PACIFIC NORTHWEST COAST

Ecoregional Assessment

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Washington Department of Fish and Wildlife

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Pacific Northwest Coast Ecoregional Assessment

Prepared by
The Nature Conservancy
Nature Conservancy of Canada
and
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Photo: Barkley Sound, Vancouver Island.

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Executive Summary

The Pacific Northwest Coast ecoregion of Oregon, Washington, and British Columbia is a highly diverse ecological region having a land area of 71,600 sq km (27,700 square miles). The ecoregion also includes an additional 15,030 sq km (5,802 square miles) of coastal waters. The ecoregion's rare combination of physical characteristics – coastal mountains, glaciers, marine shoreline and estuaries, extensive rivers, rolling coastal plains, and extreme rainfall – has created a region rich in endemic plant communities and sensitive habitats. The dominant vegetation of the ecoregion is coastal coniferous forest. However, the environmental and floristic diversity, combined with a long history of prehistoric and historic disturbances, has created over 400 natural vegetation communities and complexly interwoven terrestrial and marine ecosystems.

The ecoregion contains over 66,000 km (41,250 miles) of streams and rivers. These watercourses mostly drain directly into the Pacific Ocean with the few exceptions draining into Hood Canal and the Strait of Juan de Fuca. This ecoregion is known for its highly productive nearshore marine ecosystems and includes some of the best salmon habitat in the Pacific Northwest.

Ownership in the ecoregion is somewhat weighted toward public land that is managed for various purposes by provincial, federal and state agencies. The Provincial Government of British Columbia manages 32% of the ecoregion, the U.S. Forest Service manages 7%, the U.S. National Park Service manages 6%, while 40% of the ecoregion is private land. Other agencies such as the Bureau of Land Management and state forests manage almost 13% of the area. Existing protected areas are numerous in the Pacific Northwest Coast ecoregion and several are quite large. There are 64 US federally protected areas in the ecoregion totaling 448,129 ha, 70 British Columbia Province protected areas totaling 396,003 ha, 47 state protected areas totaling 20,087 ha, and an additional 16 private sites totaling 4429 ha. They total over 10% of the land area analyzed for this assessment.

The purpose of the Pacific Northwest Coast ecoregional conservation assessment was to identify an efficient suite of conservation sites that will contribute toward the long-term survival of all viable native plant and animal species and natural communities in the ecoregion. We were guided by the portfolio design procedures outlined in The Nature Conservancy's "*Designing a Geography of Hope*" (TNC 2000).

The assessment team, comprised of staff from The Nature Conservancy (TNC), Washington Department of Fish & Wildlife (WDFW), the Nature Conservancy of Canada (NCC), Oregon and Washington Natural Heritage Programs, the BC Conservation Data Centre, and NatureServe, worked on this effort from October 2001 through September 2005. The project was funded in part by grants from the WDFW, Oregon Department of Fish & Wildlife, NOAA-CSC, and NCC. Geographic Information System (GIS) resources were used for all data compilation, data management, and analysis tasks.

The first step in the planning process was to identify conservation targets. Conservation targets are those elements of biodiversity – plants, animals, plant communities, ecological systems, freshwater systems and marine habitats – that are included in the analysis. Targets were selected to represent the full range of biodiversity in the ecoregion and to include any elements of special concern.. The team identified 557 individual conservation targets distributed in terrestrial, freshwater and marine habitats. Considerable data, such as the distribution of all plant and animal species targets in the ecoregion, were obtained from the Heritage Programs/Conservation Data Centre and the state/provincial fish and wildlife agencies. The distribution data for wide-ranging fish were obtained from StreamNet (an aquatic information network based in the two Pacific Northwest states of Oregon and Washington), the State Heritage Programs, WDFW and the BC Conservation Data Centre. Considerable data for invertebrate species targets were obtained from the US Forest Service Interagency Survey and Managed Species database (ISMS) that is maintained for the Northwest Forest Plan. All terrestrial and freshwater conservation target data were attributed to assessment units based on HUC6 watersheds in the US and comparable third order watersheds in Canada.

An aquatic community classification was developed by using several abiotic factors to classify and map aquatic habitats. The aquatic classification model was developed in consultation with regional experts and with review of relevant literature to determine the most important physical variables that distinguish natural aquatic communities in riverine systems.

Nearshore marine ecosystems present numerous challenges as there was no complete map nor agreed upon classification for the nearshore or for estuarine habitats. Data compiled for defining marine ecosystems included Shorezone classifications from British Columbia and Washington in addition to the Environmental Sensitivity Index classification for shoreline habitats in Oregon. Estuary habitats were classified using available habitat maps from the National Wetlands Inventory of the U.S. Fish & Wildlife Service, Department of Land Conservation and Development in Oregon, the Ministry of Sustainable Resource Management and the Canadian Wildlife Service in British Columbia. Additional data for marine species and managed areas was obtained from the Oregon and Washington Departments of Fish & Wildlife and the Department of Fisheries and Oceans Canada. All marine data was attributed to 400 ha square assessment units.

Conservation goals were set for the representation of each target in the portfolio with the overall goal being to make major contributions toward the the long-term viability of the targets. Conservation goals were developed based on three primary factors: (1) the distribution of the targets across the ecoregion (2) the number of occurrences or amount of area occupied; and (3) the degree of endangerment for the conservation target.

Due to the complexity of analyzing the variety and abundance of data for conservation targets in the PNW Coast ecoregion, the planning team chose to use site selection algorithms to help design a portfolio that achieves the conservation goals most efficiently. The SITES site selection model was developed by Ian Ball at the University of Adelaide in conjunction with the National Center Ecosystem Analysis and Synthesis at the University of California, Santa Barbara and The Nature Conservancy for the expressed purpose of assembling ecoregional level conservation assessments. A similar tool called MARXAN was used for developing the marine portfolio. The optimization algorithms apply simulated annealing and iterative improvement techniques to the portfolio design problem with optimization being defined as minimizing the overall cost or size of the portfolio.

The site selection algorithm requires spatial distribution data for the conservation targets and their conservation goals along with a measure of assessment units' "cost." Assessment unit "cost" was represented with a suitability index. The suitability index, which was based on road density, GAP management status, land conversions and other factors related to the quality of assessment units, was used to influence the selection units for inclusion in the conservation portfolio. The modeled solution constituted the first draft of the portfolio. We reviewed and critiqued the draft based on our knowledge of the ecoregion. The portfolio was modified to reflect our critique, and then the final draft of the portfolio was produced. We used the final draft to solicit external expert review from a variety of organizations, including public agencies, NGOs, and academic institutions. The final draft portfolio was modified to reflect the expert review and produce the final portfolio of conservation sites for the ecoregion.

One of the products of the assessment is the prioritization of all assessment units. The prioritization was based on two types of irreplaceability which reflect each assessment unit's relative contribution to protecting biodiversity in the ecoregion. As might be expected there was considerable disparity among the assessment units in terms of their irreplaceability. Assessment units with the highest irreplaceability tended to be those that contained rare species. This product is of particular interest in Washington State where counties are expected to use it in local land use planning. We also explored how the portfolio might change given different conservation goals. We generated alternative portfolios that portray what lower and higher risk portfolios might look like.

The conservation portfolio for the Pacific Northwest Coast ecoregion contains 164 sites covering 3,623,451 ha, or roughly 45% of the assessed land area. Most of these sites are "integrated sites" in that they contain terrestrial, freshwater and/or marine areas with conservation targets representing these aspects of coastal biodiversity. There are four freshwater sites in the portfolio that are designed around buffered stream reaches that thread through watersheds. The coastal marine environment was analyzed separately, where 162 sites were identified across 400,000 hectares before integration with adjacent terrestrial sites. After integration only 20 of those sites were solely identified as marine. Site priorities were developed based on the contribution of the site to biodiversity conservation and the site's vulnerability.

The portfolio was quite variable in meeting conservation goals for conservation targets as many targets did not have a sufficient number of occurrences within the ecoregion to meet goals. In general, conservation targets whose goals are based on a percentage of their occurrences or percentage of their area such as ecological systems, freshwater systems and salmon did much better at meeting their conservation goals. Goals might be met for some targets simply through field surveys which could locate new occurrences of target species. However, given that many targets did not meet conservation goals, restoration of habitats may be an important conservation strategy in this ecoregion.

This assessment has no regulatory authority. It is a guide to help inform conservation decision-making across the ecoregion. The portfolio is intrinsically flexible. The sites described are approximate, and often large and complex enough to require a wide range of resource management approaches. Ultimately, the exact siting and management of any potential conservation area will be based on the policies, values, and decisions of the affected landowners, governments, and other community members.

Furthermore, the assessment is one of many science-based tools that will assist conservation efforts 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 all of the special considerations of salmon or game management and cannot be used to ensure adequate populations for harvest.

Preface

In the Pacific Northwest, The Nature Conservancy has teamed with the Washington Department of Fish and Wildlife and Nature Conservancy of Canada to develop ecoregional conservation assessments. This partnership has provided synergy for crafting the assessments and will be invaluable for implementing them.

The mission of The Nature Conservancy (TNC) is to preserve the plants, animals, and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. Outlined in *Conservation by Design: a Framework for Mission Success* (TNC 2000), the ecoregional conservation vision is to:

> *…conserve portfolios of functional conservation areas within and across ecoregions. Through this portfolio approach, we will work with partners to conserve a full array of ecological systems and viable native species.*

The mission of the Washington Department of Fish and Wildlife is sound stewardship of fish and wildlife and the habitats on which they depend. The Department serves Washington's citizens by protecting, restoring and enhancing fish and wildlife and their habitats, while providing sustainable fish and wildlife-related recreational and commercial opportunities.

The mission of the Nature Conservancy of Canada is to ensure the long-term survival of all of Canada's biological diversity by protecting the natural places and processes that native plant and animal species need to survive.

The partnering organizations and agencies agreed on a process to assess the biodiversity of the Pacific Northwest Coast Ecoregion and to analyze data to develop the conservation assessment portrayed in the following report. Each organization and agency in the partnership has contributed expertise and by so doing has created a more robust assessment useful to a broader community of conservation interests in the ecoregion. Each partner has benefited from this effort by developing stronger institutional ties with the other partners and by receiving specific analyses and products that meet their own planning needs.

Chapter 1 – Introduction

1.1 Introduction

Worldwide, the ever-increasing demands on natural resources require society to make important decisions about resource use and conservation. Society faces the critical challenge of protecting the planet's natural heritage while minimizing conflicts with legitimate and unavoidable uses of natural resources. However, society and its elected officials have yet to address the issue of biodiversity conservation in a comprehensive and strategic manner. Citizens, stakeholders, and elected officials should collaborate to set a vision for biodiversity conservation that is informed by the best available science and that acknowledges some level of risk. Towards this end, The Nature Conservancy, in cooperation with key partners, is helping society make informed decisions about where conservation should be done by developing scientifically rigorous conservation assessments for every North American ecoregion. These comprehensive assessments evaluate the full spectrum of biodiversity in a given ecoregion, identifying areas of biological significance where conservation efforts should have the greatest potential for success.

The Pacific Northwest Coast Ecoregional Assessment is the product of a partnership initiated in 2001 to identify priority conservation areas in this ecoregion. The Nature Conservancy (TNC), the Nature Conservancy of Canada (NCC), and the Washington Department of Fish and Wildlife (WDFW) are the primary partners in this project. NatureServe, the Oregon Natural Heritage Information Center (ONHIC), the Washington Natural Heritage Program (WNHP), and the British Columbia Conservation Data Centre (BCCDC) were major contributors of technical expertise and data. The project has also benefited from the participation of many other scientists and conservation experts as team members and expert reviewers.

1.1.1 Conservation Assessment for the Pacific Northwest Coast Ecoregion

The purpose of this ecoregional assessment is to identify priority areas for conserving the biodiversity of the Pacific Northwest (PNW) Coast Ecoregion. This assessment is a guide for planners and decision-makers, and has no regulatory authority. We have conducted this work in a transparent manner and are making it accessible to the widest range of users possible. It should be treated as a first approximation, and the gaps and limitations described herein must be taken into consideration by users. This work was prepared with the expectation that it will be updated as the state of scientific knowledge improves, methods are further refined, and other conditions change.

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 over 45 of the 81 ecoregions in the United States, and for several others outside the county, with the objective of completing assessments countrywide, and throughout the Americas, by 2008. The Nature Conservancy is leading many of these assessments, while others are led by partner organizations or agencies using the same basic methodology.

The goal for the PNW Coast Ecoregional Conservation Assessment is to:

> *Identify the suite of conservation areas that promote thelong-term survival of all native plant and animalspecies and natural communities in the ecoregion.*

This report documents the assessment process, including the steps taken to design the spatially-explicit 'conservation portfolio' for this ecoregion. It presents an ecoregion-wide assessment that identifies and prioritizes places of biological and conservation importance.

The main products of this ecoregional assessment are:

- **A portfolio** of conservation sites that contribute collectively and significantly toward the conservation of biological diversity in the PNW Coast Ecoregion.
- **A mapping of conservation priorities** that shows the relative importance of all watersheds in the ecoregion for the conservation of biodiversity.
- **A compilation of the comprehensive 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 efficiently build 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.

1.1.2 Previous Conservation Plans in the Ecoregion

The Pacific Northwest has been the focus of a number of broad-scale plans that have highlighted the need for a comprehensive approach to conservation of natural resources.

Each of these plans offers a distinct perspective and fulfills a specific and important planning purpose. In general, these plans were designed to address biodiversity conservation within an area defined by geopolitical boundary and/or to address specific species, habitats or landscapes of conservation importance. For these reasons the present ecoregional assessment, while building upon previous plans, was undertaken to address the full range of biodiversity across all ownerships and jurisdictions in an ecoregional setting.

The Northwest Forest Plan (USDA 1994) was the culmination of a decade of concern over the decline of old growth forests and its impact on the northern spotted owl and marbled murrelet in the United States. The Plan, prepared by the United States federal government with extensive stakeholder input, addressed these concerns largely on federally managed lands, resulting in new management plans for National Forests in the region. One significant outcome of the Plan was the creation of Late Successional Reserves and the Aquatic Conservation Strategy. The Plan has enriched our general understanding of mature conifer forests within the range of the northern spotted owl. This ecoregional assessment has made considerable use of the information contained in the Plan.

While the Northwest Forest Plan identified a number of areas suitable for the protection of old growth conifer forests and species associated with this habitat, the Plan by design was not a comprehensive assessment of biodiversity in the region. First, the Plan did not directly address plants and plant communities. Second, the Plan did not consider habitats other than those important to spotted owls or marbled murrelets such as sandy beaches and estuaries, meadows, or the nearshore marine environment. Third, the geographic scope of the Plan was limited to federal lands in the United States and therefore excluded private lands and Canadian territory from its analysis. The ecoregional context of this assessment will correct these shortcomings by transcending property boundaries and local, state and country lines when identifying priority areas for conservation attention.

Oregon and Washington have completed Comprehensive Wildlife Conservation Strategies to fulfill a Congressional requirement that all states develop such plans to qualify for future funding from the federal State Wildlife Grants program. These strategies identify species and habitats of special concern, factors affecting their survival, and what should be done in the future to conserve them. The Oregon strategy also identifies landscapes of particular importance to wildlife conservation. While a valuable resource for statewide wildlife planning, the sites identified by Oregon as conservation priorities are based on an analysis of fewer species and habitats than this assessment addresses. Moreover, Oregon's strategy evaluates only the portion of each ecoregion confined to Oregon and thus does not integrate or reflect ecoregional data beyond state lines. Washington State will use ecoregional assessments, such as this one, to help identify priorities.

A conservation plan of the Oregon Coast Range was prepared by Reed Noss (Noss 1992) during the time that the spotted owl/old growth forest issue was gaining momentum. This plan utilized many of the concepts for conserving landscapes that have emerged with the field of conservation biology. The Noss plan focused on terrestrial species and habitats but was limited in its analysis of the available data. There was also insufficient information to address aquatic diversity and marine conservation was not considered at all in this assessment.

Finally, several additional plans focusing on specific resources or political geographies such as states or provinces have contributed to the body of biodiversity knowledge throughout the region. The Oregon Plan (ODFW 1996) was designed to aid the recovery of coastal salmon in Oregon and address the health of watersheds supporting these stocks; however it did not address the conservation needs of biodiversity in watersheds unoccupied by salmon. The Vancouver Island Summary Land Use Plan (British Columbia 2000) addressed land use planning considerations, including conservation, on Vancouver Island; but it did not look beyond the province border. Lastly, a number of plans developed by different government agencies and specific to particular forests have been produced, but none of these are truly regional in scope.

It is this history and patchwork of regional natural resource planning efforts that explains the utility of an assessment that is geographically seamless and biologically comprehensive across the entire ecoregion.

1.2 Ecoregion Overview

From a conservation assessment perspective, ecoregions are defined as "relatively large areas of land and water that contain geographically distinct assemblages of natural communities. These communities (1) share a large majority of their species, dynamics, and environmental conditions, and (2) function together effectively as a conservation unit at global and continental scales" (Olsen et al. 2001). The Conservancy has adapted the U.S. Forest Service ECOMAP framework as the base map for all ecoregional assessment work in the United States (Bailey 1995, 1998). For the purposes of the PNW Coast Ecoregional Assessment, The Conservancy modified the USFS base map, resulting in an ecoregional boundary similar to that created by the U.S. Geological Society for the Northwest Coast in 1997 (Pater et al 1997).

1.2.1 Geographic Setting

The PNW Coast Ecoregion is a narrow, elongated ecoregion lying to the west of the Coast Range Mountains and stretching from the southern border of Oregon to the northern tip of Vancouver Island (Map 1.1). The ecoregion includes nearly all of the Olympic Peninsula and most of Vancouver Island, British Columbia encompassing some 7,112,000 ha (27,500 square miles) of temperate coniferous forests, montane forests, sub-alpine and alpine communities, wetland, beaches, and dunes (Table 1.1). The ecoregion also includes 1,503,000 ha (5,802 square miles) of coastal waters that include rocky intertidal zones, bays and estuaries, and nearshore ocean to 40m depth. Although the ecoregion's elevation averages only 445 m, the effect of the adjacent mountains, ocean intrusions, and glaciation in the northern half of the ecoregion has caused dramatic localized differences in climate, soils, and geology. The marine and estuarine environments of the outer coast add even greater diversity of communities and species. The ecoregion contains over 16,000 km of streams and rivers, and includes the lower reaches of several major rivers whose headwaters lie in adjacent ecoregions.

Table 1.1 Area of Ecoregion in Each State/Province

State/Province	Land Area (ha)	Percent of Ecoregion	Marine Assessment Area (ha)	Percent of Marine Area
British Columbia	2,897,000	41	670,000	44
Washington	1,908,000	27	460,000	31
Oregon	2,307,000	32	373,000	25
Total	**7,112,000**	**100**	**1,503,000**	**100**

Land ownership in the ecoregion is fairly evenly split between private and government entities (Table 1.2, Maps 1.2a, b, c). Publicly owned lands, including federal, state and provincial governmental agencies, account for about 58% of the ecoregion. The largest public land owner in the United States is the US Forest Service at 7% of the ecoregion. The largest public land ownership type in British Columbia is classified as Provincial Timber Farm Lease (19% of total ecoregion). Within this broad ownership are numerous land management categories, however, that have differing mandates and objectives. Private lands account for 40 percent with well over half of those lands (23% of the total ecoregion) managed as industrial timberland.

Tribal lands only cover about 1.6 percent of the terrestrial portion of the ecoregion but many First Nations land claims in British Columbia have not yet been resolved. In Washington, much of the ecoregion is within the ceded lands and usual and accustomed fishing areas of tribes residing on the Olympic Peninsula. Usual and accustomed areas are judicially defined areas where tribal members have fishing rights based on historical use patterns of their tribe. Tribes in Washington manage tribally-owned lands on reservations and are actively involved in monitoring, research and enforcement activities on ceded lands. Tribes are active participants in discussions about natural resources management and conservation activities within their usual and accustomed areas.

Table 1.2 Major land ownership within the PNW Coast Ecoregion.

Agency	Area (ha)	Percent of Ecoregion
Private Property	2,873,000	40.1
Provincial Government	2,318,000	32.3
United States Forest Service	532,700	7.4
National Park Service	399,600	5.6
Bureau of Land Management	308,600	4.3
Washington Dept of Natural Resources	259,800	3.6
Oregon Department of Forestry	222,100	3.1
Tribal Lands in U.S.	101,900	1.4
Oregon Department of State Lands	51,600	0.7
County/City Government	27,500	0.4
United States Fish and Wildlife Service	17,200	0.2
Canadian National Park Service	13,900	0.2
Oregon Parks and Recreation Department	12,400	0.2
Canadian First Nations	10,800	0.2
The Nature Conservancy	4,100	< 0.1
Washington State Parks	1,900	< 0.1
Washington Dept of Fish and Wildlife	1,800	< 0.1
Oregon Department of Fish and Wildlife	1,300	< 0.1
Department of Defense	600	< 0.1
Grand Total	**7,163,000**	**100**

Small towns are scattered throughout the ecoregion from Oregon's southern coastline to southern Vancouver Island but the ecoregion's total population is well below that of the two U.S. states and sole Canadian province that it straddles. Fueled by tourism and retirees, human development of the ecoregion has increased steadily in recent decades. The Oregon and Washington population grew by over 125% from 1950-2000 and experienced over 20% growth just in the past 10 years (U.S. Census Bureau 2005). The British Columbia population has grown by over 230% from 1951-2001 and has grown 19% in the past ten years (Statistics Canada 2005).

Irreversible habitat conversion has been confined to the coastal plain of Oregon and Washington whose accessibility and productive soils have enabled agriculture to flourish.

In contrast, higher elevations remain largely in a semi-natural state although vast acreages are intensively managed for timberland, a form of land use characteristic of most of the ecoregion. Today approximately 5% of the ecoregion has been converted to urban or tilled agricultural land, 23% is managed as private industrial timberlands, and 58% is in public ownership under varying types of management. In the offshore marine environment, impacts to biodiversity are less evident, although commercial fishing pressure has been intense to the point that many fish stocks are declining and benthic habitats have been altered in vast regions of the continental shelf.

1.2.2 Ecoregional Sections

For purposes of this assessment, the ecoregion was divided into seven sections, or ecoregional subdivisions (Map 1.1). Occurring in the following order from north to south these sections are: the Nahwiti Lowlands, North Isle Mountains, Windward Mountains and Leeward Mountains of Vancouver Island, Olympics, Willapa Hills, and Coast Range. The sections represent environmentally distinctive divisions within the ecoregion that depict different geology, physiography and soils. These factors define the vegetation of the sections and ultimately influence the composition of animal species inhabiting them. While sections are generally less distinct than ecoregions, they often are denoted by the distribution of endemic species, particularly plants, whose ranges tend to fall within section boundaries.

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 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 priority areas on a sectional basis, elements captured by the resulting conservation portfolio will be more representative of biodiversity across the ecoregion. Chapter 6 will describe how ecoregional sections were used in the analysis to design a conservation portfolio for the assessment.

1.2.3 Section Descriptions

At its northernmost extent, the PNW Coast Ecoregion covers the majority of Vancouver Island, British Columbia, with the exception of a thin strip of the Georgia Basin-Puget Trough-Willamette Valley ecoregion, which runs along the east coast of the island from just north of Campbell River south to Victoria. Vancouver Island is the largest island on the Pacific north coast. Victoria, the capital of British Columbia, is located on the southeastern tip of the island. Vancouver Island is 459 km (285 miles) in length and varies in width from 64 km (40 miles) to 130 km (80 miles) covering an area of 31,284 square km (12,079 square miles) (BC Ministry of Sustainable Resources Management 2005).

Vancouver Island is separated from the mainland by the Strait of Georgia, an area rich in marine life. The area's climate is temperate and the combination of rain and warmth creates the island’s characteristic rain forests (Lillard 1986). From sea level the island rises into towering mountains that geographically and climatically split the island down its vertical center. The highest mountain, Golden Hinde, (2,200 meters/7,219 feet) is located in Strathcona Provincial Park.

British Columbia utilizes a hierarchical classification system of natural ecosystems based on a biogeoclimatic vegetation zonation (Demarchi 1996). In British Columbia, the term *“Ecoregion”* denotes a different classification level than that used by the U.S. Forest Service (USFS) and The Nature Conservancy. According to the BC Ecoregion Classification System, the term *“Ecoregion”* as defined by USFS/TNC (Bailey 1995; 1998) is roughly equivalent to the BC *“Ecoprovince”* level of classification. For the purposes of this document, the term *“Ecoregion”* will continue to be used to define the planning area.

Vancouver Island is hierarchically nested in the Humid Temperate Ecodomain, Humid Maritime and Highland Ecodivision, Coast & Mountains Ecoprovince and the Georgia Depression Ecoprovince. The Island is divided between two BC Ecoregion Classification System areas: the Western Vancouver Island Ecoregion and the Eastern Vancouver Island Ecoregion. In these ecoregions there are four ecosections that lie within the PNW Coast Ecoregion as defined by TNC; an ecosection is equivalent to a section under the TNC terminology. On Eastern Vancouver Island east of the Vancouver Island Ranges is the Leeward Mountains section, a mountainous area from the crest of the Vancouver Island Ranges to the Nanaimo Lowlands (Demarchi 1996).

Western Vancouver Island contains three ecological sections: the Nahwitti Lowland section, an area of low to rolling topography, with high precipitation located at the north end of Vancouver Island; the North Isle Mountains section, a partial rainshadow of wide valleys and mountains located in the northern portion of Vancouver Island; and, the Windward Mountains section, the area of lowlands, islands, and mountains on the western margin of Vancouver Island (Demarchi 1996).

Nahwitti Lowlands Section

The Nahwitti Lowlands section is an area of low to rolling topography, flanked by the Pacific Ocean at the north end of Vancouver Island. The section covers approximately 250,800 ha of rugged lowlands influenced by a maritime climate that delivers high precipitation through much of the year with cool, moist summers and wet, mild winters. Average annual precipitation lies within the range of 750 – 3500 mm, with the majority of the precipitation falling in the autumn and winter. The terrain is low elevation and undulating, containing many areas with perched water tables where unproductive forests comprised of hemlock, pine and cedar bog grow in a low-nutrient conditions. The section is crossed by a number of short rivers that flow from wetlands downslope to fjords that cut deeply into the northern tip of Vancouver Island. Port Hardy is an important town in the section as it serves as the largest center of human activity in the area (Demarchi 1996).

Vegetation in the section is dominated by coastal western hemlock and Sitka spruce forests with some mountain hemlock in the interior highlands. There is a considerable area covered by hypermaritime forests in the section; these are characterized by plant associations that may have seasonally flooded soils with understories dominated by devil’s club or skunk cabbage. Productivity in many forest stands is low due to shallow water tables that have given rise to the existence of some of the largest blanket bogs on the Island and in the ecoregion. Some disturbance from timber harvest activities does occur in the section but it is relatively minor in a region that generally has limited harvest opportunities.

Wildlife species in the Nahwitti Lowlands include black-tailed deer, Roosevelt elk, black bear, and cougar as well as a full complement of small mammals, birds and fish. Species of concern in forested ecosystems include marbled murrelets and northern goshawks. Hunting for bear, deer and cougar is popular with local residents as well as others who travel to the area for this purpose. Coastal waters surrounding the land as well as the fjords that penetrate far inland harbor a wealth of waterfowl and seabird species whose numbers swell during migration. These waterways are particularly rich in marine biodiversity and support a number of healthy salmon runs. Angling for steelhead is a recreational pastime in the region enjoyed by many.

