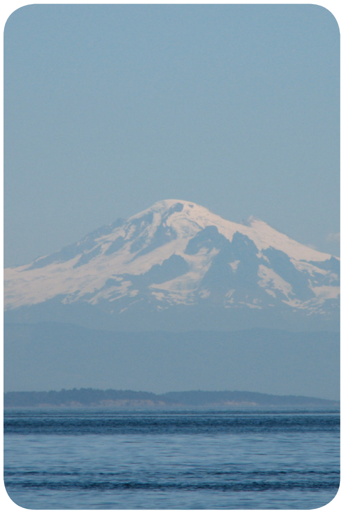

VOLUME

1

REPORT

North Cascades and Pacific Ranges Ecoregional Assessment

November 2006

Nature Conservancy Canada

Conservation de la Nature Canada

The Nature Conservancy
SAVING THE LAST GREAT PLACES ON EARTH

Washington Department of Fish and Wildlife

North Cascades and Pacific Ranges Ecoregional Assessment
Volume 1 – Report

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North Cascades and Pacific Ranges Ecoregional Assessment

November 2006

Prepared by
Nature Conservancy of Canada
The Nature Conservancy
And
The Washington Department of Fish and Wildlife

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We are indebted to the many experts who participated in a wide variety of ways throughout the process to bring the North Cascades and Pacific Ranges Ecoregional Assessment to completion. We have listed the many people who helped us in Appendices 2 and 3.

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EXECUTIVE SUMMARY

Ecoregional assessments provide a regional scale, biodiversity-based context for implementing conservation efforts. The intent of the assessments is to create a shared vision for agencies and other organizations at the regional, state and local levels to form partnerships and ensure efficient allocation of conservation resources. The assessments identify a portfolio of sites for conservation action with a goal of protecting representative biodiversity and ecologically significant populations. These assessments are the result of rigorous analysis, incorporating expert review, and are the most comprehensive and current efforts that support spatially explicit priority setting at an ecoregional scale. Biodiversity conservation in the ecoregion will attain its fullest potential if all conservation organizations coordinate their strategies to protect and restore biodiversity according to the priorities identified in this process.

The North Cascades and Pacific Ranges ecoregional assessment resulted in the selection of 341 conservation targets, including 152 terrestrial plant and animal species, 132 freshwater species targets, and 57 ecological system targets. These system targets are the major ecological systems that make up the terrestrial and freshwater environments.

Conservation goals were set for each target, defining the abundance and spatial distribution of viable target occurrences necessary to adequately conserve those targets in an ecoregion, as well as provide an estimate of how much effort will be necessary to sustain those targets well into the future. Separate terrestrial and freshwater suitability indices were utilized to determine the areas of the ecoregion that had the highest likelihood of successful conservation. This facilitated choosing amongst assessment units (the units of analysis), when multiple units contained conservation targets. The suitability indices incorporated biological and non-biological “factors”: land use (agriculture, urban, mining, timber harvest, intensive recreation); management status (GAP status); urban proximity; dams; water extraction; fish stocks; road/stream crossings; riparian disturbance; and road density (Maps 11, 12, 13). Conservation goals and the suitability index contributed to the development of a portfolio of priority conservation areas (PCAs), or NCC/TNC portfolio sites, that depict characteristic landscape settings, supporting all of the ecoregion’s biodiversity.

The terrestrial portfolio (Map 22) includes 155 PCAs with a combined area of 1,687,001 ha (4,168,665 ac), representing 35% of the total area of the ecoregion. The freshwater portfolio (Map 24) includes 121 priority conservation areas, with an area of 1,453,965 ha (3,592,821 ac) within the ecoregion boundaries and representing 39% of the ecoregion. The terrestrial and freshwater portfolios were overlaid to demonstrate the area of overlap, which represents 15% of the ecoregion (Map 26). These portfolios include the last places where many of the ecoregion’s most imperiled species occur and the last, large expanses of relatively intact natural habitat. The sites included in these portfolios are those regarded as having the highest likelihood of successful conservation according to the suitability factors utilized in the assessment. While integration of the North Cascades and Pacific Ranges terrestrial and freshwater portfolios was not achieved, future iterations of this assessment will strive to produce a fully integrated portfolio.

Threats to biodiversity in the ecoregion were compiled through assessment team members’ experience and on-the-ground knowledge of the ecoregion, interviews with experts knowledgeable about the area and through literature review. The major threats to biodiversity identified in the North Cascades and Pacific Ranges Ecoregion include:

- Forestry practices
- Urban growth and associated land conversion

- Hydropower development
- Transportation and utility corridors
- Invasive species, pests and pathogens
- Climate change
- Recreational development and use

Approximately 40% of the terrestrial portfolio is currently in designated protected areas (Table 20); while approximately 26% of the freshwater portfolio (to the extent of the terrestrial assessment units, not EDUs) is currently in designated protected areas (Table 24). Assuming the biodiversity values within the portions of the portfolios that coincide with protected areas (GAP 1 or 2) are already protected, an additional 21% of the terrestrial portfolio and 27% of the freshwater portfolio requires some form of conservation action in order to conserve the full portfolios (Maps 23 and 25).

This assessment resulted in a series of products useful to those involved in the conservation of biodiversity in the North Cascades and Pacific Ranges Ecoregion. These products can be used alone, in conjunction with one another, or with other information to enhance on-the-ground conservation and communication about biodiversity values in the ecoregion. The main products developed are:

- Terrestrial and freshwater ecological systems classifications.

- Terrestrial and freshwater conservation portfolios, showing the most important and suitable areas for conservation of ecoregional terrestrial and freshwater biodiversity, respectively. A summary of known target occurrences, land cover, land use, etc. is provided for each PCA along with an illustration of relative priority based on biodiversity value and suitability for conservation.

- Irreplaceability maps showing the relative conservation value of all places in the ecoregion.

- Overlaid terrestrial and freshwater portfolios, showing the area of overlap between the two portfolios.

- Three scenarios for biodiversity conservation, representing different levels of risk.

The conservation portfolios and utility maps are useful for a full range of biodiversity conservation strategies. Conservation projects occurring within portfolio sites and high value assessment units should receive special consideration. We therefore encourage government agencies, NGOs and other conservation practitioners to consider the portfolio and utility maps in their work. To date, the Washington Department of Fish and Wildlife has committed to using the conservation utility maps to guide their development of a State Comprehensive Wildlife Conservation Strategy (SCWCS) in coordination with other governmental and non-governmental organizations. The Nature Conservancy of Canada and The Nature Conservancy use portfolio sites to focus all of their on-the-ground conservation and policy work. Similar ecoregional assessments are being prepared for other ecoregions in support of Washington's and Oregon's SCWCS. In British Columbia, provincial government agencies will use the assessment to inform their decision-making. The ultimate vision of the ecoregional assessment process is to facilitate the thoughtful coordination of current and future conservation efforts by the growing number of federal, provincial/state, local, private and non-governmental organizations engaged in this field.

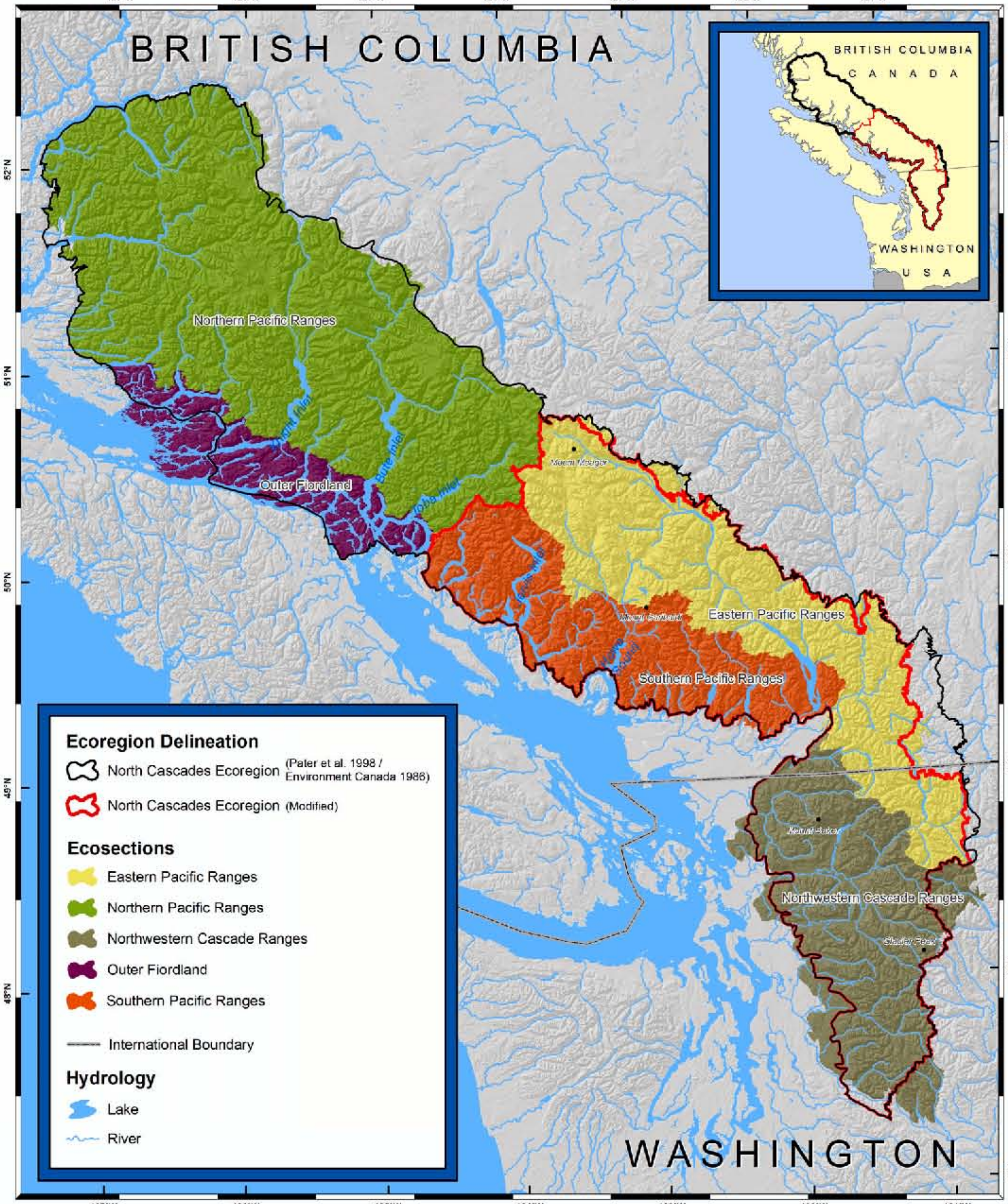

Figure 1. North Cascades and Pacific Ranges Ecoregion Boundary.

Chapter 1 – Introduction

The mountainous North Cascades and Pacific Ranges ecoregion extends south from Toba Inlet in British Columbia to just south of Snoqualmie Pass in Washington State. The entire region encompasses some 3,817,320 ha (9,432,787 ac or 14,739 square miles [sq. mi.]) with 65% (2,499,324 ha/6,175,955 ac) situated in British Columbia. In the BC portion of the ecoregion, human land use - mainly forestry - has been relatively intense, especially in the lower to mid-elevation areas. In the Washington portion, more than 96% is uninhabited and uncultivated, and has the lowest human impact of any of the state's terrestrial ecoregions. Large areas are protected in North Cascades National Park, Ross Lake National Recreation Area, and several wilderness areas, but logging has occurred widely at lower elevations.

The goal of this ecoregional assessment is to identify a suite of conservation areas in which the long-term survival of all native plant and animal species and natural communities in the North Cascades and Pacific Ranges ecoregion (hereafter referred to as the North Cascades) can be maintained. The North Cascades Ecoregional Assessment is the product of a partnership initiated in 2004 to identify priority conservation areas (PCAs), or NCC/TNC portfolio sites, in the ecoregion. The primary partners were the Nature Conservancy of Canada (NCC), The Nature Conservancy (TNC), and the Washington Department of Fish and Wildlife (WDFW). The Washington Department of Natural Resources' Natural Heritage Program (WNHP) and the British Columbia Conservation Data Centre (BC CDC) were major contributors of technical expertise and data. Many other scientists and conservation experts acted as team members and expert reviewers.

The purpose of this assessment was to integrate the best available information about the ecology of the region and to identify the lands and waters most necessary for the maintenance of the biodiversity of the ecoregion. Assessment products include: (1) a terrestrial portfolio and a freshwater portfolio of priority conservation areas, showing places of exceptional biological value and/or the most likely places for conservation to succeed based on their current condition or status; (2) maps depicting the relative irreplaceability of all sites across the entire ecoregion; and (3) "lower" and "higher" risk portfolios depicting a wide range of options for the conservation of biodiversity.

Assessment Methods

This assessment uses an approach developed by TNC (Groves et al. 2000, 2002) and other scientists to establish conservation priorities within the natural boundaries of ecoregions. Similar assessments have been completed for 14 ecoregions in Canada, over 45 of the 81 ecoregions in the U.S., and several other ecoregions around the world. The objective is to complete assessments throughout the U.S. (and in many parts of Canada and other countries) by 2008. TNC and NCC are leading a number of these assessments, while others are led by partner organizations or agencies which are using the same basic methodology.

Seven technical teams collaborated on a series of analyses. Three teams covered the terrestrial environment's plants, animals and ecological systems. A fourth team studied the ecoregion's freshwater systems and a fifth its freshwater species. The sixth team assessed human impacts to biodiversity in the ecoregion, while the seventh team handled geographic information systems (GIS) and data management tasks. The terrestrial and freshwater teams began by selecting the species, communities and ecological systems that would serve as the conservation targets. Conservation targets are those elements that are determined by the teams to be representative of the biodiversity necessary in priority conservation areas (that represent optimal concentration of biodiversity).

A computer program, MARXAN, was used to select a set of sites that meet the goals for target species and habitat types at the lowest "cost", or suite of economic, social and environmental factors. Cost was minimized by selecting the sites rated as most suitable for long-term conservation. Site suitability was described using an index of existing land management status, land uses, urban proximity, and road density. MARXAN compared each part of the ecoregion against all others and analyzed millions of possible site combinations to select the most efficient portfolio. Separate portfolios were created for terrestrial and freshwater biodiversity. MARXAN outputs were also used to generate maps that rated the conservation value and depicted the relative irreplaceability of all sites across the ecoregion.

The technical teams then worked with the MARXAN outputs to refine both the terrestrial and freshwater portfolios based on expert review. Sites in both portfolios were prioritized for action based on the irreplaceability and suitability values encompassed by each site. These portfolios highlight areas of high conservation value for terrestrial and freshwater species and systems. The terrestrial and freshwater portfolios were then overlaid in order to demonstrate areas of overlap.

Using the Assessment

The North Cascades Ecoregional Assessment is a guide for natural resource planners and others who are interested in the status or conservation of the biological diversity of this ecoregion. This assessment has no regulatory authority; it is simply a guide for prioritizing work on the conservation of habitats that support the extraordinary biological diversity of the ecoregion. It provides a tool that should be used in conjunction with other biological information, particularly at more local scales, as well as with information about social and economic priorities.

The Report

The North Cascades Ecoregional Assessment consists of four separate volumes. The main report contains an overview of the ecoregional assessment process, the methods used, and presents the results of the assessment. Details of the methods, a glossary, lists of participants, and references have been placed in separate appendices. Maps of the ecoregion, the terrestrial and freshwater classifications, and the portfolios are in a separate volume of maps. Summary reports for each of the priority conservation areas identified in NCC/TNC's preferred portfolio can be found in the site summary volume. These four volumes are also included on an interactive CD that contains an ESRI ArcReader project and data.

The results of this assessment are available to all parties interested in conserving biodiversity in the North Cascades ecoregion. The Nature Conservancy of Canada, The Nature Conservancy, and the Washington Department of Fish and Wildlife will use the assessment results and those of similar assessments to prioritize their projects and funding allocations. Governments, land trusts, and others are encouraged to use the assessment as a resource to guide conservation strategies.

1.1 Ecoregion Overview

General Description

The mountainous North Cascades ecoregion extends south from Toba Inlet in British Columbia to just south of Snoqualmie Pass in Washington State. In BC, the ecoregion extends from Desolation Sound at the mouth of Toba Inlet on the northwest boundary to the

Lillooet glacier on the northeast and then south and east thus encompassing the Resort Municipality of Whistler; Garibaldi Provincial Park; the District of Squamish; the North Shore mountains north of the heavily populated Lower Mainland and City of Vancouver; Pitt, Stave, and Harrison Lakes; the Fraser River; City of Chilliwack, and the Town of Hope. From there the ecoregion extends south into Washington State and encompasses North Cascades National Park, Mount Baker, and the communities of Concrete, Darrington, Hamilton, and Index (Map 1a). The ecoregion contains over 26,000 km (16,156 miles) of streams and rivers, including the upper reaches of a number of major (third order or larger) rivers and portions of some estuaries and inlets where the ecoregion borders the Strait of Georgia in British Columbia. Major water bodies in the ecoregion include Powell, Pitt, Lillooet, Stave, and Harrison Lakes in British Columbia and Baker, Shannon, and Ross Lakes in Washington. In BC, the northwestern edge of the ecoregion borders the coast and includes portions of Howe Sound, Jervis Inlet and Toba Inlet.

Currently, 27% of the ecoregion is classified as GAP 1 or GAP 2; and an additional 61% is classified as GAP 3 (refer to Appendix 1 - Glossary for GAP descriptions). This mountainous ecoregion is also relatively sparsely populated: approximately 122,000 people live in the BC portion; about 8,000 live in the Washington State portion. Much of ecoregion is relatively intact and dominated by semi-natural or natural vegetation. Most human impacts have been due to logging and road building; however, it is anticipated that the area between Vancouver, Whistler, and Pemberton will rapidly undergo development, particularly road building and housing development, as a result of Whistler/Vancouver hosting the 2010 Winter Olympics.

1.1.1 Biogeographical setting

Physiography

The North Cascades Ecoregion encompasses 3,817,320 hectares [ha] (9,432,787 acres [ac] or 14,739 square miles [sq. mi.]). It includes highly dissected, glaciated mountain terrain that is mostly between 300 and 2,100 m (approx. 1,000 and 7,000 ft) in elevation and is punctuated occasionally by large, composite volcanoes rising to over 3,048 m (10,000 ft) (Map 1b). The Washington portion of the ecoregion contains the greatest concentration of active glaciers in the conterminous United States.

Valley bottoms in the ecoregion extend down to 152 m elevation (500 ft). Glacially carved U-shaped valleys and cirques are prominent features. Some of these have been dammed to form large reservoirs, notably Ross and Baker Lakes. Watersheds typically begin as steep-gradient small stream drainages that feed major rivers leading out to the Fraser River delta and the Puget Sound Lowland. The major river systems in the Washington portion of the ecoregion—the Snoqualmie, Skykomish, Stillaguamish, Skagit, and Nooksack— flow toward Puget Sound (SAS 2005). In the BC portion of the ecoregion, the Squamish River, a short but very large drainage basin in the Pacific Ranges just north of Vancouver, enters the sea at the head of Howe Sound. Its main tributaries are the Cheakamus, Elaho and Mamquam Rivers. The Fraser River divides the ecoregion by Hope and flows through Vancouver to the Strait of Georgia.

Most of the ecoregion is encompassed by the high, rugged mountains of the Pacific Ranges, the southern-most mountain range in the Coast Mountains - and the Cascade Mountains north of Snoqualmie Pass and west of the crest extending northward into British Columbia.The Pacific Ranges include four of the five major coastal icecaps in the southern Coast Mountains (Demarchi 1996). The Garibaldi Ranges are the southwestern-most subdivision of the Pacific Ranges. The northern part of the Garibaldi Range, mostly comprised of Garibaldi Provincial Park, is primarily alpine and includes large icefields and numerous high peaks. To the south are the North Shore Mountains, which overlook Vancouver; to the southeast are the Douglas Ranges. Severe weather conditions in the North Shore Mountains often contrast dramatically with mild conditions in nearby Vancouver.

The ecoregion also encompasses the northern extent of the Cascades Volcanic Arc - a chain of tall volcanoes that runs north-south along the west coast of North America from Mount Garibaldi in British Columbia to the Shasta Cascade area of northern California. All of the known historic eruptions in the contiguous United States have been from Cascade volcanoes. The Garibaldi Volcanic Belt is the northernmost extension of the Arc; resulting from subduction of the Juan de Fuca tectonic plate beneath the North American tectonic plate, which meet just off the west coast of Vancouver Island. The volcanoes in this belt are generally stratovolcanoes[1] typical of subduction zone volcanoes; they include Mount Garibaldi (2,678 m [8,787 ft]), the Black Tusk (2,316 m [7,598 ft]), Mount Meager (2,680 m [8,793 ft]), Mount Silverthrone (2,957 m [9,700 ft]), Mount Baker (3,285 meters [10,778 feet], and Glacier Peak (3,213 meters [10,541 ft]) (Cannings and Cannings 2004). Mount Garibaldi was built by violent volcanic eruptions 15,000–20,000 years ago when the Squamish Valley was filled with a large glacier. Mount Meager is a dormant volcano that last erupted 2,350 years ago and deposited ash as far east as Alberta (NRC 2005). Mount Baker is the largest volcanic complex in the northern part of the Cascade Volcanic Arc. Its volume is estimated at 72 km^3, and it supports one of the largest geothermal fields in the Cascade Range. In the past 14,000 years, Glacier Peak has erupted at least a dozen times, most recently about 300 years ago (USGS 2005).

Climate

Climate in the ecoregion exhibits both maritime and montane influences (CBI 2003; McNab and Avers 1994). Due to its proximity to the Pacific Ocean, high precipitation typifies the ecoregion and varies from around 1,520 to 4,060 mm (60 to160 in.) per year. Most precipitation falls as snow or rain from October through April. High elevations in the mountains are covered with snow for many months. Middle elevations have significant snowpacks that fluctuate over the course of the winter with rain-on-snow events. Lower elevations within the ecoregion accumulate little snow or have transient snowpacks (Cassidy 1996).

The maritime climate of the Pacific Northwest, coupled with the large vertical relief of the mountains and volcanoes, produces frequent snowstorms and heavy snowfalls. The Cascades and Coast Mountains record some of the deepest snowfalls in the world (Cannings and Cannings 2004). It is not uncommon for some places in the Cascades to have over 5,500 mm (200 in.) of snow accumulation. The annual averages of nearly 17 m (700 in.) at some Cascades locations are some of the largest recorded at any measuring stations in the world. Inland precipitation decreases on the east side of the coastal ranges where less than 511 mm (20 in.) of precipitation accumulates per year (McNab and Avers 1994). Where the ecoregion borders the Strait of Georgia, the climate is characterized by generally mild temperatures that average 2–10º Celsius (36–50º F) throughout the year with summer means reaching 13.5º Celsius (56º F) in the Pacific Ranges. Rainfall is heavy, 770–3,800 mm (30–150 in.) per year, with a maximum in winter. Winters are short and mild with mean January

[1] Typically steep-sided, symmetrical cones of large dimension built of alternating layers of lava flows, volcanic ash, cinders, blocks, and bombs. The essential feature of a stratovolcano (also called a composite volcano) is a conduit system through which magma from a reservoir deep in the Earth's crust rises to the surface. The volcano is built up by the accumulation of material erupted through the conduit and increases in size as lava, cinders, ash, etc., are added to its slopes (USGS, 2006).

temperatures of about -5º Celsius (23º F) and frost free periods of over 100 days (Cannings and Cannings 2004).

Biotic Communities

Climate is the major influence on vegetation types in the ecoregion. Vegetation is stratified by both elevation and precipitation. The windward slopes of the Coast Mountains and Cascades Range are covered in temperate rainforests. Conifers predominate and can grow to enormous size, especially on the moister, western slopes. The extreme variability of soils and geology, combined with extensive effects of glaciation and topography, have led to large localized differences in climate, species, natural communities and ecological systems (Cannings and Cannings 2004).

At low elevations, Coastal Western Hemlock (*Tsuga heterophylla)* forests dominate; in higher elevations, subalpine Mountain Hemlock (*Tsuga mertensiana*) forests are more common. Small areas of dry Douglas-fir (*Pseudotsuga menziesii)* forests are found on the leeward side of the mountains. Natural stand-replacement fires occur at irregular intervals of 90–250 years. Above timberline, alpine heaths, meadows and fellfields are interspersed with barren rock, ice, and snow (Cassidy 1996). Near Garibaldi Lake, BC, the heather meadows are broken by wide swaths of lupine (*Lupinus spp.*), cinquefoil (*Potentilla spp.*), valerian (*Valeriana officinalis*), and Subalpine Fir (*Abies lasiocarpa* Nutt.) (Cannings and Cannings 2004). The region also contains forested and open wetlands, and avalanche chutes dominated by Sitka alder (*Alnus crispa)*, vine maple (*Acer cirinatum*), and blueberries (*Vaccinium spp.*) (Cassidy 1996). In riparian forests, broadleaf species such as black cottonwood and red alder dominate over conifers (McNab and Avers 1994). Rare plant species in the ecoregion are often circumboreal species on the southern edge of their range and which have populations scattered in the high Cascades. This ecoregion is one of the few in Washington that supports a variety of large carnivores, including the gray wolf (C*anis lupus)*, grizzly bear (*Ursus arctos horribilis*), and wolverine (*Gulo gulo*). Salmon (*Oncorhynchus spp.*) are found in most of the large rivers (Cassidy 1996).

1.1.2 Socioeconomic Environment

Because their greater inaccessibility made it more difficult to cut and transport the timber, the Coast Mountains and Cascades Range were some of the last areas to be logged in the Pacific Northwest. Other than logging and a large ski resort at Whistler, most of the land in the ecoregion is relatively undeveloped; however, this situation is rapidly changing as the corridor between Vancouver and Pemberton undergoes development in preparation for the 2010 Winter Olympics. The fishing industry also plays a major role in the economy of the BC portion of the ecoregion, and historically, the Coast Mountains and Cascades were important areas for gold mining. Sand and gravel extraction operations are important economic contributors in the ecoregion (CBI 2003).

The North Cascades ecoregion contains some of North America's great outdoor recreation destinations. More than a dozen national, provincial, state, and county parks, monuments, and recreation areas are scattered throughout the ecoregion. Vast national forest lands in Washington also provide campsites and recreation areas. Some of North America's best Nordic and alpine skiing facilities are also found in the region (Britannica 2006).

In British Columbia, the ecoregion overlaps five Regional Districts (RD): Squamish-Lillooet, Sunshine Coast, Powell River, Fraser Valley, and Greater Vancouver (Figure 2). Located north of Vancouver along the eastern shore of Howe Sound, the Squamish Lillooet RD is comprised of four incorporated municipalities and four electoral areas. Within the ecoregion the main population centers are Squamish, Whistler, and Pemberton. Sunshine

Coast Regional District is located on the southern mainland coast across the Georgia Strait from Vancouver Island. It borders on the Powell River RD to the north, the Squamish-Lillooet RD to the east, and the Greater Vancouver RD to the south. Within the ecoregion, the RD encompasses the District Municipality of Sechelt, Town of Gibsons, and the Sechelt Indian Government District. The Powell River RD includes the District Municipality of Powell River and a number of unincorporated areas. It is bounded by the Squamish-Lillooet and Sunshine Coast RDs. The Fraser Valley RD is located in the southwestern portion of BC and is bordered by Whatcom County, Washington to the south, the Greater Vancouver RD to the west, and the Okanagan-Similkameen RD to the east. Within the ecoregion, the main population centers are the City of Chilliwack and District Municipality of Hope. The Greater Vancouver RD occupies the southwest corner of mainland British Columbia. Within the ecoregion it encompasses the District Municipality of North Vancouver. Table 1 provides details on populations and main industries in the Regional Districts.

