KEY ELEMENTS IN THE DEVELOPMENT OF A HIERARCHICAL MARINE ECOLOGICAL CLASSIFICATION SYSTEM TO SUPPORT ECOSYSTEM APPROACHES TO MANAGEMENT IN PACIFIC CANADA

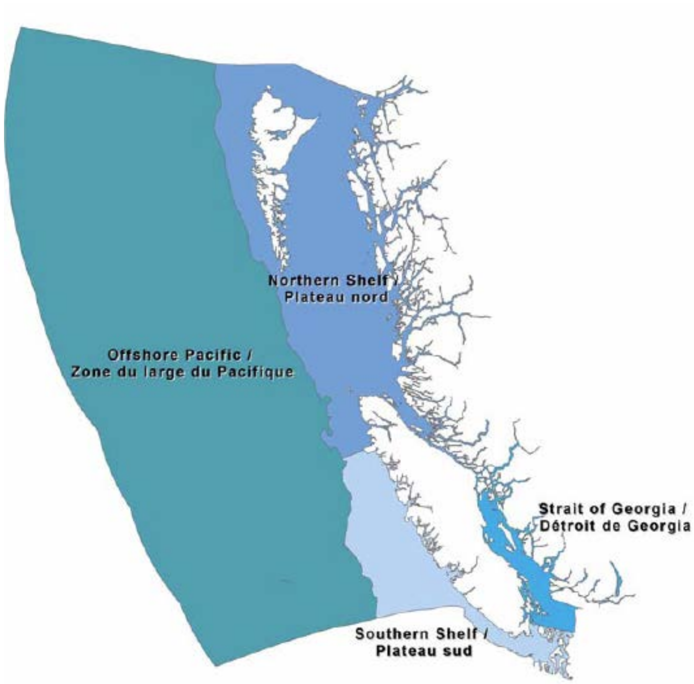

Figure 1: Four bioregion biogeographic units identified for the Canadian Pacific Ocean. Units are delineated as follows: Northern Shelf, Strait of Georgia, Southern Shelf, and Offshore Pacific. Taken from (DFO 2009).

Context:

DFO has identified twelve major biogeographic units for Canada's three oceans (four in the Pacific, five in the Arctic, and three in the Atlantic), which represent high-level spatial units that can be scaled-down (or scaled-up) into smaller (larger) units that are ecologically meaningful. The level of subdivision to be achieved with a biogeographic classification system will be guided by management or policy objectives. Development of marine biogeographic classification systems is guided by Canada's endorsement of Decision IX/20 at the 9th meeting of the Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) on the conservation and sustainable use of biodiversity in marine areas beyond national jurisdiction and the application of the scientific and technical guidance for MPA network development.

Advice was requested by Oceans and Ecosystems Management staff to provide a biogeographic framework to disaggregate the four major bioregions in Pacific Canada marine waters into ecologically meaningful sub-bioregion scale units. The advice and guidance on the development of an ecologically meaningful sub-bioregion scale biogeographic framework will be used to inform Ecosystem Approaches to Management (EAM) as implemented by DFO, to support the establishment of an ecologically coherent network of marine protected areas (MPAs) in Pacific Region, and to inform coastal zone management and planning activities at local scales in Pacific Canada marine waters.

This Science Advisory Report is from the February 12-14, 2013 Regional Peer Review meeting on Biogeographic Classification Framework to Inform Bioregional Marine Protected Area Network Design in Pacific Region. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- The key elements of a framework to subdivide the four major bioregions in Pacific Canada marine waters into ecologically meaningful sub-bioregion scale units were reviewed. The advice and guidance on the development of a biogeographic framework is intended to help inform Ecosystem Approaches to Management (EAM) of marine biodiversity including fisheries resources, the establishment of a network of bioregional marine protected areas (MPAs) in Pacific Region, and contribute to coastal zone management and planning activities at local scales in Pacific Canada marine waters.

