Ecological monitoring is important but we lack data to constrain the models and parameters are diverse so preconceptions put in can affect model results.
  - There is no need for super computing capability at this time.

The future

- Some exciting new opportunities for imaging e.g. 3-D and video on demand may change future needs for computers.

WHAT ARE THE RELATIVE ROLES OF GOVERNMENT, NGO'S, AND ACADEMIC INSTITUTIONS IN MARINE BIODIVERSITY RESEARCH?

There should be more collaboration between NGO, government and university researchers.

Government

- Must be concerned with overall policy objectives: conservation, social & economic mandate
- Research, education & centres of expertise
- Should ensure that data are archived, secure & available
- Foster good practices & collaborations
- Coordination role – funding, networks among all groups
- Ensure monitoring programs are maintained - long term commitments
- Responsibility for long-term projects and supporting curation (e.g. museums)

Universities

- Research
- Education
- Centers of expertise, creating new knowledge & technologies – tools for discovery
- Providing data
- Taking part in management issues

Museums

- Maintain collections
- Taxonomic expertise & research
- Public education

NGOs

- Participate in and interface with science initiatives
- Social awareness & communications
- Raise profile of issues
- Partnership building
- Influence decisions through public advocacy
- Industry role BINGOs
- Responsible for ensuring best practices including sustainable resource extraction
- Can participate in data collecting and sharing

Communities

- Traditional Knowledge

- Local activities (e.g. MIDI)

SUMMARY COMMENTS ON DISCUSSIONS FOR SESSION IV

Augmenting Current Monitoring

There is an urgent need for biological information to enable the conservation of the marine biodiversity both as a contribution to the global initiative through the Census of Marine life and to meet Canada's obligations under CBD. The workshop recognized that there are existing biological sampling and survey activities that provide invaluable information on marine biodiversity in each of our three oceans. These range from single site observations where information on biological diversity are collected sporadically to large-scale and long-term surveys that provide comprehensive views of the diversity and abundance of organisms over a wide geographic area and over long periods of time. However, none of these surveys presently provide a comprehensive inventory of marine biological diversity in Canada nor do any of them provide a comprehensive marine biodiversity-monitoring program. It was also recognized that the Arctic Ocean is an area of special concern in that the amount of marine biodiversity information available for this ocean is far less than for either of the other oceans. The workshop concluded that the objectives of monitoring marine biodiversity should be to allow Canada to track:

1. Spatial and temporal trends in marine biodiversity, the changes in diversity, distribution and abundance of marine organisms in time and space
2. The dynamics of the environmental & ecological processes that sustain biodiversity.
3. Recurrent patterns & behaviors to allow for the generation of testable hypotheses leading to a better understanding of cause-effect links in the dynamics of marine biodiversity
4. The effectiveness of, and compliance with, management actions designed to conserve biodiversity

Results of Discussion Groups

As was the case in the Inventory section, workshop participants were asked to debate a pre-determined series of questions relating to monitoring of biodiversity, however in this case the groups were asked to deliberate each of the question for each of the three levels of biological organization. The responses to the first question have been incorporated in the previous section.

1. What are the principles that should guide the development of a marine biodiversity-monitoring program?
2. What are the products that we need from marine biodiversity data?
3. What is the state of data storage, visualization, and analysis relative to the products required from marine biodiversity information?

The workshop concluded that such monitoring programs would require:

1. Long-term commitment and stability in supporting institutions and funding (50 year time horizons)
2. Linkage to clear goals and objectives.
3. That the effectiveness of the monitoring programs must be regularly evaluated with regard to meeting their objectives
4. Marine biodiversity monitoring programs to be integrated with or be extensions of other existing monitoring programs wherever possible.
5. They are coupled with appropriate marine biodiversity reference sites or marine biodiversity observatories.

The design of monitoring programs should include the following attributes

1. The ability to track changes in marine biodiversity over time through the periodic census of marine biodiversity reference sites. These sites to serve the dual purpose. First they should function as control areas against which the relative impacts of human activities and natural environmental variability can be evaluated. They should also function as areas of discovery both for complete taxonomic evaluation and to investigate the natural processes that control marine biodiversity in the variety of landscapes encompassed by Canada's oceans (see below for a more complete discussion of reference sites).
2. Periodic synoptic surveys (outside) of the reference sites to evaluate geographic limits and to provide marine biodiversity information for areas that are affected by human activities.
3. The surveys must be multi-dimensional in that they need to sample not only species but communities (including landscape attributes) and population (genetic) attributes where appropriate.
4. They must provide coverage of all three oceans.
5. They must be linked to an adequate support system for sample processing (including taxonomic identification), sample archiving, data processing and storage, data analysis and the timely production of products.
6. They must be coupled with surveys conducted specifically to determine the impacts of the main human activities in the marine environment. For fisheries it is essential that by-catch be more fully enumerated (by-catch records through use of observers on commercial fishing vessels), while for oil and gas long-term sampling of exploited areas for a broad range of taxa is essential to determining impacts.
7. They must be linked with programs to monitor the long-term cumulative impacts of pollutants and eutrophication.

