EAU BC

Ecological Aquatic Units of British Columbia

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The maps presented in this report are for illustrative purposes only. Do not rely on these maps as a precise indication of routes, locations of features, or as a guide to navigation.

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Executive Summary

EAU BC is a hierarchical classification of BC's freshwater ecosystems. It is a spatially explicit classification designed to aid in the management and conservation of BC's freshwater ecosystems and their associated biodiversity. EAU BC quantifies the interplay between freshwater species distribution and their ecosystem's physical habitat, and environmental processes. It defines what is currently known about freshwater ecosystems and their abundance and distribution across the Province. It is packaged as a database and accompanying geographic information system (GIS) that enables the classification and its underlying data to be queried and viewed at multiple spatial scales. Specifically, EAU BC was developed with the following applications in mind:

- Provide an environmental characterization of freshwater ecosystem types in BC that will aid in their specific conservation and management;
- Provide a spatially explicit data management system for freshwater ecosystems in BC;
- Enable regional comparisons of freshwater ecosystems;
- Help inform species / habitat relationships; and
- Provide a stratification framework for freshwater inventory / monitoring programs and state of the environment reporting on freshwater ecosystems in BC.

EAU BC classifies freshwater systems at three spatial scales - Freshwater Ecoregions, Ecological Drainage Units, and River and Lake Ecosystems - based on measurable environmental features, processes and biological data. Freshwater Ecoregions are defined based on zoogeographic patterns in fish re-colonization following the last glacial recession. Five Freshwater Ecoregions are identified in BC. Ecological Drainage Units are nested within Freshwater Ecoregions and take into account zoogeographic, climatic, and physiographic patterns that define freshwater systems. Ecological Drainage Units incorporate the known distribution of native freshwater fishes in BC. Thirty-six Ecological Drainage Units are identified in BC. River and Lake Ecosystem Types nest within both Ecological Drainage Units and Freshwater Ecoregions. They are therefore defined by zoogeographic, physiographic and climatic patterns but also take into account more localized physical habitat and dominant environmental processes that shape freshwater ecosystems. Biological information is sparse at this scale of the classification and is therefore not explicitly used to delineate ecosystem types. However, fish assemblages can be inferred for each Ecosystem Type based on the Ecological Drainage Unit it is nested within. Eleven River Ecosystem Types, twenty-three River Ecosystem Sub-Types, and twelve Lake Ecosystem Types are identified in BC.

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Background and Rationale

The biogeoclimatic ecosystem classification is a widely accepted and used classification for managing terrestrial ecosystems and their associated natural resources across the Province. Some could argue that it would not be possible to manage these ecosystems and their natural resources effectively without such a classification scheme that characterizes the ecosystems types, their relative uniqueness to each other, and identifies their location and distribution across the Province. Surprisingly, no such ecosystem classification currently exists for freshwater ecosystems.

Just as a coastal western hemlock forest is different from a spruce-willow-birch forest, not all rivers, and all lakes, are alike in their physical habitat, hydrologic regime, water chemistry and temperature, connectivity or biotic interactions. The diversity of freshwater organisms in BC is testament to the diversity of the river and lake ecosystems that are found within the province. For proper freshwater resource management, there is a critical need to characterize these river and lake ecosystem types based on their dominant environmental process, physical habitat and what is known of their biological communities.

An astounding twenty-five percent of Canada's freshwater supply (MWALP 2004), and five percent of the world's freshwater supply are held within BC (Environment Canada 2004). These rivers and lakes support an exceptional concentration of biodiversity. In general, species richness is greater relative to habitat extent in freshwater ecosystems than in either marine or terrestrial ecosystems. Lakes and rivers in BC are home to a rich assemblage of freshwater dependent species[1] including over: 76 species of fishes, 20 species of amphibians, 89 species of mollusks, 87 species of dragonflies and damselflies, 7 species of reptiles and turtles, 45 species of mammals, and 248 species of birds (BC CDC 2007).

Given the size and physiographic complexity of the province, freshwater species have been poorly inventoried and at best these numbers are only estimates of species richness. Freshwater fish have been the most rigorously inventoried yet even the most basic of management questions cannot be addressed because of a lack of basic biological data on these species, such as: What species are present in each river and lake system? Are any of the populations, or groups of populations worthy of special management? What is the current health of these populations (are populations increasing, decreasing or stable?). Given the sparseness of species inventory data, a suitable approach to understanding and spatially quantifying BC's abundant and diverse freshwater biodiversity is to combine inventory information with an abiotic or physical classification of major river and lake ecosystem types based on physical habitat and dominant environmental processes.

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[1] This total includes biological species and intraspecific forms that are of conservation concern and considered species under the Species at Risk Act.

Need for a Freshwater Ecosystem Classification in BC

In BC, the need for a freshwater ecosystem classification is pressing. There is growing pressure on freshwater resource use and extraction that is having a pronounced detrimental impact on BC's freshwater ecosystems and their associated biodiversity.

Forty-one percent of BC's freshwater fish fauna is at risk (S1-S3 listed). This is the highest percentage in any vertebrate taxa in BC (BC CDC 2007). The statistics are equally bleak for all known freshwater dependent species (Figure 1). Nonetheless, BC's protected areas strategy protects only 15% of red-listed, and 9% blue-listed fish taxa (Haas 1999). The protected areas strategy is based on conserving species through protection of the representative biogeoclimatic ecosections in which they live. Unfortunately, ecosections (and wildlife habitat areas) are terrestrial concepts that have a limited correspondence to the distribution of freshwater biodiversity or to drainage basins (Haas 1999). What is important to the native freshwater biodiversity in any given freshwater ecosystem in the province is: the ecosystem's zoogeographic history, the physical and chemical environment within the ecosystem, and its biotic environment. Within most ecosystems, historical factors (glacial and postglacial events) and connectivity within the drainage network govern what species reached the area, but abiotic and biotic factors determine the distribution of the species within that ecosystem (McPhail and Carveth 1993; Haas 1998). Characterizing river and lake ecosystem types based on these factors should capture the environmental and species variability of these system types and hence provide a sound framework for resource conservation and management of freshwater ecosystems across the Province. Nature Conservancy of Canada in partnership with the provincial government, has risen to this challenge and has developed a hierarchical freshwater ecosystem classification for BC, entitled Ecological Aquatic Units of British Columbia (EAU BC).

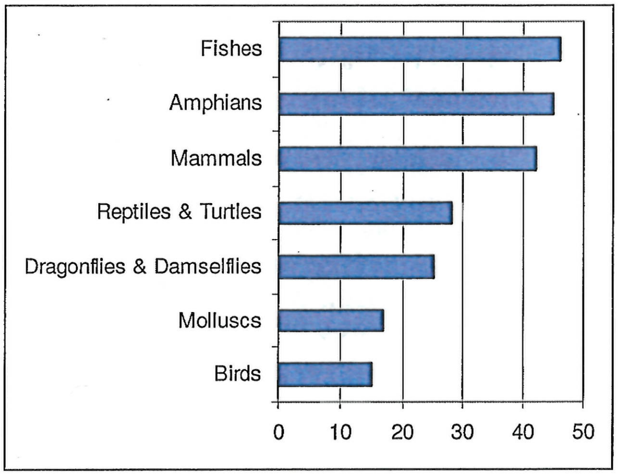

Figure 1: Percent of native freshwater dependent species at risk (S1-S3) in BC.

Introduction

Why Classify?

The characteristics of a particular river or lake result from some combination of influences from the local environment and those upstream, downstream and upslope. Hierarchical classification schemes are appropriate frameworks for addressing these spatially nested connectivity influences. Freshwater hierarchical classifications are founded on the premise that freshwater habitats and their biological components are shaped by a hierarchy of spatial and temporal processes (Vannote *et al.* 1980, Angermeier and Schlosser 1995, Angermeier and Winston 1999, Frissell *et al.* 1986, Imhof *et al.* 1996, Mathews 1998). Use of a hierarchical scheme allows the classification to capture the multitude of spatial and temporal scales on which structuring processes operate. For example, patterns of continental and regional freshwater zoogeography result from drainage connections that change over time in response to climatic and geologic events (Bussing 1985, Hocutt and Wiley 1986). Importantly, regional patterns of climate, drainage, and physiography influence river and lake ecosystem characteristics such as morphology and hydrology, temperature and nutrient regimes, which in turn influence biotic patterns of community composition and species abundance (Hamilton 1999, Hughes and James 1989, Moyle and Ellison 1991, Pflieger 1989, Poff and Ward 1989, Poff and Allan 1995, Swanson *et al.* 1988). A hierarchical ecological classification therefore captures ecological patterns and processes at multiple spatial and temporal scales (Bourgeron and Jensen 1994; Klijin 1994).

The use of a hierarchical classification scheme for freshwater ecosystems is widespread and has extensive support in the literature. Some of the important concepts and frameworks developed for freshwater ecosystems can be found in Warren (1979), Frissell *et al.* (1986), Cupp (1989), Pflieger(1989), Moyle and Ellison(1991), Leach and Herron (1996), Hudson *et al.* (1992), Naiman *et al.*(1992), Townsend and Hildrew (1994), Ward and Palmer (1994), Angermeier and Schlosser (1995), Maxwell *et al.* (1995), Rosgen (1994), Seelbach *et al.* (1997), Pahl-Wostl (1998), Haberack(2000), and Higgins *et al.* (2005).

What is EAU BC?

EAU BC is a hierarchical freshwater ecosystem classification for BC. It is a spatially explicit classification designed to aid in the management and conservation of BC's freshwater ecosystems and their associated biodiversity. EAU BC quantifies the interplay between freshwater species distribution and their ecosystem's physical habitat, and environmental processes. It defines what is currently known about freshwater ecosystems and their abundance and distribution across the Province. It is packaged as a database and accompanying geographic information system (GIS) that enables the classification and its underlying data to be queried and viewed at multiple spatial scales. Specific database fields are made reference to throughout the report as a series of box insets. Specifically, EAU BC was developed with the following applications in mind:

- Provide an environmental characterization of freshwater ecosystem types in BC that will aid in their specific conservation and management;
- Provide a spatially explicit data management system for freshwater ecosystems in BC;
- Enable regional comparisons of freshwater ecosystems;
- Help inform species / habitat relationships; and
- Provide a stratification framework for freshwater inventory / monitoring programs and state of the environment reporting on freshwater ecosystems in BC.

EAU BC Hierarchy

EAU BC classifies freshwater systems at three spatial scales - Freshwater Ecoregions, Ecological Drainage Units, and River and Lake Ecosystem Types - based on measurable environmental features and processes and biological data (Figure 2). Freshwater Ecoregions are defined based on zoogeographic patterns in fish re-colonization following the last glacial recession. Ecological Drainage Units are nested within Freshwater Ecoregions and take into account zoogeographic, climatic, and physiographic patterns that define freshwater systems. Ecological Drainage Units incorporate the known distribution of native freshwater fishes in BC. River and Lake Ecosystem Types nest within both Ecological Drainage Units and Freshwater Ecoregions. They are therefore defined by zoogeographic, physiographic and climatic patterns but also take into account more localized physical habitat and dominant environmental processes that shape freshwater ecosystems. Biological information is sparse at this scale of the classification and is therefore not explicitly used to delineate Ecosystem Types. However, fish assemblages can be inferred for each Ecosystem Type based on the Ecological Drainage Unit it is nested within.

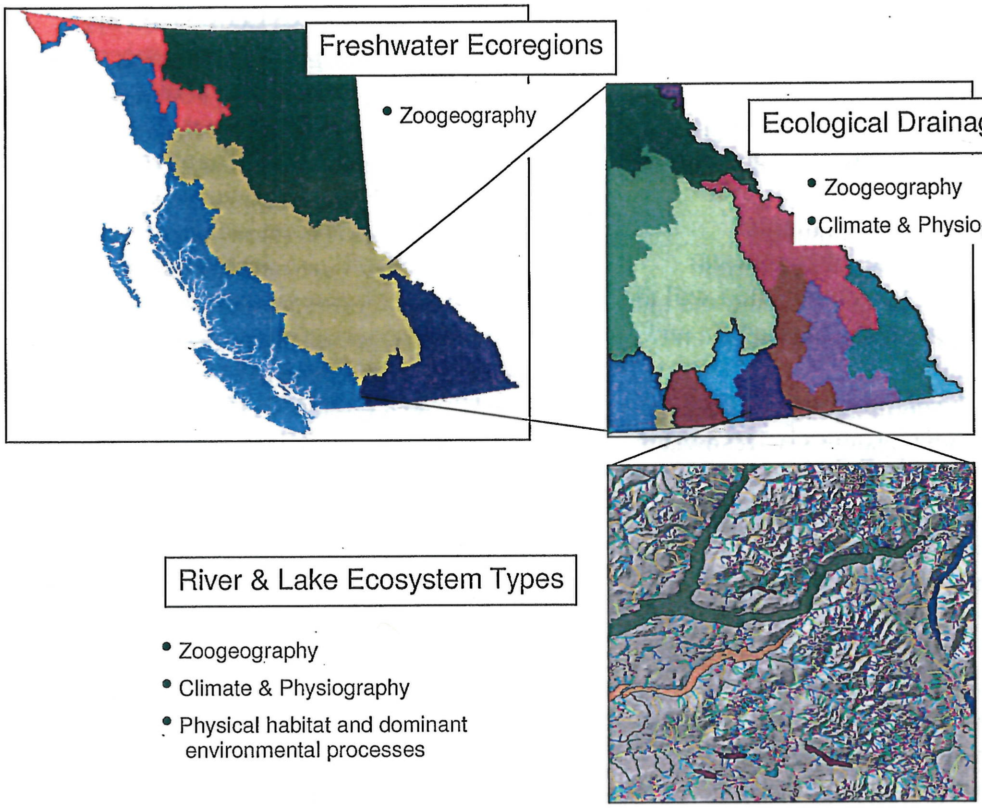

Figure 2: EAU BC's hierarchical ecological classification framework.

At each spatial scale, EAU BC classifies freshwater systems within a hierarchy of environmental variables based on their influence in structuring finer-scale environmental variables within the classification. When mapped, higher levels of the classification delineate large-scale patterns and successive levels of classification delineate increasingly smaller scale patterns. Frissell *et al.* (1986) suggested that a number of benefits arise from the use of a hierarchical characterization: 1) classification at higher levels narrows the set of variables needed at the lower levels; 2) it provides for integration of data from diverse sources and of different levels of resolution; and 3) it allows users to select the level of resolution most appropriate to meet his/her objectives.

EAU BC subdivides continuously varying environmental variables into independent categories. However, these groups and patterns do not usually exist as distinct separate entities in nature – they are more often a continuum with no discrete boundary or edge. This simplification of reality is important to bear in mind when considering a spatial ecological classification. The mapped pattern of classes is a simplification of highly complex ecological patterns.

The following sections describe the three levels of the EAU BC: Freshwater Ecoregions, Ecological Drainage Units and River and Lake Ecosystem Types.

Freshwater Ecoregions

British Columbia is the third largest province in Canada. North to south, it extends over eleven degrees of latitude and has a land area of almost 1,000,000 km^2. Summarizing the distribution of plants and animals in this vast area is a major task. For terrestrial organisms, BC uses a system of biogeoclimatic zones based on topography, climate, and plant communities. Unfortunately, because of the limited dispersal abilities of freshwater fishes, such terrestrial biogeographic systems rarely work for fishes (Abell *et al.* 2000, Hughes *et al.* 1989, McPhail and Carveth 1993). This is because freshwater fishes need water connections to migrate between drainage systems, and such connections are rare. This inability to disperse across land predisposes freshwater fishes to geographic isolation, and geographic isolation prevents gene flow. As a result, for species that are unable to disperse through the sea, drainage stability means virtually the complete geographic isolation of river systems. Consequently, when developing a classification system for Freshwater Ecoregions it is important to distinguish between organisms that are tied to freshwater throughout their entire life cycle and organisms that are associated with freshwater for only parts of their life cycles. The latter organisms are not as tightly tied to freshwater as freshwater fishes (and some molluscs) since they can, and do, disperse over land. For this reason, EAU BC is based on the taxon (freshwater fishes) that provides the simplest and most unambiguous set of Freshwater Ecoregions. Since, in a recently glaciated region like BC, the single most important factor governing what fish species reached what drainage basins is the postglacial sequence of drainage connections, it is necessary to understand both where the fishes came from, and what dispersal routes they followed in achieving their present distributions. Still, other factors also are involved. For example physiography — especially topographic features like mountain ranges, canyons, waterfalls, and climate — profoundly influence the distribution of fishes within the province. Nonetheless, the nature and timing of postglacial drainage connections clearly governed which fishes reached which drainage system. Consequently, we use the presence or absence of particular freshwater fish species to define the major *Freshwater Ecoregions* of BC.

The freshwater fish fauna of BC is unique. There are not many species but the fauna has complex origins and some of these species are found nowhere else in Canada. A few species may have survived the last Ice-Age in small, ice-free refugia within the provincial boundaries, but most of BC's fish fauna consists of postglacial immigrants. In the wake of the retreating glaciers, fishes entered the province from at least four different unglaciated areas. In addition, at least three marine species postglacially colonized freshwater, and a few species appear to have evolved within the province since the last glaciation. BC's fish fauna is therefore a complex mixture of preglacial remnants, postglacial immigrants and remarkable, recent species. Understanding the nature and consequences of this mix is important in the design of conservation and management strategies for BC's native freshwater biodiversity.

Not surprisingly, the Pleistocene expansion and contractions of ice sheets had important impacts on BC's fish fauna. As the late Pleistocene ice sheets expanded to cover most of northern North America, the interglacial fish fauna in BC was either destroyed or pushed into unglaciated regions called *refugia*. Thus, the freshwater fish that were present in BC during the last interglacial period probably survived the last glaciation – the Fraser glaciation - in one or more of the four major ice-free refugia adjacent to the province. At the height of the Fraser glaciation, the ice margin extended down to the end of Puget Sound. The unglaciated region south of Puget Sound (the Chehalis and associated rivers) is referred to as the *Chehalis refugium*. It contained a number of freshwater fishes distinct from the Columbia fauna that were isolated in the area around the southern base of the Olympic Peninsula. The unglaciated region south of the ice and west of the Continental Divide is referred to as the Columbia Refugium. The unglaciated portions of the Columbia River system were major contributors to BC's freshwater fish fauna. However, the coastal areas south of the ice sheet, and south of the Columbia River, also were important for euryhaline fishes such as Pacific salmon. The combined Columbia River and south coastal unglaciated areas are collectively referred to as the *Pacific Refugium.*

Similarly, McPhail and Carveth (1993) refers to the unglaciated regions south of the Laurentide Ice Sheet and east of the Rocky Mountains as the *Great Plains Refugium*. This is a combination of two semi-independent refugia: the Missouri Refugium and the Mississippi Refugium. The fourth unglaciated area adjacent to BC is the *Bering Refugium* (the ice-free regions of Alaska and the Yukon). A small number of species found in the north-western part of the province dispersed into BC from this refugium (McPhail 2006).

Database Field Name
FW_ECO REG

Freshwater Ecoregions represent the broadest level of the EAU BC classification. They capture historical factors (glacial and post glacial events) that govern what species reached which drainages within BC. These Freshwater Ecoregions are relatively large geographic areas that usually encompass the catchment of a major drainage system. Freshwater Ecoregions are defined by the primary postglacial source of their fauna and the presence of a diagnostic fish community (i.e., they usually contain species not found in the other provincial Freshwater Ecoregions). In total, five Freshwater Ecoregions have been identified in BC: North Pacific Coastal, Columbia Glaciated, Yukon, Mackenzie, and Interior[2] (Table 1,

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[2] Most of the Freshwater Ecoregions in BC are parts of and have the same names as five of the 76 freshwater North American ecoregions (Abell *et al.* 2000). There are two exceptions: the Interior Freshwater Ecoregion and the North Pacific Coastal Freshwater Ecoregion. The Interior Freshwater Ecoregion is specific to BC and consists of the Upper Nass and Skeena Rivers as well as the Thompson, Middle and Upper Fraser River systems. This Ecoregion contains a distinctive mix of Columbia and Great Plains species. In contrast, the North Pacific Coastal Freshwater Ecoregion is a physiographic

Appendix A: Map 1). A summary of these Freshwater Ecoregions and their biologically distinctive characteristics are found below.

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rather than a biogeographic unit. It consists of a large number of small, independent rivers that flow directly into the North Pacific Ocean and a few lower reaches of larger rivers that transect the Coast Mountains. McPhail (2006) has modified the North Pacific Coastal Freshwater Ecoregion (as defined in Abell *et al.* 2000) to reflect faunal differences between these physiographic subunits.

Table 1: Geographic extent of the Freshwater Ecoregions in BC.

Freshwater Ecoregion	Drainage(s)	Refugium(a)
North Pacific Coastal	Lower Taku, Stikine, Nass, Skeena and Fraser Rivers, and small coastal systems	Pacific and Beringian
Interior	Fraser River basin excluding its lower portion, Upper Skeena and Nass Rivers	Pacific and Great Plains
Columbia Glaciated	Entire Columbia River system within BC	Pacific
Mackenzie	Entire Mackenzie River system within BC	Great Plains
Yukon	Entire Yukon River system within BC and Nakina River and Upper Stikine River	Beringian

North Pacific Coastal

The North Pacific Coastal Freshwater Ecoregion includes all of the small drainage systems along BC's coast as well as the Taku, lower portions of the Stikine, Nass, Skeena and Fraser River systems that transect the Coast Mountains. It covers about a third of the province and, in BC, is defined by the Coast and Insular Mountains. Holland (1964) divided the Coast Mountains into three natural groupings of individual mountain ranges: the Boundary Ranges, the Kitimat Ranges, and the Pacific Ranges. The North Pacific Coastal Freshwater Ecoregion (as defined in Abell et al. 2000) has been modified to reflect faunal differences among these three physiographic units. The fish fauna of the North Pacific Coastal Freshwater Ecoregion consists of a suite of forty-nine species most of which are euryhaline species derived from the Pacific and Bering refugia.

Interior

Most of the Interior Freshwater Ecoregion lies within the Fraser River Basin. The Fraser River has the second-largest drainage basin in British Columbia. It drains approximately 25% (238,000 km^2) of the province, and is the largest drainage basin contained almost entirely within BC. Like the Columbia River, the Fraser River rises in the Rocky Mountain Trench. Its source (Moose Lake) is over 1,000m above sea level, and the river flows 1,368 km to the sea. The Interior Freshwater Ecoregion encompasses both the Upper Skeena and Nass Rivers, both of which had postglacial connections with the Fraser system. In turn, during deglaciation, the upper and mid-Fraser system had connections to both the Columbia and Great Plains refugia.

The freshwater fish fauna of the Interior Freshwater Ecoregion consists of thirty-three species with the majority being of Columbia system origin (e.g., Chiselmouth, *Acrocheilus alutaceus*; Peamouth, *Mylocheilus caurinus;* Northern Pike Minnow, *Ptychocheilus oregonensis;* Leopard Dace, *Rhinichthys falcatus;* and Redside Shiner, *Richardsonius balteatus*).

The Interior Freshwater Ecoregion differs from the adjacent Columbia and North Pacific Coastal Freshwater Ecoregions in the presence of two Great Plains species (White Sucker, *Catostomus commersoni;* and Brassy

Minnow, *Hybognathus hankinsoni*) and a Bering–Nahanni species (Lake Trout, *Salvelinus namaycush*). It shares four species with the Columbia Glaciated Ecoregion (Leopard Dace, *Rhinichthys falcatus;* Bridgelip Sucker, *Catostomus columbianus;* Mountain Sucker, *Catostomus platyrhynchus;* and Torrent Sculpin, *Cottus rhotheus*) that do not occur in other BC Freshwater Ecoregions.

Columbia Glaciated

The Columbia is the master river of Cascadia and contains one of the most distinctive fish faunas in North America (Miller 1965). At the height of the last glaciation approximately half of the drainage basin was covered in ice including the entire portion of the Columbia River drainage in BC. Although only about 15% of the drainage lies within BC, it is still the third-largest river system in the province. Together, the Columbia River and its major BC tributaries (the Flathead, Kootenay, Kettle, Okanagan, and Similkameen rivers) drain over 100,000 km^2 of southeastern BC and make up the Columbia Glaciated Freshwater Ecoregion.