- The key elements of a science-based biogeographic framework include:
  1) Consideration of species and habitat diversity within both the pelagic and benthic realms,
  2) Knowledge of management objectives and their associated spatial requirements,
  3) The application of a suite of tools to analyze and summarize biotic and abiotic data,
  4) The identification of important data sources and gaps, and
  5) A hierarchical ecological classification system.

- A prototype Pacific marine ecological classification system (PMECS) framework with standardized terminology and descriptors of both benthic and pelagic realms and information on the spatial extent and data resolution at each level in the hierarchy was developed during the meeting. The PMECS is expected to represent abiotic and biotic diversity in Canadian Pacific marine waters because it is based on similar ecological classification systems that have been successfully applied in terrestrial and other marine environments.

- Development of the PMECS framework was guided by case studies and recommendations of experienced practitioners in Pacific and Maritimes Regions.

- Twenty case studies were assessed to better understand the types of species distribution models, abiotic distribution models, and expert systems, presently used to describe biotic and abiotic diversity in the pelagic and benthic realms of Canadian Pacific marine waters, to understand the data requirements and gaps in these systems, and to identify key and common tools and approaches in marine ecological classification systems.

- It was recognized that it is important to capture and document uncertainty and drivers of uncertainty (e.g., data bias, lack of data, lack of knowledge) at each step in the framework.

- Some uncertainties were identified during the case study reviews and are documented by data type (acoustic bathymetry and bottom type, water properties, abiotic and biotic surveys, satellite, photographic, and video imagery). Procedures to address some of these issues were discussed, but guidance will need to be developed to ensure that uncertainty is documented for each of the key elements as the PMECS is tested and implemented.

- The PMECS is hierarchical with multiple levels for down-scaling spanning bioregions to micro-communities and their associated spatial scales (extent and resolution).

- Although the PMECS is expected to be used primarily to down-scale or subdivide larger biogeographic units, it has an implicit capability to scale up to larger global levels than bioregions.

- Adaptability of a biogeographic framework to new data, new model outputs, and new knowledge is recognized as an important characteristic; guidance will need to be developed on the process for incorporating new information

- It is recommended that the PMECS be considered as Pacific Region Science guidance for classifying marine biotic and abiotic diversity in Pacific Canada marine waters as ecosystem approaches to management are implemented by DFO.

- It is recommended that the performance of the PMECS prototype be evaluated with existing data and applying appropriate metrics (e.g., robustness, stability of results) and it is recommended that a method be developed to integrate the data sources into the prototype PMECS, with consideration given to current best practices on model integration, uncertainty characterization, and data gap and overlap (collection effort) analysis.

- DFO is currently conducting climate change research on trends and projections and it is recommended that the performance assessment of the proposed PMECS make use of this research.

- It is recommended that the utility of the PMECS be evaluated with respect to management objectives at varying spatial scales.

- It is recommended that a parallel pilot program be developed to evaluate the performance of several tools (e.g., predictive models of abiotic and biotic distributions) using identical high quality abiotic and biotic datasets from Pacific Canada marine waters to provide guidance on model choices to users of PMECS.

- The PMECS is data intensive and will involve DFO and numerous partners in building and contributing to the elements of the system, which includes providing and analyzing data, data products, and models.

- Based on long-standing terrestrial experience, functioning ecological classification systems are built on common standards for data collection, storage and sharing, and a community of partners. Standards for data collection, storage, and sharing will be needed as implementation of the PMECS proceeds.

- It is recognized that there is a gap in the coordination of GIS capacity for geospatial planning and management internally within DFO and externally with other agencies/partners. Filling this gap will be important to the successful implementation of the PMECS.

- The advice and guidance arising from this Regional Peer Review are steps in fulfilling national commitments to ensure that adequate MPA network design is achieved in Pacific Canada marine waters and to international commitments to apply the scientific criteria in Annexes I and II of Decision IX/20 of the United Nations Convention on Biological Diversity.