Development of an Effective Institutional framework

At present the concept of biodiversity and "healthy oceans" resonates well with policy makers, funding agencies, and the general public, but remains poorly defined. Biodiversity issues in general are front and center. Declining fish stocks, invading species, habitat destruction, and species at risk, are in the public eye but there is a general lack of understanding for what will happen if we do nothing. Within government the lead agencies have endorsed a plan for the furthering of a national biodiversity agenda and the integrated management of the Oceans has become a focus, but the specifics of what form these initiatives will take remain undefined. Given the diversity of the tasks outlined in the objectives above, coupled with the fact that Canada has three oceans to consider, it is unlikely that a single solution will emerge. It is quite probable that the institutional structure which guides the development of this work will take the form of a network of interacting individuals, existing and new physical institutions, linked by a set of common principles, standards and objectives. The Centre for Marine Biodiversity is such a model for the east coast of Canada. The duties of such an integrated network would include

1. Establishment of common goals – (this might be as inclusive as developing, maintaining, and disseminating knowledge of all marine life to increase public awareness of the diversity of marine life and the importance of conserving all life in our oceans, and to contribute to the sustainable exploitation and integrated management of Canada's oceans)
2. Establishment of standards (information networks like the marine biodiversity data registry, species lists, recommended monitoring protocols, data products, etc.)
3. Procuring funding to further the objectives of the network
4. Providing linkages between government, universities, NGO's, and the general public.
5. Providing linkages to other such networks.

Such a networked approach would also require dedicated resources for network coordination (a secretariat) and a mechanism for communication both internally and externally. The network will need to establish an overall workplan and a governing body.

During the development of the proposed network it is essential that we do not re-invent the wheel or disregard the considerable efforts that have already been expended by government, NGOs, Universities and other interest groups. There have been significant efforts leading to the development of a number of plans (one of the most comprehensive being the Canadian Biodiversity Strategy – Canada's response to the convention on biological diversity. This Strategy was developed for an overall response to the CBD for both terrestrial, aquatic and marine biodiversity. The strategic direction promulgated in that document are consistent with those resulting from the current workshop focusing on marine biodiversity, specifically;

- Implement biological and ecological inventory monitoring programs and classification systems to determine appropriate biodiversity conservation measures and provide a framework for managing aquatic resources on a sustainable basis.
- Increase our understanding of the structure, function and composition of aquatic ecosystems to enhance conservation and management practices.
- Enhance efforts to conserve aquatic biodiversity by protecting species and ecosystems at risk, endemic species, vulnerable spawning areas and unique and representative ecosystems.

The plan also emphasizes the need for the development of “ecological management approaches” and the development of sustainable management agreements. The ecological management approaches have been expressed as ecosystem management objectives (see below). It is the ability to achieve these stated objectives, specifically in Canada’s three oceans, that were the main points of deliberation for this workshop. We consider that the essence of these deliberations as extracted in this plan will provide guidance to all involved in the development and implementation of a marine biodiversity strategy.

GENERAL CONCLUSIONS

The most recently articulated ecosystem management objectives for Canada’s three oceans indicate that we will maintain enough [ecosystem] components (e.g. communities, species, populations – read biological diversity) to ensure natural resilience of ecosystems. It also states that we will maintain the function of each component of the ecosystem to allow it to play [its] natural role in food web (i.e. not cause any component of ecosystem to be altered such that it ceases to play its natural role). The workshop concluded that there are currently significant deficiencies in knowledge essential to attaining this overall goal. Our understanding of the scope of biological diversity is limited in that our inventory of diversity is complete for only a small number of organismal groups. Our knowledge of micro-fauna (including micro-invertebrates, and protists) and our knowledge of arctic, continental slope, and abyssal plain fauna is particularly lacking. Our knowledge of the range of natural variation in distribution and abundance, and the population structure of many groups is equally limited and restricted to relatively limited geographic areas. Our understanding of the processes that maintain and alter the relative abundances and distributions of organisms is also limited, as is our understanding of the distribution of marine communities in relation to existing habitats. We are further hampered by our lack of undisturbed marine areas against which we can judge the relative impacts of human activities and natural environmental variation.