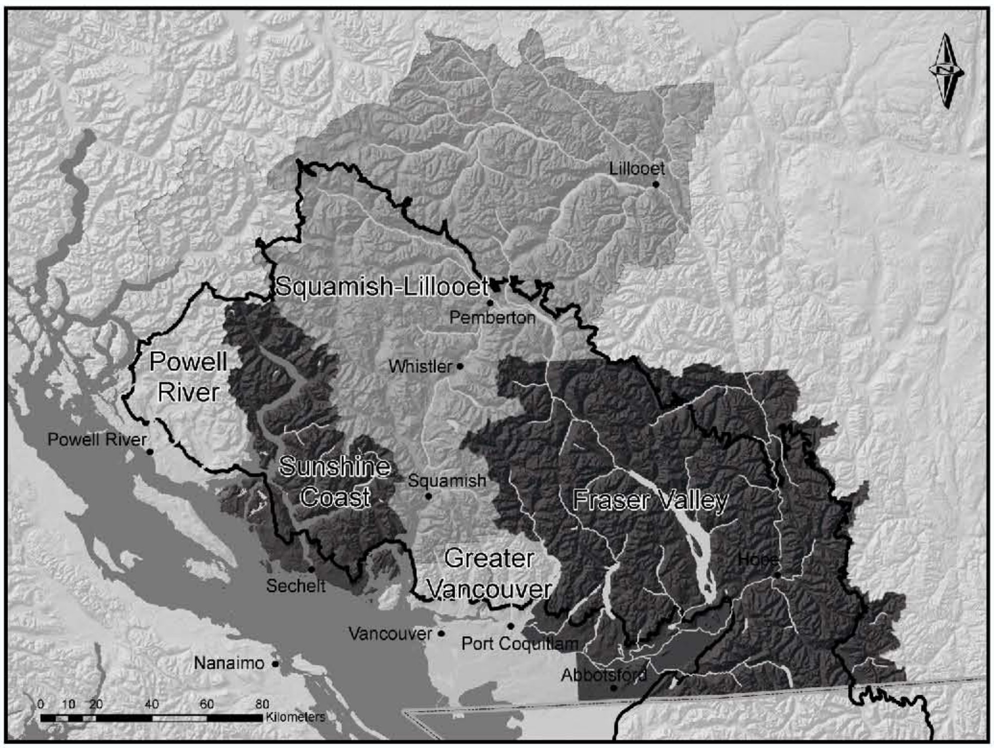

Figure 2. Regional Districts in Canada that overlap the North Cascades Ecoregion

Table 1. Regional District population and main industries (by labor force)

Regional District (RD)	% of RD in North Cascades	Population (Year)	Main Industries (by labor force)
Squamish Lillooet	46% (1,680,005 ha / 4,151,377 ac)	RD: 33,011 (2001).	Forestry, agriculture, and recreational tourism (BCStats 2006c)
		Squamish: 15,726 (2005)	Construction, manufacturing, logging and forest products, retail trade (BCStats 2006d)
		Whistler: 9,775 - permanent population; avg. of 31,351 in winter (2005)	Accommodation and food services, arts entertainment and recreation, and retail trade (BCStats 2006e)
		Pemberton: 2,517 (2005)	Construction, retail trade, arts, entertainment and recreation (BCStats 2006b)
Sunshine Coast	64% (542,587 ha/ 1,340,760 ac)	26,832 (2001)	Retail trade, health care and social assistance, manufacturing (BCStats 2004d)
Powell River	28% (680,194 ha/ 1,680,794 ac)	20,716 (2001)	Manufacturing, retail trade, health care and social assistance (BCStats 2004c)
Fraser Valley	75% (1,426,581 ha/ 3,525,152 ac)	RD: 237,550 (2001)	Retail trade, manufacturing, health care and social assistance. Agriculture is a major economic driver in the RD, accounting for approximately 32% of total provincial farm receipts (BCStats 2004a).
		Hope: 6,591 (2001)	Forestry and logging, construction, retail trade (BCStats 2006a)
		Chilliwack: 64,898 (2001)	Agriculture, manufacturing, and tourism (BCStats 2004a).
Greater Vancouver	27% (372,301 ha/ 919,973 ac)	RD: 1,986,965 (2001)	Retail trade, health care and social assistance, and manufacturing (BCStats 2004b).
		North Vancouver: 44,303 (2001)	Important shipping and rail centre and the site of a wide range of manufacturing and service operations.

In Washington State, the North Cascades ecoregion overlaps four counties: Whatcom, Skagit, Snohomish, and King (Figure 3). As of 1991, less than 2% of Washington's portion of this ecoregion had been converted to urban and agricultural development (Cassidy 1996). Although most of the area of these counties is located within the ecoregion, most of the population base is located outside, closer to the coast and urban areas such as Bellingham, Mount Vernon, Kent, and Seattle. Total population of the four counties within the ecoregion is less than 8,000. Most of the population lives along river/highway corridors that reach into the ecoregion or run from one side to another through mountain passes. Recreation and second homes have a significant influence on these developing corridors. Table 2 provides details on populations and main industries in the counties.

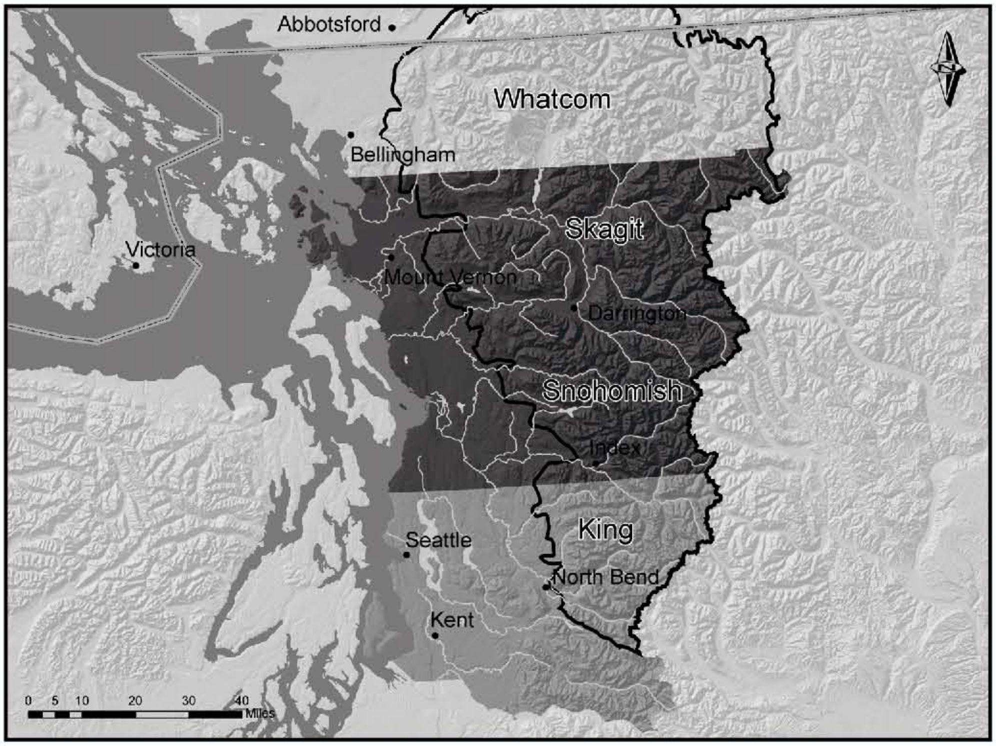

Figure 3. Counties in United States that overlap the North Cascades Ecoregion

Table 2. County population and main industries

County	% of County in North Cascades	Population (Year)	Main Industries
Whatcom	67% (648,392 ha/ 1,602,208 ac)	180,800 (2005)	Wholesale/retail trade, health care and social assistance, manufacturing (OFM 2006d)
Skagit	70% (497,389 ha/ 1,229,073 ac)	County: 110,900 (2005)	Wholesale/retail trade, health care and social assistance, manufacturing (OFM 2006b).
		Hamilton: 330 (2005)	Retail trade, health services, manufacturing.
Snohomish	61% (568,843 ha/ 1,405,639 ac)	County: 655,800 (2005)	Manufacturing, wholesale/retail trade, health care and social assistance (OFM 2006c)
		Darrington: 1,435 (2005)	Manufacturing, retail trade, agriculture, forestry, and fisheries.
		Index: 155 (2005)	Retail trade, manufacturing.

County	% of County in North Cascades	Population (Year)	Main Industries
King	31% (597,372 ha/ 1,476,136 ac)	1,808,300 (2005)	Wholesale/retail trade, health care and social assistance, manufacturing (OFM 2006a).
		Skykomish: 210 (2005)	Educational services, personal services, retail trade.

1.1.3 Land Ownership and Management

Sixty-five percent of the North Cascades ecoregion (2,499,324 ha/6,175,955 ac) is situated in British Columbia. Most of the BC portion (65%) of the ecoregion is provincial Crown land. Another 17% is in protected areas (GAP 1 and GAP 2), about 3% is privately owned land, and less than 1% is managed by conservation land trusts. Beginning in the late 19th century, concerns about logging led to the creation of government-protected lands. These formed the core of the present-day system of Crown lands in Canada and the national forests in the United States (Britannica 2006).

Human land use in the BC portion has been relatively intense, especially in lower to mid-elevation areas. Forestry, including pulp and sawlog forestry, has been extensive and accounts for most of the disturbed habitat in the BC side of the ecoregion. Transportation corridors are also extensive, particularly in the valleys south of Squamish. Recreation and tourism is increasingly becoming a major land use; hunting occurs throughout most of the BC side of the ecoregion. Other major activities include hydroelectric power production in the Pacific Ranges (CBI 2003).

More than 96% of the Washington portion of the ecoregion is uninhabited and uncultivated, and has the lowest human impact of any of the state's terrestrial ecoregions. Protected areas (GAP 1 and GAP 2) account for about 47% of this portion of the ecoregion. Large areas are protected in North Cascades National Park and Ross Lake National Recreation Area, and in several wilderness areas. Logging has occurred widely at lower elevations in the ecoregion. Recreational activities that occur in this portion of the ecoregion include hunting, fishing, hiking and snowmobiling (SAS 2005).

Less than 1% of the ecoregion is under Aboriginal/tribal landownership. In Washington, much of the ecoregion occurs within the ceded lands and usual and accustomed fishing areas of tribes. Usual and accustomed areas are judicially defined areas where tribal members have fishing rights based on their tribe’s historical use patterns. Tribes in Washington manage tribally-owned lands on reservations and are actively involved in monitoring, research and management activities on ceded lands. Tribes are also active participants in discussions about natural resources management and conservation activities within their usual and accustomed areas. In British Columbia, the North Cascades ecoregion is covered by 11 First Nations Statement of Intent areas. Statement of Intent areas are the delineations of traditional territory boundaries for those Nations involved in treaty negotiations with the provincial government. Refer to Map 2 and Table 3 for details of land ownership and management within the ecoregion.

Table 3. North Cascades Ecoregion Land Ownership and Management

	Area (ha)	Area (ac)	% of Ecoregion
British Columbia			
Federal lands			
Federal Land	65	162	<1%
Indian Reserve	10,426	25,762	<1%
Provincial lands			
Conservation Trust Land	1,207	2,982	<1%
Crown Land	1,634,334	4,038,520	52%
Provincial Park / Protected Area	427,806	1,057,130	14%
Tree Farm License	359,882	889,286	12%
Other lands			
Private Land	65,605	162,113	2%
Washington			
Federal lands			
National Park Service	212,355	524,740	13%
Forest Service: National Forest Wilderness Area	316,696	782,572	19%
Forest Service: National Forest non-Wilderness Area	388,530	960,076	23%
Bureau of Land Management	263	649	<1%
State lands			
Department of Natural Resources: Natural Area Preserve	831	2053	<1%
Department of Natural Resources: Natural Resources Conservation Area	14,546	35,945	1%
Department of Natural Resources: Other	123,965	306,323	7%
Department of Fish and Wildlife	561	1386	<1%
Parks and Recreation	2,140	5,289	<1%
Department of Transportation	17	41	<1%
Other lands			
Tribal Land	19	47	<1%
County or Municipal	11,590	28,640	1%
Private Land	246,483	609,071	15%

1.2 Biodiversity Highlights of the North Cascades Ecoregion

The rugged, mountainous terrain and extreme elevation gradients that characterize the North Cascades provide a unique array of habitats for terrestrial and aquatic species. The rock, ice, snow, and alpine habitats of the higher elevations are less hospitable to the diversity of species that occur in the forest habitats of the lower and mid-elevations; however, many of these higher elevation areas are protected as national and provincial parks and wilderness areas. Consequently, much of this area receives relatively little human use and provides important habitat for species that seek remote, undisturbed areas [e.g., grizzly bears, wolverines, mountain goats (*Oreamnos americanus*)]. While more accessible, the low- and mid-elevation forests, riparian areas, and aquatic habitats in river drainages support species that also tend to use more remote areas [e.g., northern spotted owls (*Strix occidentalis caurina*), northern goshawks (*Accipiter gentiles*), marbled murrelets (*Brachyramphus marmoratus*), gray wolves, fishers (*Martes pennanti*), and lynx (*Lynx canadensis*). Rivers within the ecoregion support a diversity of fish species, but most are known for the salmon and steelhead (*Oncorhynchus mykiss*) stocks they support. The Fraser River, which bisects the ecoregion, supports each of the Pacific salmon species and a population of white sturgeon (*Acipenser transmontanus*), which is imperiled in British Columbia. In Washington, the Skagit and Sauk Rivers are well known for supporting some of the highest densities of wintering bald eagles in the state.

At least 18 species of birds, mammals, butterflies and molluscs that occur within the ecoregion are federally, state, or provincially listed as threatened or endangered. In British Columbia, these species include the marbled murrelet, northern goshawk, peregrine falcon (*Falco peregrinus*), northern spotted owl, Townsend's mole (*Scapanus townsendii)*, Pacific water shrew (*Sorex bendirii*), mountain beaver (*Aplodontia rufa rainiei* and *Aplodontia rufa rufa.*), fisher, Johnson's hairstreak (*Callophrys johnsoni)*, blue-gray tail dropper slug (*Prophysaon coeruleum)*, dromedary jumping slug (*Hemphillia dromedaries)*, evening field slug (*Deroceras hesperium)*, Oregon forest snail (*Allogona townsendiana)*, and Puget Oregonian (*Cryptomastix devia*). Listed species in Washington include the marbled murrelet, bald eagle (*Haliaeetus leucocephalus)*, northern spotted owl, gray wolf, grizzly bear, fisher, and lynx. The Puget Oregonian, a snail that was native to British Columbia, Washington and Oregon, was last noted in British Columbia in the early 1900s and is now considered extirpated from Canada as a result of the loss of low elevation older forests. The grizzly bear, gray wolf and fisher appear to be extirpated in Washington. Many more species are listed as species of concern in the U.S. or Washington, are blue-listed in British Columbia, or are listed as species of special concern in Canada.

The decline of the northern spotted owl population in Washington and British Columbia has been well documented. Most of the remaining population (<10 breeding pairs) in BC occurs within the North Cascades Ecoregion. The decline of the northern spotted owl in British Columbia and Washington resulted from extensive habitat loss and fragmentation but was likely exacerbated by competition with the barred owl, which has invaded much of the historical range of the northern spotted owl. Protection of suitable habitat for the northern spotted owl is critical to the species' recovery, and it would likely protect habitat for other species, including the marbled murrelet and northern goshawk, which are associated with older coniferous forests. Much of the western half of the ecoregion provides habitat for the marbled murrelet, which is listed as threatened in Canada and the U.S. due to the loss of older forest habitats.

The ecoregion follows the geographical pattern of the North Cascades and Pacific mountain ranges. These ranges provide a significant habitat corridor, which historically allowed for demographic support among populations that traversed the British Columbia-Washington boundary area. Wide-ranging carnivores such as grizzly bears, gray wolves, wolverines, fishers and lynx depend on habitat corridors to maintain their large home ranges and provide demographic support among subpopulations. Mountain goats, northern spotted owls and northern goshawks also use expansive areas and depend on extensive habitat connectivity to maintain population viability. Development of the lower Fraser River bottomlands near Harrison Lake, however, has reduced the area of the corridor where the

Fraser River crosses the ecoregion and has affected its use as a travel corridor by terrestrial species. Construction of the Trans-Canada highway, Canadian National and Canadian Pacific railway lines, and a large power line corridor, all of which parallel the river as it bisects the ecoregion, has also affected the natural movement patterns of terrestrial species. Additional development and loss of habitat connectivity within the southern portion of the ecoregion in British Columbia may also impede animal movements through this corridor.

British Columbia supports populations of wide-ranging carnivores that are critically important to Washington. Washington supports populations of several species that are imperiled in BC. The North Cascades and Okanagan ecoregions are considered to be the most suitable areas in Washington for grizzly bears, gray wolves, wolverines and lynx; however, grizzly bears and gray wolves appear to be extirpated in Washington even though they are protected in the state and the rest of the United States. Protection for grizzly bears in British Columbia is limited, and gray wolves receive no protection. Sparse populations of these carnivores in southern British Columbia are unlikely to produce sufficient dispersers to reestablish populations in the North Cascades of Washington. Barriers or impediments to movement and loss of habitat connectivity may also affect the ability of grizzly bears and gray wolves in BC to reestablish populations in Washington. Habitat ranges of Townsend's moles, Pacific water shrews, and coastal giant salamanders (*Dicamptodon tenebrosus*) extend from Washington to just within the border of British Columbia. These species are relatively common in Washington but are considered at risk in British Columbia due to their small population sizes. Maintaining low-elevation valley bottom habitats for Townsend's moles, wetland and riparian habitats for Pacific water shrews, and streams surrounded by moist forests for coastal giant salamanders will be valuable in both Washington and British Columbia.

1.3 Ecoregion Boundary

The study area boundary corresponds with that of the North Cascades and Pacific Ranges Ecoregion. The boundary was originally delineated by Bailey (1995) and Environment Canada (Wiken 1986) and then modified by TNC and NCC for use in their Ecoregional Assessments in the continental United States, Alaska, Hawaii and Canada. The boundary was later modified from the original by the Coastal Forests and Mountains of Southeast Alaska and British Columbia Conservation Area Design (RRCS et al. 2003) and the Coast Information Team Ecosystem Spatial Analysis of Haida Gwaii, Central Coast, and North Coast of British Columbia (Rumsey et al. 2004). By modifying their study area boundaries these two projects encompassed the top third of the original TNC/NCC North Cascades and Pacific Ranges Ecoregion boundary. These modifications used Ecosection boundaries from the BC Ecoregional Classification scheme. Two Ecosections—Northern Pacific Ranges and Outer Fiordlands—were included in these two previous analyses and were therefore not re-analyzed for this assessment. Sections of the eastern boundary of the Ecoregion were also modified by the Okanagan Ecoregion Assessment based on updated vegetation mapping and review by ecologists with the Washington Natural Heritage Program and NatureServe (Pryce et al. 2006). Refer to Figure 4 for details of the ecoregion boundary modifications.

Figure 4. North Cascades Ecoregion Boundary Modifications.

The study area boundary used for this project also closely matches that of the Pacific Ranges Ecoregion in the BC Ecoregion Classification system. The BC classification scheme stratifies terrestrial ecosystem complexity into discrete geographical units at five hierarchical levels. The two broadest levels—Ecodomain and Ecodivision—place BC's ecosystems in a global context. The three lower levels—Ecoprovince, Ecoregion and

Ecosection— describe areas of similar climate, physiography, hydrology, and vegetation and are increasingly more detailed and relate ecosystems to each other on a provincial and state scale. Within the BC classification, the North Cascades Ecoregion falls within the Coast and Mountains Ecoprovince, which extends from coastal Alaska to coastal Oregon and consists of large coastal mountains, a broad coastal trough, and the associated lowlands, islands and continental shelf. This Ecoprovince is within the Humid Maritime and Highlands Ecodivision, which occurs along the Pacific coast from sea level to the height of land in the Coast Mountains. This Ecodivision contains some of the world's largest trees and densest coniferous forests. At the highest level in the hierarchy, the Ecoregion occurs within the Humid Temperate Ecodomain, which covers most of the mid-latitudes of North America from the east coast to the west. The climate in this Ecodomain is characterized by strong seasonal cycles of temperature and precipitation and distinct winters.

1.3.1 Terrestrial Ecosections

We divided the ecoregion into four sub-sections using the boundaries of the BC Ecoregion Classification's Ecosections. Ecoregional sections are an essential element of the ecoregional assessment as they are used to stratify the ecoregion along ecological lines. Stratification ensures that the distribution of priority conservation areas (PCAs) is a reflection of the distribution of the attributes of biodiversity that characterize the ecoregion. Using this approach, habitats and species distributed across the ecoregion will be represented in a series of potential conservation areas that correspond to their natural distribution, thus capturing the genetic diversity of species and the varied composition of habitats. By determining PCAs on a sectional basis, elements captured by the resulting conservation portfolio will be more representative of biodiversity across the ecoregion. The ecosections in the North Cascades are

- Northeastern Pacific Ranges in the northeastern portion of the ecoregion entirely within BC
- Southeastern Pacific Ranges in the central-eastern section of the ecoregion that spans the BC and WA border
- Southern Pacific Ranges in the northwestern portion of the ecoregion entirely within BC
- Northwestern Cascade Ranges in the southwestern portion of the ecoregion almost entirely within WA except for a small portion in the Lower Mainland of BC.

Refer to Map 3 and Appendix 7 for terrestrial ecosection descriptions.

1.3.2 Freshwater Ecological Drainage Units

Ecological Drainage Units (EDUs) are groups of watersheds that share a common zoogeographic history and physiographic and climatic characteristics (Map 4). We expect that each EDU will contain sets of freshwater systems with similar patterns of drainage density, gradient, hydrologic characteristics, and connectivity. This assumption is based on a large body of research that indicates that drainage basin and physiography strongly influence freshwater biodiversity patterns (Pflieger 1989; Maxwell et al. 1995; Angermeier and Winston 1999; Angermeier et al. 2000; Oswood et al. 2000; Rabeni and Doisy 2000). EDUs can be equated to terrestrial ecoregions largely because their biogeographic patterns and spatial extent are comparable. For our ecoregional assessment purposes, EDUs provide a means of stratifying freshwater systems and species in order to set appropriate goals for freshwater biodiversity conservation. The EDUs that intersect the North Cascades

Ecoregion are the Southern Coastal Streams in the northwestern part of the ecoregion, the Lower Fraser in the central part of the ecoregion, and the Puget Sound in the southern portion of the ecoregion (Maps 5 and 9).

The description of ecosections in Appendix 7 summarizes the physiography and climate of these EDUs. Appendix 9.1.2 also summarizes the zoogeographic history of these units.

1.3.3 Assessment Units

In order to use reserve selection algorithm MARXAN, the ecoregion must be divided into assessment units (AUs). AUs provide a spatially-explicit framework for compiling data on the occurrence and distribution of biodiversity features within the ecoregion (Warman et al. 2004). Determining the type and size of assessment units involves making a number of tradeoffs based on computing power, spatial resolution of the datasets, and eliminating bias in the modeling process (Appendix 13). Two types of assessment units were used for this project: 500 ha (1,236 acre) hexagons for the terrestrial analysis (Map 6), and third-order watersheds in BC (Map 9) and polygons comparable to HUC 6 watersheds in the Puget Sound EDU for the freshwater analyses.

Some ecoregional assessments have used watersheds for AUs while others have used rectangular cells, cadastral parcels, land management status, etc. Compared to watersheds or cadastral parcels, a hexagonal grid eliminates any biases due to large size differences among AUs. Compared to rectangular grids, hexagons allow for better aggregation of AUs because a hexagon shares a boundary with all its neighbours. The size of the hexagonal AUs provided sufficient accuracy in target locations while allowing for aggregation of ecological systems into extensive conservation areas (Neely et al. 2001). This analysis was selected in part to reflect the spatial resolution of the occurrence data. Large polygons, such as watersheds, can occasionally contain both high quality habitats and highly degraded areas. Smaller AUs enable only the high quality parts of the ecoregion to be selected in the portfolio.

The use of hexagons still required the team to overcome some deficiencies. For example, hexagons do not follow any ecological reality on the ground; they might split watersheds, forest blocks or other landscape patterns; and they can sometimes cause confusion during the expert review process because they are an abstract representation of the landscape. Further work will be required to refine these outputs in order to identify functional landscapes. This will entail incorporating more site-specific information on species and ecosystems and use of air photos and field inventories.

Chapter 2 –Assessment Process

This section provides a brief overview of the principal steps used in developing an ecoregional assessment. More detail on methods can be found in later chapters and appendices.

An assessment framework developed by The Nature Conservancy (TNC) and other scientists (Groves et al. 2000, 2002) was used by seven technical teams: terrestrial communities and systems; freshwater systems; terrestrial plant species; terrestrial animal species; freshwater animal species; human footprint and other impacts to biodiversity; and geographic information systems (GIS)/data management. Each team contributed to the steps described below and adopted innovations where necessary to address specific data limitations and other challenges. The technical teams were coordinated and directed by an overarching group called the Core Team, which was comprised of team leads and other scientists and conservation professionals. Refer to Appendix 2 for Core Team and technical team members and advisors.

2.1 Identify Conservation Targets

Conservation targets were selected to represent the full range of biodiversity in the ecoregion and to include any elements of special concern. In the 1970s, TNC developed the concept of coarse-filter and fine-filter conservation targets for use in conservation planning (Jenkins 1996; Noss 1987). This approach hypothesizes that conservation of multiple, viable examples of all communities and ecological systems (coarse-filter targets) will also conserve most species that occupy them. This coarse-filter strategy is a way to compensate for the lack of detailed information on numerous poorly studied invertebrates and other organisms.

Fine-filter targets are species and special features that cannot be assumed to be captured by coarse-filter targets. Special efforts are required to ensure that fine-filter targets are represented in the conservation assessment. These targets are typically rare or imperiled species, but they can include wide-ranging species that require special consideration or species that occur in other ecoregions but have genetically important disjunct populations within the ecoregion of concern.

Coarse-filter targets have to be defined before they can be selected. There are many different classifications for ecological systems and plant associations. The communities and systems teams developed classifications that could be used throughout the ecoregion, and then identified a subset of these ecological systems and vegetation associations that should be targets. The plant and animal species teams each developed criteria to guide their selection of fine-filter targets. Details of the criteria used in selecting coarse- and fine-filter targets are provided in Chapter 3 and Appendix 6.

2.2 Assemble Information on the Locations of Targets

One of the challenges of ecoregional assessments is finding data that cover the whole ecoregion. In some cases, datasets from different jurisdictions have to be combined to obtain complete coverage. In other cases, data for a target may not be available from either British Columbia or Washington; consequently, that target may not be included in the analysis.

Data on target "occurrences" (i.e., the location, and in some cases, spatial extent of a separate population or example of a species or community) were assembled from a variety of sources. Most data were gathered from existing agency databases. The teams filled in data gaps by gathering other available information and by consulting specialists for specific targets or target groups. The assembled data for plant and animal targets were screened based on the date and spatial accuracy of the record. Records that were deemed too old or spatially imprecise were omitted from the analysis.

Decisions were then made about the best way to describe and map occurrences of each target. Targets were represented as specific location points, such as rare plant population locations, or polygons that showed the spatial extent of fine- or coarse-filter targets. The data were stored in a GIS. Refer to Appendix 5 for the list of targets and Appendix 12 for a detailed description of representing occurrence data in the analyses.

2.3 Set Goals for Each Target

The computer program MARXAN (Ball and Possingham 2000; Possingham et al. 2000), used to select a portfolio of conservation areas, requires that goals be set for each target. Conservation goals define the abundance and spatial distribution of viable target occurrences necessary to adequately conserve those targets in an ecoregion and provide an estimate of how much effort will be necessary to sustain those targets well into the future.

For assessment purposes, "goal" is defined as a numerical value associated with a species or system that describes how many populations, nest sites, or breeding sites (for species targets), or how much area (for systems targets) the portfolio should include to represent each target. The goal also describes how those target occurrences should be distributed across the ecoregion to best represent genetic diversity and environmental variation.

Establishing conservation goals is a difficult task. Information on most targets is limited, which makes it difficult to estimate the number and distribution of occurrences that are needed to ensure the target's survival. Hence, the goals cannot be treated as conditions that ensure long-term survival of species. However, goals are useful tools for assembling a portfolio of conservation areas that captures multiple examples of the ecoregion's biodiversity. The goals also provide a means of gauging the contribution of different portions of the ecoregion to the conservation of its biodiversity, and the progress of conservation in the ecoregion over time.

The North Cascades teams used criteria developed by TNC and NatureServe (Comer 2001, 2003) to set goals for target species in the ecoregion. Targets were grouped according to their geographic range relative to the ecoregion. As endemism decreases, goals decrease in rough proportion to the ecoregion's share of the global distribution of that target. This is done to ensure adequate representation of targets that are rare or whose spatial distribution is more limited to the North Cascades ecoregion.

There is no scientifically established method for setting goals for coarse-filter targets; therefore, the professional judgment of ecologists from the technical teams, the provincial Conservation Data Centre and state Natural Heritage Programs was used. These ecologists have settled on a standard goal of 30% of the historical extent for matrix-forming, large-patch, and linear ecological systems. The historical extent was defined as that circa 1850 (Comer 2003). Refer to Appendices 6 and 19 for details of how goals were developed. These goals were later adjusted by the technical teams based on how MARXAN performed in capturing terrestrial systems. In cases where there was significant change from historical extent or an increase or decrease in the area of the system, the default goal was adjusted. Goals for freshwater ecological systems were set at 30% of current extent.

2.4 Rate Conservation Suitability of Different Portions of the Ecoregion

The ecoregion was divided into thousands of 500 ha hexagons which are also referred to as "assessment units" (AUs). These are described in Appendix 13 and shown in Maps 6 and 9. AUs were compared using a "suitability index". This was a set of factors the team and other experts selected to determine the relative likelihood of conservation success within each AU. The factors included the extent of roads and developed areas, and the presence of dams, which would likely impact the quality of the habitat for native species. Others factors that would likely impact the cost of managing the area for conservation were also included. These included such variables as proximity to urban areas, the percent of public versus private lands, or the existence of established conservation areas. The factors chosen for the suitability index influenced the final selection of conservation areas; a different set of factors could have produced a different conservation portfolio. Also, some factors used in the suitability index required consideration of what are traditionally policy questions. For example, setting the suitability index to favour the selection of public over private land presumes a policy of using existing public lands to meet goals wherever possible, thereby minimizing the involvement of private or Aboriginal/tribal lands. The suitability index factors chosen for this assessment are documented in Chapter 4 and Appendix 13. Chapter 5 includes a sensitivity analysis for the terrestrial portfolio that illustrates how changes in the suitability index shape the final portfolio.

2.5 Assemble Terrestrial and Freshwater Portfolios

An ecoregional assessment incorporates hundreds of different targets at thousands of locations. The relative biodiversity value and conservation suitability of thousands of potential conservation areas must be evaluated; consequently, experts cannot select the most efficient and complementary set of conservation areas through simple inspection.

In order to address the complexity and large amount of data used in the assessment analyses, the Core Team used the optimal reserve selection algorithm MARXAN. MARXAN has been used in various terrestrial and aquatic conservation assessments around the world. It uses an optimization algorithm that finds reasonably efficient solutions for selecting a system of spatially cohesive reserves that meet a suite of ecological and site suitability criteria (Ball and Possingham 2000; Possingham et al. 2000).

