DEVELOPMENT OF A FRAMEWORK AND PRINCIPLES FOR THE BIOGEOGRAPHIC CLASSIFICATION OF CANADIAN MARINE AREAS

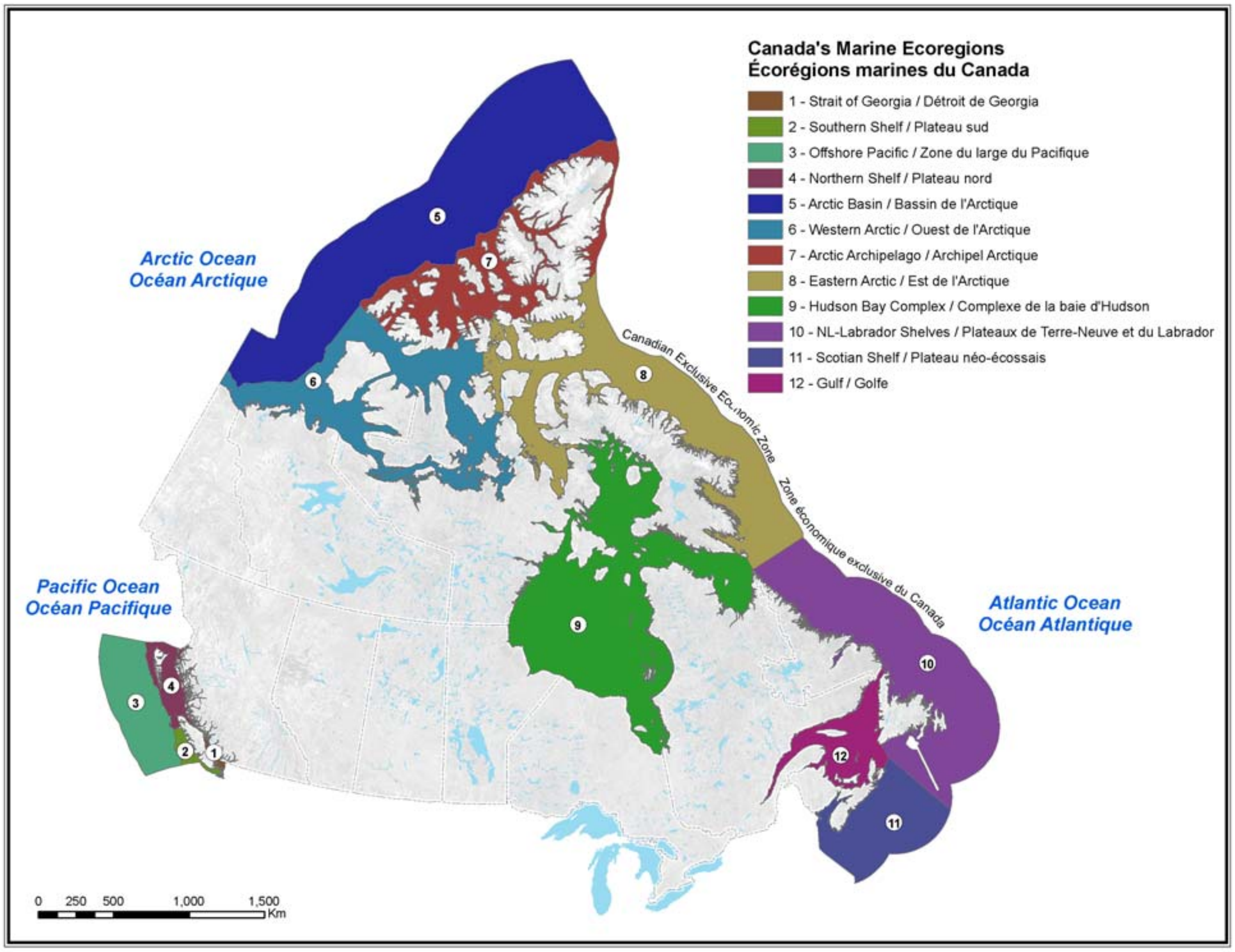

Figure 1. The recommended major biogeographic units for Canadian marine areas (DFO, 2009).

Context:

In May 2008, at the 9th meeting of the Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) Canada endorsed the adoption of Decision IX/20 [Marine and coastal biodiversity] to address issues relating to the conservation and sustainable use of biodiversity in marine areas beyond national jurisdiction.

Decision IX/20 indicates that a scientific and technical expert workshop will be convened to provide, using the best available information and data, scientific and technical guidance on the use and further development of biogeographic classification systems. Canada is co-hosting this workshop, which will take place in Ottawa, Canada from September 29-October 2, 2009.

