Standard Methods for Sampling Resources and Habitats in Coastal Subtidal Regions of British Columbia:

Part 1 — Review of Mapping with Preliminary Recommendations

1996

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STANDARD METHODS FOR SAMPLING RESOURCES AND HABITATS IN COASTAL SUBTIDAL REGIONS OF BRITISH COLUMBIA: PART 1: REVIEW OF MAPPING WITH PRELIMINARY RECOMMENDATIONS

by

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ABSTRACT

Booth, J., D. E. Hay and J. Truscott. 1996. Standard Methods for Sampling Resources and Habitats in Coastal Subtidal Regions of British Columbia: Part 1 - Review of Mapping with Preliminary Recommendations. Can. Tech. Rep. Fish. Aquat. Sci. XXXX: viii + 53 p.

This report consists of two distinct sections. The first section considers and recommends standards for the **Georeferencing** of subtidal resources and habitats. This section reviews and discusses standards for mapping scales, the status of coastal base maps presently used and standard methods for referencing resource data to base maps. The second section of the report, describes and discusses principles and problems with the **Classification** of subtidal resources and habitats. This section reviews and discusses the biophysical variables that are part of coastal habitats, the scales for practical subtidal mapping and issues about mapping of selected resources that are often mapped independently of their habitat. In this report, "subtidal" includes the coastal zone between 0-30 m. This report was prepared and related to another study (Robinson et al. 1996) that describes and recommends standards for **Sampling** subtidal resources and habitats.

RÉSUMÉ

Booth, J., D. E. Hay and J. Truscott. 1996. Standard Methods for Sampling Resources and Habitats in Coastal Subtidal Regions of British Columbia: Part 1 - Review of Mapping with Preliminary Recommendations. Can. Tech. Rep. Fish. Aquat. Sci. XXXX: viii + 53 p.

PREFACE

This report is submitted to the Resources Inventory Committee (RIC) by the Coastal Task Force. The Resources Inventory Committee members are specialists from a variety of professional disciplines and represent Provincial, Federal, Aboriginal and private sector agencies and other resource interests. RIC's objective is to develop a common set of standards and procedures for Provincial resource inventories.

The Coastal Resource Task Force has identified a number of projects to develop a common set of inventory standards for the coast of British Columbia. This manual provides documentation and recommendations for subtidal mapping standards. Funding for the RIC work, including preparation of this report, is provided by the Canada-British Columbia Partnership Agreement on Forest Resources Development: FRDA II. This is a five-year (1991-96) $200 million program cost shared equally by the Federal and Provincial governments. Funding from FRDA II does not imply acceptance or approval of any statements or information contained herein by either government. This document is not official policy of Forestry Canada or any British Columbia government ministry or agency. For additional copies and/or further information about the Committee and its task forces, please contact the Secretariat, Resources Inventory Committee, 840 Cormorant St., Victoria, B.C., V8W 1R1, phone (604) 381-5661 or FAX (604) 384-1841.

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1.0 INTRODUCTION

This document proposes standards for the mapping of coastal subtidal ecosystems, habitats and resources in British Columbia. We emphasize that these are **proposed** standards subject to revision. We hope the document will initiate discussion among people of all agencies concerned with the coastal zone of B.C. We further hope this leads to the establishment of a standard Provincial subtidal mapping system. This report is part of a series of reports commissioned by the Coastal Ecosystems Task Force of the Resources Inventory Committee (RIC). As such, we have tried to be consistent with their findings and recommendations of earlier reports.

Previous report topics include (i) reviews and surveys of coastal datasets and data needs (Coastal Resource Inventory Review, Coastal Information Resource Inventory); (ii) intertidal sampling and mapping standards (British Columbia Physical Shore-Zone Mapping System, British Columbia Biological Shore-Zone Mapping System); (iii) Subtidal sampling standards (Standard Methods for Sampling Resources and Habitats in Shallow Subtidal Regions of British Columbia).

The Provincial Resources Inventory Committee (RIC) was set up to establish standards for developing the common British Columbia data model that can provide all users with a common view of the different resource, habitat and land-use databases. The standards should be free of structural or semantic differences. Users should be able to combine data on the same resource from different sources to increase temporal or spatial coverage. Users also should be able to combine data from different resources to increase the "ecosystem" coverage.

Following the requirements in the terms of reference, this report includes: (i) a review of the principles of resource and habitat mapping; (ii) a summary of existing coastal mapping projects in British Columbia; (iii) a review of the resources and habitats that we can presently sample (including scale) and what resources or habitat features we are unable to sample at overview scales; (iv) recommendations for mapping subtidal coastal resources and habitats in the depth range of 0 to 30 meters; and (v) a proposed a system for mapping coastal subtidal habitats which can be integrated into the existing systems developed for the intertidal, backshore and terrestrial zones of British Columbia.

In separate sections, this document distinguishes between two different kinds of standards: **georeferencing** and **classification**. The first section, called **Georeferencing Standards** reviews and discusses (i) standard mapping scales for the coastal environment, (ii) the current status of coastal base maps and the need for standardization and (iii) standard data structures (methods for referencing the data to the base map). The second section, called **Classification Standards**, reviews and discusses (i) the principles of classification, (ii) biophysical variables which define "habitats", (iii) scales at which the subtidal can be sampled, (iv) existing mapping standards and other proposed mapping classification systems, and (v) resources that should be mapped independently of habitat and how they should be mapped. The

final chapter of the report proposes a subtidal mapping classification system. This report is meant to act as the starting point for a discussion between persons and agencies involved in subtidal mapping in B.C. and is not intended to be the final definition.

1.1 DEFINITIONS

For the purposes of this report, the "**Coastal Subtidal Zone**" was defined by the terms of reference as the region between the 0 and 30 m isobaths. The 30 m isobath is taken as a reasonable outer limit for coastal benthic resources. A broader definition of the coastal zone is suggested for planktonic and pelagic resources.

The terms of reference have been interpreted to interpret the term "**habitat**" in its broadest sense to mean the biophysical environment within which organisms exist. In this document, habitat classification has been set up as a hierarchy consisting of ecosystems, habitats, communities and biological resources.

Ecosystems are defined as broad, geographically contiguous regions of similar climate, physiography and biota. "Each area can be considered a discrete system which has resulted from the mesh and interplay of the geological, landform, soil, vegetative, climatic, wildlife, water and human factors that may be present" (Environment Canada 1994).

Habitats are repetitive physical or biophysical types found within ecosystems. The same habitat type may be found in several ecosystems. The definition of biophysical habitats may include key species which impact on the physical structure of the habitat.

Communities are groups of biological species which are associated with each other and with a physical habitat type. Communities are assumed to functionally interact.

Biological Resources are specific biota that may be mapped independently of habitat or communities.

Anthropogenic features such as tenures, historic or archaeological sites, contaminants and existing use are currently being inventoried and mapped by specific agencies and have been dealt with in other RIC documents along with terrestrial resources.

2.0 GEOREFERENCING STANDARDS

There are three issues related to georeferencing to be considered for developing a standard method for mapping coastal subtidal habitat and resource data:

1. scales at which data are mapped;
2. the selection of base maps to which the data are referenced; and
3. the data structure used to depict the data (points, lines, areas or as part of a habitat unit).

At the present time, data may be recorded and displayed in many different formats on maps. The choice of scales, projections and features may be appropriate for specific purpose but unsuitable for extraploation into different formats. It would facilitate data sharing if all data were collected and georeferenced at standard scales (e.g., site, local, regional), on the same series of base maps. Currently much of the coastal data have been mapped on different base maps (Howes 1992) and the same features may be depicted as a coastal segment or line by one study and as an area by another. The issues of map scales, base maps, and data structures are discussed in more detail in the sections below.

2.1 STANDARD MAPPING SCALES

While Geographic Information Systems (GIS) allow for the presentation of data at a scale appropriate for each particular use, data still need to be georeferenced to a base map with a given level of precision. The selection of an appropriate map scale will depend on two factors: (i) the scale of base maps available for the study area (discussed in the next section) and (ii) the purpose of the study. The scale must be large enough to capture all of the necessary features but not so large that the size of the database and amount of detail can make the data collection, input and analysis too costly and cumbersome. Summaries of the standard mapping scales proposed by two of the RIC terrestrial task forces are presented in Table 1 (based on reports by Westland Resource Group 1993 and Runka Land Sense Ltd 1992).

The report on Physical Shore-zone Mapping System (Howes et al. 1994) states that the effective mapping scale of the coast using Aerial Video Imagery (AVI) taken from altitudes of 150-200 m is probably 1:2,500 to 1:5,000. The interpretation of aerial photos typically results in smaller mapping scales (about 1:20,000) and the authors state *that "the units ... are dependent on the mapping scale and on the scale of the data. The same units or components might not necessarily be defined at a 1:50,000 mapping scale as at a 1:10,000 scale*." Shore units described for the Straits of Georgia were applied at a scale of 1:15,000 and resulted in unit lengths ranging from 30 m to 20 km with a median length of 485 m (Searing and Frith 1995).

Table 1. Standard terrestrial mapping scales for "Land Use" and "Range and Wildlife Habitat".

Scale	1 mm =(m)	1 mm² =(ha)	Planning Class	Types of Land Use or Wildlife Mapping Data and Projects
≥1:10^6	1,000	100	Provincial	Ecoregions, gross land use class, biogeoclimatic zones, range boundaries, Provincial planning overview
1:500,000	500	25	Provincial	Generalized land use activities and cover, ecoregion/subzone mapping, biogeoclimatic subzones, range units, general regional planning
1:250,000	250	6.25	Regional, subregional	Generalized land use activities and cover, biophysical wildlife habitat, wildlife presence/absence mapping, regional administrative management
1:50,000 - 1:100,000	50 -100	0.25 - 1.00	Local	Aggregated groups of activities and cover, wildlife range sites, sensitive and critical wildlife areas, sensitive species and ecosystems, biogeoclimatic subzone variants / habitat classes, subregional planning
1:20,000	20	0.04	Local, site	Specific classes of activities and kinds of cover, smaller sized critical wildlife areas, forest type and crown closure mapping, framework for more detailed survey or operational for lease management or range improvement
1:10,000	10	0.01	Site	Specific, block-based information and groups of species
1:5,000	5	0.0025	Site	Detailed, lot-specific information and groups of species, site level habitat information, operational planning

2.1.1 Small Mapping Scales

Unlike the terrestrial resource, coastal resources are all orientated to a narrow fringe - the coastline. At the terrestrial "Provincial" mapping scales of 1:500,000 and smaller, many of the coastal features such as reefs and small islands and bays are lost. While these small scales can be useful for display purposes the resource data must be input at larger scales to be useful. The current trend on the coast has been to use 1:250,000 base maps for Provincial analysis using GIS.

The Coastal Tourism Inventory Project (CTRIP) use the Provincial Digital Atlas 1:250,000 base maps and the Land Use Coordination Office has begun a review of the marine Protected Area Strategy using the recently available digital 1:250,000 CHS Natural Resource Series. Types of features mapped at this scale include:

i) physical features such as exposure or wave energy, ocean currents, general coastline physiography (fiord, channel, archipelago), location of river mouths and major estuaries (i.e., location of freshwater input), temperature and salinity regime.

ii) highly motile biological features such as areas where whales and coastal waterbirds concentrate.

iii) current areas of generalized use such as kayaking destination areas, cruise boat routes, or general areas where sport fishing is concentrated.

iv) many of DFO mapping requirements which may extend from the coast to the offshore. Examples include the location of DFO statistical and management areas, PSP closure areas, species distributions and migration routes, and major fishing grounds.

The mapping scale of 1:250,000 should be adopted as a standard for mapping coastal resources at the "Provincial" scale. There is probably not a need to produce a digital map of the coast at a scale smaller than 1:250,000.

2.1.2 Large Mapping Scales

At the mapping scale of 1:50,000 which is commonly used to map terrestrial wildlife habitat, the shore zones (backshore, intertidal and subtidal to 30 m depth) may be so narrow that habitats become linear features rather than polygons. It is suggested that a slightly larger scale be used for coastal resource mapping than would be used for equivalent projects on land or offshore. It is also suggested that the scales used as a standard for subtidal coastal mapping be consistent with those being developed for the intertidal and backshore zones by the British Columbia Physical and Biological Shore-zone Mapping Systems (Howes et al. 1994; Searing and Frith 1995). They describe a method for mapping the intertidal zone from aerial video imagery (AVI) which permits feature mapping to scales of 1:5,000 to 1:10,000. The estuarine mapping system of Hunter et al. (1982), is designed to work at a scale of 1:5,000 to 1:10,000. The latter is probably too detailed for a coast wide database and will probably be confined to specific sites where there is a need for more detailed information. The 1:20,000 map scale would be consistent with the B.C. Provincial atlas and much of the CHS field sheet data is currently available at this scale. In the United States the "National Wetlands Inventory" by the U.S. Fish and Wildlife Service is mapping all wetlands in the United States, including subtidal regions, at a map scale of 1:24,000.

An important feature of resource mapping in the coastal zone is that as the scale of the base map changes, so does the length of the coastline. Resources such as herring spawn or shellfish bottom culture habitat which are recorded as lengths of coastline, must be mapped at standard base map scales for comparisons between datasets to be possible. The acceptance of a standard Provincial coastal mapping scales would facilitate such comparisons.

The second alternative is the use of alongshore coastal units with a defined length such as those described in the British Columbia Physical Shore-zone Mapping System (Howes et al. 1994). The system defines the shore unit as a section of the coast where the "morphology, sediment texture and dynamic processes do not vary in an alongshore direction." This means that resources tied to a shore unit are scale independent; the alongshore length of the unit is an attribute of the shore unit rather than dependent on the scale of the base map. The disadvantage of this system is that the unit boundaries assume that all resources have boundaries coincident with those defined by the Physical Shore-zone Mapping System. Co-ordination would also be required to ensure that all units were defined in compatible manner and that a single set of units were defined for the coast. The current coastal habitat units do not fully take into consideration

subtidal habitat types and require expansion or revision before they could be extended into the subtidal zone.

