Aquatic Habitat Classification: Literature Review Towards Development of a Classification System for BC

Discussion Document

Prepared by

L. Miers
Ministry of Environment, Lands and Parks

for the

Aquatic Inventory Task Force
Resources Inventory Committee

March 1994

Digital Copies are available on the Internet at:

http://www.for.gov.bc.ca/ric

Preface

This document was prepared in 1994 to describe the current status of aquatic habitat classification systems in use or under development for potential application in British Columbia. It is understood that a significant amount of work on this subject has occurred since 1994. Much of the work referenced as in progress has since been completed and is now available for consideration. While significant work has been done since the report was completed, this document remains a useful summary to provide a basis for further work towards developing an aquatic ecosystem classification system for use in BC.

Acknowledgments

Table of Contents

1.0 Introduction

The B.C. Resources Inventory Committee and other agencies have expressed the need for standardization in the classification of aquatic and riparian habitats in this province. In response, the Aquatic Inventory Task Force has begun the onerous task of developing a framework from which an ecologically based hierarchical classification system will result.

The goals of the project are to:

1. Produce the framework for an ecologically based aquatic habitat classification system. An integrated, practical system is desirable that will: a) mesh with other ecosystem classification schemes (e.g., terrestrial, marine, riparian, and wetland) at the appropriate levels; b) conform with data types and sources currently or practically available in B.C. and; c) meet the needs of resource planners and managers in B.C.

2. Standardize terms and protocols for the classification system (e.g., data collection and interpretation by hierarchical level).

The methods by which these goals will be achieved are:

1. Review existing Aquatic Habitat Classification Systems and adapt, where appropriate, existing systems into the proposed hierarchical framework for application to ecological regions of B.C.

2. Recommend data requirements, standards and methods, identify key sources of technical information currently available in B.C. and suggest innovative methods (e.g., video) for accessing data.

The magnitude and controversial nature of this task was clear from the outset. The immense volume of published material on classification systems coupled with the varied perspectives of the participants makes this project an arduous, time consuming and often frustrating exercise.

The long range intention of this project is to systematize a wide range of inventory data on aquatic habitats into discrete classes. The resultant system must be easily comprehensible in structure and nomenclature. It must allow flexibility and be based on physical aspects of the environment rather than biological in order to meet the practical and diverse needs of resource people in management and research. It will be a regional system which will include and describe the great diversity of aquatic habitat types in the province. It is our assumption that habitat conditions dictate biological response (e.g., presence or absence of a species or species density and biomass), therefore, from an ecologically based system we get predictability.

The advantages of an hierarchical system, with increasing levels of detail, from top to bottom, are: 1) classification at higher levels narrows the set of variables needed at lower levels; 2) it provides for integration of data from diverse sources and at different levels of resolution; 3) it allows users to select the level of resolution appropriate to their objectives (Frissell *et al.* 1986).

How is this system to be used and who will be using it? The system will provide habitat managers with guidelines for estimating habitat quantity and quality within each class. It will also be useful in assessing habitat capability or suitability and habitat protection requirements. Comparisons can be made between sites of similar classes or changes at the same site can be monitored over time.

Researchers will also benefit from the predictability of the system. What are the local land use impacts? And how do we assess basin-wide cumulative impacts of human activities? An added feature of the system will be a standardization of terminology that will improve communication between researchers, managers and the public.

2.0 Literature Review

Collectively, the following references form a comprehensive survey of established systems of aquatic habitat classification. The system presented in this paper borrows from and builds on many of the concepts presented by these authors:

Busch, W.-D.N. and P.G. Sly. 1992. *The development of an aquatic habitat classification system for lakes.* CRC Press. London.

> Busch *et al.* (1992) published the results of an extensive review of the wealth of literature on lake and stream classification schemes produced at a Symposium on the Classification and Inventory of Great Lakes Aquatic Habitats. Presented as 8 separate papers they cover classification schemes for lakes, stream systems and wetlands. Three papers key to our project were:

1. Hudson, P.L., Griffiths, R.W. and T.J. Wheaton. 1992. *Review of habitat classification schemes appropriate to streams, rivers, and connecting channels in the Great Lakes drainage basin.* Chapter 5. pp. 73–107.

   The authors reviewed 70 papers on the various ways stream habitats have been classified in the past. They chose to modify the hierarchical classification system of Frissell *et al.* (1986). They also included a useful list of modifiers or habitat attributes deemed most important in influencing "presence, absence, or abundance of fish or invertebrates" in the literature they reviewed.

   Their definition of habitat "the environment of the community at a specific spatial scale" allows the flexibility to delineate habitats at a range of scales.

2. Sly, P.G. and W.-D.N. Busch. 1992. *A system for aquatic habitat classification of lakes.* Chapter 2. pp. 15–26.

   An hierarchical classification system for lake habitat is presented. At each level of this system a basic set of data describes a particular habitat. Each level is related to confining factors (morphology), forcing factors (light, heat, movement) and response factors (aquatic vegetation, sediment sorting). This scheme sub-divides a system (lake) into sub-systems (open water and nearshore), Division (Circulatory Basin and Entire Shoreline), Sub-Division (particular features of shoreline or circulatory basin) and Class (Water Column, Substrate and Plant Material). This system is organized in a way that fits well with a list of aquatic plant habitats we had prepared and with further modification should suit our needs.

