BC Biophysical Shore-Zone Mapping System— A Systematic Approach to Characterize Coastal Habitats in the Pacific Northwest

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Abstract

A biophysical shore zone mapping system has been developed as part of a coastal shoreline inventory program for the coastal zone of British Columbia. It is a systematic methodology for mapping the biophysical character of the shore zone. The system is descriptive, scale-independent, cost-effective, and has a variety of natural resource applications. There are two major components to system—physical and biological.

The physical component and its hierarchical framework are the foundation of the biophysical system. The shoreline is segmented into homogenous alongshore units. A number of physical attributes are used to describe the units and their across-shore components. The biological component uses the hierarchical physical framework for recording the bio-bands and species data. The system relies on oblique, low-tide aerial video imagery flown at spring low tides as the primary source of information.

Information provided by the system supports a number of coastal initiatives including shoreline habitat modeling, conservation and protection, Marine Protected area identification, marine ecological classifications, regional and site land use planning, tenures, research, monitoring and oil spill response. The system has recently been adopted and implemented in the State of Washington. Completion of the both countries inventory programs will result in a systematic coverage of biophysical shoreline information that extends from the Columbia River mouth to the Alaska border.

Introduction

The British Columbia biophysical shore-zone mapping system was developed in 1979 to support the systematic inventory of the British Columbia coastal zone. It is a descriptive, cost-effective mapping methodology consisting of two interdependent mapping components (physical and biological) to document the physical and biological character of the shore zone. The foundation of the biophysical system is the physical shore-zone mapping component and its hierarchical framework. The physical mapping system segments the shoreline into homogenous along- and across-shore units and components within zones. The physical character of the shoreline is described within this framework. The biotic mapping uses the framework of the physical mapping system to record shoreline biological 'bio-bands' and species data.

The shoreline mapping relies on oblique, low tide aerial video imagery flown at spring low tides as the primary source of information. Inventories conducted with these mapping systems support several coastal initiatives including conservation and protection, marine protected areas, regional and site land use planning, research, monitoring and oil spill response. The system has recently been adopted and implemented in the State of Washington. Completion of both countries' inventory programs will result in a systematic coverage of biophysical shoreline information that extends from the Columbia River mouth to the Alaska border.

Background

The conceptual framework and the physical mapping component was developed by Don Howes and Ed Owens in Victoria, British Columbia in 1979 (Howes 2000). The framework, definitions and coding for the physical system were tested on the shoreline of Saanich Peninsula and Saltspring Island in the summer of 1979. It was during this pilot project that Howes and Owens tested the use of oblique video imagery as the primary information source for the mapping. This technique has become an integral aspect of the biophysical shore-zone inventories of British Columbia. The early version of the physical mapping system has been updated and is summarized in the British Columbia Physical Shore-zone Mapping System (Howes et. al., 1995).

In the early 1990s, information on shore-zone biota was incorporated into the system. Pilot projects were conducted to test the inclusion of biotic mapping procedures and provided much of the basis for the development of these procedures (Harper and others 1994; Morris and others 1995). Based on this work, the biological mapping component of the system was documented in the Biological Shore-Zone Mapping Manual (Searing and Firth 1995).

The Land Use Coordination Office (LUCO) of the Province of British Columbia has been responsible for the development of these biophysical and other coastal mapping systems. Through its work with the Provincial Resource Inventory Committee (RIC), these mapping systems have become provincial standards. RIC is an inter-agency committee responsible for overseeing the development of common provincial mapping, inventory and data collection standards to ensure effective and consistent data collection. RIC coastal mapping standards include the biophysical mapping system (British Columbia Physical Shore-Zone Mapping System (Howes and others 1995) and Biological Shore Zone Mapping System (Searing and Firth 1995)), and the Estuary Mapping System (Howes and others 1999). These mapping systems were designed to provide baseline biophysical information for a wide range of applications and can be accessed at the RIC web site at http://www.for.gov.bc.ca/RIC.

Biophysical Mapping Systems

The biophysical shore-zone mapping system was developed to provide a systematic methodology for the inventory of the biophysical character of the shore-zone and to show its distribution, extent and location. The system is descriptive and can be used to provide baseline biophysical information at a variety of scales for a wide range of applications (e.g. planning, conservation and protection). It has been designed to support the electronic management and processing of the information, although this is not a requirement for its application.