2.2 COASTAL BASE MAPS

The coastal region of B.C. has emerged as an area of high interest both for resource and for 'land' use managers however it still sadly lacks systematic coverage by large to medium scale (<1:250,000) base maps in either hard copy or digital format. Over the past few years several agencies have independently digitized the coastline and selected contour intervals from CHS hard copy charts and other sources. For example the Land Use Coordination Office has created a digital map of the shoreline and coastal bathymetry from a combination of CHS charts, satellite imagery and TRIM data files; Parks Canada has done the same for the Gwaii Haanas Park Reserve in the Queen Charlotte Islands, and the Pacific Biological Station has created a seamless digital coastline for all of B.C. from CHS charts. Each agency has independently selected which charts or maps to digitize from and decided on how to match the edges of adjacent charts, potentially creating several different versions of the same coast. As many resources or habitats are inventoried as biomass or numbers per linear unit of coastline or as areas based specific depth strata, these differences can make comparisons between datasets difficult.

There are three key agencies involved in mapping in B.C.; from the coastline seaward the production of base maps has been the mandate of the Canadian Hydrographic Service which is a branch of the Department of Fisheries and Oceans. From the coastline landward base maps have been produced by both the Surveys and Resource Mapping Sector of Natural Resources Canada (formerly the National Topographic Service or NTS) and by the Surveys and Resource Mapping Branch (SRMB) of the B.C. Ministry of Environment, Lands and Parks (MELP). SRMB has established itself as the agency responsible for establishing standard base maps for terrestrial resources in B.C. and is in the process of creating a "Provincial Digital Atlas".

2.2.1 The Provincial Digital Atlas

The land base of B.C. has, for a long time, had complete coverage by hard copy maps at standard scales. More recently, digital terrestrial base maps including both planimetric and topographic features have been produced with a standard set of specifications (Surveys and Resource Mapping Branch, Specifications and Guidelines for Geomatics). SMRB is currently developing a Provincial Digital Atlas which is based on three distinct data sets, each at specific scales. These include:

- 1:2,000,000: a single map covering the entire province
- 1:250,000: 84 map sheets covering the entire province.

These are based on the NTS 1:250,000 map series which have been transformed to the 1983 North American Datum (NAD83). The planimetry and toponomy have been restructured to MELP specifications and the contour intervals have been converted into a DEM.

The TRIM maps are at a scale of 1:20,000. These maps are based on recent (post 1980) air photos taken at scales of 1:50,000 to 1:80,000. Ninety percent of the DEM points are accurate to within 5 m of their true elevation and ninety percent of the planimetric features are within 10 meters of their true position.

Unfortunately, at present the Provincial Digital Atlas does not provide an adequate base map for the mapping of coastal resources and habitats. There are two major deficiencies. The first is the obvious lack of marine bathymetry. The second is the not so obvious, but equally important inaccuracy of the defined coastline. The coastline defined by the Provincial Digital Atlas maps differs from that portrayed by the CHS charts at similar scales. The coastline on the Provincial Digital Atlas maps is based on the "apparent high tide mark". Terrestrial mapping has been done from air photos and the coastline (high tide mark) is estimated from vegetation or *Balanus* bands along the shoreline. CHS coastal charts define the coastline with a high water line and a low water line. High water is the line of elevation of the average of the yearly highest high waters over a 19 year tidal cycle. The low water can be considered to be concurrent with chart datum and it depicts the elevation "that is so low that the tide willl seldom fall below it" (Forrester 1983). In coastal areas with a low slope this may result in large discrepancies between the coastline on CHS charts and those on terrestrial base maps, but generally the TRIM coastline falls between the CHS high and low water lines.

2.2.2 Canadian Hydrographic Service Mapping Activities

The Canadian Hydrographic Service is the main agency currently collecting bathymetric information in a systematic way. CHS coastal soundings are measured with echosounders operated from boats run along parallel lines, generally perpendicular to the shoreline. In the past (before 1940) soundings were measured with leadlines; these soundings are still shown on many charts. The spacing of sounding tracks varies with the complexity of the bottom topography but for coastal surveys 100 meters is frequently used. The errors in the depth measurements should not exceed ± 3 decimeters or 1% of the depth (which ever is the greater). The sounders use narrow beams which increase accuracy but result in a narrow sampling width. Some bathymetry has been collected using airborne LIDAR (Light Detection and Ranging). LIDAR produces a grid of spot soundings at 25 meter spacing to a maximum depth of 30 meters. More importantly developing acoustic technologies now allow for total sounding coverage of the bottom using multibeam echo sounders. These developments produce very large volumes of digital data that describe the sea bed in detail and are also applicable to total water column acoustic mapping of plankton, fishes and other acoustic scattering phenomena.

In processing, the data are corrected in the field for sound velocity in water, tide, draft and speed of the vessel (“squat” or depth of the hull). The corrected spot depth data are transferred onto "field sheets" from which the contours are hand drawn. Some computerised contouring has been done but only as a check on the hand drawn contours. Since about 1988 new field data has been stored in a digital format. There are no plans at present to systematically convert all of the field sheet data into a digital format, however some digitizing of old field data is done as budgets permit and as priorities require. There is more detailed information on the field sheets than is

transferred to the navigational charts; a navigational chart at 1:40,000 scale is typically based on field sheet information mapped at a scale of 1:20,000. Typical scales for field data are 1:5,000 to 1:50,000. In its surveying and charting activities CHS follows International Hydrographic Organization standards which are defined in a series of special publications.

CHS has responded to the resource management and research community in Canada by producing the Natural Resource map series at a scale of 1:250,000. The maps in the series have been edge matched and there are topologically "closed" depth contours at 50 m (and in some cases 10 m) vertical intervals. The data for these maps are derived from CHS field sheet data collected between 1921 and 1971 and in some cases is supplemented by voluntary information collected by the oil and gas exploration companies. While the data are displayed at a scale of 1:250,000 the field data is typically collected at larger scales. The coastline from the CHS bathymetric map series is primarily taken from the NTS 1:250,000 map series, although in some areas where there was a large discrepancy between the CHS charts and the NTS maps sheets the coastline from the chart data was incorporated. These inaccuracies in the coastline are probably not a problem at this small scale where the maps would be used for mapping data for overview and regional planning purposes. The series is available for the entire Pacific coast of Canada in hard copy and digital format. The digital maps are stored in CARIS format but are topologically correct and available in DXF, DLG3O and ISIF formats. By 1998 the maps will all be available in DX90/S-57 digital vector format (an international standard for electronic navigational charts).

At the smaller scales, to date the mandate of CHS has been to provide charts for navigational purposes. This has resulted in several inadequacies of the small scale maps in meeting the needs of resource or habitat managers and researchers. These are listed below:

- **Lack of consistent coverage at standard scales***:* There are still portions of the coast which have only been charted at scales of 1:200,000 or smaller, and many areas where the most detailed scale is smaller than 1:50,000.
- **No systematic updating process***:* Much of the data in remote areas with low vessel traffic is old and consequently has lower precision than current mapping due to outdated mapping methods and/or poor geodetic control. In some areas the coastline may have changed since the last survey due to erosion or deposition.
- **Poor consistency between adjacent and overlapping charts***:* Edge matching between adjacent charts is difficult as contours are for the most part hand drawn by hydrographers and are not consistent between sheets.
- **Unclosed depth contour lines***:* Contours are drawn such that they cannot be converted into closed polygons of constant depth intervals.
- **Lack of GIS compatible digital data***:* While new charts are being produced and marketed in digital format there is currently no process in place to convert old charts into digital format. Those charts which are being made digitally available are not in a format that is easily converted into a seamless base map with depth polygons.

2.2.3 Recommendations for B.C. Coastal Base Maps

It is suggested that CHS work with agencies involved with coastal mapping to establish a standard series of digital base maps for the coast at appropriate scales. At the smaller scales the CHS Natural Resource Series (1:250,000) should be integrated into the 1:250,000 map series of the Provincial Digital Atlas by resolving the areas where there are discrepancies between the two coastlines. Areas of uncertainty in the coastline should be resolved jointly between CHS and SRMB and the database made available as a seamless entity. Smaller scale base maps could be derived from the 1:250,000 base map series.

At the larger scales there are two approaches which could be taken each with its own advantages and disadvantages.

i) Encourage agencies working on the coast to build a large scale coastal base map. This is what is happening now with the efforts by the Provincial Land Use Coordination Office, DFO and others. The main advantage of this strategy is that the priorities for mapping are being set by those agencies working on the coast; the disadvantages are that duplication of effort is occurring and there are no standards being followed. A solution would be to create coastal base map guidelines which specify such things as which hard copy charts to use, digitizing methods (tolerances, contour interpolation methods and edge matching procedures), and data structures. Some kind of organization would also be required to made to make sure that these base maps are shared amongst agencies and public funds are not spent duplicating efforts.

ii) Use the CHS field sheet data to create a Digital Elevation Model (DEM or perhaps better worded as a "Digital Depth Model" DDM). Users would then use the DDM to derive the contours appropriate for an individual resource. The disadvantage is that CHS does not currently have the funds to direct towards such an effort and political lobbying would be required to direct funds to such a project. The advantage would be that a single agency which already has the necessary expertise would be responsible for data quality. All new data hydrographic collection could be collected in a way to facilitate base map updates.

In both approaches, the high and low lines of the CHS coastline then need to be integrated the into the TRIM base map series (1:20,000) of the Provincial Digital Atlas. This would allow for a seamless interface between maps of marine and land based resources, a necessity for coastal zone management.

2.3 STANDARD DATA STRUCTURES

Elements in the subtidal must be depicted in four dimensional space, either explicitly or implicitly. The spatial dimension must include: (i) along shore position; (ii) across shore position; (iii) depth in water or in sediments. The fourth dimension is the temporal dimension (seasonal, diurnal etc.). For variables that vary over geological time scales such as substrate, the temporal time scale is implicitly understood. For variables such as sediments, phytoplankton biomass or salinity the time at which they are measured often iscritical information.

Ultimately, for efficient management of any extensive Geographic Information System, all data has to be attributable to geographic coodinates and to time. This requires that a coherent data system be adopted for all dimensions.

Table 2. Examples of possible data structures for georeferencing.

	Georeferencing		
Feature Type	**Along shore**	**Attributes***	**Examples**
Point	X, Y	depth	Access point, seal haulout, water or bottom sample
	X, Y, Z		Sewage outfall
Vector	along shore vector	depth, width	Physical Shorezone units, 1-km Herring spawn units
	vector in 2-D space	depth	Epibenthic sled
	X, Y, Z start and end locations		Oblique plankton tow
Polygon	2-D boundaries	depth	Kelp bed, clam bed
	3-D boundaries		Fish schools

* Time (sampling time/date) is an attribute of the feature in all cases.

Dimensions may be mapped explicitly or added as attributes to features mapped in fewer than four dimensions (Table 2). Currently most coastal features are mapped in two dimensions using geographic or projection coordinates and depth and time are entered as attributes. While all features are in reality three dimensional polygons, depending on the relative mapping scale they may be represented as points, vectors or polygons. For example a seal haulout would be represented as a polygon at a scale of 1:5,000 or larger but as a point at scales smaller than 1:10,000. Coastline habitat classification systems such as the Estuarine Classification System (Hunter et al. 1982) map coastal units as polygons with depth as an attribute (e.g., shallow subtidal is <10 m) while the "units" of the Physical Shorezone Classification System (Howes et al. 1994) are linear segments of the coast with attributes including across shore width and depth assigned to the intertidal and subtidal zones.

CHS has adopted Oracle MultiDimensional (MD) database software for its database development and is working with Oracle to expand this systems capabilities for hydrographic applications, including coastal zone mapping. Oracle MD uses a helical-hyperspatial geocoding (HHcode) methodology that provides efficient storage and seaching of the very large data sets produced by modern multibeam mapping systems (Harma et al. 1990). The HHcode can be applied to both spatial (geographic coordinates) and non-spatial (quantifiable attributes) variables.

To georeference features explicitly means that the depth and the geographic or projection coordinates of the horizontal extents of the feature are mapped. Depending on the method of sampling and the scale of mapping, it may not always be possible to map features as polygons.

The minimum resolution on a map is approximately 1 mm. At a scale of 1:20,000 one millimetre represents 20 meters; any feature which is smaller than 20 meters in one dimension (e.g., the 0-20 m zone of a steep shore) would be reduced to a vector at this scale. Any feature which is smaller than 20 meters in both dimensions (e.g., a small reef) would be reduced to a point at this mapping scale. Even at large mapping scales, depth is typically recorded as an attribute and mapping is limited to two dimensions.

Because the coastline is very long in the along shore dimension and typically narrow in the across shore dimension, features such as substrate, which are in reality polygons, are often generalized across shore and mapped as along shore segments. The Physical Shorezone Mapping System (Howes et al. 1994) divides the coast into along shore units which are classified into one of 34 shoreline "types" based on several physical variables. These along shore units have been suggested as a tool for georeferencing biological resources and communities. The advantage of using the same units for all coastal resources is that data from different sources can be added to existing digital map units as attributes thus minimizing data capture costs. This approach also insures that all variables are referenced to the same coastline and allows for analysis between data sets referenced to those units with no need for GIS. The disadvantages are that not all resources have the same breakpoints as the Physical Shorezone Units and the system presupposes that the physical units have captured all of the variables which influence the distribution of the biota. In reality the use of shoreline units for mapping subtidal habitat types may be appropriate for mapping scales of greater than 1:100,000 but operationally is difficult to apply at more detailed scales (John Harper, pers. comm.).

