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CONSERVING THE VARIETY OF LIFE

Special Elements of Biodiversity in British Columbia

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Special Elements of Biodiversity in B.C.

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[1] Also known as Biodiversity B.C. Steering Committee

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Introduction

Special elements are being identified to support the preparation of the "Status of Biodiversity in B.C." report. This is part of the science foundation for the Biodiversity Action Plan for B.C.[2]. An original list of potential special elements of biodiversity was provided to the author by the Technical Sub-Committee of the Conservation Planning Tools Committee[3] (CPTC). This preliminary list was further refined in conjunction with this steering group.

Within the context of maintaining biological diversity in British Columbia under the Biodiversity Action Plan, special elements are those elements of biodiversity that

- represent a significant aspect of biodiversity in the global or national context,
- are not identified elsewhere in the Biodiversity Status Report, *and*
- may not be managed adequately using on-going coarse filter strategies.

The special elements identified are therefore a combination of different types of elements that warrant attention under the Biodiversity Action Plan, but are not identified in other component reports[4]. In general, to be sufficiently important to be recognised here, the element has to be somehow unique, and have global or international significance. Note however - for many elements of biodiversity there is no official ranking of significance so this is a relatively subjective process. Some generic criteria for inclusion are shown in Table 1. Table 2 provides a list of Special Elements included in this report and a brief rationale.

Table 1. Generic criteria for classification as a special element.

Criteria	Threshold or Rationale
Critical habitat for species.	The critical habitat maintains a significant proportion of a population that is globally or internationally significant.
Unique ecosystem or element of biodiversity.	Unique at the national or global level. Found only or largely in B.C., or remaining only in B.C..
Global / international recognition	The element or area has an existing global or international recognition due to a particular designation.
Vulnerability	Some elements are also particularly vulnerable or sensitive and so warrant particular attention.

[2] An additional paper discusses 'key' elements – which are elements with particular functional significance. Key and Special should not be confused.

[3] Also known as Biodiversity B.C. Steering Committee

[4] All component reports can be found at: www._____.

Table 2. Special elements of biodiversity in B.C.. A summary of each element is provided.

	Special Elements	Description and Criteria
Unique Areas with International Recognition	Areas of global and national significance	A number of areas in B.C. have been recognised internationally as having some type of global significance. Many of these relate to birds and bird habitat, but others include geology, evolutionary and cultural significance.
	Wetlands of international importance	Wetland areas tend to have high biodiversity values, and in this case those that are nationally or globally recognised by RAMSAR are highlighted.
	Raised bogs	Bogs have very high biodiversity values. Burns Bog in the Lower Mainland is the largest example of a raised bog in North America, and remains highly vulnerable.
Ecosystem Related	Karst	Karst is a unique ecosystem created by soluble bedrock, particularly in areas of high rainfall. They support rare communities and are particularly vulnerable to disturbance.
	Hotsprings	Are a unique ecosystem of themselves, and provide critical habitat for a number of rare and specialised species.
	Serpentine soils	Formed from bedrock with high toxicity from heavy metals, these soils provide harsh growing conditions, and as a result tend to support specifically adapted, unique plant communities that include a large number of rare and endemic species.
	Rare Terrestrial Ecosystems	British Columbia includes globally significant ecosystems at a number of scales, including temperate rainforest, Garry oak and antelope-brush ecosystems, plus a number of globally important plant associations.
Species Assemblage Related	Marine mammal haulouts	A number of different marine mammals inhabiting the B.C. coastal waters require terrestrial areas for both breeding and resting. Although small, these areas are critical to maintaining populations of these important marine predators.
	Saline lakes	These provide critical habitat for a number of invertebrate species that do not live in other waterbodies. Species reflect unusual adaptations to this special environment.
	Fishless lakes	Lakes that are historically fishless and have never been stocked. They were formerly common, but are now rare due to extensive fish stocking practices in B.C. and elsewhere in the North America. They provide important habitat for a wide range of other species, including some that are rare and endangered.
	Microbialites	These are fossilised mats formed by microbes, primarily cyanobacteria. Globally, examples are rare and the two examples known in B.C. remain in good condition and are protected.
Genetic Level	Geographically marginal species and populations.	Geographically marginal populations are those isolated from a core population by geographic barriers. They tend to have increased genetic diversity, and it is hypothesised these are the populations that will adapt most readily to impacts such as climate change.
	Endemics and Disjuncts	Some areas in B.C. have significant concentrations of endemic species and disjunct populations, and so contribute disproportionately to intra-specific diversity. They include ice-age refugia such as Queen Charlotte Islands and areas of Vancouver Island. In addition, there are a number of evolutionary phenomena that warrant particular attention, including parallel evolution in a number of fish species and single lake endemic fish.

	Special Elements	Description and Criteria
	Special Genetic elements	Special genetic elements for B.C. include the Kermode bear, and 20% of the COSEWIC list in B.C. are for elements at levels lower than species level.
	Major hybridization zones	Hybridization zones (or suture zones) have been hypothesised to exist in B.C.. A number of examples of interesting hybridization, or coexistence of subspecies occur here. This provides a window into evolutionary phenomena.

Descriptions of Special Elements

Areas of Global and National Significance

There are a number of general areas in B.C. that have been given 'global' significance as a result of some type of designation. Many of the areas are related in some way to birds and bird habitat – (Important Bird Areas, Shorebird Reserves and Migratory Reserves), others with general biomes of importance (e.g. the Biosphere Reserves) and World Heritage Sites. Wetlands of global significance as identified by RAMSAR are dealt with separately below. Note that many species other than birds would also benefit from such designations of their key habitat, but birds have had a focus of public attention longer than most species.

Birds are an extremely diverse group of animals in their habitat and hence their conservation needs. Many species, such as the arctic tern (*Sterna paradisaea*), move widely across continents over the period of a year, while others remain resident in localised areas. Colonial nesting species such as great blue herons (*Ardea herodias*) are particularly dependent on protected nesting sites while others such as marbled murrelets (*Brachyramphus marmoratus*) or northern goshawks (*Accipiter gentilis atricapillus*) require protection of large areas of habitat to maintain populations.

A number of different designations exist which identify areas of high national and international significance for maintaining bird populations. Three different designations are Important Bird Areas (IBA), the Western Hemispheric Shorebird Reserve Network and Migratory Bird Sanctuaries.

Status

Many of these sites have differing levels of protection and many areas remain sensitive to disturbance. For example, high density marine bird breeding areas are vulnerable to changes in food supplies in the ocean and introduced species which can result in high nest failure rates. Grassland areas are influenced by invasive plant species and grazing. The Fraser River delta is impacted by large scale development and human disturbance. In general, these broad international or national designations rarely result in total protection of the area and its values, but see individual sections for details.

Important Bird Areas (IBA) are an internationally recognized network of sites identified as providing essential habitat for the conservation and preservation of the world's bird populations. IBAs include sites for breeding, wintering, and/or migrating birds. Sites vary greatly in size and may be public or private lands. Many are located on unprotected land.

Sites must meet one of three criteria to be identified as an IBA (http://www.ibacanada.com/). The site must contain habitat for:

- Species of conservation concern (e.g. threatened and endangered species), restricted-ranges species (species vulnerable because they are not widely distributed) and/or;
- Species that are vulnerable because their populations are concentrated in one general habitat type or biome and/or;
- Species, or groups of similar species (such as waterfowl or shorebirds), that are vulnerable because they occur at high densities due to their congregatory behaviour.

Currently there are approximately 10,000 IBAs identified across the world, including 597 in Canada. In B.C., 84 IBAs are distributed primarily along the coast particularly around the lower mainland and Vancouver Island, and are secondarily scattered through the centre of the province and along the southern border with the United States. A list of all these sites is provided in Appendix 1.

Sites are identified for different reasons: the area given the highest ranking in B.C. through the initiative (see http://www.ibacanada.com/ for more details) is the Boundary Bay – Roberts Bank - Sturgeon Bank site south of Vancouver. This large and complex area includes coastal wetlands, mudflats and intertidal marshes which provides habitat for an extremely high diversity and biomass of birds and is particularly important as a Pacific fly-way stop-over location. Dunlin wintering in this area can account for 8% of the North American population of this species, and in a single day during the early winter counts of more than 100,000 waterfowl can be made. More than 50 species of shorebirds are regularly seen in the area.

In contrast, the Scott Islands Group located off the northwest tip of Vancouver Island is a relatively small area that supports the largest concentration of breeding seabirds in the northern Pacific south of Alaska. Twelve species of seabirds birds breed here with numbers totalling more than two million breeding birds. Three species have populations here of particular global significance: the numbers of Cassin's auklet, rhinoceros auklet and tufted puffin constitute 55%, 7% and 2% of the global population of these species respectively.