Canadian experts met to examine various existing biogeographic classification systems and provided *scientifically-based recommendations towards the development of a framework and guiding principles for the biogeographic classification of Canadian marine areas. This science advice will be brought forward for consideration at the aforementioned CBD Workshop and will also contribute to advancing Canada's commitment to develop networks of representative marine protected areas that meet its obligations under the CBD.*

Several initiatives have delineated global and Canadian marine areas into different biogeographic units. A new system has not been devised in this report. However, based on existing biogeographic classification systems, guiding principles which should generally be applied when delineating spatial scales have been identified, and these principles have been utilised to determine acceptable major, first-order biogeographic units for Canadian marine areas.

SUMMARY

- High-level spatial units have been identified for each of Canada's three oceans which are primarily based on oceanographic and bathymetric similarities. For each ocean these units are:
    - **Atlantic Ocean** – the Scotian Shelf, the Newfoundland-Labrador Shelves, and the Gulf of St. Lawrence;
    - **Pacific Ocean** – the Northern Shelf, the Strait of Georgia, the Southern Shelf, and the Offshore Pacific Zone; and
    - **Arctic Ocean** – Hudson Bay Complex, the Arctic Archipelago, the Arctic Basin, the Eastern Arctic, and the Western Arctic.

- Transition zones are important features to consider and should be taken into account when delineating boundaries between biogeographic units.

- There are important scales below the highest spatial scale identified which are defined by similar features, and subdivision of larger biogeographic units should consider bathymetry and oceanography as well as food web structure and benthic communities.

- All available ecological information and data (including experiential/traditional knowledge) should be taken into consideration when forming hypotheses about the location of boundaries between biogeographic units. Testing should consider these data sources, as well as pattern analysis when appropriate.

BACKGROUND

Introduction and Rationale

A number of biogeographic classification systems have emerged in the past decades with differing spatial scales (highly regional to global), approach (based almost entirely on previous work to based on quantitative analyses of extant data), and scope (consideration of one ecosystem dimension versus all possible data sources).

A variety of existing biogeographic classification systems were reviewed to inform the development of a framework and principles which could be applied in a biogeographic classification system assessment. In addition, this information will be useful towards guiding the selection of representative marine protected areas, and to simplify and standardize the spatial units used for reporting on the status and trends of the Canadian marine environment.

Several global biogeographic classification systems exist which differ in spatial scale as well as in ecosystem focus. The Large Marine Ecosystems of Sherman and Alexander (1986) and Marine Ecosystems of the World (Spalding et al, 2007) both focus on coastal and shelf areas, while the bioregional provinces outlined in the Global Open Oceans and Deep Seabeds Biogeographic Classification (UNESCO, 2009) address the open and deep ocean. The Biogeochemical Provinces (Longhurst, 2007) focuses on both the coastal and offshore environments, and is based on physical and biological oceanographic processes. All of these biogeographic classification systems provide a broad perspective of marine ecosystems and applied a range of analytical procedures and data. Therefore, they were deemed relevant to the discussions of the advisory group and are presented in further detail below.

The selection of regionally-focused biogeographic classification systems to be considered was restricted to those based on North America and/or Canada. Only the most recent North American biogeographic classification system from a series of developments was considered (i.e. the Marine Ecoregion Classification of North America). Until recently, Fisheries and Oceans Canada (DFO), Parks Canada (PC), and Environment Canada (EC) have been independently developing biogeographic classification systems to respond to the specific needs of their particular mandates. The latest versions of each of these national initiatives were also considered, as was the biogeographic classification system developed by the Canadian Council of Resource Ministers (CCRM), which is used to achieve Canada's reporting needs under the CBD.

General Overview of the Biogeographic Classification Systems Considered

Large Marine Ecosystems (LME)

The development of LMEs was stimulated by the 1982 United Nations Law of the Sea Convention, which granted coastal states sovereign rights to explore, manage, and conserve the natural resources of their Exclusive Economic Zone (EEZ).

Currently, there are 64 LMEs with the overarching objective to provide a governance basis for the integrated management of ocean resources within a defined geographical area. A significant related objective is to aid in improving our understanding of the productive dynamics of ecosystems in which exploited ocean resources exist.

All 64 LMEs are distinguished on the basis of four criteria:

1) Bathymetry (bottom depth);
2) Hydrography (temperature, salinity, Sigma T, tides and currents);
3) Productivity (chlorophyll, dissolved oxygen, total zooplankton); and
4) Trophic linkages (informed using plankton, demersal and pelagic surveys)

Marine Ecosystems of the World (MEOW)

In the early 2000's, the World Wildlife Fund and the Nature Conservancy recognized i) the existence of a large number of incomplete global and regional marine classification systems, and ii) the need for a comprehensive global marine biogeographic classification system.

MEOW is a mosaic of existing and recognized spatial units with a focus on the marine coastal and shelf realms of the world's oceans. It was primarily developed to support analyses of patterns for marine biodiversity, in understanding processes, and in directing future efforts in marine resource management and conservation.

