

PROPOSED PHYSICAL MARINE REPRESENTATION METHOD and DATA SOURCES FOR the BCMCA

Working report including expert feedback
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1.0 Introduction

1.1 Objective of Report and Overview of the Expert Review Process to Define Physical Marine Representation

To date, five expert workshops have been conducted as part of the BCMCA project. These workshops identified conservation features and data sources for seabirds, marine plants, marine mammals, marine invertebrates and marine and anadromous fish. The final ecological component of the BCMCA project involves representing the physical marine diversity of British Columbia (BC). The central premise for including broad scale physical marine features in the BCMCA is that by representing the diversity of the physical marine environment, the majority of species and their supporting natural habitats will also be represented.

The intent of the Marine Representation Expert Review Process was to draw on the knowledge and expertise of scientists, resource managers and the conservation community to determine how best to represent abiotic marine features in analyses using a decision support tool for site selection. Abiotic data are commonly used by researchers as surrogates for the occurrence of specific species as well as to characterize a particular habitat or community.

In June 2008, the BCMCA drafted a document that proposed: 1) methods to spatially represent the diversity of physical marine and oceanographic features¹ in British Columbia's marine environment, and; 2) a list of data sources that would facilitate the identification of these features. Then the BCMCA invited a panel of expert reviewers to comment on proposed methods and data sources, and to provide recommendations on alternative methods and data to employ in this project. This report documents the outcome of that process and outlines the revised methods and data sources based on expert feedback.

In general, physical marine representation will be based on coarse scale features, fine scale features and unique and distinctive areas. To represent coarse scale variability we will target marine geographic regions, and to represent finer scale variability we will target intertidal zones, benthic classes based on a benthic characterization, and oceanographic classes based on an oceanographic characterization. Finally, to represent some important unique and distinctive areas, we will target these directly. Specific features, data sources and proposed target ranges for each of these categories are discussed in subsequent sections of this report. This representation only considers the abiotic components of the marine environment because biotic components were considered in a series of expert workshops, conducted between December 2006 and October 2007. The expert reviewers will be asked to comment on the maps that are created out of the recommendations in this report, before further decision support analyses are undertaken.

¹ A 'feature', as used in this report, refers to the element that Marxan is trying represent. These could include muddy substrates, areas of high current, inlets, fjords or oceanographic phenomena such as gyres or eddies.

1.2 Project Background

The overall purpose of the BCMCA is to collaboratively identify areas of high conservation utility/interest for the Pacific coast of Canada (Fig. 1). Areas of high conservation utility or interest are defined by the BCMCA as areas that, taken together, will most efficiently achieve our conservation objectives (see below). The BCMCA will identify potential areas of high conservation value by using input from experts to inform subsequent spatial analyses which will integrate all of the spatial information assembled for different biophysical features. The BCMCA Project will involve two main components/products: (1) An atlas of known ecological and human use values; and (2) use of the site selection algorithm, Marxan, to identify potential areas of high conservation value. The atlas will map ecological data, human use data, and a combination of areas of ecological value and human use hotspots. The Marxan analysis component will iteratively identify: (1) areas of high conservation value using ecological data only; (2) areas of high conservation value that minimize negative impacts to marine users and coastal communities; and (3) areas of high conservation value that incorporate reserve design principles.

The objectives of the BCMCA are to:

- Use the best available information, including the latest in marine conservation planning theory.
- Assemble and use the best available biological, ecological, oceanographic, and human use data.
- Faithfully and transparently reflect the accuracy, scale and completeness of the data.
- Draw on the knowledge and expertise of governments (federal, provincial and First Nations), other resource managers, the conservation community, academics, and other scientists to develop sound, scientifically defensible methods and products.
- Utilize methods which are transparent in their application.
- Incorporate ecological, social and economic objectives in the analysis and balance these in a range of solutions.
- Work cooperatively to achieve project goals.
- Create products which are widely supported by partner organizations.

There are several conservation objectives and principles that will guide the BCMCA analyses:

- (1) represent the diversity of BC's marine ecosystems across their natural range of variation;
- (2) maintain viable wild populations of native species;
- (3) sustain ecological and evolutionary processes within an acceptable range of variability;
- (4) build a conservation reserve network that is resilient to environmental change;
- (5) identify options that minimize negative impacts to marine users and coastal communities, while still meeting conservation objectives; and
- (6) resolve a variety of conservation scenarios and options.

Identifying areas of high conservation value involves the consideration of multiple objectives and the use of large data sets that show the distribution of ecological, biological, and human use data. The BCMCA will use the decision-support tool Marxan to help achieve conservation objectives while minimizing negative impacts to marine users and coastal communities. Marxan was developed by researchers at the University of Queensland to help in the recent rezoning of the Great Barrier Reef (Ball 2000; Ball and Possingham 2000, Day 2002). The BCMCA will draw on the recommendations of the Marxan Best Practices Workshop, which was hosted by the Pacific Marine Analysis and Research Association (PacMARA) in April 2007.