Smaller sites included as IBAs include areas such as the McFadden Creek Heronry on Saltspring Island which has around 120 heron nests. The site is of particular importance because available nesting sites for this species have decreased in the surrounding areas over the last few decades. Other examples of national importance include the Skookumchuk Prairie which is a small area of native grassland and provides habitat for around 22 pairs of long-billed curlew – constituting around 1% of the Canadian population.

The Western Hemispheric Shorebird Reserve Network is a series of sites identified that provide habitat for at least 500,000 shorebirds annually, or at least 30% of the biogeographic population for a species. In B.C., the Fraser River Estuary (31,000ha) as a whole is identified as such a site. This includes the areas included as part of the IBA network (Boundary Bay – Roberts Bank - Sturgeon Bank) and the Alaksen Wildlife Refuge (Identified below both as a Migratory Bird Sanctuary and as a Wetland of International Importance). Although there are protected areas as part of the Fraser River delta, much of the delta remains unprotected.

Migratory Bird Sanctuaries are areas legally designated under federal legislation and are protected from hunting and disturbance. In B.C., 7 sites are identified (Appendix 2). An example is Vaseaux Lake near Penticton in the southern Okanagan. It is the most natural valley bottom site remaining in the Okanagan Valley and provides habitat for a wide-variety of species including wintering habitat for Trumpeter and Tundra Swans and stop-over habitat for a wide range of migrating waterfowl.

Additional Areas of Significance:

UNESCO Biosphere Reserves are identified geographic areas "where people exemplify various ways to sustain local economies and resource use while also conserving the biodiversity found in different kinds of ecosystems" (http://www.biosphere-canada.ca/home.asp). Two examples are found in B.C. : Mountain Arrowsmith and Clayoquot Sound. Mount Arrowsmith is located on southeastern Vancouver Island and includes the peaks of Mounts Cokely and Moriarty. The reserve includes a complete range of

habitats from alpine to the dry low elevation Coastal Douglas Fir forests, lakes, floodplains and estuaries. Clayoquot Sound is located on the west side of Vancouver Island and is home to coastal temperate rainforest and the Nuu-chah-nulth First Nations.

World Heritage Sites are areas identified as having outstanding universal value. Sites in B.C. include SGang Gwaay, the Canadian Rocky Mountain Parks and Kluane / Wrangell-St Elias / Glacier Bay / Tatshenshini-Alsek .

SGang Gwaay located on a southern Island of Queen Charlotte Islands and is home to the Haida village of Ninstints where building structures and mortuary poles remain. The site is identified on the basis of being an exceptional testimony to a cultural tradition.

The Canadian Rocky Mountain Parks are a contiguous series of parks that encompass extensive wildlife habitat, and the world renowned Burgess Shale. The area is identified specifically for providing an example of the major stages of the world's evolutionary history and for geological values.

Another complex of parks - Kluane / Wrangell-St Elias / Glacier Bay / Tatshenshini-Alsek are located around the border between B.C., the Yukon and Alaska and are home to a wide variety of large mammals including grizzly bears, caribou and Dall's Sheep. It is also the largest non-polar icefield in the world. It is identified as being exceptional under both ecological and geological values.

Wetlands of International Importance

Wetlands are areas where water covers the soil for most of the year, and as a result are some of the most productive and highly biodiverse ecosystems in the world. They provide habitat for a large range of species and fulfill a broad range of ecological functions. They maintain both terrestrial and aquatic ecosystems, acting as circulatory systems for nutrients, water and carbon; wetlands are thought to help moderate global climate conditions. They also mitigate environmental fluctuations such as floods and erosion.

Inland wetlands are most common as riparian areas along rivers and streams, in isolated depressions surrounded by dry land, along the margins of lakes and ponds, and in other low-lying areas. Many of these wetlands are seasonal, with the quantity and timing of water determining wetland function. Even wetlands that appear dry for significant parts of the year, such as vernal pools, often provide critical habitat for wildlife adapted to breeding exclusively in these areas.

Three British Columbia wetlands have been identified as internationally significant and listed in the Convention on Wetlands, signed in Ramsar, Iran in 1971 - the Creston Valley Wildlife Management Area, the Columbia Wetlands and the Alaksen National Wildlife Area. RAMSAR is an international treaty that provides for national action and international cooperation for the conservation and wise use of wetlands and their resources. However, it does not specifically result in protection for the identified areas.

The Creston Valley Wildlife Management Area (CVWMA) received Ramsar designation in 1994. The area covers 7,000 hectares and is located in the south-western corner of B.C. It consists of Duck Lake (1,500 hectares), seventeen managed marshes, the Kootenay river and surrounding mountain slopes. The area provides habitat to over 265 bird species, 50 mammal species, 30 fish, plus reptiles, amphibians and thousands of invertebrate and plant species. The area provides an important stopover site for tundra swans (*Cygnus*

columbianus), greater white-fronted geese (*Anser albifrons*), and many other waterfowl – and may be second only to the lower mainland coast as a flyway route for numbers of migrating birds. The management area is also a regionally important site for wintering birds of prey in the B.C. Interior. The marshes form a valuable link in a chain of wetlands stretching from the Arctic Ocean to California.

The Columbia Valley Wetlands located in the East Kootenay Trench were recognized in 2005 as a Ramsar site. This wildlife management area is the longest contiguous network of wetlands in North America, covering more than 26,000 hectares and supporting over 260 resident and migratory bird species. The provincially red-listed (S2B) prairie falcon (*Falco mexicanus*) and the blue-listed (S3B,S2N) short eared owl (*Asio flammeus*) are two of the species found in these wetlands.

The Alaksen National Wildlife Area, also a Ramsar site recognised in 1982, is a 200ha area located in the Fraser River estuary south of Vancouver. The area supports internationally important waterfowl populations and also provides important habitat for several species at risk in Canada. The federal government purchased the property in 1972 in order to prevent commercial and recreational development of this vital bird habitat resulting in complete protection of the site. However, note that this is a very small portion of the IBA – Boundary Bay-Roberts Bank – Sturgeon Bank which remains largely unprotected. This Fraser River Estuary IBA (which includes Alaksen) is a shorebird migratory site of hemispheric importance. The Fraser River estuary supports over 500,000 western sandpipers (*Calidris mauri*) during migration and over 30,000 dunlin (*Calidris alpina*) in the winter. The provincially red-listed (S1,S2B) upland sandpiper (*Bartramia longicauda*), and the blue-listed (S2,S4B) american golden plover (*Pluvialis dominica*), long-billed curlew (S3B,S2N;*Numenius americanus*), and red-necked phalarope (S3,S4B; *Phalaropus lobatus*) are among the shorebirds that have been sighted in the estuary. The area also provides habitat for extremely high densities of over-wintering raptors including a high percentage of the province's bald eagle population.

Status

Wetlands are also some of the most impacted ecosystems worldwide since they tend to occur in low-lying areas suitable for agriculture and settlement, and because they can be significantly impacted by numerous activities such as removal of water, siltation, pollution, diversion and general human disturbance. In B.C., the Okanagan River has been fully channelised, and 85% of the original wetlands have been lost. The formerly important Sumas Lake wetlands are completely eradicated, and in the Fraser River delta – which remains of international significance, 70% of the delta has been diked and drained.

Threats to the Creston Valley wetlands include continued ecosystem loss, run-off from surrounding agricultural and urban areas and the requirement for continuous management to maintain the current artificial water levels that maintain the wetlands productivity.

The Columbia Wetlands face several threats including surrounding pesticide and fertiliser use which impact wetland function. Recreational impacts, especially motorized recreation such as power boats and jet skis have increased with increased tourism and settlement. Such motorized sport increases erosion, destruction and nest desertion as a result of the increased wave action on shores and nesting habitat. The renegotiation of the Columbia River Treaty between Canada and the United States may have profound effects on these internationally important bird habitats and wetlands since it may significantly influence water flow regimes in this region in future.

Current threats to the Fraser River Estuary IBA include a planned industrial port expansion, bird control at nearby Vancouver International Airport, and pollution from the mouth of the Fraser River. Disturbance has grown in recent years and includes adjacent greenhouse developments in the delta region, increasing boat traffic, hikers and beach walkers – all of which have potentially detrimental impacts on bird habitat and populations.

Raised Bogs

Raised bogs are ombrotrophic peat bogs that are raised above the level of the surrounding wetlands. Ombrotrophic bogs are those where the water necessary for the maintenance of life come only from direct precipitation - rainwater. Raised bogs are typified by acidic nutrient-poor water, two–layered peat deposits and peatland communities dominated by sphagnum moss and heathers (Ericaceae).

Burns Bog, in the Fraser River Delta of B.C., covers 3,000ha and is the largest raised bog in North America. It is globally unique because of its large size, chemistry and flora and fauna. The acidic nutrient-poor water has typically a pH of 3.5-5.5 and calcium levels of 0-3 mg/l. It is also important and scarce being a large ecosystem located in a metropolitan area.