The synthesis of existing available information into MEOW was guided by the following principles:

1) Strong biogeographic basis – informed by composite studies that combined multiple divergent taxa or multiple oceanographic drivers in the derivation of boundaries;
2) Practical utility – development of a nested system, operating globally at broadly consistent spatial scales and incorporating the full spectrum of habitats found across shelves; and
3) Parsimony – minimize further divergence from existing systems by adopting a nested hierarchy that uses existing systems and which fits closely within broader-scale systems or alongside regional systems.

MEOW consists of a nested system of 12 realms, 62 provinces, and 232 ecoregions (of which 15 are relevant to Canada).

Global Open Oceans and Deep Seabed Biogeographic Classification (GOODS)

The Johannesburg Plan on the implementation of the World Summit on Sustainable Development (2002) and COP7 of the CBD (2004) adopted 2012 targets related to the establishment of representative networks of marine protected areas. GOODS was the outcome of a series of three multidisciplinary expert workshops in response to these 2012 biodiversity targets.

GOODS is hypothesis-driven and based on a physiognomic approach, which uses geographic and physical characteristics of the benthic and pelagic environments to select homogeneous regions of similar habitat and associated biological community characteristics.
A set of six principles guided the analysis and delineation of the biogeographic classifications. These principles are discussed in more detail later in this report.

GOODS consists of a map of pelagic bioregions (29 provinces; five of which are of relevance to Canada) and a deep-sea benthic classification encompassing three depth zones and 29 biogeographic provinces (of which six are relevant to Canada).

Biogeochemical Provinces of the Ocean (BGCP)

Developed in 2007 by Longhurst, the overarching objective guiding the BGCP classification system is the delimitation of areas of the global ocean based upon the physical oceanographic Sverdrup processes which determine the biological oceanographic processes and thus influence the rest of the food chain.

The BGCP classification uses two spatial scales:

1) Biome - based on how winds and sunlight interact to influence Sverdrup mixing processes; and
2) Provinces – defined by a detailed examination of the Sverdrup mixing processes within each biome.

Latitudinal trends and seasonal changes in plankton composition generally support the biome boundaries. However, provincial boundaries within biomes used a wider set of factors which were able to define interfaces between physically and ecologically distinct regions (e.g. regional circulation and stratification, bathymetry, river discharges, coastal wind systems, islands, land mass distribution).

There are four biomes and 51 provinces in the BGCP classification; six of which are most relevant to Canada's three oceans.

Marine Ecoregion Classification of North America (MECNA)

The Commission for Environmental Cooperation (CEC) first introduced a combined terrestrial and marine ecosystem classification system in 1996. MECNA (2009) is the result of a largely Delphic-based approach which updated the original classification using a group of tri-national (Canada, USA, & Mexico) experts from a variety of disciplines related to marine science and planning.

A set of principles and general rules guided the development of MECNA. The resulting ecoregions may serve as a basis for regional and cooperative stewardship and management efforts, act as reference points for periodic assessments, and aid in defining representative and critical areas for the marine environment.

At the coarsest scale (Level I), there are 23 ecoregions, of which nine have specific relevance to Canada's oceans.

Marine Ecoregion Classifications of Canada

Since the mid-1980's, a number of biogeographic classifications have been developed which have focused specifically on Canadian ecosystems. These have involved a variety of government and non-government bodies such as DFO, EC, PC, CCRM, and World Wildlife Fund (WWF).

Due to the involvement of different governmental departments and non-government organisations, the various initiatives have had differing yet similar objectives:

- PC & WWF – to define representative areas in which to establish national marine conservation areas (PC) and other categories of marine protected areas as well
- EC – to define areas for marine environmental quality monitoring program
- DFO – to identify marine areas as the basis for integrated management
- CCRM – to provide spatial basis for the reporting on the status and trends of Canada's terrestrial and marine ecosystems

In general, the development of these classifications relied heavily on expert judgement. However, each initiative took a different approach to define specific units within Canada's aquatic ecosystems:

- PC – 29 ecoregions based on physical (i.e. oceanography, physiography and coastal environment) and biological features (i.e. species composition and distribution)
- EC – 5 large ecozones containing 12 ecoprovinces, 18 ecoregions, and 48 ecodistricts using a hierarchical approach which considered physical properties (e.g. shoreline configuration, bathymetry, currents, water column properties) to determine ecological boundaries
- DFO – 17 marine ecoregions which considered geological, physical oceanographic, and biological properties when defining units
- CCRM – 9 ecoregions which are generally defined at a higher spatial scale than the others and were selected based on four principles which stated that units should be

i) contiguous and integrated, ii) thematically consistent, iii) spatially exclusive, and iv) flexible in their monitoring.

ANALYSIS

Synthesis of Existing Biogeographic Classification Systems

Spatial Scale

Ecosystem processes occur at a wide range of spatial scales, often with lower-level processes hierarchically arranged within those at higher levels. The classification systems reviewed considered a wide range of spatial scales with most systems using a hierarchical approach with small units nested within larger ones. At the various spatial scales, biogeographic units were referred to using a variety of different terms; however at similar spatial scales general definitions could be applied across biogeographic classifications regardless of the specific terminology.