A different approach, taken by DFO for analyses of herring spawning habitat, has been to divide about 6000 km of the B.C. coastline into 1-km along-shore units (Hay et al. 1991). This method was chosen to facilitate statistical time series analysis of the deposition of herring spawn. The advantage of this system is that all units have the same length which reflects the precision of the data collection. A disadvantage of this system is that the length of the coastline is scale specific; its relationship to the actual length of the coastline is influenced by the configuration of the coastline. A second drawback is that islands and other breaks in the coastline may result in the coastal segments being non-continuous.

Other resources, such as kelp beds which are discontinuous along shore, are currently mapped as polygons with 2-D boundaries. The advantage of this system is that boundaries can be sampled and mapped independently of substrate and other subtidal variables which in the subtidal may be a more difficult to measure than kelp canopies. This method also allows for independent statistical tests of associations of the kelp beds with other biophysical variables.

2.3.1 Recommendations for Standard Data Structures

Neither the whole polygon mode of mapping individual resources nor the resource specific shore units such as those used for mapping herring spawn, presuppose any physical relationships. This independence allows researchers to overlay these maps with maps of physical variables such as the Physical Shorezone Units and analyze for correlations. The alternate approach, where most resource and habitat variables are attributes of a defined shorezone unit, is often prefered by coastal zone managers interested in a whole ecosystem approach to coastal management who want to integrate all of the resource and habitat layers with a minimum of effort. Depending on the sampling method and mapping scale, biological and physical variables mapped independently of one another may produce small discrepancies or "slivers" when they are overlaid. These slivers are usually artifacts of sampling or mapping and are not representative of the real world. They require rationalization to eliminate them.

This report recognises that subtidal habitats and resources are mapped differently by different agencies for different purposes. All agencies, however, would benefit from an ability to overlay resource and habitat layers as efficiently as possible. ***This report recommends that the following several steps be taken to realize this***:

1. All systems should use the same base maps that have a single scale.
2. All systems that refer to coastal units based on a defined unit length should use the same units (or some fraction or multiple thereof).
3. All systems should be cross referenced by all agencies involved. "Slivers" should be removed using agreed upon manual or computer algorithms.
4. All alongshore units should include across shore width and depth range as attributes of habitats, physical variables or resources such that they can be integrated with variables more explicitly mapped as polygons.
5. All spatial and temporal dimensions should be either explicitly mapped or implicitly recorded as attributes unless they do not vary.

3.0 CLASSIFICATION STANDARDS

Coastal subtidal resource data is needed in order to manage and protect our coastal marine resources. Typical uses of coastal resource information include: (i) assessment of the actual or potential impacts of harvesting, habitat change (including climate change and human impacts such as oil spills) or natural processes such as succession; (ii) monitoring and protecting important habitats (e.g., to preserve biodiversity); (iii) design and location of resource enhancement or aquaculture projects; (iv) prediction and preparation of plans/actions to mitigate impacts on resources from human activities.

Ideally, we would like to know the distribution and abundance of all species, how they interact, and the physical habitat that supports them. Coast wide mapping of many commercial fish and shellfish species is undertaken by DFO based on the catch and effort for each species. Certain non-commercial biological and physical features can be mapped from existing data or using remote sensing methods (e.g., exposure or kelp beds, see section 3.3) However, the proporation of the coastal subtidal biological resources that can be sampled using the commercial fishery or using remote sensing is very small.

Sampling of the resource itself may be the most logical or only approach when the resource is highly mobile. In this instance, distribution may not be predictable from the physical or biophysical habitat, or the presence of other species. Historical use, population size or proximity to habitat which meet the needs of other life stages may be more important. (e.g., marine mammals, birds). In some situations, such as kelp beds, it is simpler to monitor the resource rather than the associated physical habitat. Alternately the resource may be economically important or is highly endangered and locally distributed (e.g., sea otters).

Most subtidal species can only be sampled using site survey techniques. It is unreasonable to expect that coast wide sampling could be carried out at this scale (<1:10,000). Theoretically, as our knowledge of these species increases, their presence, and perhaps abundance, can be predicted based on the distribution of "indicator" species and/or physical habitats which can be remotely sampled (Table 3). Currently in B.C., we are just beginning to describe subtidal biological communities and have only a crude understanding of the habitat requirements of non-commercial species. The mapping systems must therefore be able to incorporate descriptive information collected at large scales with remotely sampled data collected at small scales.

The Provincial government has directed considerable resources towards mapping coastal habitats as an indicator of the real or potential distribution and abundance of the biota (e.g., the Oil Spill Response Mapping, the Estuarine Mapping Program). Habitat mapping will continue to be a useful tool for predicting the distribution of resources which are difficult to survey directly. For these purpose a single habitat classification system is needed so that data from different studies can be combined to increase spatial and temporal coverage.

Table 3. Examples of "indicator" species and/or physical habitats currently used in B.C. to predict the abundance of other species or communities which cannot be sampled by remote sensing.

Indicator	Example
Physical habitat type	The abundance of geoduck clams may be extrapolated from the extent of mud or sandy-mud substrate which can be sampled using remote sensing techniques such as hydro-acoustics. Both the remote sampling methods and the relationship between clam density and substrate have to be locally calibrated (Schlagintweit 1995).
Remotely monitored indicator species with which the resource is associated	The absolute number of juvenile rockfish can be estimated from the total kelp bed area which can be determined using remote sensing techniques. Both the remote sampling methods and the relationship between fish density and kelp density have to be locally calibrated (Levings and Thom 1994).
A combination of physical habitat and indicator species (Biophysical habitat type)	In the Hakai area the biological community was predicted from a combination of exposure, slope, substrate and indicator species such as Nereocystis, Macrocystis, and Zostera (Emmett et al. 1994).

3.1 CLASSIFICATION PRINCIPLES

Habitat is used in a broad sense to define the biophysical environment within which a species or life stage of a species may exist. The term "Ecozone" is used here to define broad, geographically contiguous regions of similar climate, physiography and biota. "Habitat types" are repetitive physical or biophysical types found within ecozones. The same habitat type may be found in several ecozones. The definition of habitats types may include key species which impact on the physical structure of the habitat.

The following series of **habitat classification system principles** have been developed as a result of a review of existing classification systems and discussions with habitat and resource managers in B.C.. These principles form the basis of the classification system developed in this report and are presented as the first point of discussion. The subsequent sections catalogue the biophysical variables that are important in determining the distribution and abundance of biological resources, what resources and biophysical habitat variables can be measured at a recognisance level and the established classification systems in B.C.

Principles of Habitat Classification

1. Subtidal habitats must be repeatable, into "types" or classes.
2. Classes must represent the full range subtidal habitats in B.C;
3. The classification system must be of use to resource managers. Classes must have biological meaning so that factors which that determine the biological community structure (or control suitability of the habitat for a particular biological resource), should be incorporated into the

classification scheme, preferably at as high a level as possible. We recognised, however, that at this time all of the factors which determine the biological community are not known.

4. The classification must be heirachical with application at various scales depending on the intended use and data sources. The top levels must be based characteristics which can be mapped at a recognisance level using remote sensing methods and will define the boundaries within which other levels are subdivisions.
5. All types of sampling techniques should result in the same habitat classes or community definitions. The level to which a habitat can be classified will however, be determined by the resolution of the sampling technique.
6. The system should recognize time scales over which variables change. Habitat variables which change over shorter time scales should be incorporated at a lower level than variables which vary over long time scales. For example substrate changes over a longer time frame than sediment type which changes less rapidly than the distribution of kelp canopies or eelgrass beds.
7. The system must attempt to incorporate established classifications where ever possible and must maintain some consistency with those outlined in the reports "British Columbia Physical and Biological Shore-Zone Mapping System(s)".
8. The system must be able to respond to foreseeable changes in information requirements and advances in processing and presentation technology.
9. The system must be sensitive to existing collection programs and be able to respond to foreseeable advances in data collection methods. At this point in time we do not know enough about communities to classify them in detail. The last level will therefore be a merely a description of the community at this time.

3.2 BIOPHYSICAL VARIABLES THAT DEFINE SUBTIDAL HABITAT TYPES

For the purpose of this report, coastal subtidal biota have been divided into three broad ecosystem categories: benthos, plankton and transients. In this division, benthos are associated with the benthic environment; plankton are in the water column and transients are motile groups such as coastal birds, marine mammals, and pelagic fishes which move through the coastal zone. Each of these ecosystems divisions are treated separately below in terms of the set of habitat variables that influence their distribution.

Most coastal species have geographic limits to their distribution resulting from barriers to migration, reproduction or survival caused by factors such as water temperature, salinity and competition with other species. These barriers result in species ranges within which a species or community of species may be expected to occur within the same habitat types. It should also be noted that, as in the terrestrial system, not all marine habitats are occupied by climax communities. "*Rocky nearshore ecosystems in B.C. are actually significantly disturbed systems which should have much higher seaweed biomass and biodiversity.*" (Hawks 1994). It has been suggested that this is a result of the removal of sea otters earlier this century and the subsequent dramatic increase in the sea urchin population (Hawks 1994). Other factors which may contribute

to the disturbance of marine ecosystems include pollution (e.g., oil spills) and erosion due to natural processes or anthropogenic activities.

3.2.1 Benthic Ecosystem

The benthos includes bottom orientated species or species life stages including those which inhabit kelp beds or eelgrass beds which are extensions of the benthic environment. The coastal benthic environment is defined by this report as the area adjacent to the coast that is inshore of the 20-30 meter isobath. This depth has been chosen as it roughly represents the bottom of the photic zone and therefore the depth limit for subtidal benthic algae. For the purpose of describing sampling methodologies, Robinson et al. (1996) grouped the species that inhabit this ecosystem into the following categories:

- canopy macroalgae
- subsurface macroalgae
- rooted macrophytes
- zooplankton associated with the vegetation or benthic substrate
- infauna (shallow and deep burrowing)
- epifauna - sessile or attached (no motility)
- epifauna - motile (low motility)
- epifauna - evasive (high motility)
- suprabenthic and benthic fish
- benthic fish eggs

The physical habitat parameters which influence the community structure in coastal subtidal benthic habitats have been studied by a number of researchers. The primary habitat variables determining the distribution of subtidal benthic algae communities include: wave and current energy, substrate, sediment, water depth, salinity, and water temperature (M. Morris, pers. comm.). Additional factors known to influence eelgrass distribution include rate of sediment deposition, and slope (Hutchinson et al. 1989); Factors correlated with marine productivity include light level (turbidity), water temperature, nutrient availability and carbon supply. In the coastal region nutrients are supplied from rivers or deep water via upwelling or turbulent mixing.

The distribution of benthic infaunal and epifaunal invertebrates are primarily influenced by substrate (sediment grain size), slope, exposure, water depth and the sediment silt content of the water (Brinkhurst et al. 1994). Certain dominant plant species such as kelp canopies and eelgrass beds have themselves been identified as important habitat components for other benthic invertebrate or plant species (Lambert 1994; Emmett et al. 1994; Brinkhurst et al. 1994).

Levings and Thom (1994) reviewed the relationship between habitat parameters and biomass of herring spawn, juvenile salmon and rockfish. Herring are known to use eelgrass and

macroalgae as spawning substrate and sediment load is known to be an important variable in determining herring spawn locations (D. Hay, pers. comm.). The complexity of the bottom (e.g., rocky reefs) has been indicated as an important variable for nearshore rockfish and marine plants such as kelp beds are important habitat components for juvenile rockfish. Chum and Chinook salmon rely heavily on the detrital food chain of estuaries during their juvenile phase while juvenile Coho, Pink and Sockeye salmon have been found in association with kelp beds.

It is therefore proposed that the physical habitat variables presented in Table 4 should form the basis of a coastal subtidal benthic benthic habitat classification system. The examples of classes represent either those in common usage or those thought to represent critical values.

Table 4. Proposed physical habitat variables with examples of classes for creating a coastal subtidal benthic habitat classification system.

Variable	Examples of classes currently used
Geographic Location	Ecozone, Ecoprovince, Ecoregion and Ecodistrict
Depth	0-2m, 2-5 m, 5-10 m, 10-20 m
Wave Exposure	Very exposed, exposed, semi-exposed, semi-protected, protected
Tidal Currents	High (>100 cm/s) medium (50-100 cm/s), low (<50 cm/s)
Substrate	Rock, rock+sediment, sediment, anthropogenic
Sediment	Gravel, sand, mud
Minimum Salinity	Marine (>30‰), estuarine (15-30‰), dilute (<15‰)
Maximum Temperature	High (>15°), medium (9-15°), low (<9°)
Suspended Sediment	High, low, none
Bottom Slope	Cliff (>20°), ramp (5-20°), platform (<5°)
Bottom Complexity	Present / absent
Estuary	Size: major, minor
	Circulation: well mixed, partially mixed, salt wedge
	Type: inlet, bay, sound, arm
Vegetation	Kelp canopy, eelgrass, other macrophyte coverage, non-vegetated

3.2.2 Planktonic Ecosystem

The plankton includes species or species life stages which inhabit the water column and whose distribution is more closely linked to the adjacent pelagic environment than to the benthos. These biota are generally unable to maintain their position in the water column and are either mixed throughout the water column or held in the surface layers of stratified water columns. Their horizontal distribution is determined largely by water movements and they may be transported several kilometres alongshore every day. While the 20-30 m isobath may be of some significance to benthos, it is a meaningless boundary for plankton. Definitions of the

coastal zone for the purpose of describing plankton have typically been either the edge of the continental shelf, the area inside of coastal headland such as defined by DFO statistical areas (e.g., area 23 vs area 123) or a prescribed distance from the shore. For the purpose of describing sampling methodologies, Robinson et al. (1996) grouped the species that make up these communities into the following categories:

- zooplankton - invertebrate holoplankton
- zooplankton - invertebrate meroplankton (benthic invertebrate larvae)
- zooplankton - icthyoplankton (pelagic fish eggs and larvae)
- phytoplankton

The term "habitat" is not typically applied to the planktonic ecosystem however it is used here to create continuity with the benthic environment. The basis of the planktonic food chain are the phytoplankton. Most of the phytoplankton species in B.C. waters are cosmopolitan species characteristic of cold, temperate, coast waters with estuarine influence (Harrison et al. 1983). Some fresh water species may be found close to river mouths but otherwise salinity does not directly influence species composition to a large extent (Harrison et al. 1983). The primary way in which salinity will influence phytoplankton is by its influence on water column stability and therefore the depth to which phytoplankton are mixed and the rate at which deep water nutrients are cycled into the surface waters.