3. Leach, J.H. and R.C. Herron. 1992. *A review of lake habitat classification.* Chapter 3. pp. 27–57.

   This is a comprehensive review of papers covering 32 categories of lake classification systems based on: a) origin, shape and location; b) physical properties of lakes; c) chemical properties of lakes; and, d) trophic status. Classification by origin, shape and location is compatible with the way we now collect lake data for the 1:50,000 NTS Watershed Atlas. At the whole lake level this appears be the appropriate system to adopt.

Church, M. 1992. *Channel morphology and typology*. Chapter 6 in Calow, P. and G.E. Petts, ed. 1992. *Rivers handbook.* Volume 1. *Hydrological and ecological principles.* Blackwell Scientific Publication. Chapter 6.

> Church suggests categorizing stream channels by size based on the relationship between channel scale and individual bounding sediment grains. The movement and deposition of sediment through a stream is viewed as the major influence on river channel behaviour and morphology. Sediment grains in small headwater streams are characteristically larger cobbles and boulders. In large streams, smaller sediments transported downstream form aggregates of grains or bars. Large streams can then be further categorized according to bar pattern. The drawbacks to this system as it stands are: a) how to define channels with bedrock substrates; and b) how to define small streams flowing through fine grained materials. We are, however, investigating the utility of this system as it applies to the "reach" level of our framework.

Demarchi, D.A. 1993. *Ecoregions of British Columbia*. Report prepared for the B.C. Ministry of Environment. Lands and Parks. Wildlife Branch.

> Demarchi has divided B.C. into ecologically distinct units, ecoregions, based on physiography and climate. His classification includes 5 levels of resolution: Ecodomain, Ecodivision, Ecoprovince, Ecoregion and Ecosection. These units can be sub-divided by Biogeoclimatic zone (Pojar *et al.* 1987) allowing interpretation of climate, elevation, surficial materials, soils, and vegetation. As ecoregions have been mapped for the whole province and are used at all scales of mapping we propose these units as a possible first level in our ecologically based hierarchical framework.

Frissell, C.A., W.J. Liss, C.E. Warren and M.S. Hurley. 1986. *A hierarchical framework for stream habitat classification: viewing streams in a watershed context.* Environmental Management Vol. 10, No. 2, pp. 199–214.

> An excellent conceptual framework for stream habitat classification proposed by Frissell *et al.* (1986) satisfied most of our criteria and formed a basis upon which to build our system. Their system is "designed to intermesh with a biogeoclimatic land classification system" as is ours. Assuming that large-scale, long-term systems set constraints on small-scale, shorter-term systems, they suggest selecting variables that are general, invariant and causal in determining the behaviour of the system to produce a spatially nested hierarchy. Stream habitat is defined and classified at five levels of resolution: stream system, segment system, reach system, pool/riffle system and microhabitat system. As we are trying to create a framework that will mesh with existing terrestrial, marine and wetland systems we have replaced 'stream system' from Frissell's framework with 'ecoregion' followed by 'biogeoclimatic zone.'

Hawkins, C.P., J.L Kershner, P.A. Bisson, M.D. Bryant, L.M. Decker, S.V. Gregory, D.A. McCulloch, C.K. Overton, G.H. Reeves, R.J. Steedman and M.K. Young. 1993. *A hierarchical approach to classifying stream habitat features.* Fisheries, Vol. 18, No. 6:3–12.

> A stream habitat classification system proposed by Hawkins *et al.* (1993) is a refinement of earlier works by Bisson *et al.* (1982) and Sullivan (1986). Homogeneous sections of stream reach are categorized at 3 levels of resolution. At the first level 'channel geomorphic units' are divided at level 1 by flow – 'fast water'/'slow water' which correspond to the two primary channel unit types, pool and riffle. Fast water (riffle) is sub-divided into high and low turbulence and slow water (pool) is sub-divided into scour and dammed pool. The third level sub-divides level two units into discrete habitat classes defined by Helm (1985; from Hawkins 1993); With some modification we hope to adapt this scheme into our framework.

'Fast water' and 'slow water' are not easy terms to define, so we will most likely use the conventional 'pool' and 'riffle.'

Kistritz, R.U. and G.L. Porter. 1993. *Proposed wetland classification system for British Columbia. A discussion paper.* Report Prepared for the B.C. Ministry of Forests, Research Branch.

This is a 3 level hierarchical system for classifying wetlands based on hydrology, class (bog, marsh, etc.) and physiognomic type currently under review by the AITF. Ministry of Forests has sent this paper out for review comments. Some criticisms of this system are: a) sometimes vague definition of terms, particularly class types, and b) terrestrial habitat task force people are concerned about using hydrology as the first level.