Cape Scott Provincial Park, the largest protected area in the Nahwitti Lowlands section, wraps around Cape Scott on the northwestern tip of Vancouver Island. The Provincial Park protects the rugged cape and coastal waters as well as headland forests that are battered by winter storms. Smaller protected areas include Quatsino and Marble River Provincial Parks along the Quatsino Sound and Raff Cove Provincial Park along the northwest coast. Offshore, the Scott Islands Provincial Park encompasses the Scott Islands chain and the surrounding coastal waters off Cape Scott.

Windward Mountains Section

The Windward Mountains Section is an area of lowlands, islands and mountains on the western margin of Vancouver Island. This section stretches from north of the Brooks Peninsula down past Nootka, Clayoquot and Barkley Sounds and includes the Pacific Rim National Park. The section covers 1,178,500 ha of exposed coastline and forested mountains that, like the Nahwitti Lowlands, are dominated by maritime climatic influences. Summers are cool and moist while winters are wet and mild with abundant rainfall and high winds generated by Pacific storms during winter. The terrain is generally rugged and often very steep and mountainous as it rises to the crest of the Vancouver Island ranges. Strathcona Provincial Park, in the central part of the section straddling the crest, is crowned by the highest point on the Island, Golden Hinde Peak at 2200 m.

Vegetation in the section is dominated by coastal western hemlock and Sitka spruce at lower elevations and mountain hemlock at higher elevations. Subalpine and alpine conditions are present in Strathcona Park where montane meadows and true fir forests can be found as well as small patches of alpine areas. The higher elevation habitats contain several endemic plant species that are not found elsewhere on the Island; these include Salish daisy (*Erigeron salishii*) and smooth Douglasia (*Douglasia leavigata var. ciliolata*). The lower elevation forests have been heavily cut in some river drainages while neighboring drainages are largely intact. Mid to high elevation forests are generally less heavily cut and many are still covered by original forests. Forest productivity is lower in the section when compared to eastern Vancouver Island forests. Much of the section is Crown land and under Timber Farm License (TFL) tenures.

One of outstanding natural features of the Windward Mountains section is its extensive coastline that contains nearly every type of shoreline habitat present on the island and provides habitats for large populations of marine wildlife. The Clayoquot and Barkley Sounds are noteworthy shoreline environments that are rich in marine biodiversity and form major interconnections between the uplands, freshwater and nearshore habitats. The nearshore region along the west coast of Vancouver Island is especially noted for marine mammals such as sea otters, orcas, Steller sea lions and gray whales.

Protected areas are numerous in the Windward Mountains section Strathcona Provincial Park and Pacific Rim National Park, two such protected areas, are representative of others that span the breadth of the section. The provincial parks are situated on some of the most ecologically diverse and important areas in the section and this is nowhere more evident than on the Brooks Peninsula that juts out into the Pacific Ocean and is completely contained within a designated protected area. There are also many designated marine provincial parks that provide protection for shorelines and underwater habitats along the coastline or just offshore. Well over half of the provincial parks are designated as “no camping” areas, signifying a high level of environmental sensitivity and corresponding protective management for these parks.

North Isle Mountains Section

The North Isle Mountains Section is a partial rainshadow of wide valleys and mountains located in the northern portion of Vancouver Island. The section stretches along Johnstone Strait from the mouth of the Nimpkish River near Port McNeil to the mouth of the Adam and Eve River, encompassing approximately 532,100 ha. The Nimpkish River drains the central portion of the section along with the Tsitika and the Adam and Eve Rivers into the Strait while the Gold River drains the southeastern corner of the section into Nootka Sound on the Pacific Ocean. Within the mountains in the interior of the section there are a number of large lakes that occupy long narrow drainages that are connected by several of these rivers. The steep mountains along the spine of Vancouver Island create a rainshadow over much of the section but the climate remains maritime with moderate temperatures and moist conditions.

Vegetation in the section is dominated by coastal western hemlock forests that have been heavily cut in the lower elevations but have experienced less cutting at higher elevations. The lower elevation forests are very productive and original stands have been replaced by second growth over large areas; higher elevation forests are less productive. The higher mountains support mountain hemlock forests and limited alpine and subalpine systems as well. High peaks in the section include Mount Cain (1840 m) and Victoria Peak (2163 m) along the southeastern border of the section.

Johnstone Strait, forming the northern border of the section, is a protected waterway that winds between Vancouver Island and smaller islands and headlands of mainland British Columbia. Transportation into the northern portion of Vancouver Island began along the protected waterway and it continues to serve as the main route for many visitors to the region. The Strait contains extensive low energy nearshore marine habitats such as mudflats and kelp beds but the strong currents in the area maintain active mixing of freshwater and salt waters, creating productive estuarine habitats. Marine biodiversity is high in these waters, offering ample fishing and recreational opportunities. The area is well known as prime habitat for orca whales. The Strait also supports healthy salmon runs, which migrate to and from the rivers and streams in the section.

Provincial parks form a network of protected areas in the North Isle Mountains section. Robson Bight Ecological Reserve, located within the Lower Tsitika Provincial Park, is legally designated to protect sensitive nearshore orca habitat and is managed to limit human activities and impacts in the area. There are a number of other provincial marine parks along Johnstone Strait that protect nearshore habitats and serve as recreational areas for boaters. Schoen Lake Provincial Park in the heart of the section contains several lakes and montane forests dominated by mountain and western hemlock. Black-tailed deer, bear, cougar and wolves are known to frequent the park and surrounding lands.

Leeward Mountains Section

The Leeward Mountains section is a mountainous area that runs from the crest of the Vancouver Island Ranges east to the Nanaimo Lowlands section. The section is the largest section on Vancouver Island, covering approximately 979,300 ha, yet it has the least amount of coastline because lands fronting the Strait of Georgia fall into the Nanaimo Lowlands section that is a part of the adjacent Willamette Valley-Puget Trough-Georgia Basin ecoregion. This section is under the climatic influence of a substantial rainshadow as it lies east of the central mountain ranges on Vancouver Island, which intercept much of the moisture approaching from the west. Therefore, this section’s climate is generally drier and receives more sunshine than other sections in the Pacific Northwest Coast Ecoregion. Nevertheless, the section still receives abundant precipitation with heavy snows occurring in the higher elevations. The terrain is dominated by mountains with Strathcona Provincial Park anchoring the highest elevations. Elongated montane lakes are scattered throughout the mountains and a number of rivers drain the section including the Salmon, Campbell, Stamp, and Cowichan Rivers.

Vegetation of the section is similar to that throughout the rest of Vancouver Island with coastal western hemlock being the dominant ecosystem at lower elevations and mountain hemlock and alpine vegetation common at higher elevations. Strathcona Park has extensive alpine habitat with lakes, bogs, mountain peaks and glaciers as well as vast stands of old growth forest. The park covers approximately 250,000 ha and is the oldest provincial park in British Columbia and the largest on Vancouver Island. Wide-ranging populations of wildlife, including black-tailed deer, Roosevelt elk, bear and cougar as well as the endemic Vancouver Island marmot and Vancouver Island white-tailed ptarmigan flourish in the park as a direct result of its large geography and limited accessibility. There are numerous other smaller provincial parks within the section, many centered on rivers and lakes that dot the area.

The Campbell River is the largest river in the section and is one of the largest rivers on Vancouver Island. The Campbell originates in Strathcona Provincial Park and runs through a series of glacially formed lakes including Buttle Lake in the park before emptying into the upper reaches of the Strait of Georgia. There are a number of anadromous fish species found in the Campbell River including Chinook, coho, chum, sockeye, steelhead trout and searun cutthroat trout. Many streams in the section also contain populations of Dolly Varden trout, a close relative of bull trout. One of the more interesting rivers in the section is the Stamp River whose headwaters are also located in Strathcona Park. From the park the Stamp River winds through Great Central Lake, bending at Port Alberni and flowing through a series of fjords eventually discharging into Barkley Sound on the Pacific Ocean. The Stamp supports numerous runs of salmon and steelhead trout.

The marine portion of the Leeward Mountains section is restricted to the area around Discovery Passage and the Discovery Islands. This group of islands stretches from Johnstone Strait to the city of Campbell River and is centered on Chatham Point that showcases Rock Bay Provincial Park. The islands themselves are not formally within the Leeward section but the waterways are and have abundant marine resources and habitats. Discovery Passage is well known for its tidal currents that make transit challenging and foster tidal mixing between the islands. Orcas, harbor seals and California seal lions are common in Johnstone Strait, as are salmon runs on which these marine mammals feed.

Olympic Section

The Olympic section is named for its location on the Olympic Peninsula, an area of abrupt topography defined by the Olympic Mountains. These mountains are an ancient slab of ocean floor that was scraped off as it collided with the North American continent about 35 million years ago (Franklin and Dyrness 1973). Most of the sea floor went beneath the continental landmass but by 13 millon years ago this slab started uplifting, becoming fractured, folded, and over-turned into a jagged mountain range. The underlying bedrock is composed of marine sandstones, siltstones, and shales interspersed with marine basalts. Radiating from the center of the uplift are eleven major rivers. Erosion by these streams and a series of glaciations created the current craggy landscape of the Olympic Mountains. The north and east flanks of the Olympics were covered by Pleistocene continental ice while glaciers formed at the higher elevations. Thick deposits of glacial till and/or outwash sand and gravel filled valley bottoms and today cover parts of surrounding coastal plains. This entire section was directly or indirectly influenced by glaciations.

The Olympic Mountains are a relatively low range with Mount Olympus, the highest peak, rising to 2428 m (7,965 feet) in only 37 miles from sea level on the Pacific Ocean and only 25 miles from sea level on the Strait of Juan de Fuca on the north. Wet marine air masses blowing ashore from the Pacific Ocean are forced up the mountain face where they cool and condense, releasing moisture as rain or snow. Glaciers at the highest peaks are maintained by snowfall. The west side of the Olympic Peninsula averages 140 inches of precipitation per year mostly as rain; Mount Olympus receives some 240 inches of precipitation mostly as snow. The mountains intercept Pacific Ocean moisture so effectively that the rain shadow immediately to the east, and a mere 30 miles northeast of Mount Olympus, receives only 17 inches of precipitation a year.

Coniferous forests dominate the vegetation of the Olympic section. They are generally characterized by Cedar-hemlock-Douglas-fir forests with Sitka spruce-western hemlock forest along the coastal plain and Pacific silver fir-hemlock forests in the high mountains. The highest elevations in the Olympic Mountains have subalpine parkland and alpine habitats. The rain shadow effect creates distinctly drier forests in the eastern Olympics than on the western slopes where dry forest types such as subalpine fir (*Abies lasiocarpa* with whitebark pine (*Pinus albicaulis*) outnumber the mountain hemlock forest and woodlands characteristic of eastern locales. Other special habitats include wetland, riparian and bog habitats.

The Olympic Mountains are rich in rare plant and animal species by virtue of their isolation and separation by marine water from other landscapes. Many rare plant and animal species in the ecoregion are endemic to the Olympic Mountains or are cut off from populations in the Cascades. Examples include the Olympic marmot (*Marmota olympus*), Flett's violet (*Viola flettii*), Piper's bellflower (*Campanula piperi*), Olympic Mountain synthyris (*Synthyris pinnatifida var. lanuginose*), Olympic chipmunk (*Tamias amoenus caurinus*), Olympic snow mole (*Scapanus townsendii olympicus*), Beardslee rainbow trout (*Oncorhynchus mykiss irideus*) and Crescenti cutthroat trout (*Oncorhynchus clarki clarki*).

Streams and rivers in this section typically begin as steep gradient drainages that eventually feed large, low-gradient river systems on the coastal plain. Freshwater lakes are dispersed throughout the section with the largest lakes, Lake Ozette and Lake Crescent in the glaciated landscape on the coastal plain. Almost all rivers in the section are home to salmon.

Winter storms numbering between 25 and 100 a year are the dominant natural disturbance along the coastal plain where wind throws and landslides are constantly modifying habitat and reshaping the landscape. Stand replacement fires occur at irregular intervals and vary in frequency by location on the Olympic Peninsula. The fire return interval for Sitka spruce forests along the wetter coast is 900 years, followed by 850 years for mountain hemlock, 630 years for montane Pacific silver fir and 235 years for lowland inland western hemlock forests. Growing in the rain shadow of the Olympics, subalpine fir and Douglas-fir forests burn every 210 and 140 years, respectively.

Early Native Americans occupied the exposed coastal plain before it was inundated by rising sea levels during the early post-glacial periods 9,000 to 12,000 years ago. Archeological evidence suggests that indigenous people occupied the area 3,000 years ago and altered their local environmental and the surrounding coastal vegetation. These people hunted terrestrial mammals, gathered roots and berries, and harvested anadromous fish runs on the peninsula. Euro-American settlement of the lowlands encircling the Olympic Mountains began in the late 1800's. Homesteaders cleared forests and introduced plant species for crop production. Industrial logging, road construction, valley bottom farming, commercial fishing, and recreational developments accelerated in the 1940’s along coastlines and on the coastal plain. Today, the dominant land use is intensive forestry but outdoor recreation plays an important part in the local economy. Together, Olympic National Park and Olympic National Forest and blocks of land managed by Washington State Department of Natural Resources or local tribes account for much of the land in this section.

Willapa Hills Section

Three large estuaries dominate and define the shoreline of the Willapa Hills section: Grays Harbor, Willapa Bay and the mouth of the Columbia River. In its northern end, the section extends from the southern flanks of the Olympic Mountains into the lowlands of Grays Harbor basin. Grays Harbor is the mouth of the Chehalis River. Just to the south are the Willapa Hills and adjacent lowlands, which are bisected by the Columbia River. The mouths of the Willapa River to the north and the Nasselle River to the south form Willapa Bay. The southern extent of the section captures the Nehalem River basin in Oregon. Barrier sand beaches characterize the low-lying coastline, behind which there are major estuaries.

The Willapa Hills have a rounded topography with deeply weathered bedrock. Boistfort Peak is the highest point in the Willapa Hills at 948 m (3,110 feet), although higher elevations exceeding 975 m occur where this section blends into the Coast Range section of Oregon. Unlike the Olympic Mountains to the north, the uplifted rocks of the Willapa Hills are an undeformed oceanic slab that extends deep under the Earth's crust. Uplifted tertiary igneous and sedimentary rocks and the adjacent broad valleys facing the Pacific Ocean characterize the surface formations of the Willapa Hills section. The underlying bedrock is marine sandstones, siltstones, and shales interspersed with marine basalts. While the uplands continue to uplift, the estuaries are sinking, as evidenced by sudden great subduction-type earthquakes, the most recent of which occurred in 1700, registered a magnitude 9 and affected more than 60 miles of coastline.

Columbia River basalt flows entered the section from the ancestral Columbia River and reached the Pacific Ocean at the mouth of the Columbia River and at Willapa Bay and Grays Harbor. While this section was unglaciated during the last ice age, it received melt water erosion and deposition from the Olympic Peninsula and from the catastrophic Missoula Floods emanating from the Northern Rockies during this period. A Pleistocene river located in the vicinity of the present-day Chehalis River valley was the conveyer belt by which glacial melt waters from the Cascades foothills and the southern end of the continental glacier entered the Puget Trough.

High precipitation is characteristic of the section's climate, averaging 60 to 120 inches that falls primarily as rain between November and April. Isolated rain-on-snow zones appear in the Willapa Hills. Winter is relatively mild and very wet; summers are cool and relatively dry. Streams and rivers typically begin as deeply incised, steep gradient drainages that eventually feed large, low-gradient river systems on the coastal plain. Freshwater lakes are rare in this section. Salmon occupy almost all rivers in the section.

Conifer forests are the most common type of upland plant community in Willapa Hills section. Along the coast the vegetation is mainly comprised of Sitka spruce-western hemlock forest, whereas cedar-hemlock-Douglas-fir forests are abundant eastward where the landscape merges with the Lower Columbia section of the Willamette Valley-Puget Trough- Georgia Basin ecoregion. Pacific silver fir-Noble fir-hemlock forests grow at the highest elevations 300-1000 m (1000-3300 feet) of Willapa Hills. Some of the largest estuaries on North America's west coast are found in this section. Other special habitats include coastal dunes, wetlands, riparian habitat and small, isolated meadows and grasslands.

Winter storms numbering between 25 and 100 a year with 50-70 mph wind (113 mph has been recorded on the Washington coast) are the dominant natural disturbance along the coastal plain where windthrows and landslides are constantly modifying habitat and reshaping the landscape. Stand replacement fire occurred historically and irregularly throughout most of this section every 200 to 250 years but now occur with higher frequency, particularly along the eastern edge bordering the WillametteValley-Puget Trough-Georgia Basin ecoregion.

The dominant land use in the section is private land industrial forestry; in addition some of the largest state forests are also located here. There are several protected areas in this section including three National Wildlife Refuges: Willapa, Lewis & Clark and Julia Butler Hansen as well as several TNC preserves including Ellsworth Creek, Blind Slough Swamp and Clatsop Plains. Several smaller protected areas are also scattered about the section.

Coast Range Section

The Coast Range Section of Oregon runs from the southern border of the Willapa Hills section south to the southern tip of the ecoregion near the Oregon/California state line. The northern border of the Coast Range section roughly corresponds to the drainage divide between the Nehalem River to the north and the Tillamook basins (Miami, Kilchis, Wilson, Trask and

Tillamook Rivers) to the south. The Coast Range Section is composed of steep mountain slopes with sharp ridges peaking at 450-750 meters. Several peaks rise above the summit ridges with Mary's Peak being the highest point in the section at 1249 m (Franklin and Dyrness 1973). Abundant rainfall and the soft parent materials that dominate the landscape are the main factors contributing to past and present erosion in the Coast Range section. The drainages carved by erosion and containing numerous rivers and major streams terminate at the coast in over 20 estuaries of appreciable size. This section has more sandy beaches than other sections in the ecoregion owing both to the easily eroded parent materials and the influence of the Columbia River drainage that has carried huge bedloads of materials from the interior of the Northwest.

Geology of the Coast Range section varies from north to south but on the whole most of the section is underlain with Eocene deposits consisting of sedimentary beds and basalts that date from the Miocene. The most prominent sedimentary beds are Tyee Formation sandstones that completely cover the central portion of the section. Along the southern Oregon coast there also occurs marine terraces of sedimentary origins that have been uplifted in and around Cape Blanco. The volcanic rocks present in the Coast Range are mostly pillow basalts that were deposited underwater and uplifted to form the prominent headlands along the northern coast as well as offshore rocks. Some of the most distinctive geology occurs at the extreme southern end of the ecoregion near the Rogue River basin where serpentine and other metamorphosed sedimentary rocks from the late Jurassic/early Cretaceous period can be found (Franklin and Dyrness 1973).

Coast Range vegetation varies with geology, elevation and proximity to the ocean but follows the general pattern of the rest of the ecoregion with temperate forests covering most of the landscape except for the immediate coastline that includes sand dune systems and beaches, headland grasslands and valley bottom wetlands. Sitka spruce forms a continuous narrow band along the coast and is replaced in the coastal mountains by Douglas fir and western hemlock forests. At the highest peaks in the Coast Range silver fir (*Abies amabilis*) and noble fir (*Abies procera*) can be found in isolated stands. The southern portion of the section contains forests more characteristic of the Klamath Mountains with grand fir (*Abies grandis*), white fir (*Abies concolor*) and red fir (*Abies magnifica*) mixing with Douglas fir and western hemlock. The coastal dunes are dominated by shorepine (*Pinus contorta contorta*) and herbaceous vegetation while coastal headlands, once covered with native grasses, are now largely dominated by weedy species. Coastal shrublands can be found along the southern reaches of the section. Wetlands display a diverse assortment of woody and emergent vegetation that have a widespread distribution across the Pacific Northwest. Coastal estuaries contain vegetative communities that range up to SE Alaska and include both high and low salt marshes and freshwater marshes as well.

1.2.4 Marine Ecosection Description

An integral part of the Pacific Northwest Coast ecoregion is the marine environment. We have added a marine ecoregion boundary to the terrestrial ecoregion that generally follows those identified by the NOAA National Estuarine Research Reserve System (NERRS). The boundary is biogeographically-based, determined primarily by the distribution of nearshore species and ecosystems (http://nerrs.noaa.gov/Background_Bioregions.html). The Pacific Northwest Coast marine ecoregion includes all shoreline, estuarine, and offshore areas down to 10 meters deep (Map 1.3).

The outer coasts of Oregon, Washington and the West Coast of Vancouver Island in British Columbia offer a wide range of intertidal and subtidal marine diversity. From exposed rocky shores of the Pacific Ocean to protected estuarine systems, the Pacific Northwest Coast Ecoregion encompasses over 9,000 km of shoreline. In general, the region is characterized by large amounts of rain in places along the coast which contribute freshwater run-off and land-derived nutrients to the marine environment.

The coastal waters of the ecoregion were delineated into nine marine sub-regions based on British Columbia's definition and delineation of marine "ecosections" (Harper et al. 2003). Ecosections are characterized as unique physiographic, oceanographic, and biological assemblages that are related to water depth and habitat (pelagic versus benthic). There are several implicit ecological factors of significance to ecosections, the most detailed level of classification after "ecozones," "ecoprovinces," "ecoregions," and "ecodistricts." Ecosections are an indicator of major community differences between benthic and pelagic biota (i.e., solid versus fluid), and an indirect indicator of primary productivity where shallow areas in the euphotic zone have higher productivity. They are also a direct indicator of oceanic stratification and associated biological assemblages.

We used this fifth order subdivision to stratify the coastal zone. The nine coastal ecosections are: Queen Charlotte Sound and Strait along the outer waters of North Vancouver Island, Johnstone Strait in the inland seas of Vancouver Island, Vancouver Island Continental Shelf along the Island's west coast, the Strait of Juan de Fuca along the shores of both British Columbia and Washington, two sections north and south of Pt. Grenville in Washington, and two sections north and south of Cape Arago in Oregon. We used the freshwater input the Columbia River as an addition parameter in delineating these ecosections. This additional parameter also accounted for the disparate data sets between Washington and Oregon.

1.3 Assessment Team and Assessment Process

Compiling information on biodiversity and assessing in it a structured, repeatable manner requires substantial organization in order to do credible work in a timely fashion. The PNW Coast Ecoregional Assessment benefited from having a tested methodology to use as well as having experienced persons actively working on it. While a number of new concerns came up in the assessment process, most of these concerns were dealt with in a spirit of consensus.

1.3.1 Ecoregional Assessment Team

The ecoregional assessment was led by a core team composed of the major partners and collaborators of the project. The core team was responsible for determining the basic direction of the assessment process, developing an initial budget, setting timelines for work products, and for maintaining progress towards the completion of the assessment. The core team met quarterly in order to update the partners involved and to review progress on various aspects of the assessment. Core team meetings were also used to discuss major decisions that would direct subteams in their individual tasks. These decisions reflected all aspects of the assessment process and eventually shaped the structure of the assessment as well as the outcomes of the project.

Members of the core team for the PNW Coast Ecoregional Assessment are as follows:

Wildlife Subteam lead	Ken Popper	TNC Oregon
GIS lead	Michael Schindel	TNC Oregon
Core Team/Botany Subteam lead	Dick Vander Schaaf	TNC Oregon
	John Christy	ONHIC
Terrestrial Systems Subteam lead	Gwen Kittel	NatureServe
	Rex Crawford	WNHP
	Dave Rolph	TNC Washington
Freshwater Subteam lead	Peter Skidmore	TNC Washington
	Pierre Iachetti	NCC
	George Wilhere	WDFW
Marine Subteam lead	Zach Ferdana	TNC Washington

The core team was led by Dick Vander Schaaf, Senior Conservation Planner for the Oregon Field Office of The Nature Conservancy. George Wilhere, conservation biologist for Washington Department of Fish & Wildlife, was the lead for the Washington state portion of the ecoregion and Pierre Iachetti, Conservation Planner for The Nature Conservancy of Canada, was the lead for the British Columbia portion of the ecoregion.

1.3.2 Ecoregional Assessment Process

Five technical teams of scientists and conservation specialists followed an assessment framework established by Groves et al. (2000, 2002). The teams included a terrestrial ecological systems team, a plant species team, an animal species team, a freshwater team, and a marine team. All the technical teams were coordinated and directed by the core team. Staff from The Nature Conservancy in Oregon led data compilation, analysis, and portfolio development for terrestrial and freshwater conservation targets with staff from TNC's Global Marine Initiative leading similar work for marine conservation targets. (See the Acknowledgements section at the beginning of this report for the complete list of team members and their affiliations.)

All technical teams contributed to each of the steps described below and adopted innovations where necessary to address specific data limitations and other challenges. Chapters 2-5 describe in detail the methods used by each team.

1. **Identify conservation targets** – Conservation targets are those elements of biodiversity – plants, animals, plant communities, ecological systems, etc., – that are included in the analysis. Targets were selected to represent the full range of biodiversity in the ecoregion and to include any elements of special concern.

   Robert Jenkins, working for The Nature Conservancy in the 1970s, developed the concept of coarse filter and fine filter conservation targets (Jenkins 1996, Noss 1987). This approach hypothesizes that conservation of multiple examples of all plant communities and ecological systems (coarse filter targets) will also conserve the majority of species that occupy them. This coarse filter strategy is a way to compensate for the lack of detailed information on the vast number of poorly studied species.

   Fine filter targets are those rare or imperiled species which cannot be assumed to be captured by coarse filter targets. Fine filter targets warrant a special effort to ensure they are represented in the conservation assessment. Fine filter targets can also include wide-ranging species that require special analysis, or species that occur in other ecoregions but have genetically important disjunct populations in the Pacific Northwest Coast ecoregion.

   As we describe in this report, identifying targets is not always a simple matter. In the marine and freshwater realms especially, the lack of information on ecosystems and species forced our team to develop new ecological systems classifications, and to perform freshwater and marine assessments with very few fine filter targets.

2. **Assemble information on the locations or "occurrences" of targets** – Data are assembled on target occurrences (e.g. the location, and in some cases, areal extent of a separate population or example of a species or community) from a variety of sources. Although existing agency databases make up the bulk of this data set, the teams often filled in data gaps by gathering information and consulting specialists for specific target groups.

3. **Determine how to represent target occurrences** – Decisions are made regarding the best way to describe and map occurrences of each target. Targets may be represented as points for specific locations, such as rare plant population locations, or polygons to show the areal extent of fine or coarse filter targets. The data are stored in a Geographical Information System (GIS).

4. **Set target goals for portfolio** – The analytical tool used for developing the portfolio requires setting goals for how many occurrences or how much habitat should be captured in the portfolio. Goals are set with the underlying assumption that they will be sufficient

to sustain each target over a 50-100 year time period. These goals are used to drive the identification and prioritization of potential conservation areas.

It is essential that users of this assessment understand the function of goals in the assessment. The goals should not be interpreted as 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. The details of each team's work to set goals are laid out in Chapters 2-4.

5. **Rate suitability of each part of the ecoregion for conservation** – The ecoregion was divided into assessment units using Hydrologic Unit Codes (HUC) watersheds of different sizes (HUC6 and HUC 7) in the US portion of the ecoregion and third order watersheds on Vancouver Island. This is fully described in Chapter 6 and shown in Map 6.1. Each of these units was compared to the others using a set of factors the team selected to determine that unit's suitability for conservation or the likelihood of conservation success. These include factors likely to impact the quality of the habitat for native species, such as the extent of roads or developed areas, or the presence of dams in rivers, as well as factors likely to impact the cost of managing the area for conservation, such as proximity to urban areas, the percent of public versus private lands, or the existence of established conservation areas.

   It is important to note that the factors chosen for this suitability index strongly influence the final selection of conservation areas, i.e., a different set of factors can result in a different conservation portfolio. Also, some factors in the suitability index require consideration of what are traditionally policy questions. For example, setting the index to favor the selection of public over private land presumes a policy of using existing public lands to conserve biodiversity wherever possible, thereby minimizing the involvement of private or tribal lands. The suitability index factors chosen for this assessment are clearly documented in this report. Chapter 6 includes a sensitivity analysis for the terrestrial portfolio that illustrates how changes in goals or the suitability index shape the final portfolio.