The productivity of the phytoplankton are determined by the annual and subannual cycles in available light and nutrients. The available light is partially determined by the latitude (geographic region). Procuctivity also is determined by the depth to which the phytoplankton are mixed (their average light exposure) which is a function of density stratification. Density stratification is primarily determined by salinity which in turn is influenced by the volume of fresh water input. Density stratification may be overcome by mixing by wind and/or currents or modified by internal waves. Productivity also is affected by the depth to which the light penetrates which is a function of the amount of suspended sediments (turbidity).

The available nutrients are influenced by rate at which nutrients are supplied from the land via runoff and the rate of diffusion of nutrients into the coastal photic layer from deep waters. This, in turn, is is a function of the availability of deep water nutrients and the mixing processes discussed above under light availability. Further, dissolved oxygen which may be a limiting factor for some species in inlets with high sills. The rate at which the phytoplankton are "flushed" from coastal areas will also determine the overall productivity of an area.

Measurement of the available light and nutrients does not necessarily provide information on the quality of the "habitat" for phytoplankton. Once there is sufficient light, all of the available nutrients will be converted into phytoplankton and once the phytoplankton begin to grow self shading reduces the depth of light penetration. The primary productivity of the phytoplankton in a "habitat" can only be determined by a time series of measurements of biomass or carbon uptake. The habitat itself must be described in terms of processes rather than variables which change rapidly over time.

The holoplanktonic invertebrates are dependent on the spatial and temporal distribution of the phytoplankton and as such their habitat requirements can be defined on a similar basis. The ichthyoplankton and invertebrate meroplankton may additionally constrained by the habitat requirements of the adult and/or other life history stages.

3.2.3 Transient Species

The "transient" species are those species generally higher up in the food chain which are highly motile and typically use a specific coastal habitat for only certain of its life requirements. These species, which include marine birds, marine mammals, and pelagic fishes are typically sampled and mapped by DFO or CWS. The definitions of "coastal" for each species is somewhat different. For fisheries DFO uses its headland to headland statistical area boundaries to separate coastal and offshore fish distributions; the coastal distribution of marine mammals and birds are monitored within a set distance from shore.

Because they are at the top of the food chain the important habitat variables tend to be the same for transient species as those for benthic and planktonic species. The use of a particular habitat by these species (e.g., haul out site or rubbing beach) may be related to its position relative to other habitats important to the species life history. Few of the transient species are in a state of population equilibrium either as a result of fishing or hunting. As a result, they may either be absent from optimal habitats or extend into marginal habitats as their numbers fluctuate.

3.3 SCALES AT WHICH THE SUBTIDAL CAN BE SAMPLED

The way in which a feature can be sampled will effect what kinds of overview classifications can be used. The highest level of a hierarchial system should be based on those variables which are sampled or can be sampled at small scales or features which can be derived from maps of the coastline such as exposure and coastal morphology. As with the supratidal and intertidal ecosystems, the shallow (≤30 m) subtidal coastal zone is extensive in the alongshore dimension while being narrow in the across shore dimension. This results in a requirement for larger sampling scales than in terrestrial and offshore environments for reconnaissance sampling . Sampling of the subtidal environment has the additional problem of being covered by water and therefore less visible by remote sensors.

Robinson et al. (1996) reviewed the sampling methodology presently available for sampling the subtidal environment. Each of these methods can sample a unique set of subtidal variables in a quantitative or qualitative way (Table 5).

In addition, physical attributes of the shore such as exposure to wind generated waves and shoreline configuration can be derived from charts and maps available coastwide at scales of 1:40,000 to 1:200,000 depending on the area.

Table 5. General categories of methods for sampling the coastal subtidal with examples of the physical and biological features they are able to map and the scales at which they can collect data.

Sampling Scale	Method	Examples
>1:30,000	Satellite mounted sensors	• SPOT, Landsat, NOAA, Radarsat
1:5,000-1:20,000	Airborne sensors	• Aerial Video Imagery (AVI) and Aerial Photography (AP) • Larsen Airborne Laser Bathymeter (LIDAR) which uses infrared and blue/green laser pulses to measure seafloor depth; possibly other information contained in backscatter characteristics such as fish schools and bottom type • Compact Airborne Spectral Imager (CASI) which is a multispectral sensor which digitally records data along the flight path.
1:1000 - 1:10,000	Hydroacoustic sensors and post processors	• High frequency echosounders for fish and or zooplankton • Lower frequency echosounders for water depth and, with computer postprocessing of the return signal systems, the substrate characteristics • Side scan sonar profiles the bottom. Surface features such as marine plants can be "visualized" and the characteristics of the backscatter may be used to indicate bottom texture.
	Automated water measurements	• Fluorometers for chlorophyll concentrations and/or CTDs mounted on towed vehicles or connected to through hull water samplers
1:10 - 1:1000	In situ visual or camera "sampling"	• Free swimming or towed divers • Remotely Operated Vehicles (ROV)
1:10 - 1:100	Removal sampling methods	• In situ sampling by divers or ROVs • Remote stationary sampling methods: water samples, grab samples, core samples, traps, pots, gillnets, angling • Remote towed sampling methods: towed nets or sleds, seines

3.3.1 Water Column

Satellite imagery currently is a widely used tool for sampling large scale sea surface characteristics including sea surface temperature, salinity, turbidity, phytoplankton pigments and under certain conditions, currents. The set of variables and the scale at which they can be measured, depend on the satellite. There tends to be an inverse relationship between the number of band widths sampled and the resolution of the sensors. For example, the Coastal Zone Colour Scanner (CZCS) currently has the best sensor for measuring phytoplankton pigments, however its resolution is about 800 meters. The SPOT satellite has a higher resolution (20 meters) but is panchromatic and cannot be used to map phytoplankton pigments. There are a large number of satellite sensors for measuring sea surface temperature at a wide range of spatial scales ranging from ten meters (e.g., Landsat TM) to hundreds of kilometres (e.g., microwave sensors aboard

Nimbus-7 and Seasat satellites). The technology associated with satellite sensors is rapidly developing and it is expected that over the next decade, sensors will be available to measure most visible sea surface phenomena at scales in the range of 4-30 meters.

It is not possible to directly measure salinity visually, however the extent of freshwater influence of some rivers, such as the Fraser, can be visually estimated from the suspended sediment load of the surface water. Salinity can be measured using passive microwave sensors with low resolution but good accuracy (Lo 1986). Another approach is to make use of the spectral reflectance values of pixels in multi-spectral sensor data related to concurrent measured sea truth data. This method has the potential for a higher resolution (4-30 m), but with less accuracy than that obtained from microwave sensors (Lo 1986).

At smaller scales airborne sampling can utilize the same or more refined sensors than those on satellites often with higher spatial resolution and greater accuracy. However, they have a much narrower sampling width, are much more expensive for covering large areas, and do not necessarily have the time series of data available as do satellites. Through hull or towed sensors linked to data loggers can be used by ships underway to continuously sample florescence, conductivity, temperature and density. These systems have a narrower sampling width than the airborne sensors but are a more direct method with the associated higher degree of accuracy. To date, the ships which operate such systems have not frequently sampled close to shore and while there is good data on the deeper water, there is little existing information close to shore (Harrison et al. 1983). A summary of the scales and methods for sampling properties of the physical water column and plankton is presented in Table 6.

Information on the species composition of the phytoplankton and on the zooplankton species and abundance are derived from samples which have to be collected and analyzed. Even at the largest mapping sales these samples are typically represented as points which can extrapolated using mathematical interpolations, geographic regions or physical "habitat" boundaries, into polygons.

Both the biological and physical variables in the coastal planktonic ecosystem, may vary on diurnal, seasonal or annual temporal scales. Satellite imagery is the only sampling method that has consistently "sampled" the sea surface over time. It can be used to map small scale seasonal variability in the coastal environment which results from the annual cycles of solar heat, wind speed and direction and of freshwater outflow. At larger scales variability may be due to diurnal movements in response to tidal currents or light cycles. These variations must either be measured using in situ sampling methods or be taken into account when using remote sampling methods. The temporal scale is very important in the sampling of the planktonic ecosystem and it must be incorporated into any mapping system.

Table 6. Methods and associated scales, data resolutions and relative costs for sampling properties of the physical water column, phytoplankton and zooplankton.

Scale	Resolution(M)	Cost / Sample	Method	Depth	Surface Temp	Surface Salinity	Surface Turbidity	Surface Current	Chla	Other
> 1:80,000	20 - 800	low	Satellite Imagery		√	√	√	√	√	
> 1:50,000	30	high	LIDAR	√	√		√			
1:12,000 - 1:20,000	12 - 20	moderate	CASI		√	√	√	√	√	
1:1,000 - 1:80,000	1 - 80	low	Aerial Photography/ Video			indirect	some			
1:5,000 - 1:10,000	1 - 2	moderate	Echosounders, SSS	√						Zooplankton Biomass
		moderate	Data Loggers	√	√	√	√	√	√	
< 1:5,000	< 1	high	Stationary Samplers	√	√	√	√	√	√	Plankton Species
		high	Towed Samplers							Plankton Species

√= method that has been proven to work ?=method that shows potential but is not yet proven

3.3.2 Depth, Bottom Substrate and Macro Vegetation

Satellite imagery, at present, does not have either the resolution or the depth penetration to be useful for subtidal sampling of bottom types. It has been suggested as a possible tool for mapping canopy forming kelp beds (C. Hodgson, pers. comm.) however the coarse resolution of current multispectral satellite sensors such as Landsat TM (>30 m) make this unlikely (G. Borstad, pers. comm.). The measurements of all coastal parameters from satellites is limited by the resolution of the multispectral sensors currently used. The long orbital cycles of the current suite of sensors and the low frequency of cloud free data at the correct tidal height also limits the usefulness of satellite data (G. Borstad, pers. comm.). In 1997, however, there are two new satellites scheduled to be launched with 1 m panchromatic and 4 m multispectral resolutions (Space Imaging and EarthWatch). These may prove to be valuable tools for mapping of kelp beds.

Aerial Photography (AP) and Aerial Video Imagery (AVI) have been the standard methods for collecting information on the substrate and general vegetative coverage of the intertidal. However, their capabilites for examination of the subtidal benthic environment are limited. Subtidal features that can be mapped from overflights under ideal conditions include the presence/absence of eelgrass beds, kelp beds and some "sea urchin barrens" (Dobson et al. 1994).

There has been recent research on methods for predicting subtidal (0-20 m) sediments based on models of available data (J. Harper, pers. comm.). These include (i) development of a model, based on intertidal substrate type, that was mapped using AVI (for parts of the B.C. coast) and wave exposure characteristics that are interpreted from maps; and (ii) an extrapolation and interpretation of Canadian Hydrographic Service sediment sample data from field sheet data and nautical charts. A study in the Baynes Sound region found that both methods could reasonably characterize sediments at mapping scales of ≥1:40,000. The model based on intertidal substrate types and exposure may be able to predict the sediments in the 0-5 m depth range at larger scales.

CASI has been used successfully to differentiate between species of intertidal rooted plants and brown and green algae (Borstad 1995). At low tides, with good light conditions, CASI is able to map subtidal vegetation to a depth of about 2/3 of that of the secchi depth which is 4-5 m (Borstad 1995). There are plans to test the capability of CASI to quantitatively map kelp canopies this summer (C. Hodgson, pers. comm.).

Ecosounders with postprocessing systems such as RoxAnn and QT View appear to be valuable tools for the mapping of subtidal sediments (Schlagintweit 1995; Praeger 1995) but the speed at which these methods can collect data (and therefore cost per unit coastline) is much slower than airborne sensors. The transducer frequencies which are currently used to differentiate sediment types do not appear to be appropriate for sampling subtidal vegetation (Schlagintweit 1995). Higher frequencies will reflect off marine algae and rooted vegetation to give a presence/absence value (H. Vandermuelen, pers. comm.). Side scan sonar can give similar information (Quinn 1995).

The standard classification system used in the Physical shorezone mapping system (Howes et al. 1994) has been recommended as the standard system for mapping coastal bottom types. It is discussed in the next section. The various sampling methods mentioned above are summarized in Table 7 with respect to their ability to differentiate between these substrate classes. All remote sampling methods require in situ calibration by divers or other samplers (e.g., ROV, cores, grabs).

Table 7. Sampling methods for mapping depth and bottom type with notes on scale, relative cost, and methodology for sampling and classification.