INTRODUCTION

A National Science Advisory Process (NAP) was conducted by the Canadian Science Advisory Secretariat (CSAS) of Fisheries and Oceans Canada (DFO) in June 2009 to review biogeographic classification systems and inform the development of a framework and principles which could be applied in a biogeographic classification system assessment (DFO 2009). This review identified twelve major biogeographic units (bioregions) for Canada's oceans (four in the Pacific, five in the Arctic, and three in the Atlantic). The four bioregion units in Canada’s Pacific waters are the Strait of Georgia, the Southern Shelf including Juan de Fuca Strait and the west coast of Vancouver Island to Brooks Peninsula, the Northern Shelf, from Brooks Peninsula to Dixon Entrance and including Queen Charlotte Sound and Hecate Strait, and the Offshore Pacific, including the continental slope and abyssal plain to the 200 mile boundary. Each of these bioregion units represents a "maximum scale" that can be subdivided into smaller units that are ecologically meaningful at finer scales. The appropriate level of disaggregation of these higher level bioregions will depend on the management objective(s) or policy requirements since information on species occurrences and ranges becomes increasingly influential in delineating smaller units. Based on these conclusions, the NAP recommended that discussion and guidance on finer scales of biogeographic units should occur and come from the various DFO regions through formal regional processes.

This report summarizes discussion and guidance from DFO Pacific Region Science on the key elements required to describe biotic and abiotic diversity at finer biogeographic scales in response to a joint request from Fisheries and Aquaculture Management and Ecosystem Management Branches. This regional advice and guidance will support DFO Pacific Region in meeting its objectives related to conserving biodiversity, productivity and habitat and it will contribute to coastal zone management and planning activities at local scales in Pacific Canada marine waters. Other government departments (Parks Canada and Environment Canada) along with the Province of British Columbia, First Nations, and other agencies involved in the Marine Protected Areas Implementation Team (MPAIT) are relying on this guidance to facilitate collaborative MPA network development and implementation.

ASSESSMENT

Resource management issues vary in scale (spatial extent and resolution) of information needs from local coastal marine use issues to regional planning issues. Information on the vulnerability, sensitivity and resilience of biological diversity, habitat diversity, and community properties (ecosystem diversity) needs to be integrated across scales so that local changes in diversity can be evaluated in relation to bioregional and global impacts and vice versa. The information needs for bioregional scale issues such as development of a network of MPAs will be driven by conservation objectives. Conservation objectives for a representative network of MPAs designed to conserve and protect the structure and function of marine ecosystems fall into three major categories: provision of an insurance policy against catastrophic events; a baseline to assess the level of natural variations and as a potential seed stock for rehabilitation of impacted species (Rice and Houston 2011).

The focus of the working paper was to discuss the development of an assessment framework for Pacific Canada to contribute to MPA planning of marine species and habitat diversity at regional coast-wide scales and to contribute to coastal zone management and planning activities at local scales. The goal of the framework, when implemented, is to provide resource managers with a plan for a collaborative, coordinated, pragmatic and science-based approach for generating inventories and maps of marine species and habitat diversity at appropriate spatial extents and resolutions.

Four major bioregions representing a maximum scale for management were identified for Pacific region (DFO 2009). Because it is logistically difficult and expensive to sample diverse marine biota at high resolution (e.g., 1:5,000) over a large spatial expanse (e.g., a bioregion), there is a need to understand some of the tools available to more effectively describe marine species and habitat distributions. Ultimately, these tools will be used to generate data upon which ecological classification and modeling systems are applied. The key elements of a science-based framework and some of the important considerations when addressing the central question of what biodiversity occurs where within a bioregion are reviewed below.

Twenty case studies were assessed with a questionnaire and literature review to better understand the types of biotic and abiotic distribution models, expert systems, and classification systems used presently in Pacific region to describe species and habitat diversity in the pelagic and benthic realms of Pacific marine waters, and to understand data requirements and gaps. This information was supplemented with information from the scientific literature, and is summarized for the pelagic realm and for the benthic realm. The main intent of the assessment was to understand where Pacific region stands today with respect to the application and development of methods to generate data for mapping species and habitat diversity in benthic and pelagic realms.