Physical Shore-Zone Mapping System Component—'Building Block of the System'

The underlying concept of the mapping system is that the shore zone can be divided into discrete shore units and systematically described on the basis of its physical character or entities**.** The system is hierarchical and each shore unit can be subdivided into smaller across- and along-shore segments (components). Subdivision of the shoreline into smaller segments forms the framework for recording and describing a number of physical characteristics such as slope, texture, and width of the shoreline.

The highest subdivision is the shore unit (Figure 1). The shore unit partitions the shore zone into discrete units on the basis of its physical character. The concept of a shore unit is the fundamental building block of the system and identifies an area where the morphology (shape), sediment texture and physical process do not vary across or along the shore. Each shore unit can be further subdivided into components that are continuous across- or along-shore. Components are systematically described in terms of their physical characteristics, such as morphology (shape), sediment texture and dominant processes. Zones provide the vertical reference or framework for the components.

Criteria used to delimit a shore unit boundary is either *a change in one or more components (form or texture) or in the process(es) operating in the shore zone* (e.g. wave exposure) (Figure 2). Shore units and components are areas that may be delineated as a line segment (regional inventories presented on small-scale maps) or polygons (local inventories presented on large-scale maps). The system is flexible and allows one to describe the physical character of the shoreline to a level appropriate to the level of survey intensity and use. The descriptive nature of the system assists non-technical users of the information to gain a basic picture of the shoreline character.

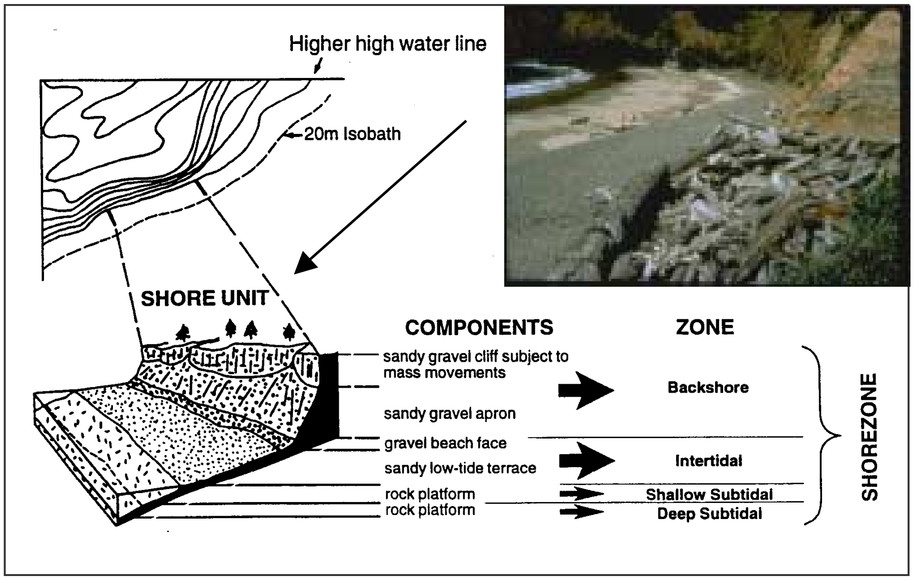

Figure 1 Schematic example of a *shore unit* showing the subdivision into *across-and along-shore components* and *zones* (after Howes and Harper 1984).

Figure 2: Two shore units (north and south of the line) defined due to a change in shoreline texture and form (morphology) between the two areas.

Key building blocks of the biophysical mapping system are:

- *Shore Unit***:** an area consisting of one or more components and processes(es) that are continuous and homogeneous along and across the shore within the unit.
- *Component*: a geomorphic feature, with unique form and texture that is uniform along and across shore. Components are areas with a length that exceeds width by several times.
- *Zones***:** the supratidal, intertidal or subtidal elevation levels that provide a vertical reference for the components.

Physical information on shoreline character is collected for the shore units and components. Unit information includes source of information for mapping, mapper and date of mapping, wave exposure, unit dimensions and tides whereas component information details the form, material type, geometry and processes within a zone context (refer Howes and others 1995 for specific details).

Biological Shore-Zone Mapping System—Biological Component

The biotic mapping system is also descriptive and used to record the distribution of biological features along the shoreline. It compliments and uses the hierarchical framework of the physical shore-zone mapping system. The physical units, zones and components provide the framework for recording the biological character (e.g. species distribution and abundance). This approach assumes the physical parameters of substrate, elevation and wave energy are the dominant determinants of species distribution.