Objectives

Most of the biogeographic classification systems considered were developed in support of some element of an ecosystem approach to management. Objectives ranged from the broad to the specific, but in general they could be categorized as based either in i) conservation (e.g. biodiversity, productivity, habitat), ii) social and economic well-being, and iii) institutional integrated management.

Classification Approaches

Although a number of approaches were used in the biogeographic classification systems considered, they shared common elements among them such as:

1. The establishment of either hypotheses or criteria at the outset to guide the process;
2. A significant information and data compilation stage, including the identification of experts; and
3. The production of maps including the agreed upon biogeographic units, which generally included expert opinion/input at some stage of the process.

Data Usage

The biogeographic classification systems reviewed utilised a wide range and quantity of ecosystem-relevant information, such as geological, physical oceanographic, and/or biological data. The data usage differences between classifications were not considered significant and are perhaps more related to the details of how the information was used (e.g. scale, weighting of data, approach, etc.). In most cases, data were used in a tiered approach with the largest spatial scale classified using the physiognomic data (i.e. geographic and physical characteristics of the benthic and pelagic environments), followed by increasing use of taxonomic and ecological information at finer scale resolutions.

Classification Products

Similarities and differences between the biogeographic classification systems delineation of units are discussed in the report prepared by O'Boyle (2009) for the purposes of this advisory group.

Guiding Principles for the Biogeographic Classification of Canadian Marine Areas

It was agreed that the six principles which guided the GOODS system were those which should be applied in a biogeographic classification system assessment; noting that in practice these principles should be adapted to the types of information available. The principles agreed upon by the advisory group were:

1. As pelagic systems are three-dimensional and dynamic, and benthic systems have a more stable, two-dimensional foundation, the benthic and pelagic environments should be considered separately;
2. Classification should not be based upon the unique characteristics of distinctive areas or upon individual focal species. Therefore, the "diagnostic species" concept should be avoided as it is counter to the goal of identifying representative areas which reflect patterns in total biodiversity;
3. Classification should reflect the taxonomic identity which is not addressed by systems which focus on biomes. As species composition is considered important, the terrestrial biome concept is not appropriate;
4. Generally recognizable communities of species should be emphasized, and do not require the presence of either a single or diagnostic species, or abrupt changes in composition between units. As such, rigid multi-taxa discontinuities should not be expected as the processes affecting distributional histories may differ. In the case of *limited* research efforts, delineating boundaries based solely on the availability of *taxonomic* data is not appropriate;
5. The influences of ecological structures and processes in defining habitats and their arrays of species should be recognized; and
6. Classification should be hierarchical with a nested structure based upon appropriate scales of features.

General Framework for the Biogeographic Classification of Canadian Marine Areas

The two primary uses of biogeographic classification systems were identified as i) assessing and reporting on ecosystem status and trends, and ii) spatial planning for the conservation of ecosystem properties and management of human activities. No ecological reasons were identified that would require using a different approach to biogeographic classification for one use or the other. However, it was agreed that there is justification for using the same classification for both identified uses.

When considering integrated spatial planning uses, the hierarchical subdivision to levels below the maximum spatial scale is important. In those applications, each use of biogeographic classifications will require consideration of the management and/or policy question(s) of concern, and the scale of classification should be matched to the scale of the question.

Spatial Scale

Physical oceanographic processes should receive primary attention at the largest spatial scale of initial interest. These oceanographic processes, combined with bathymetry, are the factors which are most likely to delineate coherent groups of species, population and community dynamics, and their responses to management and/or policy actions.

There is a maximum scale of biogeographic classification that is appropriate for the integrated planning and management of Canadian marine areas, as well as for assessing and reporting on ecosystem status and trends. Below this maximum scale, ecological heterogeneity of the defined unit is likely to dominate over any coherent responses of the fauna to management measures and/or various environmental drivers. Management measures which are implemented at finer scales than the defined maximum biogeographic scale may not always result in coherent and meaningful responses.

Each of the biogeographic units identified at the coarsest scale can be disaggregated into smaller units that are also ecologically meaningful. This subdivision can proceed in a nested manner for many levels of biogeographic units. However, as the subdivision proceeds, information on species occurrences and ranges becomes increasing influential in delineating units, making the successive levels of division increasingly data hungry. While there is no "correct" level of subdivision to seek, the level of resolution selected will depend greatly on the management or policy purpose being made of the biographic classification system in question.

Transition Zones

At the largest spatial scale, boundaries are often vague and represent transitional zones, rather than clearly defined lines between biogeographic units. In general, transition zones are considered either gradients or abrupt transitions. Gradient transition zones can range from several tens to hundreds of kilometres in width, representing a gradual transition from one type of ecosystem to another. Abrupt transitions indicate clear delineations of ecosystem types, but the position of the transition zone can move small to large distances over time.