Bogs support unique ecosystems including organisms that can survive in acidic and nutrient poor water and soils. Species in Burns bog but uncommon to the region include few-flowered sedge (*Carex paucifolia*), great sundew (*Droser angica* - a carnivorous plant), and crowberry (*Empetrun negrum*). Bogs tend to have an unusual number of carnivorous plants, a feature which is hypothesised to have evolved as an adaptation to the paucity of nutrients in the acid rich waters.

Burns Bog is also home to several endangered species including the southern red-backed vole (*Clethrionomys gapperi*), the pacific water shrew (*Sorex bendirii*), Townsend's mole (*Scapanus townsendii*), the peregrine falcon (*Falco peregrinus*) and the purple martin (*Progne subis*). Also found here are Trowbridge's shrew (*Sorex trowbriderii*), the greater sand-hill crane (*Grus canadensis*), green heron (*Butorides striatus*), bittern (*Botaurus lentiginosus*), great blue heron, trumpeter swan (*Cygnus buccinator*), California gull (*Larus californicus*), caspian tern (*Sterna caspia*), barn owl (Tyto alba), rubber boa (*Charina bottae*) and painted turtle (*Hrysemys picta*). Burns Bog is on the Pacific Flyway and provides an important stop-over for birds using the Fraser River delta.

Status

Raised bogs are valuable sources of biodiversity and homes to rare organisms and ecosystems. Peatlands are also valuable tools in the fight against climate change because they trap greenhouse gases methane and carbon dioxide. The disturbance of the bog surface increases emission of these gases.

Approximately 40% of the original area of Burns Bog has been disturbed by human activity, mainly by peat mining. Peat mining, surrounding agriculture, industry and residential developments have disturbed the natural hydrology of the bog and the bog's unique ecosystems. Much of the southern bog is occupied by a large landfill and is still privately owned. In March 2004, 2,042 ha (5,045 acres) of Burns Bog was purchased to be protected as the Burns Bog Ecological Conservancy Area, however most of the land surrounding Burns Bog has been destroyed by development, and the remaining bog is threatened by incursion of "non-bog water" which is rich in dissolved anions and cations.

Karst

Karst is an ecosystem created on soluble bedrock - typically limestone, but also dolomite, marble and gypsum. Over time water dissolves the bedrock and creates caves, sinkholes, vertical shafts, convoluted rock surfaces and disappearing and reappearing streams. About 10% of the landscape of B.C. is potentially suitable for karst formation, including the northern Rocky Mountains, Vancouver Island, Queen Charlotte Islands and the mainland coast. High rainfall areas tend to have the most interesting formations, so these occur primarily in the coastal temperate rainforest.

Karst ecosystems tend to be very productive because of dissolved minerals, fractured bedrock and well-drained soils – all of which encourage deep rooting and high growth rates of associated plants and trees. Karst ecosystems therefore tend to have both high diversity, from a species richness perspective, and also provide habitat for a number of rare plants including ferns, a recently discovered orchid species on Vancouver Island, and other rare and endemic species associated with limestone.

Within the underground cave systems created by water running through the limestone unique 'troglobites' exist– these ancient invertebrates appear to have survived the last ice-age by inhabiting the caves and they are totally dependent on the microclimates found underground. Other species – troglophiles – are capable of using caves for part of their life-history and can include some salamanders, spiders and crickets. Other species – 'trogloxenes' use caves for a critical part of their life-history and include roosting by bats and denning by bears.

Karst ecosystems can also affect more distant biodiversity values such as increasing the productivity of adjacent salmon streams: research from Alaska has indicated that karst landscapes produce cool, stable streams which have ideal properties for fish spawning, and that leaching of calcium carbonate buffers acidic streams (Bryant and Swanston 1998). Aquatic insect populations also tend to be more diverse within karst-fed streams and karst itself can result in more sites for fish to rest, breed and avoid predation.

Karst ecosystems are often associated with cultural values of First Nations, and there is also high recreational use in some areas by cavers.

Karst ecosystems occur world-wide where suitable conditions exist, and tend to have unusual ecosystems wherever they are located.

Status

No systematic survey of the condition of karst in BC has been undertaken, so overall status is unknown. However karst ecosystems in B.C. are highly vulnerable to disturbance – road building and logging practices can result in direct damage to sinkholes, under-surface water systems, and potential collapse of the entire karst ecosystem associated with caves. Indirect damage such as sedimentation from fine-textured soils and blockages caused by debris can alter the functioning of the ecosystem.

Hotsprings

Hotsprings are ecosystems created by pools of very hot, sometimes near boiling water which is heated from deep within the earth. Water becomes heated when it percolates down to meet hot rocks in the earth's crust, or, in volcanic areas when the water encounters hot volcanic magma.

Although hotsprings occur on every continent, within Canada they occur primarily in the mountainous regions of B.C. and Alberta. Each hotspring habitat is both isolated and localised. This means the ecosystem is effectively separated from surrounding habitat by the harsh environmental conditions within the hotspring (very high temperatures, little or no oxygen, and large amounts of dissolved minerals) and restricted to very specific locations distributed throughout the region.

A number of different types of unique species can live within and in the vicinity of hotspring pools. For example, species may be remnants of the warmer climate that followed the last ice age. Or alternatively, because environments within these steaming pools are very harsh, organisms that live in hotsprings often occur in no other environment because of the unique adaptations needed to survive the physical conditions. As a result hotsprings tend to be home to very simple but unique ecosystems and species.

Microbe communities within hotsprings can be unique to their environment and sufficiently simple that they have no interaction with other plants or animals. Instead, they utilize inorganic energy supplied by the dissolved minerals in the water. Recent research into these microbe communities has been supported by the search for biotechnology since there is an interest in how these organisms survive under such extreme conditions and how humans can possibly use similar mechanisms.

There are a number of specific examples of species which are found solely, or primarily, within hotspring ecosystems. The Banff Springs snail (*Physelia johnsoni*), is endemic and lives only in five hot springs within Banff National Park - it has the distinction of being the most "at risk" species in the park. This species has been studied for a number of years and is known to undergo massive annual population fluctuations thought to be related to water chemistry levels fluctuating during the course of the year, which in turn affects the primary food source of the snail (Lepitzki 2002).

In B.C., several hotsprings are also the locations of endemic species. Liard Hotsprings is home to a snail, the hotwater physa (*Physella wrightii*), and the plains forktail (*Ischnura damula*), a small damselfly which lives nowhere else in British Columbia. The Fairmont Hotsprings is home to the last four clumps of red-listed (S1) southern maidenhair fern (*Adiantum capillus-veneris*) in Canada which cling to a single ledge. Other interesting species include the blue-listed (S2S3B) orchid *Epipactis gigantea* and the blue-listed (S3) marsh muhly (*Muhlenbergia glomerata);* BC CDC*).*

Status

Hotspring ecosystems have been significantly impacted within BC and world-wide by development activities. Hotspring ecosystems are very vulnerable to human activities because they provide such specific and easily altered conditions, and because they tend to be small in size and isolated. In addition, even relatively isolated hot springs found in many locations in B.C. attract frequent human visitors interested in bathing in hot water in a wilderness setting. The potential impacts of this disturbance vary with the original uniqueness of the ecosystem and with the level of development but effects are known to be significant in many regions. For instance, in the Banff National Park hotsprings the

endangered snail has been exposed to chemicals such as deodorants and insect repellants from the skin of humans, and is thought to have resulted in loss of the snail from some of its former habitat. In addition, mats of vegetation in the hot springs are the only known place where these endangered snails lay their eggs and these mats are easily damaged by human disturbance. The effects on lesser studied species and ecosystems remain unknown.

Serpentine Soils

Serpentine Soils are derived from serpentine and other ultramafic rocks (rocks typical of the earth's mantle) which contain hydrous magnesium iron phyllosilicate and other elements such as chromium, manganese, cobalt and nickel. Soils derived from serpentine are toxic to many plants because of these high levels of minerals. In addition, serpentine soils are also characterized by low levels of potassium and phosphorous and a low calcium/magnesium ratio - minerals that are important for plant growth. As a consequence, serpentine ecosystems are often non-forested and the unique plants that typify serpentine soils are often slow-growing (Kruckeberg, A.R. 1969).

Serpentine, or ultramafic soils occur world-wide in areas of tectonic plate activity, and they cover less than 1% of the earth's surface. Hence, in B.C. serpentine soils are found from Tulameen Lake in the south to as far north as Atlin, with distribution following a line of tectonic activity along the centre of the province.