3.0 The Proposed System

This system will be designed to interlace our aquatic habitat classification scheme with terrestrial, wetland, and marine systems for B.C., so that terms are standardized and ultimately everyone is speaking the same language. Our preliminary framework consists of 3 hierarchical levels (Figure 1); ecoregion, biogeoclimatic zone (unit), and ecosystem type. Ideas on further classification terms at the Process Unit level are discussed. The level of detail increases down the hierarchy. The first two levels, Ecoregion and Biogeoclimatic Zone, are common to the terrestrial habitat classification system.

```
Ecoregion (1)
    └──────Biogeoclimatic unit/marine (2)
           ├──────── Terrestrial ecosystem (3)
           ├──────── Riparian ecosystem (3)
           └──────── Aquatic ecosystem (3)
                     ├──────── Wetland (4)
                     ├──────── Stream segment (4)
                     │         └── Reach (5)
                     │             └── Channel unit (6)
                     │                 └── Microhabitat (7)
                     ├──────── Lake (4)
                     │         ├── Open water (5)
                     │         └── Nearshore (5)
                     │
                     ├──────── Estuary (4)
                     └──────── Marine (4)
```
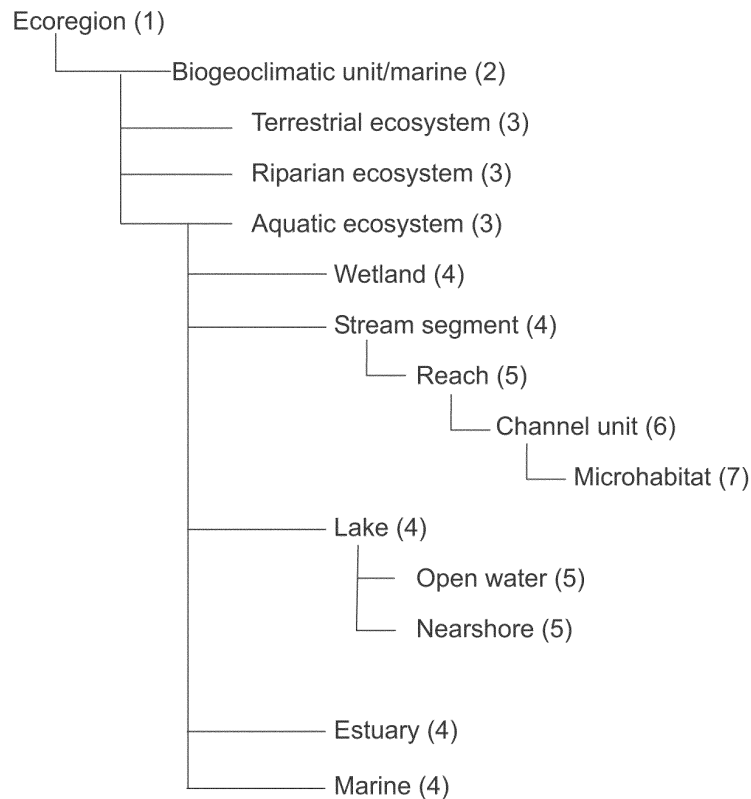
Figure 1. A preliminary framework for ecological classification of aquatic habitats in B.C (hierarchical levels shown in brackets).

3.1 System Components

Listed here in descending order of resolution:

Level 1:

Ecoregion – is the basic unit of habitat classification at the top of our framework. It is the fourth of five levels of an hierarchical biophysical classification system for B.C. devised by Demarchi (1993).

Definition: A geographical area where the ecosystem, produced by macroclimate or oceanic currents and physiography (relief and landforms), is sufficiently uniform to permit the development of characteristic types of ecological associations. Ecoregions exist in different sizes and can be identified at various scales and level of detail in a hierarchy for any area; broad ecological units based on physiography and climate (sic) processes and broad plant and animal distributions (Demarchi, 1993).

Since aquatic macrohabitat is ultimately determined by geology and climate (Minshall *et al.* 1985) it seems reasonable to assume that aquatic and terrestrial classification systems will be compatible.

Classification of aquatic systems by geology and climate is not a new concept in this province. Northcote and Larkin (1956), described 10 distinct limnological regions in B.C. based on geology, climate and their importance in determining dissolved solid content in lakes.

A comparison is planned between Hydrological Zones (developed by M. Church at U.B.C.), also based on geomorphology and climate, and Ecoregions for boundary similarities (D. Hogan, pers. comm. 1994). A close approximation of these two schemes will add justification to the use of ecoregions at the first level of our framework.

Level 2:

Biogeoclimatic Zone (Unit) – Conceived by Krajina (1965), expanded by Pojar *et al.* (1987) and mapped by Ministry of Forests (1992), this system divides British Columbia into fourteen climatically distinct zones with characteristic patterns of vegetation and soil. Biogeoclimatic Zones reflect the effects of elevation and latitude, important in the classification of lakes. This system provides a climatic framework for mapping within ecoregions and for mapping the distribution of plant communities.

Level 3:

At this level, terrestrial, riparian and aquatic ecosystems, the three major ecosystem types, are broken out. Only aquatic ecosystem classification is addressed in this paper.

Watershed, Stream System or Segment – By Frissell's classification, 'stream system' supersedes 'segment class.' The watershed provides a context to view individual segments and habitats (e.g., stream discharge, lake flushing) as well as providing an important unit for grouping and analysis. It is proposed that watersheds or stream systems not be included as levels in the classification. Watershed units as classification levels add to confusion, when used in conjunction with biogeoclimatic zones and ecoregions, since a single system may cross several ecoregion boundaries.

Level 4:

Segment –

Definition: A portion of a stream system flowing through a single bedrock type and bounded by tributary junctions or major waterfalls; it appears relatively uniform in slope on a map-derived longitudinal profile (map scale 1:20,000 to 1:80,000) (Frissell *et al.* 1986).

We have extended this definition of segment to include lake, wetland, marine and estuary as well, but the controversy rages. Frissell *et al.* (1986) argue that "lakes should be considered segment-level units of a stream system as they may persist as geomorphic features across a similar scale of space and time and play major roles in the physical and biological organization of streams."

Each segment type will be classified according to a range of useful parameters. The 1:50,000 NTS maps appear to be a reasonable level of resolution for achieving this objective. It has been suggested that instead of "segment," "process unit" might be a more appropriate term.