A conceptual overview of the present status of Pacific region with respect to generating maps of biodiversity is shown in Figure 2. Several types of survey data, multi-beam acoustic backscatter data, optical data, and water property data are used to derive abiotic and biotic information in Pacific waters. These data have been used in several species distribution models, abiotic distribution models, Delphic ecological classification schemes, and habitat classification models and the outputs from these models, schemes, and systems have been used in various combinations to produce maps of biodiversity in Pacific region. The case-study assessment revealed that:

1) Species and habitat diversity mapping in Pacific region tends to consist of one-off, single-species based projects using relatively disjoint data sets,
2) No single habitat classification system has been used in the benthic or pelagic realms,
3) A few different species distribution models have used in the region with no clear guidance on ‘best’ practices or structured application,
4) Relatively little research has been directed at pelagic realm diversity, and
5) Large gaps in acoustic data, particularly interpreted backscatter (i.e., bottom type), are limiting sufficient description of benthic realm diversity.

The key elements of a science-based biogeographic framework include:

1) Consideration of species and habitat diversity within both the pelagic and benthic realms,
2) Knowledge of management objectives and their associated spatial requirements,
3) The application of a suite of tools to analyze and summarize biotic and abiotic data, and
4) The identification of important data sources and gaps.

Biotic and abiotic diversity in pelagic and benthic realms

A biogeographic framework needs to reflect the scale of the application and address the key ecological features within both the pelagic and benthic environments. Although these realms are considered separately, they are linked (DFO 2009), and thus the approach is more pragmatic than ecologically ideal. As the subdivision of a bioregion proceeds, information on species occurrences and ranges becomes increasingly influential in delineating units relative to abiotic data such as bathymetry and oceanographic processes (DFO 2009).

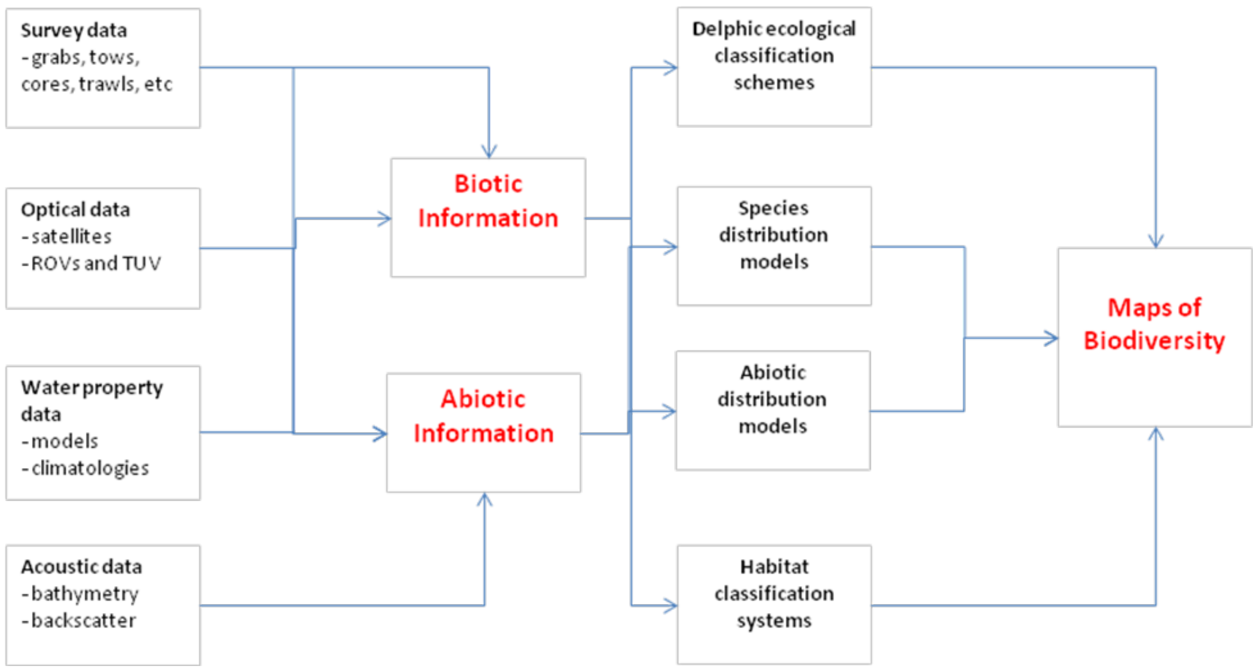

Figure 2. The present day relationships between data, models and systems, and biodiversity maps in Pacific Canada