Serpentine soils are harsh environments and it takes special adaptations for plants to succeed in this habitat. Some serpentine soil areas are termed "serpentine barrens" because they are typified by a very low density cover of trees and shrubs. They are unique however because a number of endemic species and varieties of more common species are adapted to these soils and so characterize this unique habitat. In a study on Grasshopper Mountain in southern B.C., 28% of the recorded species were found solely or primarily on serpentine areas – suggesting that these soils contribute greatly to the local and regional species diversity (Lewis and Bradfield Undated). Examples of endemic or indicator plants include Lemmon's holly fern - *Polystichum lemmonii* which is found on Mount Baldy in the Okanagan and is COSEWIC designated as threatened (S1S2B), while Mountain Holly Fern, *P. scopulinum*, is known only from the Tulameen River valley and is provincially red-listed (S1).

In addition to endemic species, serpentine ecosystems often contain significantly fewer non-native or invasive species than surrounding ecosystems.

Some serpentine-adapted species are termed "hyperaccumulators" because they concentrate metals such as nickel within their tissues. Hyperaccumulator plants have proven useful in extracting heavy metals from soils in environmental remediation projects and in extracting valuable minerals such as nickel from the soil.

Status

No systematic survey of these ecosystems has been undertaken province-wide, so overall status and condition is unknown. However serpentine soil areas and their ecosystems are vulnerable to several pressures. Serpentine soils are often regarded as "waste land", but once disturbed, these soils are highly vulnerable to erosion and the invasion of introduced plants. Farming on these soils has required introducing heavy fertilization, which encourages introduced species that crowd out endemic species. In some cases the generally poor timber present has been harvested and the site fertilised in an attempt to replace the native ecosystem entirely. Gold mining has also impacted surface soil in an attempt to reach gold-

bearing rocks and has resulted in a reversal of drainage patterns. General development through urbanisation has also caused direct damage and erosion.

Rare Terrestrial Ecosystems

There are 160 red-listed plant communities in British Columbia. Of these, one has been identified as of global concern by the Conservation Data Centre (i.e. a rank of G2 or G1), and the remaining 159 are noted as having insufficient distribution data to determine global ranking (B.C. CDC).

The one plant community identified as globally imperiled and red-listed in B.C. is the Douglas-fir / Douglas maple / step moss plant community (*Pseudotsuga menziesii / Acer glabrum / Hylocomium splendens)*. This community is found in the sub-boreal spruce zone in the central interior. It is located in small patches and is restricted to mid and upper slope positions on south and west-facing slopes.

Appendix 4 gives a list of the globally 'vulnerable' ecosystems (G3) identified by the CDC for B.C..

Alternatively, the NatureServe (http://www.natureserve.org/) lists identify 22 globally critically imperiled (G1), 51 imperiled (G2), and another 86 communities that are globally vulnerable – all of which are identified as existing in B.C.. This large discrepancy is due in part to the status of the lists within B.C. and western North America – B.C. is currently going through the process of upgrading the CDC lists and cross-referencing ecosystems with the lists from NatureServe (C. Cadrin pers. comm. B.C. CDC).

In addition to these listed plant communities a number of broader ecosystems can be considered rare in B.C. from a global context. These include the coastal temperate rainforest, the inland temperate rainforest. Plus, at a smaller scale, Garry oak ecosystems and antelope-brush in the Okanagan.

At the broadest of scales, B.C. is home to both the globally rare coastal temperate rainforest and the inland temperate rainforest. The perhumid coastal temperate rainforest of British Columbia is part of a biome that historically was found on five continents, and in North America stretched from Alaska to northern California. Approximately 2-3% of the world's temperate forest lands can be classified as coastal temperate rainforest, so this system has always been globally rare. The North American region originally represented about 50% of the original forest type globally, and today approximately 44% of the North American rainforest region has been substantially developed. Much of the remaining intact area is found in B.C. (Schoonmaker et al. 1999).

The inland temperate rainforest is even more globally unique. This area stretches from the headwaters of the Fraser and Columbia rivers in B.C. into northern Washington, Idaho and Montana. It is the only place in the world where temperate rainforests are found so far from the ocean.

The Antelope-brush (*Purshia tridentata*) community is one of the four most endangered plant communities in Canada (Dyer and Lea 2004). These Antelope-brush plant associations occupy less than 1 % of their former range. They support more species at risk than any other ecosystem in B.C. but we are still losing 2% of this habitat (90 hectares) annually. None of these plant communities are close to their original condition with healthy cryptogamic crust, as most of the surviving habitat is severely impacted, mostly by grazing

(G. Scudder pers. comm.). These rare grasslands recover slowly from disturbance due to slow plant growth and high soil sensitivity.

Garry oak (*Quercus garryana*) ecosystems are found on southern Vancouver Island, some Gulf Islands, and the Fraser Valley in B.C. This rare plant community is also one of the four most endangered ecosystems in Canada. Fourteen vertebrates associated with this endangered ecosystem are red-listed (12 globally imperiled), as are 18 invertebrate taxa. Ten percent of the 59 vascular plants are also at risk including the globally imperiled (S1) golden paintbrush (*Castilleja levisecta*) and white meconella (S1; *Meconella oregona*). Up to 82% of the herbaceous cover is invasive species including scotch broom (*Cytisus scoparius*) and invasive grasses (BC CDC).

Status

In both the coastal and temperate rainforests, the greater impact remain harvest of old-growth forests. Much of the forest on the most productive sites on the coast has been harvested already (Holt 2004; Holt and Mackinnon 2007). On-going harvest remains a significant threat particularly in the interior where approaches for ecosystem-based management are not being developed to date.

The greatest threat to Antelope-brush plant communities is complete loss as a result of vineyard and other agricultural and rural developments. Other associated threats include fire suppression which has allowed the invasion of plants that successfully out-compete the Antelope-brush association of plants. Roads fragment the landscape and all terrain vehicles damage communities and encourage invasive species spread.

Threats to the Garry oak rare plant community include habitat loss due to urbanization, fire suppression and the invasion of exotics. Fire suppression has encouraged the invasion of woody species, including Douglas fir (*Pseudotsuga menziesii*) that create a closed canopy which tends to crowd out the Garry oak association of species and encourage the invasion of shade-tolerant invaders.

Marine Mammal Haulouts

Marine mammals inhabit the entire coast of British Columbia, and a number of species have specific requirements for terrestrial habitat. This habitat is used both for resting and for breeding. Haulouts often encompass very small areas, and are therefore both critical for marine mammal populations and also vulnerable to disturbance.

Marine mammal haulouts are often single rocks, islets or remote islands that are used by sealions (California and Steller), fur seals and harbour seals as haulout sites for resting and socialising. Harbour seals are capable of resting on small rocks, or on the seabed when terrestrial sites are unavailable, but sealions require these haulout areas for resting. Of particular importance are the major breeding haulouts, or rookeries, for Steller sealions that can be found around northern Vancouver Island, Hecate Strait and around Queen Charlotte Islands. Harbour seals do not breed in large groups, but still require suitable haulout spots for pupping.

Status

Vulnerability of these sites is high because they are small areas, and the species tend to be highly vulnerable to general disturbance from boats or people. These sites are also

potentially extremely vulnerable to single-events such as oil spills, which have the potential to devastate local populations of these mammals.

Saline Lakes

Saline or 'salt' lakes have been defined as those having more than 3g/L salt content, in contrast with lakes designated as 'freshwater' which have less than 3g/L of salt. Saline lakes occur on all continents and are widespread in dry environments.

The southern interior plateau of B.C. is dotted with small saline ponds usually less than 1 km^2 in area, particularly in the Okanagan and Kamloops areas and throughout the Fraser Plateau. The 'salts' include sodium, magnesium, carbonate, bicarbonate and sulphate and salt lakes are formed where evaporation is greater than rainfall. Because these small ponds have no outlet stream the dissolved minerals become concentrated as evaporation of water increases throughout the summer. Often by the end of summer the lakes are surrounded by crystalline salts and some areas dry up completely resulting in small salt flats. The Maritime Grasswort (*Salicornia maritime*) that grows in some ponds adds a red colour, and Alkali Saltgrass (*Distichlis spicata*) can add a yellow to these crystalline rings. Saline lakes typically have few or no submergent plants and few emergents.

The unique hydrology and species composition of saline lakes distinguish them from the surrounding habitat. They often are alkaline (i.e. have a high pH value), have extremely high nutrient levels, trace metals and low oxygen.

A number of species are specifically adapted to the conditions in saline lakes including dragonflies and chironomids (midges) and a number of other invertebrates including the brine shrimp (*Artemia franciscana* Kellogg). All those adapted to live in this environment have a special ability to regulate their osmotic and ionic internal milieu below the environmental level. These lakes are enemy free space for many invertebrates. Some saline lakes like Mahoney Lake (a B.C. Ecological Reserve), are meromictic (i.e. have layers that don't mix), with a distinct bacterial plate that is vulnerable to disturbance.

In some salt lakes research has shown strong relationships between the salinity, invertebrate productivity and bird numbers that results in a very productive ecosystem. These can be particularly important in winter as these areas freeze less easily than freshwater lakes. In B.C. salt lakes are important habitats for migratory and nesting species such as phalaropes, grebes, gulls, pelicans, swans, and plovers.