Although we understand that our extractive activities in marine ecosystems (in particular fishing) have impacts on these systems, neither our description of their exact nature, or the processes through which they operate are adequate. Our understanding of the long-term, cumulative effects of human activities (eutrophication, pollution, and selective pressures) is particularly wanting.

Although we have focused on the gaps in our knowledge because we need to give guidance to those who will fill them, we must not give the impression that we are beginning from a blank slate. The regional registries list an impressive array of both existing information and information that is being added to by a variety of monitoring programs. These data have allowed us to develop an understanding of our marine ecosystems to the point where we feel competent to judge the gaps in our knowledge. Because of this information we are in a position to know what we don’t know. These data (both in Canada and elsewhere) have allowed for the development of a theoretical framework thought to describe the mechanisms that control biodiversity in general. Although these have been largely developed for terrestrial systems, at least some applicability to marine systems has been demonstrated. The importance of these theories is that they allow us to devise tests or experiments that will confirm or otherwise, they're more general applicability to marine biodiversity. Confirming such a theoretical framework greatly improves out ability to devise and implement strategies to conserve marine biodiversity. Some guidance as to the observations required and tests to be developed have been provided above.

The participants of the workshop were also cognizant of the fact that a lack of complete inventories of biodiversity, or the lack of a full understanding of the mechanisms controlling and altering marine biodiversity, should not preclude the possibility of initial actions to conserve it. Evidence for the deleterious effects of some human actions on marine biodiversity is sufficient to warrant immediate actions to conserve. It is clear that the conservation of marine biodiversity must be more closely tied to the sustainable use of exploited marine resources. The maintenance of current MPAs and areas of restricted access should be maintained and expanded. We provide guidance for the manner in which the basis for the expansion of marine biodiversity reference sites should be developed. We envision a combination of analysis of existing information to classify marine habitats and their associated communities, coupled with the taxonomic and geographic expansion of current monitoring programs to allow for a complete classification of habitats in all three oceans. This classification system will help us to determine the variety and extent of existing marine ecosystems in Canada. This classification is essential to the identification of locations for the implementation of a network of marine biodiversity reference area. The whole of this network would encompass both unique and representative areas within each of Canada's oceans.

The workshop recognized that Canada requires a long-term vision with regard to understanding and conserving marine biodiversity in its three oceans. This vision is encapsulated in the development and implementation of a network of marine biodiversity reference areas located in each of the Pacific, Arctic, and Atlantic oceans. The Marine biodiversity reference areas would be designed to provide, in microcosm, a cross-section of all available marine habitats. Once established these areas will serve a variety of purposes (see above). They will provide focal areas within which detailed, exhaustive, and repeated estimates of biodiversity across all taxa will provide ecological time capsules against which changes in non-reference areas can be judged. They will provide areas in which process oriented studies can be carried out in the absence (or near absence) of human impacts. Comparing these to processes in non-reference areas will allow us to better judge the mechanisms of human impact and provide a basis for modification or cessation of harmful deleterious activities. Over time, and assuming that they will revert back to some previous pristine state, they will also provide reference points for the re-establishment of diversity in extirpated areas, or reference levels for maintenance of biodiversity in exploited systems.

The workshop recommends that a national working group be struck to facilitate the analyses of existing data on the distribution and abundance of marine biota in relation to physical and environmental characteristics to determine processes underlying new or established patterns in species diversity. The findings of this working group would aid in the location of the marine biodiversity reference areas.

OVER-ARCHING RECOMMENDATIONS

The workshop makes the following over-arching recommendations as priorities for the development of a marine biodiversity plan:

1. That regional data inventories be completed, integrated, and that the data referenced in the inventories be made accessible and available to all researchers and managers.
2. That Canada's marine biodiversity inventories be completed and maintained.
3. That existing biological and physical ocean monitoring and observation programs be evaluated with regard to their efficacy in providing information on changes in marine biodiversity, including changes in distribution and relative abundance of taxonomic groups.
4. That current monitoring programs be augmented to provide additional information on currently poorly sampled taxonomic groups or for poorly sampled areas (Arctic, continental slope, abyssal plain)
5. That currently articulated theories regarding the control and maintenance of biodiversity be further evaluated with regard to application in the marine environment.
6. That current marine protected areas, or areas of restricted access be maintained and that significant and urgent effort be allocated to the identification and implementation of a network of marine biodiversity reference areas (discovery corridors).