Target occurrence and suitability data were attributed to each AU. For the terrestrial portion of the assessment, 500 ha hexagons were used, and target occurrence data in the form of points and polygons were attributed to the hexagons. Third-order watersheds were used as assessment units in the freshwater portion of the assessment, and target occurrence data were attributed to them. Data on suitability factors were also attributed to each hexagon and watershed.

MARXAN is designed to meet target goals in the smallest area possible while maximizing suitability. The algorithm begins by selecting a random set of assessment units, i.e., a random conservation portfolio. The model then explores improvements to this first portfolio by randomly adding or removing hexagons. At each iteration, the new portfolio is compared to the previous one, and the best one is accepted. The algorithm uses a method called simulated annealing (Kirkpatrick et al. 1983) to reject sub-optimal portfolios, which greatly increases the chance of converging on the most efficient portfolio. Typically, one run of the algorithm consists of 2 million iterations, and each output scenario (portfolio) is the result of 10 runs. Refer to Appendix 8 for more details on the MARXAN model.

2.6 Refine and Overlay the Portfolios

The freshwater and terrestrial conservation portfolios generated by MARXAN were reviewed and refined by the Core Team and other experts who were familiar with the ecoregion in order to address gaps in the input data or other limitations in the automated production of the portfolios. Feedback received from the expert reviews was used to modify the computer-generated portfolios.

The terrestrial and freshwater portfolios were then overlaid to determine where they overlapped. Areas of overlap could be used to infer greater importance of certain priority conservation areas, as they have the potential to capture both terrestrial and freshwater targets in one place.

2.7 Expert Review

Throughout the planning process, each technical team solicited expert input at workshops and through personal interviews (see list of experts in Appendix 3). Experts were asked to (1) review draft target criteria, target lists and target distributions and recommend additions and deletions to the target lists; (2) provide recommendations on modifications to the freshwater and terrestrial portfolios; and (3) provide species, communities, or systems datasets, if available.

During the portfolio review, experts' comments regarding modifications to the portfolios were recorded. The experts were also asked to identify which assessment unit or group of assessment units might best represent a potential conservation area. Members of the Core Team then reviewed the experts' comments and made final changes to the portfolios.

The experts also identified several needs including the verification of the MARXAN model results, refining the portfolios using local knowledge, and listing shortcomings in the modeling approach due to data errors and gaps (Chapters 8 and 9 discuss data gaps). All teams received additional review comments from many people. These individuals are listed in Appendices 2 and 3.

2.8 Prioritization of Portfolios

Limited resources and other social or economic considerations may make protection of the entire portfolio impractical. This situation can be addressed two ways. First, attention should focus on the most important conservation areas within the portfolio. This can be accomplished by prioritizing conservation areas. Second, decision makers should be given the flexibility to pursue other options when portions of the portfolio are too difficult to protect. Assigning a relative priority to all conservation sites in the portfolio will inform decision makers about their options for conservation action.

To facilitate prioritization of conservation areas, MARXAN was used to generate two indices that reflected the relative importance of every assessment unit: irreplaceability and conservation utility. Irreplaceability is an index that indicates the relative conservation value of a place (i.e., an assessment unit). Conservation utility is a function of both biodiversity value and the likelihood (cost) of successful conservation. For conservation utility, MARXAN is run with the AU costs incorporating the suitability index. The irreplaceability index was also incorporated into an irreplaceability versus vulnerability scatter plot that was used to prioritize conservation areas within the portfolio. Prioritization was undertaken separately for the terrestrial and freshwater portfolios. The methodology used to prioritize portfolios is detailed in Chapter 7.

Chapter 3 – Targets

The ecoregional conservation assessment process identifies a suite of viable native species and communities as the elements to be represented in an ecoregional portfolio of sites (Groves et al. 2000; Groves 2003). As previously noted, this represents the coarse-filter/fine-filter approach to biodiversity conservation developed by The Nature Conservancy and partners and refined through experience and planning. Both terrestrial and freshwater coarse-filter targets were used in designing the portfolio of conservation areas for the North Cascades ecoregion. Refer to Table 18 for a summary of all targets used in the terrestrial and freshwater assessments for the North Cascades ecoregion. The planning team's strategy with respect to coarse-filter conservation was to develop a landscape portfolio of sites that captured the size and extent of natural communities and terrestrial habitats so that natural processes such as fire and flood could continue to function across the ecoregion.

3.1 Terrestrial Targets

This section describes the processes used to select the plant communities, plant species, and animal species targets for the terrestrial environment and the results of that selection process. It also describes the process of combining and refining the results to create a terrestrial portfolio.

3.1.1 Coarse-filter Targets

Technical Team

The terrestrial plant communities and ecological systems team included experts from TNC, NatureServe, and the WNHP, and an independent consultant. The team members were

Mike Heiner	TNC, Seattle, WA
Gwen Kittel	NatureServe, Boulder, CO
Rex Crawford	WNHP, Olympia, WA
Matt Fairbarns	Aruncus Consulting, Victoria, BC

3.1.1.1 Terrestrial Ecological Systems

The technical team used ecological systems to represent the vegetation and habitat types at the coarsest scale in the ecoregional assessment. A brief conceptual definition of ecological systems follows. More detailed information can be found in Comer et al. (2003)[2].

A terrestrial ecological system is defined as a group of plant community types (associations) that tend to co-occur within landscapes with similar ecological processes, substrates, and/or environmental gradients (Comer et al. 2003; O'Neill 2001). Ecological processes include natural disturbances such as fire and flooding. Substrates may include a variety of soil surface and bedrock features, such as shallow soils, alkaline parent materials, sandy/gravelly soils, or peatlands [as described and classified by Natural Resource Conservation Service, U.S. Department of Agriculture (1998)]. Finally, environmental gradients include local climates, hydrologically defined patterns in coastal zones, arid grassland, desert areas, montane, alpine or subalpine zones (e.g., Bailey 1998, 1995; Takhtajan 1986). A given terrestrial ecological system will typically occur in a landscape at intermediate geographic scales of 10s to 1,000s of hectares and persist for 50 or more years. This temporal scale is similar to the "habitat type" approach used to describe

[2] Available from NatureServe's web site: http://natureserve.org/publications/usEcologicalsystems.jsp

potential vegetation (Daubenmire 1952; Pfister and Arno 1980), but it differs in that no "climax" vegetation is implied, and all seral components are explicitly included in the systems concept. Ecological system units are intended to provide "meso-scale" classification units for resource management and conservation applications (Walter 1985). They may serve as practical units on their own or in combination with classification units defined at different spatial scales.

Upland and wetland ecological system units are defined to emphasize the natural or semi-natural portions of the landscape. Areas with very little natural vegetation, such as agricultural row crops and urban landscapes, are excluded from the ecological system classification. The temporal scale or ecological boundaries chosen also integrate successional dynamics into each system unit. The spatial characteristics of ecological systems vary on the ground, but all fall into several recognizable and repeatable categories. With these temporal and spatial scales bounding the concept of ecological systems, multiple ecological factors—or diagnostic classifiers—may then be integrated to define each classification unit, not unlike the approach of Di Gregorio and Jansen (2000)[3].

Multiple environmental factors are evaluated and combined in different ways to explain the spatial occurrence of vegetation associations. Continental-scale climate as well as broad patterns in phytogeography are reflected in ecological division units that spatially frame the classification at subcontinental scales (e.g., Bailey 1998; Takhtajan 1986). Bioclimatic categories were integrated to consistently characterize life zones (e.g., maritime, lowland, montane, subalpine, and alpine). Within the context of biogeographic and bioclimatic factors, ecological composition, structure, and function are strongly influenced by factors determined by local physiography, landform, and surface substrate. Some environmental variables are described through existing, standard classifications (e.g., soil and hydrogeomorphology) and serve as excellent diagnostic classifiers for ecological systems (Brinson 1993; Cowardin et al. 1979; NRCS 1998). Recurrent juxtaposition of vegetation communities provides an additional input for multi-factor classification (Austin and Heyligers 1989).

Ecological classification ideally proceeds through several phases, including qualitative description, quantitative data gathering, analysis, and field-testing. The approach presented here is qualitative and rule-based, thereby setting the stage for subsequent quantitative work. Available interpretations of vegetation and ecosystem patterns across the study area were relied on, and associations of the International Vegetation Classification/National Vegetation Classification (IVC/NVC) were reviewed in order to help define the limits of ecological systems concepts (NatureServe 2005). In recent years, NatureServe ecologists have also tested how well a systems approach facilitates mapping of ecological patterns at intermediate scales across the landscape (Comer et al. 2002; Hall et al. 2001; Marshall et al. 2000; Menard and Lauver 2002; Moore et al. 2001; Nachlinger et al. 2001; Neely et al. 2001; Tuhy et al. 2002).

North Cascades Ecological Systems

By using the NatureServe Ecological System Classification (Comer et al. 2003), ecologists from WNHP and NatureServe developed a list of 29 ecological systems that occur in the North Cascades ecoregion and its buffer area. Appendix 11 contains descriptions for the 29

[3] Diagnostic classifiers (categories and examples): ecological divisions (continental bioclimate and phytogeography); bioclimatic variables (regional bioclimate); environment (landscape position, hydrogeomorphology, soil characteristics, specialized substrate); ecological dynamics (hydrologic regime, fire regime); landscape juxtaposition (upland-wetland mosaics); vegetation (vertical structure and patch type, composition of component associations, abundance of component association patches).

ecological systems, and includes ecological attributes, concept summaries and component plant associations.

Due to a lack of available spatial data the set of mapped targets was reduced to 14 matrix-forming, large patch, small patch and linear systems. The technical team developed a GIS model to map these 14 system targets, as described in Section 3.1.1.4 and in Appendix 9 and illustrated in Map 7. Spatial patterns are defined in Table 4. Table 7 lists these mapped targets, their characteristic spatial patterns, and the corresponding conservation goals.

Table 4. Spatial patterns used to describe terrestrial ecological systems and plant associations (adapted from Anderson et al. 1999)

Spatial Pattern	Definition	Range in Size
Matrix	Communities or systems that form extensive and contiguous cover, occur on the most extensive landforms, and typically have relatively wide ecological tolerances.	2,000 - 500,000 ha
Large Patch	Communities or systems that form large areas of interrupted cover. Typically not limited by localized environmental features. Disturbance regimes and successional processes are typically important in the formation and maintenance of these systems or communities.	50-2,000 ha
Small Patch	Communities or systems that form small, discrete areas of vegetation cover typically limited in distribution by localized environmental features.	1-50 ha
Linear	Communities or systems that occur as linear strips and are often ecotonal between terrestrial and aquatic systems.	NA

3.1.1.2 Rare Plant Association Targets

The technical team mapped 17 terrestrial and wetland plant associations as conservation targets based on element occurrence information maintained by the BC CDC and the WNHP. The CDC and WNHP records were reviewed and revised by Matt Fairbarns (Aruncus Consulting) and Chris Chappell (WNHP). Records that were considered to be too old or erroneous were eliminated. The resulting set of terrestrial plant community targets is listed in Table 8.

Data Collection

Available information on the known occurrences of individual plant communities and ecological systems varied considerably in quantity and quality both among associations and ecological systems and across jurisdictions. The best available data were compiled from a number of sources. Data sources are listed in Appendix 4.

Plant Associations

Known locations of rare natural communities, also known technically as plant association occurrence data, were obtained from the WNHP and BC CDC databases. Very few occurrences were documented, as shown in Table 8. This is because data collection has tended to focus on rare plant and animal species rather than on plant associations. The classification, survey, mapping, delineation and documentation of individual stands of rare and of-concern plant associations are relatively new to science and conservation biologists. Many more stands are known to occur on the landscape than are documented in conservation databases. Nonetheless, these limited datasets were used to capture small scale and rare natural communities rather than depending solely on the results of the coarse-filter analysis to represent them.

3.1.1.3 *Ecological Systems and Other Coarse-filter Criteria*

Five GIS maps were developed to represent vegetation diversity across the ecoregion. Information on methods and data sources used to create these layers is presented in Sections 3.1.1.4 to 3.1.1.9 and Appendix 9.1. The following layers were developed:

- Vegetation Map of Ecological Systems: An ecoregion-wide map of ecological systems was created by combining several existing vegetative coverages. Fourteen of the 29 ecological systems known to occur in the ecoregion could be mapped on an ecoregion-wide scale. Some map units were a combination of small patch systems (for example, montane shrubland and alpine systems). Areas which had no vegetation coverage were filled in with coarser data, and agriculture and urban areas were mapped as such.

- Riparian Areas Map: Ecoregional data for small scale wetlands (bogs, fens, riparian areas) were lacking, so a coverage was created by modeling riparian areas.

- Stratified Matrix-Forming Ecological Systems: To represent topographic variation within one system, finer scale Ecological Land Units were modeled so more detailed variation within any one ecological system could be captured (e.g., north vs. south facing slopes). Refer to Appendix 9.1 for details of this modeling process.

- Old-growth Forest Map: Remaining old-growth areas, regardless of which ecological system they belonged to, were also mapped. This information was overlaid on the map of ecological systems and these forests were specifically targeted for inclusion in the portfolio.

- Minimum Dynamic Areas: Lower elevation forests and upper montane forests were combined into two aggregated units to be able to select entire and adjoining watersheds to meet a need for large, landscape-scale preserves that are at least 30,000 ha in size. This minimum dynamic area is the threshold size required to sustain a natural or near natural fire regime in the future.

3.1.1.4 *Target Representation*

Vegetation Map of Ecological Systems

The geographic distributions of 14 upland systems were modeled as intersecting combinations of climate zone and existing vegetation. After cross-tabulating maps of climate zone and existing vegetation type, the technical team assigned each possible combination to an ecological system map unit, resulting in a tabular decision matrix that was translated into a GIS map. The GIS decision matrix and map were then subjected to several iterations of review and revision by experts in BC and WA. The GIS decision matrix is shown in Appendix 9.2**.**

Available source data varied considerably between BC and WA. In BC, climatic setting was represented by Biogeoclimatic Ecosystem Classification (BEC); existing vegetation was represented by the Broad Ecosystem Inventory (BEI). Together these are known as Broad Ecosystem Units (BEU). In WA, climatic setting was represented by the Shining Mountains Mapping Project vegetation zones; existing vegetation was represented by a vegetation map developed for the North Cascades Grizzly Bear Ecosystem Evaluation (NCGBE) and by the National Land Cover Dataset (NLCD). In order to accommodate the difference in spatial scale between the BC BEU data and the WA land cover data, both the NCGBE and NLCD were re-sampled with a 50 ha moving window to better approximate the 50 ha minimum mapping unit of the polygonal BEU data. Refer to Appendix 4 for details of the data sources.

Several additional datasets from WA were incorporated to make the following adjustments:

- the two North Pacific Douglas Fir-Western Hemlock Forest systems were divided between the Dry-Mesic and the Mesic-Wet according to Plant Association Groups (PAGs) (Henderson 2001);
- the two North Pacific Western Hemlock-Silver Fir Forest systems were distinguished as the Dry-Mesic and the Mesic according to orographic zones[4] delineated on a map from Henderson (1992, page 10); and,
- an occurrence of East Cascades Mesic Montane Mixed-Conifer Forest and Woodland in the Ross Lake Valley was manually delineated.

Finally, to remove degraded or recently converted occurrences of these upland systems, several ancillary GIS sets, specifically Baseline Thematic Mapping (BTM) in BC and the National Land Cover Dataset (NLCD) and Land Use and Land Cover dataset (LULC) in WA, were compiled to identify areas that had been recently logged or converted to urban or agricultural land use. Any system occurrences that coincided with the recently logged, urban or agricultural areas were re-assigned as such.

Alpine and Montane Composite Targets

Mapping the seven defined non-forest systems, listed below, presented a unique challenge for two reasons. First, vegetation maps derived from satellite imagery, which were used to map systems in WA, generally are not accurate in distinguishing these large-patch and small-patch occurrences from recent timber harvests. This is because the spectral signature of early-seral vegetation is similar to that of native assemblages such as herbaceous balds and bluffs, montane shrublands and grasslands, montane dry tundra and avalanche chutes. Second, BEU, the GIS dataset of existing vegetation types in BC, follows a thematic classification of non-forest vegetation types that does not match the corresponding GIS dataset in WA. Therefore, it was not possible to map these individual ecological systems accurately and consistently across the international border. Instead, two new map units were defined that would represent composites of the alpine vegetated systems and the montane non-forested vegetated systems, as shown below. These two composite map units function as terrestrial coarse-filter targets in the automated site selection. Table 5 provides details of the composite map units.

Table 5. New composite map units created from alpine and montane non-forested vegetation systems

Composite Map Unit	Vegetated System
Alpine composite map unit	North Pacific Alpine and Subalpine Dry Grassland (Large Patch)
	North Pacific Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow (Large Patch)
Montane composite map unit	North Pacific Herbaceous Bald and Bluff (Small Patch)
	North Pacific Montane Grassland (Large Patch)
	North Pacific Montane Shrubland (Large Patch)
	Rocky Mountain Dry Tundra (Large Patch)
	North Pacific Avalanche Chute Shrubland (Large Patch)

[4] Related to, or caused by, physical geography (such as mountains or sloping terrain).

3.1.1.5 *Riparian Ecological Systems*

To map riparian systems, riparian areas were initially delineated with a GIS model according to flow accumulation and local topography. Next, this preliminary delineation was edited based on photo-interpretation of GeoCover satellite imagery. Lakes and land currently under agriculture or urban land use were removed, according to land use/land cover as represented by the BTM, NLCD and LULC. Finally, the remaining riparian areas were assigned to a lowland or montane riparian ecological system based on climatic zones represented by the Shining Mountains vegetation zones. The technical details of this method are described in Appendix 9.1.

3.1.1.6 *Stratifying Matrix-forming Systems (Ecological Land Units)*

Of the 14 upland ecological systems mapped, 5 matrix-forming systems covered most of the mapped area. They spanned broad physical gradients and thereby encompassed significant ecological and genetic variability. To represent this variability, a cluster analysis was done to classify the landscape using four topographic indices that are known to correspond to vegetation patterns and that are readily mapped from a digital elevation model (DEM). The resulting clusters identified map units that function to stratify the matrix-forming systems and thereby influence the automated selection of potential conservation areas. The four topographic indices are topographic position measured by a moving window of 300 m radius; topographic position measured by a moving window of 2,000 m radius; an index of annual clear-sky insolation (SolarFlux) (Rich et al. 1995); and slope.

In each of the four ecoregional sub-sections, the landscape was classified into nine abiotic units or landforms. This produced 36 abiotic map units ecoregion-wide that were used to stratify matrix-forming systems in the coarse-filter analysis. By stratifying the large area of matrix-forming ecological systems the spectrum of diversity found on all landforms could be captured. The technical details of this method are described in Appendix 9.1.

3.1.1.7 *Old-growth Forest*

The historical extent of old-growth forest has been significantly diminished in the ecoregion. Because old-growth forest provides critical habitat for a number of declining native species, it was treated as a specific coarse-filter target. To accomplish this, a GIS delineation of existing late-seral forest stands was developed. In BC, the delineation was based on stand-level age attributes specified by forest cover (TEM 1997). In WA, the delineation was based on basal diameter (quadratic mean diameter [QMD]) specified by the Interagency Vegetation Mapping Project (IVMP 2002).

3.1.1.8 *Minimum Dynamic Area (MDA)*

The terrestrial systems team conducted a literature review to determine the minimum dynamic area (MDA) terrestrial systems historically required to ensure survival or re-colonization of the ecological system following a natural disturbance that removes most or all individuals. This is determined by the ability of some number of individuals or patches to survive, and the size and severity of stochastic events (Pickett and Thompson 1978). MDAs were used to determine the minimum patch size of each terrestrial system to be captured by the MARXAN site selection algorithm. These goals were later adjusted by the team based on how the algorithm performed in meeting the goals when capturing terrestrial systems. In areas with at least 30,000 ha of continuous forest, mapped ecological systems were generalized into lower elevation forests and higher elevation forests, and a goal of 30% of each of these aggregated systems was set. Table 6 provides details of the mapped ecological systems that were aggregated.

Table 6. Mapped ecological systems that were generalized into aggregated systems

Generalized Aggregated System	Mapped Ecological System
Aggregate Lower Elevation Forests	North Pacific Maritime Mesic-Wet Douglas-Fir-Western Hemlock Forest
	North Pacific Maritime Dry-Mesic Douglas-Fir-Western Hemlock Forest
	North Pacific Dry-Mesic Silver fir - Western Hemlock - Douglas Fir Forest
	East Cascades Mesic Montane Mixed Conifer Forest
Aggregate Higher Elevation Forests	North Pacific Maritime Mesic Subalpine Parkland
	North Pacific Mountain Hemlock Forest
	North Pacific Mesic Western Hemlock - Silver fir Forest

3.1.1.9 Setting Goals

MARXAN requires that goals be set for conservation targets. Ideally, the setting of these goals is an attempt to capture ecological and genomic variation across the ecoregion and to ensure species persistence by including a number of viable populations, all of which reduces the risk of extirpation. As yet, there is no scientific consensus about how much of an ecological system or an area of habitat is needed to maintain most species within an ecoregion (Soule and Sanjayan 1998).

Conservation goals are established for ecological systems at the ecoregion level and for each ecosection. This is to ensure that targets are represented across their natural distribution in the ecoregion so that the natural diversity of each ecological system is expressed. For ecological systems with small patch distributions and for rare communities considered as conservation targets, goals were established as numbers of occurrences to be represented within the portfolio. The number of occurrences varied for systems and communities depending on their distribution relative to the ecoregion, with distribution being classified as Endemic, Peripheral, Limited, or Widespread:

- ***Endemic:*** ≥ 90% of the species' global distribution falls within the ecoregion
- ***Peripheral:*** < 10% of the species' global distribution falls within the ecoregion
- ***Limited:*** the species' distribution is limited to 2–3 ecoregions
- ***Widespread:*** the species' global distribution falls within > 3 ecoregions

All small patch ecological systems goals were set at 3 occurrences per ecological section. Most of the large patch and matrix systems goals remained at 30% except for those systems that were deemed to be peripheral to the ecoregion or were well represented in large protected areas (such as North Pacific Mountain Hemlock Forest). Goals for ecological systems in the North Cascades ecoregion are listed in Table 7 and Appendices 5 and 6.

3.1.1.10 *Summary of Terrestrial Ecological Systems and Plant Communities*

Table 7. Mapped Terrestrial Ecological Systems with spatial pattern, conservation goal and area distribution (ha)

Map Unit Name	Spatial Pattern**	Goal	Mapped ha
North Pacific Montane Massive Bedrock, Cliff and Talus	Large/Small Patch	30%	62,474
North Pacific Maritime Mesic Subalpine Parkland	Large Patch	30%	154,673
North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest	Matrix-forming	30%	189,359
North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	Matrix-forming / Large Patch	30%	558,779
North Pacific Mesic Western Hemlock-Silver Fir Forest	Matrix-forming	30%	418,929
North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest	Matrix-forming	30%	607,503
North Pacific Mountain Hemlock Forest	Matrix-forming	30%	1,081,246
Northern Rocky Mountain Subalpine Dry Parkland	Large Patch	30%	25,546
East Cascades Mesic Montane Mixed-Conifer Forest and Woodland	Large Patch	30%	47,921
North Pacific Interior Spruce-Fir Woodland and Forest	Large Patch	10%	732
Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	Matrix-forming	10%	1,183
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	Large Patch	30%	158,994
North Pacific Lowland Riparian Forest and Shrubland	Linear	30%	57,351
North Pacific Montane Riparian Woodland and Shrubland	Linear	30%	20,228
Alpine composite *	Large and Small Patch	30%	27,085
Montane composite *	Large and Small Patch	30%	100,006
Aggregated Systems	**Minimum size**	**Goal**	
Aggregate Upper Elevation Forests***	30,000 ha	30%	1,654,849
Aggregate Lower Elevation Forests***	30,000 ha	30%	1,403,563

* these map units represent a composite of systems; see Section 3.1.1.4 for explanation
** see Table 4 for definition of spatial pattern types.
*** see Section 3.1.1.8 for explanation

Table 8. Rare Plant Community Associations

Source	Scientific Name	Common Name	G rank*	S rank*	# Element Occurrences
WNHP	*Carex (livida, utriculata) / Sphagnum* spp. Herbaceous Vegetation	Pale, Beaked Sedge / Sphagnum spp	G1?	S1	1
WNHP	*Carex aquatilis* var. *dives - Carex utriculata* Herbaceous Vegetation	Sitka Sedge - Northwest Territory Sedge	G3G4	S2	1
WNHP	*Carex cusickii - (Carex aquatilis* var. *dives) / Sphagnum spp*. Herbaceous Vegetation	Cusick's Sedge - (Sitka Sedge) / Sphagnum spp	G2	S1	1
WNHP	*Carex interior - Hypericum anagalloides* Herbaceous Vegetation	Inland Sedge - Bog St. John's Wort	G2?Q	S2?	1

Source	Scientific Name	Common Name	G rank*	S rank*	# Element Occurrences
WNHP	*Carex lanuginosa* Herbaceous Vegetation	Woolly Sedge	G5?	S1	1
WNHP	*Deschampsia caespitosa* Herbaceous Vegetation (Provisional)	Tufted Hairgrass	G4	S2?	1
WNHP	*Eriophorum chamissonis / Sphagnum* spp. Herbaceous Vegetation	Russet Cottongrass / Sphagnum spp	G4	S1	2
WNHP	*Ledum groenlandicum - Myrica gale / Sphagnum* spp. Shrubland	Bog Labrador-tea - Sweetgale / Sphagnum spp	G2	S1	1
WNHP	*Picea sitchensis / Polystichum munitum* Forest	Sitka Spruce / Swordfern	G4?	S2	2
WNHP	*Rhynchospora alba - (Vaccinium oxycoccus) / Sphagnum tenellum* Herbaceous Vegetation	Beakrush - (Bog Cranberry) / Sphagnum spp	G3	S2	2
WNHP	*Spiraea douglasii / Carex aquatilis* var. *dives* Shrubland	Douglas' Spirea / Sitka Sedge	G4	S2	1
WNHP	*Thuja plicata - Tsuga heterophylla / Lysichiton americanus* Forest	Western Redcedar - Western Hemlock / Skunkcabbage	G3	S2	5
WNHP	*Tsuga heterophylla - (Thuja plicata) / Ledum groenlandicum / Sphagnum* spp. Woodland	Western Hemlock - (Western Redcedar) / Bog Labrador-tea / Sphagnum spp	G2G3	S2	2
WNHP	*Tsuga mertensiana - Abies amabilis / Elliottia pyroliflorus* Woodland	Mountain Hemlock - Pacific Silver Fir / Copperbush	G3?	S2	2
BC CDC	*Picea sitchensis / Rubus spectabilis* Dry	Sitka Spruce / Salmonberry Dry	GNR	S1S2	2
BC CDC	*Quercus garryana - Acer macrophyllum - Prunus* spp.	Garry Oak - Bigleaf Maple - Cherry Species	GNR	S1	1
BC CDC	*Populus balsamifera* ssp. *trichocarpa / Salix sitchensis - Rubus parviflorus*	Black Cottonwood / Sitka Willow - Thimbleberry	GNR	S2	1

* See Appendix 1 - Glossary for G- and S-rank definitions

3.1.2 Terrestrial Fine-filter Plant Targets

Technical Team

The terrestrial fine-filter plants technical team was composed of the following people:

Shane Ford	British Columbia Conservation Data Centre (BC CDC)
Matt Fairbarns	Aruncus Consulting
John Floberg	The Nature Conservancy (TNC), Washington Field Office
Florence Caplow	Washington Natural Heritage Program (WNHP)

Decisions about species composition and data screening criteria were agreed upon by the plants technical team, and the interim outcomes were reviewed by other botanical experts in Washington and British Columbia.

3.1.2.1 *Selecting Plant Species Targets*

Fine-filter plant species targets were selected based on established selection criteria (TNC 2000) and the experience of the technical team members. The technical team established the following species-selection criteria for species found within the assessment area:

1. Plants listed by NatureServe as globally imperiled or critically imperiled (G1-G2);
2. Plants listed as S1 to S2 in British Columbia or Washington as well as S2-S3 plants that are tracked on both sides of the border;
3. Plants that are listed or are anticipated candidates for listing by the U.S. *Endangered Species Act* and/or the Canadian *Species at Risk Act*;
4. Plants that are endemic to the North Cascades or are disjuncts in the ecoregion (i.e., are absent from all adjacent ecoregions) and are tracked by BC CDC and/or WNHP;
5. Plants that exhibit significant, long-term declines in habitat/and or numbers, are subject to a high degree of threat, or may have unique habitat requirements that expose them to great risk; and
6. Species that are restricted to the North Cascades ecoregion or are disjunct and determined by expert recommendations but NOT tracked by WNHP or BC CDC.

The draft target list and criteria were sent to experts to review and provide recommendations for additions and deletions. Their comments were evaluated by the team and changes were made to produce a final targets list. Authorities included: Malcolm Martin, Botanist, Vernon, BC; Frank Lomer, Botanist, New Westminster, BC; Dr. Adolf Ceska, Botanist, Victoria, BC; Dr. Hans Roemer, Botanist, Victoria, BC; Dr. Mike Miller, Botanist, Revelstoke, BC; Jenifer Penny, Botanist, BC CDC, Victoria, BC; Laura Potash, Botanist, USDA Forest Service, Mount Baker-Snoqualmie National Forest, WA; and Mignonne Bivin, Plant Ecologist, North Cascades National Park, Marblemount, WA.