Status

Wetlands in general have been significantly impacted by development and drainage, particularly in areas such as the southern interior where agricultural and rural development is prevalent. In addition, climate change poses a particular threat to saline lakes because they are typically shallow lakes and not buffered from air temperature changes. Pollution and the introduction of exotic species are also threats to saline lakes. Salt lakes are also an economically important source of minerals (especially halite, and others such as uranium, zeolites, lithium and borax).

Fishless Lakes

"Fishless Lakes" is a term applied to freshwater lakes that due to historical physical isolation from other waterbodies do not contain fish and have not been seeded with either native or non-native fish. Fishless lakes occur throughout B.C. but are particularly common in mountainous regions where fish from downstream are prevented from colonising by impassable barriers such as waterfalls or canyons, or on plateaus where lakes exist in isolated conditions with no inflow or outflow.

Fishless lakes are important to the maintenance of biodiversity. Fishless lakes and headwaters provide novel environments for a number of native species because they are a refuge from native (and non-native) predatory fish. The community composition in fishless lakes is therefore different from that found in lakes with fish, and these areas may provide significant source populations for invertebrates and vertebrates. Because of their isolation they may also have an important role as sources of genetic variability.

The major threat to 'fishless' lakes is the introduction of fish. Trout are predatory and their introduction to previously fishless ecosystems can alter the distribution, abundance and interactions of native species and communities (Knapp et al. 2001; Tyler et al. 1998).

Changes due to fish introduction include the decrease or even elimination of some large benthic macroinvertebrates and large zooplankton as they are selectively hunted by the fish. As a result, smaller macroinvertebrates and zooplankton become more common and can result in significant cascading impacts throughout the aquatic ecosystem.

The introduction of fish can result in behavioural changes in the invertebrates of the lake. Invertebrates may become less active and seek refuge more often. This affects their availability as prey and their own opportunities to feed. The introduction of fish can also increase algal production as the increased predation on invertebrates regenerates nutrients previously unavailable in a naturally fishless lake. The increased algae can decrease the availability of oxygen to the ecosystem, causing further ecosystem changes. Introduced fish may also introduce otherwise unknown diseases into some lake ecosystems.

Introduced predatory fish may be responsible for numerous amphibian population declines and local extinctions as well as changes in the structure of amphibian communities. Trout introductions may fragment and isolate populations of amphibian species. Amphibians may no longer be able to move from lake to lake when some lakes are populated by predators, resulting in changes to metapopulation dynamics, and possible loss from entire landscapes (Pilliod and Peterson 2001).

Affected species can include relatively common species such as long-toed salamanders, Pacific treefrog and Columbia spotted frog – population changes have been demonstrated for each of these species with introduction of fish (McGarvie Hirner 1998). These species may be affected directly through predation, or indirectly through changes in food supply.

Of particular concern are populations of species which are already at risk, have generally low population numbers or limited distribution. An example is the tiger salamander (*Ambystoma tigrinum*) which is endangered in Canada and red-listed in B.C. and inhabits the southern Okanagan and Similkameen (Richardson et al. 2000). Adult tiger salamanders migrate to breeding ponds from terrestrial habitats during spring and then return after breeding. Newly metamorphosed tiger salamanders migrate from the breeding ponds to upland terrestrial sites in mid to late summer and their terrestrial dispersal is limited. Trout and salamander larvae are both opportunistic carnivores and act as competitors for the same food. This competition results both in fewer salamanders and fewer prey species for

both salamanders and trout. It is presumed that introduction of fish into these systems has impacted the former range of the tiger salamander, and is likely a significant barrier to recovery of the species in the long-term. Neotenic[5] populations of tiger salamanders are particularly vulnerable to predation. In addition, terrestrial impacts are also possible as species such as amphibians which are prey for terrestrial predators such as garter snakes become reduced.

Status

Loss of naturally fishless lakes has been significant. For example: approximately 95% of an estimated 16,000 mountain lakes in the western United States were fishless prior to stocking but 60% of the total number of lakes and 95% of deeper (3 m) and larger (2 ha) lakes today contain introduced trout. A similar decrease in the distribution of naturally fishless lakes is estimated to have occurred in British Columbia (McGarvie Hirner 1998).

Naturally fishless lakes differ in their sensitivity to fish introductions – when habitat conditions that provide natural prey refuges exist (e.g. certain types of vegetation are present) then the effects of predation can be mediated.

Long-term studies on the effects of introduced fish show that even when the introduced fish populations are extirpated their impacts on community structure may continue up to a decade after the last fish introduction. In other lakes, the fish become reproductive and become a permanent predator in the lake, even spreading to other previously fishless lakes in a watershed. When lakes and ponds are not suitable for fish, some have been poisoned and then aerated to improve the survival of introduced game fish. This practice has effectively eliminated the fishless lake ecosystem from many areas.

Climate change will also affect these lakes. This will, undoubtedly, further change the species composition and ecosystem structure of these lakes.

Microbialites

Microbialites are fossilized mats formed by microbes, primarily cyanobacteria. Many examples date from the Precambrian era, but some microbialites are still home to living microbes today and two examples are found in B.C.. They are both rare and vulnerable to disturbance due to their fragility.

Cyanobacteria (previously known as blue-green algae) were perhaps the first living organisms on the planet. Cyanobacteria feed on water, sunlight, and carbon dioxide and produce oxygen and calcium dioxide (lime). In fact, it is thought that cyanobacteria may have been responsible for producing enough oxygen to allow the evolution of more complex organisms on earth.

Cyanobacteria create microbialites by trapping sedimentary grains, binding the grains in a surface mucous, and then cementing them with lime into thin layers. The stromatolite structures become enlarged as the bacteria grow vertically to best reach the sunlight necessary for photosynthesis. Microbialites come in a variety of shapes: columnar, conical, branching, or stratiform. Over millennia, these structures became fossilized limestone and

[5] Larvae do not metamorphose but continue to breathe through their gills. They sexually reproduce although basic appearance does not change from a larvae. These salamanders can become larger than individuals that metamorphose, reaching totals lengths of 15 inches in some circumstances.

microbialites today have a very definite laminated structure and appearance. Fossilized bacteria sometimes found in microbialites are evidence of some of the earliest forms of life from approximately 3 and a half billion years ago.

Status

Microbialites occur all over the world, most often in hypersaline or marine environments. Those that occur in British Columbia however, are found in freshwater lakes: Kelly Lake adjacent to Downing Provincial Park where the stromatolite structures are only 1-2cm in height and in Pavilion Lake in Marble Canyon Provincial Park where they reach 2m in height. The Pavilion Lake microbialites are the largest freshwater microbialites known and contain both cyanobacteria and diatoms (Laval et al. 2000). These examples have been studied by exobiologists from NASA, because the cyanobacteria in this lake are considered to be similar to those that might be expected on Mars – if there is indeed life on Mars.

Other examples of freshwater microbialites in Canada exist, with perhaps the best-known found in Lake Superior, near Schreiber, Ontario. This example however has been worn down to the extent that they now appear only as circles on the rock (www.ontarioparks.com). Only the site in Marble Canyon Provincial Park is protected from collectors and disturbance. This protection is essential for the survival of these sites that provide a window on the origins of life on earth.

Geographically Marginal Populations

Geographically marginal or peripheral populations are those at the edge of a range for a species. Genetic variability is particularly important because it allows evolution of a species. As conditions become 'marginal' for a particular species there is growing evidence that individuals have a genetic make-up that is different from individuals in a central or core population.

Geographically marginal populations are the result of the geographic isolation from a core population. Through mechanisms such as glaciation, massive permanent flooding or mountain upheavals, the larger population is divided into two non-interbreeding groups. Eventually, if isolation of the two groups persists, natural selection results in two different species - this process is called allopatric speciation. However, even if the two species are able to interbreed, the marginal population may contain genetic information that has been lost from the larger population[6].

It is suggested that evolutionary change comes primarily from these geographically marginal populations; marginal populations of plants and animals are therefore very important to the overall biodiversity of a region and have been identified as 'evolutionary significant units'. In particular, it is suggested that conserving peripheral populations may be one of the most important approaches to maintaining the adaptive potential of species (Yakimowski and Eckert 2007).

The large size and biophysical variability of British Columbia results in many species existing as peripheral or marginal populations in this province. For example, many bird species reach the edges of 'suitable habitat' in B.C.. On the southern edge of B.C. many species are at the northern edge of their range with the core of the species range in the United States.

[6] Glacial refugia are marginal populations that have remained isolated overtime, resulting in endemic species or subspecies. These are dealt with separately below.

Alternatively, northern species reach the edges of their range in the northern sections of the province as conditions become too harsh, and some arctic species may reach their southern extremes in B.C..