Management objectives and spatial requirements

Hierarchical habitat classification approaches, including ecosystem modeling and ecological classification schemes, are tools to accomplish a given set of management objectives (Lund and Wilbur 2007). A critical element of the framework is for managers to clearly identify their objectives and requirements for biodiversity data since this information will guide the selection of tools and to identify the quality and type of data required. Management or policy objectives also provide guidance on the level of subdivision to finer-scale units that must be achieved with the framework.

Tools to analyze and map biotic and abiotic diversity

Species Distribution Models

Species distributions in marine systems are commonly described using species distribution models (SDMs). Most published SDMs consider large vertebrate taxa such as fish and marine mammals; less modeling has been done for zooplankton, benthic invertebrates and phytoplankton likely because there are few ways available to adequately represent the dynamics at the high resolution necessary for these taxa. SDMs typically assume that the abiotic environment exerts a dominant control over the natural distribution of a species. SDM modeling based on presence-absence data is more likely to reflect the existing distribution, or realized niche, of a species, while SDMs based on presence-only data are more likely to describe the potential species distribution (Palialexis et al. 2011). These authors also concluded that techniques using species presence-absence data are generally more accurate in predicting species distributions especially when derived from designed surveys and using a 'sufficient number' of high resolution abiotic variables. A wide variety of SDMs have been used in marine studies including generalized additive models, generalized additive mixed models, regression tree models, multivariate analysis and regression splines, maximum entropy, support vector machines, general algorithm for rule-set prediction, envelope scores, bioclimatic envelope models, environmental distances, and associative neural network and artificial network ensembles. Palialexis et al. (2011) noted that both the fitting efficiency and predictive capacity that characterize an SDM are highly dependent upon the quality of the data used. Although some filtering will be required to select appropriate models, SDMs are essential for spatial mapping of pelagic and benthic realm species diversity in Pacific region.

Abiotic Distribution Models

Abiotic distribution models (ADMs) segment continuous abiotic marine properties into regions or units where environmental conditions are similar and yet different enough from neighbouring regions to warrant calling them distinct regions. These units are believed to reflect differences in biological characteristics at the species level or a higher level such as community based on the assumption that differences in abiotic properties will result in distinctive shifts in biotic composition. These concepts are discussed for the benthic realm and are assumed to be relevant in the pelagic realm as well. However, species-environment relationships are seldom linear and there are few examples in the marine literature providing convincing verification of habitat-species surrogacy either because the spatial scales of abiotic and biotic variables used in models and analysis are mismatched or because there are inherent complexities in marine system that cannot be explained with a simple paradigm such as habitat-species surrogacy (Brown et al. 2011). Ultimately, abiotic distribution modeling can provide useful representations of environmental patterns and offer a starting point for understanding and mapping habitat diversity. However, no matter how abiotic data layers are analyzed or combined, at some stage it is necessary to combine abiotic and biotic data in order to create a true "habitat" map (Brown et al. 2011).