A subset of at-risk mosses and lichens was included in the list of fine-filter plant species. In BC, mosses and lichens were added if they were listed under the federal *Species At Risk Act* since these taxa are not currently tracked by the BC CDC. Mosses and lichens are tracked in Washington by the Natural Heritage Program; they were selected based on the criteria established for vascular plants.

A set of criteria was used to assess occurrence records for inclusion in the dataset. Occurrence records were excluded from the plants dataset if they:

1. had a locational uncertainty ≥ 10 km;
2. were collected and unconfirmed over 40 years ago;
3. were located in areas that have been highly modified (e.g., the area became a major population centre in the last 40 years)

Criteria such as the condition of the occurrence record or the seed banking capabilities of a species were not used because the information was not uniformly available for all records or species.

3.1.2.2 Setting Goals

Once the list of target species was established, the team went through the occurrence records – a tabular and spatial record for a given species – to determine which occurrences would be used to meet the goals for that species. The Nature Conservancy and NatureServe (Comer 2001, 2003) recommend goals for protecting specific numbers of occurrences of target species based on the extent of their distribution (e.g., endemic, limited, widespread or disjunct, peripheral) and their global conservation rank. These goal recommendations were adopted by the North Cascades Core Team as the default conservation goals that would define the mid-risk conservation portfolio. Refer to Appendices 5, 6 and 19 for details of these conservation goals.

3.1.2.3 Results

In total**,** 98 vascular plants, 4 lichens, 3 mosses, and 2 clubmosses were selected as targets (Table 9); however, many of them lacked occurrence records. Despite its proximity to major urban centres, fewer floristic studies have been conducted in the North Cascades Ecoregion than in other ecoregions in Washington and southern British Columbia.

Table 9. North Cascades Fine-filter Plant Targets

Common Name	Scientific Name	ELCODE	G RANK
Nonvascular Plants			
Cryptic Paw	*Nephroma occultum*	NLLEC1C050	G3
Lescur's Bartramiopsis Moss	*Bartramiopsis lescurii*	NBMUS0T010	G3G5
Luminous Moss	*Schistostega pennata*	NBMUS6P010	G3G5
Navel Lichen	*Umbilicaria decussata*	NLLEC5N240	G3?
Oldgrowth Specklebelly	*Pseudocyphellaria rainierensis*	NLLEC3B060	G3
Poor Pocket Moss	*Fissidens pauperculus*	NBMUS2W0U0	G3
Witch's Hair Lichen	*Alectoria nigricans*	NLTEST7860	G5
Vascular Plants			
Alaska Harebell	*Campanula lasiocarpa*	PDCAM020F0	G5
Alpine Anemone	*Anemone drummondii var. drummondii*	PDRAN04061	G4T4
Arctic Aster	*Aster sibiricus var. meritus*	PDASTEB030	G5T5
Bearded Sedge	*Carex comosa*	PMCYP032Y0	G5
Black Lily	*Fritillaria camschatcensis*	PMLIL0V050	G5
Blue Vervain	*Verbena hastata var. scabra*	PDVER0N0E2	G5T5
Blunt-sepaled Starwort	*Stellaria obtusa*	PDCAR0X0U0	G5
Bog Clubmoss	*Lycopodiella inundata*	PPLYC03060	G5
Brandegee's Lomatium	*Lomatium brandegeei*	PDAPI1B040	G3?
Brewer's Monkey-flower	*Mimulus breweri*	PDSCR1B0N0	G5
Canyon Bog-orchid	*Platanthera sparsiflora*	PMORC1Y0N0	G4G5
Cascade Parsley Fern	*Cryptogramma cascadensis*	PPADI0B040	G5
Choris' Bog-orchid	*Platanthera chorisiana*	PMORC1Y030	G3G4
Cliff Paintbrush	*Castilleja rupicola*	PDSCR0D2U0	G2G3
Clubmoss Cassiope	*Cassiope lycopodioides*	PDERI07020	G4
Cooley's Buttercup	*Ranunculus cooleyae*	PDRAN0S010	G4
Corrupt Spleenwort	*Asplenium adulterinum*	PPASP02230	G3?
Creeping Snowberry	*Gaultheria hispidula*	PDERI0F010	G5
Curved Woodrush	*Luzula arcuata*	PMJUN02030	G5

Common Name	Scientific Name	ELCODE	G RANK
Dwarf Groundsmoke	*Gayophytum humile*	PDONA09050	G5
Elegant Jacob's-ladder	*Polemonium elegans*	PDPLM0E090	G4
Elmera	*Elmera racemosa var. racemosa*	PDSAX0B012	G4G5T4
Enander's Sedge	*Carex lenticularis var. dolia*	PMCYP037A3	G5T3Q
Few-flowered Sedge	*Carex pauciflora*	PMCYP03A50	G5
Field Dodder	*Cuscuta pentagona*	PDCUS01140	G5
Flat-leaved Bladderwort	*Utricularia intermedia*	PDLNT020A0	G5
Flowering Quillwort	*Lilaea scilloides*	PMJCG01010	G5?
Geyer's Onion	*Allium geyeri var. tenerum*	PMLIL02102	G4G5TNR
Giant Helleborine	*Epipactis gigantea*	PMORC11010	G3G4
Golden Draba	*Draba aurea*	PDBRA110E0	G5
Gray's Bluegrass	*Poa arctica ssp. arctica*	PMPOA4Z085	G5T3T5
Green-fruited Sedge	*Carex interrupta*	PMCYP036L0	G3G4
Kruckeberg's Holly Fern	*Polystichum kruckebergii*	PPDRY0R0C0	G4
Lace Fern	*Cheilanthes gracillima*	PPADI090B0	G4G5
Lance-fruited Draba	*Draba lonchocarpa var. thompsonii*	PDBRA111F2	G5T3T4
Lance-leaved Figwort	*Scrophularia lanceolata*	PDSCR1S050	G5
Large Canadian St. John's-wort	*Hypericum majus*	PDCLU03120	G5
Large-awn Sedge	*Carex macrochaeta*	PMCYP03820	G5
Leafy Mitrewort	*Mitella caulescens*	PDSAX0N020	G5
Least Moonwort	*Botrychium simplex*	PPOPH010E0	G5
Lesser Bladderwort	*Utricularia minor*	PDLNT020D0	G5
Long-styled Sedge	*Carex stylosa*	PMCYP03D50	G5
Marginal Wood Fern	*Dryopteris marginalis*	PPDRY0A0K0	G5
Menzies' Burnet	*Sanguisorba menziesii*	PDROS1L030	G3G4
Mountain Sneezeweed	*Helenium autumnale var. grandiflorum*	PDAST4L031	G5TNR
Nodding Saxifrage	*Saxifraga cernua*	PDSAX0U0B0	G4
Nodding Semaphoregrass	*Pleuropogon refractus*	PMPOA4Y080	G4
Olney's Bulrush	*Schoenoplectus americanus*	PMCYP0Q020	G5
Oniongrass	*Melica bulbosa var. bulbosa*	PMPOA3X031	G5TNRQ
Pacific Waterleaf	*Hydrophyllum tenuipes*	PDHYD08070	G4G5
Phantom Orchid	*Cephalanthera austiniae*	PMORC0F010	G4
Pointed Broom Sedge	*Carex scoparia*	PMCYP03C90	G5
Poor Sedge	*Carex magellanica ssp. irrigua*	PMCYP03G31	G5T5
Pull-up Muhly	*Muhlenbergia filiformis*	PMPOA480N0	G5
Purple-marked Yellow Violet	*Viola purpurea var. venosa*	PDVIO041S1	G5T4T5
Regel's Rush	*Juncus regelii*	PMJUN012D0	G4?
Scalepod	*Idahoa scapigera*	PDBRA1G010	G5
Several-flowered Sedge	*Carex pluriflora*	PMCYP03AT0	G4
Short-fruited Smelowskia	*Smelowskia ovalis*	PDBRA2D040	G5
Skunk Polemonium	*Polemonium viscosum*	PDPLM0E0M0	G5
Slender Gentian	*Gentianella tenella ssp. tenella*	PDGEN07072	G4G5T4
Slender Spike-rush	*Eleocharis nitida*	PMCYP09180	G3G4
Small Northern Bog-orchid	*Platanthera obtusata*	PMORC1Y0J0	G5
Small-fruited Willowherb	*Epilobium leptocarpum*	PDONA060F0	G5

Common Name	Scientific Name	ELCODE	G RANK
Smoky Mountain Sedge	*Carex proposita*	PMCYP03B60	G4
Smooth Willowherb	*Epilobium glaberrimum ssp. fastigiatum*	PDONA06091	G5TNR
Snow Bramble	*Rubus nivalis*	PDROS1K4S0	G4?
Soft-leaved Willow	*Salix sessilifolia*	PDSAL022Q0	G4
Spleenwort-leaved Goldthread	*Coptis aspleniifolia*	PDRAN0A010	G5
Stalked Moonwort	*Botrychium pedunculosum*	PPOPH010T0	G2G3
Steer's Head	*Dicentra uniflora*	PDFUM040A0	G4?
Stiff-leaved Pondweed	*Potamogeton strictifolius*	PMPOT03110	G5
Tall Bugbane	*Cimicifuga elata*	PDRAN07030	G2
Thompson's Chaenactis	*Chaenactis thompsonii*	PDAST200J0	G2G3
Three-leaved Lewisia	*Lewisia triphylla*	PDPOR040H0	G4?
Treelike Clubmoss	*Lycopodium dendroideum*	PPLYC010B0	G5
Triangular-lobed Moonwort	*Botrychium ascendens*	PPOPH010S0	G2G3
Umbellate Starwort	*Stellaria umbellata*	PDCAR0X120	G5
Ussurian Water-milfoil	*Myriophyllum ussuriense*	PDHAL040E0	G3
Vancouver Island Beggarticks	*Bidens amplissima*	PDAST18020	G3
Washington Springbeauty	*Claytonia washingtoniana*	PDPOR030U0	G2G4
Water Lobelia	*Lobelia dortmanna*	PDCAM0E0C0	G4G5
Water-pepper	*Polygonum hydropiperoides*	PDPGN0L170	G5
Western Mannagrass	*Glyceria occidentalis*	PMPOA2Y0D0	G5
White Wintergreen	*Pyrola elliptica*	PDPYR04040	G5
Woodland Penstemon	*Nothochelone nemorosa*	PDSCR1F010	G5
Woody-branched Rockcress	*Arabis lignifera*	PDBRA06120	G5

3.1.3 Terrestrial Fine-filter Animal Targets

Technical Team

The terrestrial fine-filter animals team was led by Jeff Lewis, Wildlife Biologist with the Washington Department of Fish and Wildlife. Many regional biologists, taxa specialists, data managers, and ecoregional assessment specialists were consulted during this assessment (Table 10).

Table 10. Experts who reviewed target species lists, provided data, and/or attended goal-setting meetings for the North Cascades Ecoregional Assessment

Expert	Title	Affiliation
Joe Buchanan	Wildlife Biologist	Washington Department of Fish and Wildlife
Mike Davison	District Wildlife Biologist	Washington Department of Fish and Wildlife
John Fleckenstein	Zoologist	Washington Natural Heritage Program, Olympia
Laura Friis	Species Specialist	BC Ministry of Water, Land and Air Protection
Lisa Hallock	Herpetologist	Washington Natural Heritage Program, Olympia
Jared Hobbs	Ecosystem Specialist	BC Ministry of Water, Land and Air Protection
Ronald Holmes	Ecologist	North Cascades National Park
Jeff Hoyt	Data Coordinator	BC Ministry of Water, Land and Air Protection
Pierre Iachetti	Director of Conservation Planning	Nature Conservancy of Canada
Bill Jex	Ecosystems Technician	BC Ministry of Water, Land and Air Protection
Gary Kaiser	Ornithologist	Nature Conservancy of Canada

Expert	Title	Affiliation
Robert Kuntz	Wildlife Biologist	North Cascades National Park
Jeff Lewis	Wildlife Biologist	Washington Department of Fish and Wildlife
Eric Lofroth	Ecosystem Specialist	BC Ministry of Water, Land and Air Protection
Kelly McAllister	District Wildlife Biologist	Washington Department of Fish and Wildlife
Erica McClaren	Ecosystem Biologist	BC Ministry of Water, Land and Air Protection
Ruth Milner	District Wildlife Biologist	Washington Department of Fish and Wildlife
Jesse Plumage	Forest Wildlife Biologist	Mt. Baker-Snoqualmie National Forest
Ann Potter	Wildlife Biologist	Washington Department of Fish and Wildlife
Leah Ramsay	Program Zoologist	BC Conservation Data Centre
Glenn Sutherland	Wildlife Biologist	Cortex Consultants, Vancouver, BC
Sairah Tyler	Consultant	Nature Conservancy of Canada
Ross Vennesland	Species at Risk Biologist	BC Ministry of Water, Land and Air Protection
George Wilhere	Wildlife Biologist	Washington Department of Fish and Wildlife
Elke Wind	Consulting Biologist	E. Wind Consulting, Nanaimo, BC

3.1.3.1 Terrestrial Animal Target Selection

Animal species were selected as fine-filter targets if they met one or more selection criteria including: globally imperiled species (G1-G3 ranked species; refer to Appendix 1 - Glossary for Global-rank definitions); federally listed threatened or endangered species; IUCN red list species; species of special concern (declining, endemic, disjunct, vulnerable, keystone, indicator, or wide-ranging species); species aggregations; and biodiversity hotspots. Two other selection criteria were added to this list. They identify sub-nationally imperiled species (S1-S3 ranked species) and bird species that have a Partners In Flight (PIF) conservation status score of ≥23 (see Panjabi et al. 2005). PIF conservation status scores are the sum of seven biological/ecological factors, and scores ≥23 reflect significant conservation concern for a species (Mehlman and Hanners 1999). Species with PIF conservation scores of 19–22 were also considered as targets if they had a score of 5 for either the breeding area importance factor or the population decline factor. While some criteria clearly indicated that a species should be selected as a target (e.g., federally listed as endangered), other criteria can be more subjective (e.g., vulnerable or declining) and thus require confirmation by experts.

Using the above criteria, a draft target list was developed that included information about species status by state, province and country; global and sub-national ranks; and distribution. The list included species from five taxonomic groups: amphibians, birds, mammals, butterflies and molluscs. The draft list and review instructions were sent to regional biologists and taxa experts in British Columbia and Washington (Table 10). The review comments they provided allowed the list to be refined, but they also raised questions about the inclusion of other targets. After extensive review and revision, the final target list included 81 target species (Table 12): 2 amphibians, 26 birds, 16 mammals, 13 butterflies, and 24 molluscs. While most species were selected based upon a rank or status criteria, a number of birds were selected because of their PIF score.

Terrestrial Animal Data Collection and Preparation

Species occurrence data for target species were collected across the ecoregion. Data for the BC portion of the ecoregion were provided by the BC CDC; the BC Ministry of Water, Land and Air Protection; and five independent researchers. Data for the Washington portion of the ecoregion were provided by the Washington Department of Fish and Wildlife, Mt. Baker-Snoqualmie National Forest, and Washington Natural Heritage Program. Refer to Appendix 4 for a full list of the data sources.

Most occurrence data were submitted in a GIS data format or were converted to a GIS data format. Occurrence data were screened to eliminate data that were >20 years old, spatially inaccurate (accuracy of >1 km), or incomplete. Data for several species (e.g., northern goshawk, marbled murrelet in Washington, golden eagle, great blue heron) were high-graded so that only documented occurrences of reproduction were included.

3.1.3.2 Setting Goals

The Core Team selected conservation goals for terrestrial animal targets based on modifications of TNC/NatureServe-derived goal scenarios (Comer 2001, 2003; Appendix 19). These TNC/NatureServe goals were used as a measure of representation of a species' occurrence data in the site selection analysis unless more specific recommendations, such as those found in population viability analyses, recovery goals, or a consensus recommendation by experts, were available. Because very few species had alternative recommendations for goals, the TNC/NatureServe goals were commonly used to represent target species. The goals used for this assessment were based on the goals that represent the "Mid-Risk" scenario in Table 11. For species represented by element occurrence data, goal values were based on either the number of populations (P), or the number of nests (N) for some bird targets. The TNC/NatureServe goals worked well for species represented by element occurrence data but were problematic for species represented by area data such as modeled habitat area, large population centres, or recovery zones. For these species, goals were based on the percent of the area to be captured in the site selection process based on recovery goals or expert recommendations. Refer to Table 11 and Appendices 5, 6 and 19 for further details on target goals.

Table 11. Conservation goals for terrestrial fine-filter animal targets (modified from Comer, 2003).

Distribution Relative to Ecoregion	Matrix, Large Patch and Linear Ecological Systems	Small Patch Ecological Systems, All Rare Communities, and Fine Filter Targets
	Area or Length, per Ecosection or Ecological Drainage Unit	Number of Occurrences
	"Mid- Risk" Scenario	"Mid- Risk" Scenario
Endemic	30% of historical	*P*: 50 *N*: 125
Limited		*P*: 25 *N*: 67
Widespread		*P*: 13 *N*: 38
Peripheral		*P*: 7 *N*: 23

3.1.3.3 Results

Data were available for 43 of the 81 (53%) target species in the site selection analysis (Table 12), although a number of these were represented by only one documented occurrence. Thirty-eight of the 43 (88%) species were represented by occurrence data, whereas 6 species were represented by area-based data (i.e., recovery zones, modeled habitat, critical winter range, population centres). Marbled murrelets were represented by occurrence and area-based data. Among those species represented by area-based data, two were represented by recovery zone data (grizzly bears and lynx), two by population centres and critical range (mountain goats and Roosevelt elk) and four by modeled habitat (fishers, grizzly bears, marbled murrelets and northern spotted owls).

Twenty-nine of the 38 (76%) species represented by occurrence data had too few occurrences to meet the TNC/NatureServe recommended goals. For those species, the site selection analysis sought to capture every occurrence. The goals for Fisher, Mountain goat, and Roosevelt elk were set at the TNC/NatureServe goal recommendation of 30% of habitat areas used to represent these species. The goals for Marbled murrelet in BC and Lynx exceeded the TNC/NatureServe recommended goal of 30% of habitat (Appendix 5). At the terrestrial fine filter animals experts workshop in WA, lynx goals were set to capture 75% of the lynx recovery zones that fall within the ecoregion in WA. There were no conservation goals set for lynx in BC as it is not a species of concern in the province. For Marbled murrelets, experts recommended a goal of 100% of the occupancy detections in Washington, and 85% of the modeled suitable nesting habitat in BC. The experts team in BC made this 85% recommendation based on the status and conservation concerns for the species. Refer to Appendices 2 and 3 for the lists of experts involved in the terrestrial fine filter animals analysis.

Table 12. Terrestrial fine-filter animal targets for the North Cascades Ecoregion

Common Name	Scientific Name	ELCODE	G RANK
Amphibians			
Cascades frog	*Rana cascadae*	AAABH01060	G3G4
Western toad ts	*Bufo boreas*	AAABB01030	G4
Birds			
Bald eagle nests	*Haliaeetus leucocephalus*	ABNKC10010	G5
Bald eagle roosts	*Haliaeetus leucocephalus*	ABNKC10010	G5
Band-tailed pigeon	*Columba fasciata*	ABNPB01080	G4
Barrow's goldeneye	*Bucephala islandica*	ABNJB18020	G5
Common Loon	*Gavia immer*	ABNBA01030	G5
Golden Eagle	*Aquila chrysaetos*	ABNKC22010	G5
Great blue heron	*Ardia herodius fannini*	ABNGA04010	G5T4
Harlequin duck	*Histrionicus histrionicus*	ABNJB15010	G4
Marbled murrelet	*Brachyramphus marmoratus*	ABNNN06010	G3G4
Marbled murrelet habitat	*Brachyramphus marmoratus*	ABNNN06010	G3G4
Northern goshawk	*Accipiter gentilis laingi*	ABNKC12061	G5
Northern spotted owl	*Strix occidentalis caurina*	ABNSB12011	G3T3
Northern spotted owl Nests	*Strix occidentalis caurina*	ABNSB12011	G3T3
Peregrine falcon	*Falco peregrinus anatum*	ABNKD06071	G4T3
Red breasted sapsucker	*Sphyrapicus ruber*	ABNYF05020	G5
Sandhill Crane	*Grus canadensis*	ABNMK01010	G5
Vaux's swift	*Chaetura vauxi*	ABNUA03020	G5
White-tailed ptarmigan	*Lagopus leucurus*	ABNLC10030	G5
Butterflies			
Arctic blue	*Plebejus glandon*	IILEPH0050	G5
Astarte fritillary	*Boloria astarte*	IILEPJ7120	G5
common branded skipper	*Hesperia comma*	IILEP65034	G5
lustrous copper	*Lycaena cuprea henryae*	IILEPC1020	G5
Melissa arctic	*Oeneis melissa*	IILEPP1100	G5
Vidler's alpine	*Erebia vidleri*	IILEPN8010	G4G5

Common Name	Scientific Name	ELCODE	G RANK
Mammals			
Fisher*	*Martes pennanti*	AMAJF01020	G5
Gray wolf	*Canis lupus*	AMAJA01030	G4
Grizzly bear a*	*Ursus arctos horribilis*	AMAJB01021	G4T3T4
Grizzly bear b*	*Ursus arctos horribilis*	AMAJB01021	G4T3T4
Lynx	*Lynx canadensis*	AMAJH03010	G5
Mountain goat	*Oreamos americanus*	AMALE02010	G5
Mtn beaver rainieri	*Aplodontia rufa rainieri*	AMAFA01014	G5T4
Mtn beaver rufa	*Aplodontia rufa rufa*	AMAFA01015	G5T4?
Roosevelt elk	*Cervus canadensis*	AMALC01010	G5T4
Townsend's big-eared bat	*Coryhorhinus townsendii*	AMACC08010	G4
Trowbridge's shrew	*Sorex trowbridgii*	AMABA01220	G5
Wolverine	*Gulo gulo*	AMAJF03012	G4
Molluscs			
Conical Spot	*Punctum randolphii*	IMGAS47050	G4
Northern Tightcoil	*Pristiloma arcticum*	IMGAS80120	G3G4
Oregon Forestsnail	*Allogona townsendiana*	IMGAS07060	G3G4
Pacific Sideband	*Monadenia fidelis*	IMGAS21020	G4G5
Pygmy Oregonian	*Cryptomastix germana*	IMGAS36120	G3G4
Robust Lancetooth	*Haplotrema vancouverens*	IMGASC7030	G5
Striated Tightcoil	*Pristiloma stearnsii*	IMGAS47050	G3
Western Flat whorl	*Planogyra clappi*	IMGAS80010	G3G4
Western thorn	*Carychium occidentale*	IMGAS93020	G3G4

* Denotes a retrospective analysis target (see Section 6.7). Retrospective targets were not used in the MARXAN analyses but were used in a post hoc assessment to see how well their habitats were captured by the portfolio results.

3.2 Freshwater Targets

This section describes the ecoregional assessment results for the ecosystems and animal species in the freshwater environment and the processes used by the assessment teams for producing them. The section also describes the process of combining and refining these results to create a freshwater portfolio.

3.2.1 Freshwater Coarse-filter Targets

Technical Team

The freshwater coarse-filter technical team was composed of the following people:

Bart Butterfield	GIS Consultant
Kristy Ciruna	Nature Conservancy of Canada
Dušan Markovic	MTS Consulting
Peter Skidmore	The Nature Conservancy, Washington Field Office

3.2.1.1 *Freshwater Ecosystems*

Freshwater coarse-filter targets are freshwater ecosystems that consist of a group of strongly interacting freshwater and riparian/near-shore communities held together by shared physical habitat, environmental regimes, energy exchanges, and nutrient dynamics. They vary in their spatial extent, have indistinct boundaries, and can be hierarchically nested within one another depending on spatial scale (e.g., headwater lakes and streams are nested within larger coastal river systems). The features that most distinguish freshwater from terrestrial ecosystems are their variability in form and their dynamic nature. Where they exist (e.g., a migrating river channel) and when they exist (e.g., seasonal ponds) often changes within a time frame that we can experience. Freshwater ecosystems are nearly always connected to and dependent upon one another, and as such they form drainage networks that constitute even larger ecological systems or ecological drainage units (EDUs) depicted in Maps 4 and 5. Freshwater ecosystems exist in many different forms depending upon the climate, geology, vegetation, and other features of the watersheds in which they occur. In very general terms, freshwater ecosystems can be defined by three major groups: standing-water ecosystems (e.g., lakes and ponds); flowing-water ecosystems (e.g., rivers and streams); and freshwater-dependent ecosystems that more closely interface with the terrestrial ecosystems (e.g., wetlands and riparian areas).

Freshwater ecosystems support an exceptional concentration of biodiversity. Species richness is greater relative to habitat extent in freshwater ecosystems than in either marine or terrestrial ecosystems. Freshwater ecosystems contain approximately 12% of all species and almost 25% of all vertebrate species (Stiassny 1996). Freshwater species include a wide variety of plants, fishes, mussels, crayfish, snails, reptiles, amphibians, insects, micro-organisms, birds, and mammals that live underwater or spend much of their time in or on the water. Many of these species depend upon the physical, chemical, and hydrological processes and biological interactions within freshwater ecosystems to trigger their various life cycle stages (e.g., spawning behaviour of a specific fish species might need to be triggered by adequate flooding at the right time of the year, for a sufficient duration, and within the right temperature range, etc.).

Almost all terrestrial animal species depend on freshwater ecosystems for water, food and various aspects of their life cycles. In addition, freshwater ecosystems provide food, drinking water, irrigation, electricity, waste removal, and transportation; recreation sites; and areas that provide a sense of place and spiritual observance, all of which form the basis of our economies and social values.

3.2.1.2 *Methods* [5]

The types and distributions of freshwater ecosystems are characterized based on abiotic factors that have been shown to influence the distribution of species and the spatial extent of freshwater community types. This method aims to capture the range of variability of freshwater system types by characterizing different combinations of physical habitat and environmental regimes that potentially result in unique freshwater ecosystem and community types. It is virtually impossible to build a freshwater ecosystem classification founded on biological data since freshwater communities have not been identified in most places, and there is generally a lack of adequate survey data for freshwater species. Given that freshwater ecosystems are themselves important targets for conservation, serving as a coarse-filter target and environmental context for species and communities, a classification

[5] Note: Puget Sound EDU methods and results are found in Appendix 10 as they were derived for a separate ecoregional assessment.

approach that identifies and maps the diversity and distribution of these systems is a critical tool for comprehensive conservation and resource management planning. An additional advantage of such an approach is that data on physical and geographic features (e.g., hydrography, land use and soil types, roads and dams, topographic relief, precipitation), which influence the formation and current condition of freshwater ecosystems, is widely and consistently available.

The freshwater ecosystem classification framework is based largely on The Nature Conservancy's classification framework for aquatic ecosystems (Higgins et al. 2003). The framework classifies environmental features of freshwater landscapes at two spatial scales, and loosely follows the hierarchical model of Tonn (1990) and Maxwell et al. (1995). It includes ecological drainage units that take into account factors associated with regional drainage patterns (e.g., zoogeography, climatic, and physiographic), as well as meso-scale units (coarse-scale freshwater systems) that take into account dominant environmental and ecological processes occurring within a watershed.

Nine abiotic variables were used to delineate freshwater ecosystem types that capture the major abiotic drivers of freshwater systems: accumulative precipitation yield, drainage area, lake and wetland influence, glacial influence, modeled water temperature, modeled hydrologic regime, geology, and mainstem and tributary stream gradient. Table 13 describes each variable and identifies its data source. These variables are widely accepted in the literature as being the dominant variables shaping coarse-scale freshwater systems and their associated communities; they also strongly co-vary with many other important physical processes (Vannote et al. 1980; Mathews 1998; Poff and Ward 1989; Poff and Alan 1995; Lyons 1989; Hart and Finelli 1999; Lewis and Magnuson 1999; Newall and Magnuson 1999; Brown et al. 2003).

Table 13. Summary of data types used in North Cascades freshwater ecosystem classification

VARIABLE	DESCRIPTION	SOURCE
Accumulative precipitation yield	Accumulative precipitation yield per upstream drainage	ClimateSource
Drainage Area	Accumulative drainage area per upstream drainage	BC Watershed Atlas; USGS HUC calculated watersheds
Percentage of lake area to watershed polygon area	Percentage of lake area in each watershed polygon	BC Watershed Atlas; NHD dataset
Percentage of wetland area to watershed polygon area	Percentage of wetland area in each watershed polygon	BC Watershed Atlas; NHD dataset
Percent glacial influence	Percentage of accumulative upstream drainage area that is currently glaciated	BC Watershed Atlas; NHD dataset
Water temperature	Modeled water temperature classes based on air temperature, glacial influence and lake influence	ClimateSource; BC Watershed Atlas
Hydrologic Regime	Modeled hydrologic regime classes based on temperature and precipitation data	ClimateSource; BC Watershed Atlas
Geology	Percentage of accumulative upstream drainage in each of the 5 geology classes	BC Ministry of Energy and Mines at 1:250,000; WA DNR 1:100,000
Mainstem and Tributary Stream Gradient	Percentage of mainstem and tributary reaches of each watershed polygon in each of 6 gradient classes	BC Watershed Atlas, and BC 25m DEM; USGS HUC

Defining Freshwater Ecosystems

Freshwater ecosystems are defined using a statistical cluster analysis. That is, watersheds are grouped together based on their relative similarity, and each group is defined as a unique ecosystem type. Descriptive statistics (mean, standard deviation, skewness, and variance) were calculated for each variable. Variables that were highly skewed (skewness values ≥2) were log 10 transformed to help meet the assumptions of normality for parametric statistics. Variability in categorical variables such as gradient classes, biogeoclimatic zones, and geology classes was reduced into two continuous axes using nonmetric multidimensional scaling. All variables were normalized for proportional comparisons between variables. Cluster analysis was performed on all normalized variables (agglomerative hierarchical clustering [Sorensen, flexible beta of –0.25], and 12 freshwater system types were selected (Map 9). Table 14 describes the variables and categories used in the classification of freshwater ecosystem types in the North Cascades ecoregion.