Both types of transitions need to be acknowledged in biogeographic classification systems for policy, management, or reporting purposes. Biogeographic classification systems should explicitly include transition zones and not obscure them through arbitrary decisions (e.g. analytical averaging, etc). The biogeographic classification should also make clear which type of transitional zone(s) is present in the system, because appropriate management and policy measures will differ depending on the zone(s) present.

Further attention is required to determine whether policies and management measures appropriate for the core of biogeographic classification units would also be appropriate, or at least of comparable effectiveness, when applied in a transition zone. This is also true when considering the two different transition zones. These questions should be explored scientifically at an early stage in determining biogeographic units and spatial scale to allow for consideration of the most appropriate management approaches.

Additional Guidance on How to Identify Biogeographic Subdivisions

There was agreement that at the onset of subdividing major biogeographic units, the importance of species composition data (e.g. fish, plankton, and benthic communities) should receive increasing attention compared to bathymetry and oceanographic processes. However, at the first level of subdivision of the major biogeographic units, coherence of bathymetry and/or water masses will be important considerations, along with food web functionality and, when available, coherence in variation in recruitment across groups of similar taxa.

The nature of the datasets and metrics that are likely to be available on distribution and abundance of all marine taxa will be incomplete and not fully representative in a number of ways. Data density in space will usually be quite variable, and even in the more data-rich areas only certain taxa are likely to be surveyed with designs giving broad and even spatial coverage;

the level of taxonomic identification is usually highly variable among major marine taxa. Lengths of time series of data differ greatly among taxa, even in areas where spatial data are available for multiple higher taxa. As a result, it would be possible to at least partially clarify temporal and spatial variation in the distribution of some taxa. However for many taxa, any data used in pattern analyses of species occurrences would necessarily have those two types of variations fully confounded.

For the biological data likely to be available for statistical analyses of spatial patterns, the distribution of the shortcomings listed above imply that such pattern analyses also will have many shortcomings. Not withstanding this, it is still worth conducting such analyses when there are sufficient data to justify their use. However, in most Canadian marine areas it is unrealistic to expect such analyses to be robust and adequate to serve as the primary guide to finer scale biogeographic classifications. A more appropriate strategy may be to pool the expert knowledge that may be available about oceanographic processes, food web relations, and other ecological processes and species relationships in a larger region, and use that knowledge to form testable hypotheses about the location of boundaries between biogeographic units. Tests of these hypotheses with the best data available on species distributions might provide more robust empirical guidance with regard to biogeographic subdivisions than would a broadly applied pattern analysis of biogeographic data.

In formulating ecological hypotheses, it is necessary to take into account the history of human activity in the area. Past human impacts may have altered the biodiversity of an area in ways that imply that statistical analyses of current species occurrence data may not provide valid tests of the boundaries of biogeographic units within which ecological processes have historically structured species interactions (and likely would structure them in future, if human-induced pressures were not the dominant factor in the abundance and range of the species).

The way that human activities are taken into account will have to consider the particular activity and the part of ecosystem being considered in the subdivision. For example, the scale of the historical footprint of a fishery on a food web is likely to be quite large, whereas the scale of the footprint of the same fishery on the seabed and benthic communities would be much more local. Neither scale is inherently more correct; choice of scale will depend on (among other factors) the planning, reporting, and management uses to be made of the classification results. For example, the appropriate scale for biogeographic units used to manage bycatch of a fishery may be different from the appropriate scale for biogeographic units used to manage habitat impacts of the same fishery.

Because few data sets with wide spatial coverage are available in many areas, it will likely be necessary to use local, experiential, and/or traditional knowledge to augment survey data. These kinds of information are generally acquired on quite fine spatial scales which should be taken into account when using such knowledge in determining appropriate biogeographic subdivisions of larger areas.

Accepted Major Canadian Marine Biogeographic Units

Atlantic Ocean

It was agreed that three biogeographic units were appropriate for the Atlantic Ocean at the coarsest spatial scale (Figure 2). They are the *Scotian Shelf*, the *Newfoundland-Labrador Shelves*, and the *Gulf of St. Lawrence*. These biogeographic units were selected based on those identified by the Canadian Council of Resource Ministers (CCRM).

There are marked differences in the fish and plankton communities between the core areas of the Scotian Shelf and the Newfoundland-Labrador Shelves. However, the exact line between these two biogeographic units is uncertain. The respective slopes down to the Laurentian Channel are part of the respective shelf units. However, the trough itself may be best viewed as a permanent transition zone, with its greater depth contributing to unique features.

On the south end of the Scotian Shelf biogeographic unit, the Bay of Fundy-Georges Bank areas have biogeographic affinities with the Gulf of Maine, as well as with the Scotian Shelf. However, this boundary would be best represented as a first-order subdivision of the larger Scotian Shelf biogeographic unit.