(Note: The analyses to identify areas of high conservation utility using Marxan does not provide the definitive answer for conservation of an area or a resource, but provides a platform for prioritization pending expert review and stakeholder agreement.)

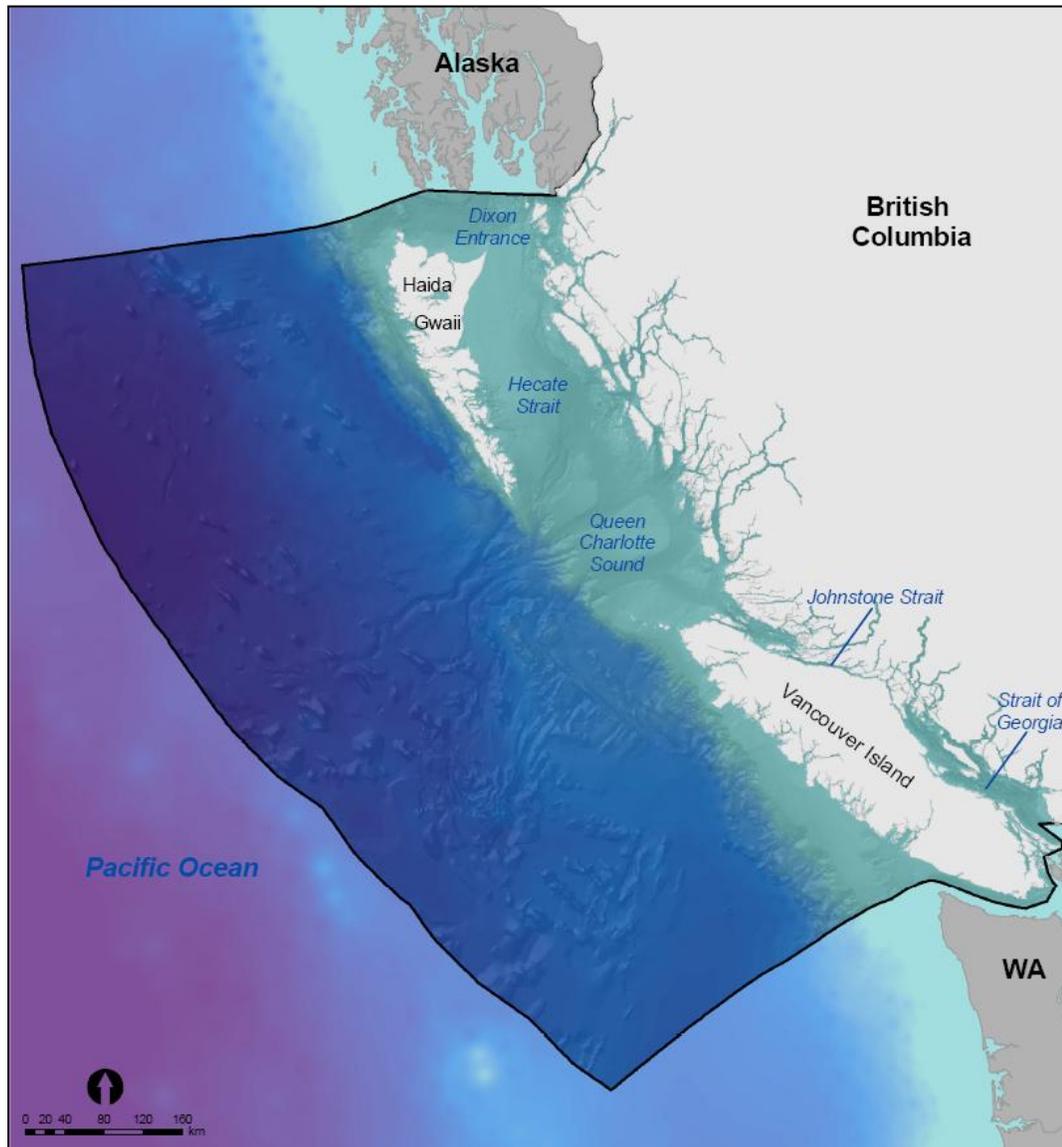


Figure 1. Map of BCMCA study area

2.0 Coarse Scale Representation

2.1 Marine Geographic Regions

2.1.1 Introduction

There are few marine geographic classification schemes specific to British Columbia that exists at an appropriate spatial scale for marine planning. Some published marine classification schemes are applied to greater extents than the Canadian Pacific and are limited in their usefulness for the BCMCA (Powles et al. 2004; Gregr and Bodtker 2007; Spalding et al. 2007). The ecosections, delineated by the Province of British Columbia in a Marine Ecological Classification (BC MEC) (Zacharias et al. 1998), are a very useful delineation in a physical sense in that they have been mapped with a focus on identifying physical differences that will tend to affect species distributions within a bio-geographic region, and they delineate the BCMCA study area comprehensively. For this reason, we are using the ecosections as appropriate marine geographic regions that will serve as the coarsest filter in this representation scheme.