6. **Assemble draft portfolios** – An ecoregional assessment entails hundreds of different targets existing at thousands of locations. The relative biodiversity value and relative conservation suitability of thousands of potential conservation areas must be evaluated. This complexity precludes simple inspection by experts to arrive at the most efficient set of conservation areas. We chose to use an optimal site selection algorithm known as SITES (Andelman et al. 1999). Developed for The Nature Conservancy by the National Center for Ecological Analysis and Synthesis, SITES is computer software that aids scientists in identifying an efficient set of conservation areas. It uses a computational algorithm developed at the University of Adelaide, Australia (Possingham et al.1999).

   To use SITES, we input data describing the biodiversity value and the conservation suitability of each of the thousands of assessment units in the ecoregion. The number of targets, amount of each target, and rarity of targets present in a particular assessment unit determines its biodiversity value. Conservation suitability is input as an index (described above) consisting of a set of weighted factors that influence the relative likelihood of successful conservation at a unit. The relative weighting of each of these suitability factors is determined by the scientists conducting the assessment.

   The SITES program strives to minimize an objective function (Appendix 6A). It begins by selecting a random set of assessment units, i.e., a random conservation portfolio. The algorithm then iteratively explores improvements to this initial portfolio by randomly adding or removing assessment units. At each iteration the new portfolio is compared with the previous portfolio and the better one is accepted. The algorithm uses a method called simulated annealing (Kirkpatrick et al. 1983) to reject sub-optimal portfolios, thus greatly increasing the chances of converging on the most efficient portfolio. Typically, the algorithm is run for 1 to 2 million iterations.

7. **Refine the portfolio through expert review –** Expert review and revision are necessary to compensate for gaps in the input data or other limitations of automated selection of assessment units. Experts review the draft portfolio to correct errors of omission or inclusion by the computer-driven process. These experts also assist the teams with refining individual site boundaries. The terrestrial, freshwater, and marine portfolios are then integrated into a single final portfolio. This integrated portfolio is in turn subjected to additional expert refinement to produce the final portfolio.

8. **Prioritize the potential conservation sites –** Ideally, the conservation portfolio would serve as the conservation blueprint to be implemented over time by nongovernmental organizations and government agencies. However, in reality, the entire portfolio cannot be protected immediately and some conservation areas in the portfolio may never be protected (Meir et al. 2004). Limited resources and other social or economic considerations may make protection of the entire portfolio impractical. This inescapable situation can be addressed two ways. First, we should narrow our immediate attention to the most important conservation areas within the portfolio. This can be accomplished by prioritizing conservation areas. Second, we should provide decision makers with the flexibility to pursue other options when portions of the portfolio are too difficult to protect. Assigning a relative priority to all assessment units in the ecoregion will inform decision makers about their options for conservation.

   To facilitate prioritization we used SITES to generate two indices that reflect the relative importance of each assessment unit: irreplaceability and utility. The irreplaceability index was also incorporated into an irreplaceability versus vulnerability scatter plot that was used to further refine priorities.

1.3.3 Integrating Terrestrial, Freshwater, and Marine Analyses

The Pacific Northwest Coast Ecoregion consists of three environments: terrestrial, freshwater, and marine. These environments have quite different geographies, ecological systems, and processes. Their differences necessitate separate assessments, which we did, but for the sake of efficient conservation we also did an integrated assessment. The integrated assessment attempts to identify places where biodiversity from all three environments might be efficiently conserved. The integrated assessment faced some challenges, however, and users of this assessment should understand how the team addressed the challenges inherent in the integration task.

The chief challenge is the imbalance of biodiversity data between environments. Terrestrial species and habitats are more fully documented than either marine or freshwater biodiversity in terms of their taxonomy, location, status, and relative condition. A major limitation on the marine assessment, for example, was the lack of comprehensive data for benthic habitats and other physical parameters in the offshore environment. This limited the marine analyses to the nearshore and a few shoal areas away from the coast for which data were available. Within the nearshore, data on fine filter (e.g., species) target occurrences and on habitat condition is lacking when compared to the terrestrial data.

The freshwater analysis, meanwhile, faced similar limitations on species-level data for invertebrates and non-salmonid fish. In addition, the freshwater analysis was not conducted within the boundaries of the terrestrially derived Pacific Northwest Coast Ecoregion, rather freshwater biodiversity was better represented within large drainage basins. It required analysis of the nine Ecological Drainage Units (EDUs) that intersect the terrestrial ecoregion, as described in Chapter 3. The analysis was based primarily on a comprehensive mapping of macrohabitats and freshwater ecological systems. We regard this work as a foundation for future freshwater conservation assessments across these nine EDUs.

Chapters 2-4 describe in detail the methods used in the independent terrestrial, freshwater, and marine biodiversity analyses. Chapter 6 describes the process of integrating these assessments into a single portfolio. That portfolio was built primarily around the terrestrial and freshwater analysis because of its more comprehensive and complementary analytical treatment. The representative portfolio of nearshore and shoreline sites developed by the marine team was matched to the terrestrial/freshwater analysis but was evaluated separately.

Salmon were another challenge in this assessment. Salmon are considered critical components (i.e., keystone species) in the freshwater ecosystems of this ecoregion. Salmon have a complex life history that requires connectivity between marine waters, estuaries and stream reaches. Even though many stocks are judged to be in poor health, the species remain widespread in the ecoregion. All salmon species in the ecoregion are economically and culturally important, and a number of them are considered imperiled by state, provincial, tribal, and federal governments. Governments, non-governmental organizations, and academic institutions are spending vast resources to address the issue of salmonid conservation in the ecoregion. Furthermore, state, tribal, and local governments have developed salmon recovery plans which have been submitted to NOAA Fisheries for approval. A similar process is underway in British Columbia. Salmon were evaluated in this assessment as conservation targets and were treated similarly to other conservation targets, with due consideration given to their biology and population structure. No portfolio sites were identified solely for the conservation of salmon. The ecoregional assessment is not intended to supplant other efforts that are specific to salmon conservation in the ecoregion.

1.4 Strengths and Limitations of This Assessment

The PNW Coast Ecoregional Assessment is a resource for planners and others interested in the conservation of the biological diversity of this area. This assessment improves on the informational resources previously available in several ways:

- The assessment was conducted at an ecoregional scale. It provides information for decisions and activities that occur at an ecoregional scale, such as establishing regional priorities for conservation action, coordinating programs for species or habitats that cross state, county, or other political boundaries, judging the importance of any particular site in the ecoregion, and measuring progress in protecting the full biodiversity of the ecoregion.

- This PNW Coast assessment has been designed to inform ongoing, steadily improving ecoregional conservation efforts. This first iteration assessment identifies and prioritizes areas that, if protected, would contribute towards conservation of existing biodiversity. It describes gaps in our knowledge that should be filled in order to strengthen the assessment in its next iteration. It provides a benchmark to measure conservation progress over time as we continue to improve our understanding of the ecosystems and species we hope to conserve.

  At the same time, it is important to recognize what this assessment is not intended to provide, and to identify several important limitations on this work. In addition to those already described, users should be mindful of the following:

- This assessment has no regulatory authority. It is simply a guide to help inform conservation decision-making across the ecoregion. The portfolio is intrinsically flexible. The sites described are approximate, and often large and complex enough to require a wide range of resource management approaches. Ultimately, the exact siting and management of any potential conservation area will be based on the policies, values, and decisions of the affected landowners, governments, and other community members.

- This assessment should be treated as a first approximation. It is more complete for some species or ecological systems than for others, reflecting the variable state of knowledge of the natural world. Generally speaking, terrestrial biodiversity is more adequately represented than that of freshwater and marine systems. The HUC (and BC third order) watersheds used as assessment units should be used only as a rough starting point for the detailed site-level planning necessary to support local land-use decisions.

- The priority conservation areas described in this assessment are not all intended to become parks or nature reserves set aside from economic activity. While some areas may warrant such protection, many will accommodate multiple uses as determined by landowners, local communities, and appropriate agencies.

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

- This assessment does not describe all the important natural places in the ecoregion. The large size of the study area and use of coarse scale datasets sometimes precludes identification of small habitats and targets. Many places outside of the ecoregional conservation portfolio described here are important for natural beauty, environmental education, ecological services, and conservation of local biodiversity. These include many small wetlands, patches of natural habitat, and other important features of our natural landscape. They should be managed to support their own special values.

- The portfolio of sites presented here should not be used as the sole guide for siting restoration projects. These priority sites include high-quality habitat that must be maintained as well as lower-quality habitat that will require restoration. Additional sites may also be needed to rebuild habitat for species, improve water quality, and meet other community objectives.

These and other issues of strengths and limitations are described in further detail in subsequent chapters.

Chapter 2 – Terrestrial Conservation Targets

Key tasks in the ecoregional assessment process include identifying coarse and fine filter targets, collecting and organizing relevant datasets, defining the appropriate spatial representations of each target, and setting conservation goals. This chapter and the two chapters that follow discuss methods used to accomplish these tasks for terrestrial, aquatic, and nearshore marine targets, respectively.

2.1 Plant Community and Ecological System Targets

Plant communities and ecological systems act as coarse filters for all biodiversity. As discussed in Chapter 1, coarse filters are meant to capture the broad spectrum of species inhabiting the ecoregion. Coarse filter targets are roughly equivalent to habitat types and are represented by a “wall to wall” mapped coverage of natural vegetation with each ecological system representing a unique conservation target.

In addition to ecological systems targets, this section also describes rare plant community targets. Rare plant communities are globally imperiled and often represent unique or unusual habitats within a matrix of more common ecological systems. Surveys for rare plant communities are very incomplete relative to other conservation targets, but known locations were included in the analysis of the PNW Coast ecoregion in order to account for the biodiversity represented by them.

2.1.1 Technical Team

The technical team involved in developing terrestrial conservation targets and goals included representatives from NatureServe, the Washington Natural Heritage Program (WNHP), the Oregon Natural Heritage Information Center (ONHIC), The Nature Conservancy (TNC) of Oregon, the U.S. Forest Service (USFS), and the British Columbia Ministry of Forestry. Team members included:

Subteam Lead	Gwen Kittel	NatureServe
Team members	Rex Crawford	WNHP
	Jimmy Kagan	ONHIC
	John Christy	ONHIC
	Carmen Cadrin	BCCDC
	Dick Vander Schaaf	TNC Oregon
	Michael Schindel	TNC Oregon
Other Reviewers	Cindi McCain	USFS
	Del Meidinger	BC Ministry of Forests

The goal of this technical team was to provide a coarse filter framework that captures the terrestrial biodiversity of the ecoregion. To accomplish this goal, the terrestrial team developed: 1) a list of and definitions for rare plant communities and ecological systems targets of the ecoregion, 2) spatial representations of the targets, 3) a statement of limitations, confidence levels and uncertainties in the representation of targets, and 4) how conservation goals were set given this context.

2.1.2 Selecting Coarse-Filter Targets

The technical team chose to use ecological systems, as developed by NatureServe, 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 found in Comer et al. (2003), which is available from NatureServe’s web site, http://natureserve.org/publications/usEcologicalsystems.jsp

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/gravelling soils, or peatlands (as described and classified by NRCS 1998). Finally, environmental gradients include local climates, hydrologically defined patterns in coastal zones, arid grassland or desert areas, or montane, alpine or subalpine zones (e.g. Bailey 1995, 1998, and Takhtajan 1986). A given terrestrial ecological system will typically manifest itself in a landscape at intermediate geographic scales of 10s to 1,000s of hectares and persist for 50 or more years. Selecting this temporal scale share some aspects with the "habitat type" approach to describe potential vegetation (Daubenmire 1952, Pfister and Arno 1980), but 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 applications to resource management and conservation (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 ecological systems. The temporal scale or bounds chosen also integrate successional dynamics into the concept of each 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, we may then integrate multiple ecological factors – or *diagnostic classifiers* - to define each classification unit, not unlike the approach of DiGregorio and Jansen (2000).

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). We integrated bioclimatic categories to consistently characterize life zone concepts (e.g. maritime, lowland, montane, subalpine, 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 (NRCS 1998, Cowardin et al. 1979, Brinson 1993). Many dynamic processes are also sufficiently understood and described to serve as diagnostic classifiers (Anderson et al. 1999). The recurrent juxtaposition of recognizable vegetation communities provides an additional criterion 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. Our approach presented here is qualitative and rule-based, setting the stage for subsequent quantitative work. We relied on available interpretations of vegetation and ecosystem patterns across the study area and we reviewed associations of the International Vegetation Classification/National Vegetation Classification (IVC/NVC) in order to help define the limits of systems concepts (NatureServe 2004). In recent years we have also tested how well a systems approach could facilitate mapping of ecological patterns at intermediate-scales across the landscape (Marshall et al 2000, Moore et al 2001, Hall et al 2001, Nachlinger et al. 2001, Neely et al. 2001, Menard and Lauver 2002, Tuhy et al 2002, Comer et al 2002). These tests have led to the rule sets and protocols presented here.

This project resulted in the identification and description of 25 upland and wetland ecological system types within the PNW Coast Ecoregion (Table 2.1). This included several matrix forest systems, as well as peripheral systems that overlap slightly from neighboring ecoregions. They represent the full range of natural variation. All information for this classification is stored in a database, allowing for numerous queries of information on each type.

Table 2.1a Ecological systems in the United States portion of the ecoregion. See section 2.1.6 for justification of goals.

Hectares	%	Ecological System Name	Type	Distribution	Patch Size	Goal
2,032,100	46%	North Pacific Maritime Wet-Mesic Douglas Fir - W. Hemlock Forest	Forest	Widespread	Matrix	30%
1,153,100	26%	North Pacific Maritime Dry-Mesic Douglas Fir-W.Hemlock Forest	Forest	Widespread	Large Patch	30%
641,400	15%	North Pacific Hypermaritime Sitka Spruce Forest	Forest	Limited	Large Patch	30%
213,700	5%	North Pacific Western Hemlock-Silver Fir Forest	Forest	Widespread	Large Patch	20%
189,300	4%	Northern California Mixed Evergreen Forest	Forest	Limited	Large Patch	20%
125,000	3%	North Pacific Mountain Hemlock Forest	Forest	Widespread	Matrix	20%
23,000	0.52%	North Pacific Dry and Mesic Alpine Dwarf-Shrubland and Meadow	Alpine	Widespread	Large Patch	10%
16,300	0.37%	North Pacific Maritime Coastal Sand Dune	Substrate	Limited	Small Patch	3 per section
3,500	>0.1%	Mediterranean California Mesic Mixed Conifer Forest and Woodland	Forest	Limited	Matrix	10%
1,900	>0.1%	North Pacific Montane Riparian Woodland and Shrubland	Wetland	Widespread	Linear	3 per section
1,800	>0.1%	North Pacific Hypermaritime Western Hemlock - Red Cedar Forest	Forest	Limited	Large Patch	30%
1,800	>0.1%	Rocky Mountain Ponderosa Pine Woodland	Forest	Peripheral	Small Patch	10%
400	>0.1%	North Pacific Coastal Herbaceous Bald and Bluff	Substrate	Limited	Small Patch	3 per section
100	>0.1%	Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland	Substrate	Limited	Small Patch	3 per section
100	>0.1%	North Pacific Oak Woodland	Forest	Limited	Small Patch	20%
>100	>0.1%	North Pacific Avalanche Chute and Talus Shrubland	Substrate	Widespread	Small Patch	3 per section
4,403,500		Total land mapped as Ecological Systems				

Table 2.1b Ecological systems in the Canadian portion of the ecoregion. See section 2.1.6 for justification of goals.

Hectares	%	Ecological System Name	Type	Distribution	Patch Size	Goal
1,409,400	47%	North Pacific Western Hemlock-Silver Fir Forest	Forest	Widespread	Large Patch	20%
558,100	18%	North Pacific Maritime Wet-Mesic Doug Fir-W. Hemlock Forest	Forest	Widespread	Matrix	30%
546,400	18%	North Pacific Hypermaritime Western Hemlock-Red-cedar Forest	Forest	Limited	Large Patch	30%
256,700	8%	North Pacific Mountain Hemlock Forest	Forest	Widespread	Matrix	20%
93,300	3%	North Pacific Avalanche Chute and Talus Shrubland	Substrate	Widespread	Small Patch	3 per section
39,300	1%	North Pacific Western Hemlock-Yellow Cedar Forest	Forest	Limited	Large Patch	20%
28,700	1%	North Pacific Coniferous Swamp	Wetland	Limited	Small Patch	3 per section
17,600	0.6%	Boreal Wet Meadow	Grassland	Widespread	Small Patch	3 per section
15,500	0.5%	Dry Shore Pine Woodlands	Forest	Limited	Small Patch	
15,100	0.5%	North Pacific Hypermaritime Sitka Spruce Forest	Forest	Limited	Large Patch	30%
15,000	0.5%	North Pacific Maritime Tidal Salt Marsh	Wetland	Limited	Small Patch	3 per section
13,000	0.4%	North Pacific Lowland Riparian Forest and Shrubland	Wetland	Widespread	Linear	3 per section
9,700	0.3%	North Pacific Dry and Mesic Alpine Dwarf-Shrubland and Meadow	Alpine	Widespread	Large Patch	10%
4,900	0.2%	Temperate Pacific Freshwater Emergent Marsh	Wetland	Widespread	Small Patch	3 per section
1,700	>0.1%	North Pacific Deciduous Swamp	Wetland	Widespread	Small Patch	20%
509	>0.1%	Boreal Fen	Wetland	Widespread	Small Patch	3 per section
100	>0.1%	North Pacific Dry Douglas-fir Forest and Woodland	Forest	Peripheral	Large Patch	20%
100	>0.1%	North Pacific Maritime Coastal Sand Dune	Substrate	Limited	Small Patch	3 per section
3,025,200		Total hectares mapped as Ecological Systems				

2.1.3 Selecting Rare Plant Community Targets

Rare plant communities include communities that are unique and have limited distributions due to unusual soils or habitats they are found in as well as communities that have declined precipitously due to habitat loss. A list of globally endangered or threatened rare communities (G1-G2 ranked) within the ecoregion was compiled from records maintained by the Oregon Natural Heritage Information Center, Washington Natural Heritage Program and the British Columbia Conservation Data Centre (Appendix 2B). In addition another list comprised of ecologically important and threatened estuarine and freshwater wetland communities was drafted by experts in these above programs (Appendix 2C). The combined list of rare communities formed the basis for selecting rare plant community targets for use in the assessment.

As noted previously, rare plant communities are poorly inventoried relative to other terrestrially based conservation targets used in this assessment. Comprehensive inventories have been completed for few of these communities with the possible exception of wetlands and estuarine communities. The locations of these types of communities are better known due to their limited extent, their degree of imperilment and the generally perceived notion of their importance to biodiversity. Because of the availability of more comprehensive data coupled with their importance, only wetlands and estuarine rare community targets were used in the analysis for the ecoregional assessment (Appendix 2C). The general consensus was that many non-wetland rare community targets would be effectively "captured" by the coarse filter ecological system targets. Efforts were made during the draft portfolio reviews to insure that rare plant community locations were included in the draft portfolio.

2.1.4 Plant Association and Ecological Systems Data Representation

2.1.4.1 U.S. Ecological Systems Map

Coarse filter vegetation information for the U.S. portion of the PNW Coast ecoregion was primarily derived from PAG (Plant Association Group) classifications developed by the USFS (Henderson et al 1989, 1992, 2002). Using climate data from weather stations throughout the Northwest, the USFS applied an interpolation technique to derive a 30-meter grid of precipitation and temperature. This raster data set was combined with topographic slope and aspect classes. Thousands of USFS vegetation plots were then used to derive a map of potential natural vegetation across most of the U.S. portion of the ecoregion. The National Land Cover Datsets for Oregon and Washington (NLCD 1992) were used to identify urban and agricultural lands. These lands were not attributed with any ecological systems.

Using the vegetation types represented by each PAG, a crosswalk was developed to aggregate PAGs into Ecological Systems, a coarser level of classification appropriate for Ecoregional Conservation Assessment (Appendix 2A).

A PAG map for Southwestern Oregon was developed independently by the southwest Oregon Forest Service area ecology program (Diane White, 2003 USFS, personal communication). This map was attributed to ecological systems by Oregon Field Office staff and combined with the larger PAG/ecological systems coverage. The final PAG/Ecological Systems coverage was clipped to the buffered PNW Coast Ecoregion. (Maps 2.1a, b, c)

A portion of the ecoregion in the Puget Sound area was not covered by existing USFS PAG maps. Ecological systems developed for the Willamette Valley-Puget Trough-Georgia Basin Ecoregional Assessment were used to complete most of the missing area. Assessment units exclusively in the buffer zone were not populated with systems data.

Because PAGs and other sources used for vegetation maps did not include stand age or stand structure information alternate sources were found for this data. In Washington the Combo100 dataset (USFWS 1997) was used to differentiate seral stages. This information was developed to assist with the Northwest Forest Plan. Each 30 x 30 meter grid cell was attributed with ownership information, average tree size, and other attributes. For Oregon most seral data came from the Coastal Landscape Analysis and Modeling Study (CLAMS 1996), Siuslaw and Siskiyou National Forest coverages. During the course of our analysis the Inter-Agency Vegetation Mapping Project (IVMP 2002) released their map of stand size for western Oregon and Washington. The final iterations of our plan used this information as it was consistent across the entire U.S. portion of the PNWC.

2.1.4.2 Vancouver Island Ecological Systems Map

No comprehensive map of the vegetation on Vancouver Island was available for the assessment. However, approximately 20% of the island had been mapped at a scale of 1:20,000 for specific projects. The mapping methodology used in these Terrestrial Ecosystem Mapping (TEM) projects was standardized and is based on the BC Biogeoclimatic Ecosystem Classification and the BC Ecoregion Classification Systems (RIC 1998, Meidinger and Pojar 1991, Demarchi 1996, Demarchi et al. 1990). These maps contained highly detailed vegetation information similar to the association level in the USNVC (NatureServe 2004), and had been completed in virtually every climate zone on Vancouver Island. These maps were used as training sets for a model to create the comprehensive vegetation map for the island (Map 2.1a).

The base of this model was created using the 30m Digital Elevation Model (DEM) of the island. A topographic position model was developed for each of the 4 sections of Vancouver Island (Fels and Zobel, 1995). This position model divided the landscape into 9 classes; ridges, flat summits, cliffs, slope crests, steep side slopes, gentle to moderate side slopes, toe slopes, flats and coves. These topographic positions have been demonstrated to correspond with patterns of natural vegetation because of varying soil depths and moisture profiles.

This base model was further refined with an annual derived solar budget. A latitude and longitude coordinate was selected for each of the 4 sections of Vancouver Island that corresponded with its centroid. These coordinates were then used to calculate solar angle and azimuth at hourly intervals for each of the equinoxes and solstices. Using the “hillshade” function in ArcMap (“Model Shadows” set to “no”), a hillshade grid was created for each hourly value output from the ephemeris generator. These grids were added together to evaluate how much solar radiation each cell received over the course of a year. This method is much more accurate than traditional surrogates such as slope and aspect as shading from adjacent landforms are taken into account. A south-facing slope in a steep, narrow valley, for example, will receive less radiation than one without an adjacent landform blocking morning and/or evening light.

The solar grid was reclassified into 4 values (Natural Breaks; Full Sun, Partial Shade, Partial Sun, Full Shade) and added to the landform grid. The output was then converted to vector coverage. Each polygon was attributed with additional information, the climate zone it intersected, the principal bedrock geology for the polygon, and its landuse/landcover designation. A centroid was calculated for each attributed polygon, and these centroids were then spatially joined to the polygons from the *TEM* mapping projects. Statistics were generated for each modeled type to predict which vegetation type most closely corresponded from the *TEM* maps. Approximately 95% of the polygons within the buffered ecoregional boundary were assigned to an association.

Del Meidinger (BC Ministry of Forests) and Gwen Kittel (NatureServe) developed a crosswalk from the BC Vegetation Association to Ecological Systems to assign each polygon to its appropriate Ecological System. These Ecological Systems were then used in conjunction with landuse/landcover data to derive our terrestrial coarse filter targets. Forested areas within the Early, Mid and Late seral classes, and shrub/herb types from all classes except "agriculture" and "urban" formed our targets.

Goals for all large-patch sized Systems were set from 10%-50% depending on rarity and distribution. Goals were set for the full ecoregional distribution (unstratified) of these Systems as well as for their sectional distributions (stratified). Small patch sized Systems were treated as "occurrences" and goals were set at 3 occurrences per section.

2.1.5 Target Representation

The ecological systems targets were represented as polygons derived directly from the input data described above. Each polygon was attributed to the underlying assessment unit as an aerial coverage in standard units of area. The vegetation map thus formed a wall to wall cover across the ecoregion exclusive of urban areas, agriculture and other human infrastructure. The rare plant community targets were represented as point occurrences that were also attributed to assessment units.

The analysis of the coarse filter targets involved some initial screening that resulted in lumping very minor occurrences of several ecological systems to more widely represented systems. The rationale for this lumping was that most of the vegetation map was developed from vegetation modeling and there was sufficient uncertainty in some of the attributed polygons. While the overall presence of the listed ecological systems in the ecoregion is fairly certain, the actual location of some of the more peripheral systems and systems that are by nature represented in very small patches is less certain. Therefore, in order to not unnecessarily skew results, those systems that could not be accurately mapped were lumped with systems that were ecologically similar. The lumped systems are noted in Table 2.2.

2.1.6 Data Gaps

We did not have map coverage for 17 Ecological Systems that are suspected to occur within the ecoregion. Peripheral forest types were generally not represented in the vegetation models used to represent this ecoregion and hence, they were not adequately covered in this assessment. We assume these systems were captured in adequate amounts in neighboring ecoregions. Inland terrestrial wetlands were covered as rare plant community occurrences.

Coastal tidal wetlands, intertidal mudflats and estuaries, were covered both as tidal marsh ecological systems as well as linear shoreline habitat types in the marine nearshore modeling and mapping. See Chapter 4 for methods used to delineate shoreline habitat types.

Table 2.2 is a list of the ecological systems thought to occur within the PNW Coast Ecoregion, but not specifically represented in the vegetation layer. The omission of these ecological systems is not expected to bias the results of the assessment as the systems generally represent small overall area in the ecoregion. Also, many of these ecological systems occur within protected areas (i.e., National Park or Provincial Parks) or they can be represented as rare plant communities that may be included as conservation targets in the assessment.

Rare plant communities represent some of the greatest data gaps in coarse filter targets as they have had few comprehensive inventories compared with rare species that have benefited from regular surveys by land management agencies and private individuals. The lack of standardized classifications of plant communities continues to hamper community survey efforts. Even though we used wetland and estuarine communities as rare community targets, these need updated surveys and mapping to bring them up to par with other conservation targets in the ecoregion.