The native fish fauna of this Freshwater Ecoregion is dominated by true freshwater species. In BC, this ecoregion contains twenty-nine native freshwater fishes, all of which survived glaciation somewhere within the Columbia system. Seven, endemic Columbia species occur in the BC portion of the Columbia Glaciated Ecoregion: Speckled Dace, *Rhinichthys osculus;* Umatilla Dace, *Rhinichthys umatilla;* Westslope Cutthroat Trout, *Oncorhynchus clarki lewisi;* Shorthead Sculpin, *Cottus confuses;* Columbia Sculpin, *Cottus bairdi;* Rocky Mountain Sculpin, *Cottus punctulatus*; and the Malheur Mottled Sculpin, *Cottus bendirei*. This last species occurs in the upper Similkameen system and is not officially recorded from the province but both morphological and molecular data suggest that this species does occur in BC. No other Ecoregion in BC contains these Columbia endemics, and it is the Columbia endemics that set the BC freshwater fish fauna apart from the rest of Canada.

Historically, a few anadromous species also reached the BC portion of this Ecoregion—Sockeye (*Oncorhynchus nerka)* and Chinook salmon (*Oncorhynchus tshawytscha),* ascended the river into BC, and Chinook salmon traveled as far upstream as Windemere Lake. Remnant populations of Chinook salmon and anadromous Sockeye salmon still reaches the lower Okanagan River, and lampreys once reached the Slocan River system (Parkham 1937).

Mackenzie

The Mackenzie is the second largest river in North America. It drains a huge catchment (about 1,800,000 km^2); although only a small fraction of the drainage basin lies within BC, it is still the largest drainage system in the province (almost 280,000 km^2). Three major rivers drain the Mackenzie Freshwater Ecoregion in BC: the Liard, Peace, and Hay rivers. The Liard River drains approximately 140,000 km^2 of north-central and northeastern British Columbia. Midway through its BC course, the Liard cuts along the northern flank of the Rocky Mountains and drops about 150 m in a distance of less than

100 km. This velocity barrier divides the river into upper and lower subregions that contain strikingly different faunas. The Peace River drains slightly over 128,000 km^2 of northeastern BC and, like the Liard River, rises to the west of the Continental Divide. Unlike the Liard, however, the Peace does not flank the northern Rocky Mountains: it cuts through them. At the point where the river cuts through the mountains, there were historically 24 km of rapids. These rapids, and their canyon, are now submerged under Williston and Dinosaur reservoirs, but the Peace Canyon originally divided the river into upper and lower reaches that contained markedly different faunas. The third river, Hay River, only has 7,500 km^2 of catchment in northeastern BC.

The Mackenzie Freshwater Ecoregion contains forty native freshwater fish species most of which originated from the Great Plains Refugium. This refugium was east of the Rocky Mountains along the south-western border of the Laurentide Ice Sheet. By 11,000 years ago there were a series of glacial lakes covering much of what is now the Peace drainage system. At various times these lakes drained south into the Missouri-Mississippi system and north into the Mackenzie system. These connections allowed Great Plains species to colonize most of northeastern BC.

The fish fauna of the Mackenzie drainage is therefore dominated by Great Plains species, and thirteen of these species occur nowhere else in the province including the White Sucker (*Catostomus commersoni*), Longnose Dace (*Rhinichthys cataractae*), Spoonhead Sculpin (*Cottus ricei*), Brassy Minnow (*Hybognathus hankinsoni*), Cisco (*Coregonus artedi*), Spottail Shiner (*Notropis hudsonius*), Emerald Shiner (*Notropis atherinoides*), and Ninespine Stickleback (*Pungitius pungitius*).

Yukon

With a total catchment area of 829,000 km^2, the Yukon River is the third-largest river system in North America; however, only about 3% (25,000 km^2) of the basin lies within British Columbia. In BC the Yukon system rises near Jennings Lake at about 1200m and drains the Teslin and Kawdy plateaus and the Tagish highlands. Three large lakes (Atlin, Teslin and Tagish) are the dominant features of the BC portion of the Yukon drainage.

The Yukon Freshwater Ecoregion is the smallest of the five Freshwater Ecoregions in British Columbia on the basis of its size and fish fauna. The Yukon Freshwater Ecoregion drains the extreme northwestern corner of the province and contains a mixed fish fauna of twenty-nine species. These rivers are characterized by the absence of saltwater-intolerant Columbia species and the presence of species, or forms, derived from the Bering Refugium. Two Yukon species that survived glaciation in the Bering Refugium and occur nowhere else in BC are the Broad Whitefish (*Coregonus nasus*) and Least Cisco (*Coregonus sardinella*).Upper Stikine and the Nakina River (a tributary of the Taku River) are grouped within the Yukon Ecoregion on the basis of their post-glacial connection with the Yukon River system and subsequent Beringian fish fauna.

Ecological Drainage Units

Freshwater Ecoregions capture which freshwater fish (and other freshwater biodiversity) likely reached what drainages in BC after the last glacial recession. However, once fish reached a drainage system, their present distribution within the system was determined by the drainages' physiography, climate and biotic interactions. ***Ecological Drainage Units (EDUs) represent distinct major drainage basins that contain unique fish assemblages based on broad zoogeographic, physiographic and climatic patterns.*** Each EDU is nested within a Freshwater Ecoregion, and contains at least one species that is not found in adjacent EDUs within the same Freshwater Ecoregion. Hocutt and Wiley (1986), Haas (1998), McPhail and Carveth (1993), and McPhail (2006) were used to delineate EDUs based on zoogeographic patterns of freshwater fishes in BC. EDUs were further defined by physiographic and climatic characteristics that are thought to drive faunal composition. These include: *underlying geology, climate, gradient, and hydrology*. Physiographic and climatic patterns were derived from an analysis of the BC provincial Watershed Atlas and associated hydrologic, climatic and physiographic information for third order watershed units throughout the province.

EDUs are hypothesized to represent major freshwater adaptive zones within BC. It is the broadest level of the EAU BC classification that explicitly uses biological and physical data to define ecological units. A total of thirty-six EDUs have been delineated in BC (Appendix A: Map 2). The zoogeography of each EDU is summarized below in Table 2. The fish community within each EDU is summarized in Table 3 and the physiography and climate of each EDU is summarized in Table 4.

Database Field Name
EDU

Table 2: Zoogeography of the Ecological Drainage Units of BC.

Ecological Drainage Unit	Refugium(a)	Zoogeography
North Pacific Coastal Freshwater Ecoregion		
Taku	Columbia, Beringian	The Taku EDU originates entirely in BC on the Taku Plateau and flows west through the Coast Mountains to enter the sea near Juneau, Alaska. Arctic smelt (*Osmerus dentex*) may occur here and some of the Pacific salmon in this region may have dispersed postglacially from Beringia. In addition, the Round Whitefish (*Prosopium cylindraceum)* occurs in the upper river and probably also in the lower river. Bull Trout (*Salvelinus confluentus)* are also present in the upper parts of this drainage system and may occur in the lower river. A minnow, the Lake Chub (*Couesius plumbeus*) occurs at least as far downstream as Tulsequah, and the Slimy Sculpin (*Cottus cognatus*) extends as far downstream as the Alaskan border.
Iskut- Lower Stikine	Columbia and Beringian	The Iskut-Lower Stikine EDU drains the Upper Stikine EDU through the Coast Mountains and enters the sea near Wrangell, Alaska. Except for salmon, the fish fauna of the Iskut-Lower Stikine EDU is not well documented. However, judging from the upstream fauna this EDU forms a transition between EDUs with some Bering influences and those that were colonized mainly from the Pacific Refugium.
Lower Nass - Portland	Columbia	The Lower Nass - Portland EDU drains the Upper Nass EDU through the Coast Mountains. The fish fauna of the Lower Nass river is not well known, except for Pacific salmon and Eulachon (*Thaleichthys pacificus*).
North Coastal	Columbia and Beringian	The North Coastal EDU consists of a series of relatively small, high gradient independent rivers north of the Central Coast of BC including the Chilkat and Unuk Rivers that arise to the east of the Coast Mountains and flow westward to drain through Alaska. The fish fauna for this EDU is poorly known but likely contains the same suite of euryhaline species that occur along the entire coast: anadromous lampreys, smelts, salmon, trout, Dolly Varden (*Salvelinus malma),* threespine sticklebacks and sculpins.

Ecological Drainage Unit	Refugium(a)	Zoogeography
Lower Skeena	Columbia	The Lower Skeena EDU drains the Upper Skeena EDU through the Coast Mountains. It is the most distinctive EDU on the north and central coasts of BC. Three minnows (Peamouth, *Mylocheilus caurinus;* Northern Pikeminnow, *Ptychocheilus oregonensis;* and Redside Shiner, *Richardsonius balteatus*) and one sucker (Largescale Sucker, *Catostomus macrocheilus*) extend downstream at least to Lakelse Lake. The rest of fauna is euryhaline and similar to that in other coastal EDUs.
Haida Gwaii / Queen Charlotte Islands	Columbia	The Haida Gwaii / Queen Charlotte Islands EDU contains the islands of the Queen Charlotte Archipelago (Haida Gwaii). The Queen Charlotte Ranges run along the west side of the islands. The highest peaks are about 1100m. To the east of the ranges lies the Skidegate Plateau, and on Graham Island the Queen Charlotte Lowlands lie to the east of the plateau. The climate is relatively mild and wet. In the ranges and on the plateau, most of the rivers are short and have high gradients, while the lakes are clear. In the lowlands, most waters are highly stained and stream gradients are low. There are no true freshwater fish on the islands; however, it is included in the North Pacific Coastal Freshwater Ecoregion on the basis of five Pacific Refugium species (Pacific Lamprey, *Lampetra tridentata*; Western Brook Lamprey, *Lampetra richardsoni;* Coastal Cutthroat Trout, *Oncorhynchus clarkii clarkii*; Rainbow Trout, *Oncorhynchus mykiss;* and Prickly Sculpin, *Cottus asper*). Although these probably are recent (postglacial) immigrants, this EDU is home to a remarkable diversity of threespine sticklebacks, some of which are shared with northern Vancouver Island.

Ecological Drainage Unit	Refugium(a)	Zoogeography
Bella Coola - Dean	Columbia and Great Plains	The Dean and Bella Coola EDU flows from the Interior Plateau down through the Coast Mountains. The usual suite of euryhaline species – lampreys, Pacific salmon, trout, sticklebacks and sculpins, occur in the lower rivers. There are differences in the fish faunas of the upper reaches of these rivers but no recorded differences in the lower reaches. The upper Bella Coola and Dean Rivers were briefly connected to the Fraser system during the last glacial recession. They contain Peamouth (*Mylocheilus caurinus*), Longnose Dace (*Rhinichthys cataractae*), Redside Shiner (*Richardsonius balteatus*), Northern Pikeminnow (*Ptychocheilus oregonensis*), Longnose Sucker (*Catostomus catostomus*), Largescale Sucker (*Catostomus macrocheilus*) as well as Bull Trout (*Salvelinus confluentus*) and Mountain Whitefish (*Prosopium williamsoni*). The upper Dean river also contains Lake Chub (*Couesius plumbeus*).
Homathko - Klinaklini	Columbia and Great Plains	The Homathko – Klinaklini River EDU flows from the Interior plateau down through the Coast Mountains. The usual suite of euryhaline species – lampreys, Pacific salmon, trout, sticklebacks, and sculpins, as well as Bull Trout (*Salvelinus confluentus)* occur in the lower rivers. There are differences in the fish faunas of the upper reaches of these rivers but no recorded differences in the lower reaches. The upper Homathko and Klinaklini Rivers were briefly connected to the Fraser system during the last glacial recession. The upper Homathko contains a sparse freshwater fish fauna: Bull Trout, Redside Shiner (*Richardsonius balteatus*), and Longnose Sucker (*Catostomus catostomus*). The freshwater fish fauna of the upper Klinaklini is richer than that of the upper Homathko river. It contains Peamouth (*Mylocheilus caurinus*), Redside Shiner, Longnose Dace (*Rhinichthys cataractae*), Northern Pikeminnow (*Ptychocheilus oregonensis*), Longnose Sucker, and Largescale Sucker (*Catostomus macrocheilus*).

Ecological Drainage Unit	Refugium(a)	Zoogeography
Central Coastal	Columbia	The Central Coastal EDU consists of a series of small, high gradient independent rivers north of Cape Caution and south of the Portland Canal on the mainland that rise to the east of the Coast Mountains and drain into the Hecate Strait. The fish fauna of this EDU consists mainly of euryhaline species. Although this EDU shares a similar fish fauna to that of the South Coastal EDU a key difference is in the migratory patterns of their anadromous species. Cape Caution in general is the boundary between northward migration to the Alaskan Gyre and southward migration to warmer waters.
Vancouver Island	Columbia	The Vancouver Island EDU includes Vancouver Island and associated islands in the Georgia Strait. The entire Island is mountainous, except for narrow lowland strips on the east, west and north coasts. The climate is mild but very wet. Consequently, the Island's rivers are short with high gradients, and the lakes have high flushing rates. Typically, the rivers and lakes are clear but in the lowland areas, especially the Nahwitti Lowland at the north end of the Island, there are blackwater regions. The native freshwater fish fauna of this EDU consists almost entirely of euryhaline species. There is, however, one primary freshwater fish (Peamouth, *Mylocheilus caurinus*) on the Island. This moderately euryhaline minnow occurs on both the east and west coasts of the Island. There is also an endemic lamprey (Vancouver Lamprey, *Lampetra macrostoma*) and the Enos Lake pair of sympatric threespine sticklebacks on the Island. Apparently, these endemics have evolved in situ within the last 12,000 years but, together with the Peamouth, they define this EDU.

Ecological Drainage Unit	Refugium(a)	Zoogeography
South Coastal	Columbia	The South Coastal EDU consists of a series of small independent rivers that rise in the Coast Mountains. All of these rivers drain directly into the Georgia, Johnston, and Queen Charlotte Straits. The freshwater fish fauna of this EDU is made-up mainly of euryhaline species, and is almost identical to the Vancouver Island EDU. There are Peamouth (*Mylocheilus caurinus)* on the Sechelt Peninsula and Nelson Island, and pairs of sympatric sticklebacks on Texada and Lasqueti islands. There is, however, one species—Bull Trout (*Salvelinus confluentus)* —that occurs in some rivers (e.g., Squamish and Southgate rivers) in the South Coastal EDU that does not occur on Vancouver Island.
Puget Sound	Columbia	Only a small portion of the Puget Sound EDU lies within BC. It incorporates the extreme headwaters of the Skagit River drainage and a few small streams in the lower Fraser Valley that are tributary to the Nooksack River. The upper Skagit system contains three native species: Dolly Varden (*Salvelinus malma*), Bull Trout (*Salvelinus confluentus*), and Rainbow Trout (*Oncorhynchus mykiss*). The Nooksack tributaries in the lower Fraser Valley not only contain euryhaline species (e.g., lampreys, salmonids, sticklebacks, and sculpins) but also two primary freshwater fishes (Nooksack Dace, *Rhinichthys* sp. and Salish Sucker, *Catostomus* sp.) that were derived from the Chehalis Refugium.

Lower Fraser	Columbia, Chehalis and Great Plains	The Lower Fraser EDU extends from the Fraser River's delta upstream to about Boston Bar. The Fraser Canyon separates the Lower Fraser EDU from the Middle and Upper Fraser system. The Fraser Canyon is a major barrier to fish and many of the anadromous species in the Lower Fraser EDU are absent above the Canyon. Although the Lower Fraser EDU contains the usual suite of euryhaline species (e.g., lampreys, sturgeon, smelts, salmon and trout, sticklebacks, and sculpins), it differs from other coastal EDUs in the presence of a substantial primary freshwater fish fauna. Five minnows (Brassy Minnow, *Hybognathus hankinsoni;* Peamouth, *Mylocheilus caurinus;* Northern Pikeminnow, *Ptychocheilus oregonensis;* Longnose Dace, *Rhinichthys cataractae;* Leopard Dace, *Rhinichthys falcatus;* and an undescribed dace (Nooksack Dace, *Rhinichthys* sp.); four suckers (Bridgelip Sucker, *Catostomus columbianus;* Largescale Sucker, *Catostomus macrocheilus;* Mountain Sucker, *Catostomus platyrhynchus;* and a genetically distinctive form (Salish Sucker, *Catostomus sp.*) of the Longnose Sucker (*Catostomus catostomus)* characterize this EDU. Most of the freshwater species in this EDU survived glaciation in the unglaciated portion of the Columbia River system; however, the Nooksack Dace, Salish Sucker and the sixty chromosome race of *Oncorhynchus mykiss* (Ostberg and Thorgaard 1999) survived in the Chehalis Refugium. These two Chehalis forms also occur in two Puget Sound drainages (the lower Skagit and Nooksack rivers) that rise in BC.
Interior Freshwater Ecoregion		
Middle Fraser	Great Plains and Columbia	The Middle Fraser EDU extends from about Boston Bar in the Fraser Canyon upstream to the confluence of the Bowron and Fraser rivers. It drains the Upper Fraser EDU. The Middle Fraser EDU flows through the relatively flat, gently sloping Interior Plateau. It retains its heavy silt load but stream gradient is less than that of the Upper Fraser, and some of its tributaries are clear and relatively warm in the summer. The surface of the Interior Plateau contains about half the small and medium sized lakes in BC and ten lakes with a surface area of over 100 km^2 (Northcote and Larkin 1963). The presence of Chiselmouth (*Acrocheilus alutaceus*), Lake Chub (*Couesius plumbeus*), and White Sucker (*Catostomus commersoni*) (a Great Plains species), as well as the absence of euryhaline species like River Lamprey (*Lampetra ayresi*), Longfin Smelt (*Spirinchus thaleichthys*), Eulachon (*Thaleichthys pacificus*), and threespine sticklebacks differentiate this EDU from the Lower Fraser EDU.

Upper Fraser	Great Plains and Columbia	The Upper Fraser EDU originates at Moose Lake (1000m above sea level) in the Rocky Mountain Trench and receives tributaries directly from glaciers in the Rocky and Cariboo mountains. Even in the summer, it is a cold, turbulent, silt-loaded system. The Upper Fraser EDU is defined by the absence of species that are present in the Middle Fraser EDU. For example, the upstream distributions of six species (Pacific Lamprey, *Lampetra tridentata;* Brassy Minnow, *Hybognathus hankinsoni;* Leopard Dace, *Rhinichthys falcatus;* Bridgelip Sucker, *Catostomus columbianus;* White Sucker, *Catostomus commersoni;* and Prickly Sculpin, *Cottus asper*) all end somewhere between Prince George and the confluence of the Fraser and Bowron rivers. It is not clear why this happens but relative to the Nechako River at Prince George, summer water temperatures decrease and gradients increase in the Upper Fraser EDU. This change in the physical environment probably influences the distribution of some species.
Upper Skeena	Great Plains and Columbia	The Upper Skeena EDU originates in the Central Plateau of BC. Postglacial connections between the Upper Skeena EDU and the Middle Fraser EDU are reflected in its freshwater fish fauna. This EDU contains most of the species that occur in the Middle Fraser system. There are five minnows (Lake Chub, *Couesius plumbeus;* Peamouth, *Mylocheilus caurinus;* Northern Pikeminnow, *Ptychocheilus oregonensis;* Longnose Dace, *Rhinichthys cataractae;* and Redside Shiner, *Richardsonius balteatus*), three suckers (Longnose Sucker, *Catostomus catostomus;* Largescale Sucker, *Catostomus macrocheilus;* and White Sucker, *Catostomus commersoni*), Lake Trout (*Salvelinus namaycush*), Bull Trout (*Salvelinus confluentus*) and three species of whitefish (Lake Whitefish, *Coregonus clupeaformis;* Mountain Whitefish, *Prosopium wiliamsoni;* and Pygmy Whitefish, *Prosopium coulterii*). It differs from the Middle Fraser EDU in the absence of Leopard Dace (*Rhinichthys falcatus*), Brassy Minnow (*Hybognathus hankinsoni*), and Bridgelip Sucker (*Catostomus columbianus*).

Upper Nass	Great Plains and Columbia	The Upper Nass EDU also originates on the Central Plateau of BC. It contains primary freshwater fishes of Columbia origin (e.g., Peamouth, *Mylocheilus caurinus;* Northern Pikeminnow, *Ptychocheilus oregonensis;* Longnose Dace, *Rhinichthys cataractae;* Redside Shiner, *Richardsonius balteatus;* Largescale Sucker, *Catostomus macrocheilus;* and Longnose Sucker, *Catostomus catostomus*). Two of these species (Redside Shiner and Longnose Sucker) reach the lower river.
Thompson	Columbia	The Thompson EDU drains the central and eastern parts of the Interior Plateau. It is a major clear water tributary of the Fraser River. There are three large lakes (Shuswap, Adams and Kamloops) associated with the Thompson system. At Kamloops, the Thompson divides into a north and south fork. The North Thompson River contains two Columbia species (Torrent Sculpin, *Cottus rhotheus* and Mountain Sucker, *Catostomus platyrhynchus*). The Torrent Sculpin is found nowhere else in the Fraser system. The South Thompson River is the only drainage unit outside the Columbia Glaciated Freshwater Ecoregion that contains native populations of the Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*).
Columbia Glaciated Freshwater Ecoregion		
Upper Columbia	Columbia	The Upper Columbia EDU originates at Columbia Lake and ends just above the Arrow Lakes. Its headwaters arise at a high altitude (800m above sea level) and it receives tributaries directly from glaciers in the Rocky and Purcell mountains. Even in the summer it is a cold, turbulent and silt-loaded system that resembles the melt-water channels and streams of early postglacial times. No native species are restricted to this EDU, and it is defined by the absence of species that occur in the downstream Columbia - Arrow Lakes EDU. Why these species are absent from the Upper Columbia EDU is unclear. There is no obvious barrier between the Upper Columbia and Columbia - Arrow Lakes EDUs; yet, the geographic ranges of both Shorthead Sculpin (*Cottus confusus*) and Columbia Sculpin (*Cottus hubbsi*) end just before lower Arrow Lake. Perhaps, the lakes themselves are barriers to these fluvial species.

Columbia - Arrow Lakes	Columbia	The Columbia - Arrow Lakes EDU drains the Upper Columbia EDU. This EDU differs from its upstream EDU in that is has a shallower gradient causing its silt load to settle out thereby creating a clear, less turbulent system. Downstream of the Arrow Lakes the number of fish species increases. Several native species (e.g., Umatilla Dace, *Rhinichthys umatilla;* Shorthead Sculpin, *Cottus confusus;* and Columbia Sculpin *Cottus hubbsi)* occur in this EDU but are absent from the Upper Columbia and Upper Kootenay EDUs.
Upper Kootenay	Columbia	Upper Kootenay EDU is similar physiographically to that of the Upper Columbia EDU. Its headwaters arise at a high altitude (800 m above sea level) in the Rocky Mountain Trench and it receives tributaries directly from glaciers in the Rocky and Purcell mountains. Even in the summer it is a cold, turbulent and silt-loaded system that probably resembles the melt-water channels and streams of early postglacial times. The Upper Kootenay EDU is defined by the absence of several species that occur in the Lower Kootenay EDU. The division between the upper and lower Kootenay EDUs is Bonnington Falls. Apparently, these falls prevented species such as Umatilla Dace (*Rhinichthys umatilla)* Shorthead Sculpin (*Cottus confusus)*, and Columbia Sculpin (*Cottus hubbsi)*, from dispersing up the Kootenay River.
Lower Kootenay	Columbia	The Lower Kootenay EDU drains the Upper Kootenay EDU. The stream gradient lessens, the silt load settles out and the rivers become clear and less turbulent in this EDU. The lower portion of this EDU contains Kootenay Lake. Downstream of the lake the number of fish species increases. Several indigenous species (e.g., Umatilla Dace, *Rhinichthys umatilla;* Shorthead Sculpin, *Cottus confusus;* and Columba Sculpin, *Cottus hubbsi*) occur in this EDU but are absent from the Upper Kootenay EDU.