2.1.2 Sources of Marine Geographic Regions data

The data source for ecosections (Fig. 2) is the Province of BC (Table 1). Although slight modifications to the existing ecosections, based on updated data, were proposed as part of the expert review of this proposal, the BCMCA does not have the time or capacity to undertake such an exercise.



Figure 2. Map of BC's marine "ecosections" (Zacharias et al. 1998).

2.1.3 Features and Targets

The specific features to be targeted are each of the ecosections, as they represent marine geographic regions. For each of the ecological features recommended for inclusion in the BCMCA at expert workshops, we asked experts to recommend conservation targets in the form of a range of values. Targets are values which define the amount of each feature required to meet our conservation objectives (Section 1.2). Experts were asked to recommend a range of values from minimum to preferred amounts, and provide a rationale for their recommendations. For the abiotic features, including these marine geographic regions, we have settled on incremental proportional targets ranging from 10 to 40 percent. Specifically, 10, 20, 30, 40 percent of the area of each ecosection will be targeted in successive site selection scenarios in order to ensure that a representative sample of each ecosection is contained in the various potential solutions. We proposed this range of values as it supported by several studies which indicate that Marine

Protected Area coverage should range from 10 to 50 percent to be effective tools for fisheries and resource management (Carr and Reed 1993, NRC 2000, Roberts and Hawkins 2000).

3.0 Fine Scale Representation

3.1 Intertidal Zone

3.1.1 Introduction

The intertidal zone includes the area between the mean high tide line and the mean low tide line where the benthic substrate is regularly exposed through tidal action. As a result of this highly variable environment, organisms living in this zone have become adapted to coping with different levels of exposure. Adequate representation of this zone will consider classes of physical habitat for species assemblages that exist as a result of varying levels of exposure.

3.1.2 Sources of Intertidal Data

The most complete intertidal dataset is the provincial ShoreZone database (Table 1). The Province of British Columbia has completed aerial low tide oblique surveys of the entire BC coastline. These surveys served to document both geologic features and biological zonation. Classes (Harper et al. 1993) and habitat features (Morris and Thuringer, 2001) identified in the ShoreZone dataset will be used as the primary source of intertidal data in the BCMCA.

3.1.3 Features and Targets

Features to be targeted are the specific shoreline types identified in the ShoreZone database (http://maps3.gov.bc.ca/imf406/imf.jsp?site=dss_coastal). Features or types will be targeted separately for each ecosection in order to ensure a wide range of shorezone types are represented in each ecosection. Inclusion of any one shorezone type may depend upon whether it is comprehensively represented in that ecosection. In addition, within each ecosection, we will either target only the unverified classification, or the verified data (ground truthed), and avoid mixing the two. ShoreZone feature classes will be targeted at intervals of 10, 20, 30 and 40 percent in a similar manner to the coarse scale marine geographic regions, again because the primary purpose of these features in the analyses is representivity.

3.2 Benthic Characterization

3.2.1 Introduction

In order to characterize the benthos in both the nearshore subtidal zone and offshore in deeper waters, the BCMCA will employ a benthic classification scheme based on Greene et al. 1999 and further developed by The Nature Conservancy (TNC) (Ferdana et al. 2006). The classification scheme combines three types of data: 1) sea-bottom or geomorphic features; 2) depth classes; and, 3) substrate type in order to identify areas of similar benthic characteristics. First, sea-bottom or geomorphic features will be identified using

the Benthic Terrain Modeller (BTM) (Rinehart et al. 2004) developed by NOAA Coastal Services, which is a step-wise algorithm that derives features such as depressions, ridges, flats, and slopes from bathymetric data and its derivatives. Second, combining the sea-bottom features with depth and substrate classes will result in a non-hierarchical benthic classification scheme for the BCMCA study area. This approach mimics that undertaken by Parks Canada to define benthic habitats in the Southern Strait of Georgia (Robinson & Royle, unpublished report) and was identified by their scientific advisors as the best approach to represent benthic diversity.

3.2.2 Sources of Benthic Data

The primary data sets required to support this classification scheme include comprehensive bathymetry and substrate data (Table 1). Best available bathymetry from Canadian Hydrographic Service (CHS), Natural Resources Canada (NRCan), Living Oceans Society (LOS), Parks Canada, Cascadia data from the United States Geologic Survey (USGS), and ETOPO1 data from NOAA will all be considered and the best will be knit together to form a comprehensive raster describing bathymetry for the entire Canadian Pacific. Substrate categories (mud, sand, hard, unknown) will be taken from an existing data layer created as input to the BC Marine Ecological Classification System (BC MEC) (MSRM 2002), and may be modified using the original grab sample data from Natural Resources Canada (NRCan). The derived sea-bottom features will be combined with four depth classes; 0-20m (kelp zone), 20-50m (lower euphotic zone), 50-200 m, and 200+m, and the aforementioned four substrate categories to delineate a total of 64 unique benthic habitat classes. The depth classes are the same as those used by Parks Canada (Robinson & Royle, unpublished report). To date, the benthic habitat classes have not been ground truthed. Sources of benthic data are listed in Table 1.