Table 2.2 Ecological Systems not represented in the vegetation map but suspected to occur within the ecoregion

Code	Ecosystem Name	Reasons for Data Gap	Target Mapping Comments
Alpine Zone			
no code	Rock and Ice	Limited or no vegetation present	Not included in analysis. Well represented in existing protected areas.
Subalpine Zone			
CES204.837	North Pacific Maritime Mesic Parkland	Rare in Coast Ranges, more common in the Cascade Mts.	Not mapped
CES306.807	Northern Rocky Mountain Subalpine Dry Parkland	Very peripheral to the Coast Range, more common in Cascade Mts.	Not mapped
CES306.828	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Peripheral in the Coast, more common in the Cascade Mts.	Not mapped
CES206.913	Mediterranean California Red Fir Forest and Woodland	Peripheral to Coast, common in the Klamath Mountains.	Lumped with Mediterranean California Mesic Mixed Conifer Forest and Woodland
Montane Zone			
CES306.823	Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland	Peripheral to the Coast Range, more common in the Cascade Mts.	Not mapped
CES204.840	Alaskan-Vancouverian Maritime Western Hemlock Forest	Minor occurrence on Vancouver Island,, more common in Coastal Forest and Mountains Ecoregion to the north (AK and BC)	Lumped with North Pacific wet-mesic Western Hemlock Forest
CES206.921	Coastal Redwood-Mixed Conifer Forest and Woodland	Peripheral to Coast, and peripheral to neighboring Klamath Mountains	Considered as rare community type
CES206.916	Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland	Peripheral to Coast, common in the Klamath Mountains	Lumped with Mediterranean California Mesic Mixed Conifer Forest and Woodland
Coastal Wetlands, Riparian Areas and Interior Wetlands			
CES200.876	Temperate Pacific Freshwater Aquatic Bed	Small patch system, poorly represented by vegetation models.	Lump with Temperate Pacific Freshwater Emergent Marsh
CES103.870	Boreal Blanket Bog	Small patch wetland, peripheral to Coast, more common further north	Considered as rare community type, may also be included in North Pacific Coniferous Swamp
CES103.871	Boreal Depressional Bog	Small patch wetland, poorly represented by vegetation models	Considered as rare community type
CES204.846	North Pacific Broadleaf Mesic Seral Forest	Small patch forest, poorly represented by vegetation models.	Not mapped
CES204.875	North Pacific Intertidal Freshwater Wetland	Small patch wetland, not represented by vegetation models	Considered as rare community type and may also be included in North Pacific Maritime Tidal Salt Marsh
CES200.882	North Pacific Maritime Eelgrass Bed	Small patch wetland, not represented by vegetation models	Not mapped but included in marine analysis
CES204.879	Temperate Pacific Intertidal Mudflat	Small patch wetland, not represented by vegetation models	Not mapped but included in marine analysis

2.1.7 Setting Goals

The analytical tool used in this assessment requires goals be set for conservation targets. These goals were a device for assembling an efficient conservation portfolio, but they were also first approximations for the necessary and sufficient conditions for long-term survival of plant communities and ecological systems. Ideally, when setting goals, we are attempting to capture ecological and genomic variation across the ecoregion and ensure species persistence by spreading the risk of extirpation. As yet there is very little theory and no scientific consensus regarding how much of an ecological system or habitat area is necessary to maintain most species within an ecoregion (Soule and Sanjayan 1998).

Setting conservation goals is perhaps the most difficult aspect in the development of an ecoregional assessment. Research and experimentation regarding necessary goal levels to insure the maintenance of biological diversity, especially with regards to habitats and natural communities, is largely lacking. Conservation goals are established for ecological systems at the ecoregion level as well as for each ecological section. This is to insure that targets are represented across their natural distribution in the ecoregion in order to portray the full expression of the diversity that is inherent within each ecological system.

We had no scientifically established method for setting goals for coarse filter targets but experience gained from previous ecoregional assessments has led us to some basic premises regarding goal setting. We also relied upon the best professional judgment of ecologists from the technical team and state Natural Heritage Programs. These scientists have settled on a generic goal for matrix-forming, large-patch, and linear ecological systems. This generic goal is 30 percent of the historic extent of the ecological system (Marshall et al. 2000, Comer 2001, Neely et al. 2001, Rumsey et al. 2003).

To establish an initial percent area goal, we considered the species/area relationship (Figure 2.1), proportional representation of biophysical gradients, and the ecological backdrop (Comer 2001). In addition to this, we considered the fact that several hundred of the most vulnerable and sensitive species are targeted either individually, or in natural communities. Because ecological systems indicate potential native vegetation and because the ecoregion remains predominantly forested (i.e., very little land has been converted to urban, surburban, or agricultural uses), we assumed the current extent is approximately equal to historic extent. In the PNW Coast, we selected an initial goal of 30% of current extent for each system in the ecoregion. This percentage, on its own, would suggest that we could lose between 15% and 35% of native species (Figure 2.1). However, we adopted this generic coarse filter goal, which might conserve well over half of the ecoregion’s biodiversity, as a reasonable benchmark for identifying high priority places for conservation.

Goals for all rare plant community targets were set at 30% of the known occurrences. Most occurrences occupy a relatively small area, often times less than 50 hectares, therefore setting a percent cover goal is not relevant in terms of capturing a viable representation of the target.

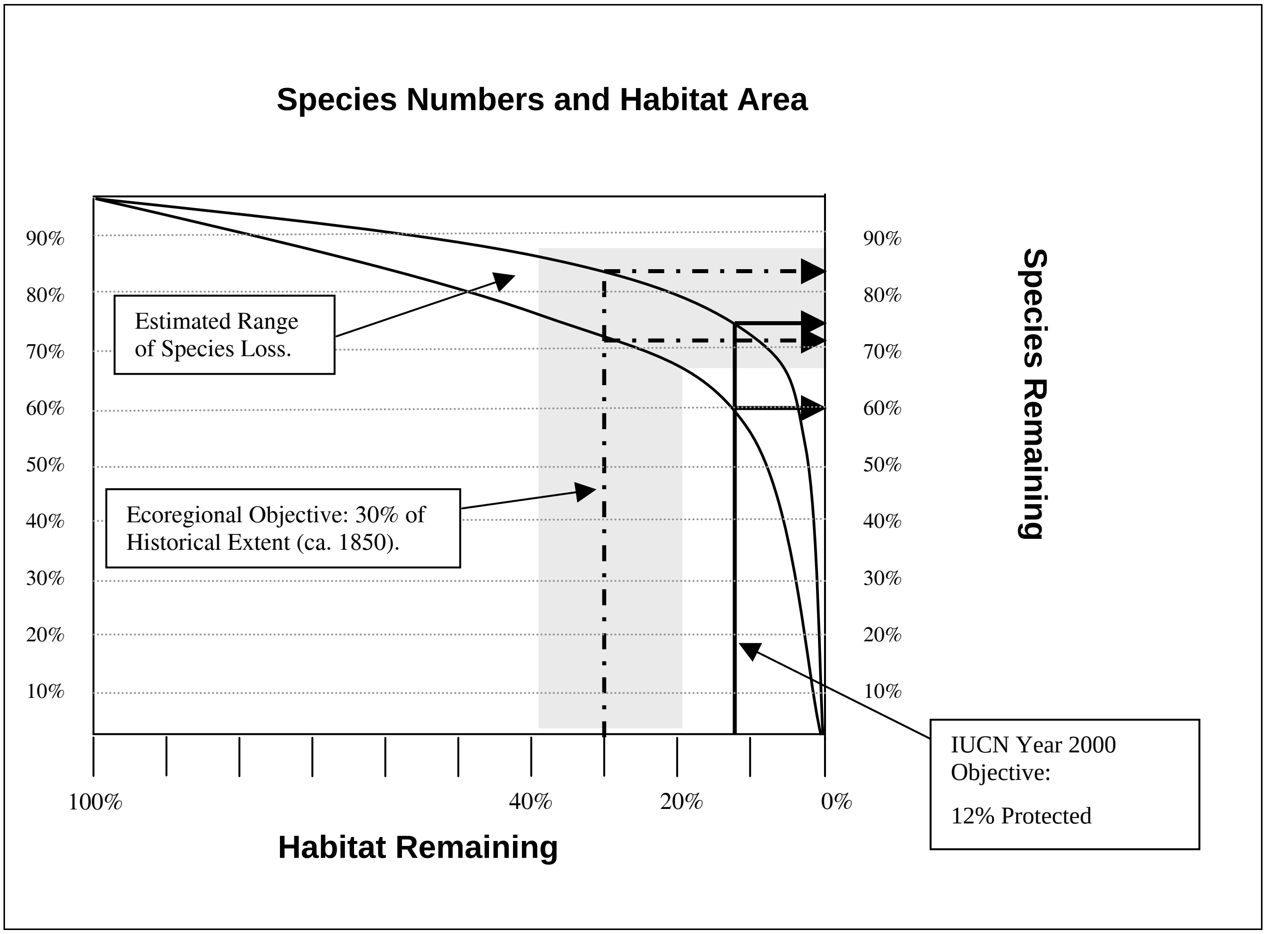


FIGURE 2.1 EXAMPLES OF SPECIES AREA CURVES SHOWING ESTIMATED SPECIES LOSS VERSUS PERCENT AREA OF HABITAT LOSS (COMER 2001).

For ecological systems that have small patch distributions and for rare communities considered as conservation targets, goals were established as numbers of occurrences to be represented within the assessment or portfolio. The numbers of occurrences varied for ecological systems depending on their distribution relative to the ecoregion with distribution being classified as Endemic, Limited, Widespread or Peripheral.

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

Goals for ecological systems in the PNW Coast are listed in Table 2.1. Table 2.3 lists the initial goal levels that were used in the assessment; as the starting point for goal setting. Goals were modified from the starting points after discussion in the subteam. 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% of current extent. For those systems that were deemed to be peripheral to the ecoregion (for example Mediterranean California Mesic Mixed Conifer Forest and Woodland) the goals was set to 10% of current extent and systems were well represented in large protected areas (such as North Pacific Mountain Hemlock Forest) where goals were lowered to 20% (Table 2.1).

Table 2.3 Conservation goals for ecological systems and rare communities (Comer 2001).

Distribution Relative to Ecoregion	Spatial Pattern	
	Matrix, Large Patch and Linear Ecological Systems (area per ecosection)	**Small Patch Ecological Systems (number of occurrences)**
Endemic	30% of current extent	50
Limited		25
Widespread		13
Peripheral		7

2.1.8 Expert Review

The ecological systems classification and accompanying map of vegetation across the ecoregion underwent continuous and extensive review by the Communities subteam and their colleagues. Input from USFS ecologists (McCain 2004, personal communication) and the BC Ministry of Forests ecologist (Meidinger 2003, personal communication) were critical in providing crosswalks to regional classifications as well as identifying ecological systems present in adjacent ecoregions. Further review of the vegetation map was conducted at conservation portfolio reviews conducted later in the assessment process (see Chapter 8).

2.2 Plant Species Fine Filter Targets

2.2.1 Technical Team

The technical team responsible for developing the plant species fine filter target list included:

Subteam Lead	Dick Vander Schaaf	TNC Oregon
Team members	Sue Vrilakas	ONHIC
	Jimmy Kagan	ONHIC
	Florence Caplow	WNHP
	George Douglas (deceased)	BCCDC
	Sharon Hartwell	BCCDC
Other reviewers	John Christy	ONHIC
	Rex Crawford	WNHP

2.2.2 Selecting Fine Filter Target Species

Potential rare plant conservation targets for the PNW Coast ecoregion were initially compiled from Heritage Program databases. The Oregon Natural Heritage Information Center, Washington Natural Heritage Program and British Columbia Conservation Data Centre provided lists of species that they currently tracked or had previously tracked and still maintained data for the taxa. The request for target nominations made to each of the heritage programs was confined to species found within the ecoregion and/or within a 10km buffer around the ecoregion. Rare plant conservation targets for the WillametteValley-Puget Trough-Georgia Basin Ecoregional Assessment (Floberg et al. 2004) were reviewed for additional candidate targets for the PNW Coast. The initial list totaled over 300 taxa across the ecoregion.

The complete list was sent out for review to heritage program botanists with the direction to delete species that were no longer of concern, species of questionable taxonomy or species that may not be appropriate as conservation targets. The heritage botanists were also requested to add species that they felt needed to be added even though they were not currently in heritage data files; this included newly described taxa. Changes to the list were minor resulting in only about 25 species being added or dropped with most of these in British Columbia.

Considerable discussion was generated regarding marine algae species that were included in the BCCDC draft list; a number of marine algae were also being considered as conservation targets for the marine conservation portfolio for the ecoregion. Range-wide data is generally lacking for many marine algae precluding their general utility as conservation targets in the ecoregional assessment. The final decision regarding marine algae was to include them as rare plant targets if they are currently tracked as species of concern by the respective heritage programs. Most of these species are only known from Vancouver Island and are on BC Provincial species of concern lists (red, blue and yellow lists). Marine algae species that were recommended as conservation targets in the marine conservation target part of the project will be noted in the corresponding section of the report.

2.2.3 Assembling and Organizing Data

Rare plant target data was assembled and organized in a spreadsheet format where targets were tracked according to their ELCODE from NatureServe methodology (NatureServe 2004). The spreadsheet format allowed for editing to occur between Natural Heritage Program botanists who were the primary botany team members. Information tracked on the spreadsheet included Global and State ranks, Scientific and Common names, recommendations for target status on a state/province basis, ecoregional target recommendation, distribution, conservation goal, and other comments. This data format was also easy for the correlation of targets to data sources.

Data sources for rare plant targets came almost exclusively from Natural Heritage Programs that are the repository for such information in the states and province. The Heritage Programs have data management agreements with nearly all federal and state agencies that collect rare plant information and therefore maintain a very complete dataset of rare plant occurrences. Rare plant data is maintained as element occurrence records that track element occurrences (EOs) with EOs being synonomous with species populations. As the datasets are interpreted as populations, conservation goals can be set as numbers of populations required to maintain the target species. We did not use data if the last observed date was before 1982, the level of accuracy was too low, or datasets were considered to be too incomplete for sufficient analysis.

2.2.4 Target Representation

Potential rare plant targets were evaluated as to their G ranks and S ranks and all species that had valid G1, G2, and G3S1 ranks were included as conservation targets. In addition, most S1 ranked species were included as targets so long as the respective heritage programs felt the taxa were taxonomically distinct and were truly S1 ranked. A number of disjunct species were included because of an S1 ranking. Sectional endemics that may be ranked lower such as *Viola flettii* (G3S3), an Olympic Mountains endemic, were also included as targets.

Several iterations of target identification took place utilizing email and telephone communication to refine the list. Justification and notations were captured on target spreadsheets. The issue of conservation goals for the potential targets was also addressed in the subteam with the individual species distribution relative to the PNW Coast Ecoregion being determined as an aid to setting conservation goals. Distribution categories are listed below:

Endemic – largely restricted to the ecoregion (90% of its range)
Limited – restricted to 2 ecoregions
Widespread – found in 3 or more ecoregions
Disjunct – found at least 1 ecoregion away from the center of its distribution

Peripheral – normally not found in the ecoregion and any locations found here are beyond its normal range, not considered a range extension nor within the edge of its normal distribution.

In nearly every case, species whose distribution was determined to be peripheral in the ecoregion were not considered as conservation targets for the ecoregional assessment.

The final assessment of rare plant conservation targets resulted in 99 taxa being included as targets (Table 2.4 and Appendix 2D).

Table 2.4 Groups of Plant targets

Taxa	No. of Targets	No. of Targets with Data	Global (or T) Heritage Rank of Targets					
			1	2	3	4	5	Unranked
Vascular	68	51	8	11	11	18	18	2
Non-vascular	2	2				1	1	
Lichen	7	4	1	1	3	1		1
Moss	6	4	1		2	1	2	
Liverwort	5	1			1	3	1	
Marine algae	11	2	3	2	4	2		
Total	99	64	13	14	21	26	22	3

2.2.5 Data Gaps

Data for rare plants are generally are of higher quality and more complete within the PNW Coast ecoregion due to a large amount of public lands that have been surveyed and the easy access to many sites. This is especially true for vascular plant species but less true for non-vascular species including mosses, lichens and liverworts, and marine algae. Data for marine algae is very incomplete and uneven across the ecoregion with the preponderance of the species included as targets coming from Vancouver Island.

The Natural Heritage Programs of Oregon and Washington have large and robust datasets for rare plant species that contributed to the abundant data for rare plant targets in the United States portion of the ecoregion. The only caveat to this is that data for Olympic National Park endemic species is not complete in the Washington Natural Heritage Program; this was remedied in part by creating skeletal EO records for these species based on general knowledge. The British Columbia Conservation Data Centre (BCCDC), in contrast, had considerably less rare plant data implying that rare plant surveys were relatively incomplete on Vancouver Island.

2.2.6 Setting Goals

Fine filter targets including rare plant and animal species but excluding fish targets had conservation goals based on Comer (2001) (Table 2.5). Most species targets are considered to have “local” spatial pattern and their goals are further stratified depending on the species distribution pattern. Species distributions are defined as following:

Endemic ≥ 90% of the species’ global distribution falls within the ecoregion
Limited = the species’ global distribution falls within 2-3 ecoregions
Disjunct = the species’ distribution in the ecoregion likely reflects significant genetic differentiation from the species’ primary range due to historic isolation; approximately > 2 ecoregions separate this ecoregion from the central parts of its range
Widespread = the species’ global distribution falls within > 3 ecoregions

Peripheral < 10% of global distribution falls within the ecoregion

Further fine tuning of these goals occurred on a target by target basis with each subteam assessing available information and biology of the target in question. Revised goals were based on issues regarding the overall distribution of the target, the innate threats to the target, its current conservation status and whether the default goal (i.e., Comer 2001) was deemed "sufficient" or "over zealous" in terms of the biology of the species. Goals that were modified from the default values were generally lessened based on better knowledge of the target's biology. Conservation goals for fine filter targets are listed in Appendix 2D.

Table 2.5 Default ecoregional conservation goals for species (Comer 2001).

Distribution	Stratification			
	Ecoregion Cluster	Section Cluster	Section	Subsection
Endemic	Case-by-case, defining core and connecting habitat components	10	18	25
Limited		5	9	13
Disjunct		5	9	13
Widespread		3	5	7
Peripheral		1	2	3

2.2.7 Expert Review

The plant target list and conservation goals were reviewed by the subteam who individually contacted experts as needed. Target list review also occurred later in the process when draft portfolios were examined by a broad-base of experts and interested public (Chapter 8).

2.3 Animal Species Fine Filter Targets

The animal target team dealt primarily with terrestrial and nearshore wildlife targets. Marine targets were primarily the responsibility of the Marine team, although shorebirds and nesting seabirds were considered by the terrestrial animal team as well.

2.3.1 Technical Team

Team members were:

Subteam Lead	Ken Popper	TNC Oregon
Team Members	Jeff Lewis	WDFW
	John Fleckenstein	WNHP
	Leah Ramsay	BCCDC
	Gary Kaiser	NCC/CWS (retired)
	Lisa Hallock	WNHP

2.3.2 Selecting Target Species

The draft target list for terrestrial animal targets for the PNW Coast Ecoregion was first formed of species tracked by the Oregon Natural Heritage Information Center (ONHIC), Washington Natural Heritage Program (WNHP) and British Columbia Conservation Data Centre (BCCDC). Our requests for data from these and other sources covered the ecoregion proper, as well as a 10 km buffer. We also considered targets from adjoining ecoregional target lists, most notably the Willamette-Puget-Georgia Basin Ecoregional Assessment (Floberg et al. 2004). Bird species were added from the Partners In Flight (PIF) database, following TNC's methodology (TNC, 2000b), of including species with a PIF score of 23 or above and considering those with a score from 19-22 if the ecoregion is within their center of abundance, or if they are rapidly declining as well as from the Northern Pacific Shorebird Conservation Plan (Drut and Buchanan 2000). We also contacted numerous experts, including presenting the list and methodologies to the Oregon Entomological Society and panels of Oregon and Washington bird experts. The marine-oriented bird and mammal species were included in the final terrestrial target list, because the terrestrial and estuarine assessment units were attributed with nearshore marine and estuarine target data (see Chapter 4 for more details on the Marine analysis). Specific criteria which warranted species to be included as targets for the Ecoregion were:

- **Imperiled species** having a global rank of G1-G3 by the Heritage Programs and NatureServe. These rankings are regularly reviewed and updated by experts. The ranks take into account the number of species occurrences, the quality and condition of the occurrences, the population size, the range of distribution, threats to the species and current protection status to the species.
- **Endangered and threatened species** are federally or state-listed as endangered or threatened (or proposed for listing).
- **Species of special concern** which include:
    - **Declining species** exhibit significant, long-term declines in habitat and or numbers. These species are subject to a high degree of threat.
    - **Endemic species** are restricted to the ecoregion or a geographic area within the ecoregion. These species depend entirely on a single area for survival and are thus often more vulnerable than widely distributed species.
    - **Disjunct species** have populations that are geographically isolated from other populations.
    - **Vulnerable species** are usually abundant, may or may not be declining, but some aspect of their life history makes them especially vulnerable like migratory concentrations or rare/endemic habitat.
    - **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 begins changes in ecosystem structure and often includes a loss of diversity.
    - **Wide-ranging or regional species depend on vast areas.** These species include top-level predators, such as the gray wolf, anadromous fish, and migratory birds. Wide-ranging species can be especially useful in examining linkages among conservation areas in a true conservation network.
    - **Globally significant** examples of species **aggregations** like **migratory stopover sites** or **over-wintering areas** that contain significant numbers of individuals of many species.
    - **Species Guilds** are major groups of species that share common ecological processes and patterns, and/or have similar conservation requirements. It is often more practical in ecoregional plans to target such groups as opposed to each individual species of concern.

- **Partners in Flight scoring:** Include all species with regional PIF score >23 based on PIF's ecoregion. Also include species with PIF score of 19-22 AND Area is center of abundance for PIF ecoregion (AI and %pop are high), OR Species is declining significantly in the ecoregion (PT = 5).

The animal team had numerous meetings, primarily by phone, to discuss target selection. In total, 244 species of terrestrial animals were considered as potential targets, and 172 of these species met the criteria listed above and/or had sufficient expert input and evidence to warrant inclusion (Table 2.6 and Appendix 2E). Freshwater targets were addressed separately (Chapter 3) and marine targets are addressed in Chapter 4. The shorebird and seabird species list was used for both the terrestrial and marine aspects of the assessment.

2.3.3 Assembling and Organizing Data

Gathering thorough datasets proved to be a difficult and time consuming task for this ecoregional assessment. In addition to datasets from ONHIC, WNHP, WDFW, and the BCCDC, we used 17 different datasets from other agencies and individuals. Additional datasets were acquired but not deemed necessary for this assessment or inadequate due to incomplete or imprecise data. We did not use data if the last observed date was before 1982, the level of accuracy was too low, or the type of data was not useful for representing that species (for most species, breeding evidence was required for species data).

Species were listed as targets regardless of whether we had sufficient data to include them in the analysis (Table 2.6). A lack of data was particularly noticeable for invertebrates due to a lack of surveys for these species, and for some relatively common PIF bird species for which there has been little survey effort across the ecoregion.

Seventy-one of the target animal species had sufficient data to be included in the analysis. An additional 17 species had data, but we did not include them in the analysis as the data represented a biased distribution for that species in the ecoregion or any one ecosection (Appendix 2E). Most occurrence data was represented as single points, but in some cases centroids were assigned to polygons or groups of points.

Table 2.6 Groups of Terrestrial Animal targets

Taxa	No. of Targets	No. of targets with data	Global (or T) Heritage Rank of targets with data					
			1	2	3	4	5	Unranked
Amphibians	13	12	0	1	7	4	0	0
Reptiles	1	1	0	0	1	0	0	0
Birds *	62	34	0	1	4	5	20	4
Mammals	24	17	2	3	3	1	4	4
Insects	47	16	6	4	2	0	0	4
Mollusks	25	8	1	3	1	0	0	3
Total	172	88	10	14	21	14	29	15

* includes mineral springs (for band-tailed pigeons), bald eagle wintering areas, shorebird concentrations, and seabirds dealt with by the marine nearshore analysis

2.3.4 Target Representation

Much of the animal data for Oregon and Vancouver Island came from ONHIC and the BCCDC, followed NatureServe methodologies, and was usable in that form. However, many data sets were not usable.

We had to construct occurrence data out of the observational USFS/BLM Interagency Survey and Manage (ISMS) dataset for the NW Forest Plan in Oregon and Washington. This was primarily data for mollusks, red tree voles, and some amphibians. For these species, we used the Natureserve Element Occurrence (EO) Specification default of a 1 km separation distance, and buffered the points to create EOs. We then cross referenced these data with data from the Heritage programs to make sure we were not double counting EOs. Additional datasets from WDFW, ODFW, BLM, USFWS, USFS, USGS, PRBO (Point Reyes Bird Observatory), CWS (Canadian Wildlife Service), and UBC (University of British Columbia), required some sort of data management and cleaning before they could be considered element occurrences and used.

The data from WDFW’s Heritage database were converted from point observations into EOs following NatureServe’s element occurrence and specifications methodology. Occurrence data were available for 16 target animals and shorebird concentrations that occurred in the Washington portion of the Northwest Coast Ecoregion. These data were available from the WDFW’s Heritage database, but were collected by many individuals from many agencies. Data for three of the target species, the bald eagle, northern spotted owl and goshawk, were converted to EOs (nests in these cases) using a computer program designed by WDFW that was similar to NatureServe’s BIOTICS computer program (NatureServe 2004). This program was used to more-efficiently convert observation data to EOs, but its use was limited to a number of trial species. Data for the remaining 13 targets were converted into EOs generally following the NatureServe EO methodology for grouping observation points into EOs using the separation distance for that species, and then labeling grouped points with a unique EO number in a shapefile attribute table. Screening of the occurrence data was done to select specific data out of some larger occurrence data sets. Examples for data selection included using only data for great blue heron rookeries that had ≥20 nests, using only nest and territory occurrences for peregrine falcons, goshawks, bald eagles and spotted owls, and using only occupancy detections for marbled murrelets.

The inferred extent distance was used as the separation distance for bald eagle, northern spotted owl and goshawk data, as the Natureserve separation distance for these species made very large EOs that were too unwieldy for use in the assessment analysis. The inferred extent, in effect, identified sub-EOs, and resulted in many more sub-EOs at a more useful spatial resolution. For marbled murrelets we derived an alternative separation distance using the diameter of the mean stand size for nest stands in Washington; this modification also increased the number of EOs and made the EOs more spatially distinct.

2.3.5 Data Gaps

Our most apparent data gaps were with invertebrates. Without adequate data and information on species status, it was difficult to select targets, and therefore we had to rely primarily on expert input. Adequate data for the site selection analysis were available for only 20 of the 72 targets while only 10 targets had enough EOs to meet our default conservation goals.

We only had EO data for 32 of 64 of our bird targets. This was primarily because 19 species were added due to their PIF scores. These additional targets tended to be more common than other target species, and the EO data associated with them was primarily collected at a spatial resolution (i.e., at the 0.25 township [9 sq. miles] resolution, or large distribution maps) that made it too coarse for use in the site selection analysis.

In general, we had much less EO data for Vancouver Island compared to data available from Oregon and Washington. To ameliorate this problem, we accumulated data sets from outside the

BCCDC (CWS and UBC) to improve the assessment. We ended up using a total of 3,985 animal EOs for Oregon, 2,547 for Washington, and 1,581 on Vancouver Island.

We used a habitat model to represent marbled murrelets on Vancouver Island because occurrence data were not available for that portion of the ecoregion. The model came from the BC Ministry of Sustainable Resource Management and is based on the BC Biogeoclimatic Ecosystem Classification.

2.3.6 Setting Goals

Default conservation goals were set for the ecoregion following guidelines by Comer (2001) and are the same as used for plant targets (see Table 2.4). These goals were primarily a device for assembling an efficient conservation portfolio, and should not be interpreted as guaranteeing the necessary and sufficient conditions for long-term survival of animal targets. Species distributions were defined as following:

Endemic ≥ 90% of the species' global distribution falls within the ecoregion
Limited = the species' global distribution falls within 2-3 ecoregions
Disjunct = the species' distribution in the ecoregion likely reflects significant genetic differentiation from the species' primary range due to historic isolation; approximately > 2 ecoregions separate this ecoregion from the central parts of its range
Widespread = the species' global distribution falls within > 3 ecoregions
Peripheral < 10% of global distribution falls within the ecoregion

Invertebrates and amphibians and some small mammals fit into the local spatial pattern, while most of the birds were categorized as intermediate.