The biota within a shore unit is described in terms of common biotic assemblages referred to as *'bio-bands.'* Bio-bands are used to characterize the distribution of conspicuous assemblages of species that occur within a unit and are visible in aerial video tapes and slide imagery (Figure 3). They are repeatable assemblages of intertidal biota that usually have a unique colour signature and intertidal position (e.g. the *Zostera band* occurs only in the lower intertidal zone). They are named by the most prominent species in the band or by the general description of the species assemblage.

Figure 3 Distinct 'bio-bands' on a rock cliff are visible from video imagery and 35 mm slides.

Bio-bands are spatially referenced to the zone and component defined by the physical mapping of a shore unit. They may occur within one or more components. Figure 4 is a schematic of the banding concepts and their relationship to the physical classification. Bio-bands are descriptive and there are no functional relationships implied in the classification. The bio-bands are simply a description of biota assemblages and species.

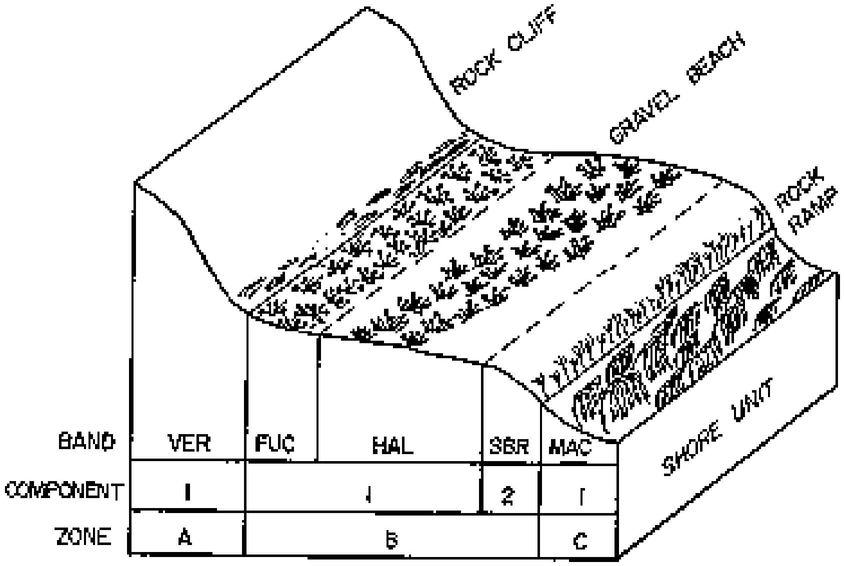

Figure 4 Schematic example of a shore unit showing bio-bands and the relationship to the physical components and zones (after Searing and Firth, 1995)

Species information within each band is also supplemented with field sampling (Figure 5). Recording species data provides a high level of detail and thus allows for flexibility in the analysis of biota among shore units.

Key elements of the biota mapping system are:

- *Bio-band***:** conspicuous assemblages of species named by the most prominent species in the band or by the general description of the species assemblage. Bio-bands are described in terms of their distribution (e.g. patchy or continuous) and are usually uniform along the shore. Like components, bio-bands are areas with a length usually exceeding width by several times.
- *Species*: species information does not provide a further subdivision of the bio-bands, however it is essential for detailing the character of each band. Species information includes abundance and microhabitat of each species.

Biological information is collected for the shore unit and components. Unit information includes data on the mapper, biological wave exposure, source of information and dimensions whereas component information includes bio-band type(s), distribution and species within the zone context (refer Searing and Firth 1995).

Figure 5: Field sampling of two bio-bands on a rock ramp with the *ulva* band (the lower band) and *fucus* band (the upper band).

Procedures and Data Management

Biophysical inventories are conducted by a team consisting of a geoscientist (geomorphologist or geologist), marine biologist and technical support staff. Aerial video imagery is used as the primary source of the information for both the physical and biological mapping. Video imagery of the intertidal zone is collected during spring low tides using low altitude helicopter or fixed-winged flights and high-quality video systems. The imagery provides sufficient detail to map the biophysical features of the shoreline and has the advantage of providing additional recorded narration of shoreline features by both specialists.