The northern boundary of the Newfoundland-Labrador Shelves biogeographic unit is unclear and this area is considered particularly data-poor. If the location of that boundary was to be important for policy or management, it would be necessary to collect new data on the changes in biodiversity from the waters off northern Labrador up into the Davis Strait. It would also be timely to review the new modelling of physical ocean processes in the north that has been conducted since the last time these biogeographic units were investigated.

For the Gulf of St. Lawrence, there are differences in the fish, plankton, and benthic communities between the southern Gulf and the northern Gulf, and some affinities of those communities in the southern Gulf with those in the Scotian Shelf biogeographic unit. Weaker affinities are also present between those communities in the northern Gulf and those in the southern Newfoundland biogeographic unit. However, the dominant oceanographic processes provide coherence to the Gulf of St. Lawrence as a distinct biogeographic unit, with a major, first-order subdivision between the northern and southern Gulf.

In general, less information is available about the biogeography of the benthos than the fish and plankton. More investigation of benthic communities and their affinities might reveal some different patterns in the benthos than reflected in these major subdivisions. This may be particularly the case with regard to the Gulf of St. Lawrence biogeographic unit.

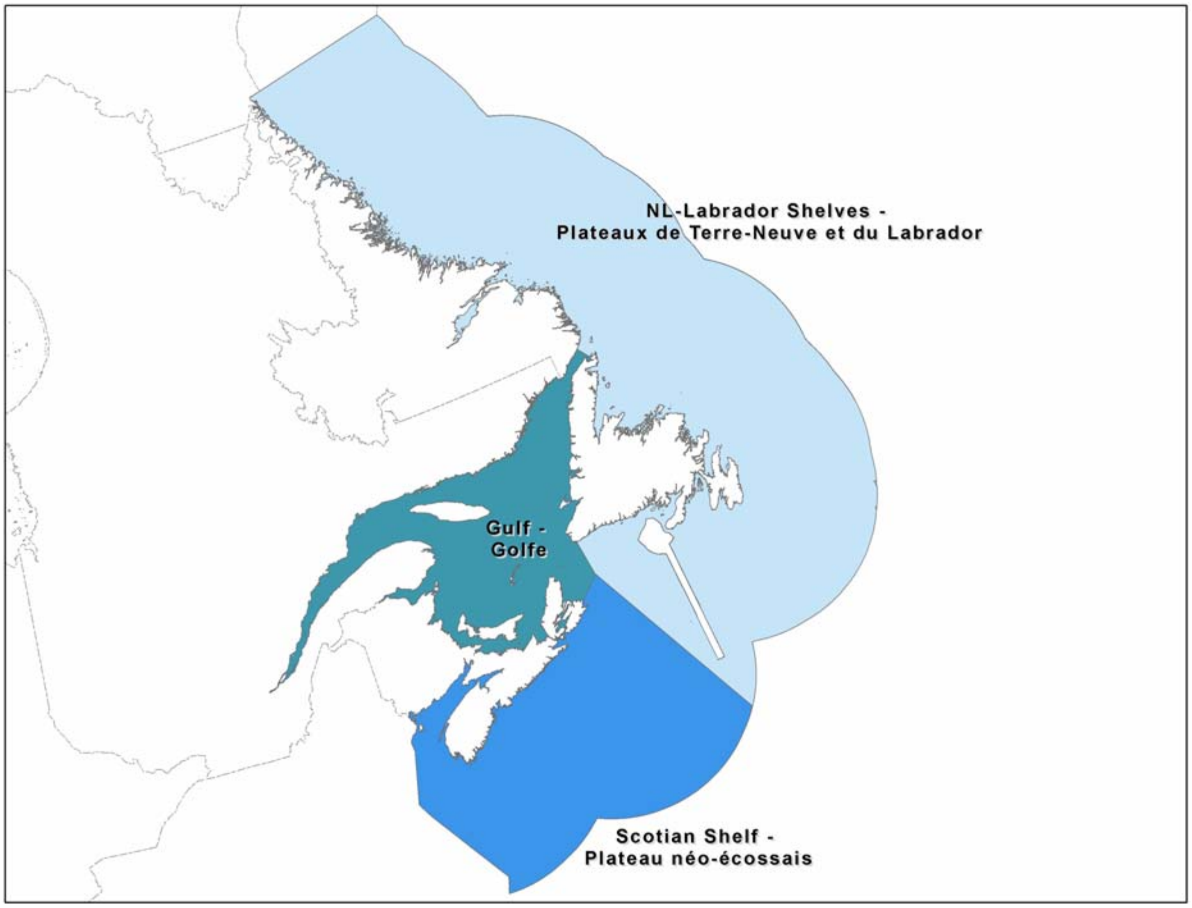

Figure 2. Accepted major biogeographic units for the Canadian Atlantic Ocean. Units are delineated as follows: Newfoundland-Labrador Shelves, Gulf of St. Lawrence, and Scotian Shelf.