Over 1300 species have peripheral populations in B.C. (Bunnell et al. 2004) however not all of these have the genetic variability that result in higher conservation value. Examples of species in B.C. with geographically marginal populations, and which may have high genetic variability, include many of the COSEWIC-listed and provincially Red-listed species which are in essence marginal populations, or peripheral species. Many of these species are confined to the South Okanagan-Similkameen (e.g. sage thrasher (*Oreoscopetes montanus*), morman metalmark (*Apodemia mormo* (C.&R. Felder)) G5S1; Behr's hairstreak (*Satyrium behrii columbia* (McD.)), G5S1; and the Gulf Islands (e.g. sand-verbena moth (*Copablepharon fuscum* Trombridge & Crabo)), G1G2S1; propertius duskywing (*Erynnis propertius* (Scudder & Burgiss)), G5S2S3; Edith's checkerspot (*Euphydryas editha taylori* (Edw.)), G5S1 are marginal populations. For maps of the butterflies, see Guppy & Shepard 2001).

There are also peripheral species or marginal populations in the northern regions of B.C.. These include the eastern pine elfin, *Callophrys niphon* (Hubner) which is a butterfly that occurs right across Canada and is ranked G4 S4S5 and in B.C. is confined to the NE (Guppy and Shepard 2001). In the northwest of B.C. the phoebus apollo, *Parnassius phoebus* (Fabricius) is a butterfly that occurs in Siberia, east across Alaska to western Yukon, and enters B.C. only in the NW corner, and ranked G5 S1S3 (Guppy and Shepard 2001). There are many other insects that show a similar distribution, for example the mirid *Polymerus vulneratus* (Panzer) (Schwartz et al. 1991) so far recorded from across the whole of the northern palaearctic, through Alaska, Yukon and Northwest Territories, and in B.C. only from Log Cabin, Tetsa Bridge and the Tatshenshini River region.

In many taxa, island populations are designated as distinct geographical subspecies because they are more clearly isolated and taxonomically recognisable. Both the Queen Charlotte Islands and Vancouver Island are home to a wide array of subspecies. The Queen Charlotte Islands was historically the home to Dawson's caribou, a small forest caribou subspecies – the last individual of which was shot in 1908. Other mammal subspecies include the largest subspecies of black bears found in North America, and a subspecies of ermine which was historically relatively common but recent surveys have not found any individuals and it is suspected may now to be extinct or in extremely low numbers. In addition, there remains a large number of bird subspecies occurring on the Islands, including subspecies of northern goshawk, Stellar's jay, hairy woodpecker, pine grosbeak, and northern saw-whet owl. Vancouver Island is also home to a number of separate species or subspecies. These include the endangered (S1) Vancouver Island Marmot (*Marmota vancouverensis*), and the Vancouver Island wolverine (*Gulo gulo vancouverensis*) which had a historical distribution on the Island though no individuals have been observed since 1982. Bird subspecies found here include the endemic white-tailed ptarmigan and the northern goshawk subspecies. A number of butterfly subspecies are also known to inhabit Vancouver Island, as are a range of plant species.

Not all marginal populations have increased conservation value – the conservation value of a marginal population depends on the genetic divergence from other populations. True 'disjunct' marginal populations (see below) are physically separated, rather than simply on the edge of ranges. Although they tend to have reduced genetic diversity, they often have genetic variants that are rare or unique to an area. These unique variants have high conservation value. In many cases however the genetic information required to test this is

unavailable. However, it is also possible that all these populations may become important in time with collapse of species and retraction to range edges (Lomolino and Channell 1995).

Endemics and Disjuncts

As outlined in the 'geographically marginal populations' section, genetic diversity is important from the perspective of maintaining the full potential of a species to adapt and evolve in the future. Where populations have been geographically isolated over significant periods of time, 'relict' species occur. These may be endemics (found only in that local area) or disjunct populations of species found elsewhere. In B.C., there are a number of areas where significant numbers of such species occur together and these areas are of particular value from a biological diversity and conservation perspective.

For instance, glacial refugia in British Columbia contain greater numbers of 'relict' species than the surrounding areas. Glacial refugia are areas that were not glaciated in the last glaciation of North America. The Cordilleran icesheet covered land in B.C. from the Pacific Ocean to the Rocky Mountains, and from northern Washington to southern Alaska and most species were pushed further south as the glaciers crept south. A few areas are hypothesised to have remained ice-free during this period and because they were isolated, the relict populations and the southern migrants evolved separately and in some cases became separate species. Typically, less mobile species such as plants or flightless invertebrates are more likely to be found as endemics, because populations are more easily isolated.

The Queen Charlotte Islands and the Brooks Peninsula on Vancouver Island are two areas in B.C. hypothesised to be major glacial refugia. The Queen Charlotte Islands is an archipelago of 250 islands which have been termed "the Galapagos of the North" because of the high levels of biodiversity and relict species occurring there. There are a number of endemic species associated with the Islands, including 5 vascular plant species, 3 bryophytes, 4 insects, 2 liverworts (hepatics) and 5 mosses plus some interesting disjuncts (Appendix 5).

Climatic modeling suggests that the glacial refugia were likely small sites on protected south-facing exposures away from the influence of glaciers and avalanches which provided sufficient growing opportunities to maintain small plant populations. Endemics and disjunct populations on the Islands today are often associated with limestone bedrock (on karst) which suggests these areas were also favourable locations for growth during the ice-age. It is also hypothesised that what we know as alpine communities today occupied refugia close to sea-level during the last ice-age. Some of the research into refugia has been informed by studying similar ecosystems which can be found today on the 'islands surrounded by a sea of ice' called nunataks – mountain tops which poke through large ice sheets in northern regions.

The Brooks Peninsula on Vancouver Island has also been identified as a probable glacial refugium – it is hypothesised that the higher elevations of this region escaped ice cover while the lower elevation areas remained ice covered. Evidence that this occurred includes that soils at higher elevations tend to be 'older' while lower elevation soils tend to be much younger in origin. On the peninsula there are a number of the so-called 'Queen Charlotte Island endemic' plant species including nine plants with restricted range (endemics) plus a number of species occurring as disjunct populations to those found further north. In addition, a number of disjunct populations of invertebrates are also found. High elevation

plant communities also provide evidence for a refugium – with alpine and subalpine communities present that resemble those found on Queen Charlotte Islands today.

There are also a large number of fish that can be included in this category (see McPhail 2007). Aquatic refugia occurred, in similar ways as terrestrial refugia described above, during the last ice-age. One such area was centred on the Chehalis River in Washington State (the Chehalis Refugium). This area contributed two unique elements – the Salish sucker and Nooksack dace - to the fish fauna of B.C.. The Salish sucker has no formal taxonomic status but is an evolutionary significant unit and both are of conservation concern. Across B.C., various pockets of geographic isolation and subsequent recolonisation from different areas resulted in species (e.g. longnose dace, *Rhinichthys cataractae*) that are slightly differentiated in different areas but have no taxonomic status; however they sometimes differ in life history or habitat use and, thus, are of management concern. Indeed, much of the within-species diversity found in B.C. freshwater fish is a product of this process of range fragmentation and genetic divergence followed by recolonization from different refugia (McPhail 2007).

Another interesting phenomenon occurred as the icesheets retreated – the land rebounded from the immense weight, and the rising of land further separated populations of anadramous species such as Pacific lamprey, (*Lampetra tridentata)* and longfin smelt, (*Spirinchus thaleichthys*) in freshwater. Cut off from gene exchange with other populations and landlocked in new environments, they rapidly diverged. In some cases this process produced "biological species" that are unique to British Columbia (Cannings and Ptolemy 1998, McPhail 2007). A well researched example is the complex genetics of sticklebacks in B.C.. For example, in six lakes on three islands in the Strait of Georgia, there are two forms of the three-spined stickleback. 'Benthics' are stout and wide-mouthed and forage around the margins of the lake while 'limnetics' are slender and slim-mouthed and forage in the open waters of the lake. Studies have shown the two forms are genetically distinct with a very limited amount of hybridization between the forms. The genetic differences are particularly interesting because they are very recent (since the last ice-age), and it is thought that the pairs diverged independently in each separate lake from a common ancestral stickleback. If correct, this shows a very interesting case of parallel evolution in this species. Alternatively, the genetic variation may have come about from a more complex series of lake colonisation events caused by a number of different sea-level changes. Whatever the mechanism, all these species are now recognised as single lake endemic species (Rundle et al. 2000). Similar patterns are found in some other groups, such as lampreys, smelts and sculpins and provides a view into 'evolution in action'. These specific examples are unique to B.C.

Another example is the Pygmy whitefish that is generally considered to be a glacial relict. They occur across northern America in scattered populations, usually in deep nutrient-poor lakes. However, in two nutrient-rich lakes in B.C., a 'giant' pygmy white fish exists. These forms are known only from two populations in B.C. and nowhere else across the whitefish's range.