Kettle	Columbia	The Kettle EDU drains the southern parts of the Monashee Mountains and the Interior Plateau. It is a relatively small, clear, warm water system. There is a velocity barrier at Cascade that separates about five km of the river between the barrier and the U.S. border from most of its BC catchment. The river below the barrier contains three species (Umatilla Dace, *Rhinichthys umatilla;* Shorthead Sculpin, *Cottus confuses;* and Columbia Sculpin, *Cottus hubbsi*) that are absent above the falls. This EDU is composed entirely of true freshwater fishes, and is the only river in Canada that contains Speckled Dace (*Rhinichthys osculus).* A few creeks in the Kettle River EDU also contain Westslope Cutthroat Trout (*Oncorhynchus clarki lewisi).* Along with the Okanagan and Similkameen rivers, the Kettle River is one of the warmest river systems in BC. All of these warm-water systems lack Bull Trout (*Salvelinus confluentus).*
Okanagan	Columbia	The Okanagan EDU drains the southern parts of the Monashee Mountains and the Interior Plateau. It is a relatively small, clear, warm water system. This EDU resembles the other warm-water Columbia drainages (the Kettle and Similkameen EDUs) in that it lacks Bull Trout (*Salvelinus confluentus).* However, the Okanagan drainage system contains a number of large, deep lakes. These lakes provide habitats that are absent, or rare, in the other warm-water EDUs. Thus, there are Pygmy Whitefish (*Prosopium coulterii*) and burbot (*Lota lota*) in Okanagan and Skaha lakes. The rest of the fishes are typical Columbia species, and there is still has a remnant run of Sockeye salmon (*Oncorhynchus nerka*) into the EDU and, at one time, lampreys reached Vaseaux Lake (Parkham 1937). The Okanagan EDU differs from the Kettle EDU in that it lacks Speckled Dace (*Rhinichthys osculus*).
Similkameen	Columbia	The Similkameen EDU drains the southern parts of the Monashee Mountains and the Interior Plateau. It is a relatively small, clear, warm water system. The Similkameen EDU consists of the Similkameen and Tulameen rivers and their tributaries. It differs from the Okanagan EDU in that it contains Mountain Sucker (*Catostomus platyrhynchus*), Umatilla Dace (*Rhinichthys umatilla*), Torrent Sculpin (*Cottus rhotheus*), Columbia Sculpin (*Cottus hubbsi*), and so far it is the only river in Canada that contains what probably are the Malheur Mottled Sculpin (*Cottus bendirei*).

Flathead	Columbia	The Flathead EDU is isolated from the rest of the Columbia system in BC by the Border Ranges. The Flathead EDU is in the headwaters of the Pend Oreille drainage and like many headwater systems it contains a relatively sparse fish fauna. It is the only place in the province where an as yet unnamed species, the Rocky Mountain Sculpin, occurs.
Mackenzie Freshwater Ecoregion		
Lower Liard	Great Plains and Beringian	The Lower Liard EDU drains the relatively flat northern half of the Alberta Plateau. Its major rivers are less turbulent than those in the Upper Liard, although still heavily silted and strongly flowing. On the Fort Nelson Lowlands there are large muskeg areas with blackwater streams, ponds and lakes. The fauna of the Lower Liard EDU is dominated by Great Plains species (e.g., Goldeye, *Hiodon alosoides*; Flathead Chub, *Platygobio gracilis*; Pearl Dace, *Margariscus margarita*; Northern Redbelly Dace, *Phoxinus eos*; and Finescale Dace, *Phoxinus neogaeus*). In addition to Great Plains species, the Lower Liard also contains two migratory Bering species (Arctic Cisco, *Coregonus autumnalis;* and Inconnu, *Stenodus leucichthys*) that are absent from the Upper Liard EDU. A third species, Chum salmon (*Oncorhynchus keta*) occasionally appears in the BC portion of the Liard system but it is not known if Chum salmon are sporadic visitors or a self-sustaining population.
Upper Liard	Great Plains and Beringian	The Upper Liard EDU originates near Dease Lake and drains the Stikine and Kechika ranges. It is separated from the Lower Laird by a velocity barrier in the Liard Canyon. With the exception of the White Sucker (*Catostomus commersoni*) and, perhaps the Lake Chub (*Couesius plumbeus*), there are no Great Plains species in the Upper Liard EDU. This EDU contains two widespread Pacific species (Rainbow Trout, *Oncorhynchus mykiss* and Dolly Varden, *Salvelinus malma*) that are not present in the Lower Liard EDU, as well as a Bering species (Round Whitefish, *Prosopium cylindraceum*). The latter species is moderately common in the Upper Liard EDU but only occurs for a short distance downstream of the Liard Canyon.

Lower Peace	Great Plains and Columbia	The Lower Peace EDU drains the Rocky Mountain foothills and the southern portion of the Alberta Plateau. Like the Lower Liard EDU, the Lower Peace EDU is dominated by Great Plains species but lacks most of the Beringian elements found in the Lower Liard EDU. Also, several Great Plains species (e.g., Cisco, *Coregonus artedi;* Emerald Shiner, *Notropis atherinoides*; Spottail Shiner, *Notropis hudsonius*; and Ninespine Stickleback, *Pungitius pungitius*) that are present in the Lower Liard EDU are absent from the Lower Peace EDU.
Upper Peace	Great Plains and Columbia	The Upper Peace EDU originates in the mountainous region west of the Continental Divide. Originally, the Upper Peace EDU was a high gradient, silt laden river formed by the junction of two rivers in the Rocky Mountain Trench: the south flowing Finlay River and the north flowing Parsnip River. A large reservoir, Williston Lake, now covers the Upper Peace from Hudson Hope to above the Finlay and Parsnip rivers. The Upper Peace EDU contains a mixed fish fauna. It contains fishes that are primarily of Pacific origin (e.g., landlocked Sockeye salmon, *Oncorhynchus nerka;* Dolly Varden, *Salvelinus malma;* Peamouth, *Mylocheilus caurinus;* Northern Pikeminnow, *Ptychocheilus oregonensis;* Redside Shiner, *Richardsonius balteatus;* and Prickly Sculpin, *Cottus asper*). There are, however, some Great Plains species (e.g., White Sucker, *Catostomus commersoni* and Brassy Minnow, *Hybognathus hankinsoni)* that occur in the Upper Peace, as well as one probable Bering species (Arctic Grayling, *Thymallus arcticus*).

Hay	Great Plains	Most of the Hay River drainage basin is in northern Alberta and the Northwest Territories. Until recently, there was no road access to the BC portion of this system and, even now, roads only reach the headwaters of the system. Consequently, the Hay EDU is poorly known. Nonetheless, its geographic location and the presence of Finescale Dace (*Phoxinus neogaeus),* Brook Stickleback (*Culaea inconstans),* Northern Pike (*Esox lucius),* and Walleye (*Sander vitreus*) indicate a Great Plains fauna. The few collections available from this system suggest a depauperate version of the lower Peace fauna.
Yukon Freshwater Ecoregion		
Lewes	Beringian	The Lewes EDU is the headwaters of the Yukon River drainage. It originates in the Coast Mountains and drains north into the Yukon Territory. The Lewes EDU consists of Atlin and Tagish lakes and their tributaries. It is isolated from the rest of the Yukon system by velocity barriers on its mainstem. This EDU contains a typical Beringian fauna: Least Cisco (*Coregonus sardinella)*, and the Bering forms of Lake Trout (*Salvelinus namaycush*), Round Whitefish *(Prosopium cylindraceum)*, Lake Whitefish (*Coregonus clupeaformis),* Slimy Sculpin (*Cottus cognatus)*, and one minnow (Lake Chub, *Couesius plumbeus*) that may be of Great Plains or Nahanni origin.
Teslin	Beringian	The Teslin EDU is the headwaters of the Yukon River drainage. It originates on the Central Plateau and Cassiar Range and drains north into the Yukon Territory. The Teslin EDU consists of Teslin Lake and its tributaries. The fish fauna of this EDU is more diverse than that of the Lewes EDU. There is a run of Chum salmon (*Oncorhynchus keta*) into the system, and the lake contains a lacustrine population of Inconnu (*Stenodus leucichthys nelma*). It is also the only EDU in BC where the Broad Whitefish (*Coregonus nasus)* occurs. Additionally, there are some lakes in the system that appear to hold two, morphological forms of Least Ciscoe (*Coregonus sardinella).*

Alsek	Beringian	The Alsek EDU contains the wild, high gradient Alsek River and its tributaries. The river is still very much effected by local glaciers within the Coastal Range. Except for salmon, this EDU is poorly known but probably contains the same suite of euryhaline species that occur along the entire coast: anadromous lampreys, smelts, salmon, trout, Dolly Varden (*Salvelinus malma*), threespine sticklebacks, and sculpins (*Cottus aleuticus* and *Cottus asper*) and Arctic Smelt (*Osmerus dentex).* In addition, the Round Whitefish (*Prosopium cylindraceum*) occurs in the upper river and probably also in the lower river. These species, suggest a Beringian component in the fauna that is absent from the Central Coastal and South Coastal EDUs. The absence of Bull Trout (*Salvelinus confluentus*) differentiates this EDU from the Taku and Iskut-Lower Stikine EDUs. During deglaciation, the Alsek EDU was tributary to the Yukon River via what is now Kluane Lake. Thus, lakes in the upper river contain the Bering forms of Round Whitefish, Pygmy Whitefish *(Prosopium coulterii)*, Northern Pike (*Esox lucius*), Lake Trout (*Salvelinus namaycush*), and Slimy Sculpin (*Cottus cognatus*). Curiously, however, they lack three species that now occur in Kluane Lake (Lake Chub, *Couesius plumbeus*; Broad Whitefish, *Coregonus nasus*; and Inconnu, *Stenodus leucichthys*) and contain native populations of two Pacific species: Rainbow Trout (*Oncorhynchus mykiss*) and Kokanee (*Oncorhynchus nerka*) that are not indigenous to the upper Yukon system. Dezadeash Lake in the upper Alsek also contains a genetically distinctive, sympatric pair of Lake Whitefish (*Coregonus clupeaformis*).
Nakina	Beringian and Great Plains	The Nakina River is a major tributary of the Taku River that postglacially captured tributaries that once flowed into the Lewes and Teslin EDUs. Thus, the upper river contains the Beringian forms of Northern Pike (*Esox lucius*), Round Whitefish (*Prosopium cylindraceum*), and Lake Trout (*Salvelinus namaycush*), as well as Lake Chub (*Couesius plumbeus*) of Great Plains or Nahanni origin. A Pacific species (Bull Trout, *Salvelinus confluentus*) also occurs in this EDU.

Upper Stikine	Beringian and Columbia	The Upper Stikine EDU originates on the Cassiar Range at an elevation of 1200m on the southern end of the Spatsizi Plateau. This EDU appears to be a transition zone. Morrow (1980) indicates the presence of the Arctic Smelt (*Osmerus dentex*) and there are some Beringian components in the upper river such as Arctic Grayling (*Thymallus arcticus*) and the Bering forms of Lake Trout (*Salvelinus namaycush*), Burbot (*Lota lota*), Longnose Sucker (*Catostomus catostomus*), and Slimy Sculpin (*Cottus cognatus*). The Round Whitefish (*Prosopium cylindraceum*) is absent from the system but Pacific species (e.g., Mountain Whitefish, *Prosopium wiliamsoni* and Bull Trout, *Salvelinus confluentus)* are present and may reach the lower river.

Table 3i-v: Summary of native freshwater fish community composition for each Ecological Drainage Unit by Freshwater Ecoregion.

i. North Pacific Coastal Freshwater Ecoregion (49 freshwater fish species)

Common Name	**Scientific Name**	Taku	Iskut-Lower Stikine	Lower Skeena	Lower Nass – Portland	Haida Gwaii	North Coastal	Central Coastal	South Coastal	Bella Coola – Dean	Homathko – Klinaklini	Lower Fraser	Vancouver Island	Puget Sound
River Lamprey	*Lampetra ayresi*	?	1	1	1	1	1	1	1	1	1	1	1	1
Vancouver lamprey	*Lampetra macrostoma*	0	0	0	0	0	0	0	0	0	0	0	1	0
Brook Lamprey	*Lampetra richardsoni*	0	1	1	1	1	0	1	1	1	1	1	1	1
Pacific Lamprey	*Lampetra tridentata*	1	1	1	1	1	1	1	1	1	1	1	1	0
Green Sturgeon	*Acipenser medirostris*	?	?	1	1	0	?	?	0	0	0	1	1	0
White Sturgeon	*Acipenser transmontanus*	1	1	1	1	0	?	?	0	?	?	1	1	0
Pink Salmon	*Oncorhynchus gorbuscha*	1	1	1	1	1	1	1	1	1	1	1	1	0
Chum Salmon	*Oncorhynchus keta*	1	1	1	1	1	1	1	1	1	1	1	1	0
Coho Salmon	*Oncorhynchus kisutch*	1	1	1	1	1	1	1	1	1	1	1	1	1
Rainbow Trout / Steelhead	*Oncorhynchus mykiss*	1	1	1	1	1	1	1	1	1	1	1	1	1
Kokanee/Sockeye Salmon	*Oncorhynchus nerka*	1	1	1	1	1	1	1	1	1	1	1	1	0
Chinook Salmon	*Oncorhynchus tshawytscha*	1	1	1	1	1	1	1	1	1	1	1	1	0
Coastal Cutthroat Trout	*Oncorhynchus clarki clarki*	1	1	1	1	1	1	1	1	1	1	1	1	1
Bull Trout	*Salvelinus confluentus*	1	1	1	1	0	0	0	1	1	1	1	0	1
Dolly Varden	*Salvelinus malma*	1	1	1	1	1	1	1	1	1	1	1	1	1
Lake Trout	*Salvelinus namaycush*	1	1	1	0	0	0	0	0	0	0	0	0	0
Grayling	*Thymallus arcticus*	1	1	0	0	0	0	0	0	0	0	0	0	0
Northern Pike	*Esox lucius*	1	0	0	0	0	0	0	0	0	0	0	0	0
Burbot	*Lota lota*	0	1	1	1	0	0	0	0	0	0	0	0	0
Pygmy Longfin Smelt	*Spirinchus* spp.	0	0	0	0	0	0	0	0	0	0	1	0	0
Longfin Smelt	*Spirinchus thaleichthys*	1	?	0	0	0	1	0	1	0	1	1	0	0
Surf Smelt	*Hypomesus pretiosus*	0	0	0	0	0	0	0	0	0	0	1	0	0
Rainbow Smelt	*Osmerus dentex*	?	?	0	0	0	0	0	0	0	0	0	1	0
Eulachon	*Thaleichthys pacificus*	1	1	1	1	1	1	1	1	1	1	1	1	0
Inconnu	*Stenodus leucichthys*	0	0	0	0	0	0	0	0	1	1	0	0	0
Lake Whitefish	*Coregonus clupeaformis*	0	0	1	0	0	0	0	0	0	0	0	0	0

i. North Pacific Coastal Freshwater Ecoregion (49 freshwater fish species)

Common Name	**Scientific Name**	Taku	Iskut-Lower Stikine	Lower Skeena	Lower Nass – Portland	Haida Gwaii	North Coastal	Central Coastal	South Coastal	Bella Coola – Dean	Homathko – Klinaklini	Lower Fraser	Vancouver Island	Puget Sound
Pygmy Whitefish	*Prosopium coulteri*	0	0	1	0	0	0	0	0	0	0	0	0	0
Round Whitefish	*Prosopium cylindraceum*	1	0	0	0	0	0	0	0	0	0	0	0	0
Mountain Whitefish	*Prosopium williamsoni*	0	1	1	1	0	0	0	0	1	1	1	0	0
Longnose Sucker	*Catostomus catostomus*	1	1	1	1	0	1	1	0	1	1	0	0	0
Bridgelip Sucker	*Catostomus columbianus*	0	0	0	0	0	0	0	0	0	0	1	0	0
White Sucker	*Catostomus commersoni*	0	0	1	0	0	0	0	0	0	0	0	0	0
Largescale Sucker	*Catostomus macrocheilus*	0	0	1	1	0	0	0	0	1	1	1	0	0
Mountain Sucker	*Catostomus platyrhynchus*	0	0	0	0	0	0	0	0	0	0	1	0	0
Salish Sucker	*Catostomus* sp.	0	0	0	0	0	0	0	0	0	0	1	0	1
Coastrange Sculpin	*Cottus aleuticus*	1	1	1	1	1	1	1	1	1	1	1	1	0
Prickly Sculpin	*Cottus asper*	1	1	1	1	1	1	1	1	1	1	1	1	1
Slimy Sculpin	*Cottus cognatus*	1	1	0	0	0	0	0	0	0	0	0	0	0
Cultus Lake Sculpin	*Cottus sp.*	0	0	0	0	0	0	0	0	0	0	1	0	0
Northern Pikeminnow	*Ptychocheilus oregonensis*	0	0	1	1	0	0	0	0	1	1	1	0	0
Lake Chub	*Couesius plumbeus*	1	1	1	1	0	0	0	0	1	0	0	0	0
Peamouth	*Mylocheilus caurinus*	0	0	1	1	0	0	0	1	1	1	1	1	0
Longnose Dace	*Rhinichthys cataractae*	0	0	1	1	0	0	0	0	1	1	1	0	0
Leopard Dace	*Rhinichthys falcatus*	0	0	0	0	0	0	0	0	0	0	1	0	0
Nooksack Dace	*Rhinichthys* sp.	0	0	0	0	0	0	0	0	0	0	1	0	1
Brassy Minnow	*Hybognathus hankinsoni*	0	0	0	0	0	0	0	0	0	0	1	0	0
Redside Shiner	*Richardsonius balteatus*	0	0	1	1	0	0	0	0	1	1	1	0	0
Threespine Stickleback	*Gasterosteus aculeatus*	1	1	1	1	1	1	1	1	1	1	1	1	1
Charlotte Unarmoured Stickleback	*Gasterosteus* sp.	0	0	0	0	1	0	0	0	0	0	0	0	0
TOTAL		**23**	**24**	**31**	**27**	**16**	**16**	**16**	**18**	**25**	**25**	**34**	**20**	**11**

ii. Interior Freshwater Ecoregion (33 freshwater fish species)

Common Name	Scientific Name	Middle Fraser	Upper Fraser	Thompson	Upper Skeena	Upper Nass
Pacific Lamprey	*Lampetra tridentata*	1	0	1	1	0
White Sturgeon	*Acipenser transmontanus*	1	1	1	0	0
Pink Salmon	*Oncorhynchus gorbuscha*	1	0	1	0	0
Coho Salmon	*Oncorhynchus kisutch*	1	0	1	1	1
Rainbow Trout / Steelhead	*Oncorhynchus mykiss*	1	1	1	1	1
Kokanee/Sockeye Salmon	*Oncorhynchus nerka*	1	1	1	1	1
Chinook Salmon	*Oncorhynchus tshawytscha*	1	1	1	1	1
Coastal Cutthroat Trout	*Oncorhynchus clarki clarki*	1	0	0	0	0
Westslope Cutthroat Trout	*Oncorhynchus clarki lewisi*	0	0	1	0	0
Bull Trout	*Salvelinus confluentus*	1	1	1	1	1
Dolly Varden	*Salvelinus malma*	1	0	0	1	1
Lake Trout	*Salvelinus namaycush*	1	1	1	1	1
Burbot	*Lota lota*	1	1	1	1	1
Lake Whitefish	*Coregonus clupeaformis*	1	1	1	1	?
Pygmy Whitefish	*Prosopium coulteri*	1	1	1	1	0
Mountain Whitefish	*Prosopium williamsoni*	1	1	1	1	1
Longnose Sucker	*Catostomus catostomus*	1	1	1	1	1
Bridgelip Sucker	*Catostomus columbianus*	1	0	1	0	0
White Sucker	*Catostomus commersoni*	1	0	1	1	0
Largescale Sucker	*Catostomus macrocheilus*	1	1	1	1	1
Mountain Sucker	*Catostomus platyrhynchus*	0	0	1	0	0
Coastrange Sculpin	*Cottus aleuticus*	1	0	0	1	0
Prickly Sculpin	*Cottus asper*	1	0	1	1	1
Slimy Sculpin	*Cottus cognatus*	1	1	1	1	1
Torrent Sculpin	*Cottus rhotheus*	0	0	1	0	0
Chiselmouth	*Acrocheilus alutaceus*	1	0	1	0	0
Northern Pikeminnow	*Ptychocheilus oregonensis*	1	1	1	1	1
Lake Chub	*Couesius plumbeus*	1	1	1	1	0
Peamouth	*Mylocheilus caurinus*	1	1	1	1	1
Longnose Dace	*Rhinichthys cataractae*	1	1	1	1	1
Leopard Dace	*Rhinichthys falcatus*	1	0	1	0	0

ii. Interior Freshwater Ecoregion (33 freshwater fish species)

Common Name	Scientific Name	Middle Fraser	Upper Fraser	Thompson	Upper Skeena	Upper Nass
Brassy Minnow	*Hybognathus hankinsoni*	1	0	0	0	0
Redside Shiner	*Richardsonius balteatus*	1	1	1	1	1
TOTAL		**30**	**18**	**29**	**23**	**17**

iii. Columbia Glaciated Freshwater Ecoregion (29 freshwater fish species)

Common Name	Scientific Name	Upper Columbia	Columbia-Arrow Lakes	Upper Kootenay	Lower Kootenay	Kettle	Okanagan	Similkameen	Flathead
White Sturgeon	*Acipenser transmontanus*	1	1	1	1	0	?	0	0
Rainbow Trout / Steelhead	*Oncorhynchus mykiss*	1	1	1	1	1	1	1	1
Kokanee/Sockeye Salmon	*Oncorhynchus nerka*	1	1	1	1	0	1	1	0
Chinook Salmon	*Oncorhynchus tshawytscha*	0	0	0	0	0	1	0	0
Westslope Cutthroat Trout	*Oncorhynchus clarki lewisi*	1	1	1	0	1	0	0	1
Bull Trout	*Salvelinus confluentus*	1	1	1	1	0	0	0	1
Burbot	*Lota lota*	1	1	1	1	0	1	1	0
Pygmy Whitefish	*Prosopium coulteri*	1	1	1	1	0	1	0	0
Mountain Whitefish	*Prosopium williamsoni*	1	1	1	1	1	1	1	1
Longnose Sucker	*Catostomus catostomus*	1	1	1	1	1	1	1	1
Bridgelip Sucker	*Catostomus columbianus*	0	1	0	1	0	1	1	0
Largescale Sucker	*Catostomus macrocheilus*	1	1	1	1	1	1	1	0
Mountain Sucker	*Catostomus platyrhynchus*	0	1	0	0	0	0	1	0
Prickly Sculpin	*Cottus asper*	0	1	0	1	?	1	1	0
Malheur Mottled Sculpin	*Cottus bendirei*	0	0	0	0	0	0	1	0
Slimy Sculpin	*Cottus cognatus*	1	1	1	1	1	1	1	1
Shorthead Sculpin	*Cottus confusus*	0	1	0	1	1	0	0	0
Columbia Sculpin	*Cottus hubbsi*	0	1	0	1	1	0	1	1
Torrent Sculpin	*Cottus rhotheus*	1	1	1	1	1	0	1	0
Rocky Mountain Sculpin	*Cottus sp.*	0	0	0	0	0	0	0	1
Chiselmouth	*Acrocheilus alutaceus*	0	1	0	1	1	1	1	0
Northern Pikeminnow	*Ptychocheilus oregonensis*	1	1	1	1	1	1	1	0

iii. Columbia Glaciated Freshwater Ecoregion (29 freshwater fish species)

Common Name	Scientific Name	Upper Columbia	Columbia-Arrow Lakes	Upper Kootenay	Lower Kootenay	Kettle	Okanagan	Similkameen	Flathead
Lake Chub	*Couesius plumbeus*	0	1	0	1	0	1	1	0
Peamouth	*Mylocheilus caurinus*	1	1	1	1	1	1	1	0
Longnose Dace	*Rhinichthys cataractae*	1	1	1	1	1	1	1	0
Leopard Dace	*Rhinichthys falcatus*	0	1	0	?	0	1	1	0
Speckled Dace	*Rhinichthys osculus*	0	0	0	0	1	0	0	0
Umatilla Dace	*Rhinichthys umatilla*	0	1	0	1	1	0	1	0
Redside Shiner	*Richardsonius balteatus*	1	1	1	1	1	1	1	0
TOTAL		**16**	**25**	**16**	**22**	**16**	**18**	**21**	**8**

iv. Mackenzie Freshwater Ecoregion (40 freshwater fish species)