Delphic Ecological Classification Schemes

Modified Delphic (or expert-driven) processes have been used in Canada, Australia, and the United States to identify marine areas that should receive enhanced management in Canada, Australia, and the United States. The thematic layers produced from the ecologically and biologically significant areas (EBSA) process in Canada, which is a Delphic approach to classification, mapped biotic information of species of fish, invertebrates, birds, marine mammals, reptiles and abiotic information on oceanographic features. The EBSA process as applied in the Pacific region used a large number of biotic data sets to identify congruence between biologically important areas and oceanographic features, including vertically mixed waters via tidal currents, thermally and salinity driven stratified waters, the Fraser River plume, and biological fronts, identified by regional experts. The value of the EBSA approach is that it used multiple taxa data and abiotic information to subdivide major biogeographic units, but it is limited by its focus on uniqueness, aggregation, fitness consequences, naturalness and resilience dimensions rather than pelagic species or habitat distribution. The EBSA process identified EBSAs in three of the four bioregions for Pacific coast of Canada including the northern shelf, the southern shelf, and the Strait of Georgia (SoG). The EBSA process proved to be a relatively quick way to derive a complex classification system and it had fewer errors in the analysis and interpretation of the datasets owing to the guidance provided by the resident experts. The use of experts is important because they understand the limitations and biases in data collections, especially when deriving spatial and temporal patterns. Experts are also needed to provide a view of the data that meets confidentiality agreements because not all sources of data are readily available publicly.

Application of any of the reviewed tools (SDMs, ADMs, Delphic models, etc.) will generate questions about which tools should/could be used in addressing a wide variety of management and policy objectives. At present, guidance on the tradeoffs between different model types, i.e., when to use abiotic model versus SDM versus a Delphic process, is limited. Standardized methods and protocols should be developed to support both the data collection and application requirements of these tools for their use in Pacific Region.

Marine ecological classification systems

Marine ecological classification systems place species and habitat distribution data into an ecological and management context. Most marine classification schemes assess similar abiotic and biotic variables in a local area and then assign standard names to describe sub-units. An effective marine habitat classification system standardizes terminology, organizes data in a logical manner, and allows features to be coded for GIS analysis. All classification systems require consistent naming and coding systems to organize the data to facilitate effective communication to users. The most effective classification systems are organized in a nested hierarchy, with top levels describing large scale (coarse) abiotic features (e.g., continental shelf), while lower classes in the hierarchy describe biotic features in greater detail and spatial resolution (e.g., eelgrass meadow). The number of classes and levels in a hierarchy depends upon the physical and biological heterogeneity of the marine environment, data availability, and the spatial scale and resolution as determined by project objectives. Thus, coastal and marine areas can be classified and mapped as narrowly or as broadly as the data and objectives require. Ultimately, a marine ecological classification system should be viewed as an evolving tool to standardize technical jargon and organize ecological information to facilitate ecosystem management (Lund and Wilbur 2007).

Effective marine ecological classification system possess four keys components:

- They incorporate both abiotic and biotic descriptors and modifiers to describe ecological sub units;
- They are hierarchical, and use abiotic data to classify coarse scale abiotic features (e.g., submarine canyon) at the top of the hierarchy, and include more biotic data to classify finer spatial scale features (e.g., eelgrass meadow) at lower levels of the hierarchy;
- They use a standard nomenclature to describe the abiotic and biotic sub-units; and
- They do not generate new sub-units from observational data or from modeled data, they merely describe ecological features.

Pacific marine ecological classification system (PMECS)

Based on a review of Pacific region marine case studies, no single ecological classification system has been used consistently and systematically in the pelagic and benthic realms. As a result, the tools currently used to describe Pacific region marine diversity are applied with little or no reference to a classification system.

Information generated from species distribution models, abiotic distribution models and/or Delphic schemes must be processed through a hierarchical, ecosystem-level classification system to adequately map biotic and abiotic diversity, and to facilitate comparison of diversity information within and among the Pacific coastal bioregions. Several hierarchical frameworks are proposed in the literature but the key to moving forward in the framework is to choose a classification system that:

1) Is designed with ecosystems in mind,
2) Is presently used, and
3) Is providing information at the spatial extent and resolution required by resource managers.