Status

Both the Queen Charlotte Islands and the Brooks Peninsula are of international significance because they provide habitat for relict species – endemics, disjunct populations and subspecies (see Special Genetic Elements below). This means they provide a home to an important component of the genetic biodiversity of B.C. and of the planet. Their island surroundings also mean they are vulnerable. Both Queen Charlotte Islands and Vancouver

Island are significantly impacted by invasive species - for example the introduced black-tailed deer on Queen Charlotte Islands have significantly altered the ecology of the entire rainforest ecosystem, with significant cascading impacts to a large number of individual species. Forestry and mining have the potential to disrupt these populations, and increasing tourism and recreation can increase pressures on these often small and potentially vulnerable populations. In addition, island populations are particularly vulnerable to relatively rare and unusual but catastrophic influences such as tsunamis or hurricanes.

The variety of fish examples are subject to a number of potential impacts, including habitat loss. A significant issue relating to conservation of these 'species' is the lack of taxonomic recognition for many of these examples, resulting in lack of protection for this important genetic diversity (MacPhail 2007). Although the mechanisms exist to list subspecies and geographically or genetically distinct populations under SARA and the recently amended Wildlife Act, much subspecies taxonomy is old and contentious, and our knowledge of distinctive populations incomplete. Therefore, these provisions are used sparingly by assessment organizations such as COSEWIC or the Conservation Data Centre.

Special Genetic Elements

In addition to the genetic special elements highlighted under 'geographically marginal populations' and 'endemics and disjuncts', B.C. is also home to a number of genetic elements that are not sufficiently diverse to be identified as species or subspecies but remain important genetic variation. In particular, approximately 20% of the COSEWIC list is focused at the level lower than species. A full list from B.C. is provided in Appendix 3.

Some examples with particularly important conservation implications are described:

A number of different ecotypes and populations of caribou are COSEWIC listed (Appendix 3). Of these, the mountain caribou (southern ecotype: *Rangifer tarandus*) is considered one of the most endangered mammals in North America. The entire population of the B.C. endemic ecotype is about 1,900 animals. This species is unique in its distribution and adaptation to the interior rainforest of British Columbia – foraging primarily on arboreal (tree-living) lichens it lives in old-growth forests from valley bottoms to mountain tops. Its life-history strategy has been to inhabit continuous forested habitats and avoid habitats that have high densities of predators. However, habitat loss through forest harvesting and road building have resulted in predators moving into its habitat, which is one factor influencing its recent dramatic decline.

Another example is the Kermode bear - a colour morph of the typical B.C. black bear that has two copies of a recessive gene that can result in a white or cream-coloured coat. The whole population of bears on the midcoast has the gene, however the highest densities of white or 'spirit bears' are found on Princess Royal and Gribell Islands where First Nations traditional ecological knowledge has suggested that around 1 in 10 bears are white. This high density of bears is a result of relative population isolation which allows an increased number of bears to express the recessive gene due to relatively high levels of inbreeding.

Pacific salmon in B.C. also provide examples of genetic diversity at the level of populations. There are six species of salmon on the B.C. coast, with each comprising hundreds of different 'stocks' - each geographically isolated by returning to specific streams and watersheds for spawning. These stocks are genetically distinct, and each is finely adapted to its specific environment such as water temperature, flow rate and chemical components. Hundreds of these stocks are already thought to have become extinct as a result of watershed disturbance and development. This loss has huge implications both to the

resilience of salmon overall, and for cascading impacts throughout watersheds. Loss of genetic resilience also has serious implications in the face of climate change.

Salmon are the species most well known for having interpopulation diversity – however the conditions and processes that created this diversity also affected many other native fish species in B.C., and they are every bit as subtly adapted to their local environment as are Pacific salmon.

Major Hybridization Zones

It has been suggested that in North America there are 13 'suture' zones, or zones where there is overlap between major biotic groups and where some 'species' tend to hybridize (Remington 1968). The idea is interesting because it suggests that major evolutionary 'breaks' and areas of hybridization occur in particular geographic locations, and so sheds light on important patterns of evolution and how it interacts with landscape patterns. The proposed hybrid or suture zone for B.C. extends up from the southeast corner of the province into the central interior and was proposed on the basis of the channelling effects of mountain ranges as species moved across the landscape because of global climate shifts.

More recent analysis has supported the existence of the suture zone in BC (Swenson and Howard 2005) and further emphasises the hypothesised general importance of geographic barriers to dispersal and climate change in species evolution.

There are a number of interesting examples of hybridization in B.C.. For example, the northern flicker (*Colaptes*) exists across North America with red-shafted and yellow-shafted subspecies in most regions. However, in a band stretching from B.C. down into Texas 95% of the flickers found are hybrids between these two (Short 1969).

For tiger swallowtail butterflies, the Okanagan and Kootenay valleys of B.C. are the only place in North America where four species of tiger swallowtails occur together, and only in this location two of these species are also known to hybridize (Brower 1959).

Another example is for winter wrens in an area close to Tumbler Ridge. This specific location is the only place in North America where the eastern and western forms of winter wren co-exist (D. Irwin Undated). These species differ in both songs and genetics, but are not known to interbreed though it is hypothesised that over time they may become reproductively isolated.

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Appendix 1. International Bird Areas in B.C..

Highest ranked sites are at the top of the list. Specific details for each area are available on the www by clicking the link in the table.

IBA site name	Number of species meeting the following thresholds			Score
	Global	Contin.	National	
Boundary Bay - Roberts Bank - Sturgeon Bank (Fraser River Estuary),B.C.	15	2	1	50
Baynes Sound,B.C.	7	2	3	28
Scott Island Group,B.C.	5	0	8	23
Barkley Sound,B.C.	6	0	2	20
Lambert Channel/Hornby Island Waters,B.C.	5	2	1	20
Englefield Bay Islands,B.C.	6	0	1	19
Moore and Byers Islands and Banks,B.C.	5	0	3	18
Little Qualicum Estuary to Nanoose Bay,B.C.	5	0	3	18
Duke of Edinburgh Ecological Reserve,B.C.	4	0	4	16
Hippa Island,B.C.	4	0	1	13
Skincuttle Inlet Islands,B.C.	3	0	4	13
Rankine and Langtry Islands,B.C.	4	0	1	13
Solander Island and Brooks Bay,B.C.	3	0	4	13
Sidney Channel,B.C.	2	2	2	12
Frederick Island,B.C.	3	0	3	12
Anthony Island,B.C.	2	1	4	12
Cleland Island & Southeast Clayoquot Sound,B.C.	3	0	3	12
Cowichan estuary,B.C.	3	0	2	11
Kyuquot Channel Islets,B.C.	2	0	4	10
Ramsay and Northern Juan Perez Sound Islands,B.C.	3	0	1	10
Big Bay south to Delusion Bay,B.C.	3	0	1	10
Creston Valley Wildlife Management Area,B.C.	3	0	1	10
Fraser Lake,B.C.	2	1	1	9
Langara Island,B.C.	2	0	3	9
Chain Islets & Great Chain Islet,B.C.	2	1	1	9
Kerouard and St. James Islands,B.C.	2	0	3	9
McIntyre Beach and Rose Spit,B.C.	3	0	0	9
Tofino Mudflats,B.C.	2	1	1	9
Active Pass,B.C.	3	0	0	9
Dodge Point & Gogit Passage Island Chain,B.C.	2	0	2	8
English Bay & Burrard Inlet,B.C.	2	1	0	8
Gillam Island,B.C.	2	0	2	8
Chehalis River Estuary,B.C.	2	0	0	6
Cumshewa Inlet north to Sheldens Bay,B.C.	1	0	3	6
Laskeek Bay,B.C.	1	0	3	6
Skidegate Inlet,B.C.	1	1	1	6
Amphitrite and Swiftsure Banks,B.C.	1	0	2	5
Kunghit Island and Luxana Bay,B.C.	1	0	2	5
Lawn Point,B.C.	1	0	2	5
Mitlenatch Island,B.C.	1	0	2	5
Kitkatla Channel, Goschen Island North to Porcher Island,B.C.	1	1	0	5
Checleset Bay,B.C.	0	0	4	4
Lepas Bay Islet,B.C.	0	1	2	4
Lucy Islands,B.C.	1	0	1	4