Table 14. Categories developed for quantitative data used in North Cascades freshwater ecosystem classification

Variable	Categories
Drainage Area (km^2)	Low =10-100; Moderate = 100-1,000, High = 1,000-10,000; Very High = 10,000-100,000, >100000
Accumulative Precipitation Yield	Low = >100,000,000; Moderate = 100,000,000-1,000,000,000; High = 1,000,000,000-10,000,000,000; Very High = >100,000,000,000
Mainstem Gradient	Shallow = <2%; Moderate = 2 - 16%; Steep = >16%
Tributary Gradient	Shallow = <2%; Moderate = 2 - 16%; Steep = >16%
Lake Influence	Low = <1% of watershed unit area; Moderate = 1 - 10%; High = 10 - 100%
Wetland Influence	Low = <1% of watershed unit area; Moderate = 1 - 10%; High = 10 - 100%
Glacial Influence	None; Low = <1.0 % of upstream drainage; Moderate = 1.0 - 5.0%; High = >5.0%

Freshwater Aquatic Assessment Units – BC Portion: Vertical Stacking

One of the components required when using automated optimized site selection programs such as MARXAN is a boundary file (*bound.dat*). The purpose of the boundary file is to allow the program to attempt to select contiguous assessment units in an effort to better represent or capture landscape scale priority conservation areas (Schindel, 2004). This method generally works well when dealing with terrestrial assessment units, but has the potential to work poorly when dealing with freshwater aquatic assessment units (AAUs) – such as third order watersheds, which were used as AAUs for the North Cascades and Pacific Ranges ecoregional assessment[6]. The potential problem in traditional horizontal grouping of adjacent assessment units, it that while watersheds may be adjacent, this does not necessarily indicate hydrological connectivity. For example, two neighbouring watersheds may meet at a ridgeline with each watershed draining into a separate drainage basin. So, while the two watersheds are adjacent, they do not have hydrological connectivity (Schindel, 2005).

Vertical Stacking is a method that was developed by Michael Schindel (TNC Oregon) designed to accommodate for these types of relationships, where adjacency between assessment units does not necessarily mean connectivity. Vertical stacking was used to generate the *bound.dat* input file for the freshwater MARXAN analysis portion of the North

[6] Only the British Columbia portion of the EDUs that fall wholly or partially within the North Cascades ecosection were analyzed as part of this ERA.

Cascades and Pacific Ranges ERA. In this case, the basic assessment units, third order watersheds, were nested within mainstem watersheds. A table containing all possible relationships between the third order watersheds and mainstems was generated by using a GIS to overlay the two layers. The resulting *bound.dat* file was used in MARXAN to ensure that the resulting portfolio would more accurately represent hydrological connectivity, than if a traditional horizontal boundary file was used. For more detailed information about Vertical Stacking, please refer to Schindel (2004), or Vander Schaaf et al. (2006).

3.2.1.3 Results and Discussion

Lower Fraser and Southern Coastal Streams ecological drainage units (EDUs) collectively consist of 829 freshwater systems that were classified into 17 freshwater system types. Table 15 summarizes the characteristics of each system type. The Lower Fraser EDU consisted of 251 watersheds that were grouped into 16 different aquatic ecological systems types. The Southern Coastal Streams EDU consisted of 578 watersheds that were grouped into 17 different aquatic ecological systems types. Map 9 spatially summarizes the abundance and distribution of these freshwater system types within each of the EDUs.

Based on the TNC/NatureServe recommendations (Comer 2001, 2003), a conservation goal of 30% was set for each freshwater coarse-filter system target type which was then stratified by EDU to ensure representation across EDUs. Freshwater ecosystem types derived from this assessment have value beyond supporting priority setting for biodiversity conservation. Freshwater ecosystem types can be used for evaluating and monitoring ecological potential and condition, predicting impacts from disturbance, and defining desirable future conditions. In addition, they can be used to inform sampling programs for biodiversity assessment and water quality monitoring, which requires an ecological framework in addition to a spatial framework to stratify sampling locations (Higgins et al. 2003).

We realize that this classification framework is a series of hypotheses that need to be tested and refined through additional data and expert review. We recommend that concurrently, data be gathered to refine/test the classification to bring the scientific rigor needed to further its development and use by conservation partners and agencies.

Table 15. Summary of coarse-filter freshwater ecosystem types in the North Cascades Ecoregion

Drainage Area (km)	Accumulative Precipitation Yield	Hydrologic Regime	Water Temp.	Glacial Influence	Lake and Wetland Influence	Mainstem Gradient	Tributary Gradient	Underlying Geology
very large	very high	rain on snow	cool	low	low	shallow	moderate	intrusive / metamorphic
small	moderate	rain and glacial melt	cold	high	low	steep	moderate	intrusive / metamorphic
small	high	rain and glacial melt	cold	high	low	moderate	steep	volcanic
small	moderate	rain and glacial melt	cold	high	low	steep	steep	intrusive / metamorphic
small	high	rain on snow	warm	low	moderate	moderate	moderate	intrusive / metamorphic

Drain-age Area (km)	Accumu-lative Precipi-tation Yield	Hydrologic Regime	Water Temp.	Glacial Influence	Lake and Wetland Influence	Main-stem Gradient	Tributary Gradient	Under-lying Geology
very small	moderate	rain and glacial melt	cold	high	low	steep	steep	intrusive / metamor-phic
small	high	rain	cool	moderate	low	steep	moderate	intrusive / metamor-phic
small	high	rain and glacial melt	cold	moderate	low	steep	moderate	intrusive / metamor-phic
very small	high	rain on snow	cool	low	low	steep	moderate	intrusive / metamor-phic
very small	high	snow melt	warm	none	moderate	shallow	shallow	hard sedimen-tary rock
very small	moderate	rain and glacial melt	cold	high	low	steep	moderate	intrusive / metamor-phic
very small	moderate	rain	cool	low	low	steep	steep	intrusive / metamor-phic
very small	moderate	snow melt	cool	none	low	moderate	moderate	intrusive / metamor-phic
very small	low	rain and glacial melt	cold	moderate	low	steep	steep	intrusive / metamor-phic
very small	moderate	rain	cool	low	low	steep	moderate	intrusive / metamor-phic
very small	moderate	rain on snow	cool	none	low	steep	steep	intrusive / metamor-phic
very small	moderate	rain on snow	cool	none	low	steep	moderate	intrusive / metamor-phic

3.2.2 Freshwater Fine-filter Animals

Technical Team

The freshwater fine-filter animals technical team was composed of experts from The Nature Conservancy (TNC), the Nature Conservancy of Canada (NCC), and Washington Department of Fish and Wildlife (WDFW):

Sairah Tyler	Veridia Consulting/Nature Conservancy of Canada
Kristy Ciruna	Nature Conservancy of Canada
Peter Skidmore	The Nature Conservancy, Washington Field Office
Joanne Schuett-Hames	Washington Department of Fish and Wildlife

3.2.2.1 *Freshwater Animal Target Selection*

The freshwater analysis used ecological drainage units (EDUs) as the ecological boundaries for target selection. Three EDUs intersect the North Cascades ecoregion and extend beyond its boundary (Southern Coastal Streams, Lower Fraser, and Puget Sound). As previously noted, the Puget Sound EDU was analyzed as part of the Willamette Valley- Puget Trough-Georgia Basin ecoregional assessment; therefore, it was not included in the freshwater fine-filter animals analysis (refer to Appendix 10 for details of the Puget Sound EDU methods and results). Two species (pink and chum salmon) were analyzed according to a different boundary than the EDUs; they were stratified by salmon ecoregion (XAN)[7] zones.

Methods used to identify fine-filter animal targets were based largely on Groves et al. (2000, 2002) and Higgins et al. (1998). Conservation targets were selected at multiple spatial scales and levels of biological organization. The freshwater animals team's objective was to develop a list of target species that require special attention, and their locational data were used to help prioritize freshwater areas for conservation. Freshwater fine-filter targets are generally defined as those species that are currently imperiled, threatened, endangered, or of special concern due to endemic, disjunct, vulnerable, keystone, or wide-ranging status, or are species aggregations or groups. Target selection criteria are shown in Table 16.

The draft target list was reviewed by regional and taxonomic experts, resulting in a final target list of 48 freshwater animal species: 27 fish (including 12 salmonids where different seasonal runs were treated as separate targets), 1 mammal, 5 amphibians, 1 bird, 8 dragonflies, and 6 stoneflies. Table 17 lists all of the freshwater fine-filter animal targets for the Southern Coastal Streams, Lower Fraser EDUs, and Fraser River and Puget Sound/Georgia Basin XAN Zones. Two of the forty-eight targets were assigned "retro status" because they were modeled habitat data and were not included in the MARXAN analyses. These targets were coastal tailed frog and steelhead habitats. We used these two datasets in a post hoc assessment of the portfolio results to evaluate the portfolio as defined by the goals and data of other targets.

Table 16. Target selection criteria

Status	Criteria
Imperiled, threatened, and endangered species	• Imperiled species have a global rank of G1-G3 or T1-T3 by NatureServe or the Conservation Data Centre in British Columbia (see www.natureserve.org for explanation of ranking system). National and Provincial Rankings were also included (N1-N3 and S1-S3). • For international programs, the IUCN Red List (www.iucnredlist.org) was used as a guide to select species in the critically endangered, endangered, or vulnerable categories. • Endangered and threatened species are those federally listed or proposed for listing as Threatened or Endangered under the ESA or COSEWIC. In British Columbia, "red-listed" species correspond to endangered or threatened. • Identified Wildlife refers to those Species at Risk and Regionally Important Wildlife that the Minister of Environment designates as requiring special management attention under the *Forest and Range Practices Act.*

[7] XANs are defined as watershed-coastal ecosystems of distinct physical characteristics, including the full sequence of riverine, estuarine, and near-shore marine habitats used by juvenile anadromous salmonids (Augerot et al. 2004).

Status	Criteria
Other species of special concern	• Declining species: Declining species exhibit significant, long-term declines in habitat and/or numbers, are subject to a high degree of threat, or may have unique habitat or behavioral requirements that expose them to great risk. • Endemic species: Endemic species are restricted to an ecoregion (or a small geographic area within an ecoregion), depend entirely on a single area for survival, and therefore are often more vulnerable. • Disjunct species have populations that are geographically isolated from populations in other ecoregions • Vulnerable species are usually abundant, may not be declining, but some aspect of their life history makes them especially vulnerable, such as habitats needed for migratory stopovers or winter range. • Keystone species are those whose impact on a community or ecological system is disproportionately large for their abundance. They contribute to ecosystem function in a unique and significant manner through their activities. Their removal causes major changes in community composition. • Wide-ranging species depend on vast areas. These species include top-level predators such as the gray wolf and northern goshawk. Wide-ranging species can be especially useful in examining linkages among conservation areas in a true conservation network.
Species aggregations, species ecological group, and hot spots	• Globally significant examples of species aggregations (i.e., critical migratory stopover sites that contain significant numbers of migratory individuals of many species). For example, significant migratory stopovers for shorebirds have been formally designated through the Western Hemi-sphere Shorebird Reserve Network. • Major groups of species share common ecological processes and patterns, and/or have similar conservation requirements and threats (e.g., freshwater mussels, forest-interior birds). It is often more practical in ecoregional plans to target such groups as opposed to each individual species of concern. • Biodiversity hotspots contain large numbers of endemic species and usually face significant threat.

Freshwater Animal Data Collection and Preparation

Occurrence data for each target were collected from seven sources; additional occurrence datasets were supplied by the terrestrial animals team. Refer to Appendix 4 for a full listing of the data sources used.

All of the freshwater fine-filter data went through the following preparation methods:

1. All non-target species were removed from the datasets
2. Data were filtered for currency and accuracy, and records were eliminated if
    a. they were collected prior to 1985;
    b. they were not from credible sources, the location was not accurate, or the sighting was not verified;
    c. they lacked basic information on species names; or
    d. the species was known to be extirpated.
3. Datasets were cross-walked to determine which attributes were similar across datasets despite different naming conventions.

4. Element Occurrences (EOs) were created through the following process:
   a. Riparian species were separated into their own files and then buffered with the appropriate species-specific separation distance. Any set of points that overlapped and represented one species were assigned the same occurrence identification (ID) and an amount of the occurrence they made up (1/2 or 1/3 of the total occurrence, etc.)
   b. Data from the BC CDC already had element occurrences assigned; therefore, buffers of any species that overlapped any BC CDC polygon occurrences of that species were assigned to the EO ID of the BC CDC data, and amounts were adjusted accordingly in both datasets to represent the full EO.
   c. BC CDC riparian polygon data were turned into point data so that they could be merged with the point data from other datasets. This resulted in one final riparian species point file.
5. All fish point datasets (from the Known Fish Observations and Royal BC Museum) were merged to create one fish point dataset. Fish arcs datasets (from the Washington Department of Fish and Wildlife, Mike Pearson's data, and the points that had been attributed to arcs) were merged and duplicate records were removed.

3.2.2.2 Setting Goals

Initial freshwater fine-filter animal conservation goals were developed using the TNC/NatureServe recommendations (Comer 2001, 2003; Appendix 19). To set final goals for the MARXAN analysis, it was necessary to first determine how many occurrences were located in each EDU. Target datasets were intersected with the freshwater assessment units (third order watersheds) in order to determine how much of each target was located in each EDU, and the TNC/NatureServe recommended goals were adjusted accordingly. Freshwater fine-filter goals are listed in Appendices 5 and 6.

Conservation goals for freshwater fine-filter data that consisted of distribution data in points and lines rather than populations were set according to percentages of distribution rather than number of populations. For all fish other than salmon, an initial distributional goal of 30% was used. Salmonid targets were defined differently from other freshwater species due to their complex and wide-ranging life history and their special consideration under COSEWIC and the Canadian *Species At Risk Act*. For the majority of salmon targets, a conservation goal was set at 50% of distribution. For two sockeye salmon populations (Cultus Lake and Sakinaw Lake), the conservation goal was set at 100% since those populations are specifically listed as endangered in Canada. Conservation goals for steelhead runs were also set at 100% because of the severe lack of distributional data for this target in the North Cascades EDUs.

3.2.2.3 Results and Discussion

Of the 24 targets that had occurrence data, only 20% (all of which were amphibians) met the TNC/NatureServe recommended conservation goals. The other 80% of the targets had too few occurrence data to meet the recommended goals. Refer to Appendices 5 and 6 for details of targets and goals results.

Table 17. Freshwater Fine-filter targets for the North Cascades Ecoregion

Common Name	Scientific Name	ELCODE	G RANK
Amphibians			
Cascades frog	*Rana cascadae*	AAABH01060	G3G4
Coastal tailed frog	*Ascaphus truei*	AAABA01010	G4
Coastal tailed frog (habitat)	*Ascaphus truei*	AAABA01010	G4
Pacific Giant Salamander	*Dicamptodon tenebrosus*	AAAAH01040	G5
Red-legged frog	*Rana aurora*	AAABH01020	G4
Western toad	*Bufo boreas*	AAABB01030	G4
Fishes			
Bull Trout	*Salvelinus confluentus*	AFCHA05020	G3
Chinook Salmon (no run info)	*Oncorhynchus tshawytscha*	AFCHA02050	G5
Chum Salmon (Fraser XAN Ecoregion)	*Oncorhynchus keta*	AFCHA02020	G5
Chum Salmon (Puget XAN Ecoregion)	*Oncorhynchus keta*	AFCHA02020	G5
Coastal Cutthroat Trout, Clarki Subspecies (anadromous)	*Oncorhynchus clarki clarki*	AFCHA0208A	G4
Coho Salmon	*Oncorhynchus kisutch*	AFCHA02030	G4
Cultus Lake Sculpin	*Cottus sp. 2*	AFC4E02270	G1
Cutthroat Trout, Clarkil Subspecies	*Oncorhynchus clarkiI clarkiI*	AFCHA0208A	G4
Dolly Varden	*Salvelinus malma*	AFCHA05040	G5
Dolly Varden (anadromous)	*Salvelinus malma*	AFCHA05040	G5
Eulachon	*Thaleichthys pacificus*	AFCHB04010	G5
Green Sturgeon	*Acipenser medirostris*	AFCAA01030	G3
Kokanee	*Oncorhynchus nerka*	AFCHA02040	G5
Mountain Sucker (ha)	*Catostomus platyrhynchus*	AFCJC02160	G5
Mountain Sucker (km)	*Catostomus platyrhynchus*	AFCJC02160	G5
Nooksack Dace	*Rhinichthys sp. 4*	AFCJB37110	G3
Pink Salmon, no run info (Fraser XAN Ecoregion)	*Oncorhynchus gorbuscha*	AFCHA02010	G5
Pink Salmon, no run info (Puget XAN Ecoregion)	*Oncorhynchus gorbuscha*	AFCHA02010	G5
Pygmy Longfin Smelt/Harrison/Pitt Lake Smelt	*Spirinchus sp. 1*	AFCHB03030	G1Q
Salish Sucker (ha)	*Catostomus sp. 4*	AFCJC02260	G1
Salish Sucker (km)	*Catostomus sp. 4*	AFCJC02260	G1
Sockeye Salmon	*Oncorhynchus nerka*	AFCHA02040	G5
Sockeye Salmon (Cultus Lake)	*Oncorhynchus nerka*	AFCHA02040	G5
Sockeye Salmon (Sakinaw Lake)	*Oncorhynchus nerka*	AFCHA02040	G5
Steelhead Salmon (modelled)	*Oncorhynchus mykiss*	AFCHA02090	G5

Common Name	Scientific Name	ELCODE	G RANK
Steelhead Salmon (no run info)	*Oncorhynchus mykiss*	AFCHA02090	G5
Steelhead Salmon (summer)	*Oncorhynchus mykiss*	AFCHA02090	G5
Steelhead Salmon (winter)	*Oncorhynchus mykiss*	AFCHA02090	G5
Threespine stickleback	*Gasterosteus aculeatus*	AFCPA03010	G5
Western Brook Lamprey	*Lampetra richardsoni*	AFBAA02090	G4G5
White Sturgeon	*Acipenser transmontanus*	AFCAA01050	G4
Birds			
Western grebe	*Aechmophorus occidentalis*	ABNCA04010	G5
Mammals			
Pacific water Shrew	*Sorex bendirii*	AMABA01170	G4
Insects			
Autumn Meadowhawk	*Sympetrum vicinum*	IIODO61140	G5
Beaverpond Baskettail	*Epitheca canis*	IIODO29030	G5
Black Petaltail	*Tanypteryx hageni*	IIODO02010	G4
Blue Dasher	*Pachydiplax longipennis*	IIODO53010	G5
Emma's Dancer (nez Perce)	*Argia emma*	IIODO68150	G5
Grappletail	*Octogomphus specularis*	IIODO89010	G4
Spring Stonefly trictura	*Cascadoperla trictura*	IIPLE22010	G3G4
Stonefly fraseri	*Isocapnia fraseri*	IIPLE05040	G1
Stonefly gregsoni	*Bolshecapnia gregsoni*	IIEPE02010	G2
Stonefly sasquatchi	*Bolshecapnia sasquatchi*	IIEPE02050	G3
Stonefly tibilalis	*Setvena tibilalis*	IIPLE2A020	G4
Stonefly vedderensis	*Isocapnia vedderensis*	IIPLE05110	G4
Vivid Dancer	*Argia vivida*	IIODO68290	G5
Western Pondhawk	*Erythemis collocata*	IIODO39020	G5

3.3 Summary of targets and goals

Table 18. Summary of targets used in the terrestrial and freshwater assessments by target groups

Ecoregion or EDU	Environ-mental Realm	Biological Level	Taxonomic Group	Target Count	Count of Targets with Data	Count of Targets with Data and Goals
North Cascades Ecoregion	Terrestrial	Ecological Systems		19	19	19
North Cascades Ecoregion	Terrestrial	Plant Communities		17	17	17
North Cascades Ecoregion	Terrestrial	Other Ecological Features		4	4	4
North Cascades Ecoregion	Terrestrial	Species	Amphibians	2	2	2
North Cascades Ecoregion	Terrestrial	Species	Birds	24	18	18

Ecoregion or EDU	Environ-mental Realm	Biological Level	Taxonomic Group	Target Count	Count of Targets with Data	Count of Targets with Data and Goals
North Cascades Ecoregion	Terrestrial	Species	Insects	6	6	6
North Cascades Ecoregion	Terrestrial	Species	Mammals	14	10	9
North Cascades Ecoregion	Terrestrial	Species	Molluscs	9	9	9
North Cascades Ecoregion	Terrestrial	Species	Nonvascular Plants	7	3	3
North Cascades Ecoregion	Terrestrial	Species	Vascular Plants	87	65	65
Lower Fraser EDU	Freshwater	Ecological Systems		17	17	17
Puget Sound EDU	Freshwater	Ecological Systems		7	7	7
Southern Coastal Streams EDU	Freshwater	Ecological Systems		16	16	16
Lower Fraser EDU	Freshwater	Species	Amphibians	5	4	4
Lower Fraser EDU	Freshwater	Species	Birds	1		0
Lower Fraser EDU	Freshwater	Species	Fishes	32	20	20
Lower Fraser EDU	Freshwater	Species	Insects	14	12	12
Lower Fraser EDU	Freshwater	Species	Mammals	1	1	1
Southern Coastal Streams EDU	Freshwater	Species	Amphibians	5	1	1
Southern Coastal Streams EDU	Freshwater	Species	Birds	1	1	1
Southern Coastal Streams EDU	Freshwater	Species	Fishes	29	13	13
Southern Coastal Streams EDU	Freshwater	Species	Insects	14	4	4
Southern Coastal Streams EDU	Freshwater	Species	Mammals	1	1	1

Chapter 4 – Suitability Index

Technical Team

The Suitability Index technical team was composed of the following people:

Dave Nicolson	Nature Conservancy of Canada
George Wilhere	Washington Department of Fish and Wildlife
Kristy Ciruna	Nature Conservancy of Canada
Pierre Iachetti	Nature Conservancy of Canada

4.1 Introduction

MARXAN was used to identify an efficient set of conservation areas. MARXAN searches for the lowest cost set of assessment units that will meet representation levels for all conservation targets. This set of assessment units is defined as an efficient or "optimal" solution. "Cost" corresponds to economic, socio-political, and environmental factors operating on the landscape that either support or impede management regimes for biodiversity conservation (Groves 2003); it is represented in MARXAN by the suitability index. Used in this context, cost refers not only to financial considerations but also refers to *likelihood of success,* especially in terms of species viability or persistence. In other words, conservation investment (whether financial or effort-based) has a higher return if it sustains biodiversity for the long-term.

Land use suitability is a well established concept among planners (Hopkins 1977; Collins et al. 2001), and there are many different methods for constructing an index (Banai-Kashini 1989; Carver 1991; Miller et al. 1998; Stoms et al. 2002). Suitability indices have been used to locate the best places for a wide range of land uses, from farms to nuclear waste sites. In this assessment, a suitability index was applied in an optimization algorithm in order to identify the best places for biodiversity conservation in the North Cascades ecoregion.

MARXAN requires that "cost" be represented as a single value for each assessment unit (AU). This value must represent the combination of all factors that may affect successful conservation at each AU and their relative importance. Our suitability index was a linear combination of several factors.

MARXAN will still select areas of high cost/low suitability if they are required to meet representation goals. For example, rare species or those with limited range will have fewer places for MARXAN to choose from, which may force the selection of "high cost" areas. The suitability index simply ensures that if there is a high suitability/low cost alternative, it will be preferentially selected.

4.1.1 Assumptions

The suitability index was developed using three assumptions:

1. Existing public land is more suitable for conservation than private land.
2. Rural areas are more suitable for conservation than urban areas.
3. Areas with low habitat fragmentation are more suitable for conservation than areas with high fragmentation.

The first assumption was based on the work of the Gap Analysis Program (Cassidy et al. 1997; Kagan et al. 1999). The Oregon and Washington GAP projects rated nearly all public lands as better managed for biodiversity than most private lands. Furthermore, conservation biologists have noted that existing public lands are the logical starting point for habitat protection programs (Dwyer et al. 1995). The team also reasoned that by focusing conservation on lands already set aside for public purposes, the impact on private or Aboriginal/tribal lands and the overall cost of conservation would be less than if public and private lands were treated equally. Therefore, existing public lands could form the core of large, multiple-use landscapes where biodiversity conservation is a major management goal.

The second assumption was based on the definition of urban area. In general, urban areas make intensive use of land for the location of buildings, structures, and impermeable surfaces to such a degree as to be incompatible with large-scale conservation of native biodiversity. However, this definition of urban does not preclude a need for natural areas or habitat restoration within the urban environment. The third assumption was based on the work of Diamond (1975) and Forman (1995), among others, and is a well-accepted principle of conservation biology. The third assumption is addressed indirectly in the index through two of the factors that are used: road density and percent of habitat in different land uses (i.e. urban, agriculture, etc.).

The validity of the first two assumptions is debatable. That is, other organizations or stakeholders may contend that biodiversity conservation on private lands is just as feasible as conservation on public lands, or that no distinction should be made between urban and rural areas with respect to biodiversity conservation. Certainly, there are situations where both these contentions are true. However for this assessment, it was assumed that public lands are the most sensible starting point for biodiversity conservation and that "urban area" is a land use designation that is mostly incompatible with maintaining a full suite of existing biodiversity.

Although the simple index used in this assessment cannot account for the many complex local situations that influence successful conservation, it is believed that some reasonable generalities are still quite useful for assessing conservation opportunities across an entire ecoregion. For a more detailed account of the suitability index, refer to Appendix 13.

4.2 Methods

The suitability index used in this project was based on the analytic hierarchy process (AHP) (Saaty 1980; Banai-Kashini 1989). AHP generates an equation that is a linear combination of factors that are thought to affect suitability. Each factor is represented by a separate term in the equation, and each term is multiplied by a weighting factor. AHP is unique because the weighting factors are obtained through a technique known as pair-wise comparisons (Saaty 1977) where expert opinion is solicited for the relative importance of each term in the equation. To simplify the elicitation process, the "abbreviated pair-wise comparisons" technique was used. That is, perfect internal consistency for each expert was assumed, which allowed the number of comparisons to be reduced. AHP has been used in other conservation assessments where expert judgments are used in lieu of empirical data (Store and Kangas 2001; Clevenger et al. 2002; Bojorquez-Tapia 2003).

Several experts - from the Nature Conservancy of Canada, The Nature Conservancy, Washington Department of Fish and Wildlife, NatureServe, and the Washington Natural Heritage Program - with knowledge of the ecoregion were sent a spreadsheet and asked for their opinion on the ranks and relative importance values of factors used in the suitability index. They were asked to do the same for sub-terms for management status and land use.

Responses were separated by jurisdiction, since inputs were slightly different between BC and Washington, and then were collated. Outliers were discarded. Weights for each factor were calculated by finding the dominant eigenvector of each comparisons matrix (Saaty 1977).

Two similar cost suitability indices were built—one for terrestrial areas and one for freshwater areas—by compiling spatial data related to the human use footprint (e.g., road density, urban growth, conversion of natural landscapes), current management, and aquatic factors such as the presence of dams. These data were incorporated into the AHP equation and a single suitability value or cost for each assessment unit was generated.

The use of suitability indices for assessing the likelihood of successful conservation has some potential drawbacks. For example, the index for this assessment was built using expert opinions about which factors to include and the relative importance of each factor. Also, few if any of these GIS data are ever ground-truthed for their accuracy. In most cases, these datasets would be greatly improved by field checking the accuracy of analytical results (Rumsey et al. 2003). To address these concerns, a sensitivity analysis on the suitability index was performed (Chapter 5).

4.2.1 Terrestrial Suitability Index

The terrestrial suitability index consists of four terms and is expressed as:

Terrestrial Suitability = A * management_status + B * land_use + C * road_density + D * future_urban_potential

A, B, C, and D are weighting factors calculated from expert input and pairwise comparison, which collectively sum to 100%. The individual index factors are shown in Map 11. Map 12 shows the combined terrestrial suitability index factors.

Two terms in the main equation were also linear combinations of other sub-factors. Weights, summing to 100 within each term, were also applied to sub-factors within management status and land use class. For example:

land_use = q * % urban + r * % agriculture + s * % mine + t * % timber harvest + u * % intensive recreation

Values for each factor (or sub-factor) were based on the percent area of that factor in the assessment unit. Values for each factor were normalized prior to applying the weights according to the following equation:

Normalized score = (score for that AU / highest score for all AU)*100

Appendix 14 provides details on how each factor was developed, including rationale for inclusion in the index, processing methods, factor weights and sub-weight values and data sources. The appendix also provides details on other factors that were considered for inclusion, including the rationale for not including the factors in the index.

4.2.2 Freshwater Suitability Index

The freshwater suitability index consisted of eight terms and is expressed as

Freshwater Suitability = A * management_status_score + B * land_use_score + C * dams_score + D * water_extraction_score + E * fish_stock_score + F * road_density_>50%_gradient_score + G * road_stream_crossing_score + H * riparian_disturbance_logging_score

A, B, C, D, E, F, G and H are weighting factors calculated from expert input and pairwise comparison, which collectively sum to 100. Map 13 shows the combined freshwater suitability index factors.