While the default goal was used for most target species, an alternative goal could be used if there was sufficient reason and agreement for the alternative goal among the animal team members. Alternative goals for individual species were used for two main reasons: the data was not in 'population' or Heritage Element Occurrence format (e.g. spotted owls were tracked by nesting pairs, marbled murrelets were tracked in Oregon by occupied habitat locations), or the target was distributed in disjunct populations and we wanted to be sure to capture the full range (e.g. some amphibians). Default goals were increased, but never decreased. When recovery goals for species listed under the Endangered Species Act were available and transferable to our data, we used them (e.g. bald eagles, peregrine falcons). For other listed species, we set goals on a percentage of occurrences, which were nests for spotted owls, occupied areas for marbled murrelets in Oregon and Washington, and nesting areas for snowy plovers. Goals were set both for the entire ecoregion and by section. The sectional goals were set based on the distribution of the species to ensure stratification across its range. We also set percentage goals for marine-oriented targets, particularly seabirds. These goals were set both at 30% of total counts of birds by section and 30% of the total number of colonies by ecoregion, because they did not fit the model of a typical fine filter target. This ensured that although the model would likely select the largest colonies, it would also have to get at least 30% of the total number of colonies.

2.3.7 Expert Review

In addition to the people on the Animal Team, others who provided input on the animal target list or data sets are listed below.

Marcy Summers	TNC Washington
Debbie Pickering	TNC Oregon
Elissa Arnheim	TNC Oregon volunteer
Terry Frederick	TNC Oregon
Pierre Iachetti	NCC
George Wilhere	WDFW
Anita McMillan	WDFW

Roy Lowe	USFWS
Eric Scheuering	ONHIC
Syd Cannings	BCCDC
Ken Stewart	University of North Texas
Richard Baumann	Brigham Young University
Richard Nauman	USFS
Erica McClaren,	BCMWLAP
Mace Vaughn	Xerces Society
Terry Frest	Diexis Consultants
Jim LaBonte	ODA
Steve Valley	OES
Paul Hammond	Oregon
Paul Opler	Colorado
Bob Wisseman	Aquatic Biology Associates
Bob Altman	ABC, Oregon
Mike Green	USFWS
Ray Korpi	OFO

Chapter 3 – Freshwater Conservation Targets

This chapter describes the methods used for identifying important freshwater conservation areas. The freshwater technical team adhered to the same assessment process and principles as the terrestrial and marine teams (Chapters 2 and 4), but the freshwater analysis was not confined to the PNW Coast ecoregion. Instead, freshwater analysis is conducted in the context of an *ecological drainage unit* (EDU) - a type of region more suited to freshwater ecosystems. This presents a challenge for the integration of freshwater and terrestrial assessments. Methods applied to integrate freshwater, terrestrial and marine assessments are described in Chapter 8. Six EDUs intersect the ecoregion; all extend beyond the ecoregion boundary (Map 3.1). Thus, the freshwater assessment and integrated portfolio described here includes areas within the six EDUs. Three of the EDUs, the Oregon Coastal, Olympic/Chehalis, and Vancouver Island EDUs, fall almost entirely within the ecoregion. The remaining three have only small portions within the ecoregion.

Freshwater assessment methods varied among the six EDUs. Methodological differences among EDUs are detailed throughout this chapter. In particular, freshwater assessments of EDUs that fall within Washington have been conducted as part of separate freshwater assessments. In contrast, some EDUs in Oregon and British Columbia have not yet been assessed in the context of an EDU. The analysis of these systems should be considered as the foundation for assessing freshwater biodiversity that will benefit from further analysis and review.

3.1 Technical Team

The technical team that identified the freshwater ecological systems and species in the EDUs intersecting the PNW Coast ecoregion was composed of experts from The Nature Conservancy, the Nature Conservancy of Canada, and the Washington Department of Fish and Wildlife. The team consisted of the following people:

Subteam Lead	Peter Skidmore	TNC Washington
	Mark Bryer	TNC Maryland
	Kristy Ciruna	NCC
	Tracy Horsman	TNC Washington
	Pierre Iachetti	NCC
	Kirk Krueger	WDFW
	Cathy Macdonald	TNC Oregon
	Michael Schindel	TNC Oregon
	Dick Vander Schaaf	TNC Oregon

3.2 Selecting Conservation Targets and Collecting Target Data

Our analysis of freshwater biodiversity in the PNW Coast ecoregion included the identification of targets at both the species (fine filter) and ecological system (coarse filter) levels. Criteria applied to the selection of targets at both levels are based largely on Groves et al. (2000 and 2002) and Higgins et al. (1998).

3.2.1 Defining Ecological Drainage Units

As a basis for the freshwater assessment we used ecological drainage units (EDUs). EDUs are groups of watersheds that share a common zoogeographic history, physiography, and climatic characteristics, and are therefore likely to have a distinct set of freshwater communities and habitats. Several researchers have demonstrated that drainage basin and physiography are important determinants of freshwater biodiversity distribution patterns (Jackson and Harvey 1989; Pflieger 1989; Maxwell et al. 1995; Angermeier and Winston 1999; Angermeier et al. 2000; Oswood et al. 2000; Rabeni and Doisy 2000). Additionally, drainage and physiography have been incorporated into region-specific freshwater classification schemes in Missouri (Pflieger 1989) and California (Moyle and Ellison 1991).

EDUs are spatial units that are more appropriate than ecoregions for analysis of freshwater biodiversity. Their boundaries follow major watershed boundaries and take into account biogeographic patterns of freshwater fauna. They are subdivisions of freshwater zoogeographic units (*sensu* Maxwell et al. 1995) and spatially stratify ecological variation across larger zoogeographic regions. In the PNW region, they are roughly equivalent in scale to terrestrial ecoregions, such as the PNW Coast Ecoregion. However, ecological drainage unit boundaries are geographically independent of ecoregion boundaries. Typically, several will intersect a single ecoregion. The EDUs that intersect the PNW Coast Ecoregion include a variety of freshwater habitat types influenced by geology, channel morphology, valley physiography, and water sources.

EDUs in the PNW Coast Ecoregion were defined based on two main sources of information:

1. **Native species zoogeography** determined at a regional scale by Hocutt and Wiley (1986), World Wildlife Fund's freshwater ecoregions (Abell et al. 2000), and the U.S. Forest Service (USFS) (Maxwell et al. 1995). Additional sources consulted include the U.S. National Marine Fisheries Service (Evolutionary Significant Unit (ESU) boundaries for salmonids), Haas (1998), and McPhail and Carveth (1994).

2. **Ecoregional/ecozone attribute***s* as defined by the U.S. Forest Service (McNab and Avers 1994, Pater et al. 1998) and ecozones from Environment Canada (http://www.ec.gc.ca/soerree/English/Framework/NarDesc/).

EDUs consist of aggregated USGS 8-digit Hydrologic Unit Code (HUC) areas (Seaber et al. 1987) or British Columbia Watershed Atlas units based on the following criteria:

- Similarity in patterns of physiography and climate, which were visually interpreted from USFS and Environment Canada resources

- Similarity in fine scale patterns of zoogeography, interpreted from the following sources:

    1) Descriptions of fish biogeography found in Hocutt and Wiley (1986) and Haas (1998)

    2) Results of a multivariate (cluster) analysis performed using historical presence/absence data of fish at the scale of the 8-digit HUC (data from Larry Master, NatureServe)

- Similarity in patterns of watershed connectivity (i.e., the networks formed by freshwater systems, including lakes, wetlands, glaciers, streams, and coastal waters)

The team defined six EDUs intersecting the PNW Coast ecoregion (Map 3.1). The EDUS are described in Table 3.1.

Table 3.1. EDUs intersecting the PNW Coast Ecoregion

EDU	Physiography	Climate	Zoogeography	Stream Types
Oregon Coastal	mid-elevation, predominantly unglaciated mountains (Coast Range) progressing to coastal lowlands	high precipitation (up to 250 in/yr)	Mid Pacific Coastal	small to medium, deeply incised, steep dendritic systems connected to coast; small lakes occasional; predominant geology sedimentary and basalt
Rogue/ Umpqua/ Lower Klamath Rivers	extensive monadnock ranges (Klamath mountains) of highly variable geology, progressing to coastal lowlands	high precipitation (~40-120 in/yr)	Mid Pacific Coastal	many rapid flowing streams in bedrock controlled channels draining to moderately sized rivers; numerous glacial lakes above 5000’
Vancouver Island	numerous, steep-sided, transverse valleys, inlets, and sounds dissect the north and western portion; east and south: generally low relief mixed with areas of sharp crests and narrow valleys	in the north and west, mild and wet (1500 to 3800 mm/yr); in the east and south it is also mild but drier (800 – 2500 mm/yr)	North Pacific Coastal	short, steep coastal systems) with some blackwater systems in the northern lowlands; lakes have high flushing rates; depauperate fauna
Puget Sound	low elevation morainal valley surrounded by mid- to high-elevation glaciated mountains; complex of oceanic islands	high variability between valley and mountains (20–150 in/yr)	North Pacific Coastal	small to medium river systems (e.g., Skagit, Snohomish, Nooksack) with predominantly volcanics at high elevations and sedimentary rock at lower elevations, estuaries and wetlands abundant
Olympic-Chehalis	mid-elevation predominantly unglaciated mountains	high precipitation (up to 250 in/yr)	North Pacific Coastal	small to medium, deeply incised, steep river systems connected to coast; predominant geology greenschist and greywacke
Lower Columbia	valley through portions of Cascade and Coastal Ranges	high variability between valley and mountains (20–150 in/yr)	Columbia Unglaciated	mainstem Columbia river from Cascades to ocean, and associated Cascadian and coastal tributaries (Cowlitz, Klickitat, Sandy)

3.2.2 Selecting Conservation Targets

We selected conservation targets at multiple spatial scales and levels of biological organization. Targets are typically determined for each EDU intersecting the ecoregion. Targets were selected by EDU in the context of a separate freshwater assessment for the Olympic/Chehalis, Puget Sound and Lower Columbia EDUs. Targets were selected within the Vancouver Island and Oregon Coastal EDUs without the benefit of separate EDU assessments but using similar guidelines as assessments conducted in Washington. In the Rogue/Umpqua EDU only freshwater targets within the area common to the EDU and ecoregion were evaluated. Conservation targets included both coarse filter ecological systems and fine filter species targets. Additional targets included expert-nominated physical communities such as small wetlands and lakes that were not otherwise captured by the coarse filter and fine filter targets.

3.2.3 Coarse Filter Targets − Freshwater Systems

The overall basis for our approach stems from an expert workshop that TNC held in 1996 (Lammert et al. 1997). We defined freshwater ecological systems using the hierarchical classification framework described in Higgins et al. (1998, Higgins et al. 2005). The EDU level approach used in the classification framework is particularly important for freshwater biodiversity, since region-wide data exist for few non-game species and rarely, if ever, for aquatic communities. The classification system was used to identify coarse filter targets – freshwater ecological systems – for all of the area within five of the six EDUs intersecting PNW Coast Ecoregion. In the sixth EDU, Vancouver Island, the coarse filter targets were only classified to the macrohabitat level. Freshwater ecological systems are defined as follows:

1. Watersheds defined by statistically distinct assemblages of macrohabitat types (defined below);

2. Types of watersheds (or stream networks) assumed to possess distinct ecological characteristics because of a their distinct assemblage of macrohabitat types; and

3. A cohesive and distinguishable, hydrologically defined spatial unit.

The multi-scale, landscape-based classification framework for freshwater ecological systems is based on key principles of freshwater ecology supported by empirical studies. For example, local patterns of freshwater physical habitats and their biological components are the products of regional spatial and temporal processes (Tonn 1990; Angermeier and Schlosser 1995; Angermeier and Winston 1999; Mathews 1998; Frissell et al. 1986). Continental and regional freshwater zoogeographic patterns result from drainage connections changing in response to climatic and geologic events (e.g., Hocutt and Wiley 1986). Regional patterns of climate, drainage, and physiography determine freshwater ecological system characteristics (morphology, hydrology, temperature and nutrient regimes) that, in turn, influence biotic patterns (Hawkes et al. 1986; Maret et al. 1997; Poff and Ward 1989; Poff and Allan 1995; Pflieger 1989; Moyle and Ellison 1991). Within regions, there are finer-scale patterns of stream and lake morphology, size, gradient, and local zoogeographic sources that result in distinct freshwater species assemblages and population dynamics (e.g., Maxwell et al. 1995; Seelbach et al. 1997; Frissell et al. 1986; Rosgen 1994; Angermeier and Schlosser 1995; Angermeier and Winston 1999; Osborne and Wiley 1992. See Mathews 1998 for an extensive review).

We applied the classification framework in a three-step process for each EDU to identify coarse filter targets. In the first step, we classified and mapped the diversity of stream reach characteristics, which resulted in hundreds of macrohabitat types. In the second step, we characterized each watershed according to its assemblage of macrohabitat types. In the third step, we lumped together watersheds with similar assemblages of macrohabitat types to form ecological system types. Methods for determining ecological system types from assemblages of macrohabitats varied among EDUs, as did the variables applied to the macrohabitat classification. The resulting ecological system types became the coarse filter conservation targets. Due to time and resource limitations, macrohabitats were used as freshwater coarse filter targets for Vancouver Island.

3.2.3.1 Macrohabitats

Macrohabitats are stream reaches types defined by abiotic characteristics such as parent geology, network position, channel attributes, topography, and water source. Each macrohabitat type represents a different physical setting that correlates with patterns in freshwater biodiversity (Vannote et al. 1980). For example, a macrohabitat type could be a headwater stream (<100 km^2), dominated by volcanic geology, steep gradient (0.10 – 0.20 feet per mile), high elevation (> 1000 m), unconnected upstream, and connected to a small river downstream. Macrohabitats are easily mapped in GIS.

We reviewed relevant literature (e.g., Whittier et al. 1988, Altman et al. 1997, Carpenter and Waite 2000, Waite and Carpenter 2000) and consulted with regional experts to determine which physical attributes were most important for structuring freshwater communities. We identified the important attributes for each EDU (Appendix 3A), and incorporated them into macrohabitat models. Differences among EDUs in macrohabitat classification variables and classes within variables reflect differing biogeographic traits, climate, and availability of relevant data.

Using GIS, we applied the classification framework in order to partition and map environmental variables that influence the distribution of freshwater biodiversity at the scale of stream reaches.

The following classification variables were common among most of the EDUs:

- *Size of contributing basin*. Measured as the contributing drainage area to each segment of stream, as mapped in the GIS database. Watershed area is applied as a correlate for channel morphology, hydrologic flow regime (assuming constant climatic gradients throughout an EDU), and dominant discharge. The classes chosen reflect broad changes in stream habitat and flow rates.

- *Geology*. Dominant geology measured in the contributing watershed area, for each segment in the GIS database. This variable is intended to represent the variability in water chemistry, stream substrate composition, and stream morphology. The classes chosen were based on an integration of geological types from numerous data sources, and were selected using guidelines from Quigley et al. (1997) to reflect major differences in chemistry, erodability, and structure. In EDUs predominantly within the United States, the dominant geology of the entire upstream contributing basin was attributed to the stream reach. In the Vancouver Island EDU, the dominant geologic type underlying the stream reach was used.

- *Stream gradient*. Slope of a stream segment, measured for each segment in GIS. This variable influences stream morphology, stream power (energy), and habitat types. Classes were derived from a combination of sources including Rosgen (1994), Ian Waite at USGS (personal communication), and Tony Cheong at the British Columbia Ministry of Sustainable Resource Management (personal communication).

- *Elevation*. Average elevation of segment. This variable corresponds to some species' range limits, flow regime (snowmelt amount and timing), and stream temperature. Classes are based roughly on level 4 ecoregions from Pater et al. (1998).

- *Connectivity*. Type of macrohabitat immediately upstream and downstream. Downstream connectivity captures local zoogeographic variation by considering differences in the species pool in downstream habitats; upstream connectivity captures effects from upstream segments on both hydrologic regime and chemistry.

- *Biogeoclimatic zone*. This was used on Vancouver Island as a surrogate for climate and elevation.

- *Stream Order*. This was used in place of contributing area on Vancouver Island because freshwater systems were not developed in that EDU.

Each macrohabitat type was defined as a unique combination of the variables shown in Appendix 3A. Any single variable or combination of variables can be mapped to display patterns in the occurrences of each macrohabitat type.

We have not created an equivalent macrohabitat classification for lakes for these EDUs assessments. We did not address lakes directly. We have assumed that the variety of freshwater communities that lakes encompass would be captured in the watersheds that constitute freshwater ecological systems.

3.2.3.2 Freshwater Ecological Systems

Macrohabitats create a detailed and often complex picture of physical diversity. Freshwater ecological systems, on the other hand, provide a means to generalize about patterns in macrohabitats and capture the ecological processes that link groups of small watersheds. Freshwater ecological systems provide a practical tool that combines macrohabitats on a scale that can be used for the ecoregional assessment process.

Methods for defining freshwater systems varied among EDUs. However, in all EDUs a stratification of systems based on size of contributing watershed area was applied. Four scales of watersheds – equivalent to the macrohabitat size classes of < 100 km^2, 100-999 km^2 , 1000-10,000 km^2, and > 10,000 km^2 – were used to assess macrohabitat diversity and classify ecological systems (Classes 1-4, respectively). Small tributary and headwater watersheds, <100 km^2, are distributed fairly densely across the landscape. These Class 1 systems typically contribute their flow to larger rivers, though there are many Class 1 coastal watersheds whose streams flow directly into saltwater or estuaries.

Where basins exceed 100 km^2, they become Class 2 systems. Class 2 systems typically consist of aggregated Class 1 tributary streams and a mainstem river corridor. Similarly, where basins exceed 1,000 km^2, they become Class 3 systems. A Class 3 system typically consists of one or more Class 2 watersheds, and numerous Class 1 tributary watershed systems. Thus, in larger river systems, varying size class systems are nested and aggregated. In smaller coastal systems, Class 1 or Class 2 systems may terminate at the coast.

Freshwater system types are determined by the macrohabitat assemblage of the entire contributing watershed area. Macrohabitat lengths were measured relative to watershed area to discount differences in watershed size within class. We classified each set of watersheds within a given size class independently of other size class sets. Methods for analyzing the relationships among macrohabitat types within watershed boundaries varied among EDUs. The classification approach used for each EDU or group of EDUs is provided below:

1. **Rogue/Umpqua EDU**. The Rogue-Umpqua outside the PNW Coast ecoregion had an existing macrohabitat classification prepared for the Klamath Mountains Ecoregional assessment. That classification extended only to the border between the Klamath and the PNW Coast ecoregions. Since the unclassified area within the PNW Coast ecoregion was relatively small the core team decided to delineate a macrohabitat classification that was consistent with the classification used in Klamath Mountains Assessment and then define freshwater ecological systems from the macrohabitats. The class breaks from the previous Rogue-Umpqua work were applied to the stream reaches in the Rogue-Umpqua EDU.

2. **Oregon Coastal EDU**. The disjunct portion of the Coast EDU in the southern end of the PNW Coast (see Map 3.1) used class breaks from the previously classified northern portion of the Coast EDU. Polygons were created to represent the various class sizes. The macrohabitats were then aggregated to watershed polygons, and those were then cross-walked to the systems classification from the northern portion of the EDU. Nearly all the polygons classified in this way fit neatly into existing types defined for the northern portion of the EDU. The primary exception was where serpentine substrate-dominated system types were added to the systems classification. The northern portions of the Coast Range EDU had been classified only for Class 1 size polygons. As the contributing area of a stream system crossed the threshold from one size class to the next, the polygon at that tipping point was listed as the new size class. All downstream polygons received that same class rating until the next size class tipping point was achieved. Nested polygons were created for the larger class sizes.

3. **Olympic/Chehalis EDU, Lower Columbia EDU and Puget Sound EDU.** Ecological system types were defined using multivariate analysis to group watersheds that share similar macrohabitat patterns. Using the PC-ORD multivariate analysis software (McCune and Mefford 1995), we determined the most consistent set of parameters for analysis was an agglomerative clustering algorithm, Euclidean distance measure, and Ward’s group linkage method. The final clusters for each EDU were determined with manual editing and review, comparison with other ecoregional units (e.g., Pater et al. 1997), and expert review with individuals from WDFW, WDNR, U.S. Army Corps of Engineers, USFWS, USFS, British Columbia MSRM, University of British Columbia, and Canadian Department of Fisheries and Oceans.

4. **Vancouver Island EDU.** The PNW Coast Ecoregion includes the majority of Vancouver Island. A macrohabitat classification for the island had previously been

constructed for the Willamette Valley-Puget Sound-Georgia Basin Ecoregional Assessment (Floberg et al. 2004). Limited time and resources prohibited a systems classification for this EDU. Based on our expert opinion, we replaced biogeoclimatic zones with the elevation breaks of the previous classification. There are 4 biogeoclimatic zones on Vancouver Island: Coastal Douglas Fir, Coastal Western Hemlock, Mountain Hemlock, and Alpine Tundra. The midpoint of each reach was used to determine its biogeoclimatic zone. An additional difference was the use of stream order in the classification that was not applied in other EDUs. The final classified macrohabitats were then attributed to the freshwater planning units used on Vancouver Island.

3.2.4 Fine Filter Targets

Fine filter target lists are typically developed for each EDU intersecting the ecoregion. As discussed above, EDUs are defined by hydrologic boundaries and are therefore more appropriate assessment units than ecoregions for evaluation of freshwater species.

In this assessment, the geographic context of fine filter target selection varied among EDUs. In those EDUs predominantly contained within the ecoregion, fine filter target lists were developed by considering all freshwater species within the EDU. For the Rogue-Umpqua EDU, that extends for a considerable area beyond the ecoregion, fine filter targets were only determined for that portion of the EDU that was within the ecoregion.

To identify species that are naturally rare, under severe threat, endemic to the EDU, and/or declining in abundance, the freshwater technical team followed a similar approach to that of the animal targets subteam. The fine filter freshwater data was composed primarily of fish targets, the vast majority of which were salmon (Appendix 3B). Data used to compile the list were obtained from the BCCDC, WNHP, ONHIC and state, provincial (e.g., Haas 1998), and federal sources (e.g., National Marine Fisheries Service). Spatial data used to map occurrences of each target were collected from the same sources, but were not available for all targets. A significant component of the GIS data used in this plan were developed specifically for this assessment, with the exception of some of the stream maps showing salmon spawning and rearing habitats. Original data sources represented occurrences of species targets either as points or lines in a GIS layer. For the purposes of data analysis, we attributed these points and lines to the HUC 6 assessment unit coverage, along with the freshwater Class 1 systems or macrohabitats.

Development of species target lists for salmon varied slightly from those for other species. In this assessment, each major seasonal run of each salmon evolutionary significant unit (ESU) (Federal Register 1991) or an equivalent run in British Columbia was considered a separate target. While British Columbia and the rest of Canada do not use the ESU terminology, we chose to identify all target salmon runs as ESUs for consistency of target descriptions in the assessment. Sixty ESU/species combinations exist in the PNW Coast Ecoregion.

The base occurrence data layers for salmon came from state and provincial game agencies. Target occurrence data for salmon was further developed to be consistent with data standards for other fine filter species. Data sources and data development methods employed include:

- BC Fisheries, BC Ministry of Sustainable Resource Management provided salmonid distributions, digitized stream reaches for the central and southern portions of Vancouver Island, and point locations in the north. Intersecting the points with digitized stream reaches allowed us to identify occupied stream habitats in the north, matching the data from the rest of the island. Comments in the data attribute tables indicated the life history stages utilizing each reach.

- Washington Department of Fish and Wildlife is currently working to compile anadromous salmonid distribution information (WALRIS) from the various fish mapping initiatives in Washington (LFA, SSHIAP, CREP, StreamNet, Bull Trout). They provided a draft of this information for our use in the ecoregional assessment. This data links various species and life history stages to a 1:24000 stream coverage.

- Oregon Natural Heritage Information Center has been linking fish information from the Oregon Department of Fish and Wildlife to a 1:24000 stream coverage. This data was provided to us for our target salmon species. Both the Washington and Oregon data contained fields indicating which life history stages were represented by every stream reach for every species. Spawning and rearing habitats were selected from these datasets for use in our planning. Both of these layers are the best available distribution/life history information for salmon for their respective states.

The datasets were merged, and the output represented all documented spawning and rearing habitats within the ecoregion for the target salmonid species. Federal Register Notices and NOAA Fisheries on-line images were used to define the ESU boundaries for each species in the U.S. In British Columbia local experts were consulted to devise Vancouver Island Salmon Analysis Units (SAUs). The geography of Vancouver Island naturally splits the island into 3 distinct regions, the northern lowlands, nearly completely separated from the rest of the island by a fjord, and the east and west halves of the remainder split by the mountainous spine of the island. These three regions were used as the SAUs for all salmonids on Vancouver Island. In the U.S., ESU boundaries often differed from species to species. Polygonal coverages were produced to represent the ESUs for each species. These ESU boundaries were then intersected with salmon stream arcs to assign each species to an ESU. The lengths of the attributed reaches were then summed in the freshwater assessment units they corresponded to.

Our freshwater fine-filter targets covered nearly every major stream reach in the ecoregion. Since Class 1 polygons are not wall-to-wall, and since we wished one set of freshwater polygons to represent both coarse and fine filter targets, Class 1 Systems and freshwater fine filter data were all attributed to HUC6 polygons within the PNW Coast. The Class 1 Systems generally nested fairly well within these polygons. In the few cases where that fit was not very good, the HUC6 containing the centroid of the Class 1 System was attributed with that System. As with all polygonal targets attributed to assessment polygons, the original data must always be compared to any outputs to see how well the targets are represented in the outcome. The Class 2 and Class 3 Systems retained their original polygonal format, and were related to the terrestrial and freshwater assessment units underlying them by boundary relations. This allowed those Class 2 and 3 polygons to exert some influence over the small-scale terrestrial and freshwater assessment units selected in the portfolio, and visa-versa.

3.2.5 Expert Review

We sought review from experts across the ecoregion at all steps in the freshwater assessment process, from developing a classification system to identifying targets through portfolio assembly. Varying approaches to EDU assessment detailed previously resulted in equally varied context for expert review. Independent freshwater assessments have been initiated for the Olympic/Chehalis, Lower Columbia and Puget Sound EDUs. Preliminary freshwater-specific portfolios were developed for these EDUs as well as the Oregon Coastal EDU. Freshwater-specific portfolios have not yet been developed for the remaining EDUs in the ecoregion.

Freshwater portfolios provided an opportunity for experts to review freshwater conservation priorities separately from an integrated conservation portfolio. In many cases, regional biologists highlighted streams they considered of great general value to freshwater conservation because they were in good condition, were important for salmonid conservation, or represented unique freshwater communities. This attribute information was recorded for each site. Experts also identified sites that were included in the portfolio that they felt did not accurately represent the target, or were in poor condition.

Experts consulted for Olympic/Chehalis, Puget, and Lower Columbia EDUs included:

Curt Kraemer	WDFW
Chad Jackson	WDFW
Thom Johnson	WDFW
Chuck Baranski	WDFW
George Pess	NOAA Fisheries
Marty Ereth	Skokomish Tribe
Wendy Walsh	Pacific NW Mussels Worksgroup
Sam Brenkman	Olympic National Park
Pete Bisson	USFS Research Station
John McMillan	Wild Salmon Center
Jerry Gorsline	Washington Environmental Council

Review of the Oregon Coast EDU was conducted in conjunction with the broader peer reviews that are described in Chapter 8. Review of the Rogue-Umpqua EDU was conducted during the Klamath Mountains Ecoregional Assessment (Vander Schaaf et al 2003).