Scale	Continuous Coverage	Cost / Sample	Method	Depth	Bottom Type	Notes On Sampling	Notes On Classification
> 1:50,000	yes	high	LIDAR	√	?	Uses intensity of backscatter	Hard, coarse, fine which could be extrapolated to a classification of bedrock, bedrock + gravel, sand or mud
1:5,000 - 1:10,000	yes	moderate	SSS	√	√	Uses intensity of backscatter of acoustic energy for indicating substrate; timing of backscatter for bottom features such as vegetation, debris, large boulders	As above
	yes	low	Echosounder	√	√	Uses analysis of the 135 aspects of the shape of the return signal for single beam or 500 aspects of dual beam	With calibration can probably classify surface sediments into primary classes. Currently only general classes have been used.
< 1:5,000	no	moderate	Surface operated samplers	√	√	Sieve samples produce a breakdown of sediment sizes; cannot sample bedrock or very coarse substrate	Can be used for calibration of other systems or with caution spot samples can be extrapolated into a surface
	yes	high	Scuba, ROV		√	Visually extrapolate coverage by sediment type; can collect samples to calibrate fine sediments	Can be used to calibrate other systems or provide coverage for small areas

√= method that has been proven to work ?= method that shows potential but is not yet proven

There has been less consistency in the classifications used for marine vegetation than there is for sediments. The attributes that should be used to classify vegetation at scales smaller than the site survey scale include:

i) presence/absence

ii) percent cover. There are several classifications in use.

One recognizes five categories:

1) no cover or 0%
2) sparse cover or <25%
3) moderately sparse or 26-50% cover
4) moderately dense with 51-75% cover
5) dense with 75-100% cover

Another (Emmett et al. 1994) recognizes four categories:

1) no cover or 0%
2) present with 1-5% cover
3) common with 5-50% cover
4) abundant with 50-100% cover

iii) biomass. High, medium and low categories have been used (C. Hodgson, pers. comm.)

iv) species groups: brown algae, green or red algae, kelp beds, eelgrass beds

v) species

There are a number of techniques that are currently used or being tested for mapping subtidal marine plants (Table 8). MAFF has qualitatively mapped most of the major kelp beds (Laminaria, Macrocystis and Nerocystis) on the B.C. coast, mainly using aerial photography. In some areas field surveys made quantitative estimates of biomass to calibrate the aerial photos. Smaller commercial kelps such as Alaria and the red algal species cannot be mapped using aerial photography or video imagery. MAFF recently tested the CASI system for quantitative mapping red and less conspicuous brown algae species. Satellite imagery was investigated for mapping the extent of kelp beds. (C. Hodgson, B. Carswell, pers. comm.). A report of the capabilities of these alternate sampling methods is in preparation (Joe Truscott, pers. comm.).

Sampling of submerged marine vegetation in water depths of greater than 5 meters requires a different sampling methodology to that used for shallow and surface (floating) vegetation (Table 9). Airborne electromagnetic sensors are unable to adequately sample most subtidal marine vegetation. LIDAR which can penetrate to depths of over 30 m can resolve patches of marine plants which are >10 m but provides little information beyond presence/absence. The use of CASI for sampling marine macro vegetation is limited to depths less than 5 m and conditions of adequate light, good water clarity and low reflectance off the water surface (Robinson at al. 1996). The use of hydroacoustics to sample subtidal bottom features is just being developed and may in future allow prove a useful tool for this purpose.

Table 8. Methods for sampling aquatic macrophytes at the surface, or submerged in water depths of less than 5 m, and the attributes which can be measured at the given resolution.

Scale	Resolution (m)	Cost / Sample	Method	Presence/ Absence	% Cover	Biomass	Species Group	Species
> 1:80,000	20 - 120	low	Satellite imagery	√				
> 1:50,000	30	high	LIDAR	?	?			
1:12,000 - 1:20,000	12 - 20	moderate	CASI	√	√		√	
1:1,000 - 1:80,000	1 - 80	low	**Aerial photography/ video**	√	√		√	
	1 - 2	**high**	**in situ samples**	√	√	√	√	√

√= method that has been proven to work ?= method that shows potential but is not yet proven

Table 9. Methods for sampling submerged aquatic macrophytes in water depths of greater than 5 m and the attributes which they can be used to sample at the given resolution.

Scale	Resolution	Cost/ Sample	Method	Maximum Sampling Depth (M)	Presence/ Absence	% Cover	Biomass	Species Group	Species
> 1:50,000	30	high	LIDAR	30	?	?		?	
1:5,000 - 1:10,000	1 - 2	moderate	Echo-sounders, SSS	> 30	√	√		?	
< 1:5,000	< 1	moderate	Surface Operated Samplers	> 30	√	√	√	N/A	√
		high	Scuba, ROV	30	√	√	√	N/A	√

√= method that has been proven to work ?= method that shows potential but is not yet proven

3.3.3 Epibenthic and Suprabenthic Fauna

The attributes which can be used to classify the epibenthic and suprabenthic fauna include the presence/absence, % cover, or biomass broken down by species, species group (defined by sample signal type), or of any type of fauna in general. The degree to which the species can be identified depends on the species and on the sampling method (Table 10). Most coastal fish and

invertebrate species can only be identified using sampling methods such as SCUBA, grab samples or epibenthic sled tows. These are very intensive sampling methods and can only be considered for surveys done at local scales. The very visual phenomena resulting from herring spawn and sea urchin "barrens" can be picked up using remote sampling methods. In addition species which are commercial fished are in practice "sampled" coastwide by the fishery and/or monitored by DFO.

Table 10. Methods for sampling epibenthic and suprabenthic fauna and the associated scales, relative cost and variables which can be measured.

Scale	Resolution (M)	Cost/ Sample	Method	Maximum Sampling Depth (M)	Presence/ Absence	% Cover	Biomass	Signal Type	Urchins Herring Spawn	Species
>1:50,000	30	high	LIDAR	30	?	?		√	?	
1:12,000 - 1:20,000	12 - 20	moderate	CASI	2/3 secchi					√	
1:1,000 - 1:80,000	1 - 80	low	AP, AVI	5-7 m					√	
1:5,000 - 1:10,000	1 - 2	moderate	Echo-sounders,SSS	>30	√	√		√	?	
< 1:5,000	< 1	moderate	Surface Operated Samplers	>30	√	√	√	N/A		some
		high	Scuba, ROV	30	√	√	√	N/A	√	√

√= method that has been proven to work ?=method that shows potential but is not yet proven

3.3.4 Benthic Infauna

The attributes which can be used to classify the benthic infauna are the same as those used for epifauna, but at present there are no species sampled using remote sensing techniques. There is possibility that some of the larger species could be sampled using echosounders with post processing of the return signal. This method is currently being researched. As with the epifauna, commercial species such as clams and geoducks are "sampled" by the commercial fishery.

3.4 EXISTING MAPPING SYSTEMS

In the terrestrial environment in B.C. a mapping system has evolved over the past few decades which is in fact a succession of mapping systems. At the smallest scale are geographic regions or "land systems" classified as ecozones. Within the ecozones are classes of broad habitat

types called "biogeoclimatic" zones within which plant or site associations are identified. Most, if not all coastal subtidal habitat classification systems have been developed as an extension of intertidal systems or systems which encompass terrestrial and wetland environments as well. A review of habitat classifications systems with an assessment of their suitability to coastal B.C. was completed for the province in 1993 to aid in the development of an intertidal habitat classification system (Frith et al. 1993). The existing methods for mapping of the coastal environment tend to fall into one or the other of the above mapping types. Those relevant to subtidal mapping in B.C. are reviewed below.

3.4.1 Pacific Ecozone Classification

In the terrestrial environment in B.C. a mapping system has evolved over the past few decades which is in fact a succession of mapping systems. At the smallest scale are geographic regions or "land systems" classified as ecozones. Within the ecozones are classes of broad habitat types called "biogeoclimatic" zones within which plant or site associations are identified. Most, if not all coastal subtidal habitat classification systems have been developed as an extension of intertidal systems or systems which encompass terrestrial and wetland environments as well. A review of habitat classifications systems with an assessment of their suitability to coastal B.C. was completed for the province in 1993 to aid in the development of an intertidal habitat classification system (Frith et al. 1993). The existing methods for mapping of the coastal environment tend to fall into one or the other of the above mapping types. Those relevant to subtidal mapping in B.C. are reviewed below.

Table 11. Pacific ecozone classification.

Ecoprovinces	Ecoregions	Ecodistricts	Coastal Component
Northeast Pacific	Northeast Pacific	Northeast Pacific	No
Transitional Pacific	Transitional Pacific	Transitional Pacific	No
	Continental Slope	Continental Slope	Yes
Pacific Shelf / Fjords	Pacific Shelf / Fjords	Dixon Entrance	Yes
		Hecate Strait	Yes
		Queen Charlotte Sound	Yes
		Queen Charlotte Strait	Yes
		Johnstone Strait	Yes
		Vancouver Island Shelf	Yes
	Georgia Basin / Puget Sound	Strait of Georgia	Yes
		Juan de Fuca Strait	Yes

The Pacific ecodistricts define real ecological units within which regional differences in biota exist. Subtidal algal communities are determined to a large extent by the geographic location (M. Morris, pers. comm.) . While a single habitat type might possibly be found in all of the Pacific ecodistricts the presence or absence of a species may be explained by barriers to movement between regions or species distributional ranges. The ecodistrict classification is a useful tool to place habitats in a regional context.

3.4.2 Benthic Habitat Mapping

A number of systems have been developed and a selection relevant to coastal habitats in B.C. has recently been reviewed (Frith et al. 1993). The focus of these systems is on the intertidal regime. Although many of the principles they propose could be applied to coastal subtidal habitats, there is little detailed classification of this regime.

The review by Frith et al. (1993) was used in the development of the "British Columbia Biological Shore-zone Mapping System" for classifying intertidal biophysical habitats (Searing and Frith 1995). The physical and biological classification systems developed for RIC are discussed in detail below. It is felt to be important that a subtidal classification system relate to this system although the nature of the subtidal precludes the direct transfer of the intertidal classification. Subtidal benthic classification systems are then reviewed followed by the few studies which have attempted to classify the coastal water column into "habitats". The last section summarizes the current mapping systems used for "transient" resources including commercial fish species, coastal and marine birds, and marine mammals.

3.4.2.1 Marine habitat "Biounits"

The Land Use Coordinating Committee has been working on a habitat classification for the Pacific marine ecozone which they have called "BIOUNITS" (below Ecodistrict). It proposes to use these habitat units for the development of a Protected Area Strategy for the Pacific Marine Region. This classification which has just been completed in its draft form is referenced to the digital 1:250,000 CHS Natural Resource Series bathymetric map and has been applied to the marine waters of British Columbia out to the 200 mile limit. The final list variables used in the classification include:

i) wave energy H M L (lumping of the wave energy classes defined by "Shore-zone Physical mapping" project);
ii) depth <20, 20-200, 200-1000, >1000 m (from 1:250,000 CHS Natural Resource Series bathymetric map series);
iii) relief L H (based on larger scale charts)
iv) substrate mud, sand, hard (rock), unknown (based on CHS charts and geological survey data)
v) current H, L (based in information from charts and coastal pilot)

These variables can currently be mapped using existing data sources. This system is designed for all marine waters in B.C. and is not specific to the coastal region; only those polygons that fall into the 0-20 m depth range would be considered "coastal". A total of 31 of the 48 possible combinations in the 0-20 m depth range actually occur. Any polygon < 250 Ha was incorporated into adjacent polygons based on variable values. Other variables considered but later dropped were: (i) proximity to land which was suggested as an estimate of turbidity and salinity. This was dropped because its ability to predict these two factors was inconsistent;ii)

water masses as measured by salinity and stratification was dropped as it was thought to be picked up at Ecodistrict level using this mapping scale;

3.4.2.2 Physical shorezone mapping system for British Columbia

At a scale larger than the "BioUnit" classification the Ministry of Environment, Lands and Parks has classified and mapped much of the B.C. intertidal shoreline using the "Physical Shorezone Mapping System for British Columbia" (Howes et al. 1994). This system subdivides the shorezone into alongshore units which are classified as one of 34 shoreline types according to the substrate, sediment type, width and slope within the unit. Within a unit, the morphology, sediment texture and dynamic physical processes do not change in an alongshore direction. The mapping for the intertidal is done using 1:20,000 air photos, Aerial Video Imagery (AVI) at a scale of 1:2,500 to 1:5,000 from 200 feet and ground surveys. The system is hierarchial and can be used at variety of scales as shown below:

Table 12. Physical shorezone mapping system for B.C.

Variables Included	Number of Possible Classes	Typical Mapping Scale
Substrate	3	1:100,000
Substrate, sediment	10	1:50,000
Substrate, sediment, width	17	1:20,000
Substrate, sediment, width, slope	34	1:10,000

Additional attributes of a unit which can be mapped at small scales (Table 13), and the classes which this mapping system may assign them include:

Table 13. Attributes and classifications of small scale shoreline classifications.

Attribute	Possible Classifications
Exposure category	Very protected, protected, semi-protected, semi-exposed, exposed
Unit type	Area, line, point
Sediment Transport Source	Alongshore, backshore derived, fluvial, offshore
Sediment Transport Abundance	Abundant, moderate, sparse
Sediment Transport Direction	N, NE, E, SE, S, SW, W, NW
Shoreline Change	Accreting, erosional, stable

Exposure may be mapped for larger units than the geomorphological/sediment units and exposure classifications are based on the modified effective fetch and the maximum fetch as described in Howes et al. (1994, Appendix C).

At larger scales, the physical shorezone units may be further subdivided into across shore vertical tidal zones within which are one or more components (Table 14). Components are

geomorphic features with unique form and feature that are uniform alongshore within the unit. Each component is classified according to the following attributes:

Table 14. Attributes and classifications of large scale shoreline classifications.

Attribute	Possible Classifications
Vertical tidal Zone	Backshore, intertidal, shallow subtidal and deep subtidal
Primary Form	Anthropogenic, Beach, Cliff, Delta, Dune, Reef, Lagoon, Marsh, Offshore Island, Platform, River Channel, Tidal Flat
Secondary Form Modifier	Specific to each form (see Howes et al. 1994); further defines the type or nature of the form.
Primary Material	Anthropogenic, Biogenic, Clastic, Ice, Bedrock
Secondary Material Modifier	Specific to each material (see Howes et al. 1994); further defines the type or nature of the material.