3.2 Stream Classification

Level 4:

Stream Segment: Variables or processes recommended for the classification of streams at the segment level include stream class, channel floor lithology, channel floor slope, position in drainage network, valley sideslopes, potential climax vegetation and soil associations at a scale of 1:20,000 to 1:80,000 (Frissell *et al.* 1986). In practical terms for B.C., a 1:50,000 map based segment classification system is desirable because: a) the watershed atlas is being developed at the 1:50,000 map scale; and, b) the Fisheries Information Summary System, intended to (eventually) summarize fish and fish habitat information for the province, is linked to the watershed atlas. Because provincial coverage is desired at this level, practicality suggests 1:50,000 maps and the watershed atlas provide the information base. Air photo interpretation is viewed as a "Reach" level technique.

Variables proposed at the 1:50,000 "Segment" level include stream size, 'stream order' or 'magnitude,' 'gradient' and 'channel morphology.' Channel 'magnitude,' whereby each link of a stream system has a magnitude equal to the sum of all links draining into it, is suggested by Church (1992) to be a more reliable indicator of channel size than stream order. Both will be available from the watershed atlas.

Channel morphology is being classified as part of the Fisheries Information Summary System (D. Tredger, MELP, pers. comm., 1994). Classes include:

R   rock-controlled channels

A   alluvial channels, subdivided as follows:

iA   irregular morphology, including irregular meanders;

mA   regular meanders, may include ox-bow cutoffs;

aA   anastomosed; channel divides about persistent islands;

bA   braided channel: water flows in more than one, frequently shifting channel, with unstable bar surfaces dividing them

These classes have been adapted from more detailed systems (Kellerhals and Church 1989) to reflect what information can practically be interpreted from 1:50,000 mapping.

Level 5:

Reach –

Definition: A length of stream segment lying between breaks in channel slope, local sideslopes, valley floor width, riparian vegetation and bank material; typically possesses a characteristic range of channel bed materials; length is measured in metres to 10's of metres in small steep streams, or perhaps hundreds of metres or more in fifth-order and larger streams (Frissell *et al.* 1986).

Riparian vegetation would constitute a reach boundary in cases of human manipulation.

Attributes at the reach level will be obtained from 1:20,000 air photo map interpretation and/or by field reconnaissance. In addition to more accurate reach boundary locations and gradients, details of channel morphology, riparian characteristics, in-channel habitats, debris and possibly substrate characteristics are available. The AITF is sponsoring a Watershed/Channel Classification project which will add insight into important variables and classification appropriate at the reach level (D. Hogan, M.O.F., pers comm.).

Church (1992), proposes classifying channels by size – small, intermediate and large channels – based on the relative size of channel and bounding sediment where channel units are observed and classified at low flow.

Small channels are characterized by a D/d (ratio between grain diameter and flow depth) usually exceeding 1.0, channel confinement by large cobbles and boulders and by a gradient in the range of 4% to 35%. For intermediate channels 1.0 > D/d > 0.1, the substrate is dominated by aggregates of many grains, channel confinement is by bars, jams and tree roots with pool:riffle:bar forming the major physical element, and gradient remains less than 2%.

Large channels have a D/d <0.1 and flow is a "deep, sheer flow with a well defined velocity profile. Bed structure is dominated by pool-riffle sequences amongst major bar-forms, or by meandered bend-pool and crossover sequences" (Church, 1992).

Church categorizes intermediate channels by channel morphological units (from Sullivan 1986) and/or by logjam morphologies as defined by D. Hogan (megajam, macrojam, mesojam, microjam and individual log pieces).

Large channels can be classified by channel pattern – straight, sinuous, irregular, wandering, irregular meanders, regular meanders and tortuous meanders – by island pattern, by bar structures and by lateral activity (Kellerhals & Church 1989).

Frissell *et al.* (1986) used gross typology (erosional, constructional), morphogenetic class, morphogenetic process, relative length, mean slope, dominant substrate, developmental trend and potential persistence to classify reaches.

At a recent meeting of the Aquatic Inventory Task Force, Dan Hogan (UBC), outlined a system he is working on to classify channels according to, stream type (3 types based on hillslope steepness to valley flat), and channel pattern, bar pattern and debris jam morphology. He asserts that the last two variables are good indicators of stream stability.

Level 6:

Channel Unit –

Definition: Quasi-discrete areas of relatively homogeneous depth and flow that are bounded by sharp physical gradients (e.g., riffles and pools). Individual units are formed by interactions among discharge, sediment load and channel resistance to flow. Different types of units are usually in close enough proximity to one another that mobile stream organisms can select the type of unit that provides the most suitable habitat (Hawkins *et al.* 1993).

The channel unit level will rely almost exclusively on field survey data.