3.2.3 Features and Targets

Each of the resulting 64 benthic classes will be treated as an individual feature and will be targeted at proportional intervals of 10, 20, 30 and 40 percent, because the purpose of these features in the Marxan analyses is to represent BC's diversity of physical habitat types. These benthic features will be targeted separately for each ecosection in order to ensure that all existing types of benthos are represented within each ecosection.

3.3 Oceanographic Characterization

3.3.1 Introduction

The physical oceanographic properties of Pacific Canada are the most ephemeral and amorphous features to characterize in the BCMCA study area. Lucas et al. (2007) described the major oceanographic properties and processes that characterise regions within the Pacific North Coast Integrated Management Area (PNCIMA) and Robinson and Royle (unpublished report) report similarly for the Strait of Georgia (SoG) region. These two exercises employed different methods to 'regionalize' the oceanographic properties of their respective study areas which do not overlap, so it is difficult to assess and compare these two methods. To date, no attempt has been made to classify the physical oceanography of the entire Canadian Pacific into discrete features or classes, thus the BCMCA needs to take this on. The intent is to classify into zones of similar physical properties and/or zones influenced by persistent physical processes,

and these zones should be at a finer scale than the BC MEC ecosections (i.e. oceanographic zones are generally smaller than ecosections) It should be noted that the BCMCA chose not to use the ecounits of the BC MEC based on expert feedback that additional properties should be taken into account.

The BCMCA proposed two approaches and asked our expert reviewers to comment:

1. Build on the methods described in the British Columbia Marine Ecological Classification (BC MEC) (see Zacharias et al. 1998; AXYS 2001) to characterize oceanographic features in the BCMCA study area. In the BC MEC, ‘pelagic ecounits’ (spatial areas) were delineated based on salinity, vertical stratification and tidal velocity. The BCMCA would add sea-surface temperature (SST) contours and spring chlorophyll *a* indices. Although chlorophyll *a* is a biotic feature it is used here to portray areas of enhanced upwelling (Ware & Thomson 2005). Note: chlorophyll *a* and SST were not used in Zacharias et al. (1998) & AXYS (2001).
2. Use an unsupervised classification algorithm to identify areas of similar oceanographic properties, similar to the analysis outlined in Gregr and Bodtker (2007). This type of analysis is very similar to analyses used to classify backscatter data collected during multibeam sonar surveys of the ocean bottom. We propose that the input layers would include SST, salinity, vertical stratification, tidal or average surface current velocity, and an index of spring chlorophyll *a*. The result of the analysis would be a set of classes (or regions) with similar properties.

Expert comments included these thoughts:

1. Both methods are rather similar, and both are valid approaches. I am not strongly in favour of one versus the other. If pushed to prefer one, I would choose (1) because a purely machine-based classification is likely to produce non-contiguous areas (i.e. in which the same habitats occur in many widely separated locations) which, if there are too many of these, may not be what is needed here.
2. The two approaches would probably lead to a similar result. The advantage of the unsupervised approach (2) would be in no built in assumptions with respect to “ecounits”.
3. The oceanographic data sets are relatively complete spatially compared to other physical data sets. Oceanographers describe BC oceanography as being driven by “capex and canyons”. These are not ephemeral and amorphous features and could help constrain those components of the oceanographic character of BC that are less stable. The impact of these bathymetric features of BC oceanography should be emphasized. Some method of capturing this could perhaps be considered.
4. With regards to the approach to combine multiple layers of information to delineate units I would not recommend looking at variables in isolation, as many of these are interrelated. Temp and Salinity are the two co-determinants of Water masses – these are analogues to climate and larger marine regions and if you can map these easily encompass all variables that T and S drive like Temperature, Stratification and Salinity. It makes more sense to look at these variables together (if the data allow this) in a cluster analysis provided what you are delineating and applying is at the right scale.
5. If you deal with water masses and cluster analyses you have to recognize that these masses are 3 dimensional. You need depth referenced data to map these accurately and you have to realize that in deeper regions you will have more than one water mass on top of another.
6. The oceanographic variable are dynamic, both annually and inter-annually and any data driven approach for classification is going to run into problems without the adequate temporal (and

spatial) resolution – so it makes sense to supplement any data intensive approach with expert opinion and guidance.

7. For the pelagic, I would generally tend to stay away from over complex classifications, a water mass analysis can capture many of the interrelated variables.