Common Name	Scientific Name	Upper Liard	Lower Liard	Upper Peace	Lower Peace	Hay
Chum Salmon	*Oncorhynchus keta*	0	1	0	0	0
Rainbow Trout / Steelhead	*Oncorhynchus mykiss*	1	0	1	1	0
Kokanee/Sockeye Salmon	*Oncorhynchus nerka*	0	0	1	1	0
Bull Trout	*Salvelinus confluentus*	1	1	1	1	0
Dolly Varden	*Salvelinus malma*	1	0	1	0	0
Lake Trout	*Salvelinus namaycush*	1	0	1	0	0
Yellow Perch	*Perca flavescens*	0	0	0	1	0
Walleye	*Sander vitreus*	0	1	0	1	1
Grayling	*Thymallus arcticus*	1	1	1	1	0
Northern Pike	*Esox lucius*	1	1	0	1	1
Burbot	*Lota lota*	1	1	1	1	0
Goldeye	*Hiodon alosoides*	0	1	0	1	0
Inconnu	*Stenodus leucichthys*	0	1	0	0	0
Lake Cisco	*Coregonus artedi*	0	1	0	0	0
Arctic Cisco	*Coregonus autumnalis*	0	1	0	0	0
Lake Whitefish	*Coregonus clupeaformis*	1	1	1	1	0
Pygmy Whitefish	*Prosopium coulteri*	1	0	1	0	0

iv. Mackenzie Freshwater Ecoregion (40 freshwater fish species)

Common Name	**Scientific Name**	**Upper Liard**	**Lower Liard**	**Upper Peace**	**Lower Peace**	**Hay**
Round Whitefish	*Prosopium cylindraceum*	1	1	0	0	0
Mountain Whitefish	*Prosopium williamsoni*	1	1	1	1	0
Longnose Sucker	*Catostomus catostomus*	1	1	1	1	1
White Sucker	*Catostomus commersoni*	1	1	1	1	1
Largescale Sucker	*Catostomus macrocheilus*	0	0	1	1	0
Prickly Sculpin	*Cottus asper*	0	0	1	1	0
Slimy Sculpin	*Cottus cognatus*	1	1	1	1	1
Spoonhead Sculpin	*Cottus ricei*	0	1	0	1	0
Northern Pikeminnow	*Ptychocheilus oregonensis*	0	0	1	1	0
Lake Chub	*Couesius plumbeus*	1	1	1	1	1
Peamouth	*Mylocheilus caurinus*	0	0	1	1	0
Flathead Chub	*Platygobio gracilis*	0	1	0	1	0
Pearl Dace	*Margariscus margarita*	0	1	0	1	0
Northern Redbelly Dace	*Phoxinus eos*	0	1	0	1	0
Finescale Dace	*Phoxinus neogaeus*	0	1	0	1	1
Longnose Dace	*Rhinichthys cataractae*	1	1	1	1	0
Brassy Minnow	*Hybognathus hankinsoni*	0	0	1	0	0
Emerald Shiner	*Notropis atherinoides*	0	1	0	0	0
Spottail Shiner	*Notropis hudsonius*	0	1	0	0	0
Redside Shiner	*Richardsonius balteatus*	0	0	1	1	0
Troutperch	*Percopsis omiscomaycus*	0	1	0	1	0
Brook Stickleback	*Culaea inconstans*	0	1	0	1	1
Ninespine Stickleback	*Pungitius pungitius*	0	1	0	0	0
TOTAL		**16**	**28**	**21**	**28**	**8**

v. Yukon Freshwater Ecoregion (29 freshwater fish species)

Common Name	**Scientific Name**	**Alsek**	**Teslin**	**Lewes**	**Nakina**	**Upper Stikine**
Pacific Lamprey	*Lampetra tridentata*	1	0	0	0	0
Pink Salmon	*Oncorhynchus gorbuscha*	1	0	0	0	0

v. Yukon Freshwater Ecoregion (29 freshwater fish species)

Common Name	Scientific Name	Alsek	Teslin	Lewes	Nakina	Upper Stikine
Chum Salmon	*Oncorhynchus keta*	1	1	0	0	0
Coho Salmon	*Oncorhynchus kisutch*	1	0	0	0	0
Rainbow Trout / Steelhead	*Oncorhynchus mykiss*	1	0	0	0	0
Kokanee/Sockeye Salmon	*Oncorhynchus nerka*	1	0	0	0	0
Chinook Salmon	*Oncorhynchus tshawytscha*	1	1	0	0	0
Coastal Cutthroat Trout	*Oncorhynchus clarki clarki*	1	0	0	0	0
Bull Trout	*Salvelinus confluentus*	0	1	0	1	1
Dolly Varden	*Salvelinus malma*	1	0	0	0	0
Lake Trout	*Salvelinus namaycush*	1	1	1	1	1
Grayling	*Thymallus arcticus*	1	1	1	1	1
Northern Pike	*Esox lucius*	1	1	0	1	0
Burbot	*Lota lota*	1	1	1	1	1
Rainbow Smelt	*Osmerus dentex*	1	0	0	0	1
Eulachon	*Thaleichthys pacificus*	1	0	0	0	0
Inconnu	*Stenodus leucichthys*	0	1	0	0	0
Lake Whitefish	*Coregonus clupeaformis*	1	1	1	1	1
Broad Whitefish	*Coregonus nasus*	0	1	0	0	0
Least Cisco	*Coregonus sardinella*	0	1	1	1	0
Pygmy Whitefish	*Prosopium coulteri*	1	1	0	0	0
Round Whitefish	*Prosopium cylindraceum*	1	1	1	1	0
Mountain Whitefish	*Prosopium williamsoni*	0	0	0	0	1
Longnose Sucker	*Catostomus catostomus*	1	1	1	1	1
Coastrange Sculpin	*Cottus aleuticus*	1	0	0	0	0
Prickly Sculpin	*Cottus asper*	1	0	0	0	0
Slimy Sculpin	*Cottus cognatus*	1	1	1	1	1
Lake Chub	*Couesius plumbeus*	0	1	1	1	1
Threespine Stickleback	*Gasterosteus aculeatus*	1	0	0	0	0
TOTAL		**23**	**16**	**9**	**11**	**10**

Table 4: Summary of the physiography and climate of each Ecological Drainage Unit of BC.

Ecological Drainage Unit	Geology	Mean Annual Peak Flow	Wetland Influence	Lake Influence	Alpine Tundra Cold Water Influence	Glacial Influence	Water Temperature	Degree Days	Stream Gradient
North Pacific Coastal Freshwater Ecoregion									
Taku	Sedimentary and volcanic with some intrusives	Moderate to high	Moderate	Low	High	High	Cold	Low to moderate	Moderate to steep
Iskut- Lower Stikine	Volcanic and sedimentary with some intrusives	High to very high	Moderate	Moderate	High	High	Cold	Low to moderate	Steep
Lower Nass - Portland	Intrusives with some volcanic and sedimentary	Very high	Low	Low	High	High	Cold	Moderate	Steep
North Coastal	Intrusives with some volcanic	High	Low	Low	High	High	Cold	Low	Moderate to steep
Lower Skeena	Mix of volcanic, intrusives and sedimentary	High to very high	Low	Moderate	High	High	Cold	Moderate	Steep

Ecological Drainage Unit	Geology	Mean Annual Peak Flow	Wetland Influence	Lake Influence	Alpine Tundra Cold Water Influence	Glacial Influence	Water Temperature	Degree Days	Stream Gradient
Haida Gwaii / Queen Charlotte Islands	Volcanic with some sedimentary	High to very high	Very high	Moderate	Moderate	None	West coast cold; moderate interior; east coast warm	High	Shallow
Bella Coola - Dean	Mix of volcanic, intrusives and alluvium	Moderate to high	High	High	Drainage pattern none to high	High	Cold	Low to moderate	Shallow to steep
Homathko - Klinaklini	Intrusives with some alluvium, volcanic and sedimentary	High	Low	Low	High	High	Cold	Low to moderate	Steep
Central Coastal	Intrusives with some volcanic	Very high	Low	High	High	High	Cold-cool	Drainage pattern of moderate to high	Steep
Vancouver Island	Volcanic and intrusives with some sedimentary	Very high	Moderate	High	Low	Low	Warm	High	Moderate

Ecological Drainage Unit	Geology	Mean Annual Peak Flow	Wetland Influence	Lake Influence	Alpine Tundra Cold Water Influence	Glacial Influence	Water Temperature	Degree Days	Stream Gradient
South Coastal	Intrusives	Very high	Low	High	High	High	Drainage pattern cold to warm	Drainage pattern of moderate to high	Steep
Puget Sound	Sedimentary with some volcanic	High	Low	Low	Low	None	Warm	High	Shallow
Lower Fraser	Intrusives with some sedimentary and volcanic	High to very high	Moderate	High	High	High	Cold (Lillooet) to warm	Moderate to high	Steep to moderate
Interior Freshwater Ecoregion									
Middle Fraser	Volcanic with some sedimentary, alluvium and intrusives	Low to moderate	High	Very high	Moderate	Moderate	Moderate (mixed)	Low to moderate	Shallow
Upper Fraser	Sedimentary with some volcanic	High	Moderate	Moderate	High	High	Drainage pattern cold to moderate	Low to moderate	Moderate
Upper Skeena	Sedimentary and volcanic	Moderate to high	Moderate	Very high	High	Moderate	Cold to cool	Low to moderate	Steep to shallow
Upper Nass	Sedimentary with some	High	Moderate	Moderate	High	High	Cold	Low to moderate	Steep to shallow

Ecological Drainage Unit	Geology	Mean Annual Peak Flow	Wetland Influence	Lake Influence	Alpine Tundra Cold Water Influence	Glacial Influence	Water Temperature	Degree Days	Stream Gradient
	volcanic								
Thompson	Volcanic and intrusives with some sedimentary and alluvium	Moderate to low	Low	High	Low	High to low	Drainage pattern cold to warm	Moderate to high	Moderate to shallow
Columbia Glaciated Freshwater Ecoregion									
Upper Columbia	Sedimentary with some intrusives and alluvium	High	Moderate	Low	High	High	Cold	Low to moderate	Steep
Columbia - Arrow Lakes	Intrusives with some sedimentary and volcanic	Moderate to high	Low	High	Moderate	Low	Drainage pattern cold to warm	Moderate	Steep
Upper Kootenay	Sedimentary with some intrusives and alluvium	Moderate	Low	Low	High	High	Drainage pattern cold to warm	Low to moderate	Steep
Lower Kootenay	Sedimentary and intrusives	Moderate to high	Low	High	High	Low	Drainage pattern cold to warm	Low to moderate	Steep

Ecological Drainage Unit	Geology	Mean Annual Peak Flow	Wetland Influence	Lake Influence	Alpine Tundra Cold Water Influence	Glacial Influence	Water Temperature	Degree Days	Stream Gradient
Kettle	Intrusives with some sedimentary and volcanic	Moderate	Low	Moderate	Low	None	Warm	Moderate	Moderate
Okanagan	Intrusives and volcanic with some sedimentary and alluvium	Low	Low	Very high	None	None	Warm	High	Moderate
Similkameen	Intrusives and volcanic with some sedimentary	Moderate	Low	Low	Low	None	Warm	Moderate	Shallow to moderate
Flathead	Sedimentary with some alluvium	Moderate	Low	Low	High	None	Cold	Moderate	Moderate
Mackenzie Freshwater Ecoregion									
Lower Liard	Sedimentary	Low to moderate	Very high	Moderate	Drainage pattern high to low	Moderate	Drainage pattern cold to warm	Low	Shallow
Upper Liard	Sedimentary and intrusives with some	Moderate	Moderate	Moderate	High	Low	Drainage pattern cold to warm	Low	Shallow to moderate

Ecological Drainage Unit	Geology	Mean Annual Peak Flow	Wetland Influence	Lake Influence	Alpine Tundra Cold Water Influence	Glacial Influence	Water Temperature	Degree Days	Stream Gradient
	volcanic								
Lower Peace	Sedimentary	Low to moderate	Very high	Very high	Drainage pattern high to low	None	Warm	Low to moderate	Shallow to moderate
Upper Peace	Mix of sedimentary, intrusives and volcanic	Moderate to high	Moderate	Moderate	High	Low	Drainage pattern cold to warm	Low to moderate	Shallow to moderate
Hay	Sedimentary	Low	Very high	Moderate	None	None	Warm	Low	Shallow
Yukon Freshwater Ecoregion									
Lewes	Intrusives with some sedimentary and volcanic	Moderate to high	Moderate	Very high	High	High	Cold	Low	Moderate
Teslin	Sedimentary and intrusives with some volcanic	Moderate	High	High	High	None	Cold	Low	Shallow

Ecological Drainage Unit	Geology	Mean Annual Peak Flow	Wetland Influence	Lake Influence	Alpine Tundra Cold Water Influence	Glacial Influence	Water Temperature	Degree Days	Stream Gradient
Alsek	Sedimentary and intrusives with some volcanic	High	Low	Low	High	High	Cold	Low	Moderate
Nakina	Volcanic and sedimentary with some intrusives	Moderate	Moderate	Low	High	Low	Cold	Low	Moderate
Upper Stikine	Volcanic and sedimentary with some intrusives	Moderate to high	Moderate	Moderate	High	Low	Cold	Low	Shallow to steep

River and Lake Ecosystems

Ecological Drainage Units and Freshwater Ecoregions capture broad scale patterns in zoogeography, physiography and climate. ***River and lake ecosystems, as defined by EAU BC, are nested within Ecological Drainage Units and Freshwater Ecoregions, and are groupings of rivers and lakes that share similar physical habitat and dominant environmental processes. They are hypothesized to share similar freshwater communities.*** Ecosystem Types are derived from a suite of key environmental factors identified in the scientific literature as driving community composition and structure in lakes and rivers. These factors include: physical habitat, hydrology, water temperature and chemistry, and connectivity. Although a mix of environmental and geographic factors determine actual species distributions, the physical environment is likely to explain a large amount of variation occurring within a given drainage basin. Freshwater biodiversity has been poorly inventoried in BC and hence it is not feasible to be incorporated into this level of the classification. However, fish assemblages associated with each Ecological Drainage Unit can be inferred in the River and Lake Ecosystem Types that reside within each Ecological Drainage Unit. Ecological Drainage Units can therefore be used to further sub-divide the number of Ecosystem Types across the province.

The aim of this level of the classification is twofold: to identify **what** River and Lake Ecosystem Types exist in BC based on the range of variability of a suite of key environmental factors; and to identify **where** these Ecosystem Types are distributed across the Province.

Numerous river and lake classifications have been developed with a diverse range of uses. EAU BC's river ecosystem classification is based on classification work by Higgins *et al.* (2005); Snelder *et al.* (2004); and Seelbach *et al.* (1997). EAU BC's lake ecosystem classification is based on classification work by Northcote and Larkin (1956, 1963), Winter (1977), Cupp (1989), Busch and Sly (1992), Trainor and Church (1996), Seelbach *et al.* (1997), and Schiefer and Klinkenberg (2004).

The units of analysis for river ecosystems in BC are the smallest watershed unit in the BC Watershed Atlas at a scale of 1:50,000. There are a total of 19,264 watershed units in BC. However 1,164 of these watershed units do not have stream networks associated with them at the scale of 1:50,000. Environmental data is attributed to these watershed units where feasible but due to the lack of river attributes these units are excluded from the river ecosystem classification. In total, 18,100 watershed units are used in the classification of River Ecosystem Types.

The BC Watershed Atlas is at a scale of 1:50,000 and identifies 218,207 lakes in BC. Lakes less than one hectare are likely wetlands or ponds that have been incorporated into various wetland classifications for BC. Only lakes with a surface area of one hectare and greater (67,484 lakes) have been included in the lake ecosystem classification.

The following steps are used in classifying River and Lake Ecosystem Types: assembly of relevant environmental and biologic data; analysis of the relationship between biological and environmental data to identify the best predictors of biological patterns from the environmental data; delineation of Ecosystem Types; and an evaluation of the statistical significance of the Ecosystem Types. These steps are discussed below.

Data Inputs

Environmental Data Inputs

Numerous environmental variables have been modeled and attributed to the BC Watershed Atlas for the development the River and Lake Ecosystem Type classifications (Tables 5 and 6). This information should be used in conjunction with the River and Lake Ecosystem Type classifications as it provides specific values for each environmental variable for each river and lake unit in BC.

Table 5: Environmental variables derived and attributed to river ecosystems in BC.

River Environmental Variables	Database Field Name	Source[3]
Unique ID	GIS_TAG	WSA
Freshwater Ecoregion	FW_ECOREG	EAU BC, Abel et al. 2000
Ecological Drainage Unit	EDU	EAU BC
Watershed reverse stream order	W_LEVEL	EAU BC, WSA, DEM
Percent of watershed unit in each BEC Zone: Boreal Altai Fescue Alpine Bunchgrass Boreal White and Black Spruce Coastal Douglas-Fir Coastal Mountain-heather Alpine Coastal Western Hemlock Engelmann Spruce-Subalpine Fir Interior Cedar-Hemlock Interior Douglas-fir Interior Mountain-heather Alpine Mountain Hemlock Montane Spruce Ponderosa Pine Sub-Boreal Pine-Spruce	BAFA BG BWBS CDF CMA CWH ESSF ICH IDF IMA MH MS PP SBPS SBS SWB	EAU BC, BEC

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[3] WSA = BC Watershed Atlas 1:50,000 (2007); DEM = BC 30m digital elevation model (2007); BEC Classification = BC Biogeoclimatic Ecosystem Classification (2007)

River Environmental Variables	Database Field Name	Source[3]
Sub-Boreal Spruce Spruce-Willow – Birch		
Mean watershed elevation (m)	MEAN_ELEV	EAU BC, WSA, DEM
Minimum watershed elevation (m)	MIN_ELEV	EAU BC, WSA, DEM
Maximum watershed elevation (m)	MAX_ELEV	EAU BC, WSA, DEM
Standard deviation of watershed elevation	STD_ELEV	EAU BC, WSA, DEM
Melton's R (watershed area / sqrt max-min elevation)	MELTONS_R	EAU BC, WSA, DEM
Total upstream drainage area (km^2)	DRAIN_KM2	EAU BC, WSA, DEM
Mainstem stream gradient classes:		EAU BC, WSA, Macroreach Dataset
<0.02	GRAD1_M	
0.02-0.08	GRAD2_M	
0.08-0.12	GRAD3_M	
0.12-0.16	GRAD4_M	
0.16-0.20	GRAD5_M	
>0.20	GRAD6_M	
Tributary stream gradient classes:		EAU BC, WSA, Macroreach Dataset
<0.02	GRAD1_T	
0.02-0.08	GRAD2_T	
0.08-0.12	GRAD3_T	
0.12-0.16	GRAD4_T	
0.16-0.20	GRAD5_T	
>0.20	GRAD6_T	
Mean monthly precipitation (mm) per watershed unit:		EAU BC, WSA, ClimateSource
January	PPT_JAN_M	
February	PPT_FEB_M	
March	PPT_MAR_M	
April	PPT_APR_M	
May	PPT_MAY_M	
June	PPT_JUN_M	
July	PPT_JUL_M	
August	PPT_AUG_M	
September	PPT_SEP_M	
October	PPT_OCT_M	
November	PPT_NOV_M	
December	PPT_DEC_M	
Mean annual precipitation (mm)	PPT_ANN_M	EAU BC, WSA, ClimateSource

River Environmental Variables	Database Field Name	Source[3]
Mean monthly air temperature (°C) (buffered to stream reaches per watershed unit):		EAU BC, WSA, ClimateSource
January	TEMP_JAN_M	
February	TEMP_FEB_M	
March	TEMP_MAR_M	
April	TEMP_APR_M	
May	TEMP_MAY_M	
June	TEMP_JUN_M	
July	TEMP_JUL_M	
August	TEMP_AUG_M	
September	TEMP_SEP_M	
October	TEMP_OCT_M	
November	TEMP_NOV_M	
December	TEMP_DEC_M	
Mean annual air temperature (°C)	TEMP_ANN_M	EAU BC, WSA, ClimateSource
Maximum July temperature (°C) per watershed	MAX_JUL	EAU BC, WSA, ClimateSource
Percent of watershed unit in each underlying bedrock geology class:		EAU BC, WSA, BC Energy and Mines Bedrock Geology Dataset
Intrusives and metamorphic bedrock	INT_META	
Volcanic bedrock	VOLCANIC	
Hard sedimentary bedrock	HARD_SEDS	
Soft sedimentary bedrock	SOFT_SEDS	
Carbonate sedimentary bedrock	CARB_SEDS	
Serpentine and other chemical sedimentary bedrock	CHEM_SEDS	
Alluvium	ALLUVIUM	
Accumulative precipitation yield	ACC_PPT_YL	EAU BC, WSA, ClimateSource
Watershed unit's primary drainage	PRIMARY_ID	EAU BC, WSA
Maximum stream magnitude of the watershed unit's primary drainage	MAX_P_MAG	EAU BC, WSA
Maximum stream magnitude of the watershed unit	MAG_MAX	WSA
Ratio of watershed unit's maximum stream magnitude over its primary drainage's maximum stream magnitude	MAG_RATIO	EAU BC, WSA
Maximum stream order of the watershed unit	ORDER_MAX	EAU BC, WSA
Ocean connection (estuary present)	TERMINAL	EAU BC, WSA

River Environmental Variables	Database Field Name	Source[3]
Revised 41 hydrologic zones by watershed divide	HYDRO_GRP	EAU BC, WSA, Church *pers. comm.*
Percent glacial influence of the watershed unit	PCT_GLAC	EAU BC, WSA, TRIM
Percent tundra influence of the watershed unit	PCT_TUNDRA	EAU BC, WSA, BEC
Percent wetland area per watershed unit	PCT_WETL	EAU BC, WSA, TRIM
Number of wetlands within the watershed unit	NUM_WETL	EAU BC, WSA, TRIM
Percent lake area per watershed unit	PCT_LAKE	EAU BC, WSA
Number of lakes within the watershed unit	NUM_LAKE	EAU BC, WSA
K factor (Mean annual peak flow)	KFACTOR	EAU BC, WSA, Church 1996
Number of degree days above 0°C per watershed unit	DD0	EAU BC, WSA, ClimateSource
Mean valley flat width per watershed unit (m)	VFW_MEAN	EAU BC, WSA, Macroreach Dataset
Stream gradient model	GRAD_MOD	EAU BC, WSA, Macroreach Dataset
Flow regime model	HYDRO_MOD	EAU BC, WSA, ClimateSource
Temperature model	TEMP_MOD	EAU BC, WSA, ClimateSource
Nutrient model	NUTR_MOD	EAU BC, WSA, BC Energy and Mines Bedrock Geology Dataset
River Ecosystem Class	RIVER_CLAS	EAU BC, WSA
River Ecosystem Type	RIVER_TYPE	EAU BC, WSA, ClimateSource
River Ecosystem Sub-Type	RIVER_SUBT	EAU BC, WSA, ClimateSource

Table 6: Environmental variables derived and attributed to lake ecosystems in BC.