A central component of the science-based marine biogeographic framework for Pacific region is the development and application of a hierarchical ecosystem level classification system. Last et al. (2010) developed a hierarchical framework for classifying Australian seabed biodiversity. This Australian approach along with a scheme used in Maritimes region (Greenlaw et al. 2013) were used as templates to derive the prototype Pacific marine ecological classification system (PMECS) for Pacific Canada marine waters (Table 1) during the Regional Peer Review meeting. PMECS shares characteristics of the system proposed by Last et al. (2010) in that it explicitly recognizes the overarching influence of fine-scale biodiversity patterns and captures the scale-dependence and hierarchical organization of the biota in both the pelagic and benthic realms. At each level of the hierarchy, attributes and surrogates are defined to reflect the scale and range of biogeographic and ecological processes that determine the spatial and temporal distribution of marine biota. The PMECS is hierarchical with multiple levels spanning bioregions to micro-communities and their associated spatial scales (extent and resolution) and it uses standardized terminology and descriptors of both benthic and pelagic realms developed for Pacific Canada marine waters. Although the PMECS is based on similar ecological classification systems that have been successfully applied in terrestrial and other marine environments and should represent abiotic and biotic diversity in Pacific Canada marine waters, it’s performance has not been tested at present.

The case studies revealed gaps and problem areas were identified with respect to data and models. Abiotic and biotic data from a variety of sources including government, industry, academia, environmental organizations, and community groups are required to feed the models, schemes, and systems in the framework. Effective collaboration on this scale will require standards for the collection, management, storage and accessibility of data. Furthermore, an analysis of current data gaps and overlap with current data collection efforts is needed to identify areas in which investments in new data acquisition are needed. At present, there is a large, evolving, and growing literature on the use of SDMs, but no standardized guidance of the most “appropriate” SDMs to generate data for biodiversity mapping in Pacific region. Testing of several SDMs using the same abiotic and biotic datasets to understand their utility in the Pacific region context in needed. Mapping of biotic diversity in both the benthic and pelagic realms would benefit greatly from the development of abiotic distribution models that are tested with biotic data.

Sources of Uncertainties

It is expected that knowledge gaps and data uncertainty will be challenges as the PMECS is applied. Further data collection and research will be needed to close these gaps.

Marine ecological classification systems do not capture the temporal component well. Temporal change can be accommodated with modifiers to the classification and the implementation of a process for updating the system on an ongoing basis.

CONCLUSIONS AND ADVICE

The development of a biogeographic framework to disaggregate the four major bioregions in Pacific Canada marine waters into ecologically meaningful sub-bioregion scale units are outlined in a prototype Pacific marine ecological classification system (PMECS). PMECS uses standardized terminology and descriptors of both benthic and pelagic realms and information on the spatial extent and data resolution at each level in the hierarchy. The PMECS is expected to represent abiotic and biotic diversity in Canadian Pacific marine waters because it is based on similar ecological classification systems that have been successfully applied in terrestrial and other marine environments. The PMECS is hierarchical with multiple levels spanning bioregions to micro-communities and their associated spatial scales (extent and resolution).

The key elements of a science-based biogeographic framework include:

1) Consideration of species and habitat diversity within both the pelagic and benthic realms,
2) Knowledge of management objectives and their associated spatial requirements,
3) The application of a suite of tools to analyze and summarize biotic and abiotic data,
4) The identification of important data sources and gaps, and
5) A hierarchical ecological classification system.

Table 1. Prototype design of the Pacific Marine Ecological Classification System (PMECS) developed at the Pacific RPR Meeting, 12-14 Feb 2013.