For each of these over-arching recommendations the workshop has provided a series of specific questions to be addressed, or principles to be used. The workshop further proposes that a number of national working groups be struck to steer these activities in the following broad categories

1. The completion and maintenance of a marine biodiversity inventory and dissemination of marine biodiversity information
2. The evaluation of current monitoring and observation programs and recommendations for augmentation of these programs
3. The development of tests to evaluate competing theories of biodiversity based both on existing data and that available from augmented monitoring programs
4. The classification of marine habitats and their associated communities with the objective of identifying and implementing marine biodiversity reference sites.
5. The development of an effective infrastructure to support the development of this plan

The workshop recognizes and confirms that the number of inter-relationships between these broad categories of tasks dictates that working groups cannot work independently but must carry out their work in close cooperation. An effective coordination group is required.

CONCLUDING REMARKS

The material presented during the course of this workshop followed (by design) the overall conceptual framework established during its development. It was hoped that the presentations would touch on all of the elements of our conceptual matrix and we consider that they did this quite admirably. The presentations gave us a sense of the state of the art for each of the requisite elements. As is the case with any endeavor whose outcome is not prescribed and whose course is guided by the intellects of a large number of people, we made some additions to our framework (scientists love to re-define the question before offering an answer), and we had a vast array of informed opinions as to what the future of each of our framework elements should be. These are both welcome and encouraging outcomes.

The modifications to the conceptual framework that guided the development and execution of the workshop are presented below. You will note that the reference to the three levels of biological organization has been replaced with a more operation-oriented time-line of immediate, near-term and long-term action horizons. It was also recognized that an effective institutional framework is required to make this all happen. There remains a challenge to merge this present operational framework with the framework that recognized explicitly that all actions would be directed at specific levels of biological organization.

In these proceedings we have tried faithfully to record the results of the deliberations of the break-out groups for each of the major theme sessions. We have also tried to condense these by identifying common themes and issues. We have carefully read all of the comments recorded from each of the presentations and working groups and, using the modified conceptual framework, have tried to distill from the discussions, statements that give direction (either general or specific) to the development of an action plan for marine biodiversity in Canada’s three oceans

For any endeavor of this nature, and with such an ambitious agenda, there will be shortcomings and things that we might have done better. In all cases these are attributed to the organizers and not the participants. As in most workshops, the time used for presentations and discussions expanded to leave no time for a more general “wrap up” discussion. Given this it has fallen on the few to interpret and record the will of the many. Although this can be a dangerous and contentious endeavor, the quality and clarity of many of the presentations and deliberations made this a far less onerous task than it might have been. The proof will; however, be in the pudding and we urge all of the participants to look at these proceedings carefully to ensure that there were no words put in mouths where they should not have been and that there are no words that are not that should have been.

It is inevitable that some will feel that too many liberties of interpretation were taken. It is equally inevitable that we will not all agree on the final outcome of the PLAN. It is however out sincere wish that the former can be minimized while maximizing the latter.

Actions	Inventory	Monitor	Institutional	Conserve
Immediate	Complete regional registries/inventories and make data widely available through various means (e.g. OBIS, VDC, etc.)	Evaluate existing monitoring programs to determine ability to provide information on biodiversity composition and change	Establish network; consolidate collections	Apply scientific principles and theories to determine processes underlying new or established patterns in species diversity
Near-term	Fill-in gaps identified above	Pilot project to evaluate monitoring methodologies Extend current surveys to better observe mbiodiv	Re-build taxonomic expertise/enhance support for museums	
Long-term	Complete identification of Can Mar B-D	Observatories	Sustain expertise	Theoretical framework to allow for rational development of MPAs

APPENDIX A: MAILING ADDRESSES OF ATTENDEES

Mary Arai
Senior Volunteer Investigator
Pacific Biological Station
Nanaimo, BC V9R 5K6
(T) 250-756-7307
(F) 250-756-7053
email: araim@island.net

or

University of Calgary
2500 University Dr NW
Calgary, AB T2N 1N4
(T) 403-222-5110
(F) 403-282-8413
email: arai@acs.ucalgary.ca

Jesse Ausubel
Program for the Human Environment
Box 234, The Rockefeller University
1230 York Avenue
New York, NY 10021
(T) 212-327-7917 (T)
(F) 212-327-7519 (F)
email: ausubel@mail.rockefeller.edu