Lake Environmental Variables	Database Field Name	Source[4]
Unique ID	WB_KEY_WG	WSA
Freshwater Ecoregion	FW_ECOREG	EAU BC, WSA

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[4] WSA = BC Watershed Atlas 1:50,000 (2007); DEM = BC 30m digital elevation model (2007); BEC Classification = BC Biogeoclimatic Ecosystem Classification (2007)

Lake Environmental Variables	Database Field Name	Source[4]
Ecological Drainage Unit	EDU	EAU BC, WSA
Elevation (m)	ELEV_LK	WSA
Elevation (based on current 2007 DEM)	ELEV_CALC	EAU BC, WSA, DEM
Outflow stream order	L_ORDER	WSA
Outflow stream magnitude	L_MAG	WSA
Perimeter (m)	PERIMETE	WSA
Shoreline Complexity	SHORE_CO	WSA
Surface Area (ha)	AREA_HEC	WSA
Occurrence of Red-Listed Species	RED_LIST	WSA
Occurrence of Blue-Listed Species	BLUE_LIS	WSA
Ever Been Stocked	EVER_STO	WSA
Currently Stocking	CUR_STOC	WSA
Number of inlets	NUM_INLE	WSA
Number of outlets	NUM_OUTL	WSA
Maximum depth (m) measurements for select lakes	MAXD_FLD	MOE
Flushing rate measurements for select lakes	FLRATE_F	MOE
pH measurements for select lakes	PH_FLD	MOE
Total dissolved solids measurements for select lakes	TDS_FLD	MOE
Secchi (m) depth measures for select lakes	SECCHI_F	MOE
Upstream drainage area for the lake (km^2)	DRAIN_KM2	EAU BC, WSA
Percent of lake surface area in each underlying bedrock geology class: intrusives and metamorphic bedrock volcanic bedrock hard sedimentary bedrock soft sedimentary bedrock carbonate sedimentary bedrock serpentine and other chemical sedimentary bedrock alluvium	INT_META VOLCANIC HARD_SED SOFT_SED CARB_SED CHEM_SED ALLUVIUM	EAU BC, WSA, BC Energy and Mines Bedrock Geology Dataset
Percent glacial influence of the lake	PCT_GLAC	EAU BC, WSA, TRIM
Percent tundra influence of the lake	PCT_TUNDRA	EAU BC, WSA, BEC
Number of degree days above 4°C per lake	DD4	EAU BC, WSA, ClimateSource
Number of degree days above 8°C per lake	DD8	EAU BC, WSA, ClimateSource
Accumulative precipitation yield	ACC_PPT_YL	EAU BC, WSA, DEM, ClimateSource

Lake Environmental Variables	Database Field Name	Source[4]
Maximum July temperature (°C) per lake	MAX_JULY	EAU BC, WSA, ClimateSource
Limnological Region: Insular and Coastal Mountains; Insular Lowland; Lower Fraser Valley; Southern Interior Plateau; Southern Interior Highland; Columbia Mountains; Rocky Mountain Trench; Northern Interior Plateau and Mountains; Rocky Mountains and Foothills; Liard Plain; Peace River Basin; Fort Nelson River Basins	LIMNO_REG	EAU BC, WSA, Northcote and
Number of lake inflows revised	INLE_REV	EAU BC, WSA
Number of lake outflows revised	OUTL_REV	EAU BC, WSA
Percent of lake surface area in each BEC Zone:		EAU BC, WSA, BEC
Boreal Altai Fescue Alpine	BAFA	
Bunchgrass	BG	
Boreal White and Black Spruce	BWBS	
Coastal Douglas-Fir	CDF	
Coastal Mountain-heather Alpine	CMA	
Coastal Western Hemlock	CWH	
Engelmann Spruce-Subalpine Fir	ESSF	
Interior Cedar-Hemlock	ICH	
Interior Douglas-fir	IDF	
Interior Mountain-heather Alpine	IMA	
Mountain Hemlock	MH	
Montane Spruce	MS	
Ponderosa Pine	PP	
Sub-Boreal Pine-Spruce	SBPS	
Sub-Boreal Spruce	SBS	
Spruce-Willow - Birch	SWB	
Dominant BEC zone for each lake	BEC_ZONE	EAU BC, WSA, BEC
Modelled mean depth (m)of the lake	MOD_MDEPTH	EAU BC, WSA
Modelled temperature classes	SURFTEMP_C	EAU BC, WSA, TRIM
Modelled lake volume (m^3)	MOD_VOL	EAU BC, WSA
Modelled lake flushing rate	FLRATE_MOD	EAU BC, WSA
Modelled lake flushing rate classes	FLRATE_CLA	EAU BC, WSA
Number of degree days above 4°C per lake classes	DD4_CLASS	EAU BC, WSA, ClimateSource
Modelled lake surface temperature classes	TEMP_CLASS	EAU BC, WSA, ClimateSource, TRIM
Modelled dissolved nutrient classes	DISSNUTR_C	EAU BC, WSA, BC Energy and

Lake Environmental Variables	Database Field Name	Source[4]
		Mines Bedrock Geology Dataset
Bedrock geology classes	GEO_CLASS	EAU BC, WSA, BC Energy and Mines Bedrock Geology Dataset
Lake Ecosystem Class	LAKE_CLASS	EAU BC, WSA
Lake Ecosystem Type	LAKE_TYPE	EAU BC, WSA

Preliminary classification work involved the development of coarse scale models of several key environmental factors of river and lake ecosystems including: river flow regime, stream gradient, river and lake water temperature, lake flushing rate, and lake dissolved nutrients across BC. Descriptions of these coarse scale models and their results have been made available as Appendix B of this report.

Biological Data Inputs

Biological data is used to determine which environmental variables are best at modeling the river and lake ecosystems, and therefore, which were selected for use in the development of the classifications. Freshwater fish are the only taxa group to which any attempt has been made to inventory across the province. The freshwater fish data set is comprised of data from a wide collection of provincial, UBC and museum collected data from 1970 to present. The dataset contains records for 6,611 watersheds and 5,073 lakes and for 76 species (after excluding non-native species and general classifications). However, due to the practical difficulties associated with species inventory across the province, these datasets are unevenly distributed with respect to both environment and geography.

Data Preparation

Nonmetric Multi-Dimensional Scaling

Variables such as percent underlying geology type and biogeoclimatic zone, percent stream reaches within each stream gradient class, and mean monthly temperature and precipitation yield have numerous fields of data summarizing one predominant environmental variable. To avoid artificially weighting these variables in the classification, these variables are independently run through a nonmetric multidimensional scaling (NMS) analysis to summarize the variability of their information into two axes. For example, the twelve variables representing mean monthly temperature are run through an NMS analysis to reduce the variability to two axes representing temperature. NMS is generally regarded as the most effective ordination method for ecological community data as it is well suited to non-normal and categorical data.

Descriptive Statistics and Data Transformations

Descriptive statistics (mean, standard deviation, skewness, and variance) are calculated for all environmental variables. Variables that are highly skewed (skewness values >=2) are log(e) transformed to meet the assumptions of normality for parametric statistics.

Avoidance of Multi-Collinearity

The challenge of selecting a suite of environmental variables to delineate River and Lake Ecosystem Types is to select variables that both capture the range of environmental variation in river and lake ecosystems yet are both distinct enough in and of themselves so as to avoid multi-collinearity with other selected variables but co-vary strongly with additional important variables not explicitly selected for classification. The strength of the relationships among the environmental variables including those with resulting NMS output axes, are assessed using a Pearson Product Moment correlation matrix (Pearson 1920). Highly correlated variables are removed from the analysis to avoid multi-collinearity. Table 7 summarizes the sub-set of environmental variables identified for further investigation as to their correlation with the fish assemblage dataset. These variables are widely accepted in the literature as being the dominant variables shaping river and lake ecosystems and their associated communities and also strongly co-varying with many other important physical processes (e.g., Larkin and Northcote 1953; Loptspeich 1980; Tonn and Magnuson 1982; Eadie and Keast 1984; Osborne and Wiley 1992; Poff and Allan 1995; Lyons 1996; Lewis and Magnuson 1999).

Table 7: List of environmental variables identified for correlation with the fish assemblage dataset.

River Ecosystems (21)	Lake Ecosystems (16)
Axis 1 of NMS of % underlying Biogeoclimatic Ecosystem Classification classes	Axis 1 of NMS of % underlying Biogeoclimatic Ecosystem Classification classes
Axis 2 of NMS of % underlying Biogeoclimatic Ecosystem Classification classes	Axis 2 of NMS of % underlying Biogeoclimatic Ecosystem Classification classes
Axis 1 of NMS of % underlying Geology Classes	Axis 1 of NMS of % underlying Geology Classes
Axis 2 of NMS of % underlying Geology Classes	Axis 2 of NMS of % underlying Geology Classes
Axis 1 of NMS of % stream reaches within Mainstem Stream Gradient Classes	Log of Surface Area
Axis 2 of NMS of % stream reaches within Mainstem Stream Gradient Classes	Log of Shoreline Complexity
Axis 1 of NMS of % stream reaches within Tributary Stream Gradient Classes	Outflow Stream Order
Axis 2 of NMS of % stream reaches within Tributary Stream Gradient Classes	Log of Drainage Area

River Ecosystems (21)	Lake Ecosystems (16)
Mean Annual Precipitation	Degree Days above 4°C
Mean Annual Temperature	Log of Accumulative Precipitation Yield
Mean Watershed Elevation	Elevation
Standard Deviation of Watershed Elevation	Number of Inflows
Log of Drainage Area	Number of Outflows
Log of Accumulative Precipitation Yield	Maximum July Temperature
Maximum Stream Order	Percent Glacial Influence
Log of Percent Glacial Influence	Percent Tundra Influence
Percent Tundra Influence	
Log of Percent Wetlands Influence	
Log of Percent Lake Influence	
Average Annual Peak Flow	
Log Mean Valley Flat Width	

Identifying Environmental Variable Inputs Based on Fish Species – Environment Relationships

Canonical correspondence analysis (CCA) of environmental variables and fish species composition is used to examine which environmental variables correlate highly with river and lake fish species composition in BC and hence further refine the environmental variables used to define River and Lake Ecosystem Types. It is acknowledged that there are relatively few lakes and rivers that have been surveyed for fish species in BC. However, it is the best information available to date.

CCA (ter Braak 1986) is a form of direct gradient analysis that uses a combination of ordination and multiple regression techniques to examine the correlation of a particular set of environmental variables with species composition. The statistical model underlying CCA is that a species' frequency of occurrence is a unimodal function of position along environmental gradients, i.e., a species' niche. CCA summarizes the maximum amount of species variation in a community while simultaneously forcing this species matrix to correlate with axes based on linear composites of environmental data. Therefore, relationships between species are summarized in such a way that the community relationships and the gradients in the environmental variables are maximally correlated. The resulting ordination diagram expresses not only a pattern of variation in species composition, but also the relationship between the species and each of the environmental variables (ter Braak 1986).

Biplot of Species – Environment Relationship

An ordination biplot is a graphic representation of the species-environment relationship. For each ordination plot, species are plotted as points. Environmental variables are represented as vectors. The length of a vector indicates the importance of an environmental variable in summarizing species variation. The direction indicates how well the environmental variable is correlated with the various ordination axes. The angle between arrows indicates the correlation between environmental variables. Each environmental vector determines a direction or axis in the diagram, obtained by extending the arrow in both directions. From each species point, a line can be drawn perpendicular to this environmental axis. Its location along the environmental axis indicates the species' optimum niche for that particular environmental gradient in comparison to the other species (ter Braak 1994).

Results

The results of the river and lake CCAs are plotted as ordination biplots in Figures 3 and 4. Eigenvalues of the first two axes are 0.535 (p=0.005)[5] and 0.311 for rivers and 0.482 (p=0.005)[5] and 0.256 for lakes. The ordination biplots for rivers and lakes therefore represent 85% and 74% of the variance in the fish species data respectively.

The species – environment correlations for the first two axes are 89.8% (p=0.005)[5] and 79.0% for rivers and 83.3% (p=0.002)[5] and 70.3% for lakes.

Environmental variables which account for most of the variation in fish species composition in rivers ranked in order from greatest to least are: mean elevation, first NMS axis of percent watershed area in each BEC zone, mean annual precipitation, mean annual temperature, first NMS axis of percent of tributary stream reaches in each gradient class, first NMS axis of percent watershed area in each geology class, log of wetland influence, first NMS axis of percent of mainstem stream reaches in each gradient class, standard deviation of elevation, and drainage area.

Environmental variables which account for most of the variation in fish species composition in lakes ranked in order from greatest to least are: first NMS axis of percent surface area in each BEC zone, elevation, outflow stream order, drainage area, accumulative precipitation yield, number of degree days above 4°C, surface area, shoreline complexity, and number of inflows.

These subsets of environmental variables are selected for the classification of Lake and River Ecosystem Types as they correlate highly with fish community composition. Although percent glacial influence and percent lake influence for river ecosystems did not correlate highly with fish composition, they are included as environmental variables for the River Ecosystem Type Classification as they have been shown in the scientific literature to be important ecological variables that define fish community composition (Billiard *et al.* 1997; Oberdorff *et al.* 1997; Grenouillet *et al.* 2004). The fish community dataset used in the CCA is poorly inventoried for a cross section of glacially influenced streams.

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[5] Significance value is not reported for axes two and higher as using a simple randomization test for these axes may bias the p values.

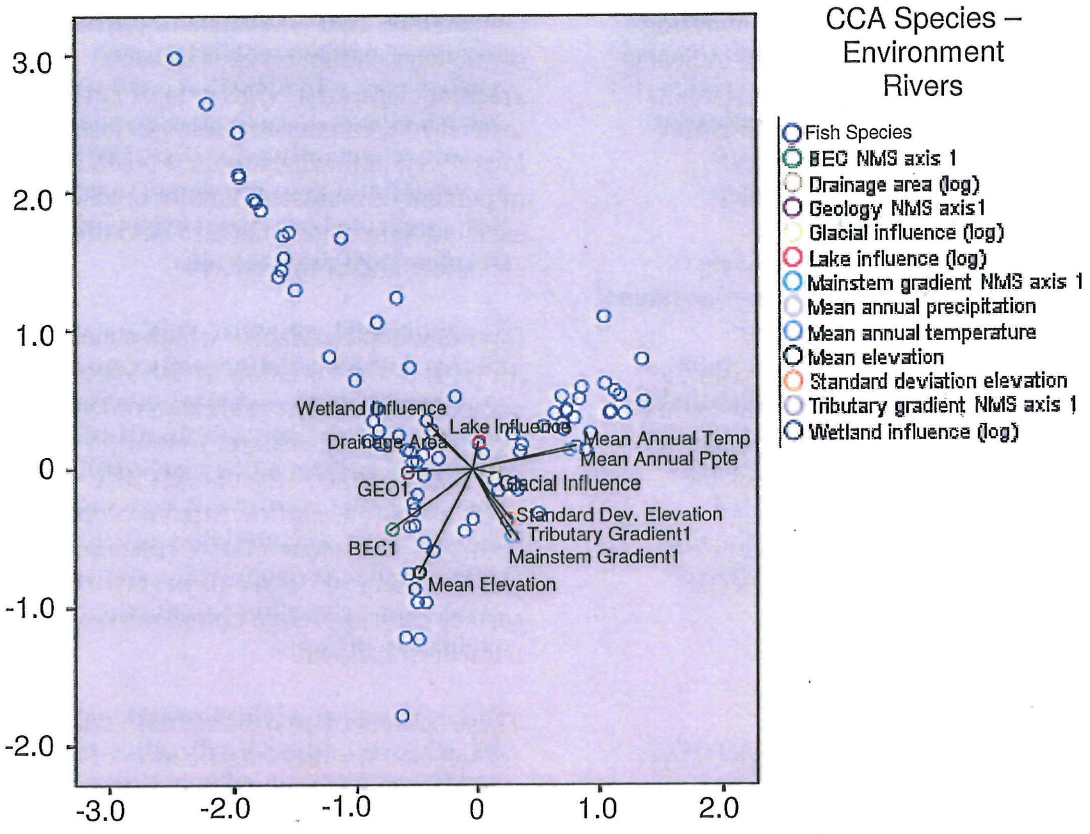


Figure 3: CCA bi-plot of river species – environment relationships.

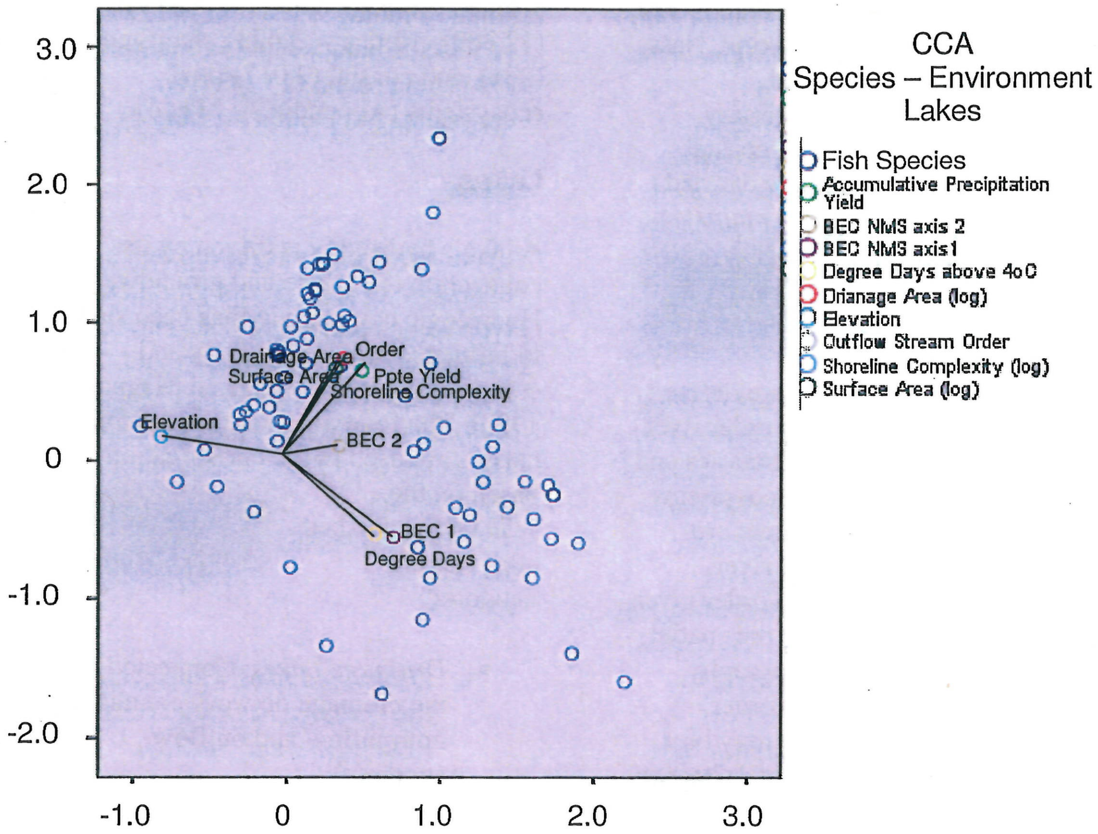


Figure 4: CCA bi-plot of lake species – environment relationships.

Classification Procedure

Connectivity Classes

Hydrologic connectivity is a prominent factor in understanding and characterizing lake and river ecosystems. Water is dynamic and flowing and hence the environment of a lake or river is dependent upon what drains into it as well as what it flows into. Capturing the relative position of a river or lake ecosystem within its larger drainage network is therefore an important component of a freshwater ecosystem classification. River ecosystem size and connectivity are highly correlated with drainage area, sediment erosion / deposition regimes, and energy inputs (e.g., Osborne and Wiley 1992; Vannote *et al.* 1980). Similarly, lake connectivity is highly correlated with a lake's flushing rate, primary productivity, and thermal stratification regime (e.g., Dickman 1969; Ahlgren *et al.* 1988). Therefore, the first step in classifying river and lake ecosystems is to subdivide these ecosystems into classes based on their hydrologic connectivity.

Rivers

A total of 2,129 primary drainage networks are identified and delineated for BC based on the Watershed Atlas (Appendix A: Map 3). Nine of these primary drainages are greater than 8,000 km^2: Alsek, Yukon, Taku, Stikine, Nass, Skeena, Fraser, Columbia and Mackenzie. The remaining primary drainages are relatively small coastal systems. River ecosystems are divided into *headwater*, *tributary* and *mainstem* river ecosystems using stream order as a measure of hydrologic connectivity. First to third order river ecosystems are defined as headwaters, fourth to fifth order river ecosystems are defined as tributaries and sixth order and higher river ecosystems are defined as mainstems. There are inherent issues with defining river connectivity based on stream order given that stream order varies with the spatial scale of the underlying hydrography dataset. For example, a first order stream at a scale of 1:50,000 may be a third order stream at a scale of 1:20,000. However, given that the EAU BC classification is based on the BC Watershed Atlas at a scale of 1:50,000 the use of stream order is likely the most reasonable variable to use in classifying river connectivity.

Database
Field Name
RIVER_CLAS

All river ecosystems containing estuaries are defined as *coastal* river ecosystems. Their connectivity to the nearshore marine environment differentiates them from interior river ecosystems. The majority of these coastal river ecosystems (1,995) are first to fifth order primary drainage networks. Only twenty-two of these coastal river ecosystems are sixth order or higher.

Therefore 18,100 river ecosystems are grouped first and foremost into four connectivity classes that incorporate the relative drainage network position of each river ecosystem in relation to its primary drainage network: headwater (12,389), tributary (3,423), mainstem (271), and coastal (2,017) river ecosystems (Appendix A: Map 4).

Lakes

A lake's hydrology is driven by its connection to surface and groundwater. Hydrologic connectivity has been shown to influence species diversity and composition (e.g., Lewis and Magnuson 1999). The following lake connectivity classes are used in the classification based on the 1:50,000 watershed atlas stream network:

Database Field
Name
LAKE_CLASS

- *Drainage Lakes*: Connected to the drainage network containing both inflow and outflow stream(s);
- *Headwaters Lakes*: Start of the drainage network. They contain no inflow streams but contain an outflow stream(s). Source water is primarily from atmospheric deposition and diffuse (unchannelized) runoff (both surface and subsurface) from its watershed;
- *Closed Basin Lakes*: End of the drainage network. They contain an inflow stream(s) but no outflow. These lakes are usually saline; and
- *Isolated Lakes*: Not connected to the drainage network. They contain no inflow or outflow streams. Groundwater recharge (seepage) is its major source of water. Source water is also derived from atmospheric deposition on lake surface area and diffuse runoff from the

> immediate shoreline area. Isolated, groundwater driven lakes are more likely to contain unique biota due to temporal isolation, as long as human-caused introductions or exploitations have been minimal.

There are a total of 67,484 lakes of 1ha in size and larger in BC as summarized in the Watershed Atlas. These lakes are grouped into three hydrologic connectivity classes: drainage lakes (33,698); headwater lakes (23,862); and isolated lakes (9,924) (Appendix A:Map 5). No closed basin lakes are present in BC.

Classification of Ecosystem Types

For each hydrologic connectivity class for river and lake ecosystems, a two-step cluster analysis is performed using the selected sub-set of environmental variables identified from the CCAs shown to have the strongest correlations with fish species composition. *Two-Step Cluster Analysis* is used to determine natural groupings of lakes and rivers based on the environmental data inputs. It groups lakes and rivers into pre-clusters which are treated as single cases. Standard hierarchical clustering is then applied to the pre-clusters in the second step. This is a recommended clustering method for large datasets. Schwarz Bayesian Criterion is used to determine the number of significant clusters.

The Two-Step Cluster Analysis has several desirable features that differentiate it from traditional clustering techniques:

- Handling of categorical and continuous variables - A joint multinomial-normal distribution can be placed on categorical and continuous variables by assuming variables to be independent;

- Automatic selection of number of clusters - The procedure can automatically determine the optimal number of clusters by comparing the values of a model-choice criterion across different clustering solutions; and

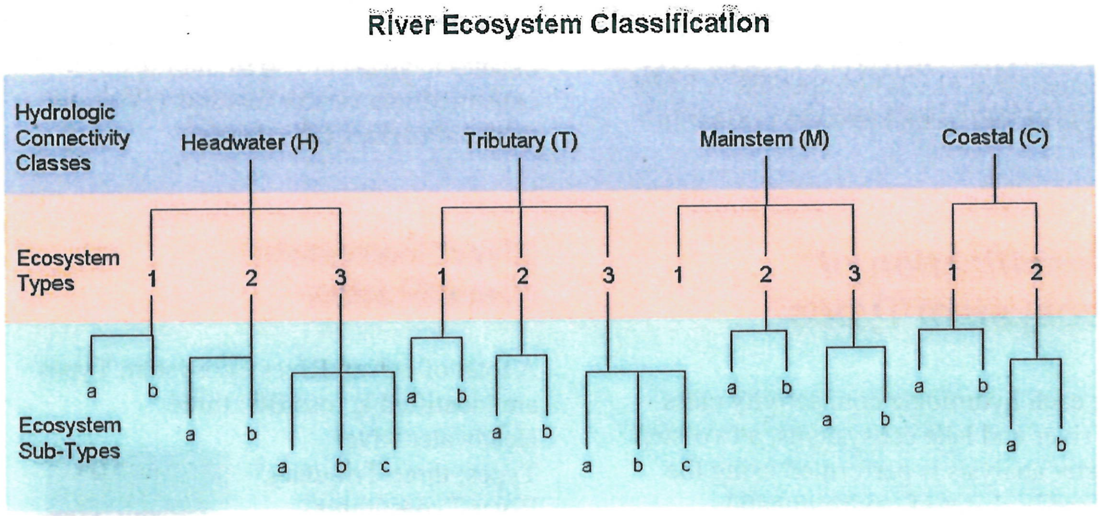
- Scalability - The Two-Step algorithm enables analysis of large data files by constructing a cluster features (CF) tree that summarizes the records.