Level	Unit	Spatial extent	Spatial resolution	Benthic description	Pelagic description
0	Realm	10,000's km	1,000 km^2	Broad-scale geographic units such as the north Pacific Ocean.	
1	Province	1,000's km	~100 km^2	Broad-scale geological units such as continental blocks, basins and abyssal plains.	Zoogeographic provinces (e.g., Oregonian, Aleutian).
2	Bioregions	1,000's km	~10-100 km^2	Distinctive, recurring and small-scale physical oceanographic processes (e.g., separation between California Current and Alaska Current regions). Four major bioregions in Pacific marine waters. Research and analysis is required to understand how marine species diversity differs among these Bioregions.	
3	Ecosections	100's-1,000's km	~10-100 km^2	Ecosections are primarily related to abiotic pelagic oceanographic processes; relation to benthic ecosystems requires further research.	Distinct, recurring and large--scale physical oceanographic processes and topographic or bathymetric features. For example, the Vancouver Island Coastal Current and the Juan de Fuca Eddy.
4	Bathomes	100's-1,000's km	~10 km^2	Nearshore and littoral zone, continental shelf, continental slope, abyssal plain.	Neritic zone, epipelagic zone, mesopelagic zone, bathypelagic zone, abyssopelagic zone.
5	Geozones	100s km	1-10 km^2	Mappable areas with similar seabed geomorphology and usually with distinct biota (e.g., seamounts, canyons, rocky banks, inlets).	Mappable structures based on oceanographic processes assumed to be surrogates for distinctive biological assemblages (tidal mixing areas, fronts, upwellings).
6	Primary biotopes	10's-100's km	<1km^2	Nested within Geomorphic Units are soft, hard or mixed substrate-based units, together with their associated substrate-based units and their associated biological communities.	Combinations of physical and chemical water property data (sea surface temperature and salinity, dissolved oxygen, stratification) and associated biological communities.
7	Secondary biotopes	100's-1000's m	100's m^2	Smaller-scale abiotic and biotic sub structural units characterized by specific types of substrate (e.g., seapen beds, sponge reefs).	Detailed combinations of physical data to describe water masses (e.g., chlorophyll maxima, pycnocline).
8	Biological facies	100's m	<10 m^2	Fundamental unit for management of biodiversity. Mappable units that act as surrogates for all levels below. (e.g., species of seagrass, group of hard corals or sponges).	Pelagic (mobile) taxa less informative descriptors of facies than sessile plants and animals.
9	Micro-communities	10's m	< 1 m^2	Assemblages of species that depend on member species of the Biological Facies, e.g., holdfast communities in giant kelp.	
10	Species	Discussion of the hierarchy did not proceed to these lower levels as their descriptions are inconsistent with the hierarchical nature of the benthic and pelagic descriptions of higher levels.			
11	Populations				
12	Genes				

Capturing and documenting uncertainty and the drivers of uncertainty (e.g., data bias, lack of data, lack of knowledge) at each step is an important attribute of a biogeographic framework. Some uncertainties were identified during the case study reviews and were documented by data type (acoustic bathymetry and bottom type, water properties, abiotic and biotic surveys, optical). Procedures to address some of these issues were discussed, but guidance will need to be developed to ensure that uncertainty is documented for each of the key elements as the PMECS is tested and implemented.

A critical attribute in the implementation of a biogeographic framework is the ability to incorporate new data, new model outputs, and new knowledge in an ongoing manner. Moving forward with this process will require the development of guidance on the process for incorporating new information and regenerating appropriate outputs from the framework.

There is long-standing experience with the application of ecological classification systems in the terrestrial realm. Based on this experience, functioning ecological classification systems are built on common standards for data collection, storage and sharing, and a community of partners. Standards for data collection, storage, and sharing will be needed as implementation of the PMECS proceeds.

Finally, there is a gap in the coordination of GIS capacity for geospatial planning and management internally within DFO and externally with other agencies/partners. Filling this gap will be important to the successful implementation of the PMECS.

Recommendations

It is recommended that the PMECS be considered as Pacific Region Science guidance for classifying marine biotic and abiotic diversity in Pacific Canada marine waters as ecosystem approaches to management are implemented by DFO.

It is recommended that the performance of PMECS be evaluated with existing data and applying appropriate metrics (e.g., robustness, stability of results).

It is recommended that a method be developed to integrate the data sources into the prototype PMECS, with consideration given to current best practices on model integration, uncertainty characterization, and data gap and overlap (collection effort) analysis.

DFO is currently conducting climate change research on trends and projections and it is recommended that the performance assessment of the proposed PMECS make use of this research.

It is recommended that the utility of the PMECS be evaluated with respect to management objectives at varying spatial scales.

It is recommended that a parallel pilot program be developed to evaluate the performance of several tools (e.g., predictive models of abiotic and biotic distributions) using identical high quality abiotic and biotic datasets from Pacific Canada marine waters.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 12-14, 2013 Regional Peer Review meeting on Biogeographic Classification Framework to Inform Bioregional Marine Protected Area Network Design in Pacific Region. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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