Richard Bailey
Institut Maurice Lamontagne
PO Box 1000
Mont-Joli, QC G5H 3Z4
(T) 418-775-0585
(F) 418-775-0542
email: baileyR@dfo-mpo.gc.ca

Paul Bentzen
DFO Chair, Fisheries Resource Conservation Genetics
Dept. of Biology, Dalhousie University
Halifax, NS B3H 4J1
(T) 902-494-6567
(F) 902-494-3736
e-mail: Paul.Bentzen@dal.ca

Jerry Black
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-2950
(F) 902-426-1406
email: blackJ@mar.dfo-mpo.gc.ca

Jim Boutillier
Head Shellfish and Mamals Assessment
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
(T) 250-756-7048
(F) 250-756-7138
email: boutillierJ@dfo-mpo.gc.ca

Bob Branton
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-3537
(F) 902-426-1406
e-mail: brantonB@mar.dfo-mpo.gc.ca

Heather Breeze
Department of Fisheries and Oceans
P.O. Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-2574
(F) 902-426-3855
email: breezeH@mar.dfo-mpo.gc.ca

Kate Bredin
Zoologist
Atlantic Canada Conservation Data Centre
Mount Allison University
P.O. Box 6416
Sackville, NB E4L 1G6
(T) 506-364-2660
(F) 506-364-2656
email: kbredin@mta.ca

Pierre Brunel
Département de sciences biologiques
Université de Montréal
C.P. 6128 Succursale Centre-ville
Montréal, QC H3C 3J7
(T) 514-343-7461 (office)
(T) 514-737-5124
(F) 514-343-2293
email: pierre.brunel@umontreal.ca

Alida Bundy
Research Scientist
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-8353
(F) 902-426-1506
email: bundyA@mar.dfo-mpo.gc.ca

Manon Cassista
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-2665
(F) 902-426-1862
email: cassistaM@mar.dfo-mpo.gc.ca

Mark Costello
Huntsman Marine Science Centre
1 Lower Campus Road
St. Andrews, NB E3B 2L7
(T) 506-529-1224
(F) 506-529-1212
email: costello@huntsmanmarine.ca

Cliff Cunningham
Duke University
Durham, NC
27708 USA
(T) 919-660-7356
(F) 919-660-7293
email: cliff@duke.edu

Derek Davis
10 Forest Road
Dartmouth, NS B3A 2M3
(T) 902 469-9469
(F) No Fax
email: ddavis@access wave.ca or ap775@chebucto.ns.ca

Cynthia Decker
CORE Suite 800
1755 Massachusetts Ave. NW
Washington, DC 20036-2102
(T) 202-332-0063 ext. 265
(F) 202-332-9751
email: cdecker@core ocean.org

Bob DeWreede
Department of Botany
3529-6270 University Blvd.
Vancouver, BC V6T 1Z4
(T) 604-822-6785
(F) 604-822-6089
email: dewreede@ interchange.ubc.ca

Julian Dodson
Directeur/Chair
Département de biologie
Université Laval
Ste-Foy, QC G1K 7P4
(T) 418-656-3102
(F) 418-656-2043
email: biojdo@hermes. ulaval.ca

Richard Eisner
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-7564
(F) 902-426-8484
email: eisnerR@mar.dfo-mpo.gc.ca

Derek Fenton
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-2201
(F) 902-426-3855
email: fentonD@mar.dfo-mpo.gc.ca

Jonathan Fisher
Department of Biology
Dalhousie University
Halifax, NS B3H 4J1
(T) 902-426-4136
(F) 902-426-9710
email: jfisher2@is2.dal.ca

Kenneth Foote
Woods Hole Oceanographic Institution
Applied Ocean Physics & Engineering, MS#10
Woods Hole, MA 02543
(T) 508-289-2445
(F) 508-457-2194
email: kfoote@whoi.edu

Ken Frank
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-3498
(F) 902-426-9710
email: frankK@mar.dfo-mpo.gc.ca

Jean-Marc Gagnon
Canadian Museum of Nature
PO Box 3443 STN D
Ottawa, ON K1P 6P4
(T) 613-364-4066
(F) 613-364-4022
email: jmgagnon@mus-nature.ca

Kent Gilkinson
Aquatic Resources Division
Ecosystem Processes
Science, Oceans and Environment Branch
Northwest Atlantic Fisheries Centre
P.O. Box 5667
St. John's, NL A1C 5X1
(T) 709-772-4718
(F) 709-772-4188
email: gilkinsonk@dfo-mpo.gc.ca