River Ecosystem Classification

A total of eleven River Ecosystem Types are identified across BC: three Headwater River Types; three Tributary River Types; three Mainstem River Types; and two Coastal River Types (Appendix A: Maps 6-9). An environmental summary of each River Ecosystem Type is found in Appendix C. These broad Ecosystem Types are further subdivided into twenty-one Sub-Types based on a 2-step cluster analysis of the environmental variability within each of the Ecosystem Types (Appendix A: Maps 10-13). An environmental summary of each River Ecosystem Sub-Type is found in Appendix C. The three-tier ecosystem classification hierarchy is summarized in Figure 5. Note that there is insufficient environmental variability within the Mainstem #1 Ecosystem Type for it to be further divided into Sub-Types.

Database Field Names
RIVER_TYPE
RIVER_SUBT

Rivers classified as the same Ecosystem Type or Sub-Type are expected to share similar physical environments and ecological processes, and similar responses to human disturbance despite the possibility that they are geographically separated. Their biotic communities are not apparent given that species inventory information could not be incorporated into the classification due to the sparseness of species inventory information across the province. Therefore, it must be assumed that rivers within the same River Ecosystem Type (Sub-Type) that span more than one EDU are potentially different Ecosystem Types given the different species assemblages within each EDU. Tables 8 and 9 below summarize the ecological characteristics of each River Ecosystem Type and Sub-Type respectively.



H, T, M:

1 = Coast

a = High Relief
b = Low Relief

2 = Interior, Low Relief

a = NE
b = Central Interior

H, T, M:

3 = Interior, High Relief

a = South Rockies and Coast
b = North Rockies and Cassiar
c = Foothills

C:

1 = Outer Coast & Islands

a = Exposed
b = Sheltered

2 = Inner Coast and Fjords

a = Upper
b = Lower

Figure 5: Summary of the three-tier river ecosystem classification.

Table 8: Description of River Ecosystem Types in BC.

River Type	Description
Headwater (H) River Types (N=12,390; 68% of All Rivers)	
H1 **N=2,142 17% of H Type**	**Coast headwaters.** Moderate mean elevation (881m). Moderate to steep mainstem gradients with steep tributary stream gradients with an overall steep, V-shaped watershed valley. Second highest mean annual precipitation (2,081mm/yr) of all river types. Third highest mean annual temperature (4.48°C) of all river types and highest of the headwater river types. Second smallest average drainage area of all river types and second smallest of the headwater river types. Third highest average glacial influence (3.77% of drainage area) of all river types and highest of the headwater river types. Third lowest average wetland and lake influence (0.29% and 0.91% of watershed area respectively) of all river types and second lowest of the headwater river types. Predominately flows through CWH (49%), MH (26%) and CMA (20%) BEC Zones and intrusive-metamorphic and volcanic bedrock.
H2 **N= 3,730 30% of H type**	**Interior, low relief headwaters.** Moderate average elevation of 993.65m. Shallow mainstem and tributary stream gradients and therefore overall shallow watershed slope with the lowest standard deviation of mean watershed elevation of all river types. Third lowest mean annual precipitation (612 mm/yr) of all river types and the lowest of the headwater river types. Mean annual temperature of 0.88 °C. Third smallest average drainage area of all river types but largest of the headwater rivers group. Third lowest average glacial influence (0.02% of watershed area) of all river types and lowest of the headwater types. Third highest average wetland influence (7.86% of watershed area) of all river types. Moderate average lake influence (1.31% of watershed area). Predominately flows through CWH BEC Zone and intrusive – metamorphic and volcanic bedrock.
H3 **N= 6,518 53% of H Type**	**Interior, high relief headwaters.** Highest mean elevation (1,521m) of all river types. Shallow to moderate mainstem stream gradients with steep tributary stream gradients creating an overall U-shaped valley. Moderate mean annual precipitation of 1,027mm/yr. Lowest mean annual temperature (-0.28 °C) of all river types. Smallest average drainage area of all river types. Moderate average glacial influence (1.57% of watershed area). Second lowest average wetland influence (0.24% of watershed area) of all river types and lowest average lake influence (0.33% of watershed area) of all river types. Flows predominately through ESSF (40%) and BAFA (24%) BEC Zones and soft and hard sedimentary bedrock.
Tributary (T) River Types (N=3,421; 19% of All Rivers)	
T1	**Coast tributaries.** Lowest mean elevation (879m) of the tributary

River Type	Description
N=448 13% of T Type	rivers type. Shallow mainstem stream gradients with steep tributary stream gradients with an overall V-shaped watershed slope having the second highest standard deviation of watershed elevation of all river types and highest of the tributary river types. Highest mean annual precipitation (2,938mm/yr) and mean annual temperature (4.01°C) of all tributary river types. Fourth smallest average drainage area of all river types and smallest of the tributary river types. Second highest average glacial influence (4.49% of watershed area) of all river types and highest of the tributary river types. Fourth lowest average wetland influence (0.42% of watershed area) of all river types and lowest of the tributary river types. Fourth lowest average lake influence (1.31% of watershed area) of all river types and second lowest of the tributary river types. Predominately flows through CWH (48%) and MH (25%) BEC Zones and intrusive-metamorphic and volcanic bedrock.
T2 N= 1,012 30% of T Type	**Interior, low relief tributaries**. Moderate mean elevation (947m). Shallow mainstem and tributary stream gradients with an overall shallow watershed slope with the second lowest standard deviation of watershed elevation of all river types and lowest of all tributary river types. Second lowest mean annual precipitation (586mm/yr) of all river types and lowest of all tributary river types. Fourth lowest mean annual temperature (0.86°C) of all river types and second lowest of the tributary river types. Largest average drainage of all tributary river types. Lowest average glacial influence (0% of watershed area) of all river types. Highest average wetland influence (9.36% of watershed area) of all river types and the highest average lake influence (2.07% of watershed area) of all tributary river types. Predominately flows through BWBS (35%) and SBS (29%) BEC Zones and soft sedimentary and volcanic bedrock.
T3 N= 1,961 57% of T Type	**Interior, high relief tributaries**. Second highest mean elevation (1,428m) of all river types and highest of the tributary river types. Shallow mainstem stream gradients with steep tributary stream gradients creating a V-shape watershed slope having the second highest standard deviation of watershed elevation of the tributary rivers type. Second highest mean annual precipitation (990mm/yr) of the tributary rivers type. Second lowest mean annual temperature (-0.22°C) of all river types and lowest of the tributary rivers type. Second smallest average drainage area of the tributary rivers type. Second highest average glacial influence (1.66% of watershed area) of the tributary rivers type. Second lowest average wetland influence (0.47% of watershed area) of the tributary rivers type. Second lowest average lake influence (0.7% of watershed area) of all river types and lowest of the tributary rivers type. Predominately flows through ESSF (36%) and BAFA (19%) BEC Zones and soft and hard sedimentary rock.
Mainstem (M) River Types **(N=271; 2% of All Rivers)**	

River Type	Description
M1 N= 20 7% of M Type	**Coast mainstems**. Third lowest mean elevation (711m) of all river types and lowest of the mainstem river types. Very shallow mainstem gradients with steep tributary gradients creating a U-shaped valley with the highest standard deviation of elevation of all river types. Highest mean annual precipitation (1,928mm/yr) and mean annual temperature (4.03°C) of mainstem river types. Largest average drainage area of all river types. Highest average glacial influence (6.12% of watershed area) of all river types. Second lowest average wetland influence (1.15% of watershed area) of mainstem river types. Third highest average lake influence (3.43% of watershed area) of all river types but lowest of the mainstem river type. Predominately flows through CWH (43%), MH (12%) and CMA (11%) BEC Zones and intrusive-metamorphic and volcanic bedrock.
M2 N = 112 41% of M Type	**Interior, low relief mainstems**. Fourth lowest mean elevation (769m) of all river types and second lowest of the mainstem river types. Very shallow mainstem stream reaches with shallow tributary stream reaches creating a shallow watershed slope with the fourth lowest standard deviation of watershed elevation of all river types and lowest of the mainstem river types. Lowest mean annual precipitation (545mm/yr) of all river types. Second lowest mean annual temperature (1.48°C) of the mainstem rivers type. Second highest average drainage area of all river types and second highest of the mainstem river types. Smallest average glacial influence (0.27% of watershed area) of all mainstem river types. Second highest average wetland influence (8.82% of watershed area) of all river types and highest of the mainstem river types. Highest average lake influence (5.34% of watershed area) of all river types. Predominately flows through BWBS (36%) and SBS (33%) BEC Zones and soft sedimentary and volcanic bedrock.
M3 N= 139 52% of M Type	**Interior, high relief mainstems**. Third highest mean elevation (1,154m) of all river types and highest of the mainstem river types. Shallow mainstem stream gradients with steep to moderate tributary gradients creating a U-shaped watershed slope. Third highest standard deviation of watershed elevation of a river types and second highest of the mainstem river types. Fourth lowest mean annual precipitation (804mm/yr) of all river types and second lowest of the mainstem river types. Third lowest mean annual temperature (0.6°C) of all river types and lowest of the mainstem river types. Third largest average drainage area of all river types and smallest of the river mainstem types. Second lowest average glacial influence (1.39% of watershed area) of mainstem river types. Lowest average wetland influence (0.89% of watershed area) of mainstem river types. Lowest average lake influence (0.89% of watershed area) of the mainstem rivers type. Flows through a range of BEC Zones ESSF (21%), BWBS (19%), ICH (15%) and SWB (14%). Flows predominately through soft and hard sedimentary bedrock.
Coastal (C) River Types	

River Type	Description
(N=2,018; 11% of All Rivers)	
C1 **N= 1,286** **64% of C Type**	**Outer coast and island coastal rivers.** Lowest mean elevation (182m) of all river types. Shallow mainstem and tributary stream gradients creating a shallow watershed valley. Third lowest standard deviation of watershed elevation of all river types and lowest of the coastal river types. Third highest mean annual precipitation (3,012mm/yr of all river types and lowest of the coastal river types. Highest mean annual temperature (7.99°C) of all river types. Smallest average drainage area of the coastal river types. Lowest average glacial influence (0% of watershed area) of all river types. Highest average wetland influence (0.65% of watershed area) and lake influence (2.72% of watershed area) of the coastal river types. Flows predominately through CWH (94%) BEC zone and intrusive-metamorphic and volcanic bedrock.
C2 **N= 732** **36% of C Type**	**Inner coast and fjord coastal rivers.** Second lowest mean elevation (643m) of all river types. Steep to moderate mainstem stream gradients with steep tributary stream gradients creating steep V-shaped valleys. Highest standard deviation of elevation of the coastal rivers type and fourth highest of all river types. Highest mean annual precipitation (3,576mm/yr) of all river types. Second highest mean annual temperature (5.58°C) of all river types and lowest of the coastal river types. Largest average drainage area of the coastal rivers type. Fourth highest average glacial influence (2.03% of watershed area) of all river types and highest of the coastal rivers type. Lowest average wetland influence (0.12% of watershed area) of all river types. Lowest average lake influence (1.37% of watershed area) of the coastal rivers type. Predominately flows through CWH (69%) and MH (20%) and intrusive-metamorphic bedrock.

Table 9: Description of River Ecosystem Sub-Types in BC.

River Sub-Type	Description
H1 Sub-Types	
H1a **N= 1,012** **47% of H1 Sub-Type**	**High relief, coast headwaters.** Moderate mean elevation (1,202m). Steep to moderate mainstem stream gradients and steep tributary stream gradients creating V-shaped valleys with the highest standard deviation of watershed elevation of headwater river types. Second highest mean annual precipitation (2,677mm/yr) of headwater river types. Moderate mean annual temperature (1.88°C). Second largest average drainage area of headwater river types. Highest average glacial influence (7.98% of watershed area) of all river types. Second lowest average

River Sub-Type	Description
	wetland influence (0.15% of watershed area) of all river types and lowest of the headwater river types. Fourth lowest average lake influence (0.44% of watershed area) of all river types and moderate lake influence of headwater river types. Predominately flows through CMA (39%) and MH (35%) BEC Zones and intrusive-metamorphic bedrock.
H1b N=1,130 53% of H1 Sub-Type	**Low relief, coast headwaters.** Fourth lowest elevation (593m) of all river types and lowest of the headwater river types. Combination of shallow to moderate and steep mainstem stream gradients with steep tributary stream gradients. Fourth lowest standard deviation of watershed elevation of headwater river types. Second highest mean annual precipitation (3,442mm/yr) of all river types. Fourth highest mean annual temperature (6.81°C) of all river types and highest of the headwater river types. Smallest average drainage area of all river types. Lowest average glacial influence (0% of watershed area) of all river types. Moderate average wetland influence (0.42% of watershed area). Second highest average lake influence (1.33% of watershed area) of headwater river types. Predominately flows through CWH (75%) and MH (20%) BEC Zones and intrusive-metamorphic and volcanic bedrock.
H2 Sub-Types	
H2a N= 1,639 44% of H2 Sub-Type	**Interior, low relief headwaters in the NE.** Second lowest mean elevation (891m) of the headwater types. Very shallow mainstem and tributary gradients and therefore shallow watershed slope, with the lowest overall standard deviation of watershed elevation of all river types. Third lowest mean annual precipitation of all river types (554mm/yr) and lowest of the headwater rivers type. Fourth lowest mean annual temperature (-0.71°C) of all river types and second lowest of the headwater rivers group. Largest average drainage area of the headwater lakes group. Third lowest average glacial influence (0.03% of watershed area) of the headwater rivers type. Highest average wetland influence (14.64% of watershed area) of all river types. Third highest average lake influence (1.02% of watershed area) of all the headwater river types. Predominately flows through BWBS BEC Zone and soft and hard sedimentary bedrock.
H2b N=2,091 56% of H2 Sub-Type	**Interior, low relief headwaters in the central interior.** Third lowest mean elevation (1,074m) of the headwater rivers type. Shallow mainstem and tributary stream gradient and therefore overall shallow watershed slope having the third lowest standard deviation of watershed elevation of all river types and second lowest of headwater river types. Second lowest mean annual precipitation (112.55mm/yr) of the headwater river types.

River Sub-Type	Description
	Second highest mean annual temperature (2.13°C) of the headwater river types. Third highest average drainage area of the headwater river types. Second lowest average glacial influence (0.02% of watershed area) of the headwater river types. Third highest average wetland influence (2.55% of watershed area) of all river types and second highest of the headwater river types. Highest average lake influence (1.53% watershed area) of the headwater river types. Predominately flows through SBS (50%) and ESSF (20%) BEC Zones and volcanic bedrock.
H3 Sub-Types	
H3a **N= 2,491** **38% of H3 Sub-Type**	**Interior, high relief headwaters in the southern Rockies and Coast Mountains.** Highest mean elevation (1,628m) of all river sub-types. Moderate to steep mainstem stream gradients with steep tributary stream gradients creating V-shaped valleys with the second highest standard deviation of watershed elevation of headwater river types. Third highest mean annual precipitation (1,255mm/yr) of the headwater river types. Third lowest mean annual temperature (0.05°C) of the headwater river types. Third smallest average drainage area of all river types and headwater river types. Second highest average glacial influence (3.67% of watershed area) of the headwater river types. Third lowest average wetland influence (0.21% of watershed area) of the headwater river types. Third lowest average lake influence (0.41% of watershed area) of all river types and headwater river types. Predominately flows through ESSF (51%) and BAFA (19%) BEC Zones and soft and hard sedimentary bedrock.
H3b **N= 3,046** **47% of H3 Sub-Type**	**Interior, high relief headwaters in the northern Rockies and Cassiar Mountains.** Fourth highest mean elevation (1,450m) of all river types and third highest of headwater river types. Moderate mainstem stream gradients with steep tributary gradients with the third lowest standard deviation of watershed elevation of headwater river types. Third lowest mean annual precipitation (884mm/yr) of headwater river types. Second lowest mean annual temperature (-1.32 °C) of all river types and lowest of the headwater river types. Second smallest average drainage area of all river types and headwater river types. Third highest average glacial influence (0.35% of watershed area) of headwater river types. Fourth lowest average wetland influence (0.2% of watershed area) of all river types and second lowest of headwater river types. Lowest average lake influence (0.26% of watershed area) of all river types. Predominately flows through BAFA (34%), ESSF (29%), and SWB (25%) BEC Zones and soft and hard sedimentary bedrock.

River Sub-Type	Description
H3c N= 981 15% of H3 Sub-Type	**Interior, foothills headwaters.** Third highest mean elevation (1,473m) of all river types and second highest of headwater river types. Moderate mainstem stream gradients with steep tributary stream gradients. Third highest standard deviation of watershed elevation of headwater river types. Moderate mean annual precipitation (889mm/yr). Third highest mean annual temperature (2.09°C) of headwater river types. Fourth smallest average drainage area of all river types and headwater river types. Moderate average glacial influence (0.05% of watershed area). Third highest average wetland influence (0.45% of watershed area) of headwater river types. Second lowest average lake influence (0.33% of watershed area) of all river types and headwater river types. Predominately flows through ESSF (47%) and ICH (17%) BEC Zones and intrusive-metamorphic and volcanic bedrock.
T1 Sub-Types	
T1a N= 279 62% of T1 Sub-Type	**High relief, coast tributaries.** Third lowest mean elevation (1,046m) of the tributary river types. Shallow mainstem stream gradients with steep tributary stream gradients creating V-shaped valleys having the third highest standard deviation of watershed elevation of all river types and the highest of tributary river types. Second highest mean annual precipitation (2,692mm/yr) and mean annual temperature (2.23°C) of tributary river types. Third largest average drainage area of tributary river types. Second highest average glacial influence (7.09% of watershed area) of all river types and highest of tributary river types. Lowest average wetland influence (0.41% of watershed area) of tributary river types. Moderate average lake influence (1.04% of watershed area). Flows predominately through CMA (33%), CWH (30%) and MH (29%) BEC Zones and intrusive-metamorphic and volcanic bedrock.
T1b N= 169 38% of T1 Sub-Type	**Low relief, coast tributaries.** Lowest mean elevation (603m) of tributary river types. Shallow mainstem stream gradients with steep tributary stream gradients creating U-shaped valleys with a moderate standard deviation of watershed elevation. Third highest mean annual precipitation (3,345mm/yr) and mean annual temperature (6.95°C) of all river types and highest of the tributary river types. Smallest average drainage area of tributary river types. Third lowest average glacial influence (0.2% of watershed area) of tributary river types. Second average lowest wetland influence (0.44% of watershed area) of the tributary river types. Second highest average lake influence (1.77% of watershed area) of the tributary river types. Flows predominately through CWH

River Sub-Type	Description
	(78%) BEC Zone and volcanic and intrusive-metamorphic bedrock.
T2 Sub-Types	
T2a N= 445 44% of T2 Sub-Type	**Interior, low relief tributaries in the NE**. Second lowest mean elevation (805m) of tributary river types. Very shallow mainstem stream gradients with shallow tributary stream gradients with an overall shallow watershed slope with the second lowest standard deviation of watershed elevation of all river types and lowest of the tributary river types. Second lowest mean annual precipitation (531mm/yr) of all river types and lowest of the tributary river types. Second lowest mean annual temperature (-0.65°C) of the tributary river types. Largest drainage area of the tributary river types. Lowest average glacial influence (0% of watershed area) of all river types. Second highest average wetland influence (16.75% of watershed area) of all river types and highest of the tributary river types. Third highest average lake influence (1.31% of watershed area) of the tributary river types. Predominately flows through BWBS (80%) BEC Zones and soft and hard sedimentary bedrock.
T2b N= 567 56% pf T2 Sub-Type	**Interior, low relief tributaries in the central interior.** Moderate mean elevation (1,058m). Very shallow mainstem stream gradients with shallow tributary stream gradients creating a shallow watershed slope with the second lowest standard deviation of watershed elevation of tributary river types. Second lowest mean annual precipitation (629mm/yr) of the tributary river types. Third highest mean annual temperature (2.05°C) of the tributary rivers type. Second largest average drainage area of the tributary river types. Second lowest average glacial influence (0.01% of watershed area) of the tributary river types. Fourth highest average wetland influence (3.55% of watershed area) of all river types and second highest of tributary river types. Highest average lake influence (2.67% of watershed area) of the tributary river types. Flows predominately through SBS (51%) and ESSF (16%) BEC Zones and volcanic bedrock.
T3 Sub-Types	
T3a N= 673 34% of T3 Sub-Type	**Interior, high relief tributaries in the southern Rockies and Coast Mountains**. Second highest mean elevation (1,528m) of all river types and highest of the tributary river types. Shallow mainstem stream gradients with steep to moderate tributary stream gradients creating U-shaped valleys with the second highest standard deviation of watershed elevation of tributary river types. Third highest mean annual precipitation

River Sub-Type	Description
	(1,221mm/yr) of tributary river types. Third lowest mean annual temperature (-0.16°C) of tributary river types. Third smallest average drainage area of tributary river types. Second highest average glacial influence (4.26% of watershed area) of tributary river types. Third lowest average wetland influence (0.45% of watershed area) and lake influence (0.83% of watershed area) of tributary river types. Predominately flows through ESSF (45%), BAFA (18%) and ICH (12%) BEC Zones and intrusive-metamorphic bedrock.
T3b N= 792 41% of T3 Sub-Type	**Interior, high relief tributaries in the northern Rockies and Cassiar Mountains.** Second highest mean elevation (1,383m) of the tributary river types. Shallow mainstem stream gradients with steep to moderate tributary stream gradients creating U-shaped valleys with the third lowest standard deviation of watershed elevation of the tributary river types. Third lowest mean annual precipitation (833mm/yr) of tributary river types. Lowest mean annual temperature (-1.55°C) of all river types. Second smallest average drainage area of tributary river types. Third highest average glacial influence (0.37% of watershed area) of tributary river types. Moderate average wetland influence (0.47% of watershed area). Lowest average lake influence (0.54% of watershed area) of tributary river types. Flows predominately through SWB (33%), BAFA (29%) and ESSF (22%) BEC Zones and soft and hard sedimentary bedrock.
T3c N= 496 25% of T3 Sub-Type	**Interior, foothill tributaries.** Third highest mean elevation (1,366m) of the tributary river types. Shallow mainstem stream gradients with steep to moderate tributary stream gradients creating U-shaped valleys with the third highest standard deviation of watershed elevation of the tributary river types. Moderate mean annual precipitation (926mm/yr) and mean annual temperature (1.83°C) of tributary river types. Moderate average drainage area of tributary river types. Third lowest average glacial influence (0.2% of watershed area) of tributary river types. Third highest average wetland influence (0.53% of watershed area) of tributary river types. Second lowest average lake influence (0.77% of watershed area) of tributary river types. Flows through predominately ESSF (46%), BAFA (18%) and ICH (12%) BEC Zones and intrusive-metamorphic, volcanic and hard sedimentary bedrock.
M2 Sub-Types	

River Sub-Type	Description
M2a N=43 38% of M2 Sub-Type	**Interior, low relief mainstems in the NE.** Lowest mean elevation (612m) of the mainstem river types. Very shallow mainstem and tributary stream gradients creating a shallow watershed slope with the lowest standard deviation of watershed elevation of the mainstem river types. Lowest mean annual precipitation (486mm/yr) of all river types. Third lowest mean annual temperature (-0.79°C) of all river types and lowest of the mainstem tributary types. Second largest average drainage area of all river types and second largest in the mainstem river types. Lowest average glacial influence (0.06% of watershed area) of the mainstem river types. Highest average wetland influence (19.95% of watershed area) of all river types. Lowest average lake influence (1.25% of watershed area) of mainstem river types. Flow predominately through BWBS (93%) BEC Zone and soft and hard sedimentary bedrock.
M2b N= 69 62% of M2 Sub-Type	**Interior, low relief mainstems in the central interior.** Moderate mean elevation (867m). Very shallow mainstem stream gradients with shallow tributary stream gradients creating shallow watershed slope with the second lowest standard deviation of watershed elevation of the mainstem river types. Fourth lowest mean annual precipitation (582mm/yr) of all river types and second lowest for the mainstem river types. Second highest mean annual temperature (2.89°C) of the mainstem river types. Moderate average drainage area. Second lowest average glacial influence (0.4% of watershed area) of the mainstem river types. Second highest average wetland influence (1.88% of watershed area) of the mainstem river types. Highest average lake influence (7.89% of watershed area) of all river types. Flows predominately through SBS (51%) and IDF (14%) BEC Zones and volcanic bedrock.
M3 Sub-Types	
M3a N= 50 36% of M3 Sub-Type	**Interior, high relief mainstems in the southern Rockies and Coast Mountains.** Highest mean elevation (1,237m) of the mainstem river types. Very shallow mainstem stream reaches with steep tributary stream gradients creating U-shaped valleys with the fourth highest standard deviation of watershed elevation of all river types and the second highest of the mainstem river types. Second highest mean annual precipitation (884mm/yr) of the mainstem river types. Third highest mean annual temperature (2.3°C) of the mainstem river types. Fourth largest drainage area of all river types and second smallest of the mainstem river types. Second highest average glacial influence (1.79% of watershed area) of the mainstem river types. Lowest average wetland influence (0.66% of watershed area) of the mainstem river types.