Each component may have up to 3 primary forms and each primary form may have up to 3 secondary form modifiers. The physical materials within the component may be described by up to 3 primary material codes and each primary material may have up to 3 secondary material modifiers.

While the "Forms" used in this system have been specific to the intertidal zone, the "Materials" classification system could be directly applied to the subtidal. The Material classes are hierarchical and the level to which a bottom is classified would depend on the scale of sampling and presentation. At the top level is the substrate which can be defined as either Rock, Rock + Sediment, Sediment, or Anthropogenic. Table 15 shows the next level of classification for clastic sediments which has been derived from Howes et al. (1994) with some modification in size ranges and additional categories of sand added according to recommendations of Harper (1995).

In a "patchy" environment the bottom type could be classified, to the best available precision, as a combination of the types present with the area covered by each type given as a percentage (Harper 1995). For instance, a classification of Sand and Gravel should try to estimate, with the best possible precision, the percentages of each according to spatial coverage.

An important consideration of this system is that the effective mapping scale may not always be the same as the presentation mapping scale. The effective mapping scale is dependent on the procedures used to collect the data. Air photos are typically available at scales of 1:10,000 to 1:20,000 while aerial video imagery is often flown at low altitudes providing an effective mapping scale of 1:2,500 to 1:5,000. Data may be presented at a smaller scale (e.g., 1:40,000) than that at which it was effectively collected (e.g., 1:10,000). The effective mapping scale will also determine how the units and components are defined; the same units or components might not necessarily be mapped at a 1:40,000 mapping scale as at a 1:10,000 mapping scale.

Table 15. Classification of clastic sediments (from Howes et al. 1994) and modified by Harper (1995)

Sediment Class General	Sediment Class Primary	Size Range (diameter)	Particle Shape or Description of Mixture
Gravel	Rubble	> 1 m	Usually angular
	Boulders	>256 mm	Rounded and sub-rounded
	Blocks	> 256 mm	Angular
	Angular fragments	>256	A mixture of blocks and rubble; may include some interstitial sand
	Cobbles	64-256 mm	Rounded and sub-rounded
	Pebbles	4-64 mm	Rounded and sub-rounded
	Granules	2-4 mm	Rounded and sub-rounded
	Diamicton	various	A non-sorted to poorly sorted mixture of sand and large rounded and angular particles in a matrix of sand and clay
Sand	Coarse sand	1-2 mm	
	Medium sand	0.25-1	
	Fine sand	0.0625-0.25 mm	
Organic/ Fines	Silt	0.0195-0.0625 mm	
	Clay	<0.0195 mm	
	Fines, mud	<0.0625	A mixture of silt and clay; may include a minor fraction of sand

3.4.2.3 Biological shore-zone mapping system

A hierarchical system for mapping the British Columbia intertidal biotic environment has recently been proposed (Searing and Frith 1995) that descriptively maps the biota within the units, zones and components defined by the physical classification system. This system does not attempt to classify the intertidal region but rather to provide a means of mapping it. The authors of this system state:

"While physical parameters can be determinants of the distribution of species, biotic factors are equally important, and may dominate in some cases .... The definition of shore unit boundaries for the biological database using the distribution and abundance of species would be preferred rather than assuming the physical boundaries define breaks in the biological distribution. Unfortunately, the expense and time required to collect the necessary biological data for defining biological divisions is prohibitive at this time."

They also point out that while much of the physical data can be surveyed using remote sensing techniques such as aerial overflights, little biological data can be collected this way. They believe that the mapping of benthic, sessile species in concordance with physical shorezone types will eventually lead to a biotic classification system. The description of the biota includes information on the distribution and species composition within the physical classification divisions. To enable mapping at various scales, information on the attributes shown in Table 16 can be included with varying amounts of detail.

Table 16. Attributes of a biological shoreline system.

Attribute	Description
Unit ID	Physical unit ID number
Zone	Vertical Tidal Zone: backshore, intertidal, shallow subtidal and deep subtidal
Component	Physical component ID
Form	Form within a component (up to three forms per component)t
Material	Material of form (up to three material per form)
Band	Distinct biotic assemblages within a level described as either across shore bands, tide pools or "other pattern" (e.g., eelgrass or kelp beds). Either identified from aerial or ground surveys.
Distribution	Classified as patchy or continuous; for splash zone classified as wide, medium, or narrow
Width	The average across-shore dimension of the component
Tidal elevation	Min/max height above mean sea level of the community
Methods	Who collected the data, How they collected it and When it was collected and last updated

A second table links species to each of the bands with information on its abundance within the band and the microhabitat within which it is found. The abundance categories were more qualitative than quantitative and included classes of rare (1-2 individuals), few (sporadic or small patches), common (present in moderate numbers throughout the band) or abundant (present in large numbers throughout the band).

A summary of how the Physical and Biological Shorezone Classification Systems could be applied together to the coastal zone in B.C. (Table 17). There are a total of six hierarchical levels; the number of levels would increase with the mapping scale.

Table 17. Summary of physical and biological shoreline classification systems.

Level	Map Units or Attributes
1	Exposure units based on exposure regime
2	Alongshore units classified into types based on physical geomorphological characteristics and characterised in terms of a sediment transport and shoreline change regime
3	Across shore zones based on tidal coverage
4	Components of zones described in terms of form and material; up to 3 "levels" described.
5	Bands described in terms of conspicuous biotic characteristics
6	Communities described in terms of the species composition and distribution

3.4.2.4 B.C. Parks coastal habitat mapping system

B.C. Parks has developed a method for mapping the intertidal and subtidal based extensively on the Physical Shorezone Classification System. This system developed in the Hakai Recreation Area (Emmett et al. 1994) mapped physical shore units using a method similar to that of the Physical Shorezone Classification System (Howes et al. 1994). An additional criterion used was coastline morphology. Three morphological types were used in the Hakai Recreation Area: Straight Coastline, Bay, and Headland with Islets.

It was found that neither the physical shoreline units nor key species such as *Nereocystis* were adequate to predict the distribution of biological communities. Instead the authors defined "Biophysical Units" which combined key species and important physical habitat parameters including the wave exposure, substrate and slope. Within these "Biophysical Units" the species assemblage could be predicted. Each physical shorezone unit could have one or more biophysical units within it and a biophysical unit could be found in more than one physical unit type. The biophysical units with the physical features and dominant species which characterize them are shown in Table 18.

The conclusion of this study is that "key" species need to be incorporated into the classification at a higher level than other species and are as important in determining species composition or communities, as are key physical parameters. This is similar to what has been found in terrestrial ecosystems and incorporated into the "biogeoclimatic" mapping system.

Table 18. Biophysical units.

Unit	Exposure	Substrate	Slope	Biological Indicators
1	Exposed	rock	shelf	Exposed west coast Nereocystis luetkeana kelp bed community
1A	Exposed	rock	cliff/ramp	Encrusting invertebrates on the cliff face, Nereocystis community on the boulder bed at the cliff base
1B	Semi-Exposed	rock	shelf	High densities of red urchins Strongylocentrotus franciscanus forming extensive "Urchin Barrens"
2	Semi-Exposed	rock with sand/ shell at depth	cliff/ramp	Distinct vertical zonation with a narrow nearshore fringe of a Nereocystis Canopy
3	Semi-Exposed	rock with cobble / pebble at depth	shelf	Macrocystis integrifolia kelp bed with associated understorey community
4	Semi-Exposed	sand	shelf	Eelgrass, Zostera marina community
5	Semi-Protected	sand	shelf	Shallow Zostera marina beds with some Macrocystis and Nereocystis. Deeper areas with polychaete work mats.
6	Semi-Protected	sand/shell/silt	shelf	Coarse substrate: Fucus-Entromorpha-red algae and barnacles Soft substrate: Clam beds and burrowing worms
7	Semi-Protected	sand, cobble, boulder	shelf	Mix of Zostera and Macrocystis Canopy
8	Protected	mud, sand	shelf	Blue Green Algal Mat, tidal channels with stands of Phyllospadix

Emmett et al. (1994) point out that the communities found in physical habitat types vary in different geographic regions. They suggested that the set of biophysical units would be expanded or replaced in the various geographic regions of the coast. For example the classification developed by Diether (1990) for Washington State classifies *Zostera* as a species diagnostic of low energy areas while Emmett et al. (1994) in the Hakai area found semi-exposed areas is dominated by *Zostera* (biophysical unit number #4). The main difference between the biophysical units in the B.C. Parks mapping system and the "Bands" used in the Biological Shorezone Mapping System (Searing and Frith 1995), is that former are defined as repetitive units while the latter are defined as purely descriptive units at present.

3.4.2.5 Biophysical estuarine habitat mapping and classification system for B.C.

The B.C. Estuarine Habitat Mapping and Classification system was developed by the wildlife unit of MELP in the early 1980's in response to the known importance of estuaries and the associated wetlands to fish and wildlife species (Hunter et al. 1982). This system recognises three subtidal estuarine biophysical habitat types; reefs (bedrock outcrops), shallow (< 10 m) and deep (> 10 m). Using this system the estuary is divided into geographically distinct units with a single habitat type designation. Each unit can then be modified by one or more of the following variables (Table 19). Because this system was designed only for estuaries the parameters such as exposure and slope were not included. The important addition over other systems is the addition of the three classes of salinity.

Table 19. Biophysical units of estuaries.

Variable	Possible Classes
Substrate	clay, silt, fines, sand, small pebble, large pebble, cobble, boulders, bedrock, organic, shell
Vegetation	non-vascular, submerged vascular
Salinity	fresh, brackish, or marine
Anthropogenic	various anthropogenic uses or influences such as pollution, water intake, log debris, aquaculture

In the intertidal and backshore Hunter et al. (1982) define many more habitat types such as bars, berms, river channels, low marsh, high marsh and so on. These habitat types already contain some information on the expected substrate and vegetation types that might be present. This approach is opposite to that of the Physical Shorezone Classification System (Howes et al. 1994) which uses the intertidal substrate, sediment, slope and width to predict the coastal geomorphological type. The Physical Shorezone Classification System does not, however, define subtidal geomorphological types and its intertidal types are more general than those defined by the Estuarine mapping system. The Estuarine mapping system was designed to work at scales of 1:5,000 to 1:10,000.

3.4.2.6 NOAA Coastwide Change Analysis Project (C-CAP) subtidal classification system

In the United States the classification system proposed by the U.S. Fish and Wildlife Service (Cowardin et al. 1979) has been adapted by NOAA for monitoring change in all wetland habitats, including the subtidal regime (Dobson et al. 1994). The goal of the C-CAP project is to provide national coverage of all wetlands at a scale of 1:24,000 using satellite imagery or aerial photography at least twice a decade (Dobson et al. 1994). The goal of the C-CAP project which is frequent overviews of the wetlands of the entire nation, resulted in the modification of the Cowardin classification system to better reflect what was achievable using remote sensing methods. The C-CAP classification system (Table 20) lumps all deepwater habitats, irrespective of salinity, into a single class.

Table 20. Subtidal classification system used by NOAA CoastWatch Change Analysis Project.

Water - rock or unconsolidated bottoms. May include undetected plants or reefs		
	Marine/Estuarine	
	Riverine	
	Lacustrine	
	Palustrine	
	Marine/Estuarine Reef	
Marine/Estuarine Aquatic Bed		
	Algal	
	Rooted Vascular	
		High salinity (>5‰; true seagrasses)
		Low salinity (< 5‰; freshwater tolerant species)

3.4.3 Coastal Water Column Mapping

The coastal water column has been mapped as geographic regions at the Ecodistrict and larger mapping scales. Within these geographic units repeatable habitat "types" have been identified. For example there are a number of geographically unique water bodies such as the major estuaries and inlets within the Strait of Georgia ecodistrict (Fraser River Estuary, Saanich Inlet, Howe Sound, etc.). The boundaries of coastal water bodies are defined on the basis of Temperature-Salinity characteristics which can be crudely defined by satellite imagery and refined using data loggers such as CTD's, XBT's or sensors linked to through hull water intakes.

The Salmon Farm Suitability Mapping project (Ricker 1989) sponsored by MAFF, classified the Strait of Georgia, Johnstone Strait and west coast of Vancouver Island using oceanographic, geomorphic or pollution limit constraints. The geographic areas defined by this study on the east coast of Vancouver Island included high runoff fjords (Howe Sound, Toba Inlet, Bute Inlet), intermediate runoff fjords with deep sills (Jervis Inlet, Loughborough Inlet, Ramsey Arm); intermediate runoff fjords with shallow sills (Jervis-Sechelt system, Phillips and Frederick Arms); low runoff fjords and silled bays or harbours (Pendrell Sound, Forward Harbour etc) southern through passageways (Agamemnon Channel, Desolation Sound, etc); northern through passageways (Nodales Channel, Okisollo Channel etc.).

The remainder of the coast could be similarly divided into coastal estuarine, inlet, passageway, and open coast regions. This is very close to the statistical subarea system that DFO uses for defining statistical reporting and management areas (see section 3.4.4.1, part (c) below).

Within geographic areas, repeatable water column "habitat" types may be identified. The Salmon Farm Suitability mapping project divided the geographic regions into habitat units which were assigned suitability ratings for salmon farming based on sixteen biophysical variables. Most of these variables would be of relevance to other habitat models however only the final rating was applied to the unit polygons and the attributes of the parameters are presented in a way that would require considerable reinterpretation for other uses. While there are legitimate

reasons for the way in which the Salmon Farm Suitability project mapped its data, an alternate approach, with much broader utility, would be to map each of the variables independently and utilize a GIS to classify the coast for the purpose at hand.