Consideration is being given to a classification of discrete channel units proposed by Hawkins *et al.* (1993) (Figure 2) which is a modification of Bisson *et al.* (1982) and, Sullivan (1986) wherein, Hawkins, attempts to eliminate some of the problems with previous systems; such as, habitat proliferation and use of similar terms to describe dissimilar habitats. At the same time he attempts to provide a means of quick field classification based on visual appearances. This system will still have to be tested against empirical data.
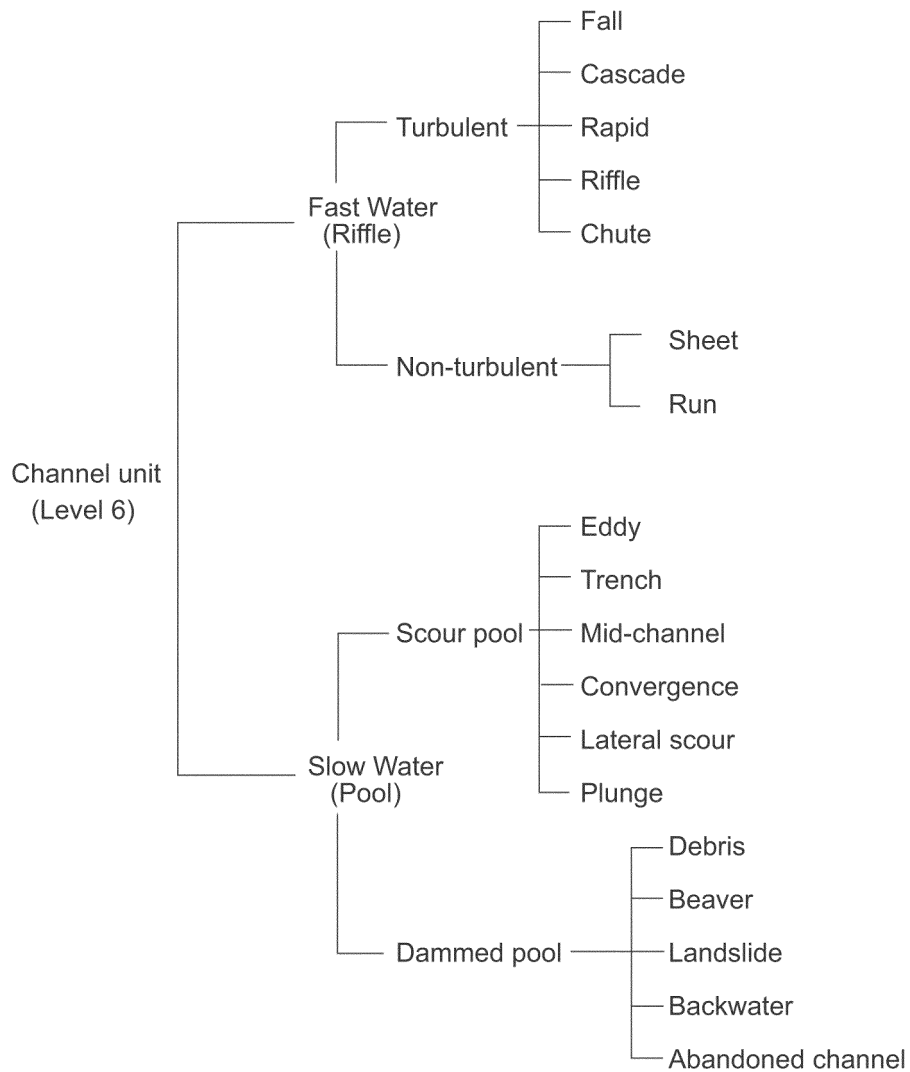
Figure 2. Classification of channel units (from Hawkins *et al.* 1993).

Difficulties with this system include: 1) defining 'fast water' and 'slow water' so that they are measurable ('pool' and 'riffle' may be substituted and defined); 2) the physical character of pool/riffle habitats will change seasonally with flow. Thus, sampling must be done at base flow conditions; and, 3) the extent to which channel units are dependent on stream size is unclear.

Level 7:

Microhabitat –

Definition: Patches within pool/riffle systems that have relatively homogeneous substrate type, water depth, and velocity (Frissell *et al.* 1986).

Microhabitats have low temporal stability. Microhabitat classes will vary according to study objective. Underlying substrate, overlying substrate, velocity, depth and overhanging cover are suggested as useful variables by Frissell *et al.* (1986). Hudson *et al.* (from Busch *et al.* 1992) used instream structure, hydraulic radius, periphyton and benthos.

3.3 Lake Classification

Level 4:

Lake segment: Whole lakes can be classified by origin, shape and location (Hutchinson 1956, from Busch *et al.* 1992). This is the approach taken for FISS lake classification data collected from 1:50,000 map based information. Variables include:

> origin – water level regulation/control and basin boundary

> shape – area, perimeter and shoreline development location – latitude and altitude

The addition of field data (or other variables determined from regional averages) allows for further detail and classification systems.

Sly *et al.* (1992) suggest that mean depth, hydraulic residence time, trophic state and morphoedaphic index are useful at this level but clearly require field sampling. Alternatively, ranges of values can be implied from lake origins, ecoregions, etc. e.g., TDS may be predicted on the basis of bedrock and precipitation (Northcote & Larkin 1958).

Level 5:

Open water/Nearshore – The lake habitat classification system of Sly *et al.* (1992) (Figure 3) appear to fit with Pat Warrington's views on organizing lake habitats for vegetation (Appendix 1). Sly *et al.* (1992), suggest the terms "open water" and "nearshore" in place of pelagic and littoral because they "more reasonably characterize the edge effect."

Definition: The nearshore/open water boundary is defined as "either the sand-silt sediment boundary or the boundary formed by attached vegetation, depending upon whichever reached the greater depth" (Sly *et al.* 1992).