River Sub-Type	Description
	Second highest average lake influence (6.63% of watershed area) of all river types and mainstem river types. Flow predominately through ICH (30%) and ESSF (26%) BEC Zones and intrusive-metamorphic and soft sedimentary bedrock.
M3b **N= 89** **64% of M3 Sub-Type**	**Interior, high relief mainstems in the northern Rockies and Cassiar Mountains.** Second highest mean elevation (1,107m) of the mainstem river types. Very shallow mainstem stream gradients with steep to moderate tributary stream reaches creating U-shaped valleys with a moderate standard deviation of watershed elevation. Moderate mean annual precipitation (758mm/yr). Second lowest mean annual temperature (-0.48°C) of the mainstem river types. Smallest average drainage area of the mainstem river types. Moderate average glacial influence (1.17% of watershed area). Second lowest average wetland influence (1.02% of watershed area) of the mainstem river types. Third highest average lake influence (4.32% of watershed area) of all river types and mainstem river types. Predominately flows through BWBS (29%), SWB (23%) and ESSF (18%) BEC Zones and soft and hard sedimentary bedrock.
C1 Sub-Types	
C1a **N= 1,115** **87% of C1 Sub-Type**	**Exposed outer coast and island coastal rivers.** Lowest mean elevation (181m) of all river types. Shallow mainstem stream gradients with a combination of shallow to steep tributary stream gradients. Fourth lowest standard deviation of watershed elevation of all river types and lowest of the coastal river types. Fifth highest mean annual precipitation (3,223m) of all river types and second lowest of the coastal river types. Second highest mean annual temperature (7.85°C) of all river types and coastal river types. Smallest average drainage area of the coastal river types. Lowest average glacial influence (0% of watershed area) of all river types. Second highest average wetland influence (0.55% of watershed area) of coastal river types. Highest average lake influence (2.93% of watershed area) of coastal river types. Flow predominately through CWH (98%) BEC Zones and intrusive-metamorphic bedrock.
C1b **N= 171** **13% of C1 Sub-Type**	**Sheltered outer coast and island coastal rivers.** Second lowest mean elevation (185m) of both all river types and coastal river types. Shallow mainstem stream gradients with shallow to moderate tributary stream gradients with the second lowest standard deviation of watershed elevation of coastal river types. Lowest mean annual precipitation 1,636mm/yr) of coastal river types. Highest mean annual temperature (8.88°C) of all river types and coastal river types. Largest average drainage area of coastal river types. Lowest average glacial influence (0% of watershed

River Sub-Type	Description
	area) of all river types. Highest average wetland influence (1.33% of watershed area) of coastal river types. Second average lowest lake influence (1.35% of watershed area) of coastal river types. Flows predominately through CWH (69%) and CDF (29%) BEC Zones and hard sedimentary and volcanic bedrock.
C2 Sub-Types	
C2a N=234 32% of C2 Sub-Type	**Upper inner coast and fjord coastal rivers.** Highest mean elevation (863m) of the coastal river types. Shallow mainstem stream gradients with steep tributary stream gradients creating U-shaped valleys with the second highest standard deviation of watershed elevation of all river types and the highest of the coastal river types. Fourth highest mean annual precipitation (3,255mm/yr) of all river types and the second highest of the coastal river types. Lowest mean annual temperature (4.13°C) of the coastal river types. Second largest average drainage area of the coastal river types. Third highest average glacial influence (6.29% of watershed area) of all river types and highest of the coastal river types. Third lowest average wetland influence (0.19% of watershed area) of all river types and second lowest of the coastal river types. Lowest average lake influence (1.09% of watershed area) of the coastal river types. Flows predominately through CWH (48%), MH (28%) and CMA (20%) BEC Zones and intrusive-metamorphic bedrock.
C2b N= 498 68% of C2 Sub-Type	**Lower inner coast and fjord coastal rivers.** Third lowest mean elevation (539m) of all river types and second highest of the coastal river types. Steep mainstem and tributary stream gradients creating steep V-shaped valleys with the second highest standard deviation of watershed elevation of the coastal river types. Highest mean annual precipitation (3,727mm/yr) of all river types. Second lowest mean annual temperature (6.26°C) of coastal river types and fifth highest of all river types. Second smallest average drainage area of coastal river types. Second highest average glacial influence (0.03% of watershed area) of coastal river types and seventh lowest of all river types. Lowest average wetland influence (0.09% of watershed area) of all river types. Second highest average lake influence (1.5% of watershed area) of coastal river types. Flow predominately through CWH (78%) and MH (17%) of BEC Zones and intrusive-metamorphic bedrock.

Discriminant Analysis of River Ecosystem Types and Sub-Types

Discriminant analyses (DA) (Legendre and Legendre 1983) are performed to test for significant differences between River Ecosystem Types and Sub-Types based on their environmental characteristics. DA is a multivariate statistic that was used to maximally contrast River Ecosystems Types and Sub-Types based on their environmental variation in order to examine whether statistically significant differences exist between them. The resultant discriminant function is the maximum difference between the Ecosystem Types / Sub-Types.

Fifteen discriminant analyses are performed to test for significant differences between and within each of the Ecosystem Types and between all Ecosystem Types combined using the environmental variable inputs to the river ecosystem classification (mean and standard deviation of watershed elevation, mean annual temperature and precipitation, drainage area, percent lake, wetland and glacial influence, mainstem and tributary stream gradient, BEC zone and underlying bedrock geology). F-test and Wilk's Lambda resulted in significant ($p<0.0001$) differences between all River Ecosystem Types within each of the connectivity classes, Sub-Types of each Ecosystem Type as well as all River Ecosystem Types combined. Table 10 below summaries the percent of rivers classified into the correct River Ecosystem Type based on the discriminant analyses. Tables 11 to 25 summarize the predicted group membership results based on the discriminant analyses. Appendix D summarizes the environmental differentiation of each River Ecosystem Type and Sub-Type as a series of principal component analysis (PCA) ordinations.

Table 10: Summary of percent of rivers classified correctly in their appropriate Ecosystem Type or Sub-Type based on a discriminant analysis.

Discriminant Analysis Groupings	% Rivers Classified into the Correct Grouping based on a Discriminant Analysis
Headwater River Ecosystems	96.9%
H1 Sub-Types	96.6%
H2 Sub-Types	97.9%
H3 Sub-Types	92.5%
Tributary River Ecosystems	95.4%
T1 Sub-Types	96.4%
T2 Sub-Types	97.9%
T3 Sub-Types	92.0%
Mainstem River Ecosystems	94.8%
M2 Sub-Types	99.1%

Discriminant Analysis Groupings	% Rivers Classified into the Correct Grouping based on a Discriminant Analysis
M3 Sub-Types	97.7%
Coastal River Ecosystems	97.5%
C1 Sub-Types	96.5%
C2 Sub-Types	97.4%
All River Ecosystem Types	75.4%

Tables 11 – 14 summarize resulting predicted group membership based on a discriminant analysis of Headwater Rivers (Table 11), H1 Sub-Types (Table 12), H2 Sub-Types (Table 13), and H3 sub-Types (Table 14).

Table 11.

	Predicted Group Membership (%)		
	H1	H2	H3
H1	**99.5**	0.1	0.4
H2	0.7	**94.2**	5.1
H3	0.2	2.1	**97.7**

Table 12.

	Predicted Group Membership (%)	
	H1a	H1b
H1a	**96.4**	3.6
H1b	3.2	**96.8**

Table 13.

	Predicted Group Membership (%)	
	H2a	H2b
H2a	**99.7**	0.3
H2b	3.3	**96.7**

Table 14.

	Predicted Group Membership (%)		
	H3a	H3b	H3c
H3a	**90.6**	8.2	1.2
H3b	1.5	**93.3**	5.2
H3c	2.7	4.5	**92.8**

Tables 15 – 18 summarize resulting predicted group membership based on a discriminant analysis of Tributary Rivers (Table 15), T1 Sub-Types (Table 16), T2 Sub-Types (Table 17), and T3 sub-Types (Table 18).

Table 15.

	Predicted Group Membership (%)		
	T1	T2	T3
T1	**98.9**		1.1
T2	0.2	**94.1**	5.8
T3	0.1	4.5	**95.4**

Table 16.

	Predicted Group Membership (%)	
	T1a	T1b
T1a	**95.9**	4.1
T1b	2.9	**97.1**

Table 17.

	Predicted Group Membership (%)	
	T2a	T2b
T2a	**99.8**	0.2
T2b	3.5	**96.5**

Table 18.

	Predicted Group Membership (%)		
	T3a	T3b	T3c
T3a	**87.7**	5.8	6.5
T3b	0.8	**92.6**	6.7
T3c	1.4	0.8	**97.9**

Tables 19 – 21 summarize resulting predicted group membership based on a discriminant analysis of Mainstem Rivers (Table 19), M2 Sub-Types (Table 20), and M3 Sub-Types (Table 21).

Table 19.

	Predicted Group Membership (%)		
	M1	M2	M3
M1	**85.7**	3.6	10.7
M2		**94.7**	5.3
M3		3.1	**96.9**

Table 20.

	Predicted Group Membership (%)	
	M2a	M2b
M2a	**100**	
M2b	1.4	**98.6**

Table 21.

	Predicted Group Membership (%)	
	M3a	M3b
M3a	**100**	
M3b	3.8	**96.2**

Tables 22 – 24 summarize resulting predicted group membership based on a discriminant analysis of Coastal Rivers (Table 22), C1 Sub-Types (Table 23), and C2 Sub-Types (Table 24).

Table 22.

	Predicted Group Membership (%)	
	C1	C2
C1	**98.1**	1.9
C2	3.6	**96.4**

Table 23.

	Predicted Group Membership (%)	
	C1a	C1b
C1a	**97.6**	2.4
C1b	8.9	**91.1**

Table 24.

	Predicted Group Membership (%)	
	C2a	C2b
C2a	**93.6**	6.4
C2b	0.8	**99.2**

Discriminant analysis is also performed on all eleven River Ecosystem Types combined. The F-test and Wilk's Lambda are both highly significant ($p<0.0001$). 75.4% of all rivers are correctly classified into the appropriate groups (Table 25).

The tight groupings reinforce the ecological significance of the hydrologic connectivity classes. The loosest grouping is C1 – Outer Coast and Island Coastal Rivers. It is closely associated with H2 and H3 Low and High Relief Headwater Rivers respectively. C1 is environmentally similar to H2 and H3 based on the environmental variables used in the classification. However, it is differentiated from H2 and H3 based on its coastal connectivity.

Table 25: Resulting predicted group membership based on a discriminant analysis of all River Ecosystem Types combined.

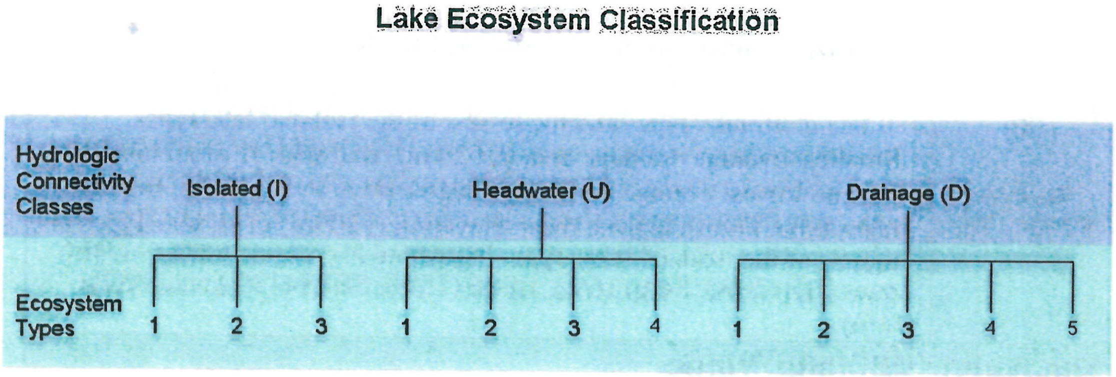
Predicted Group Membership (%)											
	H1	H2	H3	T1	T2	T3	M1	M2	M3	C1	C2
H1	**75.5**				2.3	0.1	15.9				6.3
H2		**90.6**	8.0	0.3					0.6	0.5	
H3		1.7	**71.8**	10.5		0.1			1.5	14.3	
T1	0.1		14.3	**69.7**	0.2				0.1	15.5	0.1
T2	2.4	21.8		0.1	**83.6**					0.1	13.8
T3						**86.2**	6.9	6.9			
M1	17.0	0.1			0.1	3.0	**75.9**	1.4	0.1		2.5
M2						6.7	2.2	**85.1**			6.0
M3						4.8		9.5	**71.4**	14.3	
C1	0.2	12.1	15.5	11.0					4.0	**57.2**	
C2	3.6				17.0		1.3	5.3	0.2	0.1	**72.5**

Lake Ecosystem Classification

Database Field Name
LAKE_TYPE

A total of twelve Lake Ecosystem Types are identified across BC: three Isolated Lake Types; four Headwater Lake Types; and five Drainage Lake Types. These Ecosystem Types are not further subdivided into sub-types as they represent an appropriate number for lake management across the province. Appendix A: Maps 14 - 16 illustrate the distribution of Lake Ecosystem Types across the Province. The two-tier lake ecosystem classification hierarchy is summarized in Figure 6.

Lakes classified as the same Ecosystem Type are expected to share similar physical environments and ecological processes, and similar responses to human disturbance despite the possibility that they are geographically separated. Their biotic communities are not apparent given that species inventory information could not be incorporated into the classification due to the sparseness of species inventory information across the province. Therefore, it must be assumed that lakes within the same Lake Ecosystem Type that span more than one EDU are potentially different Ecosystem Types given the different species assemblages within each EDU. Table 26 below summarizes the ecological characteristics of each Lake Ecosystem Type. An environmental summary of each of these Lake Ecosystem Types is found in Appendix E.



I, U, D:
1 = Coastal

I:
2 = Interior, Low Relief in the NE
3 = Interior excluding the NE

U:
2 = Interior, Foothills
3 = Small
4 = Large

D:
2 = Interior, Low Relief in the NE
3 = Interior, Low Relief in the Central Interior
4 = Moderate to High Relief
5 = Large

Figure 6: Summary of the two-tier lake ecosystem classification.

Table 26: Description of Lake Ecosystem Types in BC.

Lake Type	Description
Isolated (I) Lake Types **(N= 9,923; 15% of All Lakes)**	
I1 **N= 1,502** **15% of I Type**	**Coastal isolated lakes.** Second smallest average surface area (1.95 ha) of all lake types and the isolated lakes type. Fourth most complex shoreline on average (1.5) of all lakes types and most complex of the isolated lakes type. Smallest average drainage area (0.02 km^2) of all lake types tied with I3. Highest average number of degree days above 4°C of all lake types. Lowest mean elevation (174m) of all lake types. Located predominately within the CWH (97%) BEC Zone.
I2 **N= 2,180** **22% of I Type**	**Interior, low relief isolated lakes in the NE.** Third smallest average surface area (2.17 ha) of all lake types but the largest of the isolated lakes type. Fifth least complex shoreline on average (1.38) of all lake types and second least complex of the isolated lakes type. Second smallest average drainage area (0.17 km^2) of all lake types. Fourth lowest average number of degree days above 4°C of all lakes types and lowest of the isolated lakes type. Fourth lowest mean elevation (632m) of all lake types and the second lowest of the isolated

Lake Type	Description
	lakes type. Located predominately within BWBS (96%) BEC Zone.
I3 N= 6,232 63% of I Type	**Interior, isolated lakes excluding the NE.** Smallest average surface area (1.92 ha) of all lake types. Third least complex shoreline (1.31) of all lake types and the lowest of the isolated lake types. Smallest average drainage area (0.02 km^2) tied with I1 of all lake types. Second lowest average number of degree days above 4°C of the isolated lakes type. Fourth highest mean elevation (1205m) of all lake types and highest of the isolated lakes type. Distributed across a number of BEC Zones IDF (20%), SBS (16%), ESSF (15%), SBPS (13%) and SWB (11%).
Headwater (U) Lake Types (N= 23,862; 35% of All Lakes)	
U1 N= 3,827 16% of U Type	**Coastal headwater lakes.** Second largest average surface area (6.77 ha) of the headwater lakes type. Second most complex shoreline on average (1.49) of the headwater lakes type. Second smallest average drainage area (0.43 km^2) of the headwater lakes type. Third highest average number of degree days above 4°C of all lake types and the highest of the headwater lakes type. Third lowest mean elevation (234m) of all lake types and the lowest of the headwater lakes type. Located predominately within the CWH (98%) BEC Zone.
U2 N= 4,012 17% of U Type	**Interior, moderate relief – foothills headwater lakes.** Second smallest average surface area (4.18 ha) of the headwater lakes type. Second least complex shoreline on average (1.3) of all lake types and the headwater lakes type. Third smallest average drainage area (0.48 km^2) of the headwater lakes type. Second lowest average number of degree days above 4°C of all lake types and the lowest of the headwater lake types. Highest mean elevation (1,628m) of all lake types. Located predominately within the ESSF (99%) BEC Zone.
U3 N= 8,649 36% of U Type	**Small interior headwater lakes.** Fourth smallest average surface area (2.43 ha) of all lake types and the smallest of the headwater lakes type. Least complex shoreline on average (1.25) of all lake types. Fourth smallest average drainage area (0.3 km^2) of all lake types and the smallest of the headwater lakes type. Fourth highest average number of degree days above 4°C of all lake types and the second highest of the headwater lakes type. Third highest mean elevation (1,224m) of all lake types and the second highest of the headwater lakes type. Located primarily within the BAFA, SWB, SBS and BWBS BEC Zones.
U4 N= 7,374 31% of U Type	**Large interior headwater lakes.** Third largest average surface area (12.11 ha) of all lake types and the largest of the headwater lakes type. Fourth most complex shoreline on average (1.5) of all lake types and the most complex of the headwater lakes type. Largest average drainage area (1.06 km^2) of the headwater lakes type. Second lowest average number of degree days above 4°C of the headwater lakes type. Second lowest mean elevation (907m) of the headwater lakes type. Located

Lake Type	Description
	primarily within the BWBS (34%) and SBS (24%) BEC Zones.
Drainage (D) Lake Types (N= 33,698; 50% of All Lakes)	
D1 **N= 5,017** **15% of D Type**	**Coastal drainage lakes**. Second large average surface area (37.36 ha) of all lake types and the drainage lakes type. Second most complex shoreline on average (1.69) of all lake types and drainage lake types. Second largest average drainage area (135.04 km^2) of all lake types and drainage lakes type. Second highest average number of degree days above 4°C of all lake types and highest of the drainage lakes type. Second lowest mean elevation (182m) of all lake types and lowest of the drainage lakes type. Average stream outflow order of two. Located predominately within the CWH (95%) BEC Zone.
D2 **N= 5,445** **16% of D Type**	**Interior, low relief drainage lakes in the NE**. Fifth largest average surface area (9.3 ha) of all lake types but second smallest of the drainage lakes type. Third least complex shoreline (1.44) of the drainage lakes type. Third largest average drainage area (9.16 km^2) of both all lake types and the drainage lakes type. Lowest average number of degree days above 4°C of all lakes types. Second lowest mean elevation (672m) of the drainage lakes type. Average stream outflow order of two. Located predominately within the BWBS (100%) BEC Zone.
D3 **N= 5,508** **16% of D Type**	**Interior, low relief drainage lakes in the central interior**. Fourth largest average surface area (11.01 ha) of all lake types and the third smallest of the drainage lakes type. Second least complex shoreline on average (1.42) of the drainage lakes type. Fourth largest average drainage area (6.31 km^2) of all lake types but the second smallest of the drainage lakes type. Third lowest average number of degree days above 4°C of all lake types and the second lowest of the drainage lakes type. Third lowest mean elevation (880m) of the drainage lakes type. Average stream outflow order of two. Located predominately within the SBS (100%) BEC Zone.
D4 **N= 12,293** **37% of D Type**	**Interior, moderate to high relief drainage lakes**. Smallest average surface area (5.58 ha) of the drainage lakes type. Fourth least complex shoreline on average (1.37) of all lake types and least complex of the drainage lakes type. Fifth largest average drainage area (3.89 km^2) of all lake types but smallest of the drainage lake types. Fifth lowest average number of degree days above 4°C of all lake types but third highest of the drainage lakes type. Second highest mean elevation (1,306m) of all lake types and highest of the drainage lakes type. Average outflow stream order of two. Located primarily within the ESSF (26%), IDF (15%), SWB (14%) and BAFA (13%) BEC Zones.

Lake Type	Description
D5 **N= 5,435** **16% of D Type**	**Large drainage lakes.** Largest average surface area (293.31 ha) of all lake types. Most complex shoreline on average (2.01) of all lake types. Largest average drainage area (330.61 km^2) of all lakes types. Second highest average number of degree days above 4°C of the drainage lakes type and sixth lowest of all lake types. Second highest mean elevation (992m) of the drainage lakes type. Average outflow stream order of three. Located primarily within the IDF (14%), SWB (14%), SBS (13%) and SBPS (13%) BEC Zones.

Discriminant Analysis of Lake Ecosystem Types

Discriminant analyses (DA) (Legendre and Legendre 1983) are performed to test for significant differences between Lake Ecosystem Types based on their environmental characteristics. DA is a multivariate statistic that was used to maximally contrast Lake Ecosystem Types based on their environmental variation in order to examine whether statistically significant differences exist between them. The resultant discriminant function is the maximum difference between the Ecosystem Types.

Four discriminant analyses are performed to test for significant differences between each of the ecosystem types within each connectivity class, as well as between all lake ecosystem types combined using the environmental variable inputs used to develop the lake ecosystem classification (elevation, surface area, shoreline complexity, drainage area, outflow stream order, accumulative precipitation yield, number of degree days above 4°C, and dominant BEC zone). F-test and Wilk's Lambda resulted in significant ($p<0.0001$) differences between all Lake Ecosystem Types within each of the connectivity classes, and all Lake Ecosystem Types combined. Tables 27 to 31 summarize the predicted group membership results based on the discriminant analyses. 99.6% of the Isolated Lakes are correctly classified into their appropriate groups. Similarly, 95.2% and 93.1% of the Headwater and Drainage Lakes respectively are correctly classified into their appropriate groups. Lastly, 64.3% of all lakes combined are correctly classified into their appropriate Lake Ecosystem Type. Appendix F summarizes the environmental differentiation of each Lake Ecosystem Type as a series of principal component analysis (PCA) ordinations.

Table 27: Predicted group membership based on a discriminant analysis of Isolated Lakes.

	Predicted Group Membership (%)		
	I1	I2	I3
I1	**98.8**		1.2
I2	0.3	**99.1**	0.6
I3	0.1		**99.9**

Table 28: Predicted group membership based on a discriminant analysis of Headwater Lakes.