Graham Gillespie
Research Biologist, Stock Assessment
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
(T) 250-756-7215
(F) 250-756-7138
email: gillespieg@dfo-mpo.gc.ca

Patricia Gonzalez
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-9781
(F) 902-426-1506
email: gonzalezP@mar.dfo-mpo.gc.ca

Rajashree Gouda
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-1700
(F) 902-426-1862
email: goudaR@mar.dfo-mpo.gc.ca

Michel Harvey
Institut Maurice-Lamontagne
Mont-Joli, QC G5H 3Z4
(T) 418-775-0677
(F) 418-775-0542
e-mail: HarveyM@dfo-mpo.gc.ca

Bruce Hatcher
Professor, Biology Department
Dalhousie University
1355 Oxford Street
Halifax, NS B3H 4J1
(T) 902-494-6530
(F) 902-494-3736
email: bhatcher@is.dal.ca

Erica Head
Department of Fisheries
and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-2317
(F) 902-426-9388
email: headE@mar.dfo-
mpo.gc.ca

Paul Hebert
Canada Research Chair
Molecular Biodiversity
Professor of Zoology
Department of Zoology
University of Guelph
Guelph, ON N1G 2W1
(T) 519-824-4120 ext. 6668
(F) 519-767-1656
email: phebert@uoguelph.ca

Lea-Anne Henry
Department of Fisheries
and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 426-8338
(F) 426-6695
email: henryL@mar.dfo-
mpo.gc.ca

Glen Jamieson
Research Scientist
MEHS
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
(T) 250-756-7223
(F) 250-756-7138
email: jamiesong@dfo-
mpo.gc.ca

Andres Jaureguizar
Department of Fisheries
and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-2298
(F) 902-426-1506
email: jaureguizarA@
mar.dfo-mpo.gc.ca

Ellen Kenchington
Department of Fisheries
and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-2030
(F) 902-426-1862 or
426-5622
email: kenchingtonE@
mar.dfo-mpo.gc.ca

Dale Kiefer
Professor of Biological
Sciences
Division of Marine Biology
and Biological
Oceanography
University of Southern
California
3620 S. Vermont Ave.
KAP 246
Los Angeles, CA 90089-
2538
(T) 213-740-5814
(F) 310-573-1579 (home)
(F) 213-740-8123 (office)
email: kbkiefer44@
hotmail.com

David Kulka
Northwest Atlantic
Fisheries Centre
Box 5667 Whites Hills
St. Johns, NL A1C 5X1
(T) 709-772-2064
(F) 709-772-4188
email: Kulkad@dfo-
mpo.gc.ca

Phil Lambert
Invertebrate Curator
Royal British
Columbia Museum
675 Belleville St.
Victoria, BC V8W 9W2
(T) 250-387-6513
(F) 250-356-8197 or
387-0534
email: plambert@royal
bcmuseum.bc.ca

Alan Longhurst
Place de l'Eglise
46160 Cajarc
France
(T) +33 65 40 76 37
email: longh@crdi.fr

Connie Lovejoy
Biological Oceanographer
Dept de biologie &
Centre d'etudes nordiques
Laval University
Sainte-Foy, QC G1K 7P4
(T) 418-656-5644
(F) 418-656-2043
email: Connie.Lovejoy@
giroq.ulaval.ca

Kathleen Martin
Arctic Marine Ecosystem
Dynamics
Department of Fisheries
and Oceans
501 University Crescent
Winnipeg, MB R3T 2N6
(T) 204-983-5131
(F) 204-984-2403
email: martinK@dfo-
mpo.gc.ca

Barry McCallum
Science, Oceans
and Environment
Northwest Atlantic
Fisheries Centre
St. John's, NL A1C 5X1
(T) 709-772-4915
(F) 709-772-4105
email: mccallumb@dfo-
mpo.gc.ca

Chris Mckindsey
Institut Maurice-Lamontagne
Mont-Joli, QC G5H 3Z4
(T) 418-775-0667
(F) 418-775-0718
email: mckindseyC@dfo-
mpo.gc.ca

Arran McPherson
Department of Fisheries
and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-8503
(F) 902-426-2331
email: mcphersonA@mar.
dfo-mpo.gc.ca

Ken Minns
Department of Fisheries
and Oceans
867 Lakeshore Road
Burlington, ON L7R 4A6
(T) 905-335-4874
(F) 905-336-6437

email: minnsK@dfo-mpo.gc.ca

Lene Mortensen
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-9917
(F) 902-426-9710
email: mortensenL@mar.dfo-mpo.gc.ca