Upon completion of the aerial surveys, the geoscientist maps and interprets the video imagery and adds audio comments to describe the physical aspects of the shoreline. The imagery is used to delineate the shore unit boundaries and describe the physical character of the unit and components. Unit boundaries are delimited on the base map, digitized and entered into a GIS system. The unit and component physical information are recorded in the physical unit and component databases linked to the shore unit (Figure 6). The geoscientist also classifies the shore units according to the wave exposure model detailed in the physical mapping system and records this information in the wave exposure database. Alternatively, all this information can be recorded on maps or charts (for the spatial location of the unit) and tabular forms (for the descriptive attributes).

The completed physical maps and databases are provided to the biologist who interprets the video imagery to identify and describe the bio-bands and biota of each unit. The biota information is recorded in the biota database. The biologist identifies different bio-bands according to colour variations from the video and characterizes the distribution of conspicuous assemblages of species that occur within a shore unit (Table 1). A field survey is conducted following these initial interpretations to collect further information on physical and biological characteristics of a site not available from video imagery (e.g. subsurface substrate, detailed species information) and to verify the video tape interpretations.

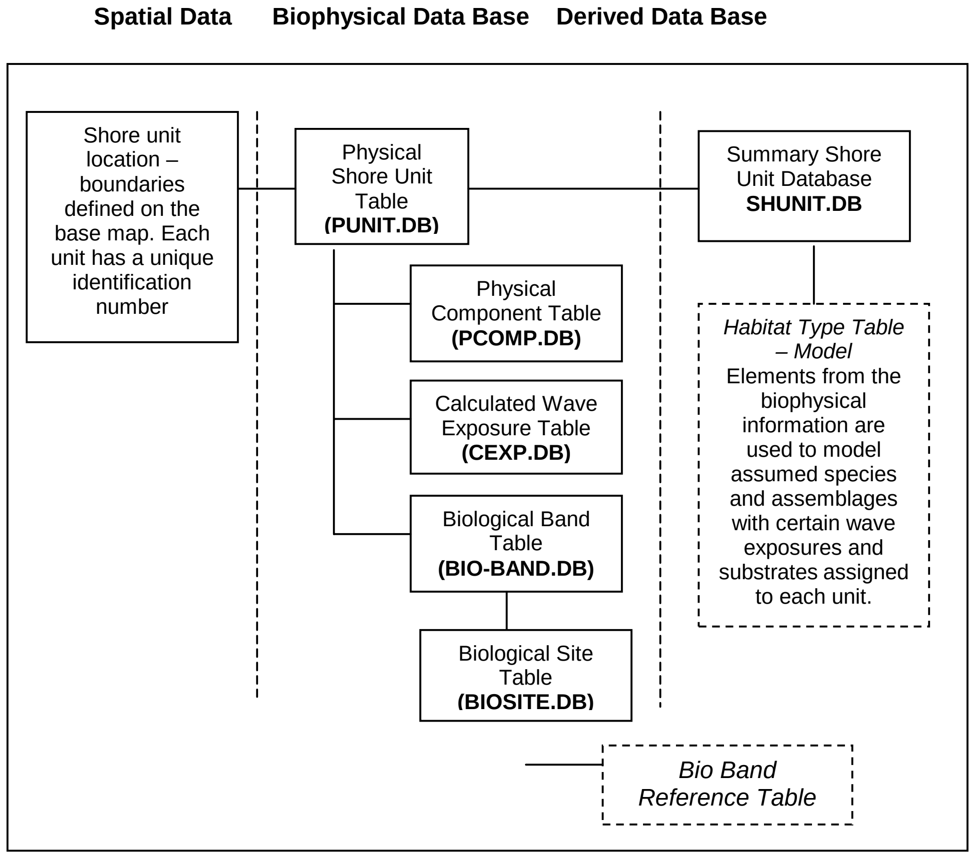

Figure 6 General Structure of the Biophysical Data Base (Ogborne and Howes, 1999)

Table 1: Some of the Biological Colour Band Descriptions Used for Mapping on the West Coast of Vancouver Island (Howes et. al., 1999)