	Predicted Group Membership (%)			
	U1	U2	U3	U4
U1	**98.1**		1.0	.9
U2		**99.7**	.3	
U3	.3		**95.1**	4.6
U4	.1	.1	8.5	**91.3**

Table 29: Predicted group membership based on a discriminant analysis of Drainage Lakes.

	Predicted Group Membership (%)				
	D1	D2	D3	D4	D5
D1	**99.4**			4.8	.8
D2		**100**			
D3			**100**		
D4				**99.3**	.6
D5	1.4	9.8	12.9	12.0	**63.9**

Discriminant analysis is also performed on all lakes combined using all twelve Lake Ecosystem Types together. The F-test and Wilk's Lambda are both highly significant ($p<0.0001$). 64.3% of all lakes are correctly classified into their appropriate Lake Ecosystem Types (Table 30).

The tight groupings reinforce the ecological significance of the hydrologic connectivity classes. The loosest groupings are U3 and U4 Small and Large Interior Headwater Lakes respectively. U3 is closely associated with U2 Interior Moderate Relief – Foothills Headwater Lakes. U4 is closely associated with the larger Drainage Lake Types – D2, D3, and D4.

Table 30: Predicted group membership based on a discriminant analysis of all Lake Ecosystem Types combined.

Predicated Group Membership (%)												
	I1	I2	I3	U1	U2	U3	U4	D1	D2	D3	D4	D5
I1	**95.8**		1.5	2.5				.3				
I2		**93.9**	.3					.6	2.0	.5	2.4	.2
I3	.1		**91.2**		7.0	.4				1.3		
U1	20.5		.2	**59.3**				19.1			.8	
U2			10.9		**63.8**	11.7	.7				12.7	.2
U3		8.8	15.9	.1	26.5	**24.0**	.1		.9	11.7	11.9	
U4		14.4	1.5		5.1	5.9	**8.2**	.1	19.5	24.1	19.1	2.1
D1	1.6			21.2		.5	.4	**73.9**			1.6	.9
D2		6.2							**93.8**			
D3			.5							**99.5**		
D4			1.0	.1	15.7	6.7	2.0	.3			**70.7**	3.5
D5					.1		.6	2.2	9.0	8.1	11.7	**68.4**

Primary Drainage Summaries

This section summarizes the three tier hierarchical EAU BC classification for each of the major primary drainages in BC based on their respective Freshwater Ecoregions, Ecological Drainage Units and River and Lake Ecosystem Types (Table 31).

Table 31: Summary of the major primary drainages in BC by Freshwater Ecoregion, Ecological Drainage Unit and Freshwater Ecosystem Types.

Mackenzie Primary Drainage	
Mackenzie Freshwater Ecoregion	
Upper Peace Ecological Drainage Unit	
River Ecosystem Types (#; % of rivers in EDU)[6]	**Lake Ecosystem Types** (#; % of lakes in EDU)[7]
H2a (50; 4%)	I2 (119; 3%)
H2b (215; 18%)	I3 (339; 8%)
H3a (23; 2%)	U2 (440; 10%)
H3b (622; 52%)	U3 (769; 18%)
H3c (20; 2%)	U4 (551; 13%)
T2a (1; <1%)	D2 (403; 9%)
T2b (50; 4%)	D3 (854; 20%)
T3a (2; <1%)	D4 (562; 13%)
T3b (143; 12%)	D5 (295; 7%)
T3c (54; 4%)	
M2b (3; <1%)	
M3b (20; 2%)	
Lower Peace Ecological Drainage Unit	
River Ecosystem Types	**Lake Ecosystem Types**
H2a (356; 41%)	I2 (253; 14%)
H3a (13; 2%)	I3 (55; 3%)
H3b (297; 35%)	U1 (1; <1%)
T2a (94; 11%)	U2 (217; 12%)
T3b (23; 3%)	U3 (110; 6%)
T3c (63; 7%)	U4 (266; 14%)
M2a (6; 1%)	D2 (668; 36%)
M3b (6; 1%)	D3 (41; 2%)
	D4 (169; 9%)
	D5 (86; 5%)

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[6] -999 rivers represent watershed units with no associated stream network at a scale of 1:50,000. They are excluded from the summary.

[7] -999 lakes represent lakes under 1ha otherwise classified as ponds or wetlands. They are excluded from the summary

Upper Liard Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H2a (254; 27%)	I2 (478; 10%)
H3a (4; <1%)	I3 (245; 5%)
H3b (470; 49%)	U3 (982; 21%)
H3c (1; <1%)	U4 (788; 16%)
T2a (62; 6%)	D2 (1,043; 22%)
T3a (1; <1%)	D4 (807; 17%)
T3b (143; 15%)	D5 (405; 8%)
M2a (7; 1%)	
M3b (12; 1%)	

Lower Liard Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H2a (587; 48%)	I2 (762; 16%)
H3a (10; 1%)	I3 (45; <1%)
H3b (299; 25%)	U3 (515; 10%)
T2a (199; 16%)	U4 (966; 20%)
T3a (7; 1%)	D2 (2,285; 46%)
T3b (77; 6%)	D4 (209; 4%)
M2a (24; 2%)	D5 (128; 3%)
M3b (7; 1%)	

Hay Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H2a (75; 77%)	I2 (294; 37%)
T2a (21; 21%)	U3 (36; 4%)
M2a (2; 2%)	U4 (153; 19%)
	D2 (282; 36%)
	D5 (25; 3%)

Columbia Primary Drainage

Columbia Glaciated Freshwater Ecoregion

Upper Columbia Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H3a (263; 70%)	I2 (5; <1%)
H3c (21; 6%)	I3 (194; 18%)
T3a (87; 23%)	U2 (272; 26%)
M3a (6; 2%)	U3 (84; 8%)
	U4 (120; 11%)
	D4 (307; 29%)
	D5 (78; 7%)

Columbia – Arrow Lakes Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H3a (104; 52%)	I3 (32; 11%)
H3c (46; 23%)	U2 (126; 37%)
T3a (31; 16%)	U3 (20; 6%)

T3c (14; 7%)	U4 (15; 4%)
M3a (4; 2%)	D1 (2; 4%)
	D4 (117; 34%)
	D5 (30; 9%)
Upper Kootenay Ecological Drainage Unit	
River Ecosystem Types	**Lake Ecosystem Types**
H3a (287; 71%)	I2 (3; <1%)
H3c (28; 7%)	I3 (136; 17%)
T3a (63; 16%)	U2 (213; 27%)
T3c (21; 5%)	U3 (48; 6%)
M3a (7; 2%)	U4 (59; 7%)
	D1 (5; <1%)
	D4 (261; 33%)
	D5 (63; 8%)
Lower Kootenay Ecological Drainage Unit	
River Ecosystem Types	**Lake Ecosystem Types**
H3a (192; 66%)	I1 (2; <1%)
H3c (32; 11%)	I2 (2; <1%)
T3a (46; 16%)	I3 (60; 9%)
T3c (19; 7%)	U1 (1; <1%)
M3a (3; 11%)	U2 (291; 46%)
	U3 (22; 3%)
	U4 (16; 2%)
	D1 (10; 2%)
	D4 (190; 30%)
	D5 (39; 6%)
Flathead Ecological Drainage Unit	
River Ecosystem Types	**Lake Ecosystem Types**
H3a (34; 76%)	I3 (8; 17%)
T3c (10; 22%)	U2 (18; 38%)
M3a (1; 2%)	U3 (2; 4%)
	U4 (1; 2%)
	D4 (15; 32%)
	D5 (3; 6%)
Kettle Ecological Drainage Unit	
River Ecosystem Types	**Lake Ecosystem Types**
H2b (30; 24%)	I3 (25; 11%)
H3a (1; 1%)	U2 (29; 13%)
H3c (70; 56%)	U3 (53; 24%)
T3c (22; 17%)	U4 (14; 6%)
M2b (1; 1%)	D1 (1; <1%)
M3a (2; 2%)	D4 (83; 37%)
	D5 (19; 8%)

Okanagan Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H2b (34; 35%)	I1 (9; 2%)
H3c (40; 42%)	I2 (2; <1%)
T3c (21; 22%)	I3 (41; 10%)
M2b (1; 1%)	U1 (9; 2%)
	U2 (22; 5%)
	U3 (73; 18%)
	U4 (33; 8%)
	D1 (49; 12%)
	D4 (109; 27%)
	D5 (55; 14%)

Similkameen Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H2b (22; 11%)	I3 (47; 16%)
H3a (7; 4%)	U2 (29; 10%)
H3c (126; 64%)	U3 (42; 14%)
T2b (8; 4%)	U4 (27; 9%)
T3c (32; 16%)	D1 (3; 1%)
M3a (2; 1%)	D4 (111; 37%)
	D5 (39; 13%)

Fraser Primary Drainage

North Pacific Coastal Freshwater Ecoregion

Lower Fraser Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
C1b (1; <1%)	I1 (53; 5%)
H1a (104; 41%)	I2 (3; <1%)
H1b (75; 30%)	I3 (81; 8%)
H3a (14; 6%)	U1 (90; 9%)
H3c (6; 2%)	U2 (45; 4%)
T1a (29; 12%)	U3 (277; 28%)
T1b (11; 4%)	U4 (80; 8%)
T3a (4; 2%)	D1 (84; 8%)
T3c (2; 1%)	D4 (246; 25%)
M1 (5; 2%)	D5 (41; 4%)

Interior Freshwater Ecoregion

Middle Fraser Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H1a (13; 1%)	I1 (9; <1%)
H2b (1,044; 53%)	I2 (12; <1%)
H3a (182; 9%)	I3 (2,273; 17%)
H3b (8; <1%)	U1 (14; <1%)
H3c 189; 10%)	U2 (547; 4%)
T2b (348; 18%)	U3 (1,313; 10%)
T3a (59; 3%)	U4 (1,599; 12%)

T3b (1; <1%)	D1 (1; <1%)
T3c (63; 3%)	D3 (3,455; 26%)
M1 (1; <1%)	D4 (2,673; 20%)
M2b (45; 2%)	D5 (1,581; 12%)
M3a (9; <1%)	

Upper Fraser Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H2a (1; <1%)	I2 (3; <1%)
H2b (113; 24%)	I3 (146; 12%)
H3a (251; 53%)	U2 (285; 23%)
H3c (6; 1%)	U3 (132; 11%)
T2b (25; 5%)	U4 (135; 11%)
T3a (45; 10%)	D3 (262; 21%)
T3c (23; 5%)	D4 (213; 17%)
M2b (3; 1%)	D5 (63; 5%)
M3a (2; <1%)	
M3b (2; <1%)	

Thompson Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H2b (282; 31%)	I1 (3; <1%)
H3a (183; 20%)	I2 (8; <1%)
H3c (235; 26%)	I3 (801; 15%)
T2b (71; 8%)	U1 (1; <1%)
T3a (47; 5%)	U2 (577; 11%)
T3c (85; 9%)	U3 (656; 12%)
M2b (6; 1%)	U4 (458; 8%)
M3a (8; 1%)	D1 (42; <1%)
	D3 (260; 5%)
	D4 (1,979; 36%)
	D5 (667; 12%)

Skeena Primary Drainage

Interior Freshwater Ecoregion

Upper Skeena Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H1a (1; <1%)	I1 (3; <1%)
H2a (3; <1%)	I2 (2; <1%)
H2b (216; 24%)	I3 (220; 10%)
H3a (42; 5%)	U1 (2; <1%)
H3b (333; 36%)	U2 (383; 18%)
H3c (111; 12%)	U3 (227; 11%)
T2b (37; 4%)	U4 (203; 9%)
T3a (12; 1%)	D1 (2; <1%)
T3b (106; 12%)	D3 (415; 19%)
T3c (37; 4%)	D4 (497; 23%)
M2b (7; 1%)	D5 (195; 9%)

M3a (3; <1%)	
M3b (5; 1%)	

North Pacific Coastal Freshwater Ecoregion

Lower Skeena Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
C2a (2; 1%)	I1 (57; 9%)
H1a (138; 52%)	I3 (50; 8%)
H1b (42; 16%)	U1 (74; 12%)
H2b (3; 1%)	U2 (31; 5%)
H3a (17; 6%)	U3 (98; 16%)
H3c (12; 5%)	U4 (69; 11%)
T1a (40; 15%)	D1 (75; 12%)
T3a (6; 2%)	D3 (11; 2%)
T3c (3; 1%)	D4 (118; 19%)
M1 (2; 1%)	D5 (49; 8%)

Nass Primary Drainage

Interior Freshwater Ecoregion

Upper Nass Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H1a (1; <1%)	I3 (47; 5%)
H2a (1; <1%)	U2 (167; 17%)
H2b (51; 8%)	U3 (141; 15%)
H3a (78; 13%)	U4 (107; 11%)
H3b (338; 55%)	D1 (7; <1%)
T1a (1; <1%)	D3 (7; <1%)
T2b (10; 2%)	D4 (319; 33%)
T3a (40; 7%)	D5 (170; 18%)
T3b (85; 14%)	
M2b (1; <1%)	
M3b (8; 1%)	

North Pacific Coastal Freshwater Ecoregion

Lower Nass – Portland Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
C2a (30; 19%)	I1 (8; 2%)
C2b (17; 10%)	I3 (41; 9%)
H1a (63; 39%)	U1 (35; 8%)
H1b (7; 4%)	U2 (16; 4%)
H2b (9; 6%)	U3 (104; 23%)
H3a (10; 6%)	U4 (62; 14%)
T1a (20; 12%)	D1 (35; 8%)
T2b (1; <1%)	D4 (95; 21%)
T3a (2; 1%)	D5 (48; 11%)
M1 (1; <1%)	

Stikine Primary Drainage

Yukon Freshwater Ecoregion

Upper Stikine Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H2a (92; 12%)	I2 (50; 3%)
H3a (17; 2%)	I3 (189; 10%)
H3b (456; 61%)	U2 (8; <1%)
T2a (16; 2%)	U3 (516; 28%)
T3a (9; 1%)	U4 (214; 12%)
T3b (144; 19%)	D2 (123; 7%)
M3b (11; 1%)	D3 (2; <1%)
	D4 (532; 29%)
	D5 (186; 10%)

North Pacific Coastal Freshwater Ecoregion

Iskut - Lower Stikine Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H1a (168; 18%)	I1 (16; <1%)
H2a (15; 2%)	I2 (23; 2%)
H3a (373; 40%)	I3 (123; 12%)
H3b (148; 16%)	U1 (22; 2%)
T1a (49; 5%)	U2 (81; 8%)
T3a (121; 13%)	U3 (208; 20%)
T3b (45; 5%)	U4 (91; 8%)
M1 (6; 1%)	D1 (42; 4%)
M3b (9; 1%)	D2 (31; 3%)
	D3 (38; 4%)
	D4 (259; 24%)
	D5 (131; 12%)

Taku Primary Drainage

Yukon Freshwater Ecoregion

Nakina Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H2a (19; 18%)	I2 (2; <1%)
H3a (61; 57%)	I3 (13; 4%)
T2a (8; 7%)	U2 (11; 4%)
T3a (17; 16%)	U3 (63; 22%)
M3b (2; 2%)	U4 (34; 12%)
	D2 (47; 16%)
	D3 (12; 4%)
	D4 (74; 26%)
	D5 (31; 11%)

North Pacific Coastal Freshwater Ecoregion

Taku Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types

H1a (22; 10%)	I1 (1; <1%)
H2a (51; 22%)	I2 (8; <1%)
H3a (104; 45%)	I3 (150; 14%)
T1a (7; 3%)	U1 (6; <1%)
T2a (9; 4%)	U2 (33; 3%)
T3a (28; 12%)	U3 (284; 26%)
T3b (3; 1%)	U4 (141; 13%)
M1 (1; <1%)	D1 (12; 1%)
M2a (1; <1%)	D2 (52; 5%)
M3b (3; 1%)	D3 (20; 2%)
	D4 (275; 25%)
	D5 (118; 11%)

Yukon Primary Drainage

Yukon Freshwater Ecoregion

Lewes Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H1a (4; 3%)	I2 (91; 9%)
H2a (23; 15%)	I3 (82; 8%)
H3a (83; 55%)	U2 (20; 2%)
H3b (10; 7%)	U3 (198; 19%)
T1a (1; 1%)	U4 (134; 13%)
T2a (6; 4%)	D2 (158; 15%)
T3a (19; 13%)	D3 (52; 5%)
T3b (3; 2%)	D4 (149; 14%)
M3b (2; 1%)	D5 (154; 15%)

Teslin Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H2a (112; 49%)	I2 (35; <1%)
H3b (65; 28%)	I3 (238; 12%)
T2a (29; 13%)	U3 (424; (21%)
T3b (19; 8%)	U4 (284; 14%)
M2a (3; 1%)	D2 (323; 16%)
M3b (1; <1%)	D4 (484; 24%)
	D5 (249; 12%)

Alsek Primary Drainage

Yukon Freshwater Ecoregion

Alsek Ecological Drainage Unit

River Ecosystem Types	Lake Ecosystem Types
H1a (18; 22%)	I2 (14; 6%)
H3a (44; 55%)	I3 (47; 19%)
T1a (3; 4%)	U3 (47; 19%)
T3a (13; 16%)	U4 (51; 21%)
M1 (1; 1%)	D2 (30; 12%)
M3b (1; 1%)	D4 (37; 15%)

		D5 (21; 8%)

Small Coastal Primary Drainages

North Pacific Coastal Freshwater Ecoregion

North Coastal Ecological Drainage Unit

	River Ecosystem Types	Lake Ecosystem Types
	H1a (105; 60%)	I1 (1; 4%)
	H3a (30; 17%)	I3 (31; 10%)
	T1a (32; 18%)	U1 (6; 2%)
	T3a (7; 4%)	U2 (12; 4%)
	M1 (1; <1%)	U3 (71; 24%)
		U4 (25; 8%)
		D1 (6; 2%)
		D4 (114; 38%)
		D5 (35; 12%)

Haida Gwaii / Queen Charlotte Islands Ecological Drainage Unit

	River Ecosystem Types	Lake Ecosystem Types
	C1a (85; 79%)	I1 (138; 26%)
	H1b (21; 20%)	I3 (3; <1%)
	T1a (1; 1%)	U1 (176; 33%)
		U3 (10; 2%)
		U4 (10; 2%)
		D1 (194; 36%)
		D4 (3; <1%)
		D5 (1; <1%)

Central Coastal Ecological Drainage Unit

	River Ecosystem Types	Lake Ecosystem Types
	C1a (564; 42%)	I1 (817; 12%)
	C2a (123; 9%)	I2 (5; <1%)
	C2b (247; 18%)	I3 (75; 1%)
	H1a (179; 13%)	U1 (2,035; 31%)
	H1b (178; 13%)	U3 (290; 4%)
	T1a (54; 4%)	U4 (225; 3%)
	M1 (1; <1%)	D1 (2,811; 42%)
		D3 (7; <1%)
		D4 (279; 4%)
		D5 (94; 1%)

South Coastal Ecological Drainage Unit

	River Ecosystem Types	Lake Ecosystem Types
	C1a (90; 16%)	I1 (168; 8%)
	C1b (39; 7%)	I2 (1; <1%)
	C2a (75; 13%)	I3 (66; 3%)
	C2b (139; 24%)	U1 (527; 25%)
	H1a (99; 17%)	U3 (280; 13%)
	H1b (101; 18%)	U4 (214; 10%)
	T1a (22; 4%)	D1 (599; 28%)

T1b (9; 2%)	D4 (230; 11%)
	D5 (49; 2%)
Bella Coola – Dean Ecological Drainage Unit	
River Ecosystem Types	**Lake Ecosystem Types**
C2a (2; 1%)	I1 (1; <1%)
H1a (36; 20%)	I2 (1; <1%)
H2b (60; 33%)	I3 (209; 16%)
H3a (15; 8%)	U1 (5; <1%)
H3c (19; 10%)	U2 (114; 9%)
T1a (12; 7%)	U3 (210; 16%)
T2b (17; 9%)	U4 (124; 10%)
T3a (1; 1%)	D1 (2; <1%)
T3c (17; 9%)	D3 (72; 6%)
M2b (1; 1%)	D4 (388; 30%)
M3a (2; 1%)	D5 (170; 13%)
Homathko – Klinaklini Ecological Drainage Unit	
River Ecosystem Types	**Lake Ecosystem Types**
C2a (2; 2%)	I1 (4; <1%)
H1a (28; 28%)	I2 (1; <1%)
H1b (2; 2%)	I3 (92; 16%)
H2b (12; 12%)	U1 (28; 5%)
H3a (23; 23%)	U2 (20; 3%)
H3c (18; 18%)	U3 (127; 21%)
T1a (6; 6%)	U4 (52; 9%)
T3a (6; 6%)	D1 (13; 2%)
T3c (4; 4%)	D4 (194; 33%)
	D5 (62; 10%)
Vancouver Island Ecological Drainage Unit	
River Ecosystem Types	**Lake Ecosystem Types**
C1a (376; 26%)	I1 (193; 8%)
C1b (124; 8%)	I2 (3; <1%)
C2b (95; 6%)	I3 (37; <1%)
H1a (18; 1%)	U1 (791; 31%)
H1b (693; 48%)	U3 (208; 8%)
T1b (147; 10%)	U4 (51; 2%)
M1 (1; <1%)	D1 (1,021; 40%)
	D4 (186; 7%)
	D5 (50; 2%)
Puget Sound Ecological Drainage Unit	
River Ecosystem Types	**Lake Ecosystem Types**
C1b (7; 10%)	I1 (19; 34%)
H1a (15; 21%)	I3 (1; 2%)
H1b (11; 15%)	U1 (4; 7%)
H3a (26; 37%)	U2 (5; 9%)
H3c (1; 1%)	U3 (9; 16%)

	T1a (2; 3%)	U4 (2; 4%)
	T1b (2; 3%)	D1 (1; 2%)
	T3c (6; 8%)	D4 (9; 16%)
	M3a (1; 1%)	D5 (5; 9%)

Conclusions

EAU BC is a hierarchical freshwater ecosystem classification for BC. It is a spatially explicit classification designed to aid in the management and conservation of BC's freshwater ecosystems and their associated biodiversity. EAU BC quantifies the interplay between the distribution of freshwater fishes and their ecosystem's physical habitat, and environmental processes. It defines what is currently known about freshwater ecosystems and their abundance and distribution across the province. It is packaged as a database and accompanying geographic information system (GIS) that enables the classification and its underlying data to be queried and viewed at multiple spatial scales. Specifically, EAU BC was developed with the following applications in mind:

- Provide an environmental characterization of freshwater ecosystem types in BC that will aid in their specific conservation and management;
- Provide a spatially explicit data management system for freshwater ecosystems in BC;
- Enable regional comparisons of freshwater ecosystems;
- Help inform species / habitat relationships; and
- Provide a stratification framework for freshwater inventory / monitoring programs and state of the environment reporting on freshwater ecosystems in BC.

EAU BC classifies freshwater systems at three spatial scales - Freshwater Ecoregions, Ecological Drainage Units, and River and Lake Ecosystem Types - based on measurable environmental features, processes and biological data. Freshwater Ecoregions are defined based on zoogeographic patterns in fish re-colonization following the last glacial recession. Ecological Drainage Units are nested within Freshwater Ecoregions and take into account zoogeographic, climatic, and physiographic patterns that define freshwater systems. Ecological Drainage units incorporate the known distribution of native freshwater fishes in BC. River and Lake Ecosystem Types nest within both Ecological Drainage Units and Freshwater Ecoregions. They are therefore defined by zoogeographic, physiographic and climatic patterns but also take into account more localized physical habitat and dominant environmental processes that shape freshwater ecosystems. Biological information is sparse at this scale of the classification and is therefore not explicitly used to delineate Ecosystem Types. However, fish assemblages can be inferred for each Ecosystem Type based on the Ecological Drainage Unit it is nested within.

EAU BC provides a critical and necessary foundation for understanding freshwater ecosystems and their associated biodiversity. It is realized that this classification framework is a series of hypotheses that need to be tested and refined through rigorous groundtruthing and expert review. It is vulnerable to the type, resolution, and overall quality of available spatial data. We recommend that data be gathered to refine and test the classification to further its development and use by Provincial Ministries and partner organizations.

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Appendices