Clyde Murray
Science Stock Assessment Division
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
(T) 250-756-7175
(F) 250-756-7053
email: murraycl@dfo-mpo.gc.ca

Ransom Myers
Prof. Ransom A. Myers (RAM)
Killam Chair of Ocean Studies
Department of Biology
Dalhousie University
Halifax, NS B3H 4J1
(T) 902-494-1755
(F) 902-494-3736
email: Ransom.Myers @Dal.Ca

Bob O'Boyle
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-3526
(F) 902-426-5435
email: oboyleB@mar.dfo-mpo.gc.ca

Howard Powles
Directeur, Sciences de la biodiversité - Director, Biodiversity Science
Pêches et Océans - Fisheries and Oceans
200, rue Kent –
200 Kent Street
Ottawa, ON K1A 0E6
(T) 613-990-0280
(F) 613-954-0807
Cell: 613-296-0871
Courriel: powlesH@dfo-mpo.gc.ca

Kirsten Querbach
Centre for Marine Biodiversity
Bedford Institute of Oceanography
1 Challenger Dr.
P.O. Box 1006
Dartmouth, NS B2Y 4A2
(T) 902 426-7958
(F) 902 426-2331
email: querbachK@mar.dfo-mpo.gc.ca

Robert Rangeley
Marine Program Director
Atlantic Regional Office
World Wildlife Fund Canada
Suite 504, Duke Tower
5252 Duke Street
Halifax, NS B3J 1P3
(T) 902-482-1105
(F) 902-482-1107
email: rrangeley@wwf canada.org

Ray Ratynski
Species At Risk Coordinator
Freshwater Institute
501 University Cr.
Winnipeg, MB R3T 2N6
(T) 204-983-4438
(F) 204-983-5192
email: ratynskiR@dfo-mpo.gc.ca

Jake Rice
Department of Fisheries and Oceans
200 Kent Street
Ottawa, ON K1A 0E6
(T) 613-990-0288
(F) 613-954-0807
email: riceJ@dfo-mpo.gc.ca

John Roff
University of Guelph
Guelph, ON N1G 2W1
(T) 519-824 4120 ext: 3834 Zoology, 26
(F) 519-767 9798
email: john.roff@acadiau.ca

Daniel Ruzzante
Danish Institute for Fisheries Research
Department of Inland Fisheries
Vejlsoevej 39
Silkeborg - DK 8600
Denmark
(T) (45) 89 21 31 04
(F) (45) 89 21 31 50
email: ruzzante@dal.ca

Jean-Marie Sévigny
Institut Maurice Lamontagne
Mont-Joli, QC G5H 3Z4
(T) 418-775-0636
(F) 418-775-0542
email: Sevignyjm@dfo-mpo.gc.ca

Nancy Shackell
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-455-5486
(F) 902-426-9710
email: shackellN@mar.dfo-mpo.gc.ca

Jason Simms
Ocean Biologist
Department of Fisheries and Oceans
Northwest Atlantic Fisheries Centre
PO Box 5667
St. John's, NL A1C 5X1
(T) 709-772-8014
(F) 709-772-5315
email: simmsJa@dfo-mpo.gc.ca

Norman Sloan
Gwaii Haanas
Box 37
Queens Charlotte, BC
V0T 1S0
(T) 250-559-6342
(F) 250-559-8366
email: Norm.Sloan@pc.gc.ca

Darlene Smith
Senior Advisor Biodiversity
Biodiversity Science Branch
Department of Fisheries
and Oceans
200 Kent St.
Ottawa, ON K1A 0E6
(T) 613-991-1284
(F) 613-954-0807
email: smithDar@dfo-mpo.gc.ca

Paul Snelgrove
Biology Department and
Fisheries Conservation Chair
Memorial University of
Newfoundland
St. John's, NL A1C 5R3
(T) 709-778-0652
(F) 709-778-0669
email: psnelgro@caribou.mi.mun.ca

Wayne Stobo
Department of Fisheries
and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-3316
(F) 902-426-1406
email: stoboW@mar.dfo-mpo.gc.ca

Margaret Treble
Freshwater Institute
501 University Cr.
Winnipeg, MB R3T 2N6
(T) 204-983-5131
(F) 204-984-2403
mpo.gc.ca