3.3 Data Gaps

Assessment of freshwater biodiversity is significantly limited by a lack of data on species presence and status. Typically, only game fishes are well studied and documented, making analysis of freshwater communities difficult. In fact, no documented occurrence or habitat data were available for many of the species targets identified. The classification of freshwater systems presented here has been in large part developed and endorsed by freshwater experts. It was intended to represent environmental conditions known to influence species distribution and freshwater community composition. It is not designed or intended to represent the actual distribution of the species or communities themselves. As such, the assessment would benefit substantially from further assessment and evaluation of the status and distribution of freshwater species, as well as development of freshwater community data.

The absence of comprehensive and uniform freshwater species occurrence data does not mean that no data are available. Many agencies and organizations, including state, federal and non-government and research, have generated substantial data on freshwater species. However these data are typically localized or limited to the geographic jurisdiction in terms of coverage and are highly variable with regards to content and quality. As such, these data are of limited value for regional assessments, as they are insufficient to develop regional perspectives and comparative analyses across an EDU.

Lakes were not explicitly targeted in this analysis. In future efforts a more deliberate approach is required in order to adequately represent lakes within the freshwater portfolio. While there are a number of lakes data sets available, none are consistent and comprehensive across EDUs; even when combined the available lakes data are not sufficient to compare lakes relative to factors which may influence or determine species and community occurrences.

3.4 Setting Goals

3.4.1 Goals for Freshwater Coarse Filter Targets

Portfolio goals for coarse filter targets, or freshwater systems, varied among EDUs. Goals for the EDUs in Oregon and Washington were set at 30% of occurrences of all system types (i.e, 30% of class 1 wateseds). In these EDUs, preliminary freshwater portfolios captured 30% of occurrences without regard to ecoregional boundaries. To meet goals for the independent freshwater assessments, and in an effort to maximize consistency between these and terrestrial ecoregional assessments, the PNW Coast assessment used the number of occurrences within each ecoregion as the basis for setting goals for these systems within the ecoregion. This differs somewhat from the “percent cover” goals established for terrestrial ecological systems (see

Chapter 2). The rationale of choosing occurrences over absolute percent cover is that it will enhance the overall distribution of selected freshwater systems in the assessment and, more importantly, it ensures that a functioning occurrence or watershed is selected in its entirety.

For Vancouver Island, goals were set for each macrohabitat type by rarity, ranging from 10% - 50% with the goal increasing with rarity (Table 3.2).

Table 3.2 Goals for Macrohabitats on Vancouver Island

Total Length within Ecoregion	Goal (per distribution of ecological group)
> 1,000 km (> 620 miles)	5%
101 - 1,000 km (62 – 620 miles)	10%
11 - 100 km (6.8 – 62 miles	20%
< 11 km (< 6.8 miles)	50%

3.4.2 Goals for Freshwater Species Targets

Our strategy for addressing salmon species conservation is based upon recommendations for the recovery of listed salmonids produced by the National Marine Fisheries Service (NMFS) Technical Recovery Teams (TRTs). Generally, the range of each species is broken into evolutionarily significant units (ESUs), which are then subdivided into populations. The goal for recovery is to protect and enhance the runs for up to 50% of the populations within each federally listed ESU. Since populations have not been defined for most salmonids, our goal was focused on protecting up to 50% of the spawning and rearing habitat for each listed ESU. Goals were set at 30% of stream km for non-listed species, and 50% for listed species. These goal levels were also applied to non-salmonid fish targets.

Chapter 4 – Nearshore Marine Conservation Targets

This chapter describes the assessment of ecological systems and species for the marine nearshore component of the Pacific Northwest Coast ecoregion. The purpose of the assessment was to develop a portfolio of priority conservation areas that, if conserved, will protect a representative subset of the nearshore marine biodiversity. The Northwest Coast marine assessment covers all shoreline and estuarine areas. We define the shoreline and estuarine environments as the "nearshore zone," the area extending from the supratidal zone above the ordinary or mean high water line (i.e., the top of a bluff or the extent of a high salt marsh or dune grass community) to roughly the 10 meter depth below mean lower low water. The assessment does, however, address a few shoal areas away from the coast for which data were available.

4.1 Marine Biodiversity Assessment

An integral part of the Pacific Northwest Coast ecoregional assessment is the marine environment. We have added a marine region boundary to the terrestrial ecoregion that generally follows those identified by the NOAA NERRS program (Map 1.3). These are biogeographically-based, determined primarily by the distribution of nearshore species and ecosystems (http://nerrs.noaa.gov/Background_Bioregions.html). TNC made some modifications to the NERRS system largely based on expert advice. In particular, we modified the boundaries to better line up with terrestrial ecoregions for a more integrated land-sea analysis in the coastal zone. The boundaries that have been adjusted to line up with terrestrial ecoregions are those between (i) the Northwest Coast and the Central & Northern California regions and (ii) between the Northwest Coast and Puget Sound in the Strait of Juan de Fuca.

Through the marine assessment we constructed a conservation portfolio that represents the full distribution and diversity of native species, natural communities and ecological systems. The marine conservation portfolio is not intended to become marine protected area network or to supplant fishery management plans. The areas identified through this assessment exist in complex ecological and social environments and will require an equally complex suite of strategies to be conserved.

4.2 Technical Teams

In conducting our nearshore marine analysis and evaluating the site selection process we have relied on three marine technical teams assembled in Oregon, Washington, and British Columbia. These teams assisted in the design of the nearshore methodology, providing scientific and technical advice, and participating in the expert review process. These teams represent a variety of state and federal agencies, universities, nonprofit organizations, and consulting firms.

The marine team lead is Zach Ferdana, Marine Conservation Planner for the Global Marine Initiative, TNC.

Agencies and organizations that are represented in Oregon include:

Michele Dailey	Ecotrust
Cristen Don	ODFW Marine Resources Program
Tanya Haddad	DLCD Oregon Ocean-Coastal Management Program
Gayle Hansen	OSU Hatfield Marine Science Center
Steve Rumrill, PhD	ODSL South Slough National Estuarine Research Reserve
Maggie Sommer	ODFW Marine Resources Program

In Washington:

Helen Berry	WDNR Aquatic Resources Division
Philip Bloch	WDNR Aquatic Resources Division
Mary Lou Mills	WDFW Marine Resources Division

In British Columbia:

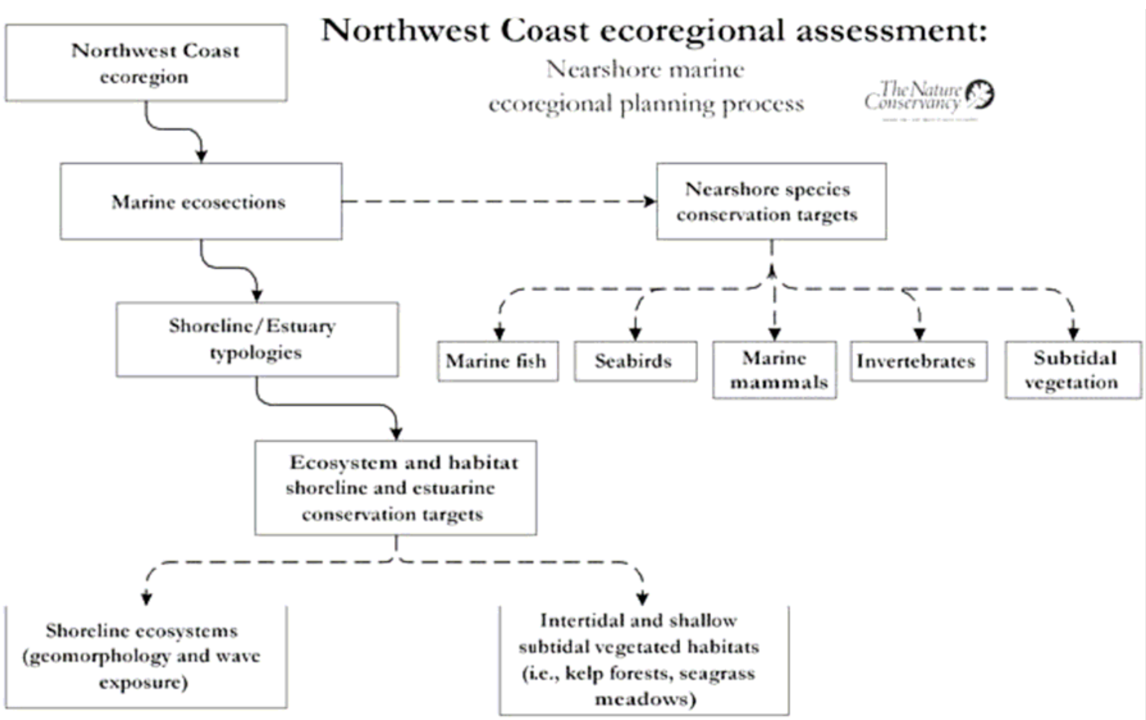
John R. Harper	Archipelago Marine Research Ltd.
Carol Ogborne	MSRM, British Columbia
Rob Paynter	MSRM, British Columbia
Mark Zacharias, PhD	MSRM, British Columbia

4.3 Selecting and Representing Nearshore Marine Targets

The nearshore marine technical teams and other experts identified 197 nearshore conservation targets comprising 108 coarse filter targets (58 shoreline ecosystems, 26 supratidal/intertidal/shallow subtidal vegetation habitat types, and 24 area-based estuarine targets comprising 18 substrate types and six vegetation types) and 89 fine filter targets (25 marine fish, 39 seabirds and shorebirds, 12 marine mammals, and 13 marine invertebrates). These targets were selected to represent nearshore marine biodiversity within the ecoregion, highlight threatened or declining species and communities (i.e., seabird colonies), or indicate the health of the larger ecosystem.

To recognize the unique ecological characteristics of outer coast, estuaries, and embayment environments, we stratified targets by coastal ecosections and further divided the shoreline ecosystem and intertidal targets into typological units within and outside of estuaries (Figure 4.3).

FIGURE 4.3 THE PROCESS UNDERGONE TO CATEGORIZE MARINE CONSERVATION TARGETS



4.3.1 Coarse Filter Targets

For spatial representation of coarse filter targets, we have focused on spatial data development related to: (1) shoreline characteristics, (2) coastal zone habitats, and (3) estuaries.

4.3.1.1 Shoreline Characteristics

Shoreline ecosystem types were derived from a single summary classification developed in British Columbia, the ShoreZone mapping system. The Province of British Columbia developed its physical and biological ShoreZone mapping system based on shore types after Howes et al. (1994) and Searing and Frith (1995). Shore types are biophysical types that describe the substrate, exposure, and vegetation across the tidal elevation, as well as the anthropogenic features. The British Columbia and Washington ShoreZone data sets are built on shore types that aggregate precise community or habitat types according to their landform, substrate, and slope (Berry et al. 2001). There are 34 coastal classes and 17 representative types within the classification system. See Berry et al. (2001) for the rationale and definitions of the 34 coastal classes. We also considered the Dethier classification system (Dethier 1990) of intertidal communities in constructing our shoreline ecosystem and habitat conservation target list. For Oregon we used NOAA's Environmental Sensitivity Index (ESI) classification based on combinations of substrate types in different sections of the intertidal zone (NOAA 1996). ESI combines substrate/morphology and wave energy, ranking the 23 coastal types according to oil spill sensitivity. However, there is not explicit mapping of biota within ESI.

We combined a derived version of British Columbia's representative shore types and ESI combinations into 15 shoreline ecosystems based on landform and slope. We then added an observed exposure, or fetch, type that was either derived directly from the data (ShoreZone) or calculated with a wave energy algorithm. For the Oregon coast we chose to calculate fetch using a model developed by LTL Limited (Victoria, British Columbia, Canada). We did not use the wave energy attributes from ESI because not all shorelines were classified and many individual shoreline units contained multiple classes. These multiple wave energy classes (i.e., wave-cut platforms and exposed pier structures/ sheltered tidal flats) attempted to depict the landward to seaward shoreline characterization, but yielded too many combinations (41 unique classes as opposed to 17 representative types) and were therefore difficult to summarize. In addition, some classes did not make logical sense (i.e., wave-cut platforms and exposed pier structures/sheltered rocky shores and coastal structures) where the exposure type conflicted between landward and seaward types. We therefore stripped the exposure classes out of ESI and combined the substrate types with the representative shore types based primarily on landform. Next we added the observed and calculated exposure classes onto the seamless ecoregion-wide landform classes. Both the observed and maximum and effective fetch calculations were classified into four categories using Morris (2001). These included shorelines that were very exposed (VE), exposed (E), protected (P), and very protected (VP). Combining shore and exposure types yielded 58 shoreline ecosystem targets (Appendix 4A). All of these targets were represented spatially in the GIS geodatabase.

In order to select these shoreline ecosystem targets across the ecoregion we intersected them with the nine coastal ecosections. That yielded 210 stratified targets (i.e., exposed sand flat in the Strait of Juan de Fuca). A further division was made in order to separate shorelines within and outside of estuaries. These typological units (outer coast shorelines, estuary shorelines) increased the number of unique shorelines to 304 (i.e., exposed sand flat in the outer coast of Strait of Juan de Fuca). Although we identified man-made and undefined shore types these types were not considered conservation targets.

4.3.1.2 Coastal Zone Habitats

There were 26 individual supratidal, intertidal, and shallow subtidal vegetation types initially considered as conservation targets. Of these, 11 of them were represented in the seven coastal zone habitats and these habitats became conservation targets used in the assessment (Appendix 4B). Six vegetated, coastal zone habitats were identified between the supratidal and the shallow subtidal: dune grasses (*Leymus mollis* and others), saltmarshes (*Salicornia, triglochin, deschampsia*, and sedges), eelgrass (*Zostera*), surfgrass (*Phyllospadix*), algal beds (*Fucus* and mixed red algae) and kelps (*Macrocystis, nereocystis*). These categories are either recognized to be ecologically important, known to be highly productive, or sensitive to human impacts.

Although these categories alone do not represent the entire range of supratidal to shallow subtidal habitats or the most diverse habitat types, they are believed to be good rough surrogates at the ecoregional scale. One additional category, rocky intertidal (habitat type 3 in Morris 2001), was considered its own target. This habitat type can be identified in the lower intertidal by assembling indicator intertidal species on semi-exposed rocky shores (immobile substrates) including chocolate brown algae (*Hedophyllum, Egregia, L. setchellii, Eisenia*), California mussels (*Mytilus californianus)*, surfgrasses (*Phyllospadix*), kelps (*Nereocystis*), and rich red algae beds (*Odonthalia* and others). This habitat type may have more likelihood of spatial diversity/heterogeneity and include specific habitats such as tidepools.

Most of the spatial vegetation types were attributes to the ShoreZone data in British Columbia (MSRM 2003) and Washington (Berry 2001). In Oregon we used the Estuary Plan Book (DLCD 1987) and The National Wetlands Inventory (USFWS) to attribute these types to the shoreline. As with the shoreline ecosystems, we stratified the seven habitats by coastal marine ecosection, yielding 44 types (i.e., algal beds in the Strait of Juan de Fuca). We also used the same typologies to separate the biological communities in and outside of estuaries. This brought the total number of unique types to 75 (i.e., algal beds in the outer coast of Strait of Juan de Fuca).

We utilized additional data sets illustrating areas of canopy kelps (*Macrocystis, nereocystis*) throughout the ecoregion, and eelgrass beds (*Zostera*) in the Strait of Juan de Fuca and Vancouver Island shelf ecosections. In Washington existing floating kelp planimeter data was collected for the years 1989 to 2000 WDNR (200x). We created a kelp persistence index, adding all years together (1 thru 11) and classifying them into three distinct categories (1 to 3 years in class 1; 4 to 7 years in class 2; 8 to 11 years in class 3). These classes approximate the “observed once/outlier class,” “regularly observed, but not always class,” and the “always there/core sites class” and were analyzed as three spatial entities in an attempt to select the more persistent kelp beds. For Oregon and British Columbia areas of kelp beds were indicated as present when the surveys were done. In Oregon ODFW contracted with Ecoscan Resources to photograph and map bull kelp (*Nerocystis leutkeana*) beds of the entire coast. Aerial photography occurred in summer of 1990. Kelp beds delineated off Cape Arago include giant kelp (*Macrocystis*). *Macrocystis* was not found elsewhere on the coast. In British Columbia kelp and eelgrass beds were delineated off of Canadian Hydrographic Service charts. These data sets were left distinct from the kelp bed data in Washington. However, all types of spatial variation were considered as two conservation targets (“kelps” and “eelgrass”). Although we stratified these data by ecosection we did not further divide them into outer coast and estuarine typologies because the data was considered to be mostly in the subtidal zone (deeper than zero Mean Lower Low Water or MLLW).

4.3.1.3 Estuaries

An estuary (or embayment) is a zone of transition between the marine-dominated systems of the ocean and the upland river systems, a zone where the two mix yields one of the most biologically productive areas on Earth (DLCD 1987). Delineation and characterization of estuaries, however, varies among researchers, agencies and geographies. Even among regional estuary mapping projects definitions and objectives of the mapping vary widely. We used four primary estuary mapping systems for this assessment, including: the British Columbia estuary mapping project from the Pacific Estuary Conservation Program (PECP), the ShoreZone mapping system in British Columbia and Washington, the National Wetlands Inventory (NWI), U.S. Fish & Wildlife Service, in both Washington and Oregon, and the Estuary Plan Book from Department of Land Conservation and Development (DLCD 1987) in Oregon.

The British Columbia estuary mapping project from PECP estimates the boundaries of an estuary using chart datums, water marks, and surface salinity intrusion referenced to specific spatial data. The intertidal zone features for each estuary system or complex were captured as polygons within the area found below the provincial Terrain Resource Information Mapping (TRIM) 1:20,000 coastline or island shoreline (< Mean higher high water mark) and above the zero chart datum contour line (> Lowest normal tide) depicted on Canadian Hydrographic

Service (CHS) charts (Ryder et al. 2003). The TRIM coastline or island shoreline was used to separate the backshore/intertidal zones and the CHS charts were used to separate the intertidal/subtidal zones. Subtidal features below the zero chart datum contour were not included. The supratidal/backshore and upstream zone features for each estuary system or complex were captured as polygons within the area found above the provincial Terrain Resource Information Mapping (TRIM) 1:20,000 coastline or island shoreline (> Mean higher high water mark) and above the river/stream mouth(s). The upstream extent of each estuary was delineated at the approximate limit of surface salinity intrusion from data collected at Campbell River (Vancouver Island). An upstream breakline of 500m distance from the river/stream mouth was used in most cases. Estuary complexes included multiple river/streams flowing into a shared intertidal zone. Although the PECP estuaries were delineated as polygons they did not contain any information on substrate characterization within them.

The ShoreZone mapping system conducted surveys at low-tide collecting aerial imagery during minus tides (below Mean lower low water) in June of the year (see Berry et al. 2001). Survey data was collected by a marine ecologist, coastal geomorphologist, and a navigator who flew in a helicopter at flight speeds of 60 knots and about 300 feet in altitude. A geomorphologist interpreted the survey data: he delineated homogeneous units on Washington Department of Natural Resources (WDNR) orthophotos, and described the units and components in tabular data. Spatial data was based on the WDNR digital shoreline (water level line). For British Columbia information was gathered from helicopter and float plane video. Shore units were identified on the video and were transferred to 1:40,000 CHS charts for the west coast of Vancouver Island. Most of the ShoreZone database contains linear shoreline features. Polygons were used when a feature had a unique spatial characteristic not captured by a single line segment. An example would be a feature that spanned the entire "shore- zone" from supratidal to subtidal, like a large wetland area with associated fringing mudflat. The ShoreZone's description of a representative estuary, marsh or lagoon is as follows: estuaries are characterized by high variable distributions in texture, although muds and organics are common. Marshes frequently rim the estuary at the high water mark. Brackish water conditions are common due to freshwater input to the estuary from stream runoff. These features are exclusively confined to low wave exposure environments (Carol Ogborne, personal communication). In addition to delineating the features as polygons, ShoreZone attributed them with their dominant substrate type (e.g., organics/fines, sand flat, mud flat).

The National Wetlands Inventory (NWI) Database is an inventory system developed in 1974 by the U.S. Fish and Wildlife Service. Mapped at a scale of 1:24,000 or 1:62,000, NWI identifies wetlands and deep water habitats as either polygons or linear features. Attached to the mapped wetlands are descriptive codes based on the Cowardin classification system (Cowardin et al., 1979). Under the Cowardin system, wetlands are classified within a hierarchical organization according to plants, soils, and frequency of flooding. NWI data is collected through stereoscopic analysis of high altitude color infrared aerial photographs. For Washington and Oregon the digital photography was done in the 1980s. We primarily used the estuarine polygons from NWI to delineate the extent of the estuary and the estuarine substrate and vegetation components delineated within them. The estuarine description is as follows: Deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the ocean, with ocean water at least occasionally diluted by freshwater runoff from the land. The upstream and landward limit is where ocean-derived salts measure less than .5 parts per thousand during the period of average annual low flow. The seaward limit is (1) an imaginary line closing the mouth of a river, bay, or sound; and (2) the seaward limit of wetland emergents, shrubs, or trees when not included in (1).

The Estuary Plan Book developed by the Department of Land Conservation and Development (DLCD 1987) in Oregon also delineates the extent of estuaries and substrate/vegetation polygons within them. Original Base maps were prepared by the Division of State Lands in 1972 and 1973 using aerial photographs from the U.S. Geological Survey (USGS EROS Data Center, NASA). These base maps were used in 1978 and 1979 by the Oregon Department of

Fish & Wildlife (ODFW) in its mapping of estuarine habitats as part of DLCD's estuary inventory project. ODFW used aerial photography, published studies, and some onsite investigation to prepare its maps of estuarine habitats. Habitat information for the Columbia River was prepared by staff of the Columbia River Estuary Study Task Force (CREST) in 1985. The origins of both the delineation and characterization of these estuaries are from Cowardin et al. (1979) and modified by ODFW.

Given these variations for depicting estuaries we did not attempt to adopt a single definition of the extent of an estuary. Likewise we did not construct a single summary classification for substrate/vegetation types, but preserved them in our conservation target list. With this in mind, we combined the different data sets on extent and characterization into a single conservation assessment process.

We collected spatial information on 187 estuaries in the ecoregion. There are 33 estuaries mapped on the Oregon coast (DLCD/NWI - approximately 89,281 hectares including all of Columbia River estuary), 16 mapped on the Washington coast (WDNR/NWI - approx. 67,016 hectares), and 138 mapped along the west coast Vancouver Island (CWS/MSRM/Ministry of Forests - approx. 8,345 hectares). These estuaries were used as assessment units within the terrestrial analysis (see Chapter 6). Benthic substrate and vegetation types within these delineated estuaries were identified for 101,856 hectares out of a total 164,642 hectares (62%). Stated another way, we have benthic data contained within 89 out of 187 mapped estuaries (48%). Most of these data are contained within Oregon and Washington estuaries; smaller estuaries in British Columbia often lacked identified benthic types. We preserved the original substrate types across the data sets and did not attempt to combine types (i.e., mud from the Estuary Plan Book was not combined with mud flat in ShoreZone). This was done because we lacked information to determine actual conditions in the various estuaries, and some individual data sets also preserved these distinctions (i.e., in the Estuary Plan Book sand and sand flat remained distinct). The result was 18 unique benthic substrate types and six vegetation types (Appendix 4C). Some of these types were also represented in the shoreline ecosystem and coastal zone habitat targets (i.e, mud flat and saltmarsh types were identified in both), but others were unique (i.e., boulder and aquatic beds). We decided to keep these additional 24 area-based estuarine targets separate from the shoreline and habitat targets, which are linear-based features.

4.3.2 Fine Filter Targets

4.3.2.1 Nearshore Marine Species

The marine technical teams selected species as fine filter targets generally following the criteria in Groves et al. (2002) and Beck (2003). Workshops with regional experts resulted in a long list of species for consideration. When compiling species location data, we tried to compile data for the entire marine region. Coastal, nearshore, and offshore species were therefore considered. After evaluation of available data we decided to focus our efforts on coastal/nearshore species and treat offshore species in a later assessment.

The final list of nearshore marine conservation targets consisted of 89 species made up of 25 marine fish, 12 marine mammals, 39 seabirds/shorebirds, and 13 invertebrates (Appendix 4D). Of these targets we used spatial data representing 18 (two marine fish, one marine mammal, 13 seabirds/shorebirds, and two invertebrates), or 20%, of them in the analysis.

Our information collection efforts focused on empirical data for the locations of specific life stage of target species. We tended to avoid location information based on modeled, predicted, or generalized species distributions. We collected species information on targets observed regionally and locally, but only analyzed those data where they were compiled across at least one coastal ecosection. More site-specific data was used to complement site selection output (see Chapter 8 – Conservation Portfolio) in determining areas of nearshore marine biodiversity and high priority. Although this limited our spatial analysis of conservation targets to only a few regional data sets, we had high confidence in them in terms of data accuracy and comprehensiveness.

4.3.2.2 Forage Fish Spawning Beaches

Information was collected on two species of forage fish: Pacific Herring (*Clupea pallasi*) and Surf Smelt (*Hypomesus pretiosus*). Pacific Herring had comprehensive coverage in Washington (WDFW) and British Columbia (MSRM); Surf Smelt information was only available for Washington (WDFW). All spawning data was represented as presence of eggs on specific beach locations, although in both regions an absence of spawned eggs may mean a lack of survey effort rather than a true absence.

The Washington forage fish data represented historic and current spawning beaches over the last 10 years. This information is continually being updated and is not meant as a long-term indicator of presence or absence. The methods of data collection have steadily improved; therefore, updates are meant to augment older spawning locations. The data was collected on U.S. Geological Survey (USGS) maps at 1:24,000 then digitized into polygons for Pacific Herring and as linear features for Surf Smelt. We transformed the polygonal Herring data to linear features coinciding spatially with the ShoreZone mapping system in order to match a similar data set in British Columbia. We included historic site spawning locations for the analysis because of their known importance in the recent past. The Surf Smelt data was kept as a separate linear data set; the spatial extent of these data covered the Strait of Juan de Fuca on the Washington side, and the North and South Pt. Grenville ecosections.

The British Columbia Pacific Herring data was assembled as linear features using the same spatial shoreline as ShoreZone. Original attribute data indicated the Relative Importance (RI) of the feature per location. The RI values are only comparable within project regions (i.e., West Coast Vancouver Island) and not to other coastal zones in British Columbia. We selected RI values of one and two to identify places of relatively low occurrence of Herring, and between three and five to identify relatively high occurrences. Presence of Pacific Herring were attributed to ShoreZone beach segments in a similar manner to those in Washington, allowing for a seamless identification of spawning beaches throughout the ecoregion.

4.3.2.3 Marine Mammal Haulout Sites

Steller sea lion (*Eumetopias jubatus*) haulout sites were the only marine mammal data included in this analysis. In Washington we utilized the atlas of seal and sea lion haul out sites (Jefferies et al. 2000) and a database (WDFW) showing current locations. For Oregon we received tabular location information (Robin Brown, personal communication 2003) that we made spatial as point features. In British Columbia we used point locations from University of British Columbia surveys; they distinguished haulout sites from rookery sites in the database, and we treated these as two spatial entities for one conservation target in the analysis.