Another comment made more generally:

8. Some integration of expert knowledge especially with respect to the workings of the coastal oceanographic regime could be beneficial.

Based on this expert feedback and an opportunity to synergise with work that Parks Canada is undertaking, which will result in delineation of pelagic or oceanographic regions for the entire Canadian Pacific EEZ, the BCMCA has decided to wait until Parks Canada finishes their work on this and then adopt the regions delineated, providing they meet our needs. The process to delineate and describe oceanographic regions developed and used by Parks Canada does integrate expert knowledge along with many of the same physical properties we had intended to consider (Robinson and Royle, unpublished report). This approach seems to be the best compromise given the range of advice that the BCMCA received on this component.

3.3.2 Sources of Oceanographic Data

During a Parks Canada pilot project to delineate pelagic regions for the Southern Strait of Georgia, these types of information and data were used to identify small scale oceanographic regions with fuzzy boundaries, typical of summer:

1. grey and primary literature;
2. expert knowledge of at least 15 oceanographers;
3. maps of tidal velocity, sea surface temperature, and sea surface salinity;
4. typical satellite images of sea surface temperature, suspended sediments and ocean colour;
5. thermal and stratification maps and phytoplankton maps from field samples collected by Dr. D. Maasson (IOS) and Dr. A. Pena (IOS), respectively;
6. stratification derived from modeled tidal velocity and modeled bathymetry using Simpson-Hunter (1974);
7. spring chlorophyll-*a* concentrations derived from MODIS remotely sensed data for the years 2003-2006 during the Julian days of 080 to 171.

These are the types of data being considered in the delineation of oceanographic regions for the entire Canadian Pacific EEZ. As Parks Canada will undertake this process on behalf of the BCMCA and will document the types of information used in the process including specific data sources, we have not listed any proposed data sources in this document in Table 1.

3.3.3 Features and Targets

The oceanographic regions delineated by the Parks Canada process will be targeted as features at proportional intervals of 10, 20, 30, and 40 percent in the Marxan analysis, in order to ensure equal representation of each type of region. These regions will likely be each unique and different from each other so there is no need to target these within the ecoregions.

4.0 Unique and Distinctive Areas

4.1 Introduction

The idea of targeting unique and distinctive areas was left out of our original proposal. Comments by experts suggested that this was a gap worthy of reconsideration, so we propose to include some features recommended as unique and distinctive areas. The rationale is that rare or unique habitats are special and therefore in need of particular attention and/or focus, and so the search for such rare habitats should be a priority activity and recognised somewhere in this analysis. With this rationale and based upon additional suggestions, we have identified a few types of unique features and distinctive areas to be targeted: 1) areas of high tidal current (both sheltered and exposed); 2) areas of high rugosity; and, 3) unique seafloor features.

Areas of high tidal current support distinctive species assemblages and are important to larval transfer and nutrient exchange. Rugosity is defined as a measure of the ratio of the surface area to planar area and is used as a measure of benthic terrain complexity or “roughness”. Areas of high rugosity are distinctive and are thought to support a higher than average diversity of species. Unique seafloor features that warrant particular attention include seamounts and hydrothermal vents.

4.2 Sources of Distinctive Data

Data to support defining areas of high tidal current will be derived from an oceanographic circulation model for the North-East Pacific developed at IOS. Rugosity will be derived using the Benthic Terrain Modeller (BTM) tool, a collection of ArcGIS terrain visualization tools developed by the Oregon State University Department of Geosciences and the National Oceanic and Atmospheric Administration (NOAA) Coastal Center (<http://www.csc.noaa.gov/products/btm/>). Data to locate seamounts is available from the Bering to Baja (B2B) project and may be supplemented by the results of our BTM work. Locations of hydrothermal vents may be available from NRCan. These and possible other sources for data related to unique and distinctive areas are listed in Table 1. Experts also commented that, in reality, we often do not have adequate data to support comprehensive mapping of unique and distinctive features, so attempts to collate data here may reveal data gaps and these will be documented.