Percent total area and mean depth, determined from 1:20,000 air photos, are suggested variables at this level.
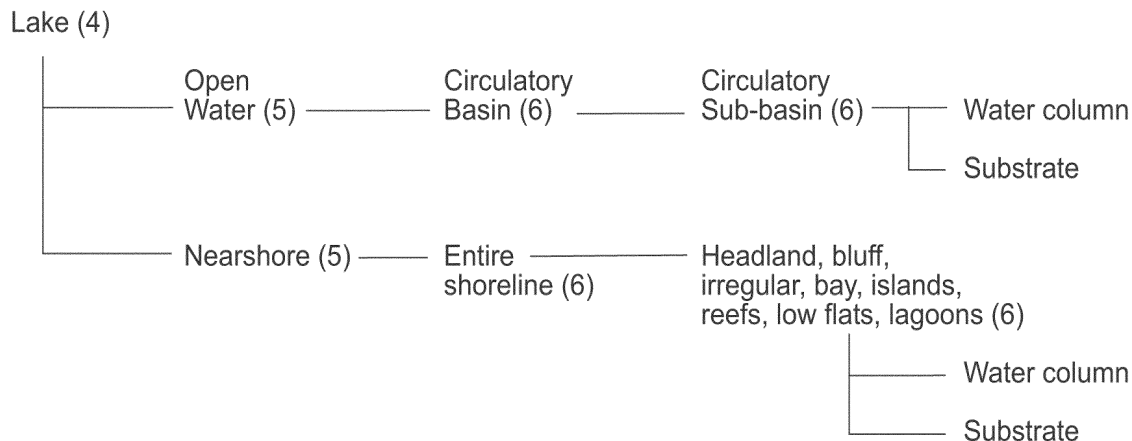
Lake (4)

```
         ┌──── Open           Circulatory       Circulatory
         │     Water (5) ───── Basin (6) ─────── Sub-basin (6) ──┬── Water column
         │                                                       │
         │                                                       └── Substrate
         │
         │
         └──── Nearshore (5) ── Entire ──────── Headland, bluff,
                                shoreline (6)    irregular, bay, islands,
                                                 reefs, low flats, lagoons (6)
                                                                  ┌──── Water column
                                                                  │
                                                                  └──── Substrate
```

Figure 3. Classification for lakes (adapted from Sly *et al.* 1992).

Level 6:

Circulatory Basin/Entire Shoreline – Habitat classification at Sly *et al's* division and sub-division levels is based on size and complexity of physical features. The sub-division level of 'Entire Shoreline' is only useful where distinct features exist, such as headland, bay, islands, etc. Relict features (e.g.) deep-water reefs are considered sub-divisions of circulatory basins.

Definition of Circulatory Basin: Circulatory basins or sub-basins "are defined by the distributions of fine lake bed materials (silt and clay size) and large-scale water motions" (Sly *et al.* 1992).

Level 7:

Class – A habitat class, according to Sly (1992), consists of 3 major components: water column, substrate and plant material. We may characterize class by water column and substrate only. Microhabitats identified by Pat Warrington (Appendix 1) appear to fit as sub-classes.

For example, water column could be sub-divided into surface, above thermocline, below thermocline, below chemocline/anoxic classes within a circulatory basin. Substrate could be sub-divided into surficial, interstitial and sub-surface classes.

3.4 Wetland Classification

Level 4:

Wetland – Within RIC, wetlands are the jurisdiction of the Terrestrial Ecosystem Task Force. We must ensure that the wetland classification covers the needs of aquatic inventory. For example, accessibility of wetland to migratory fish is important as is the amount of open water.

The system currently under review is one proposed by Kistritz and Porter (1993). This paper lists seven definitions of wetland. Of these seven, we favoured the definition proposed by Runka and Lewis (1981, in Kistritz and Porter 1993): " Wetlands are lands that are wet enough or inundated frequently enough to develop and support a distinctive natural vegetative cover that is in strong contrast to the adjacent matrix of better drained lands." An additional

definition has been suggested by A. Banner (MOF, pers. comm), " Wetlands: terrain that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation, and various kinds of biological activity which are adapted to a wet environment. Wetlands include peat-dominated classes (bogs, fens, and some swamps), mineral-dominated classes (marshes, swamps, wet meadows, and shrub carrs), as well as a shallow open (standing) water class (up to 2 m deep). Wetlands may be either forested (>10% tree cover including coniferous, deciduous, and mixed types) or non-forested (<10% tree cover including shrub, herbaceous/graminoid, and moss dominated types)."

We are currently working on making clear, measurable distinctions between lakes, ponds and wetlands and formulating a definition for 'shallow open water.' Cowardin *et al.* (1977) characterized deep-water and wetland habitats of the lacustrine system as: 1) situated in a topographic depression or a dammed river channel; 2) < 30% vegetation cover; and 3) > 8 ha. If smaller than 8 ha, inclusion in the Lacustrine system depends on presence of active wave-formed or bedrock shoreline feature forming all or part of the boundary, or if maximum depth >2 metres at low water. Wetland are categorized as part of the palustrine system if they are: 1) dominated by vegetation; or if lacking vegetation are 2) < 8 ha; 3) lacking an active wave-formed or bedrock shoreline feature; and, 4) maximum depth of <2 metres at low water.

3.5 Riparian Classification

Level 3:

Riparian – Riparian zones and estuaries are also being handled by the TETF. We will classify the aquatic habitats that occur in the riparian areas and rely on TETF for the terrestrial classification system. Again, we must indicate to them our needs for the terrestrial component (e.g., canopy cover, closure, bank/riparian area vegetation as it relates to bank integrity and tree size for organic debris supply).