IBA site name	Number of species meeting the following thresholds			Score
	Global	Contin.	National	
Comox Valley,B.C.	1	0	1	4
Smith Sound Islets,B.C.	0	0	4	4
White Islets and Wilson Creek,B.C.	1	0	1	4
Somenos Marsh Wildlife Refuge,B.C.	1	0	1	4
Tachick and Nulki Lakes,B.C.	0	2	0	4
Mussel and Kynoch Inlet and Sheep Passage,B.C.	1	0	1	4
Nootka Island banks,B.C.	0	0	3	3
Kilpoola Lake Area,B.C.	0	0	3	3
South Thompson River,B.C.	1	0	0	3
Alder Island,B.C.	1	0	0	3
Douglas Lake Plateau,B.C.	1	0	0	3
Squamish River Area,B.C.	1	0	0	3
Desolation Sound,B.C.	1	0	0	3
Vaseux Lake Area,B.C.	0	0	3	3
Porlier Pass,B.C.	1	0	0	3
Tian Bay/Port Louis Area,B.C.	0	0	3	3
Stuart, Tachie and Middle Rivers,B.C.	1	0	0	3
Snake Island,B.C.	0	0	2	2
Major Brown Rock,B.C.	0	0	2	2
McFadden Creek Heronry,B.C.	0	1	0	2
Holden Lake,B.C.	0	1	0	2
Pacific Spirit Regional Park,B.C.	0	1	0	2
Osoyoos Oxbows,B.C.	0	0	1	1
Grey and Green islets,B.C.	0	0	1	1
Cecil Lake,B.C.	0	0	1	1
Greater Vancouver Watershed,B.C.	0	0	1	1
Jervis Inlet/McRae Islet,B.C.	0	0	1	1
Goose Island Group and Banks,B.C.	0	0	1	1
White Lake Area,B.C.	0	0	1	1
Klaskish River and East Creek Watersheds,B.C.	0	0	1	1
Kotcho lake,B.C.	0	0	1	1
Chilcotin Junction,B.C.	0	0	1	1
Chopaka Customs,B.C.	0	0	1	1
Megin, Moyeha, Watta and Pretty Girl Watersheds,B.C.	0	0	1	1
Sumallo River/Skagit Valley,B.C.	0	0	1	1
Skookumchuck Prairie,B.C.	0	0	0	0
Hesquiat Lake area,B.C.	0	0	0	0
Carmanah Walbran Forest,B.C.	0	0	0	0
TOTAL	140	21	129	

Appendix 2. Migratory Bird Sanctuaries in B.C..

Sanctuary	Location
Christie Islet Bird Sanctuary	Howe Sound
Esquimalt Lagoon Bird Sanctuary	Vancouver Island
George C. Reifel Bird Sanctuary	(Alaksen Wildlife Refuge) – Delta
Nechako River Bird Sanctuary	Localised areas of the Nechako River.
Shoal Harbour Bird Sanctuary	Shoal Harbour and Roberts Bay, Vancouver Island
Vaseux Lake Bird Sanctuary	Southern Okanagan
Victoria Harbour Bird Sanctuary	Vancouver Island.

Appendix 3.Table of entities listed by COSEWIC in B.C.

19% - (46/242) are subspecies or populations below the species level.

	Elements	Status (Cosewic).
1	Caribou ssp Dawson ' s	Extinct
2	Caribou Southen Mtn	Threatened
3	Caribou Boreal	Threatened
4	Caribou Northern Mt	Special Concern
5	Ermine haidarum ssp	Threatened
6	Grizzly Bear NW	Special Concern
7	Horned Lark strigata ssp	Endangered
8	Screech-Owl macfarlanei subspecies	Endangered
9	Sparrow affinis subspecies, Vesper	Endangered
10	Falcon anatum subspecies, Peregrine	Threatened
11	Goshawk laingi subspecies, Northern	Special Concern
12	Owl brooksi subspecies, Northern Saw-whet	Threatened
13	Falcon pealei subspecies, Peregrine	Special Concern
14	Heron fannini subspecies, Great Blue	Special Concern
15	Screech-Owl kennicottii subspecies, West	Special Concern
16	Gophersnake, Pacific	Extirpated
17	Turtle, Western Painted Coastal	Endangered
18	Gophersnake, Great Basin	Threatened
19	Turtle, Western Painted Rocky mountain pop	Special concern
20	Stickleback, Benthic Hadley Lake	Extinct
21	Stickleback, Limnetic Hadley Lake	Extinct
22	Dace, Nooksack	Endangered
23	Lamprey, Morrison Creek	Endangered
24	Stickleback, Benthic Enos Lake	Endangered

	Elements	Status (Cosewic).
25	Stickleback, Benthic Paxton Lake	Endangered
26	Stickleback, Limnetic Paxton Lake	Endangered
27	Stickleback, Benthic Vananda Creek	Endangered
28	Stickleback, Limnetic Enos Lake	Endangered
29	Stickleback, Limnetic Vananda Creek	Endangered
30	Stickleback, Misty Lake Lentic	Endangered
31	Stickleback, Misty Lake Lotic	Endangered
32	Sucker, Salish	Endangered
33	Lamprey, Vancouver	Threatened
34	Sculpin, Cultus Pygmy	Endangered
35	Stickleback, Charlotte Unarmoured	special concern
36	Stickleback, Giant	special concern
37	Trout, Westslope Cutthroat	special concern
38	Smelt, Pygmy Longfin	Data deficient
39	Salmon, Coho interior Fraser	Threatened
40	Salmon, Sockeye Cultus Lake	Endangered
41	Salmon, Sockeye sakinaw lake	Endangered
42	Salmon, Chinook Okanagan	threatened
43	Marbled, Island insulanus	Extirpated
44	Blue, Island	endangered
45	Checkerspot Taylors	endangered
46	Catchfly, Coastal Scouler's	endangered

Appendix 4. Globally vulnerable (G3) plant associated identified by CDC.

Note, this list is considerably different from that identified by NatureServe, and is currently being updated and consolidated by B.C. CDC.

Latin	Common
Abies lasiocarpa / *Vaccinium membranaceum* / *Brachythecium* spp.	subalpine fir / black huckleberry / ragged-mosses
Betula occidentalis / *Rosa* spp.	water birch / roses
Picea engelmannii x *glauca* / *Spiraea douglasii*	hybrid white spruce / hardhack
Picea glauca / *Ribes triste* / *Gymnocarpium dryopteris*	white spruce / red swamp currant / oak fern
Picea glauca / *Ribes triste* / *Mertensia paniculata*	white spruce / red swamp currant / tall bluebells

Picea glauca / Vaccinium membranaceum / Hylocomium splendens	white spruce / black huckleberry / step moss
Pinus contorta / Festuca altaica / Stereocaulon spp.	lodgepole pine / Altai fescue / foam lichens
Pinus contorta - Picea mariana / Pleurozium schreberi	lodgepole pine - black spruce / red-stemmed feathermoss
Pinus contorta / Vaccinium membranaceum / Cladina spp.	lodgepole pine / black huckleberry / reindeer lichens
Pseudotsuga menziesii - Picea engelmannii x *glauca / Ptilium crista-castrensis*	Douglas-fir - hybrid white spruce / knight's plume
Pseudotsuga menziesii / Pleurozium schreberi - Hylocomium splendens	Douglas-fir / red-stemmed feathermoss - step moss

Appendix 5. Endemic and Disjunct species on Queen Charlotte Islands (QCI) and/or Brooks Peninsula (BP) on Vancouver Island (from G. Scudder pers. comm.).

Group	Queen Charlotte Islands / refs	Brooks Peninsula / refs
BRYOPHYTES[1]		
Seligeria careyana Vitt & Schofield	7	
Wijkia carlottae (Schofield) Crum.	7	
Heterophyllium n.sp.	7	7
VASCULAR PLANTS		
Enemion savilei (Calder & Tayl.) Keener (Ranunculaceae)	10	6
Geum schofieldii (Calder & Taylor (Rosaceae)	10	6
Ligusticum caldera Mathias & Const. (Apiaceae)	10	6
Saxifraga taylori Calder & Savile (Saxifragaceae)	10	6
Sinosenecio newcombei (Greene) Janovec & Barkley (Asteraceae)	10	
INSECTA		
Order HEMIPTERA		
Aphrophora regina Hamilton (Cercopidae)	2,3,8,9	
Order LEPDIOTERA		
Xanthorhoe clarkeata Ferguson (Geometridae)	1,9	
Order COELOPTERA		
Nebria charlottae Lindroth (Carabidae)	4,5,8,9	
N. louisae Kavanaugh (Carabidae)	4,5,8,9	
HEPATICS[2]		
Dendrobazzania griffithiana (Steph.) Schust. & Schof. [Himalayas]		
Radula auriculata Steph [S.E. Asia]		
MOSSES[2]		
Daltonia splachnoides (Sm. ex. Sm. & Sowerby) Hook. & Tayl. [Madeira,		

Scotland]		
Dicranodontium subporodictyou Broth [Scotland, Himalayas]		
Leptodontium recurvifolium (Tayl.) Lindb. [Spain, Britain]		
Sphagnum junghuhnianum Dozy & Molk. [S.E. Asia]		
Zygodon gracilis Wils. ex. Berk. [Britain, Alps]		

1: Note: Not all the Bryophytes listed as endemic to the QCI in Schofield (1989) are still considered endemic: some have been found in Alaska or synoymized.

2: Note: Schofield (1989) has also documented a number of very interesting disjuncts on the QCI. These include the following, with distribution elsewhere in square parenthesis

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