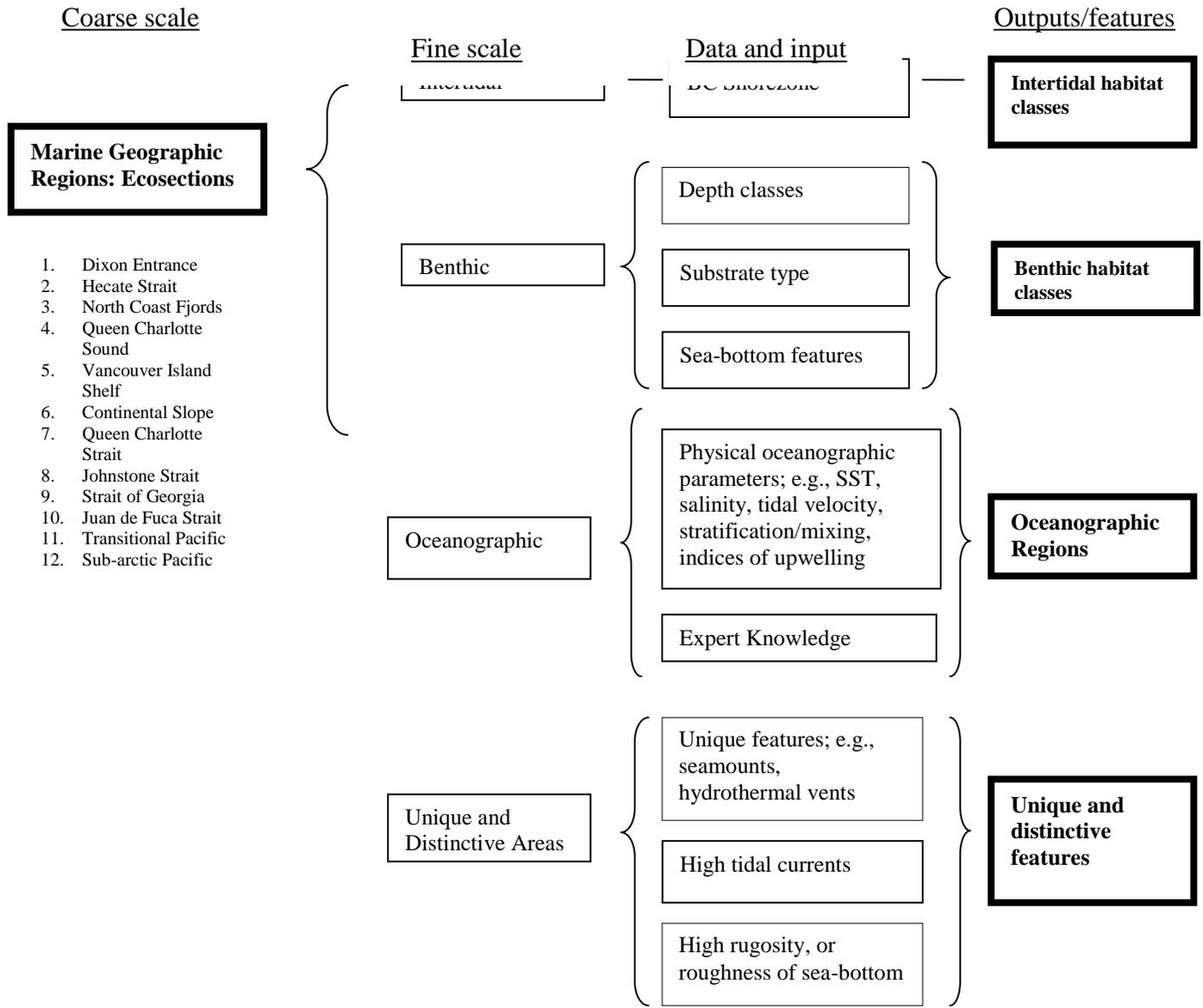
4.3 Features and Targets

Since the purpose of including unique and distinctive areas in the analysis is not strictly one of representation, but includes the idea that these features are rare and possibly of greater ecological value, they may be targeted differently than the rest of the physical marine features. We propose to develop maps of these features and canvas the experts again in order to obtain advice on appropriate targets.

Table 1: Physical Marine Representation Data Sources

Category	Dataset / Features	Description	Geometry	Data Custodian	Extent	Comments / Reference
1. Marine Geographic Regions	BC MEC	12 ecosections based on dominant oceanography and bathymetry	Polygon (see Appendix 1)	Province of British Columbia, ILMB. Contact: Carol Ogborne	Coastwide	Zacharias et al. 1998 AXYS 2001
2. Intertidal	BC Shorezone	36 classes: Several substrate and exposure 'fetch' classes	Line, Poly	Province of British Columbia, ILMB. Contact: Carol Ogborne	Coastwide	Howes et al. 1997
3. Benthic	Substrate	4 Classes: Mud, Sand, Hard, Unknown	Polygon	Province of British Columbia, ILMB. Contact: Carol Ogborne	Coastwide	AXYS 2001
	Bathymetry	raster of varying resolution	Raster	CHS, NRCan, LOS, PC, Cascadia data from USGS, ETOPO1 data from NOAA Contact: NRCan: Robert Kung	varies with dataset	PC and/or LOS will knit the datasets together to create a comprehensive raster dataset. Then depth classes will be extracted
	Bottom type grab samples	grab sample data at point locations	points	NRCan Contact: Robert Kung	On shelf	These are the raw data from which substrate classes were initially derived; they may be referred to refine the substrate classes provided by Province (and used in BC MEC)
4. Unique and distinctive areas	Seamounts,	Known locations of seamounts in North Pacific	points/polygons	B2B project Contact: LOS	Coastwide	May be supplemented by additional seamount locations identified in BTM work and verification from regional experts.
	High tidal current	Model data	raster	Institute of Ocean Sciences. Contact: Mike Foreman	coastwide	Model output on average tidal speeds can be analysed to identify areas of high tidal current, may require expert advice to delineate
	Hydrothermal vents	Locations of known hydrothermal vents	Point/polygon?	Maybe NRCan	?	Will require some research and verification from regional experts.
	Rugosity	Highly complex bottom structure	raster	A derivative of bathymetry, maybe available from Parks Canada, or will need to be derived	Coastwide	

Figure 3. Relationship of the different physical marine features and outputs for the BCMCA.