Riparian ecosystem has been defined by A. Banner (MOF, pers. comm.) as "distinct ecosystems occurring adjacent to water bodies and non-forested wetlands. Riparian ecosystems and their adjacent water body or wetland are mutually influenced by one another. Vegetation is distinct from adjacent freely drained uplands as well as from adjacent poorly drained non-forested wetlands and aquatic habitats. Riparian ecosystems represent the ecotone between aquatic/wetland habitats and adjacent uplands. They include floodplains, lower seepage slopes, and level or depressional areas adjacent to streams, rivers, and lakes as well as the transitional forested wetlands adjacent to non-forested wetlands. Forested wetlands are included in this practical definition of riparian ecosystems only where they occur adjacent to non-forested wetlands or water bodies; otherwise they are included in the (non-riparian) forest mosaic."

The difficulty here is that classifying things implies defining ranges for all these parameters and this is next to impossible at this stage since we have no basis to do this. Many of these variables are continuous (not rank variables), and are subject to interpretation for many purposes (e.g., large lake vs. small lake and deep lake vs shallow lake).

The next step towards completing this project is to define the lower levels of the framework from segment to microhabitat.

'Microhabitats' for streams and lakes have yet to be identified. Once the entire framework is established, classifying habitat attributes must be decided for each level so that empirical testing can proceed. The last step will involve the creation of mapping codes for the system.

Problems, remaining from the first stage of the project, must now be addressed:

- How 'Marine' segment fits under a Biogeoclimatic Unit classification when Biogeoclimatic zones do not cover marine ecosystems.
- To adapt 'small,' 'intermediate' and 'large' stream channel classification (Church 1992) to habitat classification.
- Complete a definition for 'pond'
- How human manipulation of habitats (e.g., reservoirs or streams flowing through cutblocks) fits into the system.
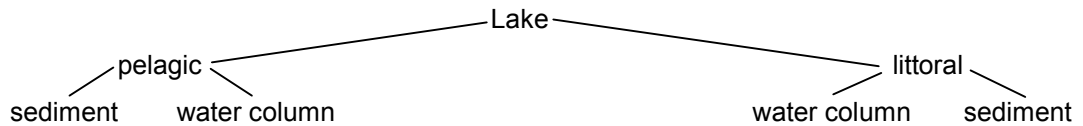
References

Busch, W.-D. and P.G. Sly, ed. 1992. The development of an aquatic habitat classification system for lakes. CRC Press. London.

Church, M. 1992. Channel morphology and typology. Chapter 6 in P. Calow and G.E. Petts, ed. 1992. Rivers handbook. Volume 1. Hydrological and ecological principles. Blackwell Scientific Publications.

Cowardin, L.M., F.C. Golet, and E.T. LaRoe. 1977. Classification of wetlands and deep-water habitats of the United States (An Operational Draft). Report for the U.S. Fish and Wildlife Service.

Demarchi, D.A. 1993. Ecoregions of British Columbia. Report prepared for the Ministry of Environment, Lands and Parks.

Frissell, C.A., W.J. Liss, C.E. Warren and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: Viewing streams in a watershed context. Environmental Management Vol. 10, No. 2, pp. 199–214.

Hawkins, C.P., J.L. Kershner, P.A. Bisson, M.D. Bryant, L.M.Decker, S.V. Gregory, D.A. McCullough, C.K. Overton, G.H. Reeves, R.J. Steedman and M.K. Young. 1993. A hierarchical approach to classifying stream habitat features. Fisheries, Vol. 18, No. 6, pp. 3–12.

Kellerhals, R., M. Church and D.I. Bray. 1976. Classification and analysis of river processes. American Society of Civil Engineers Proceedings, Journal of the Hydraulics Division 102:813–829.

Kistritz, R.U. and G.L. Porter. 1993. Proposed wetland classification system for British Columbia. A discussion paper. Report prepared for the Ministry of Forests, Research Branch.

Krajina, V.J. 1965. Biogeoclimatic zones and classification of British Columbia. Ecol. West. N. Am., 1:1–17.

Minshall, G.W., K.W. Cummins, R.C. Petersen, C.E. Cushing, D.A. Bruns, J.R. Sedell, and R.L. Vannote. 1985. Developments in stream ecosystem theory. Can. J. Fish. Aquat. Sci., Vol. 42:1045–1055.

Northcote, T.G. and P.A. Larkin. 1956. Indices of productivity in British Columbia Lakes. J. Fish. Res. Bd. Can. 13:515–540.

Pojar, J., K. Klinka and D.V. Meidinger. 1987. Biogeoclimatic ecosystem classification in British Columbia. Forest Ecology and Management, 22:119–154.

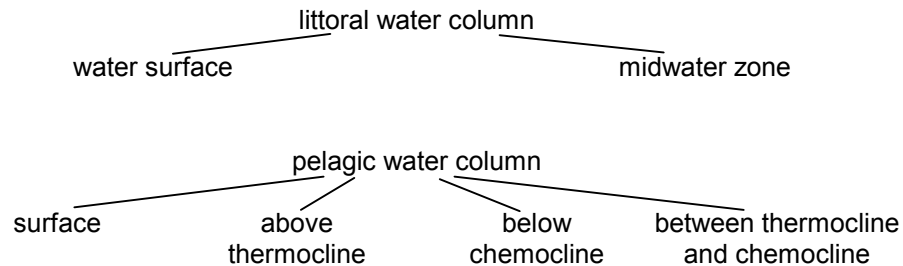# Appendix 1. Some ideas on a lake classification scheme[1]

A number of factors like the hierarchial stream classification code number for the lake, the parent material of the bed or basin, soil type, bedrock geology, latitude and longitude, elevation, biogeoclimatic zone, ecoregion, etc. should be appended attributes of a site but not part of the ecological basis for separating one site from another.