Lou Van Guelpen
Curator of Fishes and
Collections Manager
Atlantic Reference Centre
Huntsman Marine
Science Centre
1 Lower Campus Road
St. Andrews, NB E5B 2L7
(T) 506-529-1203
(F) 506-529-1212
email: arc@dfo-mpo.gc.ca

Scott Wilson
Department of Fisheries
and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-3318
(F) 902-426-1506
email: scottW@mar.dfo-mpo.gc.ca

Kees Zwanenburg
Department of Fisheries
and Oceans
PO Box 1006
Dartmouth, NS B2Y 4A2
(T) 902-426-3310
(F) 902-426-1506
email: zwanenburgK@mar.dfo-mpo.gc.ca

APPENDIX B: FINAL AGENDA

Workshop on Canadian Marine Biodiversity
Co sponsored by The Census of Marine Life and the Canadian Department of Fisheries and Oceans

February 25 – 28, 2002
White Point Beach Resort
Nova Scotia, Canada

<u>Monday, February 25, 2002</u>

Participants arrive and are shuttled by bus to White Point Beach Resort from BIO and the airport. Buses depart Bedford Institute of Oceanography at 3:30 pm.

07:00 - Buffet and mixer

<u>Tuesday, February 26, 2002 – Morning</u>

07:30 - Breakfast

09:00 - Workshop conveners open the workshop and give an outline of events and overview of workshop objectives

Session I - Background

09:45 - Marine Biodiversity – Dr. Pierre Brunel

10:15 - Break

10:30 - Conservation of marine biodiversity in Canada: Instruments and Issues? (Howard Powles)

11:00 - Canadian obligations, issues and actions related to biodiversity – an NGO perspective (Bob Rangeley WWF)

Session II – Patterns

What we know and don't know about species, population, and community diversity in Canada's oceans?

11:30 - The Unreliable Pelagic Ecosystem or Why we can't manage fish stocks? (Alan Longhurst)

12:00 - Classification of benthic marine communities (John Roff)

12:30 - Comparing histories of North Atlantic Marine Invertebrates (Cliff Cunningham)

1:00 - Lunch

<u>Tuesday, February 26, 2002 – Afternoon</u>

2:00 - Pacific Marine Biodiversity Presentation (Clyde Murray)

2:30 - Arctic Marine Biodiversity Presentation (Kathleen Martin)

3:00 - Gulf of St. Lawrence Marine Biodiversity Presentation (Richard Bailey)

3:30 - Atlantic Marine Biodiversity Presentation (Lou van Guelpen)

4:00 - Break (refreshments) and split into discussion group

6:30 - Dinner

8:30 - Social time

<u>Wednesday, February 27, 2002 - Morning</u>

07:30 - Breakfast

Session III - Mechanisms

Key processes in the maintenance and alteration of marine biodiversity in Canadian oceans

09:00 - Ocean control of biogeographic processes - Phytoplankton and protist diversity (Connie Lovejoy)

09:30 - How does fishing change marine biodiversity? (Jake Rice)

10:00 - Species area relationships and species habitat associations (Ken Frank)

10:30 - Break

10:45 - What is the basic unit of conservation? (Paul Bentzen)

11:15 - Diversity within species – population diversity (Paul Hebert)

12:30 - Lunch

Wednesday, February 27, 2002 - Afternoon

1:30 - **Break into discussion groups**

4:00 - Workshop reconvenes in plenary for break-out group reports of Sessions II and III

6:30 - Dinner

8:00 - Demonstration of the Virtual Data Center (Jerry Black and Bob Branton)

8:30 - Social time

Thursday, February 28, 2002 - Morning

Session IV – Visualization, metrics, monitoring, and implementation

09:00 - Data management and visualization GMBIS / OBIS (Dale Kiefer)

09:30 - Biodiversity metrics – products of biodiversity information (Mark Costello)

10:00 - How do we decide on what to measure? - Principals of developing a marine biodiversity monitoring program (Ken Minns)

10:30 - Break

10:45 - Options for Developing (Howard Powles)

11:15 - Break out groups – the questions for discussion need to be developed for these sessions

1:00 - Lunch

Thursday, February 28, 2002 - Afternoon

2:00 - Workshop reconvenes in plenary for break-out group reports of Sessions IV

3:30 - Workshop Wrap-up and major findings relative to the Census of Marine Life Science Plan (TBA)

7:00 - Workshop Banquet

Friday, March 1, 2002 – Morning

08:00 - Breakfast

Most workshop participants will depart on the shuttle bus at 09:30 to BIO.

09:00 - Writing team will ensure that all written materials is available and as much as possible begin outlining the report.