5.0 Assumptions and limitations

The data sources for oceanographic, benthic and shorezone features in BC have also been identified in some previous workshops (fish, invertebrates, marine birds and marine mammals) and were recommended for use as surrogates for biological community types. In some cases the data are not comprehensive for the entire Canadian Pacific EEZ. In general, data gaps, the relative quality and consistency of data, and any assumptions made during the preparation of the data will be documented so that future iterations of the analysis can be improved. This is in keeping with the rest of the ecological data assembly, preparation, and documentation for the BCMCA.

6.0 Summary

One course scale feature type, three fine scale physical classes, and a few unique or distinctive areas will be used to represent the physical marine diversity of the BCMCA study area. For all of these features except the unique and distinctive areas, conservation targets will be incremental percentages of 10, 20, 30 and 40% in each of the site selection scenarios. Two of the fine scale feature classes (shorezone and benthic) will be targeted within each ecosection, to ensure that representation of the classes is spread throughout the marine geographic regions. Proportional targets were recommended as it is widely accepted that equal habitat representation across the province is the most effective way to represent the diversity of marine physical features in BC waters. Assembly and pre-processing of these data sets will be undertaken to prepare the features for the BCMCA atlas. When these features have been prepared and mapped, the draft maps will be available for review before site selection analyses begin. At this time we will ask for recommendations for appropriate conservation targets for the unique and distinctive areas.

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Appendix 1.0 – Description of BC's Marine Ecosections (Zacharias et al. 1998)

Marine Ecosections	Physiographic Features	Oceanographic Features	Biological Features	Boundary Rationale
Johnstone Strait	Narrow, constricted channels	Protected coastal waters with strong currents; well-mixed, poorly stratified	Migratory corridor for anadromous fish; rich sessile, hard substrate invertebrate community; diverse species assemblage of benthic fish	Johnstone Strait has greater mixing and more channels than areas to south; Queen Charlotte Strait more marine
Continental Slope	Steep sloping shelf	Strong across slope and downslope turbidity currents	Upwelling zone; productive coastal plankton communities and unique assemblages of benthic species	Transitional area between continental slope and abyssal plane
Dixon Entrance	Across-shelf trough with depths mostly < 300m; surrounded by low-lying coastal plains (Hecate Depression)	Strong freshwater influence from mainland river runoff drives north-westward flowing coastal buoyancy current and estuarine-like circulation	Mixture of neritic and subpolar plankton species; migratory corridor for Pacific salmon; some productive and protected area for juvenile fish and invertebrate development	Distinguished from area to south by strong freshwater discharge influence
Strait of Georgia	Broad shallow basin surrounded by coastal lowlands (Georgia Depression)	Protected coastal waters with significant freshwater input, high turbidity and seasonally stratified; very warm in summer	Nursery area for salmon, herring; abundant shellfish habitat; neritic plankton community	Stronger Fraser R. Signature than areas to north or west
Juan de Fuca Strait	Deep trough; a major structural feature accentuated by glacial scour	Semi-protected coastal waters with strong "estuarine-like" outflow current (coast-hugging buoyancy current to north); major water exchange conduit with "inland sea"	Migratory corridor for anadromous fish; moderately productive; mixture of neritic and oceanic plankton species	Much more marine than Strait of Georgia; less "open shelf" than Vancouver Is Shelf