Lake Habitats

At the first level of restriction a lake has a pelagic and a littoral zone. At the second level, within each zone there are water column and bottom sediment habitats.

```
                              Lake
                  pelagic                      littoral
          sediment    water column      water column    sediment
```

At the third level there are some zones within the pelagic and littoral water columns and some types of pelagic and littoral sediments.

```
                  littoral water column
          water surface              midwater zone


                  pelagic water column
     surface      above       below      between thermocline
               thermocline   chemocline     and chemocline
```

The sediment types include bedrock, boulders, cobbles, pebbles, sand, silt organic and wood debris. There are also slope groups for each sediment type and whether the habitat is on the surface of the sediment on within it as for some burrowing benthic organisms. Water and sediment chemistry provide further breakdown into distinct habitats each with its unique species assemblage.

These also apply to ponds and smaller water bodies except that the pelagic zones are absent. Further subgroups for many habitats would be formed by taking water chemistry, pH, alkalinity, salinity, TDS, secchi depth, temperature, etc. into account. This is not a complete list, more habitats are possible and sometimes available.

---

[1] P. Warrington, MELP, March 1994.

- littoral, sediment, steep-slope beach, bedrock
- littoral, sediment, steep-slope beach, cobbles, surficial
- littoral, sediment, steep-slope beach, cobbles, interstitial
- littoral, sediment, steep-slope beach, sand, surficial
- littoral, sediment, steep-slope beach, silt, surficial
- littoral, sediment, steep-slope beach, organic, surficial
- littoral, sediment, steep-slope beach, sand, sub-surface
- littoral, sediment, steep-slope beach, silt, sub-surface
- littoral, sediment, steep-slope beach, organic, sub-surface

- littoral, sediment, offshore, bedrock
- littoral, sediment, offshore, cobbles, surficial
- littoral, sediment, offshore, cobbles, interstitial
- littoral, sediment, offshore, sand, surficial
- littoral, sediment, offshore, silt, surficial
- littoral, sediment, offshore, organic, surficial
- littoral, sediment, offshore, sand, sub-surface
- littoral, sediment, offshore, silt, sub-surface
- littoral, sediment, offshore, organic, sub-surface

- littoral, sediment, on marginal bedrock cliffs
- littoral, on permanently submerged wood
- littoral, on seasonally submerged wood
- littoral, on submerged aquatic vegetation
- littoral, on floating aquatic vegetation
- littoral, on emergent aquatic vegetation
- littoral, on sub-surface aquatic vegetation
- littoral, on floating wood
- littoral, among the roots of floating aquatic plants
- littoral, within mid water aquatic plant beds

- littoral, sediment, seasonally inundated beach, bedrock
- littoral, sediment, seasonally inundated beach, cobbles, surficial
- littoral, sediment, seasonally inundated beach, cobbles, interstitial
- littoral, sediment, seasonally inundated beach, sand, surficial
- littoral, sediment, seasonally inundated beach, silt, surficial
- littoral, sediment, seasonally inundated beach, organic, surficial
- littoral, sediment, seasonally inundated beach, sand, sub-surface
- littoral, sediment, seasonally inundated beach, silt, sub-surface
- littoral, sediment, seasonally inundated beach, organic, sub-surface

- pelagic, water column, on the surface
- pelagic, water column, above thermocline
- pelagic, water column, below thermocline and above chemocline
- pelagic, water column, below chemocline, anoxic

- pelagic, sediment, bedrock
- pelagic, sediment, cobbles, surficial
- pelagic, sediment, sand, surficial
- pelagic, sediment, silt, surficial
- pelagic, sediment, organic, surficial
- pelagic, sediment, cobbles, interstitial
- pelagic, sediment, sand, sub-surface
- pelagic, sediment, silt, sub-surface
- pelagic, sediment, organic, sub-surface

- littoral, water column, on the surface
- littoral, water column, mid-water
- littoral, water column, in spring basins

- littoral, sediment, inlet fan, bedrock
- littoral, sediment, inlet fan, cobbles, surficial
- littoral, sediment, inlet fan, cobbles, interstitial
- littoral, sediment, inlet fan, sand, surficial
- littoral, sediment, inlet fan, silt, surficial
- littoral, sediment, inlet fan, organic, surficial
- littoral, sediment, inlet fan, sand, sub-surface
- littoral, sediment, inlet fan, silt, sub-surface
- littoral, sediment, inlet fan, organic, sub-surface

- littoral, sediment, flat to low-slope beach, bedrock
- littoral, sediment, flat to low-slope beach, cobbles, surficial
- littoral, sediment, flat to low-slope beach, cobbles, interstitial
- littoral, sediment, flat to low-slope beach, sand, surficial
- littoral, sediment, flat to low-slope beach, silt, surficial
- littoral, sediment, flat to low-slope beach, organic, surficial
- littoral, sediment flat to low-slope beach, sand, sub-surface
- littoral, sediment, flat to low-slope beach, silt, sub-surface
- littoral, sediment, flat to low-slope beach, organic, sub-surface

Some mobile and extensive organisms pose a problem when it comes to assigning them a habitat; they need to be assigned to several habitats within a lake simultaneously so that their interactions and relationships with other more restricted organisms are clear. Mobile animals like fish roam over several habitat types within a lake and have an influence on all of them; some aquatic plants are rooted in the bottom and pass through several zones before emerging into the air above the water.