Another example of habitat mapping with broader applicability would be to map "habitats" such as fronts and gyres which can be defined on the basis of how they influence processes which determine the rates of nutrient renewal and horizontal advection. These habitats are usually identified by the phytoplankton biomass associated with them. Other physical variables such as nutrient concentrations, density stratification, turbidity, plankton species assemblage and zooplankton species and biomass would be mapped as attributes of the habitat unit.

3.4.4 Transient Resources

3.4.4.1 Pelagic Fish

a) **Herring spawn**

Information on the distribution of herring spawn is currently collected and mapped by DFO. The information is collected primarily by Fishery Officers making observations from the shore on the alongshore distribution of spawn while estimating the density of spawn and its across shore distribution. In some areas this information is supplemented by dive surveys. The observations of herring spawn are then georeferenced to predefined 1 km alongshore units. The units are currently being defined from a digital base map created by DFO from the largest scale charts available. As the scale of the charts vary between regions from less than 1:12,000 to greater than 1:80,000, the actual length of the coastline will vary somewhat between "1-km" units. The degree to which they vary will depend on the complexity of the shoreline but given the collection methods used is probably not a significant source of error.

The DFO herring spawn mapping method works well for the Herring researchers and fishery managers as it allows for the incorporation of the poorly georeferenced historical data on herring spawn while providing an easy format for statistical analysis. The methods work less well for persons wishing to overlay the data with information referenced using the physical shorezone mapping system (Howes et al. 1994). When the physical shoreline units and herring spawn 1-km units are overlaid, there is a potential that many insignificant slivers will be created where the two unit types do not quite match up. Herring spawn is a very important food source for many species of coastal fish, birds and mammals. It is important that it can be integrated with the physical and vegetative habitat characteristics.

b) **Salmon escapement**

The nearshore use of salmon is concentrated in the estuaries downstream of the rivers in which they spawn. The actual use of the estuaries is species dependent and may vary between years depending on the water levels in the rivers. DFO maintains a database of annual salmon escapement by species linked to stream codes. The river system upstream of an marine estuary may be divided into several different streams, each with its own code. An estimate of the expected abundance of adult and juvenile salmon passing through the estuary may be obtained by summing the escapement for all of the streams that eventually flow into that estuary. The timing of the salmon in the estuary is not recorded in this database. The coastal mapping units are specific river estuaries.

The use of an estuary by salmon also changes the habitat quality for species which feed upon the salmon on either while they are milling around the estuary prior to moving upstream to spawn or on the smolts as they move out of the river into the ocean. It is useful to be able to tie the salmon escapement database to coastal habitat units as an additional attribute.

c) **Fisheries catch and effort data**

Commercial, recreational and first nation fishery catch and effort are monitored by DFO by statistical areas. The statistical areas are geographically unique regions. The largest unit is the division between the North and South Coast divisions. Within these two divisions there are 29 coastal Areas each which may be divided into up to 50 subareas. Each area is a geographically intact unit. Each of the Vancouver Island and Mainland inlet systems are a unique Area as is the Fraser River estuary, the Gulf Islands, Juan de Fuca Strait, Nitnat Lake, Queen Charlotte Sound, Chatham Sound, North Graham Island and the east and west sides of the Queen Charlotte Islands. To a large extent the coastal DFO Fisheries Statistical Areas can be nested within the ecodivisions of the Pacific ecosystem classification system as shown in Table 21.

Table 21. Correspondence of the Ecodistricts (also see Table 11) with the Statistical Areas used by the Department of Fisheries and Oceans.

Ecodistrict	Coastal DFO Statistical Areas
Continental Slope	2W
Dixon Entrance	1, 3, 4
Hecate Strait	2E, 5
Queen Charlotte Sound	6, 7, 8, 9
Queen Charlotte Strait	10,11
Johnstone Strait	12, 13
Vancouver Island Shelf	21, 22, 23, 24, 25, 26, 27
Strait of Georgia	14, 15 ,16, 17, 18, 28, 29
Juan de Fuca Strait	19, 20

Catch and Effort statistics are generally available for statistical Areas. In some years and areas the statistics may be available for some of the fisheries by Subareas. There is more site specific data for certain fisheries such as trawl fisheries and certain shellfish fisheries, however this is generally collected from commercial log books and is confidential information.

Anecdotal information on the timing and relative use of locations within the DFO statistical areas/subareas is being collected at this time. These data are linked to points or polygon features; for example sport fishing holes are coded as points while general sport fishing areas are coded as polygons. Each fishery is treated as a separate data layer with each entity on that level linked to a database entry with information on the effort, timing, depths, species targeted, sources of data and additional site specific comments. The boundaries of the polygons are determined by the nature of the fishery or species but are all nested within the DFO coastal statistical areas.

3.4.4.2 Coastal bird species

Information on the distribution of coastal bird species is primarily collected by the wildlife branch of MELP or by the Canadian Wildlife Service. There are several types of data collection and mapping methods:

1. Surveys of sea bird, eagle, falcon and heron nests or colonies are referenced to a point location usually based on a 1:50,000 NTS map sheet. Larger colonies are mapped out as polygons at large scales (<1:1000). The attributes assigned to the colony are the number of breeding pairs or nests by species for each survey year. The survey method used to document the number of nests/pairs should be indicated.
2. Individual bird observations: the Royal B.C. Museum maintains a card file of terrestrial, coastal and marine bird sightings. These are generally single observations linked to a place name which is assigned geographic coordinates based on the B.C. Gazetteer. Attributes assigned to each sighting include the number of birds of each species, activity of the birds, date, time, location, observer and observation method.
3. Non-breeding survey data: Systematic aerial surveys have been carried out along the coast of B.C. and supplemented by boat and ground surveys. This information was consolidated in into the "Coastal Waterbird Inventory File" as part of a program of coastal waterfowl and habitat inventory initiated by Ducks Unlimited (Canada) and the Wildlife Branch of MELP.

In the Coastal Waterbird Inventory File, data are georeferenced into discrete, hierarchically classified land units. The coast is divided into 91 major zones. . Each zone is further subdivided into 2-15 subzones. All data can be assigned to a specific subzone. Subzones may be subdivided again into biophysically homogeneous "areas"; areas are verbally described either as a specific feature such as a bay, coastal lake, estuary, reach, or channel or as a stretch of coast between two features. The areas tend to be specific to a survey program and the same areas have not always been defined by each survey; for example, the Alberni Inlet-Barkley Sound region is a zone within which there are 5 subzones. One of those subzones is Alberni Canal and within that subzone there are 10-12 areas defined by different surveys (e.g., China Creek, Snug Basin, Nahmint River Estuary).

Each data record includes:

i) location (zone, subzone, and area);

ii) survey information (date, time, weather, agency, observers); and

iii) number of birds observed by species or species group or a note of no birds seen. A total of 35 bird categories are routinely used and up to 20 additional categories are occasionally used. The groups reflect the ease with which birds can be identified from airplanes. For example using aerial surveys many duck species may be individually identified however shorebirds are seldom identifiable to species. The program ended in 1983. Surveys after that date have been added to the database on an ad hoc basis.

3.4.4.3 Marine mammals

Marine mammals are under the jurisdiction of DFO. Seals and sea lions are systematically surveyed by aerial census while they are concentrated on coastal haulout sites during low daytime tides. Animals swimming, rafting or resting on the bottom in clear shallow waters are also counted. All sightings are referenced to the nearest haulout, resting or rafting site. Each site is assigned a unique number which all survey data is referenced to. The sites are given a place name and geographic coordinates taken from a large scale CHS chart. Areas where several small reefs are concentrated close together such as Race Rocks are entered as a single point location.

There is no well developed system for mapping the geographic distribution of cetaceans in B.C. The systems which are in place include:

i) point locations of migratory Gray whale sightings (J. Darling, pers. comm.)

ii) point locations for the recovery of dead or stranded cetaceans of all species

iii) point locations for historical captures by whaling ships

iv) point locations or geographic regions linked to a database of whale sightings.

Additional information includes the individuals and/or pods present, number of whales, time, date, observer, method and notes on behaviour (G. Ellis, pers. comm.).

4.0 SUBTIDAL CLASSIFICATION SYSTEM

Based on the information presented in Chapter 3, a series of classification issues have been identified. Each issue is summarized under a heading called 'considerations', and the relevent facts and issues are listed. This is followed by a list of recommendations listed under a separate heading. The final sections consolidate the issues into a coordinated approach to classifying and mapping the subtidal ecosystem in B.C. coastal waters.

4.1 CLASSIFICATION ISSUES

4.1.1 Mapping of Geographic Regions

Considerations

1. The range of many subtidal coastal species includes only part of the entire B.C. coast and community structures may differ in the same habitat type in different geographic regions.
2. Existing geographic units in common usage for mapping subtidal habitats or resources on the B.C. coast include the Pacific Ecozone Classification system (section 3.4.1), the DFO statistical areas and sub-areas (section 3.4.4.1.), and the Coastal Waterbird Inventory zones, subzones and areas (section 3.4.4.2).
3. The DFO statistical sub-areas were designed to differentiate between waterways while the CWS zones represent areas over which bird habitat changes with break points which can be identified during aerial surveys. There is no reason for these two reporting units to be coincident however minor boundary differences should be rationalized into single break points.

Recommendations

1. The boundaries of the three existing geographic mapping systems should be rationalized such that arbitrary differences in the boundaries are removed. As the DFO statistical areas have the longest and most extensive time series of data attached to them, they should be used as the deciding factor.
2. Both the Coastal Waterbird Inventory zones, and the DFO statistical reporting units should be nested as parallel geographic mapping systems within the Ecodistricts of the Pacific Ecozone Classification system.
3. Any new geographic reporting system should either adopt one of the existing systems or ensure that its boundaries coincide where ever possible.

4.1.2 Mapping of Subtidal Physical Characteristics

Considerations

1. The physical variables which determine subtidal benthic habitat suitability include:
   - energy: wave and current energy.
   - water quality: suspended sediments, freshwater influence (salinity), temperature.
   - bathymetric features: depth, slope, complexity.
   - bottom type: substrate, sediment.
   - the physical processes associated with estuaries
2. Physical variables that can be currently mapped or sampled using aerial or satellite remote sensing include current and wave energy, suspended sediments, freshwater influence, temperature, bathymetric features. The location and extent of estuaries can be determined from the salinity and suspended sediment variables.
3. The maximum depth at which multispectral visual sensors are capable of sampling is about 5 m.
4. Echosounders linked to post processing computer systems are likely capable of mapping subtidal sediments with a similar accuracy to that currently found in the use of AVI as it is used in the intertidal. Both systems require ground truthing and calibration.
5. The sampling scale of echosounder systems for mapping subtidal bottom sediments are about an order of magnitude larger than those used for mapping intertidal sediments with AVI. The width of the coastal subtidal zone (0-30 m) is also typically much wider than that of the intertidal zone. This will result in a much greater effort to map subtidal sediments than that required for intertidal sediments.
6. It appears that the intertidal units and wave exposure defined by the Physical Shorezone Mapping System may be a useful tool for predicting subtidal substrate and associated sediments at least in the area where it has been tested. The accuracy and precision of the method increases inside of the five meter isobath.
7. A standard classification system exists for mapping the intertidal physical shorezone and many of the variables on which it is based are important to subtidal benthic ecosystems. Physical variables important to the subtidal biota which are not included in the existing system include currents, salinity, temperature, suspended sediments, bottom complexity and the combination of processes which make estuaries such productive ecosystems.
8. A standard classification system exists for mapping marine sediments and it has been consistently applied to the intertidal zone of B.C.
9. The estuarine mapping system recognises the fact that in estuaries, subtidal habitats are not linear features in the same way as the intertidal.
10. The estuarine mapping system uses three salinity classes to define habitats: fresh (≤15‰), brackish (15-30 ‰), or marine (≥30‰). While the Pacific Ecozone Classification system differentiates between water bodies which are generally marine or brackish, it does not capture the high degree of variability in the coastal surface waters that occurs around estuaries.

11. The Marine Habitat "Biounits" incorporate most of the reconnaissance level variables which are important in the coastal zone including wave and current energy, bottom complexity (relief), substrate, and general sediment information.

Recommendations

1. The B.C. Physical Shore-zone Classification system should be adopted with some modification for mapping coastal subtidal physical units. The following modifications should be made:
   - incorporate current energy in addition to wave energy (exposure).
   - modify the sediment transport attributes to better reflect the abundance of suspended sediments.
   - incorporate salinity (or freshwater influence) into the system using the classification of the Estuarine Mapping system.
   - in units with a rock substrate, bottom complexity should be added at the same level as sediment type is on sediment substrate. A measure of bottom complexity should be developed in conjunction with DFO habitat researchers. The measure used for mapping B.C. waters out to 200 m into "Biounits" may be at too coarse a scale for the coastal subtidal zone but should be considered.
   - the coastal benthic subtidal zone should be divided into depth zones which reflect the depth of wave energy and the ability to use remote sensing methods.
2. The same substrate-sediment classes should be used for the subtidal as for the intertidal and standard methods for calibrating echosounder post processing systems to these standards should be developed.
3. CHS should be encouraged to collect information on subtidal sediments using the echosounder data collected for mapping bathymetry. Similar data should be collected by DFO on its research cruises on an opportunistic basis.
4. Until such time as there is information available through data from echosounders or other direct sampling methods the current efforts to map subtidal sediments from existing data should continue to be researched and/or implemented. These include:
   - the model using the Physical Shorezone Units to predict subtidal substrate and sediments. This system should be further tested; preferably in wide range of geographic areas and habitats.
   - CHS should be encouraged to make their database of bottom substrate and sediment samples available in digital format.
5. Subtidal habitat units should not be constrained by the shoreline into linear units. While at small mapping scales (<1:40,000) most of the coastal subtidal zone (0-30 m) will be reduced to a linear feature with width as an attribute, this may not be true in areas such as estuaries or shallow bays where units in the centre of the channel may be distinct from those along the shore.
6. The hierarchy of physical variables should be adjusted to better reflect the scale at which they can be mapped using current technology.