4.3.2.4 Seabird Colonies and Shorebird Nesting Sites

We relied exclusively on seabird colony data in representing specific seabird species in the ecoregion. The Washington seabird colony database contains locations surveyed for breeding seabirds as documented in 'Catalog of Washington Seabird Colonies' by Speich and Wahl (1989). There were 18 species of seabirds listed as attributes in the colony data, of which we identified 12 species as targets. These included Brandt's Cormorant (*Phalacrocorax penicillatus*), Cassin’s Auklet (*Ptychoramphus aleuticus*), Caspian Tern (*Sterna caspia*), Common Murre (*Uria aalge*), Double-crested Cormorant (*Phalacrocorax auritus*), Fork-tailed Storm Petrel (*Oceanodroma furcata*), Leach’s Storm Petrel (*Oceanodroma leucorhoa*), Pelagic Cormorant (*Phalacrocorax pelagicus*), Pigeon Guillemot (*Cepphus columba*), Rhinoceros Auklet (*Cerorhinca monocerata*), and Tufted Puffin (*Fratercula cirrhata*). An additional target, Black Oystercatcher (*Haematopus bachmani*), is a shorebird but is most often listed under seabird colony data sources. These species were also catalogued in Oregon from a USFWS database (surveys from 1979 to 2001). This seabird colony catalog contains 16 species; the same 12 target species found in Washington were matched in this database.

The British Columbia seabird colony inventory (Canadian Wildlife Service 2001) includes the locations of all known seabird colonies along the coast of British Columbia, and provides a compilation of the most recent (up to 1989) population estimates of seabirds breeding at those colonies. Fifteen species of seabirds, (including two storm petrels, three cormorants, one gull and nine alcids) and one shorebird (Black Oystercatcher *Haematopus bachmani)* breed along the entire coast of British Columbia. Over 5.6 million colonial birds are currently estimated to nest at 503 sites. Five species (Cassin's Auklets *Ptychoramphus aleuticus*, Fork-tailed Storm-petrels *Oceanodroma furcata,* Leach's Storm-petrels *Oceanodroma leucorhoa,* Rhinoceros Auklets *Cerorhinca monocerata, and* Ancient Murrelets *Synthliboramphus antiquus)* comprise the vast majority of that population, although Glaucous-winged Gulls (*Larus glaucescens)* and Pigeon Guillemots (*Cepphus columba)* nest at the most sites. All 12 seabird colony targets were represented in this database for the west coast and northern region of Vancouver Island.

One other seabird/shorebird target where we were able to gather spatial data was the Western Snowy Plover (*Charadrius alexandrinus nivosus*). These data represented significant point locations in Washington’s (WDFW) priority habitats and species database, and polygonal data illustrating nesting sites and significant site locations during the breeding season (ODFW, ORNHIC) in Oregon. The point and polygon data sets remained as two distinct spatial entities for one conservation target. In addition, nesting and significant sites in the Oregon data were treated separately in the analysis, with the same target goal assigned to each distinct polygon feature type.

The Pacific Northwest Coast Ecoregional Assessment conducted separate terrestrial and marine analyses (see Chapter 8 – Conservation Portfolio). A consequence of this was that some targets were analyzed in both (i.e., seabird colony targets) while others were only treated in one (i.e., dabbling and diving ducks were treated only in the terrestrial analysis). Clearly ducks, as well as other terrestrial/marine targets such as Great Blue Heron (*Ardea herodias*) and Bald Eagle (*Haliaeetus leucocephalus*), play an important role in the marine environment. They were not included in the marine analyses, however, because technical teams either thought that the spatial data was too generalized or did not represent a specific life stage. The separation of these targets in the analyses also reflects the different criteria set forth between terrestrial and marine teams (e.g., the marine teams did not include spatial data for targets that covered less than one coastal ecosection).

4.3.2.5 Intertidal Marine Invertebrates

Of the 13 invertebrates species recognized as conservation targets, we have assembled spatial data for only the mussels and barnacles (*Mytilus californianus* - *Semibalanus carious* with scattered *Pollicipes*). ShoreZone in both Washington (WDNR) and the west coast of Vancouver Island (MSRM) lumped mussel and barnacle observations as a single mid-intertidal species attribute. We treated these observations as two distinct targets.

There was much debate about what to consider an invertebrate conservation target based on the target selection criteria. There are many data gaps in our knowledge of invertebrate abundance, those that may be vulnerable regionally, those thought to be in decline, and those considered ecosystem engineers/keystone species. Although introduced shellfish, for example, can be ecosystem engineers and beneficial to the environment (i.e., filter feeding can cleanse the water column of toxins), they are never considered as conservation targets. As is often the case we simply did not have the information necessary to evaluate the status and condition of invertebrate communities, leaving us with a non-comprehensive list of invertebrate targets representing the region’s diversity.

4.4 Data Gaps and Limitations

4.4.1 Coarse filter targets

The nearshore is subject to forces both oceanic and terrestrial, producing ecosystems that are dynamic and "open" in nature. This openness of marine populations, communities, and ecosystems probably has marked influences on their spatial, genetic, and trophic structures and dynamics in ways experienced by only some terrestrial species (Carr 2003). The nearshore is therefore not easily defined and mapped, making conservation planning more difficult than on land. Given that all data in a Geographic Information System (GIS) is represented at a specific time or limited time frame, and at a specific scale or resolution, there were inherent limitations in surveying the shoreline environment.

Although the ShoreZone mapping system is comprehensive in its representation of shoreline characteristics, we accepted some limitations when adopting this data set to develop our coarse filter targets. Tide, weather, visibility into the nearshore water column, and season all play important factors when conducting a shoreline inventory. Further, given the amount of shoreline in the ecoregion, these ShoreZone inventories had to be done over years, and undoubtedly survey methods were refined in later projects. We tried to account for this in the selection process, giving more weight to regions that had been surveyed more recently. ShoreZone also does not distinguish between differences in the integrity of occurrences of the same ecosystem type. To some extent we compensated for this limitation by using data on shoreline modifications in the suitability index, so that the site selection model favored less altered sites. Updates to the shoreline inventories, therefore, need to occur at more frequent intervals, especially the biological component where species assemblages can dramatically change from year to year. Finally, there is inadequate data to represent the marine counterpart to terrestrial plant communities, i.e., associations of marine algae and sessile invertebrates. Likewise few algal species are adequately mapped across regions.

Mapping and characterization of estuaries varied throughout the ecoregion. This made it difficult to combine them into a single database or build a single, spatially defined set of estuarine conservation targets. Benthic substrate type definitions varied between Oregon, Washington and British Columbia estuaries, and often there was no characterization of them. This was also true of delineations of biological communities. Finally, the photographic imagery used to both delineate the boundaries of estuaries and identify substrate and biological communities within them was quite old. For instance, the Estuary Plan Book in Oregon is still considered the official estuary mapping product even though the base maps used are over 30 years old. Likewise the ShoreZone and National Wetlands Inventory mapping of estuaries varies, with most regions mapped 10 to 20 years ago. Given the fluctuation of conditions in estuaries and their degradation rates from dredging and development, we need more up-to-date estuary mapping products focused explicitly on biological assemblages.

The largest data gap in the nearshore is between five to 10 meters below Mean Lower Low Water (MLLW) and around 50 meters of water. This area, although surveyed either using multibeam or side-scan technologies at specific sites, has not been done regionally. This area is more labor intensive to survey, where more track lines need to be set to cover the same area as in deeper water. In addition, fisheries and fishery-independent surveys usually start at 50 meters or deeper. This gap is evident in regional vessel surveys conducted by NOAA, who have focused their attention on collecting multibeam information and conducting trawl surveys outside of bays, estuaries and the relatively shallows of the coastal zone. There is therefore a need to comprehensively survey nearshore waters for benthic and biological factors, and utilize technologies such as LIDAR to construct more detailed nearshore bathymetry across larger areas.

4.4.2 Fine filter targets

Nearshore marine species data are either very coarse in scale (i.e., depicting a species' general distribution) or collected at very fine resolution (i.e., detailed survey transects a specific intertidal sites). Data sets were screened for inclusion in the regional analysis through an examination of data confidence and comprehensiveness. Our rule for including information in the analysis was whether the target was represented over at least one coastal ecosection. And because we favored data that included a species' specific life stage (i.e., spawning, feeding areas) over data that represented general distributions or observations or modeled data, we were limited by the amount of information included in the analysis. Without a rigorous evaluation through a process similar to the creation of element occurrences, the inclusion of general polygon distribution or observed point locations may not represent the most persistent populations. In addition, marine species data usually does not indicate an association with habitat and is biased to places where positive observations were recorded.

For marine fish we had no fishery-independent survey information, and we did not have any forage fish spawning data for Oregon. Only Pacific Herring spawning data allowed for a comparison across a substantial portion of the ecoregion (British Columbia and Washington). We did collect fisheries-independent trawl data from NOAA, but this did not extend into shallower waters. As noted above, marine technical teams chose not to include general distribution data or local data sets on marine fish (or any other taxa group) because these data were not enough to support selection of priority conservation areas beyond the defined nearshore zone for this assessment. Therefore more intensive survey work needs to be done to sample waters between Mean Lower Low Water and roughly 50 meters. In addition, programs like Essential Fish Habitat (NOAA - EFH) in Southeast Alaska that sample for juvenile rockfish utilization in estuaries needs to continue and increase in scale.

Marine mammal data either came to us as general distribution areas depicted as polygons, or as random site observations from whale watching vessels. Neither of these data types was included in the analysis, reflecting the general limitation of marine mammal data. Most species are wide ranging and although we have a general sense of their home ranges and migratory corridors we often lack specific site information on feeding areas and other life stages. More work needs to be done to evaluate the use of wide ranging species data in ecoregional assessments and whether models of habitat suitability for these species similar to those done in the terrestrial environment would be useful.

We had spatially explicit data for seabird colonies throughout the region, but shorebird data other than Black Oystercatcher colonies and Western Snowy Plover sites did not represent a specific life stage at the appropriate scale of analysis. Shorebird areas depicted by large concentration areas using the more explicit area-based estuarine targets, such as tidal mudflats, served as a better surrogate for shorebirds than using the limited occurrence data.

Our largest data gap was for marine invertebrates in the intertidal and subtidal zones. Without a comprehensive, continuous survey effort, we were limited by the places where species were found at distinct locations. These data were used to evaluate the results of the draft portfolio at specific sites, but were not comprehensive enough to use without biasing the analysis. It was therefore difficult to get a sense of abundance of specific vulnerable or threatened species across the region. Although this is a systemic problem for all spatial analyses, it is particularly problematic for sessile invertebrates that may utilize large areas of benthic habitat types. These sparse data reflected neither the best nor the only sites where these species occur. Where there are a very limited number of species observed regionally (i.e., ShoreZone), these data did not decipher quality of the invertebrate communities or track rare species.

4.5 Setting Goals

The analytical tool used in this assessment requires that goals be set for conservation targets. These goals are a device for assembling an efficient conservation portfolio, but they are also first approximations of the necessary conditions for long-term survival of plant communities and ecological systems. Ideally, when setting goals we are attempting to capture ecological variation across the ecoregion and enhance species persistence by spreading the risk of extirpation.

Our objective was to find an efficient number of places to begin addressing conservation in the nearshore; this does not mean that these places capture all that is sufficient to conserve nearshore biodiversity. This approach attempts to answer the question 'where do we start?' in evaluating places for nearshore biodiversity, as opposed to 'how much area is enough?' to conserve that biodiversity. Given these considerations, we set conservative (low) goals to help the algorithm assemble an efficient portfolio of sites important to multiple targets.

In working with agency partners we agreed that there should be a no net loss of nearshore marine targets. Theoretically goals should therefore be set at 100% of existing occurrences. However, in order to produce an optimized conservation portfolio, we set goals so that the site selection algorithm would have to choose places that capture multiple targets in the fewest possible places. Thus we set goals of between 10 and 50% (see below).

4.5.1 Ecosystem, Habitat, and Area-based Estuarine Goals

Goals for coarse filter targets were based on linear meters of shoreline whereas goals for the area-based estuarine targets were based on hectares. ShoreZone data were the most uniform across the ecoregion, providing the best data for describing a portfolio representative of the ecoregion's nearshore habitats. We examined a variety of goal levels for shoreline ecosystems ranging from 10 to 40%. Goals were set 10% higher for targets with a biological component (i.e., protected organics/fines) than one without (i.e., exposed rock platform). We initially selected three scenarios, setting goals at 10 to 20%, 20 to 30%, and 30 to 40%. We concluded that the 20 to 30% scenario was appropriate to identify priorities in evaluating the conservation of the diverse coastal environment. Reviewers indicated that the 10 to 20% scenario omitted some critical sites, especially where extensive dikes have been built or invasive species were prevalent but ecological processes were still in tact (i.e., adequate fresh and tidal flow regimes in estuaries for juvenile fish rearing habitat). Further, reviewers indicated that the 30 to 40% identified too many sites that were often felt to be low in potential quality. Given that the algorithm attempts to filter a large amount of information into a representative subset, we felt that the 20 to 30% scenario was the appropriate level to test efficiency and overrepresentation of targets within a selection arrangement.

Likewise we examined multiple goals for the coastal zone habitats, also ranging them from 10 to 40% of the target's current extent. Within each scenario we grouped specific habitats and gave preference to some by setting their goals 10% higher. Of the seven coastal zone habitats, we set goals 10% higher for: saltmarsh, surfgrass, eelgrass, kelp beds, and the habitat type 3. Goals were 10% lower for dune grasses and algal beds. Marine technical teams determined that these habitats were either outside of the intertidal zone (dune grasses in the supratidal) or they were abundant (algal beds) relative to the other habitats. However, teams identified these two groups as contributing significantly to the representation of nearshore biodiversity and were therefore used in the analysis. For the reasons stated above we again chose the 20 to 30% scenario as the optimal setting for site selection. In this way the selection algorithm chose more occurrences of the biologically richest sites to ensure representation of the wider range of species that occupy them. This approach to goal setting attempted to integrate intertidal and shallow subtidal habitats with their associated shoreline ecosystems. The final goals chosen for the analysis of shoreline ecosystems and coastal zone habitats are shown in Appendices 4A and 4B.

We conducted a similar procedure for estuaries, establishing the same three goal scenarios and settling on the 20 to 30% range. Similar to the coarse filter ecosystem and habitat target goals, there was a 10% hike in area-based estuarine targets with a biological component (i.e., wood debris/organic as opposed to sand) as well as preference given to area-based saltmarsh and seagrass targets (goals set 10% lower for dune grasses, aquatic beds, and algal beds). Estuarine target goals can be found in Appendix 4C.

4.5.2 Species Goals

In setting goals for species targets we considered the relative abundance, distribution, and number of occurrences as well as our confidence in the data. Data sets that were more comprehensive across the ecoregion, recently compiled, represented a specific life stage (i.e., spawning) as opposed to observational or modeled data, received higher goals. With these factors in mind, we examined various goal scenarios for each taxa group.

We set goal scenarios at 20 to 30%, 30 to 40%, and 40 to 50% for all taxa groups except invertebrates. For forage fish goals were set 10% higher for Pacific Herring spawning beaches in British Columbia with Relative Importance (RI) values from three to five; all recently surveyed spawning beaches in Washington were given this same goal. All Surf Smelt beaches were given the same goal level. Steller sea lions represented as rookery sites in British Columbia were given a 10% hike in their goal as opposed to haulout sites. Western Snowy Plover sites were evaluated for their “significant use” during the breeding season and values were 10% higher for locations deemed to have more frequency of utility. For the forage fish, marine mammals, and Plovers the 30 to 40% range was selected for the draft nearshore portfolio. Seabird/shorebird species represented in colonies were all given the same goal, with percentages set at 20, 30 and 40% across scenarios. This was also set for the mussels-barnacles target. The 30% goal of all existing colonies and presence of mussels-barnacles was selected for the draft portfolio. See Appendix 4D for a list of all species targets and final goals used in the construction of the draft portfolio.

Chapter 5 – Protected Areas

Existing protected areas are the starting point for a comprehensive biodiversity conservation network. This chapter discusses existing protected areas and their contribution to the conservation of biodiversity in the ecoregion.

5.1 Definitions

Only level 1 and 2 protected areas were included in our protected areas assessment. Level 1 and 2 protected areas have the highest degree of biodiversity protection and management (TNC 2000). These levels are analogous to protection status 1 and 2 categories used by Natural Heritage Programs and management status 1 and 2 categories used by GAP Programs. They are defined as follows:

Level 1 – Lands owned by private entities and managed for biodiversity conservation or owned and administered by public agencies and specially designated for biodiversity conservation through legislation or administrative action where natural disturbance events proceed without interference. The agency acting alone cannot change these designations without legislative action or public involvement.

Level 2 – Lands generally managed for their natural values, but which may incur use or habitat manipulations that degrade the quality of natural communities.

Table 5.1 Types of protected areas in the Pacific Northwest Coast Ecoregion

Type of Protected Area	Management Status
Forest Service Special Interest Area	1
Private Nature Preserve	1
Wilderness	1
U.S. & Canadian National Parks	1 or 2
Forest Service Scenic Research Area	2
BC Provincial Park & Provincial Marine Park	1 or 2
BC Ecological Reserve	1
BLM Outstanding Natural Area	2
BLM Congressionally withdrawn area	2
BLM Area of Critical Environmental Concern	2
Conservation Easements to TNC	2
Municipal Lands like Portland's Forest Park	2
National Estuarine Research Reserve	2
BC Provincial Recreation Area	2
National Recreation Area	2
National Wildlife Refuge	2
Research Natural Area	1
State Protected Lands (Parks, Natural Areas, Natural Area Preserves, Wildlife Management Areas)	2

5.1.1 Conservation on Public Lands

The U.S. Forest Service and Bureau of Land Management have sizable tracts of land within the PNW Coast Ecoregion. These U.S. federal lands are managed for a variety of purposes including watershed protection, timber production and recreation. However, overriding these purposes are several management directives that conserve aspects of biodiversity. The directives help conserve rare species and unique areas and contribute to the overall health of ecosystems through comprehensive planning and management. While this analysis does not include all federal lands under the broad category of existing protected areas (level 1 and 2 categories), we do recognize the significant contribution that federal land management makes towards conservation in general, on lands classified as GAP level 3. This contribution is addressed more specifically within the analysis in terms of suitability of areas for conservation (see Chapter 6).

The Northwest Forest Plan (USDA 1994) set aside Late Successional Reserves (LSRs) for the protection of the northern spotted owl and other species that rely on similar old growth forest habitats. Lands set aside as LSRs cover a sizable area of the assessed area, 581,300 ha. These administrative designations were not included as Level 1 or 2 protected areas for two reasons. First, many of these areas contain significant amounts of disturbed and altered habitats including clear cuts, plantations and roads that at present degrade the integrity of the areas. Active management of younger stands within LSRs is condoned in the Northwest Forest Plan and may have adverse impacts on biodiversity. Secondly, because these areas are administratively designated, there is less certainty that the levels of protection will remain high in the face of public policy changes, as compared with congressional designations such as wilderness areas. Policy changes can occur even in response to natural events such as wildfire and can have devastating impacts on protected areas by promoting management actions that have the effect of impairing ecosystem processes. If the current management direction for LSRs is maintained, their overall condition will improve with time and they will make a very significant contribution to biodiversity conservation in the ecoregion.

5.1.2 Marine Protected Areas

In the broadest sense there are many different types of marine protected areas including coastal National Wildlife Refuges, coastal State and Provincial Parks, publicly owned beaches and submerged lands owned by the state. While all of these designations and land ownerships may contribute to conservation, for the purposes of this chapter we will restrict the definition of marine protected areas to include only those areas that offer protection to tidal and subtidal habitats and are not principally land-based. Thus most coastal State and Provincial Parks and state managed submerged lands are not considered adequately protected to be included in this definition (Robison 2002).

5.2 Data Sources

Land management data, which was used to assess protected area status, was difficult to obtain. Land ownership and management status are fairly fluid creating an elusive, moving target for the planner. Ownership in British Columbia was compiled from at least 5 separate sources, each at a different spatial resolution. Additionally, Canadian land management categories are very different from American categories, making it even more difficult to create a consistent dataset across the ecoregion.

The Washington ownership/management layer started with the Combo-100 product (USFWS. 1997 unpublished data). This was updated by independent coverages showing the state agency ownerships, private and public lands operating under Habitat Conservation Plans (HCPs), TNC preserves, and the latest Federal land management information downloaded from the Regional Ecosystem Office (REO) website.

Oregon data was compiled from a similar collection of datasets. The basic ownership information came from the Coastal Lands Analysis Management System (CLAMS) data (US Forest Service 1991). Areas outside the CLAMS project area were attributed with the management layer compiled by the Oregon Heritage program in the late 1990’s and updated by TNC staff. This was further refined with TNC preserves, private and public lands operating under HCPs, and the latest Federal land management information downloaded from the REO website. A current coverage of the USFWS National Wildlife Refuges was obtained directly from that agency (Dave Dreshler personal communication 2004).

British Columbia data on land management was compiled from several provincial government datasets. The provincial government's Parks and Protected Areas coverage was used as well as a 1:2,000,000 scale dataset of private land in the province. This includes the boundaries of the E&N Railway grant which covers over 1.2 million hectares (2 million acres) of private land on southeast Vancouver Island. Forest Companies also hold large amounts of public lands on Vancouver Island in the form of Tree Farm Licenses (TFLs) and private forestry land. Management status was also developed from Baseline Thematic Mapping (BTM) a 1:250,000 scale dataset of present land use which is derived from Landsat TM5 imagery from 1992-1999 (MELP 2001).

All the state/province layers were then merged, and a common management status code was applied to each parcel. These codes were refined from the "GAP Status" codes used by state GAP Programs. This layer was then intersected with the various assessment units, and the sum of hectares was calculated for Management Status 1 & 2 within each assessment unit to determine the extent of existing protected areas.

5.3 Summary of Existing Protected Areas

There are 206 terrestrially-based protected areas in the assessment area, covering 899,000 ha or roughly 10.5 % of the assessment area (Appendix 5A). The number and areal extent of protected areas are not distributed evenly across the ecoregion (Table 5.2, Maps 5.1a, b, c).

Table 5.2 Number and area of protected areas in the assessment area by ecoregional section.

Section	Section Area (ha)	Number of Areas	Protected Area (ha)	% of Section
North Isle Mountains	532,100	11	278,300	52.3
Wind Isle Mountains	1,178,500	33	202,800	17.2
Lee Isle Mountains	1,265,800	22	3,100	0.2
Nahwitti Lowlands	250,800	5	19,300	7.7
Olympics	1,158,700	14	401,800	34.7
Willapa Hills	1,581,100	33	30,200	1.9
Coast Range	2,557,600	88	42,100	1.6
Total	**8,524,700**	**206**	**899,100**	**10.5**

The largest terrestrial protected area in the ecoregion is Olympic National Park and adjacent wilderness areas at over 400,000 ha. The National Park makes up nearly all of the protected area coverage in the Olympics section and includes essentially all of the high elevation forests and subalpine habitats within the section. The North Isle Mountains section contains the greatest percentage of protected areas (52.3%) of all the sections in the ecoregion. The protected areas in the North Isle Mountains are dominated by Strathcona Provincial Park at 251,000 ha. Overall, eight out of the ten largest protected areas in the ecoregion are located on Vancouver Island. At the other end of the scale, the Lee Isle Mountains (0.2% protected), Coast Range (1.6% protected) and Willapa Hills (1.9% protected) contain the lowest percent of protected lands.

The 206 protected areas within the assessment area vary tremendously in their size with 72 areas being less than 100 ha. in size and only the two largest areas (Olympic NP and Strathcona PP) being over 100,000 ha. Another 89 protected areas are between 100 and 1000 ha in size and only 39 areas are larger than 1000 ha. An additional issue about the distribution of the smaller protected areas is that the Coast Range section (Oregon) has 88 protected areas, but all but 9 of these areas are less than 1000 ha. The Lee Isle Mountains has no protected areas over 1000 ha and the Olympics section has only one area greater than 1000 ha, that being Olympic National Park. In summary, most protected areas are quite small and may not be part of a larger protected network or watershed, which brings into question their viability, as well as their contribution to conservation of biodiversity overall.

Data on existing protected areas were used to (1) assess the current level of biodiversity protection in the ecoregion, and (2) assist in the selection and prioritization of portfolio sites. These uses are both explained in the following sections.

5.4 Marine Protected Areas

Along the PNW coast lie a number of marine protected areas that offer varying levels of protection to the marine environment. These areas are relatively recent additions to the protected area network and generally offer less than full protection of the biodiversity that they contain, as fishing is often not prohibited within designated marine protected areas. Nevertheless, these areas offer critical protection to at least some of the biological attributes and habitats present, and are therefore important in coastal and nearshore conservation. A list of all protected areas, marine and terrestrial, is in Appendix 5A.

The sites vary considerably in their size with the largest area being the Olympic Coast National Marine Sanctuary, which covers 857,000 ha (3,310 square miles) of ocean off the Olympic coast of Washington. The Sanctuary is managed by NOAA. The usual and accustomed areas of four tribes on the Olympic Peninsula – Makah, Hoh, Quileute and Quinault Nation – overlap the national marine sanctuary and extend beyond the Sanctuary's boundaries. Usual and accustomed areas are judicially defined areas where tribal members have fishing rights based on historical use patterns of their tribe. Tribes are active participants in discussions about natural resources management and conservation activities within their usual and accustomed areas. Fishing is regulated but not prohibited within the Sanctuary. The Sanctuary is the largest protected area on land or sea within the ecoregion.

Many marine protected areas are located on Vancouver Island where the government has designated Ecological Reserves, Provincial Parks, a Wildlife Management Area, Pacific Rim National Park and several other designations that involve marine resources. There are at least 30 Provincial Parks that provide some protection for marine or estuarine resources on Vancouver Island.

Washington State has a number of marine or coastal protected areas that are located in coastal estuaries or on the outer coast. There are six coastal National Wildlife Refuges including two refuges that are offshore, Quillayute Needles NWR and Flattery Rocks NWR. There are also six Natural Area Preserves managed by the Washington State Department of Natural Resources that include marine or estuarine habitats. Finally there are other state designations such as Seashore Conservation Areas that protect portions of the marine environment.

The Oregon coast has six National Wildlife Refuges including one comprised of every offshore island on the Oregon coast (the Oregon Islands NWR), although protection for subtidal habitats on the islands is limited. Oregon also has the only National Estuary Research Reserve in the ecoregion at South Slough, and two National Estuary Program sites, Tillamook and the Lower Columbia (which falls within Washington as well). Land use zoning offers varying amounts of protection to all of Oregon’s estuaries, with nearly half of them protected in their natural state, limiting commercial development and dredging. There are 20 coastal sites and offshore reefs regulated by ODFW with designations that offer seasonal closure and protection from some activities, such as collecting marine organisms for non-research purposes.

5.5 Protected Areas Assessment

As is the case throughout the world, most protected areas in the Pacific Northwest Coast were not originally established for the purpose of protecting biodiversity. Many geographic and political constraints came into play with most area designations such that the existing protected area network is not ideal in terms of its conservation values. This is not to say, however, that the existing network should be substantially modified or that areas should be re-classified. If anything, it calls for the recognition that current protected areas may never suffice to protect biological diversity at the ecoregional scale and a careful analysis of the contributions of future designated areas should be undertaken to understand their contribution to conservation.

Protected areas in the Pacific Northwest Coast Ecoregion make significant contributions toward the conservation of a number conservation targets. Nevertheless, many targets have few or no occurrences within existing protected areas and thus will be reliant upon new areas for their conservation. Appendix 5B displays the protection of conservation targets by percent of conservation goals met within protected areas with the targets organized by target groups. The target groups selected for this summary reflect target taxonomy (herptiles, mammals, birds, vascular plants etc) and logical groupings of coarse filter habitats. This provides a summary as to how important the protected areas are for conservation within the ecoregion.