Two terms in the main equation were also linear combinations of other sub-factors. Weights, summing to 100 within each term, were applied to sub-factors within management status and land use class. For example

land_use = q * %_urban + r * % agriculture + s * % mine

Values for each factor (or sub-factor) were based on the percent area of that factor in the assessment unit. Values for each factor were normalized prior to applying the weights according to the following equation:

Normalized score = (score for that AU / highest score for all AU)*100

Weights were obtained from input received from two people—one member of the technical team and one outside expert. All of the respondents were from BC. Weights were assigned to the eight assessment units in the Lower Fraser EDU, which are located in Washington State. Data were lacking for many factors in Washington State; therefore, the weights were prorated and adjusted to sum to 1 for those factors for which there were data.

Appendix 13 provides details on how each of the factors were developed, including rationale for inclusion in the index, processing methods, factor weights and sub-weight values and data sources. The appendix also provides details on other factors that were considered for inclusion, in the index.

Chapter 5 – Prioritization of Assessment Units

5.1 Introduction

Organizations, agencies and landowners should be given the flexibility to pursue other options when portions of the portfolio are too difficult to protect. Assigning a relative priority to all AUs in the ecoregion will help planners explore options for conservation.

In this assessment, the optimal site selection algorithm MARXAN was used to assign a relative priority to each AU in the ecoregion. The relative priorities were expressed as two indices—irreplaceability and utility. Irreplaceability is an index that indicates the relative biodiversity value of a place (i.e., an assessment unit). Conservation utility is a function of both biodiversity value and the likelihood of successful conservation.

The prioritization results in this assessment should not be the only information used to direct conservation actions. Unforeseen opportunities have had and should continue to have a major influence on conservation decisions. Local attitudes toward conservation can hinder or enhance conservation actions. Considerations such as these are difficult to incorporate into long-range priority setting schemes but must be dealt with case by case.

5.1.1 Sensitivity Analysis

A sensitivity analysis is necessary whenever there is considerable uncertainty regarding modeling assumptions or parameter values. A sensitivity analysis determines what happens to model outputs in response to a systematic change of model inputs (Jorgensen and Bendoricchio 2001). Sensitivity analysis serves two main purposes: (1) to measure how much influence each parameter has on the model output; and (2) to evaluate the potential effects of poor parameter estimates or weak assumptions (Caswell 1989). A sensitivity analysis can be used to ascertain the robustness of the prioritization results and to judge the level of confidence in the conclusions.

Chapters 4 and 5 explain the inputs to MARXAN. The input with the greatest uncertainty was the suitability index. It was not a statistical model; rather, variable selection and parameter estimates for the index were based on professional judgment. For this reason, the sensitivity analysis focused on the suitability index. The methods for the sensitivity analysis are thoroughly explained in Appendix 18.

5.2 Methods

5.2.1 Irreplaceability

Irreplaceability is an index that indicates the relative conservation value of a place (i.e., an assessment unit). Irreplaceability has been defined a number of different ways (Ferrier et al. 2000; Noss et al. 2002; Leslie et al. 2003; Stewart et al. 2003); however, the original operational definition was created by Pressey at al. (1994). They defined irreplaceability of a site as the percentage of alternative reserve systems in which it occurs. Following this definition, Andelman and Willig (2002) and Leslie et al. (2003) each exploited the stochastic nature of the simulated annealing algorithm to calculate an irreplaceability index. Andelman and Willig's (2002) index is:

$$I_j = (1/n) \sum_{i=1}^{n} s_i \qquad (1)$$

where I is relative irreplaceability, n is the number of solutions, and s_i is a binary variable that equals 1 when AU_j is selected but 0 otherwise. I_j has values between 0 and 1, and is obtained from running the simulated annealing algorithm *n* times at a single representation level.

Irreplaceability is a function of the desired representation level (Pressey et al. 1994; Warman et al. 2004). Changing the representation level for target species often changes the number of AUs needed for the solution. For instance, low representation levels typically yield a small number of AUs with high irreplaceability and many AUs with zero irreplaceability, but as the representation level increases, some AUs attain higher irreplaceability values. The fact that some AUs go from zero irreplaceability to a positive irreplaceability demonstrates that Willig and Andelman's index is somewhat misleading; at low representation levels, some AUs are shown to have no value for biodiversity conservation when they actually do. For this assessment, an index for relative irreplaceability that addresses this shortcoming was created. This global irreplaceability index for AU_j was defined as:

$$G_j = (1/m) \sum_{k=1}^{m} I_{jk} \qquad (2)$$

where I_{jk} are relative irreplaceability values as defined in equation (2) and m is the number of representation levels used in the site selection algorithm. G_j has values between 0 and 1. Each I_{jk} is relative irreplaceability at a particular representation level. MARXAN was run at ten representation levels for coarse- and fine-filter targets. At the highest representation level, nearly all AUs attained a positive irreplaceability.

Many applications of irreplaceability have implicitly subsumed some type of conservation efficiency (e.g., Andelman and Willig 2002, Noss et al. 2002, Leslie et al. 2003, Stewart et al. 2003). Efficiency is usually achieved by minimizing the total area needed to satisfy the desired representation level. All AUs were 500 ha hexagons, and therefore, MARXAN minimized area by minimizing the total number of AUs.

5.2.2 Conservation Utility

The concept of irreplaceability was expanded upon by using conservation utility (Rumsey et al. 2004). Conservation utility is defined by equation (2), but the optimization algorithm is run with the AU costs incorporating a suitability index. To generate irreplaceability, AU cost equals the AU area. To create a map of conservation utility values, AU cost reflects practical aspects of conservation—current land uses, current management practices, habitat condition, etc. (see Chapter 4). In effect, conservation utility is a function of both biodiversity value and the likelihood (cost) of successful conservation.

5.2.3 Representation Levels

Coarse-filter

It was assumed that there is a logarithmic relationship between the risk of species extinction and the amount of habitat, based on the species-area curve. The species-area curve is one of the most thoroughly established quantitative relationships in all of ecology (Conner and McCoy 1979; Rosenzweig 1995). The curve is defined by the equation $S=cA^z$, where S is the number of species in a particular area, A is the given area, c and z are constants. The equation states that the number of species (S) found in a particular area increases as the habitat area (A) increases. The parameter z takes on a wide range of values depending on the taxa, region of the earth, and landscape setting included in the study.

Most values lie between 0.15 and 0.35 (Wilson 1992). A frequently cited rule-of-thumb for the z value is Darlington's Rule (MacArthur and Wilson 1967; Morrison et al. 1998). It states that a doubling of species occurs for every 10-fold increase in area, hence z = log (2) or 0.301. This relationship was used in this study to derive representation levels that roughly corresponded to equal increments of biodiversity—i.e., each increase in coarse-filter area captured an additional 10% of species.

Fine-filter

For fine-filter targets, each representation level corresponds to a different degree of risk for species extinction. Although the actual degree of risk cannot be estimated, it is understood that risk is not a linear function of representation. It is roughly logarithmic.

Fine-filter representation levels specify the number of species occurrences to be captured within a set of conservation areas. The relationship between species survival and number of isolated populations is also a power function:

$$\text{Species Persistence Probability} = \quad 1 - [1 - \text{pr}(P)]^{n}$$

where pr(P) is the persistence probability of each isolated population and n is the number of populations. This equation states that the probability of species persistence increases as the number of populations increases; however, there is a diminishing increase in persistence probability as the number of populations increases. According to this relationship, if the intent is to have representation levels correspond to equal degrees of risk, then fine-filter representation levels should not increase linearly but logarithmically. However, the above equation will not work in this study since pr (P) is unknown. Even if it were, it would not be equal across all populations.

Other relationships, however, were available. The Natural Heritage Programs/Conservation Data Centres use many criteria to determine global and subnational ranks (G- and S-Ranks). These criteria indicate the degree of imperilment—i.e., the risk of extinction according to the number of occurrences or the number of populations (Appendix 1 - Glossary) (Master et al., 2003). The relationship between the number of occurrences (or populations) and degree of imperilment follows a power function. The Natural Heritage Program/Conservation Data Centre G- and S-Rank criteria were used in this study to develop 10 representation levels.

5.2.4 Sensitivity Analysis

Sensitivity to the suitability index was examined by altering the index's parameter values, running the selection algorithm with the new index, and then quantifying the resulting changes in the conservation utility map. Recall that the suitability index equation is a weighted linear combination of factors:

Suitability = A • management status + B • %converted land + C • road density + D • %urban growth area

where A + B + C + D = 1; and management status, %converted land, road density, and %urban growth area were each normalized to a maximum value of 1. Also, recall that MARXAN tries to minimize the cost of AUs; therefore, the suitability index is actually formulated as an "unsuitability" index.

The values for parameters A, B, C, and D were determined by averaging expert opinion using the Analytic Hierarchy Process (AHP) (Saaty 1980). Each parameter was changed by +0.1 and parameters A and B were also changed by -0.1. After changing a parameter value, the other parameters were adjusted so that they all still summed to 1. Only the suitability index parameters were changed; none of the other inputs to the selection algorithm used to produce the original utility map were changed.

Resulting changes in the algorithms output were quantified several ways. First, three similarity measures were calculated to compare the conservation utility maps generated: mean absolute difference (also known as mean Manhattan metric), Bray-Curtis similarity measure, and Spearman rank correlation (Krebs 1999). The Bray-Curtis similarity measure normalizes the sum absolute difference to a scale from 0 to 1. Hence, mean absolute difference and the Bray-Curtis similarity measure give the same result but on different scales. Because utility will be used for prioritizing AUs, the rank correlation is particularly informative. Rank correlation indicates how the relative AU priorities change in response to changes in the suitability index. To prioritize AUs, the mean absolute difference in rank was also calculated.

5.3 Results

5.3.1 Terrestrial Analysis

The irreplaceability and utility maps for the terrestrial analysis are shown in Maps 14 and 15. The categories on these maps correspond to deciles. That is, the statistical distribution of utility and irreplaceability scores were each divided into 10% quantiles. The decile map indicates where the AUs with a selection frequency (or score) in the top 10 or 20% of all AUs are. Scores at the 90th percentile were 60 for both irreplaceability and utility. Additionally, the percentage of AUs with a score greater than 90% was 2.1% and 2.7% for irreplaceability and utility, respectively (see Appendix 15).

AUs with scores equal to 100 were those selected in every replicate at every representation level; 1.4% had irreplaceability equal to 100, 1.7% had utility equal to 100, and 1.3% had both scores equal to 100 (Table 19).

At the lowest representation level, the best solutions for irreplaceability and utility consisted of 2.2% and 2.3% of AUs, respectively. Scores of 100 were attained by 64% of AUs in the irreplaceability best solution and 75% of AUs in utility best solution, which demonstrates that few options existed for meeting the lowest representation level. That is, rare targets could only be captured at the high scoring AUs. This also shows how incorporating suitability into the analysis narrows the number of options.

Table 19. Percentage of Assessment Units (AUs) with high selection frequencies for both terrestrial and aquatic analyses of irreplaceability, conservation utility, and both combined

Realm	Number of AUs	Selection frequency	Irreplace-ability	Utility	Both
Terrestrial	9587	100 %	1.4	1.7	1.3
		≥ 95%	1.8	2.0	1.6
		≥ 90 %	2.1	2.7	2.0
Aquatic: Puget Sound EDU	442	100 %	1.4	1.6	1.4
		≥ 95%	3.6	3.8	3.2
		≥ 90 %	7.0	7.2	6.8
Aquatic: Lower Fraser River and Southern Coastal EDUs	909	100 %	1.9	2.9	1.4
		≥ 95%	3.0	4.7	2.3
		≥ 90 %	5.0	6.6	3.6

5.3.2 *Freshwater Analysis*

The irreplaceability and utility maps for the freshwater analysis are shown in Maps 16 and 17. A score greater than 90 was attained by 76 AUs for irreplaceability and 92 AUs for utility. Twenty-three AUs had an irreplaceability score of 100, 33 had a utility score of 100, and 19 had both scores equal to 100 (Table 19). The number AUs that attained perfect utility scores was greater than the number that attained perfect irreplaceability scores because when the optimization involved suitability, the higher suitability scores of some AUs caused them to be selected in every replicate.

5.3.3 *Sensitivity Analysis*

In general, changes to suitability index parameters result in changes in AU utility scores. Positive changes to all four parameters resulted in approximately the same values for mean absolute difference, Bray-Curtis similarity measure, and Spearman rank correlation (Table 20). However, among positive parameter changes, parameter C caused the greatest effect on similarity measures. Negative changes to parameters A and B resulted in larger values for mean absolute difference than those resulting from positive changes to A, B, C, and D (Table 20). For changes to all parameters, the null hypothesis was accepted for all similarity measures. That is, none of the changes to index parameters resulted in significant changes to the overall utility map. All values for weighted Spearman rank correlation were larger than those for unweighted Spearman rank correlation, which demonstrates even greater similarity among AUs with higher utility scores than lower scores.

Table 20. Similarity measures comparing original utility scores obtained after changing parameter values in the Suitability Index

	A		B		C	D
	-0.1	**+0.1**	**-0.1**	**+0.1**	**+0.1**	**+0.1**
Mean absolute difference	3.3	3.0	3.4	2.8	3.1	3.0
Bray-Curtis Measure	0.979	0.981	0.978	0.982	0.980	0.981
Spearman Rank Correlation	0.986	0.990	0.990	0.990	0.987	0.989
Weighted Rank Correlation	0.992	0.994	0.993	0.993	0.993	0.993

According to the similarity measures, there was little overall difference between the original and altered utility maps; however, many individual AUs did change, and some showed statistically significant changes in utility (Appendix 15). When each of the parameters was changed, about 50% of AUs changed utility score but only about 2–3.5% had a statistically significant change. Changes to parameter C, which modifies the relative influence of road density, caused the greatest number of significant changes.

Since utility will be used to prioritize AUs for conservation, the sensitivity of AU rank to changes in the suitability index is especially important. This analysis used only AUs that were highly ranked. For AUs with ranks from 1 to 100 (i.e., the top 11% of AUs), changes to A, which modifies the relative influence of management status, caused the greatest mean absolute difference in rank, followed by D, then B, and then C (Appendix 15). For AUs with the rank equal to 1 (i.e., utility=100; n=159), parameter B caused the greatest mean absolute change in rank followed by parameter A. Overall, few AUs with rank equal to 1 changed rank in response to parameters changes. Changes to B caused only 2.5% of them to change rank.

5.4 Discussion

How should the irreplaceability and conservation utility indices be interpreted? These indices were constructed by running MARXAN at ten representation levels. The first level captured a very small amount of each target, and the last level captured everything—i.e., all known occurrences of all targets. The first representation level should be thought of as the amount of biodiversity to be captured in an initial set of reserves, the second level as an additional amount to be captured by an enlarged set of reserves, the third level as an even greater additional amount, and so on. At each level, MARXAN's output indicates the relative necessity of each AU for efficiently capturing that particular amount of biodiversity. When the outputs from each level are summed, the result specifies the most efficient sequence of AU protection that will eventually represent all biodiversity. The sequence in which AUs should be protected is one way to gauge their relative importance. AUs that have the highest irreplaceability or utility scores should be protected first, and therefore, are the most important AUs for biodiversity conservation.

MARXAN generates a set of AUs corresponding to a local minimum of the objective function (see Appendix 8). AUs are included in a solution because they serve to minimize the objective function. Therefore, AUs with high irreplaceability or high utility scores are those that (1) contain one or more rare targets and/or (2) contain a large number of target occurrences. High utility scores are also attained by AUs with low unsuitability (i.e., high suitability). AUs with scores of 100 are those that were selected in every replicate at every representation level. To be chosen in every replicate the AU must contain target occurrences that were found in no other AU, contain a substantially larger number of occurrences than other AUs, or contain target occurrences and have a substantially lower unsuitability than other AUs.

Utility and irreplaceability scores are different ways to prioritize places for conservation. Irreplaceability has been the most commonly used index (e.g., Andelman and Willig 2002; Noss et al. 2002; Leslie et al. 2003; Stewart et al. 2003), and it assumes that the amount of land area where biodiversity values are found is the sole consideration for efficient conservation. Utility incorporates other factors, such as land management status and current condition, which can affect efficient conservation. In this analysis, many AUs attained scores of 100 for both utility and irreplaceability. These results demonstrate that for scores at or near 100, cost had little influence on selection frequency and that occurrence data drove the results. More importantly, it demonstrates that the results are robust. Under two different assumptions about efficiency (area versus unsuitability), the highest priority AUs were very similar.

Utility and irreplaceability scores were significantly different for many individual AUs at the middle and low end of the utility score range (see Appendix 15). This is useful information for prioritization. AUs at the low end of utility (or irreplaceability) typically are unremarkable in terms of biodiversity value. They contribute habitat or target occurrences, but they are interchangeable with other AUs. For these AUs, prioritizing on the basis of suitability rather than biodiversity value makes most sense. If a distinguishing feature of an AU is that conservation can be conducted there more successfully and inexpensively than in other AUs, then that AU should be a higher priority for action. For these AUs, the utility score should be used for prioritization.

The basic conclusion of the sensitivity analysis is that AU utility and rank change in response to changes in the suitability index. Similarity measures that compare "before" and "after" utility maps of the entire ecoregion indicate that the overall map is relatively insensitive to changes in suitability index parameters. That is, the average change over all AUs is small. However, the utility and rank of many AUs do change and some exhibit significant changes. The number of AUs that change significantly depends on which index parameter is changed and by how much.

The sensitivity of the utility map to changes in the suitability index was examined due to uncertainty about the index. The variable selection and parameter estimates for the index were based on best professional judgment. The sensitivity analysis considers how much utility scores would change if the subjective judgments were slightly different. The results of the sensitivity analysis had two implications for conservation planning. First, highest priority AUs (about ranks 1 through 10; the top 3% AUs) are rather robust to changes in the suitability index. Therefore, regardless of the uncertainties in the suitability index, confidence can be placed in the selection of the most highly ranked AUs. These AUs were selected mainly for their relative biological value, not relative suitability. For similar reasons, the lower ranked AUs (ranks >100), tend to be robust to changes in the suitability index—they maintain a low rank because they have relatively little biological value. Second, the utility of moderately ranked AUs (those ranked from 10^{th} to 100^{th}; about 12% of AUs), is sensitive to changes in the suitability index. When choosing among AUs of moderate rank, assumptions about how suitability affects rank must be examined.

Chapter 6 – Portfolio of Conservation Areas

This chapter presents the development of the mid-risk conservation portfolio and the results of the assessment. A conservation portfolio is a set of places where resources should be directed for the conservation of biodiversity. The conservation areas that make up the portfolio are summarized and how the overall portfolio captures fine- and coarse-filter targets is discussed. Alternative conservation portfolios reflecting different conservation goals for targets are reviewed.

6.1 Portfolio Development Process

Successful conservation will involve making choices about where limited resources should be expended (Ando et al. 1998; Pressey and Cowling, 2001). Portfolio creation is a major step toward making informed choices about where conservation areas or reserves should be located. Selecting a set of sites that efficiently capture multiple occurrences of hundreds of targets from thousands of potential sites is a task that cannot be accomplished by expert judgment alone. For this reason, MARXAN was used to help create the portfolio. Further explanation of MARXAN can be found in Appendix 8. Optimal reserve selection analyzes the trade-offs between conservation values and conservation costs to create an efficient set of conservation areas that satisfies conservation goals (Possingham et al. 2000; Cabeza and Moilanen 2001). The conservation value of a site is represented by the presence of target species, habitats, and ecological communities. The number, condition, and rarity of targets present at a particular site determine the conservation value of that place.

The portfolio design process for the North Cascades Ecoregion resulted in the creation of two portfolios: one for the terrestrial environment, the other for the freshwater environment (Maps 18 and 20). Portfolio creation was an iterative process that balanced the use of the optimal reserve selection algorithm with expert knowledge about important places for biodiversity conservation.

6.1.1 Terrestrial Assessment

The terrestrial portfolio identified a set of assessment units (AUs) that met conservation goals for all terrestrial conservation targets in a way that maximized portfolio suitability (Map 18). Terrestrial conservation targets included coarse-filter targets, such as terrestrial ecological systems, and fine-filter targets, such as rare plants, rare animals and rare communities (see Chapter 3).

Once the MARXAN analysis was complete, teams of experts were asked to examine the results and recommend additions and deletions to the selected areas based on their knowledge and experience of conservation target occurrences. Experts were also asked to identify potential habitat connectivity corridors between selected areas, since habitat connectivity is not targeted in the MARXAN analysis. Results of both the computer identified and expert selected areas were then used to create groups of AUs that would become terrestrial portfolio sites. The terrestrial portfolio refers to the complete set of these areas in the ecoregion.

6.1.2 Freshwater Assessment

The assessment of freshwater biodiversity was based on a different set of geographic boundaries than the ecoregion; it was based on ecological drainage units (EDUs) that overlap or connect with ecoregion boundaries (Map 5 and Chapter 3). The freshwater portfolio was developed independently from the terrestrial portfolio, reviewed by experts, and then overlaid with the terrestrial portfolio. Development of the preliminary freshwater portfolio relied on MARXAN spatial analysis to identify a set of watersheds that have both high biodiversity value and high suitability for conservation. The objective in creating the freshwater portfolio, like the terrestrial, was to select the most efficient set of areas that meet goals for all targets and to do it at the least cost, as defined by the suitability index (Chapter 4). The watersheds selected in this MARXAN analysis were then subjected to expert review. The watersheds selected by analysis and expert review were then combined into groups of watersheds to make up freshwater portfolio sites (Map 20).

6.2 Conservation Goals

Both the terrestrial and freshwater portfolios were created using conservation goals that specified a given number and distribution of populations (for species) and areas (for habitats) that were needed to sustain biodiversity in the ecoregion (for terrestrial) or ecological drainage unit (for freshwater) over the long term.

The intent of the analysis was to capture sufficient occurrences to meet conservation goals in the most efficient way possible, while also preferentially choosing occurrences with the least human impacts, according to the suitability index (Chapter 4). For this ecological assessment, conservation goals were set that reflected a high likelihood of target species survival and functioning ecological systems. However, there is much uncertainty, for example, regarding threats like future land conversion and climate change and little information regarding the number of occurrences or the area of an ecological system necessary to maintain all species within an ecoregion (Soule and Sanjayan 1998). In short, we had no scientifically established method for setting conservation goals for the vast majority of coarse- and fine-filter targets. Where we lacked better information, we adopted a set of generic conservation goals developed by ecologists from The Nature Conservancy and NatureServe (Marshall et al. 2000; Comer et al. 2001, 2003; Neely et al. 2001; Rumsey et al. 2003; Floberg et al. 2003; see also Appendix 19).

While the goals cannot be treated as conditions for ensuring long-term survival of species, they are an important device for assembling a portfolio of conservation areas that captures multiple examples of the ecoregion's biodiversity. These goals also provide a metric for gauging the contribution of different portions of the ecoregion to the conservation of its biodiversity and measuring the progress of conservation in the ecoregion over time.

6.3 Summary of Results

6.3.1 Terrestrial and Freshwater Portfolios

The terrestrial portfolio, shown in Map 18, covers 1,687,001 ha (4,168,665 ac) or 35% of the North Cascades ecoregion. The freshwater portfolio, shown in Map 20, covers 1,453,965 ha (3,592,821 ac) or 39% of the North Cascades Ecoregion.

The combined portfolio (Map 26) is the result of the overlay of the terrestrial and freshwater portfolios. Interestingly, little overlap occurs between the two realms (15%). This is probably because the freshwater portfolios often involved selection of whole systems from headwaters to mainstem rivers, while terrestrial selection was more focused on core areas representing the highest quality occurrences and important habitats. Since the lower elevation freshwater mainstem rivers tended to have higher human impacts, the terrestrial selection process tended to gravitate to upland or more pristine riparian sites to capture its targets, in areas removed from mainstem freshwater priorities.

While the conservation areas were designed with knowledge of the area requirements of conservation targets, they do not specifically describe the lands and waters needed to maintain each target at that location. Finer-scale conservation planning is needed to more precisely map the lands and waters that are necessary to ensure conservation of the targets in any particular area. Also, because of the way in which portfolio conservation areas were assembled, it may be appropriate to aggregate conservation areas at a later time. Conversely, it may be necessary to segregate individual conservation areas from larger ones. This refinement will be completed during later analyses that consider site-specific targets, threats, and goals. Thus, the current boundaries of the ecoregion are starting points for further analyses. The iterative nature of ecoregional assessments requires that results be interpreted carefully. The intent is to clarify and fill information gaps over time and to revisit and refine the portfolio as new information becomes available.

6.3.2 Terrestrial Portfolio

Of the total 155 portfolio sites resulting from the terrestrial analysis, 91 are entirely within British Columbia and 59 are entirely in Washington. Five portfolio sites are shared between British Columbia and Washington. They ranged in size from 500 ha (i.e., 1 hexagon; 1,236 ac) to landscapes of 204,000 ha (504,094 ac).

6.3.2.1 Protected Status and Land Ownership Patterns

Approximately 40% of the terrestrial portfolio is currently in designated protected areas. Assuming the biodiversity features in the portion of the portfolio within GAP 1 or GAP 2 lands are already protected, an additional 21% of the ecoregion requires some form of conservation action in order to conserve the full terrestrial portfolio (Map 23). A full breakdown of the protected status of the portfolio is shown in Table 21.

The patterns of land ownership and management within the terrestrial portfolio of conservation areas are shown in Table 22. Public lands, both federal and state/provincial, make up the majority of the ecoregional portfolio; 48% of the land in the BC portion of the portfolio is provincial Crown land while over 71% of the land in the WA portion of the portfolio is US federal land and more than 12% is state land. Private lands account for 5% of the portfolio in BC and 14% in WA. First Nations/tribal lands comprise less than 1% of the portfolio in both BC and WA.

Table 21. Protected areas within the terrestrial portfolio

	GAP 1	GAP 2	GAP 3	GAP 4
Area in Ecoregion (ha)	1,266,592	4,3681	2,945,583	172,754
% of Ecoregion	26%	1%	61%	4%
Terrestrial Portfolio (ha)	652,179	20,751	876,047	47,370
% of Portfolio	39%	1%	52%	3%
GAP Status in BC portion of Terrestrial Portfolio (ha)	349,613	5,686	621,674	46,393
% of BC portion	34%	1%	61%	5%
GAP Status in WA portion of Terrestrial Portfolio (ha)	302,566	15,065	254,373	977
% of WA portion	46%	2%	38%	<1%

Table 22. Land ownership within the terrestrial portfolio

Jurisdiction	% in Portfolio	Area in Portfolio (ha)	% in Ecoregion	Area in Ecoregion (ha)
Brtish Columbia				
Provincial Crown Land	48%	492,130	64%	1,982,360
Private Land	5%	53,402	5%	161,733
Provincial Park / Protected Area	34%	350,089	16%	511,827
Tree Farm License	12%	121,170	14%	444,641
Indian Reserve	<1%	5,433	1%	17,881
Conservation Trust Land	<1%	1,077	<1%	2,123
Federal Land	<1%	65	<1%	94
Washington – Federal Lands				
Forest Service: non-wilderness	32%	210,753	26%	430,305
Forest Service: Wilderness	24%	161,316	26%	431,423
National Park Service	15%	99,777	14%	233,544
Other Federal	<1%	1,222	<1%	1,706
Bureau of Land Management	<1%	98	<1%	263
Washington - State Lands				
Department of Natural Resources: Other	11%	7,0321	9%	147,114
Department of Fish and Wildlife	<1%	667	<1%	734
Department of Natural Resources: NRCA	1%	8,269	1%	15,321
Parks and Recreation	<1%	814	<1%	2270
Department of Natural Resources: NAP	<1%	734	<1%	946
Washington - Other Lands				
Private Land	14%	9,2471	22%	371,136
Tribal Land	<1%	19	<1%	19
County or Municipal	2%	14,027	2%	32,139
Conservation Land (TNC/Other)	<1%	3,288	<1%	7,955

6.3.3 *Freshwater Portfolio*

Of the total 121 portfolio sites resulting from the freshwater analysis, 59 are entirely within British Columbia and 59 are entirely in Washington. Three sites are shared between British Columbia and Washington. They range in size from single watersheds of 729 ha (1,802 ac) to combined watershed areas of 203,259 ha (502,263 ac).

A total of 258 watersheds were part of the freshwater conservation portfolio. Together they covered 3,475,256 ha (8,587,532 ac) and equalled 40% of the area contained in the three EDUs analysed (Map 5). The freshwater portfolio was aggregated and delineated as portfolio sites for watersheds that intersect the ecoregion. A number of watersheds were added to the portfolio to improve drainage network connectivity.

Sixty delineated freshwater Priority Conservation Areas (PCAs) are fully or partially in the North Cascades ecoregion[8]. They cover 2,008,055 ha (4,962,003 ac) or 39% of the ecoregion. Twenty-eight of them are entirely within British Columbia and 24 are entirely in Washington. One site is shared between British Columbia and Washington. They range in

[8] Including the full extent of the terrestrial assessment units.

size from partial watersheds of 828 ha (2,046 ac) to freshwater systems of 203,259 ha (502,262 ac).

6.3.3.1 Protected Status and Land Ownership Patterns

Approximately 26 % of the area of the freshwater portfolio (to the extent of the ecoregion[9], not EDUs) is currently in designated protected areas (GAP 1 or 2). Assuming the biodiversity values within the portion of the portfolio that coincides with parks (GAP 1 or 2) are already protected; an additional 13 % of the ecoregion requires some form of conservation action in order to conserve the full freshwater portfolio (Map 25). A full breakdown of the protected status of the portfolio is found in Table 23.