Marine Ecoregions

	Physiographic Features	Oceanographic Features	Biological Features	Boundary Rationale
Queen Charlotte Strait	Predominantly shallow (< 200 m), high relief area with deeper fjord areas	High current and high relief area; very well mixed; moderate to high salinities with some freshwater inputs in the inlets and fjords	Very important for marine mammals; migratory corridor for anadromous fish; moderate shellfish habitat	More marine than Johnstone Strait; much more shallow with high relief and high currents than Queen Charlotte Sound
North Coast Fjords	Deep, narrow fjords cutting into high coastal relief	Very protected waters with restricted circulation and often strongly stratified.	Low species diversity and productivity due to poor water exchange and nutrient depletion; unique species assemblages in benthic and plankton communities	Unique physiography and stratification compared to bordering surrounding regions
Hecate Strait	Very shallow strait dominated by coarse bottom sediments; surrounding coastal lowlands	Semi-protected waters with strong tidal currents that promote mixing; dominantly "marine" waters	Neritic plankton communities with some oceanic intrusion; nursery area for salmon and herring; abundant benthic invertebrate stocks; feeding grounds for marine mammals and birds	Marine in nature but much shallower, with associated greater mixing, than areas to the south
Subarctic Pacific	Includes abyssal plain and continental rise; a major transform fault occurs along the west margin and a seamount chain trends NW/SE	The eastward flowing subarctic current bifurcates at coast with northerly flowing Alaska Current ; current flow is generally northward throughout the year	Summer feeding ground for Pacific salmon stocks; abundance of pomfret, Pacific saury, albacore tuna and kack mackerel in summer, boreal plankton community	The northern and western boundaries are undefined. The eastern boundary is coincident with the shelf break. The southern boundary is indistinct but is meant to be located
Queen Charlotte Sound	Wide, deep shelf characterised by several large banks and inter-bank channels	Ocean wave exposures with depths mostly >200m and dominated by oceanic water intrusions	Mixture of neritic and oceanic plankton communities; northern limit for many temperate fish species; lower benthic production	More oceanic (deep) and marine than Vancouver Island Shelf and Hecate Strait

Marine Ecosections	Physiographic Features	Oceanographic Features	Biological Features	Boundary Rationale
Transitional Pacific	Includes abyssal plain, and continental rise; also includes spreading ridges, transform faults, triple junction and plate subduction zone	Area of variable currents; southerly areas may be affected by southward-flowing California Current in summer but remainder of area characterised by weak and variable currents; Davidson Current along shelf edge flow north in winter, south in summer	Transition zone between southerly, temperate, and northerly boreal plankton communities; mixing of oceanic and coastal plankton communities adjacent to the coastal shelf	The northern boundary is indistinct and approximately coincident with the southern limit of the Alaskan Current (winter). The eastern boundary is at the shelf break. The southern and western boundaries are undefined
Vancouver Island Shelf	Narrow, gently sloping shelf	Open coast with oceanic wave exposures; northward, coast-hugging buoyancy current due to freshwater influence; seasonal upwelling at outer margin	Highly productive with neritic plankton community; northern limit for hake, sardine, northern anchovy, and Pacific mackerel; productive benthic community; rich fishing grounds for benthic fish and invertebrates	More open shelf than Juan de Fuca Strait; more freshwater influence (coastal buoyancy current) than Queen Charlotte Sound

Appendix 2.0 – Detailed expert feedback not addressed in this revised plan, and BCMCA response

Inserted below are additional review comments received from the four experts who participated in the review of our draft plan. Suggestions and comments that we addressed directly in this revised plan are not included here for the most part. Names and other individual identifiers have been removed.

1. **Re: benthic habitat classification:** "... comparative analyses using select benthic species distributions and their association habitat types are needed to test the validity of abiotic classifications and models (I would actually consider conducting a species-habitat association analysis as part of your benthic type characterization. These have been done on a local scale, but few at the regional scale. This will add a lot of credibility to your model output.)"
BCMCA response: We agree whole-heartedly. This type of species-habitat association analysis was also recommended at the Marine and Anadromous Fish Workshop for the BCMCA. There are many analyses, including developing specific habitat models, that have been recommended for us to undertake as part of the BCMCA. We are documenting all of the suggestions for future versions, but we doubt that we will have the capacity to undertake many of them.

2. **Re: targets in general:** "Also, I would suggest targets should be set based on rarity and risk of impact, threat to a feature in addition to ecological requirements."
BCMCA response: In general we have asked experts to recommend target ranges and provide rationale. In some cases we have not received recommendations or targets have been suggested without firm rationale. Your point is well-taken and if the BCMCA project team finds that we need provide target values we will take these factors into account.

3. **Re: physical features in general:** "You also need to recognise, and perhaps distinguish, those features which have strong temporal dependence – e.g. hydrographic properties that may vary on ENSO cycles and with increasing global change, versus those features which can be considered (at least within a human lifespan) as being time-invariant, such as bottom type. You want your results to be able to have some ‘temporal persistence’".
BCMCA response: Great idea. We had planned to introduce the issue of climate change in our Marxan workshop to take place in May 2009, and we can make sure the issue of temporal persistence of certain features over others factors into this discussion as well.

4. **Re: terminology:** [Note: I would consider changing "Marxan Spatial Analysis" to something like "decision support for site selection", or "alternative scenarios for site selection." I wouldn't necessarily put Marxan up front as this has been a problem for other teams – the emphasis should be on decision support and multiple scenarios, not the tool used. And really what this is is site selection, not spatial analysis...]
BCMCA response: Agreed, however this is one of a series of reports (on ecological workshops) and we have not been shy about specifying Marxan as the tool of choice for our study. Having said that, we did alter some of the language in this report.