Pacific Ocean

It was agreed that four biogeographic units were appropriate for the Pacific Ocean at the coarsest spatial scale (Figure 3). These major biogeographic units were selected based on those identified by the Fisheries and Oceans Canada classification system. The four major biogeographic units for the Pacific are:

i) a complex *Northern Shelf Zone* (including the Queen Charlotte Sound, the Hecate Strait, the west coast of the Queen Charlotte Islands, the Queen Charlotte Strait, and Northwest Vancouver Island);
ii) the Strait of *Georgia*;
iii) a *Southern Shelf* (off West Vancouver Island which includes the Strait of Juan de Fuca); and
iv) a large *Offshore Pacific Zone* extending outward from the shelf break which includes the Alaska Gyre, the California Gyre, and a transition zone.

There is a permanent transition zone which generally begins near Brooks Peninsula and extends north to the Northern Shelf Zone and out to the continental shelf break. The southern boundary of this transition zone can move north as much as several hundred kilometres with strong El Niño conditions, extending it even further along the Pacific coast. Although the boundaries of this transition zone are generally known, they are not fixed in space and management should be designed to be responsive to the dynamic nature of this area (in particular changes in biodiversity and oceanographic conditions).

There are major inshore and offshore differences in the Northern Shelf Zone, particularly in the fiordlands, but it was agreed that those are best represented as a major, first-order subdivision in a hierarchical system. Also, based on the unique characteristics of the Alaska Gyre, the transition zone, and the California Gyre, the Offshore Zone should be subdivided into three biogeographic units at the next level of biogeographic subdivision.

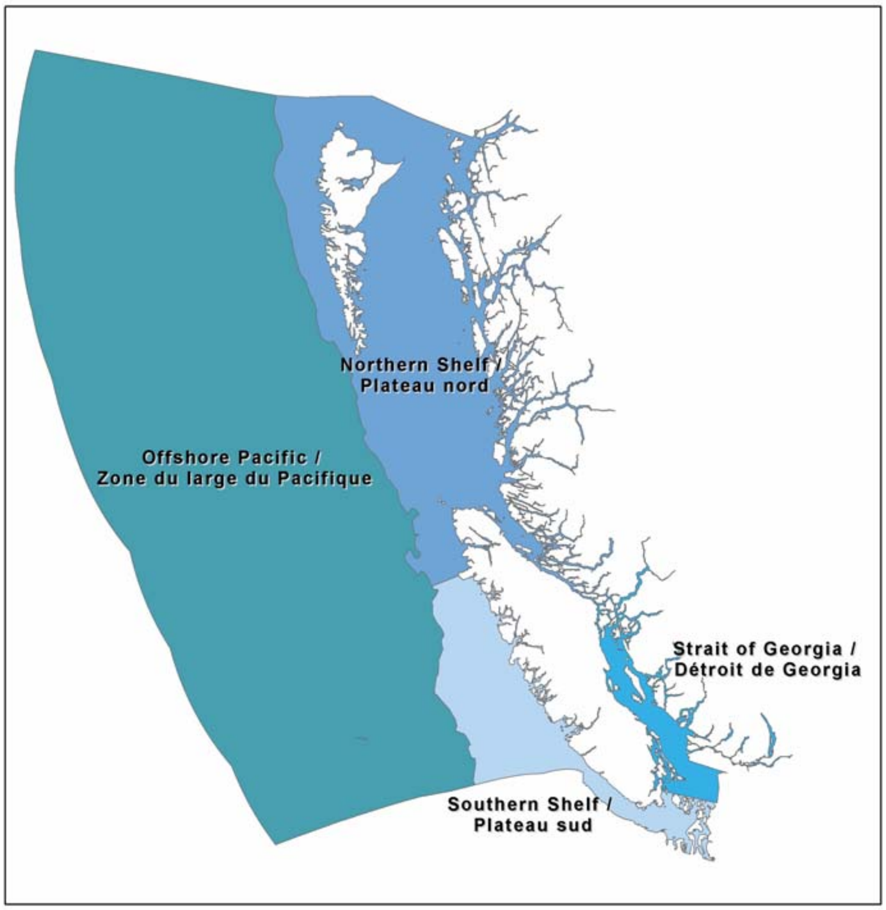

Figure 3. Accepted major biogeographic units for the Canadian Pacific Ocean. Units are delineated as follows: Northern Shelf, Strait of Georgia, Southern Shelf, and Offshore Pacific Zone.

Arctic Ocean

It was agreed that five major biogeographic units are appropriate for the Arctic Ocean at the coarsest spatial scale: the *Arctic Basin*, the *Arctic Archipelago*, the *Western Arctic* (includes the Beaufort Sea, the Queen Maud Gulf, and Viscount-Melville Sound), the *Hudson Bay Complex* (includes the Hudson Strait, Foxe Basin, James Bay, and Hudson Bay), the *Eastern Arctic* (includes Lancaster Sound and the Baffin Bay-Davis Strait) (Figure 4). These major biogeographic units are based on those identified in the Parks Canada classification system.