Zone	Colour Band Name	Code Name	Colour	Description	Exposure Category
Supra-tidal (A)	*Verrucaria*	**VER**	black or bare rock	splash zone: sometimes marked by black encrusting lichen & blue-green algae. May include "yellow lichen" in splash esp. at higher exposures	width can be an index of wave exposure
	grasses & *Salicornia*	**SAL**	light/bright green	marsh grasses, halophytes, *Salicornia*	protected, semi-protected,
Inter-tidal (B)	*Fucus*	**FUC**	golden brown	dominated by *Fucus*, includes *B. glandula*. At semi-exposed sites, this band includes *Pelvetiopsis*, same colour	semi-exposed to protected
	upper barnacle	**BAR**	gray-white	continuous band of *B. glandula*, may also be bare rock, upper intertidal	semi-protected, protected
	barnacle mussel	**MUS**	gray-blue	dominated by *Mytilus californianus* - *Semibalanus carriosus* - with scattered *Pollicipes*	exposed, semi-exposed
	Ulva	**ULV**	bright green	*Ulva/'Ulvaria'* greens, filamentous greens. Colour band is sometimes due to complex of bleached reds in lower intertidal	semi-protected, protected, estuary

Summary of the Biophysical Mapping System
The biophysical mapping system is a descriptive system designed to support the systematic inventory of the biophysical character of the shore zone. It is a bottom-up approach where each shore unit is considered unique. Various features of the physical and biological character are described and documented within a framework of units, zones and components. The system can be applied and easily adjusted for use in most marine environments and has been applied in the Pacific Northwest, Arctic Canada and Australia.

Attributes of the system can be aggregated to provide summary information about a unit, or more importantly, modeled to develop habitat and other resource models. The former allows one to develop summary information for comparison purposes whereas the latter provides resource managers and scientists with a flexible tool to model information including intertidal habitats (see below). The descriptive and flexible nature of the system provides an environment for the easy adjustment to changes in scientific knowledge and new research results.

Shore-Zone Habitat Modelling

The capability to model shoreline habitats is critical for coastal planning, environmental assessment, conservation and protection. Systematic detailed habitat mapping is not feasible in British Columbia due to the extensive length and inaccessibility of the shoreline, and the cost of such surveys. A habitat model has been developed to classify the intertidal zone of the shore zone. It is a knowledge-based model that relies on information obtained from the biophysical shoreline surveys. The independent and descriptive nature of this information, however, provides researchers and resource managers with the flexibility to develop multiple approaches to predict intertidal habitats.

Recent work conducted on the west coast of Vancouver Island provides an example of the knowledge-based habitat model (Howes and others 1999). This method involves defining a set of preliminary habitat types on the basis of wave exposure, shore type, biotic band(s) and species (Figure 7). Shore type is a generalized classification of the physical shore units on the basis of the overall morphology and substrate of the unit. It is based on a model that combines the form, substrate and width of a unit (for details refer to Howes and others 1999).

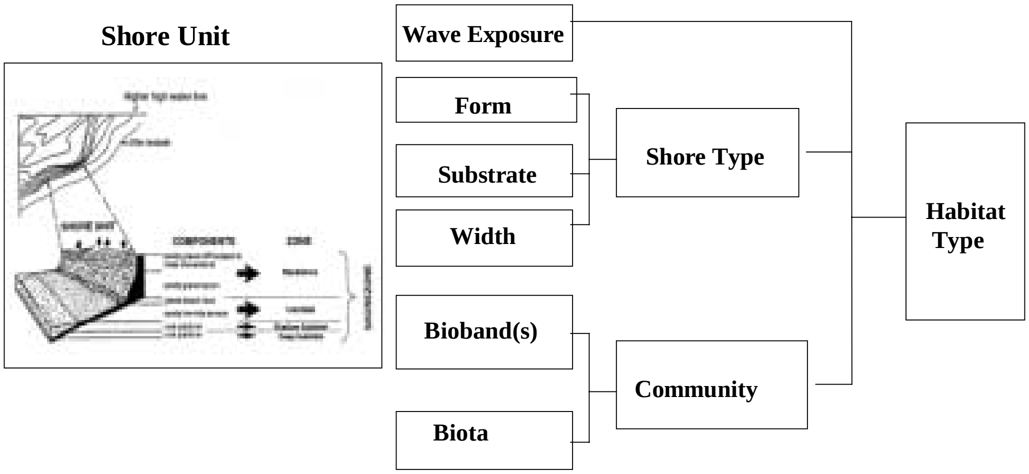

Figure 7 Habitat model applied for west coast of Vancouver Island, British Columbia (Searing and Firth 1995; Howes 2000).