The patterns of land ownership and management within the freshwater portfolio of conservation areas are shown in Table 24. Public lands, both federal and state/provincial, make up most of the ecoregional freshwater portfolio; 53 % of the freshwater portfolio in BC is provincial Crown land, while just over 50% of the portfolio in WA is US federal land and over 15% is state land. Private lands encompass y 6 % of the freshwater portfolio in BC and and 33% in WA. First Nations/tribal lands comprise less than 1 % of the freshwater portfolio.

Table 23. Protected areas within the freshwater portfolio

	GAP 1	GAP 2	GAP 3	GAP 4
Area in Ecoregion (ha)	1,266,592	43,681	2,945,583	172,754
% Ecoregion	26%	1%	61%	4%
Freshwater Portfolio (ha)	443,060	11,062	1,046,005	79,602
% of Portfolio	25%	1%	59%	5%
GAP Status in BC portion of Freshwater Portfolio (ha)	247,592	5,151	868,802	79,548
% of BC portion	21%	<1%	72%	7%
GAP Status in WA portion of Freshwater Portfolio (ha)	195,468	5,911	177,203	54
% of WA portion	35%	1%	32%	<1%

Table 24. Land ownership within the freshwater portfolio

Jurisdiction	% in Portfolio	Area in Portfolio (ha)	% in Ecoregion	Area in Ecoregion (ha)
British Columbia				
Provincial Crown Land	53%	635,298	64%	1,982,360
Private Land	6%	70,884	5%	161,733
Provincial Park or Protected Area	21%	249,971	16%	511,827
Tree Farm License	19%	231,656	14%	444,641
Indian Reserve	1%	12,254	1%	17,881
Conservation Trust Land	<1%	964	<1%	2,123
Federal Land	<1%	65	<1%	94
Washington - Federal Lands				
Forest Service: non-wilderness	20%	111,926	26%	430,305
Forest Service: Wilderness	14%	81,046	26%	431,423
Other Federal	<1%	1,651	<1%	1,706
Bureau of Land Management	<1%	95	<1%	263
National Park Service	16%	90,842	14%	233,544

[9] Including the full extent of the terrestrial assessment units.

Jurisdiction	% in Portfolio	Area in Portfolio (ha)	% in Ecoregion	Area in Ecoregion (ha)
Washington - State Lands				
Department of Natural Resources: Other	14%	79,582	9%	147,114
Department of Fish and Wildlife	<1%	610	<1%	734
Department of Natural Resources: NRCA	1%	3,366	1%	15,321
Parks and Recreation	<1%	1,243	<1%	2,270
Department of Natural Resources: NAP	<1%	746	<1%	946
Washington - Other Lands				
Private Land	33%	183,615	22%	371,136
Tribal Land	<1%	19	<1%	19
Conservation Land (TNC/Other)	1%	5,335	<1%	7,955
County or Municipal	<1%	1,456	2%	32,139

6.4 Target Representation and Conservation Goals

Major ecological gradients and variability are well represented across the portfolio of conservation areas as evidenced by the high degree of representation of ecological systems and the ecological variables used to represent them (vegetation, elevation, landform, geologic substrate, etc.). For the terrestrial systems targets 100% of the conservation goals were achieved in 3 of the 4 ecosections. Overall, 100% of terrestrial systems conservation goals were achieved for the ecoregion. Refer to Table 25 for a summary of goal performance for terrestrial ecological systems.

Table 25. Summary of goal performance for terrestrial ecological systems

Ecosection	Number of Systems Targets	Targets with Goals	Targets Meeting Goals for Ecosection	% Targets Meeting Goals for Ecosection
Northeastern Pacific Ranges	19	14	13	93
Northwestern Cascade Ranges	19	15	15	100
Southeastern Pacific Ranges	19	16	16	100
Southern Pacific Ranges	19	11	11	100
Ecoregion	19	19	19	100

For the terrestrial fine filter animals analysis, there were 43 of 81 targets (53%) with spatial data that were used in the MARXAN analyses: 2 of 2 amphibian targets, 15 of 26 bird targets, 11 of 16 mammal targets, 6 of 13 butterfly targets, and 9 of 24 mollusc targets. Of those targets with spatial data, only 13 of 43 (30%) met the conservation goals that were set for them (Table 26). The success of meeting nearly all conservation goals for terrestrial systems contrasted with only meeting 30% of terrestrial fine filter animals goals provides insights into the performance of the MARXAN model. The terrestrial systems dataset provided complete coverage of the ecoregion, therefore MARXAN had enough information and choice to balance portfolio costs with meeting conservation goals for all targets. Whereas for the terrestrial fine filter animals targets data, those targets that were represented as occurrence data generally had too few occurrences to meet conservation goals, and those targets that were represented using habitat data generally met conservation goals. This also applies to the freshwater coarse- and fine-filter targets and goals.

Table 26. Summary of the number of terrestrial animal targets with spatial data, and targets with sufficient spatial data to meet conservation goals, by taxon

Terrestrial Animal Taxa Group	# of Targets in Taxa Group	# of Targets with Spatial Data (%)	# of Targets Meeting Conservation Goals (% of targets with data)
Amphibians	2	2 (100%)	1 (50%)
Reptiles	0	---	---
Birds	26	15 (58%)	5 (33%)
Mammals	16	11 (69%)	6 (55%)
Butterflies	13	6 (46%)	0 (0%)
Molluscs	24	9 (38%)	1 (11%)
Total	81	43 (53%)	13 (30%)

As with the terrestrial portfolio, the freshwater portfolio well represented major ecological gradients and variability across the portfolio of conservation areas as evidenced by the high degree of representation of the ecological systems and ecological variables used to represent them.Goals were met for 16 of the 17 freshwater system types in the Lower Fraser EDU, 5 of the 7 freshwater system types in the Puget Sound EDU, and 16 of the 16 freshwater system types in the Southern Coastal Streams EDU (Table 27).

Table 27. Summary of goal performance for freshwater ecological systems

EDU	Number of Targets	Systems Targets with Goals	Targets Meeting Goals for EDU	% Targets Meeting Goals for EDU
Lower Fraser EDU	17	17	16	94%
Puget Sound EDU	7	7	5	71%
Southern Coastal Streams EDU	16	16	16	100%

For the freshwater fine-filter animals analysis, goals and targets were stratified by EDU and each EDU was treated as its own study area for the purposes of running the MARXAN analysis. Therefore, each EDU had its own set of targets and goals. For the Lower Fraser EDU: 2 of 4 amphibian targets met the stated conservation goals, 12 of 12 insects, and 1 of 1 mammal targets, while no fish targets met stated conservation goals. For the Southern Coastal Streams EDU: 1 of 1 amphibian targets, 3 of 4 insect targets, and 1 of 1 mammal targets met the stated conservation goals, while 0 of 1 bird targets, and 0 of 14 fish targets met stated conservation goals. Refer to Table 28 for a summary of targets and conservation goals. As previously noted, the Puget Sound EDU was assessed as part of another ecoregional assessment process and the resultant information was included as part of the North Cascades freshwater analysis. Refer to Appendix 10 for details of the Puget Sound EDU methods and results.

Table 28. Summary of freshwater fine-filter animals targets

EDU	Freshwater Fine Filter Taxa	Number of Targets	# of Targets with Goals	# of Targets Meeting Goals for EDU	% of Targets with Data Meeting Goals for EDU
Lower Fraser EDU	Amphibians	5	4	2	50%
Lower Fraser EDU	Birds	1	0	---	---
Lower Fraser EDU	Fishes	32	20	0	0%

EDU	Freshwater Fine Filter Taxa	Number of Targets	# of Targets with Goals	# of Targets Meeting Goals for EDU	% of Targets with Data Meeting Goals for EDU
Lower Fraser EDU	Insects	14	12	12	100%
Lower Fraser EDU	Mammals	1	1	1	100%
Southern Coastal Streams EDU	Amphibians	5	1	1	100%
Southern Coastal Streams EDU	Birds	1	1	0	0%
Southern Coastal Streams EDU	Fishes	29	13	0	0%
Southern Coastal Streams EDU	Insects	14	4	3	75%
Southern Coastal Streams EDU	Mammals	1	1	1	100%

6.5 Alternative Portfolios

The size of the conservation portfolio is mainly determined by the goals – the larger the goals for representing targets, the larger the area of the portfolio. For this reason, goal setting is possibly the most critical step in creating a portfolio. Hence, we created additional portfolios with higher and lower goals to demonstrate how changing goals changes the total size and configuration of the portfolio.

6.5.1 Methods

The methods used to develop the alternative terrestrial and freshwater portfolios were essentially the same.

Risk is related to the amount of habitat or the number of target occurrences that are protected in the portfolio. More habitat area and number of occurrences correlates with a lower level of risk. The goals for the lower risk and higher risk portfolios were based on the goals of the mid-risk portfolio. For higher risk, the goals were reduced. All mid-risk coarse-filter goals were multiplied by 0.6 and fine-filter goals by 0.5, but the goals could not be less than 1 for targets with occurrence goals. For the lower risk, the goals were increased. The mid-risk coarse-filter goals were multiplied by 1.6 and fine-filter goals by 1.5, but the goals could not exceed the maximum available.

Higher and lower risk alternative portfolios that were derived from the mid-risk portfolios were created. All of the AUs in the higher risk portfolio belong to the mid-risk portfolio and all AUs in the mid-risk portfolio belong to the lower risk portfolio. MARXAN has a feature for locking AUs into or out of the optimal solution. To create a nested higher risk portfolio, all AUs that were not in the mid-risk portfolio were locked out. This limited the algorithm's selection space to only the mid-risk portfolio. To create a nested lower risk portfolio, all AUs that were in the mid-risk portfolio were locked in. Hence, the low-risk portfolio started with these locked-in AUs so the algorithm added more AUs to the mid-risk portfolio.

The site selection algorithm for both the lower risk and higher risk portfolios was run with the same targets and with the same boundary modifier and target penalty factors as those used for the mid-risk portfolio.

6.5.2 *Results*

The alternative portfolios for terrestrial and freshwater biodiversity are depicted on Maps 19 and 21. The terrestrial mid-risk portfolio included 30 % of the hexagonal assessment units (Table 29). However, the assessment units in the freshwater portfolio tended to be among the largest watersheds, and consequently, the freshwater portfolio captured about 39 % of the land area (Table 30).

The number of AUs in the terrestrial higher risk portfolio was roughly 0.54 times the mid-risk portfolio (Table 29) and the number of AUs in the terrestrial lower risk portfolio was about 1.56 times the mid-risk portfolio. These ratios were roughly the same that were used to alter the mid-risk goals. The same ratios for the Puget Sound EDU alternatives were 0.50 and 1.56, which was about the same as those used to alter the mid-risk goals.

Table 29. Percent of all Assessment Units (AUs) in ecoregion or Ecological Drainage Unit (EDU) that was captured by each of the alternative portfolios

Analysis	Percent of AUs selected			Total number of AUs available
	higher risk	mid-risk	lower risk	
Terrestrial	16.2	29.8	46.6	9,587
Freshwater: Puget Sound EDU	13.1	26.2	41.0	442
Freshwater: Lower Fraser River and Southern Coastal EDUs	8.5	15.3	30.5	909

Table 30. Percent of land area in ecoregion or Ecological Drainage Unit (EDU) that was captured by each of the alternative portfolios

Analysis	Percent of area selected			Total area available (ha)
	higher risk	mid-risk	lower risk	
Terrestrial	16.2	29.8	46.6	4,793,500
Freshwater: Puget Sound EDU	24.4	39.0	57.1	3,603,000
Freshwater: Lower Fraser River and Southern Coastal EDUs	27.6	39.7	57.0	5,272,000

6.5.3 *Discussion*

The three alternative portfolios represent different tolerances of risk to biodiversity loss. The low risk portfolio covers the largest geographic area; the high risk covers the smallest. The three portfolios are also an acknowledgment of the uncertainty involved in determining how much area is enough to conserve biodiversity. However, any portfolio's absolute risk to the loss of biodiversity over the long-term is unknown.

6.6 Portfolio Integration Efforts and Overlay Results

There is an underlying assumption in ecoregional assessment methodology, as described in *Geography of Hope* (TNC 2001): we want efficiency in selecting sites to reduce the cost of conservation, and minimizing portfolio area is one way of increasing efficiency. This assumption also applies to the integration of the terrestrial and the freshwater biodiversity values. Ideally, we would address common ecological functions, processes and biological elements that operate between terrestrial and freshwater systems in our conservation plan. However, no claims are made, even implicitly, that this was achieved through this project. Post-assessment analysis at the sub-ecoregional scale is needed to determine the extent to which such things as ecological functions are shared.

In this assessment, an attempt was made to create an integrated portfolio by combining terrestrial and freshwater targets into one MARXAN run as described in Appendix 17. However, several challenges presented themselves. While the initial results did provide a portfolio that was efficient with respect to size of the ecoregional footprint, the sacrifices made to achieve this efficiency were not satisfactory.

Specifically, the goal of integration is to select areas of the highest quality for terrestrial and freshwater biodiversity in order to achieve a smaller spatial footprint. In this study, the integration process exchanged too many high quality sites for marginal quality areas for the sake of creating a smaller footprint. During integration, it was also difficult to combine priority freshwater watersheds meaningfully within selected terrestrial hexagons, since watersheds and stream reaches would sometimes be selected in fragments. This attempted integration required more compromise (too little area chosen, too many goals met in areas of marginal quality and too much fragmentation of freshwater priorities) than was considered acceptable by the Core Team. Future iterations of this assessment will produce a fully integrated portfolio.

6.6.1 Combined Portfolios

The mid-risk terrestrial and freshwater portfolios were combined by overlaying one portfolio over the other. Map 26 shows both portfolios, and the areas of overlap. Given the ecological and technical challenges discussed above, a simple overlay of the terrestrial and freshwater portfolios was considered appropriate because:

1. it is easy to identify why an area is selected
2. the footprint of the expert-reviewed terrestrial and freshwater portfolios is maintained
3. neither the terrestrial or freshwater portfolio is compromised
4. areas where biodiversity values from each portfolio coincide are depicted

The overlapping portfolio area is also a relatively small portion of the ecoregion (15%). These areas may be further evaluated by using the prioritization analyses of the freshwater and terrestrial portfolios (Chapter 7). However, because freshwater conservation must occur at the watershed scale and terrestrial conservation must take place in areas large enough for natural disturbances to be maintained, those referencing the areas of overlap are advised to also consult the underlying freshwater and terrestrial sites.

The portfolios include a suite of sites that collectively represent the biodiversity of the ecoregion. In addition to showing areas that are most important for terrestrial or freshwater species and natural systems, Map 26 depicts areas of overlap where terrestrial and freshwater priorities co-occur. The overlapping areas do not include many areas identified by experts, generally do not meet goals, and frequently contain only partial target occurrences. However, they have utility for those interested in conserving both priority freshwater and terrestrial targets in the same area, by directing practitioners to areas where the potential exists to incorporate both terrestrial and freshwater targets in their conservation strategies.

6.7 Retrospective Analysis

For most target species, data are used to define the portfolio of sites by incorporating it into the analysis and defining the goals for capturing that target in the site selection process. However for a few species, we do not include their data and goals in the site selection process that defines the portfolio, but rather we evaluate the portfolio by how well it captures the data that represent these species. We refer to these species as retrospective targets. If the goal of the species is not met, modifications to the site selection process can be made such as including the species data in the site selection analysis.

A species may be represented by so much data and such large goals that its inclusion results in a portfolio that mimics that species' data (i.e. weighted too much for that species), and consequently the portfolio does not include areas that are important to a large number of other targets. This was the case for two wide-ranging carnivores that were selected as targets for the North Cascades assessment: the grizzly bear and the fisher. For example, the grizzly bear recovery zone coincides with >75% of the Washington portion of the ecoregion and the default goal for grizzly bears is 30% of that area. This amount of data and the 30% goal would significantly influence the result of the site selection analysis, in effect driving the solution to mimic the recovery zone within the Washington portion of the ecoregion.

6.7.1 Grizzly Bear

In BC, data was obtained from a spatial modeling project on grizzly bear habitat capability, suitability, and effectiveness in southwestern British Columbia (Apps and Hamilton 2002). Based on advice from the authors (C. Apps and A. Hamilton, pers. comm.), the team used the habitat effectiveness data in the retrospective comparison. Effectiveness was based on habitat suitability values and a habitat security sub-model (Apps and Hamilton 2002). Habitat effectiveness classes and corresponding bear densities are listed in Table 31.

Table 31. Grizzly bear Habitat Effectiveness Ratings (Apps and Hamilton, 2002)

BC Grizzly Bear Habitat Effectiveness Class Rating	
Habitat Class	**Bears/1000 km2**
1	76 – 100
2	51 –75
3	26 – 50
4	6 – 25
5	0 – 5

In Washington, grizzly bear habitat was identified as those areas within the ecoregion that overlapped with the grizzly bear recovery area (USFWS 1993). This area was further delineated to define core grizzly habitats by excluding (buffering and removing) areas near roads, trails and developed areas.

6.7.2 Fisher

The fisher was considered a target in the Washington portion of the ecoregion but was not included among the targets listed for British Columbia as the ecoregion is largely outside the species range within the province (Weir 2003). While the fisher is presumed extirpated from Washington, habitat modeling has been undertaken within the fisher's historical range in the North Cascades to identify suitable areas for fisher reintroductions (Lewis and Hayes 2004). The fisher was used as a retrospective target because a large amount of suitable habitat was identified within the Washington portion of the ecoregion and a relatively large goal (30%) was used.

6.7.2.1 Results

The terrestrial portfolio captured 42% of core habitat in Washington for grizzly bears and 35% of habitat effectiveness classes 1–5 in British Columbia (Table 32, Maps 30a,b). The goals for grizzly bear habitat (30%) were exceeded in British Columbia (35%) and in Washington (42%). As expected, the goals for grizzly bears in British Columbia were met largely through the selection of areas in habitat classes 4 and 5 (i.e., habitats that support lower grizzly densities), as they made up >98% of the grizzly habitat in the British Columbia portion of the ecoregion (Table 33). Despite the small amount of area in habitat classes 2 and 3 (i.e., habitats that support greater grizzly densities), large percentages of these areas (55 and 42%, respectively) were captured by the portfolio (Table 33).

There was a remarkable overlap between the portfolio and suitable fisher habitat (Map 29). The portfolio captured 54% of fisher habitat in Washington, greatly exceeding the goal of 30% (Table 32, Map 29).

Table 32. Summary of the retrospective analysis for Fisher and Grizzly bear

Terrestrial Retro Target Analyses	Hectares (ha)	Acres (ac)	Percent captured
Fisher Habitat (within 5km buffer) (WA only)	255,799	632,092	
Fisher Habitat Captured (within 5km buffer) (WA only)	138,603	342,495	54%
Grizzly Bear Core Habitat Total Area (WA only)	807,686	1,995,832	
Grizzly Bear Core Habitat Area (WA only) Captured	336,921	832,550	42%
Grizzly Bear Effectiveness Habitat Area (BC only: classes 1 - 5)**	1,484,514	3,668,308	
Grizzly Bear Effectiveness Habitat Area Captured (BC only: classes 1 - 5)**	514,076	1,270,308	35%

Table 33. The availability of Grizzly bear habitat and the amount captured by the portfolio, by habitat class, in the British Columbia portion of the ecoregion

BC Grizzly Bear Habitat Capability, Suitability and Effectiveness Class Rating		Amount of habitat available and captured, by class	
Habitat Class	**Bears/1000 km^2**	**Amount available (km^2) (% of available)**	**Amount captured (% of available)**
1	76 – 100	0.25 (<0.1%)	0.0 (0%)
2	51 –75	21 (0.14%)	12 (55%)
3	26 – 50	133 (0.89%)	55 (42%)
4	6 – 25	1744 (11.7%)	569 (33%)
5	0 – 5	12947 (87.2%)	4505 (35%)

6.7.3 Northern Spotted Owl

Northern Spotted owls are listed as federally threatened in the United States and as endangered (listed by COSEWIC in 2000) in Canada. At the onset of the North Cascades

ERA team members debated whether or not to use the Northern Spotted owl as a focal species and create a habitat-based model for inclusion into the MARXAN analysis. However, a habitat model was not available to us at that time, so we used point locations of spotted owl nests and observations to represent the species. Given the importance of conserving Northern Spotted owls and the fact that the ecoregion contains all of Canada's remaining spotted owls and spotted owl habitat, we conducted a post hoc assessment of how well the portfolios captured northern spotted owl habitat.

In Washington, the team used spotted owl occupancy data, which included point locations for spotted owl nests and locations where resident pairs were observed. In BC we also used point locations for documented nests and locations of spotted owl detections. These data were part of the fine-filter animals analysis. Goals were set for Northern Spotted owl based on expert input. The goals were to capture all of the 169 nests (in BC and Washington) and resident pair sites (Washington only), and 25 of the 34 owl detection sites (other than nests) in BC.

Although not treated as a focal species, Northern Spotted owl habitat and occurrences were captured directly in the fine-filter analysis and indirectly in the terrestrial systems analysis where old-growth forests were mapped and given special emphasis (Chapter 3 and Appendix 9). Northern Spotted owls are largely dependent on landscapes dominated by low-elevation old-growth forests for habitat.

Northern Spotted owl habitat and corridors were also directly captured in the assessment through expert input. Experts in Washington and British Columbia identified connectivity corridors for wide-ranging species including the Northern Spotted owl, with considerable attention focused on areas where the ecoregion narrows, north of the international boundary. All expert recommended areas were added in to the assessment as expert identified areas (Map 22).

For a post hoc assessment of how well the portfolios captured Northern Spotted owl habitat, we obtained Northern Spotted owl habitat data from the Western Canada Wilderness Committee (WCWC) and overlaid it with the North Cascades assessment portfolios. This data provided by the WCWC is based on the following datasets:

- Chilliwack Forest District forest cover data, 1:20,000 scale. MoF, BC, 2001.
- Squamish (excluding TFL38) Forest District forest cover data, 1:20,000 scale. MoF, BC, 2001.
- Former Lillooet Forest District (now amalgamated with the Merritt Forest District to form the larger Cascades Forest District) forest cover data, 1:20,000 scale. MoF, BC, 1999.
- Chilliwack and Cascades Forest Districts, Consolidated Forest Development Plans, 1:20,000 scale. MoF, BC, 2005.
- GVRD Watersheds forest cover data, 1:20,000 scale. GVRD, BC, 1991.
- TFL#38 forest cover data, 1:20,000 scale. Interfor, 1996.
- Baseline Thematic Mapping, 1:250,000 scale. MoE, BC, 1996.
- Digital Elevation Model, 1:20,000 scale. MoE, BC, 1996.

- Biogeoclimatic ecosystem classification (BEC) mapping data, 1:250,000 scale. MoF, BC, 2001.

6.7.3.1 Results

In general, the terrestrial, freshwater, and combined portfolios captured from 54% to 76% of identified northern spotted owl habitat in British Columbia (Table 34 and Map 31). This high level of data capture is important for this species of concern. However, emphasis placed on identifying important areas for spotted owl and old growth protection have not hindered our ability to efficiently identify areas of importance for the many other conservation targets encompassed in this assessment.

Table 34. Amount of Northern Spotted owl habitat captured in terrestrial, freshwater, and combined portfolios

	Hectares	Acres	Percent
Spotted Owl Habitat (within Terrestrial AUs)	308,654	762,700	
Spotted Owl Habitat Captured by Terrestrial Solution	165,997	410,186	54%
Spotted Owl Habitat Captured by Freshwater Solution	152,162	376,000	49%
Spotted Owl Habitat Captured by Union of Terrestrial and Freshwater Solutions	233,752	577,613	76%

Chapter 7 – Prioritization of Portfolios

7.1 Introduction

Limited resources and other social or economic considerations may make protection of the entire portfolio impractical. Ecoregional assessments typically identify a large number of conservation areas (Rumsey et al. 2003; Floberg et al. 2004). By virtue of its selection, each conservation area is worthy of conservation action; however, not all areas are of equal conservation value or in need of attention with the same degree of urgency. The challenge of conserving all of the identified areas in an ecoregional assessment is overwhelming if not impossible for any single organization or agency. By using a practical approach to priority setting, this challenge can be focused on an ambitious set of objectives, which if undertaken by the conservation community as a whole, is within our collective reach (Groves 2003).

The portfolio delineation phase of the North Cascades Ecoregional Assessment identified a very large proportion of the ecoregion as priority areas for conservation. With 54% of the ecoregion included within both the terrestrial and freshwater results, it was necessary to apply a prioritization scheme to help distinguish which conservation areas require conservation action more immediately than others.

7.2 Methods

The method described below can provide conservation strategists who are working in the North Cascades Ecoregion with a means of evaluating priorities based on quantitative measures that emerged from this assessment. This work was based on criteria established in TNC's *Geography of Hope* (Groves et al. 2000) and methods applied by Noss et al. (2002) in the Utah-Wyoming Rocky Mountains ecoregional plan. A more thorough evaluation of priorities is required and planners/decision-makers will need to build on the quantitative summary presented here with more subjective qualitative measures related to conservation feasibility, opportunity and leverage.

7.2.1 Irreplaceability versus Vulnerability Scatter plot

One approach for prioritization is to plot biodiversity value of a site against the degree of threat to that site. The irreplaceability versus vulnerability scatter plot was first used by Pressey et al. (1996, as described by Margules and Pressey 2000) and was more recently used by Noss et al. (2002) and Lawler et al. (2003). In this study, irreplaceability versus vulnerability was plotted for the sites in the conservation portfolio. Irreplaceability has been defined a number of different ways (Pressey et al. 1994; Ferrier et al. 2000; Noss et al. 2002; Leslie et al. 2003; and Stewart et al. 2003). The definition of irreplaceability used in this study (see Section 6.2.1) was similar to that of Andelman and Willig (2002) and Leslie et al. (2003). Irreplaceability was normalized by dividing all values by the maximum value and multiplying by 100.

Margules and Pressey (2000) defined vulnerability as the risk of an area being transformed by extractive uses, but it could be defined more broadly as the risk of an area being transformed by degradative processes. The broader definition encompasses adverse impacts from invasive species and fire suppression. Vulnerability could also be defined from the perspective of target species—the relative likelihood that target species will be lost from an area. Since target persistence depends on habitat, a vulnerability index would be a function of current and likely future habitat conditions. Future habitat conditions are generally determined by the management practices and policies associated with an area. The suitability index used in this study incorporated factors that reflected both current habitat conditions and management; therefore, for the purposes of prioritization, it was assumed that the suitability index could also be used as a vulnerability index. The "integrated" vulnerability index was calculated by averaging the terrestrial and freshwater suitability indices for each AU. Like the suitability index, vulnerability was normalized by dividing all values by the maximum value and multiplying by 100.

Margules and Pressey (2000) and Noss et al. (2002) divided their scatter plots into four quadrants which corresponded to priority categories: high irreplaceability, high vulnerability (Q1); high irreplaceability, low vulnerability (Q2); low irreplaceability, low vulnerability (Q3); and low irreplaceability, high vulnerability (Q4) (Figure 5). Potential conservation areas in Q1 were considered the highest priority; in Q3 they were the lowest priority. Quadrants Q2 and Q3 included conservation areas of moderate priority. However, the importance of each quadrant is debatable (Pyke 2005). Some have argued that the highest priorities should be potential conservation areas in Q2 because such places have high biological value and a high likelihood of successful conservation.

The purpose of dividing the scatter plot into quadrants is to assign conservation areas to priority categories. The scatter plot quadrant divisions used by Margules and Pressey (2000) and Noss et al (2002) implied that irreplaceability and vulnerability are equally important. Lacking a strong rationale for favouring either axis, the same convention was used in this study.

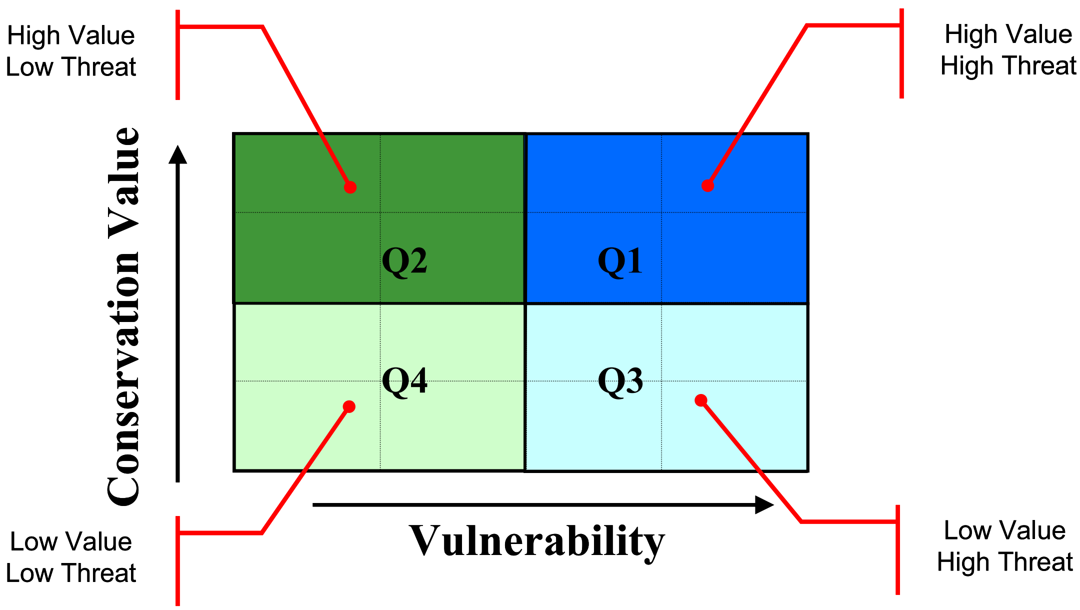

Figure 5. Graphing Relative Conservation Value and Vulnerability Scores

7.2.2 Prioritizing Terrestrial and Freshwater Portfolios in the North Cascades

Terrestrial and freshwater portfolios were prioritized separately using identical methodology. The first step was to define measures of conservation value and vulnerability. For this analysis, the measures were a function of readily available GIS data that were compiled through the ecoregional assessment process. Conservation value was based on irreplaceability measures, an output from running the MARXAN model; for vulnerability, the suitability index that was an input to the model was used (for specific detail see Appendix 17). These data were populated into a custom Microsoft Excel spreadsheet, which allowed interactive weightings for each independent factor. Weightings included two different factors: certainty and importance. Certainty can be considered as a measure of how much confidence can be placed in the data, and how well the data reflect what is intended. Importance represents the user's assumptions of which factors best reflect conservation value, or alternatively which factors best reflect an organization's mandate. Weightings for certainty and importance were input as a range from zero to one (with 1 being greatest), then multiplied for a final cumulative weighting for each factor. The core team came to consensus on one set of weightings, which resulted in the preliminary site prioritization (Appendix 17).