Major process-related determinants for the selection of the biogeographic units were bathymetry, influence of freshwater inflows, and distribution of multi-year ice. Several of the units have major, first-order subdivisions that could be considered should a finer spatial scale be desired:

a) Hudson Bay Complex – Hudson Bay, James Bay, Hudson Strait, and Foxe Basin;
b) Eastern Arctic – Lancaster Sound and Baffin Bay-Davis Strait; and
c) Western Arctic – Beaufort Sea-Amundsen Gulf, Queen Maud Gulf, and Viscount Melville Sound.

The Arctic is a very dynamic system with high inputs of freshwater occurring on a regular basis. With changes in freshwater magnitude and occurrence expected, especially considering climate change, the boundaries between the biogeographic units may change in the future. In particular, the transition zone between the Eastern Arctic biogeographic unit and the Newfoundland-Labrador Shelves unit is unknown and data limited. Without more information, it is unknown if the boundary between these biogeographic units is a stable gradient or some other pattern.

Figure 4. Map representing accepted major biogeographic units for the Canadian Arctic Ocean. Units are delineated as follows: the Arctic Basin, the Arctic Archipelago, the Western Arctic, the Hudson Bay Complex, and the Eastern Arctic.

Specific Guidance on Subdividing the 12 Canadian Marine Biogeographic Units

At the first level of subdivision below the 12 major biogeographic units, where knowledge exists to delineate functional food webs, their geographic scale should receive strong consideration. Scientific strategies for delineating functional food web scales are well-developed. These strategies focus on the interactions of major functional feeding groups, which generally occur on scales larger than the ranges of individual predators and prey.

This approach may produce more biogeographic units than would arise from solely conducting a pattern analysis of the species occurrence data, depending on the nature of the trophic relations in the area. It is plausible that very large areas may show few coherent discontinuities in species composition, but have more than one functional food web present. If functionally differentiated food webs can be identified, they should be represented in the biogeographic subdivisions of the larger area.

The other major consideration in the higher-order subdivisions of the 12 primary biogeographic units are the major water mass and/or bathymetric features. Specifically, those that are likely to retain populations increase the likelihood that they interact within rather than across feature boundaries. Pressure barriers that are present at some depth zones along continental shelves may be important to consider when seeking subdivisions of the major biogeographic units.

The scale of biogeographic subdivisions appropriate for reporting, policy development, and management in near-coastal areas is likely to be finer than in offshore areas. The considerations and approaches outlined above for marine areas are relevant for the coastal areas as well, but on smaller scales where habitat features of the seabed and coastal inputs to the ocean both strongly influence biogeographic patterns for the entire water column. How far offshore these coastal scale factors will be dominant is case-specific.

In general, for the finer-scale biogeographic subdivisions, and particularly for the coastal areas, threat analyses will play an important role in matching the scale of the biogeographic unit(s) to management and policy needs. Threat analyses should take account of both the scale of the pressures (anthropogenic or environmental) and the scales of occurrence of the ecosystem features vulnerable to the threats, in informing which scale for finer biogeographic units is appropriately matched to particular management needs. The choice of scale and units also needs to take into account the possibility that spatial management of threats may prompt displacement of the activity posing the threat. The planning units should be large enough and homogeneous enough (relative to suitability for the activity being managed) to allow consideration of future as well as present spatial patterns of the threat(s). It is also noted that some threats may have quite local scales, while those of others (e.g. climate change) may be very large. Strategies for selecting appropriate biogeographic units when undertaking integrated management of multiple threats, potentially operating at multiple scales, warrants further attention.

It is expected that knowledge about the strengths and weaknesses of alternative approaches to identification of biogeographic units, particularly at moderate and small scales, will grow as experience is gained with use of spatial management tools. Data on species occurrences and knowledge of ecological processes giving coherence to species distributions will also increase over time. It will be important to periodically revisit the finer scale biogeographic units being used, to ensure that they have a sound ecological basis, and are appropriate for the policy, management, and reporting needs of government. It is also essential to fully document the information used, the approaches considered, and the decisions made, when there are scientific efforts to identify biogeographic units for use in policy and management.

CONCLUSIONS AND SCIENCE ADVICE

High-level spatial units have been identified for each of Canada's three oceans which are primarily based on oceanographic and bathymetric similarities. For each ocean these units are:

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Transition zones are important features to consider and should be taken into account when delineating boundaries between biogeographic units.

There are important scales below the highest spatial scale identified which are defined by similar features, and subdivision of larger biogeographic units should consider bathymetry and oceanography as well as food web structure and benthic communities.

All available ecological information and data (including experiential/traditional knowledge) should be taken into consideration when forming hypotheses and testing should consider these data sources, as well as pattern analysis when appropriate.

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