4.1.3 Mapping of Subtidal Vegetation

Considerations

1. Vegetation is an important habitat component for many fish and invertebrate species.
2. Vegetation varies on a shorter time scale than substrate or sediments and may not reflect a climax community. The rate at which marine vegetation changes over time is phenomena which researchers wish to measure.
3. Certain types of subtidal vegetation can be mapped from aircraft or perhaps even satellites; these include canopy forming kelps and eelgrass beds. Using a somewhat more intensive aerial sampling technique such as CASI, shallow subtidal vegetation (~5 m) can be identified, possibly to class (red, brown, or green).
4. It is expected that while changes in the subtidal vegetation may not reflect sediment or substrate boundaries, sediment or substrate boundaries will result in changes in the vegetation either in terms of presence/absence, biomass, or species composition.
5. By combining the physical subtidal units and key biotic variables it appears that biological communities can be predicted within a geographic area with some accuracy.
6. It is possible that in some subtidal areas we may have mapped information on the presence of kelp canopies or eelgrass beds, but we have no direct information on the sediments.

Recommendations

1. Where subtidal physical units have been defined in the subtidal, mapping of subtidal vegetation should recognize unit boundaries and utilize them in the interpretation of remote sensing data. Within these units, vegetation may have boundaries which can be mapped as polygons or smaller alongshore units depending on the sampling and mapping scale.
2. Depending on the sampling scale the attributes recorded for subtidal coastal vegetation units should include (in order of increasing sampling scale):

   Regional scale:

   – presence or absence of species visible from aerial surveys or satellites: kelp canopy, eelgrass bed, and possibly shallow subtidal algae

   Local scale:

   – presence/absence of subsurface vegetation
   – taxonomic group: kelp (*Laminaria*, *Macrocystis*, *Nerocystis*), eelgrass (*Phyllospadix, Zostera*), shallow subtidal algae (red, brown, green), deep subtidal algae.

   Site:

   – biomass and/or % cover; MAF, MELP and DFO should agree on a hierarchy of break points
   – species present

3. Attempts should be made to research and standardize methods for remote sensing of subtidal vegetation including the use of visual satellite and airborne sensors and the use of echosounders or Side Scan Sonar.

4.1.4 Mapping of Planktonic Ecosystems

Considerations

1. Phytoplankton productivity is influenced by available light and nutrients. The controlling factors are primarily the stability of the water column (temperature-salinity structure), proximity to nutrient sources (deep water or runoff), the rate of advection and suspended sediments.
2. Zooplankton biomass and species composition is related to the phytoplankton species and productivity.
3. The only biotic variable that can be sampled using aerial or satellite mounted remote sensing methods is phytoplankton biomass.
4. The physical variables which can be measured using aerial or satellite mounted remote sensing methods include surface temperature, surface salinity, surface turbidity, and surface currents.
5. For the most part, mapping of the plankton has identified distinct water bodies and mapped the spatial distribution of phytoplankton biomass (chl*a*) within them indicating local areas where processes which increase nutrient availability, decrease available light or effect the vertical or horizontal advection of the phytoplankton cells.

Recommendations

1. The desirability of planktonic "habitat" units should be assessed. The system would have to be tested using available time series of data and satellite imagery where available. Such a system would have to allow for extrapolation of productivity and species composition at specified times of year from the "habitat" unit type and geographic location.

4.2 RECOMMENDED SUBTIDAL CLASSIFICATION SYSTEM

It is proposed that the system which best meets the criteria set out in this document would have several complimentary levels (Table 22).

Table 22. Summary of the recommended subtidal classification system.

<table>
<tr><td colspan="4">Geographic Units
Method for delineating geographic regions within which species assemblages are expected to be consistent and which can be used for summarizing other reporting units or habitats.</td></tr>
<tr><td colspan="3">General Coastal Habitat Units
Habitat units would be of relevance to both the benthic and planktonic ecosystems and be represented by small scale coastal units applied to all inside waters and to the coastal regions of the outer coast to a depth of 30 m. The units would be defined on the basis of energy, suspended sediments, salinity & temperature.</td><td>Individual Resource
Mobile coastal species which are mapped using currently established mapping units or methods.</td></tr>
<tr><td colspan="2">Benthic Environment</td><td>Planktonic Environment</td><td rowspan="6">• Fisheries catch/effort data
• Salmon escapement
• Herring spawn
• Coastal bird distributions
• Sea bird breeding sites
• Marine mammal distributions
• Marine mammal haulout sites</td></tr>
<tr><td>Physical Habitat Units</td><td rowspan="2">Vegetative Habitat Units</td><td rowspan="2">Phytoplankton biomass units</td></tr>
<tr><td>Physical Components</td></tr>
<tr><td colspan="2">Biophysical Habitat Units</td><td rowspan="2">Descriptive Process and Biotic Information</td></tr>
<tr><td colspan="2">Descriptive Biotic Information</td></tr>
</table>

Level 1. Geographic Units (Table 22)

These are geographic regions within which certain habitat type and associated species and communities exist. They can be used to put all resources and habitats in a regional context. The existing Pacific Ecozone Classification mapping system established by Environment Canada can be used to summarize data and to define regions where species assemblages are expected to be constant.

Agencies such as DFO and CWS use reporting units for recording the distribution of fish, coastal bird species and marine mammals. While these units do not necessarily represent ecosystem boundaries, wherever possible the boundaries should be coincident. The Ecodistrict boundaries of the Pacific Ecozone Classification mapping system should be modified such that they coincide with the DFO Statistical Area boundaries. Other less well established systems (e.g., the Coastal Waterbird Inventory mapping system) and any data collection programs should recognize the existing boundaries and incorporate them into their mapping system as far as possible.

Level 2. Generalized Coastal Habitats (Table 22)

The next levels of classification would broadly classify the types of habitats that occur within specific geographic areas. These habitat units would be of relevance to both the benthic and planktonic ecosystems. Small scale coastal units would be defined on the basis of the

following variables an applied to all inside waters and to the coastal regions of the outer coast to a depth of 30 m. Estuaries would be identified in this system on the basis of the minimum value and timing of salinity. All variables would be jointly considered in assigning unit boundaries.

Table 23. Variables for the definition of small coastal units.

Attribute	Possible Classifications
Wave exposure category	Very protected, protected, semi-protected, semi-exposed, exposed
Current energy category	High (≥100 cm/s), medium (50-100 cm/s), low (≤50 cm/s)
Sediment transport source	Alongshore, backshore derived, fluvial, offshore
Suspended sediments	Abundant, moderate, sparse
Minimum annual surface salinity	Marine (≥30‰), dilute (15-30 ‰), fresh (≤15‰), unknown
Freshwater timing (<15‰)	Continuous, episodic, freshet, none, unknown
Maximum annual surface temperature	High (≥15°), medium (9-15°), low (≤9°)

Level 3a. Physical Benthic Habitats

Within the small coastal units (Table 23), benthic physical habitat units would be defined on a hierarchical basis using the variables shown in Table 24. The levels are selected such that the more easily mapped variables are at the top of the hierarchy.

Table 24. Classification of variables of benthic physical habitats.

Level	Attribute	Possible Classifications
1	Depth/Wave Energy	shallow/high (0-2 m), shallow/mod (2-5 m), shallow/low (5-10 m), deep (10-20 m)
2	Slope	steep (≥20°), inclined (5-20°), flat (≤5°)
3	Substrate	rock, rock and sediment, sediment
4a	Sediment	(n/a on rock substrate), gravel, sand & gravel, sand, sand & mud, organics/fines
4b	Bottom complexity (relief)	(n/a on sediment substrate), high, low

Within each physical benthic unit there would be components which would be described in terms of a more detailed description of the bottom materials (sediment and substrate types). The same classes as those used in the Physical Shorezone Classification system could be applied (Howes et al. 1994, p. 54-57). The form modifiers used in the Physical Shorezone Classification system are not applicable to the subtidal and the term is less widely used in this environment.

Level 3b. Vegetative Benthic Habitats

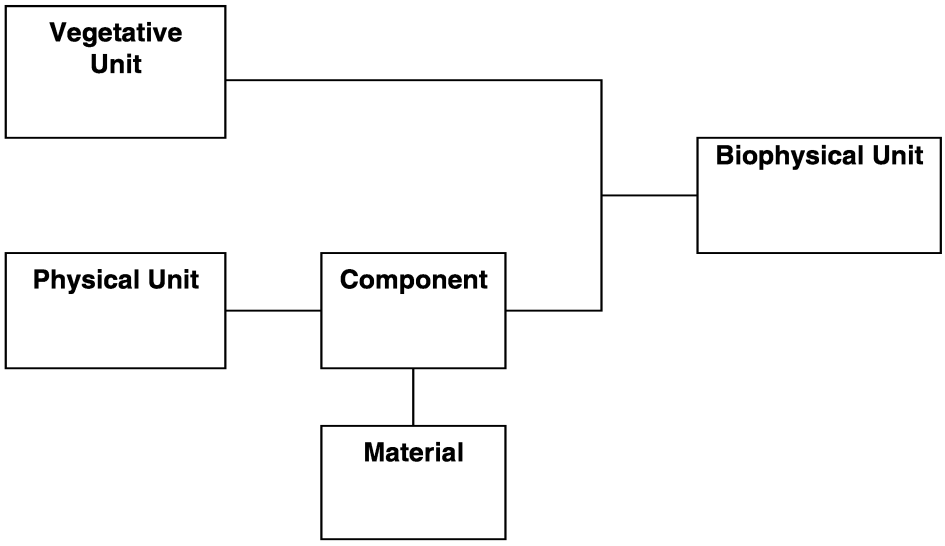
Within the coastal units, in a system parallel to that of the benthic units there would be benthic biotic units which would be based on those biological variables which can be remotely sampled. Where benthic physical habitat unit boundaries are known, they should be used in the interpretation of remote sensing data to insure that where appropriate, boundaries are coincident. As these vegetative variables can all be sampled using information gathered from aerial surveys, or in the near future possibly satellite sensors, it is possible that they may be mapped before the physical shorezone units. The units would be defined as follows:

Table 25. Attributes and classification of vegetative benthic habitat.

Level	Attribute	Possible Classifications
1	Surface vegetation	Presence / absence of kelp canopy or eelgrass bed
3	Subsurface vegetation	Presence / absence, unknown

Level 4. Biophysical Benthic Habitats

The physical and vegetative benthic units could be combined into broad based biophysical benthic units similar to those described in the B.C. Parks coastal habitat mapping system (Emmett et al. 1994) or the "Bands" defined by the Biological Shorezone Classification System (Searing and Frith 1995). The term band is adopted for the subtidal as it is more appropriate in the subtidal where biota are not frequently found in bands as is the intertidal zone. These biophysical units, however, would be more general than either of the other systems to allow them to be mapped using information which can be derived from charts or remote sampling methods for subtidal areas. The classification system is shown below:



Level 5. Benthic Communities

All of the information below level 4 (Biophysical Unit) would require site surveys to generate new data, given the current and foreseeable capabilities of remote sensing methods. Detailed descriptive information on each of the biophysical units could be added in a manner similar to that of the Biological Shorezone Classification System. A suggested format follows:

Biophysical Unit	Species Code	Species Name	Abundance	Distribution	Microhabitat

4.3 METHODS FOR MAPPING INDIVIDUAL RESOURCES

The more mobile or economically important coastal species groups, fish, birds and mammals, will continue to mapped as individual resources using whatever system is in place. This section suggests ways in which these systems can be linked to the physical or biophysical mapping units either by utilizing those units in the mapping process or cross referencing the two mapping systems.

4.3.1 Herring Spawn

There are a number of reasons for the DFO Herring division scientists selection of the 1-km shoreline herring units. The units reflect the accuracy with which the data has and is being collected, provide a mapping unit in the absence of existing subtidal physical or biophysical units and allows for easy statistical analysis. Once subtidal physical or biophysical units have been delineated however, it would be advantageous if the two systems could be overlain and insignificant "slivers" between the two sets of mapping units eliminated by making the herring units attributes of the physical subtidal shorezone units. As emphasized in section 2.2.3, the existence of a standard base map for the coastal zone would also aid in comparison of these two mapping systems.

4.3.2 Salmon Escapement

The salmon escapement database is currently tied to a river or one of its tributaries. The use of an estuary by a salmon species is related to the sum of all of the upstream escapement. Currently there is no standard method for linking that escapement to the estuary. It is proposed that an estuary code be tied to each escapement unit (RAB code) and that code entered as an attribute of the General Habitat Unit(s) which define the estuary.

4.3.3 Fisheries Catch and Effort Data

Data will continue to be reported by DFO statistical areas and subareas. The mapping of site specific log book data and anecdotal information could be refined by the use of physical or biophysical subtidal mapping units. Such information is often based on assumed knowledge of the biophysical environment and the use of habitat maps would reduce the "noise" created by different interpretations of that habitat.

4.3.4 Coastal Bird Species

The Coastal Waterbird Inventory mapping system could be retained for mapping of waterbird abundance however the boundaries should be rationalized with the DFO Statistical Area boundaries taking precedence and organized within the Ecodistricts. Bird colonies and nesting sites should continue to be mapped as points or polygons depending on the mapping scale.

4.3.5 Marine Mammals

Site specific data such as seal and sea lion haulout locations should continues to be mapped as points or polygons depending on the mapping scale. There is relatively little mapped information on cetaceans because of their highly mobile nature. There is some information derived from behaviourial studies on the habitat preferences of many cetacean species. The delineation of biophysical habitat units would provide the kinds of information needed to map "probable" distributions of these species.

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