7.3 Results

The following three products resulted from the prioritization process:

1. Scatter plots that show the relative position of portfolio sites for conservation value and vulnerability (Figures 6 and 7). Each of the factors that comprised value and vulnerability were given weights reflecting the importance and confidence of each factor;

2. A table of portfolio sites organized by quartile position in the scatter plot (Maps 27a and 28a); and

3. A color-coded map that combined the conservation value quartiles with the vulnerability quartiles results in 16 possible bins, represented by a 16-color scatter plot grid and map (Maps 27 and 28).

For planners working at an ecoregional scale, the prioritization process allows potential conservation sites to be clearly sorted according to factors that are important for biodiversity value as well as those that pose threats. Relative positioning of sites on the scatter plot complements relative priority positioning of sites on the ecoregional map.

The measures of value and vulnerability are composed of the relative importance and confidence weightings applied to the various factors. Through quantification of practical differences between factors, this prioritization method allows alternative prioritization perspectives to be easily applied and compared. These alternatives, whether they involve a subset of factors used in this exercise or an entirely new set of factors, are accommodated and examined by changing the values or value weights in an EXCEL spreadsheet. Future analysis could allow interested parties to experiment with different prioritization scenarios. The ability to quantify the relative relationship of conservation value and vulnerability provides a basis for strategic planning and fosters debate on conservation needs.

The scatter plots created by using the methods described in Section 8.2 are shown below. The terrestrial priority conservation area results for individual sites are shown on Map 27; the scatter plot of terrestrial priority conservation areas is shown in Figure 6. The scatter plot of weighted freshwater conservation areas is shown in Figure 7. Individual site results for freshwater priority conservation areas are shown on Map 28.

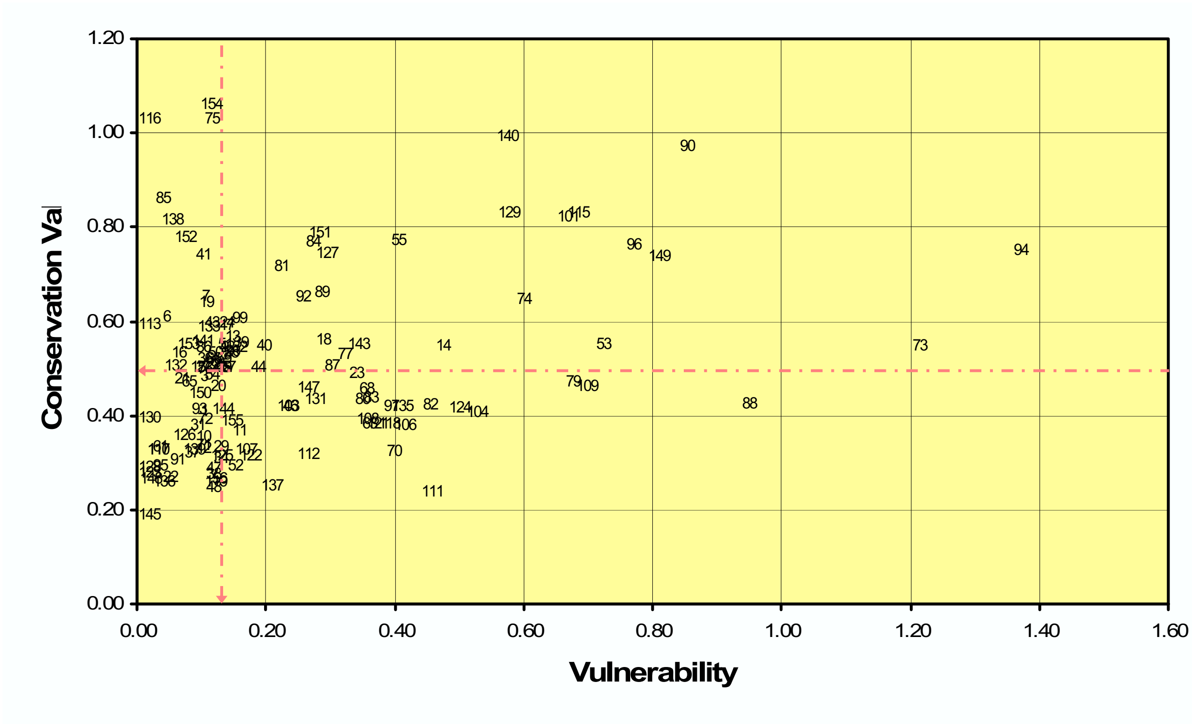

Figure 6. Terrestrial Priority Conservation Areas Scatter plot

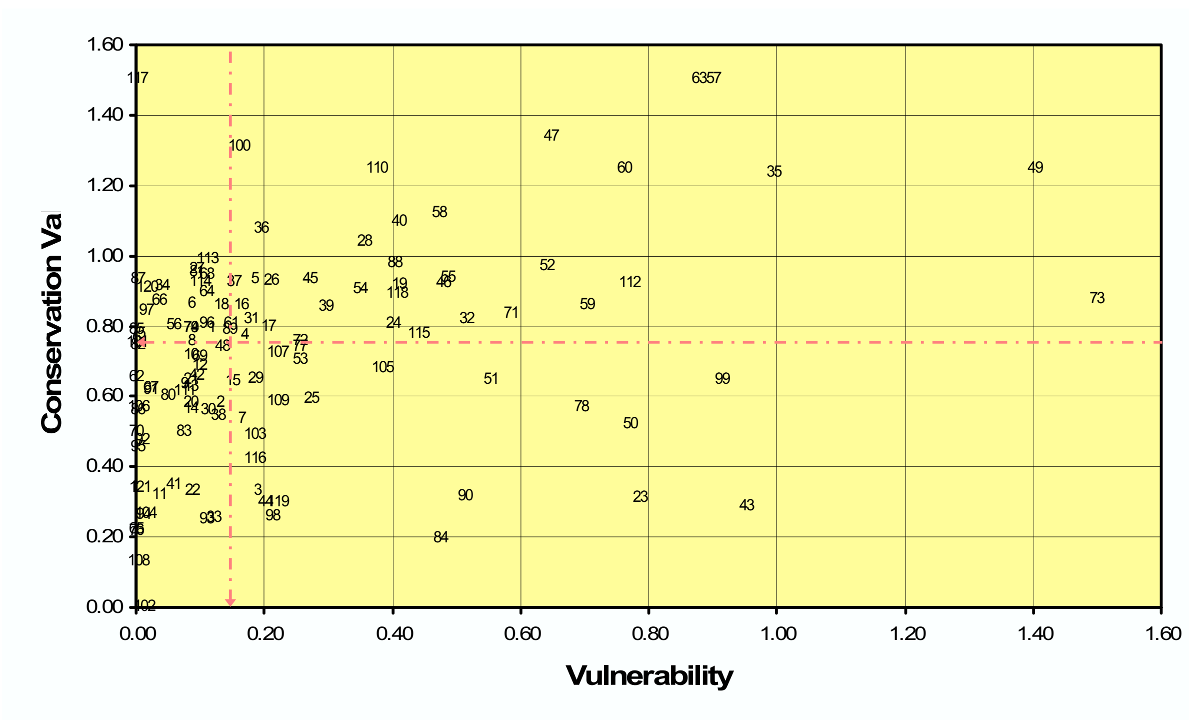

Figure 7. Freshwater Priority Conservation Areas Scatter plot

Chapter 8 – Recommendations for Future Iterations

Ecoregional assessments represent the current state of knowledge for identifying the most important places for biodiversity conservation in an ecoregion and establishing conservation priorities. It is expected that future iterations of assessments will be produced as new needs are recognized, methods are improved and new data become available. What follows is a list of suggestions to address in future iterations of these assessments.

8.1 Data

There were a number of species, communities and natural systems for which the desired occurrence data did not exist, including many invertebrate species, non-vascular plants, and imperiled and rare species and plant communities. As a result, most of the ecoregion's biodiversity must be represented through the surrogate of coarse-filter habitat types or ecological systems. New survey efforts should focus on finding additional occurrences of these species and communities and documenting the condition of known occurrences. Up-to-date survey data would add considerably to the overall quality of the analysis.

A low cost method for overcoming the lack of occurrence data is to use species-habitat models to predict species occurrences (Scott et al. 2002). However, there were a number of reasons why predictive models were not used in this assessment. First, reasonably accurate species-specific habitat models were not available. Those that were (e.g., Cassidy et al. 1997) had low spatial precision and untested accuracy. Second, resources were not available for developing models for a large number of species. Third, species-specific habitat models have both false negatives and false positives (areas where species exist or do not exist that are incorrectly represented in model results). Scientific literature indicates that false negatives inherent in survey data are likely to be less damaging than the false positives of habitat models. Freitag and Van Jaarsveld (1996) and Araujo and Williams (2000) recommended using only occurrence data because of the potential for false positives in habitat models. Loiselle (2003) recommended that species-specific habitat models be used cautiously. Given the lack of readily available models of proven accuracy, and without the resources needed to develop models for this assessment, it was deemed that the most prudent approach was to use primarily occurrence data (except where models were used for five large mammals: grizzly bear, lynx, fisher, bighorn sheep and mountain goat).

There are also data gaps for several terrestrial ecological systems. For example, non-forest ecological systems are relatively poorly represented compared with forest systems *(discussed in 3.1.1.4. Alpine and Montane Composite Targets)*. In addition, the best available spatial data were not adequate to map the four wetland systems accurately and consistently across the ecoregion. It is assumed, however, that many were captured as part of the mapped area of matrix and large patch ecological systems, especially as low-lying landforms. The unmapped wetland system types are Temperate Pacific Subalpine-Montane Wet Meadow (small patch), Temperate Pacific Tidal Salt and Brackish Marsh (small patch), North Pacific Bog and Fen (small patch), and North Pacific Hardwood-Conifer Swamp (large patch). Development of a comprehensive data source for terrestrial ecological systems would enhance future iterations.

Finally, gathering freshwater data was more challenging than gathering terrestrial data. The freshwater analysis was somewhat limited in precision, comprehensiveness, and reliability due to a number of data gaps: (1) No occurrence or satisfactory habitat data were available for 95 of the 143 (66%) target freshwater animal species (see Table 23). Over 90% of these species were invertebrates. This reflects our extremely poor understanding of invertebrate species diversity, geographic distribution, and habitat requirements. Eighteen of the species for which there were data had fewer than 10 known occurrences in the ecoregion. Lack of data is likely a function of low survey effort or inconsistent data collection methods; (2) Freshwater plants were not included in this iteration; and (3) the target list should be reevaluated for each EDU to determine if there are any species that should be targets for only one EDU rather than both EDUs. These data gaps should be addressed in subsequent assessment iterations. Additionally, we realize that the freshwater classification framework is a series of hypotheses that need to be tested and refined through additional data and expert review. We recommend that concurrently, data be gathered to refine/test the classification to bring the scientific rigor needed to further its development and use by conservation partners and agencies.

8.2 Conservation goals

Establishing conservation goals is among the most difficult scientific endeavors in biodiversity conservation. There is much uncertainty regarding threats such as future land conversion and climate change and little information regarding the number of species occurrences or the area of an ecological system necessary to maintain all species within an ecoregion (Soule and Sanjayan 1998).

Hence, the goals cannot be treated as conditions that ensure long-term survival of species and ecological systems; however, they are useful tools for assembling a portfolio of conservation areas that includes multiple examples of the ecoregion's biodiversity. These goals also provide a metric for gauging the contribution of different portions of the ecoregion to the conservation of its biodiversity, and the progress of conservation in the ecoregion over time.

8.3 Expert opinion

All judgments are made with imperfect knowledge, and expert opinion may be affected by motivational biases (e.g., judgments influenced by political philosophy) and cognitive biases (e.g., poor problem solving abilities; Tversky and Kahneman 1974). A group of experts working together may be adversely affected by "groupthink", personality conflicts, and power imbalances (Coughlan and Armour 1992). Nevertheless, the reliance on expert opinion in the assessment process was decidedly advantageous since experts were able to fill in data gaps and address shortcomings in the methodology, such as adding locations of target occurrences that were not yet recorded in standard datasets. Future assessments should use more elicitation techniques that reduce subjectivity and error in expert opinion (e.g., Saaty 1980).

8.4 Integration of terrestrial and freshwater portfolios

Integration of the terrestrial and freshwater portfolios posed many challenges. Perhaps most importantly, the freshwater and terrestrial analyses were based on different types of planning units. The terrestrial analysis used hexagons, and the freshwater analysis used watersheds. While each type of assessment unit may be appropriate to its respective realm, combining terrestrial and freshwater data into one planning unit (required by MARXAN) created too great a compromise. Attributing freshwater data to terrestrial hexagons unacceptably fragmented freshwater stream reaches and created slivers of watersheds that were less useful to planners than the stand-alone freshwater and terrestrial portfolios.

The terrestrial suitability index was intended to guide AU selection towards places that are far from human development; the freshwater portfolio must include main stem reaches, which typically are places heavily impacted by development. Since lands along many of the main stem reaches are in poor condition, they do not contribute to terrestrial goals. The overall effects of integrating terrestrial and freshwater realms was that the portfolio became less efficient, there was little overlap between portfolios, and the size of the total portfolio increased. In fact, the there was only 15% overlap between the terrestrial and freshwater portfolios.

Although integration of terrestrial and freshwater values was attempted, a satisfactory analytical method for integration was lacking in the final analysis. Developing a system in which terrestrial, marine and freshwater information can be assigned to a common AU would greatly benefit integration efforts. Additionally, integration might be improved by incorporating the ecological processes, threats, or targets that explicitly link terrestrial and freshwater into the selection algorithm.

8.5 Connectivity

The draft terrestrial portfolio used the solution provided by MARXAN that offered the set of assessment units meeting conservation goals with the maximum suitability (least human impact). This approach does not adequately deal with habitat connectivity because it only selects places where populations are located, and it lacks the capacity to select areas that populations might use for migration. Consequently, the MARXAN solution may exclude some assessment units that are essential for habitat connectivity. Expert review was used to address this deficiency by explicitly adding corridors to maintain habitat connectivity. In the future, a more sophisticated algorithm could possibly be used to specifically address corridor needs.

8.6 Vegetation mapping

A vegetation map was constructed by piecing together land cover data from a number of sources. The accuracy of the source data was variable or in some cases unknown, and the accuracy of the resulting vegetation map was not fully tested across the ecoregion. However, a number of positive responses from reviewers led to increased confidence that the map accurately reflected existing vegetation at a scale that was suitable for the assessment. In addition, because the analysis was stratified by ecological sections, and the vegetation data were generally uniform across a section, the effects of the data gaps were generally restricted by sectional boundaries.

Weaknesses in the vegetation map could be improved by quantitatively evaluating its accuracy for all system types and seral stages, particularly where the map was developed with restricted plot data.

8.7 Update of assessments

Updates or new iterations of ecoregional assessments are driven by the needs of specific conservation projects within an ecoregion or the availability of new methods and data. Since ecoregional assessments are large, expensive, and complex undertakings that typically take a number of years to complete, the decision to do a new iteration is not trivial. At the same time, conservation biologists have become increasingly aware that in order to respond to rapid changes, more frequent and consistent updates are critical. This is because habitat, ownership, and land use patterns across the ecoregion will change, abundance and spatial distribution of some species will change, understanding of ecosystems will increase, analytical methods will improve, and occurrence data will become more comprehensive. Additionally, as further research on climate change is conducted, future iterations will have the opportunity to incorporate the predicted effect on portfolio boundaries, accommodating potential shifts in the ranges of species, communities and systems.

Conservation biologists have recently realized that information is needed that will enable effective response to dynamic landscapes (Poiani et al., 2000). Depending on the magnitude of change, actions may need to be re-prioritized using up-to-date information about the status of the landscape and alterations that are likely to occur in the near future. Developing a formal process for updating ecoregional assessments will ensure that planners and decision makers have recent, applicable information on which to base strategies and decisions.

8.8 Involvement of decision makers

The assessment process was largely a scientific endeavor that did not involve the general public or policy makers. While certain aspects of the assessment must remain purely scientific, the usefulness, and hence effectiveness, of the assessment may be enhanced by involving the public and decision makers. For example, Rumsey et al. (2004) worked with stakeholders and decision makers on an ecoregional assessment in British Columbia that resulted in a decision by the provincial government to designate a network of parks and protected areas.

MARXAN and other such algorithms used for this analysis are expected to become fully interactive in the next several years and will for allow real-time scenario building. This should help public decision makers who become involved in the assessment process. In Australia, an interactive computer program was used by stakeholder negotiators to prioritize potential reserves and make land use designations (Finkel 1998). By using the computer interactively, negotiations took place in an objective and transparent environment.

One of the original motivations for using site selection algorithms was the limitation of funds for conservation (Pressey et al. 1993; Justus and Sarkar 2002); therefore, developing cost-efficient reserve networks is essential for maximizing biodiversity conservation. The cost index deals with the economic cost of conservation in a superficial way. To fully inform decision makers, the social and economic costs of conservation must be examined more closely (Shogren et al. 1999; Hughey et al. 2003).

The next iteration of this assessment should include both socio-economic factors and conservation targets in the target list. These may include high value farm or forest land or lands for recreation and urban development, rendering the assessment more inclusive in terms of supporting human needs.

8.9 Climate change

Much more attention needs to be given to the effects of climate change on the ecoregion. In the ecoregional assessment process, climate change was taken into account only superficially by selecting examples of conservation targets along a variety of physical gradients. However, global climate models for the next 100 years can be used to predict temperature and precipitation changes for large areas in the ecoregion. The spatial information from these models can show areas that are expected to be most and least affected by climate changes. This information could be used in computer vegetation models to predict the vulnerability of basic vegetation types to change. It could also be used to predict which areas and groups of species might need special attention now to prepare for coming changes. For example, some areas could serve as species refugia, while others would be areas of change that could perhaps be managed for future conditions. As additional research concerning impacts of climate change on ecological systems and biological diversity becomes available, it must be discretely incorporated into future iterations of ecoregional assessments.

Chapter 9 – Assessment Products and Their Uses

Three principal products emerged from this effort: conservation portfolios, irreplaceability maps, and a comprehensive compilation of conservation data for the ecoregion. A number of important ancillary products were also produced. These should be useful to groups who need answers to specific questions about threats, freshwater conservation, and conservation site priorities in the North Cascades ecoregion. Products include:

- **a portfolio** of conservation areas that contribute collectively and significantly toward the conservation of biological diversity in the North Cascades Ecoregion
- **a map of conservation priorities** that shows the relative importance of all parts of the ecoregion in terms of conserving biodiversity
- **a compilation of biodiversity information and data** that were used to develop the ecoregional assessment
- **a thorough documentation of the assessment process**, portfolio identification and site prioritization methods, and data management so that future iterations can be created efficiently based upon past work
- **a description of the lessons learned** during the assessment process and any innovative analytical techniques or data management practices that were developed
- **an explanation of major limitations** and important data gaps that, if addressed, would improve the next iteration of the assessment

The data that have been compiled and developed for this assessment are useful to anyone involved in conservation planning, priority setting, and decision making. In addition, they can be used for other analyses that address different conservation-related questions. These data are especially useful because they are in a GIS format and have undergone extensive review to correct data errors.

The conservation portfolios depict a set of conservation areas that most efficiently meet a specific set of conservation goals defined for the ecoregion. The conservation areas identified in each portfolio are important for a number of reasons. First, some are the only places where one or more species or plant community targets are known to occur. This is particularly true for those associated with low-elevation, old-growth coniferous forests. Second, some areas, such as parks and wilderness areas comprise the last large, relatively undisturbed landscapes in the ecoregion, which are especially important to wide-ranging species such as grizzly and black bears, wolves, wolverines, northern spotted owls, northern goshawks, and fishers. These places are vital to conserving ecoregional biodiversity and maintaining landscape-scale ecological processes. Third, wherever possible, the portfolios identify areas where conservation is most likely to be successful.

The irreplaceability maps depict a prioritization of all assessment units (AUs) (Maps 14 and 16). One type of irreplaceability map, conservation utility, is based on the both relative irreplaceability and relative suitability of AUs (Maps 15 and 17, Chapter 6). This map can be used to compare AUs with one another when making ecoregion-level conservation decisions, and it can inform smaller scale conservation decision making as well. The alternative portfolios are intended as an illustration of how the conservation areas change based on different goal levels for species and ecosystems. These particular alternatives were selected to bracket the scientific uncertainty in the relationship between successful biodiversity conservation and different amounts of habitat conservation.

9.1 Caveats for users

This assessment has no regulatory authority. Rather, it is a guide to help inform conservation decision making across the North Cascades ecoregion. The sites described are approximate and often large and complex enough to allow (or require) a wide range of resource management approaches. Ultimately, the boundaries and management of any priority conservation area will be based on the policies, values, and decisions of the affected landowners, conservation organizations, governments, and other community members.

Many of the high priority conservation areas described in this assessment may accommodate multiple uses as determined by landowners, local communities and appropriate agencies. Rather than creating protected areas in the usual sense, we speak of the need for portfolio sites to be conserved. While effective conservation can necessitate restricted use, it does not necessarily exclude all human activities.

A reliable assessment of restoration priorities would require a different approach than the one presented in this report. Assessment units and portfolio sites were selected for the habitats and species that exist there now, not for their restoration potential. However, many high priority areas will contain lower-quality habitats in need of restoration, and this restoration could greatly enhance the viability of these areas and the conservation targets they contain.

Users must be mindful of the large scale at which this assessment was prepared. Many places deemed low priority at the ecoregional scale are, nevertheless, locally important for their natural beauty, educational value, ecosystem services, and conservation of local biodiversity. These include many small wetlands, small patches of natural habitat, and other important parts of the natural landscape. They should be managed to maintain their own special values. Furthermore, due to their large size, high priority assessment units and conservation portfolio sites may include areas unsuitable for conservation. It is expect that local planners who are equipped with more complete information and higher resolution data will develop refined boundaries for these sites. Users should remember that the intended geographic scale of use of the analysis and much of its data is 1:100,000. Finally, the scale and concept of matrix-forming terrestrial systems, by definition, contain considerable environmental, ecological and genetic variation. Spatial data developed for this assessment are accurate only at a coarse scale.

Some factors in the suitability index require consideration of what are traditionally policy questions. For example, setting the index to favour the selection of public over private land presumes a policy of using existing public lands to meet goals wherever possible, thereby minimizing the involvement of private or tribal lands.

This assessment is one of many science-based tools that will assist conservation efforts undertaken by government agencies, non-governmental organizations, and individuals. It cannot replace recovery plans for endangered species or the detailed planning required in designing a local conservation project. It also does not address the special considerations of salmon or game management, and consequently the plan cannot be used to ensure adequate populations for harvest.

Chapter 10 – Summary and Conclusions

Although degraded in some areas, the North Cascades still provides an opportunity for conservation of wildlife and natural systems in the ecoregion (CBI 2003). Based on the results of this assessment, the following conclusions can be made:

10.1 Ecoregional goals

Establishing conservation goals is one of the most crucial steps in the ecoregional conservation assessment process as it forms the basis from which to gauge the success of how well the North Cascades portfolio of conservation areas performs in conserving the ecoregion's biodiversity. Conservation goals set the context for planning and implementation, and measuring progress towards meeting established goals and objectives. These goals also provide a clear purpose for decisions and lend accountability and defensibility to the assessment (Pressey, Cowling, and Rouget, 2003).

Setting conservation goals is also one of the most difficult steps in the assessment process. As a result, setting goals for conservation targets in the assessment primarily involves reliance on expert opinion and informed guesswork and is likely to have a high degree of uncertainty (Groves *et al*., 2000). However, given the global "biodiversity crisis", there are irreparable consequences in delaying conservation efforts until new procedures or better estimates become available. As human populations continue to grow, many large habitat blocks will face development pressure to meet human needs.

Although goals established for terrestrial and freshwater ecological systems (having to do with how much area of habitat is selected in the portfolio) were largely met in this assessment, goals established for fine filter targets were largely unmet. While it is arguably relatively more important that we met goals for terrestrial and freshwater ecological systems, since by protecting these systems we also protect the vast majority of species that are unknown or poorly understood, it is still a potential concern to fall short of the majority of the species goals. However, while not meeting goals for species targets may be an indication of too few actual species occurrences in the ecoregion, it could also indicate poor survey data. Given the relatively good condition of the North Cascades ecoregion, we suspect the more probable reason for not meeting many species goals is that the ecoregion is still poorly studied and documented. Moreover, where goals are met for species and habitats in the ecoregion, it only means that there are adequate target occurrences that exist within the ecoregion. If all these occurrences and the areas that contain them are conserved, the intent is that biodiversity would be maintained, subject to many uncertainties associated with our knowledge of species, natural communities and future conditions. Of course, we have no way of knowing how well our goals will reflect the actual needs of biodiversity, and future iterations will no doubt improve on these estimates. In the meantime, organizations can use the stated goals as starting place to address gaps in biodiversity protection and track progress. It is important to realize however that meeting goals only means that a number of occurrences of species and habitats have been identified in the ecoregion, not that they are necessarily protected in any way.

10.2 Sensitivity analysis results

High irreplaceability values, i.e., greater than about 85 to 90, are mostly insensitive to the suitability index. AUs achieve high scores because of their biological contents not because of suitability. In contrast, moderate scores, about 50 to 80, tend to be much more sensitive to the suitability index. Since the suitability index relies on the subjective judgments of individuals, AUs with moderate irreplaceability scores should be examined more closely.

Software programs like MARXAN are often referred to as "decision support tools." Such tools can best support decisions by enabling us to explore the effect of various assumptions and differing perspectives. Both Davis et al. (1996) and Stoms et al. (1998) did the equivalent of a sensitivity analysis for their suitability indices. However, they referred to their different indices as "model variations" or "alternatives"; an implicit recognition that different sets of assumptions may have equal validity. To address uncertainties in suitability indices, AU priorities, especially for moderately ranked AUs, should be derived from several different analyses using different indices. This will enhance the robustness of analytical results and lead to more confident decision making.

10.3 Alternative portfolios

The alternative portfolios are intended to illustrate how conservation areas change based on different goal levels for species and ecosystems. Deciding which goal level alternative is most appropriate is ultimately a decision for the user and society to make based on the best available science, value-based policy decisions, and results of tracking biodiversity persistence over time. These particular alternatives were selected to bracket the scientific uncertainty in the relationship between changes in biodiversity and different amounts of habitat loss.

The alternative portfolios were referred to as "higher" and "lower" risk. The higher risk portfolio appears to be pessimistically small. As "higher risk" implies, if this portfolio were implemented, some species would very likely vanish from the ecoregion. On the other hand, the lower risk portfolio appears to be impractically large. The land area captured is enormous, but even under this alternative not all land would be set aside for preservation. Undoubtedly, much habitat must be conserved in multiple-use landscapes where land uses, such as forestry, can be compatible with biodiversity conservation. The mid-risk portfolio strikes a balance between the risk of species loss and the impracticality of conserving extremely large areas. This portfolio is also based on the stated conservation goals regarding the number, area, and distribution of species and habitats that might be required to maintain biodiversity.

The higher risk portfolio imposes a higher degree of risk than the mid-risk portfolio and the lower risk portfolio a lower degree of risk, but it is not known how much higher and lower the risk is. In fact, the "mid-risk" portfolio could actually be high risk. That is, it might result in a high probability of ecoregional extinction or extirpation for some species. For a small number of species, we may have the scientific capacity to determine the level of risk imposed by each portfolio, but given the enormous human changes to the ecoregion that have occurred and are expected to occur, certainty of the persistence of biodiversity cannot be *guaranteed* by meeting ecoregional goals. As much as possible, future ecoregional assessments should attempt to overcome this shortcoming.

10.4 Use of Assessment

Biodiversity conservation in the ecoregion will attain its fullest potential if all conservation organizations, government agencies and private landowners coordinate their conservation strategies according to the priorities identified through this assessment. The North Cascades Ecoregional Assessment puts forth a baseline to be built upon and refined by site-scale planning efforts. It is intended to guide users to areas with high biodiversity value and suitability. The specifics of conservation site delineation, planning and management will rely on more localized expertise.

Priority Conservation Areas (portfolio sites) span lands and waters that fall under various ownerships and within various jurisdictions and we recognize that some organizations and agencies will be better suited to work in specific areas than others may be. The ultimate vision of the ecoregional assessment process is to facilitate the thoughtful coordination of current and future conservation efforts by the growing number of federal, provincial, state, local, private and non-governmental organizations engaged in this field. To that end, we encourage wide use of the data and products developed and welcome comments on how future iterations may be improved.

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