The biotic bands and knowledge of the biota are used to develop community assemblages that in turn are correlated to the shore types and wave exposures to create descriptive habitat types. Each shore unit is assigned a preliminary habitat type according to its wave exposure and biophysical properties. A field program of representative sites is conducted to verify the interpretation of the bands and shore types, and to identify species presence or absence associated with the habitat types. Based on the results of the field survey, the habitat types are revised and each unit is assigned a final predictive habitat type. Nine different habitat types were identified along the shoreline on the west coast of Vancouver Island (Table 2). Figure 8 provides an example of one of these habitat types. The model follows the rationale of linking physical attributes, primarily substrate type and exposure to predictable biological assemblages.

Table 2: Shoreline habitat types identified on the west coast of Vancouver Island (Howes, et. al., 1999)

Code	**Habitat Type**	**Characteristic Species**	**Substrate**	**Wave Exposure**
			Immobile	
H2	Exposed, bedrock	Postelsia, goose-neck barnacles, Lessoniopsis	Bedrock	exposed
H3	Semi-exposed, bedrock/boulder	California mussel, surfgrass, feather boa kelp, *Hedophyllum* kelp	bedrock and/or boulder	semi-exposed
H4	Semi-protected, bedrock/gravel	*Sargassum,* mixed bleached reds	bedrock and/or gravel	semi-protected
H5	Protected & very-protected, bedrock/gravel	*Fucus, Ulva,* eelgrass	bedrock and/or gravel	protected and very protected
			Mobile	
H6	Moderate energy, sand and gravel beach	*Sargassum,* mixed bleached reds	sand and gravel	semi-protected
H7	low energy, sand and gravel beach	*Fucus, Ulva,* eelgrass	sand and gravel	protected and semi-protected
H8	Estuary	upper intertidal grasses, sedges, and *Salicornia*	sand and/or mud	semi-protected, protected, very protected
H9	high energy sand beach	no intertidal macrobiota	sand, small gravel	semi-exposed, exposed, very exposed
H10	Current-dominated	mix of species from low exposures to high	bedrock or sediment	any

Figure 8 Example of a habitat type from the West Coast of Vancouver Island (Howes and others 1999)

<u>Semi-protected Bedrock/Boulder</u>
A narrow splash zone, often a lush *Fucus* (FUC) band occurs on the immobile substrate of this type. These habitat types have semi-protected wave exposure. The lower intertidal zone may show an assemblage of smaller red algae, often bleached and golden yellow colour of the HAL band. Common species of the HAL band include *Gastroclonium, Odonthalia* and *Pironitis.* Some sites show a soft brown band (SBR) comprised of *Sargassum,* an indicator species of semi-protected wave energy. Urchin barrens may be present (URC band) in nearshore subtidal.

An analytical approach to habitat classification modelling has also been tested in the Strait of Georgia combining biophysical shoreline morphology and biological site data with additional physical information (Zacharias and others 1999). The abiotic component of this study included physical shoreline type, wave exposures based on modified effective fetch (Howes and others 1995) as well as salinity, temperature and current velocity from a hydrodynamic model. The biotic component of the model included information on macrobiota species abundance for 39 field-sampled sites. The objective of the study was to develop statistical associations between the abiotic and biotic components to create meaningful habitat types (or biotopes). A two-way indicator species analysis (Twinspan) was used to define species associations that, in turn, were used as the response variables in a regression tree analysis based on the abiotic data. The results of this study are promising. The probability that the tree model correctly predicted the habitat types is about 72%. Limitations to this study include low number of field samples and no sampling in fine-grained sediments. This approach requires further testing, however it may prove to be another approach for classifying shoreline habitats and does illustrate the flexible application of the biophysical shoreline information.

Summary

The British Columbia biophysical shore-zone mapping system is a well-documented and proven approach for conducting coastal inventories of the shore zone. It provides a systematic, cost-effective mapping methodology to record the physical and biological character of the shore zone. This information forms the basis of a predictive, knowledge-based intertidal habitat model that is being applied to the British Columbia shoreline in lieu of systematic detailed habitat mapping. The system has been applied in a variety of marine environments in Canada, United States and Australia. Completion of these surveys in British Columbia and Washington State will result in a systematic coverage of biophysical shoreline information that extends from the Columbia River mouth to the Alaska border.

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