Appendix 5B shows the conservation goals for target groups are not uniformly protected in the ecoregion. In the PNW Coast Ecoregion, when comparing the target groups whose goals are met at the 76 percentile and above, it can be seen that high elevation forests, wetland systems, special habitats and rare plant communities had the greatest percentage with goals met in protected areas. These results make sense when examined in context of the protected area network in the ecoregion which tends to favor high elevation, wetland, and rare ecosystems. The two largest protected areas in the ecoregion, Olympic National Park and Strathcona Provincial Park, occupy vast areas of montane and subalpine forests that fall into the high elevation forests group. Smaller, more localized habitats that are conservation targets such as wetlands, special habitats and rare plant communities often enjoy enhanced protection as well because they have been selected by TNC and various public agencies for protection as wildlife refuges, botanical areas and preserves.

In contrast, aquatic systems, birds, mammals, and salmon in British Columbia faired poorly in terms of the role that existing protected areas played in meeting our conservation goals. Because aquatic systems include entire watersheds and subwatersheds, it is rare that a protected area will be large enough to protect an entire drainage. Also, many lower elevation watersheds have been settled for centuries, making them highly unsuitable for the establishment of protected areas that have traditionally been located away from settlements and urban areas. Regarding the poor showing for rare birds, mammals and salmon in British Columbia in the protected area network, this is in part the result of the mobility of these species and their broader habitat needs which make it impractical to set aside large enough areas to protect their populations. Also, protected areas were generally not originally designated in order to effectively protect biodiversity but were often designated due to some remarkable natural feature such as a scenic area.

Existing protected areas often form the nucleus for the development of a conservation area in this conservation assessment. There are several good reasons for this, in that the protected area is already designated and may be well be on its way to providing protection for conservation targets and supporting ecological processes that act to maintain biodiversity at an ecoregional scale. A number of protected areas have been established in order to protect rare species or unique habitats, including many Nature Conservancy preserves. Larger protected areas, those approaching 1000 ha or greater, are also perfect areas for building conservation networks encompassing whole subwatersheds. These areas contribute large patches of native vegetation and often already contain stream networks supporting salmonids and other species, all within a landscape free from significant habitat disturbance or land conversion.

Chapter 6 – Assessment Units and Suitability

Chapter 6 discusses the primary analytical tool used in the conservation assessment and its use. The tool is called the SITES (Andelman et al. 1999) and has been widely applied for this sort of work around the world.

6.1 Assessment Units

For the purposes of analysis, the ecoregion was divided into thousands of assessment units (AUs, also known as planning units; Table 6.1). For terrestrial biodiversity, we used U.S.G.S. HUC 6 polygons and where available HUC 7 polygons (Map 6.1). These were used as AUs because they approximate distinct ecological units, i.e., watersheds, and cover the full extent of the ecoregion in both Washington and Oregon. Third order watersheds were used in the British Columbia portion of the ecoregion. Because the watershed boundaries to not match the ecoregion boundaries, our AUs extended into adjacent ecoregions. Hence, the assessment area does not match the ecoregion area, and, in fact, the assessment area exceeds the ecoregion area by about 1 million hectares. Most of the assessment results are reported for the assessment area.

Table 6.1 Terrestrial Assessments Unit Statistics for the Assessment Area.

Statistic	Value
Number of units	2707
Mean size (ha)	3138
Maximum size (ha)	18980
Minimum size (ha)	10.5
Range (ha)	18970
Standard deviation (ha)	3360

Aquatic AUs were represented by three classes of polygonal watersheds: tributary and headwater drainages less than 100 square kilometers (Class 1), small river drainages between 100 - 1000 square kilometers (Class 2) , and large river drainages more than 1000 square kilometers (Class 3). These three classes of watersheds were all represented by polygons depicting their full contributing area. These polygons "nested" with the class 3 polygons fully containing the class 2 polygons within them, and the class 1 polygons nesting within the class 2 polygons. Some watersheds don't drain into others, as when a small coastal creek flows directly into the ocean. For the vast majority of watersheds, this "nesting" was used to relate each polygon to the polygons contributing to them and the ones they contributed to.

The Columbia River mainstem is the only class 4 watershed intersecting the ecoregion. It was identified as an important river during the Willamette Valley-Puget Trough-Georgia Basin ecoregional assessment (Floberg et al. 2004), and was required to be a part of any subsequent aquatic portfolio.

Three types of nearshore marine AUs were used in the assessment depending upon the conservation targets being analyzed and the specific realm (terrestrial or marine) being addressed. First, the marine assessment used a grid of 400 ha squares (Map 6.2). There were 6560 such assessment units, totaling over 2.6 million hectares. The squares intersected the entire coastline of the ecoregion as well as offshore islands, all estuaries, and upstream tidal reaches of major rivers and streams. One advantage of a square grid is that different sized units can be nested. Second, line segments corresponding to reaches of shorezone habitats (see Chapter 4) were used for shoreline habitats in both the terrestrial and marine assessment. These were highly variable in length.

Third, estuary AUs were represented by polygons in the terrestrial assessment. In the US portion of the ecoregion, the larger polygons were defined by salinity zones and estuarine vegetation. On Vancouver Island they were merely polygonal depictions of the extent of each estuary. Vancouver Island estuaries tend to be quite small, as they tend to occur at the heads of narrow fjords, and are fed by smaller streams. To give our model the context to discriminate between Vancouver Island estuaries the sum of the shorezone habitats intersecting each estuary was attributed to the polygons.

6.2 SITES Selection Algorithm

Chapters 2, 3, and 4 identified hundreds of different conservation targets. These fine- and coarse-filter targets exist at thousands of widely distributed locations. Section 6.3 describes an index that assigned to each AU a value corresponding to its relative suitability for conservation. The complexity of information precluded simple inspection by experts to arrive at the most efficient, yet comprehensive, set of conservation priority areas. To help us identify and map a set of conservation priority areas we used an optimal site selection algorithm known as SITES (Andelman et al. 1999).

SITES uses a heuristic algorithm known as simulated annealing (Kirkpatrick et al. 1983). The algorithm works toward finding a set of AUs that minimize an objective function. The objective function consists of three terms corresponding to AU suitability, AU adjacency, and a penalty for failing to meet target goals. The algorithm begins by selecting a random set of AUs. Next, it iteratively explores improvements to this random set by randomly adding or removing other AUs. At each iteration the new solution set is compared with the previous set and the one with the lower objective function is retained. The simulated annealing algorithm utilizes mathematical analyses to reject sub-optimal portfolios, thus greatly increasing the chances of converging on the most efficient portfolio. An optimal solution is not guaranteed, but near optimal solutions will always be achieved given enough iterations. Typically, the algorithm is run for 2 to 5 million iterations. Appendix 6A gives more details about SITES.

6.3 Conservation Suitability of Selection Units

Successful conservation will entail choices about where conservation should and should not be pursued. Optimal reserve selection is an analytical technique that addresses this issue (Ando et al. 1998, Pressey and Cowling 2001). Optimal reserve selection analyzes the trade-off between conservation values and conservation costs to arrive at an efficient set of conservation areas that satisfies conservation goals (Possingham et al. 2000, Cabeza amd Moilanen 2001). The conservation value of a place is represented by the presence of target species, habitats, and ecological communities. The number of targets, amount of each target, and rarity of targets present at a particular place determines the conservation value of that place.

The optimization algorithm searches for the lowest "cost" set of AUs that will meet goals for all conservation targets. The actual "cost" of conservation encompasses many complicated factors: acquisition or easement costs, management costs, restoration costs, and the cost of failing to maintain a species at a site. Because determining the monetary cost of conservation for every AU would be an extremely demanding task, we used a surrogate measure for cost called a *suitability index*. A place with a high “cost” for maintaining biodiversity has low suitability for conservation. Suitability indicates the relative likelihood of successful conservation at each AU.

Land use suitability is a well-established concept amongst land use planners (see Hopkins 1977, Collins et al. 2001 for reviews), 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. We are using a suitability index in an optimization algorithm that will guide us toward best places for biodiversity conservation.

Our indices are based on the analytic hierarchy process (AHP; Saaty 1980, Banai-Kashini 1989). AHP generates an equation that is a linear combination of factors 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) through which experts are asked for the relative importance of each term in the equation. AHP has been used in other conservation assessments where expert judgments are needed in lieu of empirical data (Store and Kangas 2001, Clevenger et al. 2002, and Bojorquez-Tapia 2003).

We readily admit that our simple index cannot account for the many complex local situations that influence successful conservation, but we believe that some reasonable generalities are still quite useful for assessing conservation opportunities across an entire ecoregion.

Separate suitability indices were calculated for the three major components of our analysis; terrestrial, aquatic, and nearshore/estuarine. The factors considered for each suitability index varied slightly. We will describe the data collected for each factor used in any suitability equation and then describe the calculations for each index separately.

6.3.1 Factors Considered in the Terrestrial and Aquatic Suitability Indices

The following factors were included in the suitability indices:

Landuse/landcover Data - The landuse/landcover (LULC) data for the Northwest Coast Ecoregion was compiled from several sources. The best available data was used for each region. Vancouver Island had a comprehensive 1:250,000 scale Baseline Thematic Mapping dating from 1992-1999. This map contained 19 classes including three seral stages (early, mid and late), burns, glaciers, agriculture, converted lands and mines. CLAMS (Coastal Landscape Analysis and Modeling Study) covered the majority of the Oregon portion of the ecoregion. Their 1996 vegetation map contained 4 seral stages (small, medium, large and very large). Converted lands, agriculture, open water and barrens were attributed from a 1:100,000 scale landuse/landcover map originally developed by the USGS and updated in 2000 by Pacific Meridian Resources.

A small portion of southern Oregon was not covered by the CLAMS project. Information from the Forest Service and personal communications with local experts were used to complete the seral stage information in those areas. Converted lands were attributed in that area using the *PMR* landuse/land cover map.

The Combo-100 coverage contained 10 landuse classes including 3 seral stages. This coverage used a 90-meter grid cell, which provides information at approximately 1:100,000 scale.

All of these individual grids were put together in a mosaic to provide a continuous landuse layer across the entire ecoregion plus a 10 km wide buffer surrounding the ecoregion. The attributes were crosswalked to a set of 9 classes: agriculture, alpine, barrens/unvegetated, early seral (0-10” DBH), mid-seral (10-30” BDH), late seral (>30” DBH), urban, wetlands, and open water. This map is nominally at 1:100,000 in the U.S. portion of the ecoregion, and 1:250,000 for the BC portion.

Information from the LULC layer was used to provide summations for every AU on the number of hectares in each landuse condition. The LULC classes used in the suitability index were urban conversion, agricultural conversion, and early seral forests. The sum of each conversion type in hectares was calculated for every AU.

Ownership/Management - Land management data was the most difficult to obtain. Land ownership and management status are fairly fluid creating difficulties related to their changing natures. Ownership in British Columbia was comprised from at least 5 separate sources, each at a different spatial resolution. Additionally, Canadian land management categories are very different from those in the United States, making a smooth dataset across the ecoregion even more difficult to create.

The Washington ownership/management layer started with Combo-100. This was updated by independent coverages showing the state agency ownerships, coverages which showed private and public lands operating under a valid HCP agreement, The Nature Conservancy ownerships, and the latest federal land management information downloaded from a U.S. Forest Service website.

Oregon data was compiled from a similar collection of datasets. The basic ownership information came from the CLAMS data compiled in 1991. Areas outside the CLAMS project area were attributed with the management layer compiled by the Oregon Heritage program in the late 90's and updated sporadically by TNC staff. This was further refined with TNC preserves, private and public lands operating under a valid HCP agreement, and the latest federal land management information downloaded from a U.S. Forest Service website. A current coverage of the USFWS National Wildlife Refuges was obtained directly from that agency.

All the state/province layers were then merged, and a management status code was applied to each parcel. This data layer was then intersected with the various AUs, and the percentage was calculated for each management type within each AU.

Roads - Road data was collected separately for each jurisdiction within the ecoregion. British Columbia information came from *Watersheds BC*, an application developed for watershed planners in British Columbia. The watersheds used for the *Watersheds BC* application were slightly different than our AUs. An area-weighted average was used to calculate road densities for AUs of varying sizes. The units were then converted to achieve the kms/hectare measurement used in the US portion of the Ecoregion.

All roads were treated equally in this assessment. This was largely because much of the base data didn't include information on road types. Major highways may have greater impacts than logging roads, but averaged across our large AUs these differences are minor.

For Washington, DNR's *POCA Transportation* layer was used . Oregon road data was obtained from the Oregon State GIS Service Center. The density of digitized roads differed between all three jurisdictions because of the various scales of the original coverages. Several calibration sites were selected within each jurisdiction to compare mapped densities across the ecoregion. These calibration sites included AUs with similar proportions of high density urban, Private Industrial Forests, and General Use Public Lands. Within similar land use conditions road density data in Oregon were found to be 25% lower than Washington, and Vancouver Island's were 10% lower than Oregon's. The values were standardized between the different datasets for the political jurisdictions and normalized on a scale from 1 - 100.

303D Streams - Coverages were obtained from the Washington Department of Ecology, and the Oregon Department of Environmental Quality. The identified 303d reaches were intersected with the aquatic AUs to derive "presence/absence" of 303d streams byAU.

Dams - Information was compiled from 4 separate databases. Nature Conservancy Canada (NCC) provided *BC Hydro's* dam coverage and the provincial government's Dam Safety Group's dataset. In the U.S. information was compiled from *EPA's Basins* data, *Streamnet* and *the Washington Department of Ecology's (DOE) Dams* coverage. Each dam was assessed for its impact to hydrology and fish passage. If multiple dams were present in an AU, the effects were additive. Impacts were modeled such that dams affected the AU containing the dam and also the downstream AUs. In the suitability index, impacts diminished with downstream distance from the dam. Fish passage impacts did not diminish with upstream distance from a dam.

There are only 14 dams in the BC portion of the Ecoregion. The small number made it feasible to talk to local experts and derive clear indications of the size and impacts of each dam. In general, the dams in BC are large hydroelectric dams with severe impacts.

Each of the datasets in the US portion of the ecoregion contained some dams missing from the others. In Washington, the *DOE Dams* coverage contained the best information with specific measures of fish passage impacts for many dams. Dams from the *Streamnet* coverage were added where DOE data was missing. The final comprehensive coverage was then sent to WDFW for additional assessment of hydrologic and passage impacts.

Streamnet was used as the basis for dam information in Oregon. Dams from the *EPA Basins* data were added where *Streamnet* data was missing. Each dam from this comprehensive coverage was then assessed by Oregon TNC staff for impacts to hydrologic and passage impacts. Those impacts tend to be proportional to a dams size, though management regime (diversion, flood control, reservoir, etc) may alter those impacts somewhat. 367 documented dams are listed for the US portion of the ecoregion. Many of these are small diversion structures, and only 7 attain the highest level of impact.

Finally, the British Columbia, Washington and Oregon dam coverages were merged. The impacts to hydrology and passage were recorded on a 7-point (100, 200, 500, 1000, 2000, 5000, 10000) scale in the suitability index for every effected planning unit. For example, a high hydropower dam might earn a planning unit a penalty of 10,000. The adjacent, downstream planning unit contains an undammed stream that is fed by the dammed stream. The penalty in that planning unit would fall to 5000, as only half its flow is controlled. Similarly, all downstream planning units from that point would receive diminished penalties unless another dam affected the system. Theoretically, the number of downstream planning units that would receive a penalty would be 6 (assuming no additional dams and average stream densities), but virtually no planning unit is more than 4 steps from the border of the ecoregion or the ocean.

It should be noted that all dams affect passage, if not for salmonids then for the myriad of other aquatic creatures that are not powerful swimmers. Dams effectively truncate the ranges of populations that may otherwise interbreed. Downstream populations may still receive breeding individuals from upstream habitats, but individuals above the blockage are, to varying degrees, isolated from the lower basin.

Hatcheries - We considered including hatcheries in the suitability index but we dropped them as the information on species raised and released was very unreliable. This problem is compounded by the common practice of trucking smolts to other drainages for release. Also, the effects of hatcheries vary with management and size of the hatchery. If an accurate assessment of the impacts of hatcheries could be derived, it could be a valuable addition to the suitability index.

6.3.2 Terrestrial Suitability Index

We used road density and percent converted land (i.e., urban and agricultural) as surrogates for habitat fragmentation.

Management status, percent converted land and road density were the three terms in the suitability index. Suitability for each HUC was calculated as:

SUITABILITY = A * N (management status score) +
B * N (converted land score) +
C * N (road density)

Where A+B+C = 1; N(x) is the normalized value of x; and management status, converted land, and road density are normalized by dividing each HUC’s value by the maximum value of all HUCs.

The values for A, B, and C were determined through expert opinion using the pair-wise comparisons technique. To simply the elicitation process, we used the abbreviated pair-wise comparisons technique. That is, we assumed perfect internal consistency for each expert, which allowed us to reduce the number of comparisons. For the terrestrial index, three members of the technical team and one outside expert were asked to assign relative importance values to each of the three terms. Weights were calculated for each expert from the eigenvalues of their pair-wise comparisons matrix. The weights from all four experts were averaged and then normalized to yield: A = 47, B= 30, C= 23.

For the management status term we started with the categories used in the state GAP programs (Cassidy et al. 1997, Kagan et al. 1999). We then created new sub-categories which resulted in 9 status types. Experts were asked about the relative impacts on biodiversity of these different types of land management. Again, the relative impact values were calculated using the pair-wise comparisons technique (Table 6.2). The values sum to 100. They were applied to an ownership grid in GIS and a mean value was calculated for each HUC.

Table 6.2 Relative impact values for different types of ownership and management.

(GAP refers to status assigned by GAP program; fed LSR, fed AMA, and HCP mean federal late successional reserve, federal adaptive management area, and habitat conservation plan, respectively)

Management Status	Impact Value
GAP 2	2
GAP 1	1
GAP 3 / fed LSR	4
GAP 3 / fed AMA	6
GAP 3 / fed Matrix	7
GAP 3 / HCP	10
GAP 3	13
GAP 4 / HCP	27
GAP 4	30

The experts agreed that existing public land is generally more suitable for conservation than private land. This result is consistent with the Gap Analysis Program (Cassidy et al. 1997, Kagan et al. 1999). Both the Oregon and Washington GAP projects rated most public lands as better managed for biodiversity than most private lands. Furthermore, eminent conservation biologists have noted that existing public lands are the logical core areas for large multiple-use landscapes where biodiversity is a major management goal (Dwyer et al. 1995). By focusing conservation on lands already set aside for public purposes the overall cost of conservation would be less than if public and private lands were treated equally.

Two well-accepted principles of conservation biology (Diamond 1975, Forman 1995) state that:

1) Large areas of habitat are better than small areas.

2) Habitat areas close together are better than areas far apart.

To direct the selection algorithm toward larger and closer conservation areas the management status GIS layer was process as followed. The ecoregion boundary was buffered by 10 km to include any existing public lands that were just outside the ecoregion but could be part of the conservation network. Each polygon with GAP status 1, 2, or 3 was buffered by 10 concentric rings. Width of the buffers was a function of the polygon area. Area of the first concentric buffer was approximately half the GAP polygon area. The next nine buffers had the same width as the first. Bigger “reserves” had wider buffers and so their influence extended further out from their boundary. One purpose of the buffers is to “attract” new conservation areas to existing protected areas in portfolio assembly, thereby building large, well-connected conservation landscapes. Ownership pixels were assigned values according to Table 6.2. The values assigned to each successive concentric buffer increased linearly to 30. Where buffers from two or more GAP polygons overlapped, the costs at that point in space were reduced to reflect the conservation benefits of multiple nearby conservation areas.

The percent converted land was also decomposed into parts. Experts were asked to assign weights to the sub-terms:

Converted land score = j *(%urban) + k * (%agricultural)
Where j = 92 and k = 8.

The HUCs in the NW Coast ecoregion exhibit a wide range of sizes from 1,700 ha to 180,000 ha. HUC area should influence site selection because the real cost of a conservation site is related to its area. Larger conservation sites are more costly to obtain and to maintain, smaller HUCs are more efficient. To account for area, we combined suitability and HUC area with the weighted geometric mean:

$$\text{COST} = [N(\text{suitability})^{X} * N(\text{HUC area})^{Y}]^{[1/(X+Y)]}$$

If X + Y = 1, then the equation simplifies to:

$$\text{COST} = N(\text{suitability})^{X} * N(\text{HUC area})^{Y}$$

The geometric mean is commonly used for habitat suitability indices (USFWS 1981). We used the geometric mean for two reasons. First, if the suitability of a HUC equals zero, then that HUC is highly desirable and its overall cost should be zero regardless of area. Second, suitability and area are grossly incommensurate, and therefore, should not be summed. The values of X and Y for the final cost equation were set to 0.75 and 0.25, respectively. Terrestrial suitability is shown in Map 6.3.

6.3.3 Freshwater Suitability Index

Management status, percent converted land, road density and purely aquatic factors (dams and 303d streams) were the four terms in the aquatic suitability index. Suitability for each aquatic planning unit was calculated as:

$$\begin{aligned}\text{SUITABILITY} = {} & A * N(\text{management status score}) + \\ & B * N(\text{converted land score}) + \\ & C * N(\text{road density}) + \\ & D * N(\text{aquatic factors})\end{aligned}$$

Where A+B+C+D = 1; N(x) is the normalized value of x; and management status, converted land, road density and aquatic factors are normalized by dividing the value of each by the maximum value of all HUCs.

The values for A, B, C and D were determined through expert opinion using the pair-wise comparisons technique. To simply the elicitation process, we used the abbreviated pair-wise comparisons technique. That is, we assumed perfect internal consistency for each expert, which allowed us to reduce the number of comparisons. For the terrestrial index, three members of the technical team and one outside expert were asked to assign relative importance values to each of the three terms. Weights were calculated for each expert from the eigenvalues of their pair-wise comparisons matrix. The weights from all four experts were averaged and then normalized to yield: A = 9, B= 61, C= 9 and D= 21.

For the management status term we started with the categories used in the state GAP programs (Cassidy et al. 1997, Kagan et al. 1999). We then created new sub-categories which resulted in 9 status types. Experts were asked about the relative impacts on biodiversity of these different types of land management. Again, the relative impact values were calculated using the pair-wise comparisons technique. The values sum to 100. They were applied to the ownership coverage in GIS and a mean value was calculated for each HUC.

The percent converted land was also decomposed into parts. Experts were asked to assign weights to the sub-terms:

> Converted land score = i *(%urban) + j *(%agricultural) + k *(%early seral)
> Where i = 93, j = 6, and k = 2.

The aquatic factors were also decomposed into parts. Experts were asked to assign weights to the sub-terms:

> Aquatic factor score = u * (fish passage impacts from dams) + v *(hydrologic impacts from dams) + w *(303d stream presence/absence)
>
> Where u = 26, v = 41 and w = 33.

Planning unit area should influence site selection because the real cost of a conservation site is related to its area. Larger conservation sites are more costly to obtain and maintain, smaller sites are more efficient. To account for area, we combined suitability and planning unit area with the weighted geometric mean:

$$COST = [N\ (suitability)^{X} * N(HUC\ area)^{Y}]^{[1 / (X+Y)]}$$

If X + Y =1, then the equation simplifies to:

$$COST = N\ (suitability)^{X} * N(HUC\ area)^{Y}$$

The values of X and Y for the final cost equation were set to 0.75 and 0.25, respectively.

6.3.4 Integrated Suitability Index

The aquatic and terrestrial suitability indices were derived separately. The suitability index for the integrated runs for all AUs with both aquatic and terrestrial targets was roughly the average of the aquatic and terrestrial suitability indices, as described in the following paragraph. Estuaries and small coastal watersheds which had no aquatic targets retained their terrestrial suitability index value.

The combined suitability index was derived as follows. The normalized terrestrial and aquatic suitability values were increased so that their sum was roughly equal to the sum of the boundaries in the objective function (sum of the suitability costs + sum of boundaries + sum of penalty factors). This prevented either parameter from overwhelming the objective function and producing an erroneous output. The terrestrial costs were allowed to be slightly higher than the aquatics as we had more confidence in the terrestrial information. For the entire ecoregion, the sum of the aquatic AU costs was 70% of the sum of the terrestrial suitability costs.

6.3.5 Marine Suitability Index

The nearshore environment is not easily defined or mapped. It is subject to forces both oceanic and terrestrial, producing ecosystems that are dynamic and "open" in nature. It is not surprising, that coastal areas are affected by human activities in nearby watersheds, the marine environment, and on the shore itself.

When the marine technical teams began designing a nearshore suitability index it was evident that terrestrial, freshwater, and marine impacts had to be considered. The nearshore suitability index refers to factors that either adversely affect the health of an ecosystem (human impacts) or make conserving a particular area less feasible (designation of land use and socio-economic values). Using an index for site selection tends to reduce selection of places where human uses or modifications restrict conservation options. These “costs” indicate whether a place is either more or less suitable for conservation action.

The nearshore suitability index was characterized around three main categories: a) shoreline impacts, b) adjacent terrestrial, freshwater, and marine factors, and c) management designations across all environments (Map 6.4).

6.3.5.1 Shoreline Impacts

The nearshore has been described as having a high degree of biological productivity, is the part of the marine ecosystem that includes and is most likely influenced by riparian interactions, and is also affected the most from anthropogenic disturbances/interactions (Brennan and Culverwell, in press). Coastal development, a major threat to estuarine and nearshore ecosystem function, alters the physical condition of the shoreline which in turn changes the biological structure and functioning of shoreline habitats (see Shreffler et al. 1994).

In the Pacific Northwest Coast ecoregion some of the most dramatic alteration of the shoreline environment has come from shoreline armoring, or bulkheading. Placing vertical seawalls, riprap, and other coastal structures in the intertidal zone dramatically changes sediment and species composition. In addition, the fish and timber industry heavily utilizes the nearshore for transferring logs and growing exotic finfish and shellfish. Logging practices along the coast can lead to significant surficial erosion that result in lost topsoil, siltation and burial of aquatic life. Once the logs are piled in estuaries and embayments they can further damage the coastal environment by impacting the soft bottoms utilized by shellfish and seagrasses. Aquaculture also impacts the nearshore by exposing the environment to high amounts of nitrogen, phosphorus, and fecal matter (see Pew Oceans Commission 2003). Exotic fish that escape their pens can alter native species composition by establishing themselves in surrounding stream systems. Facilities including sewerage treatment buildings, pulp mills, and agricultural fertilizer and chemical plants were also considered causes of nearshore species decline and habitat degradation.

All the shoreline impacts were given a relative score. In our scoring system we assumed that finfish tenures or leases for fish farming and log transfer sites have the highest shoreline impacts, followed by coastal structures and facilities. Bulkheads were separated into two categories where they were consider high if the armoring covered at least half of the entire length of a shoreline unit. The shellfish tenures or leases were also broken into two categories, here separated by the density of tenures in any coastal area. Most all of the sites were determined to be of low density, but a few places in British Columbia contained two or more tenures per shoreline unit. In these cases they were considered to be of high density. Hatcheries were given the lowest relative score because this impact was not considered as detrimental to the nearshore environment. Coastal hatcheries were not considered to be a direct impact to the nearshore, unlike fish farming. We recognize that these scores can be debated and need further examination (e.g., some argue that aquaculture practices are not nearly as detrimental to the marine environment as suggested here, while others view hatcheries as a beneficial factor in increasing fish production and therefore should be removed from the index). Due to limitations in the data, hatcheries in Washington and Oregon were not included in the analysis.

Data sources included shoreline armoring and bulkheading data (ODFW, WDNR, MSRM), fish and shellfish aquaculture sites (WDNR, MSRM, BC Department of Fisheries & Oceans (DFO), log transfer sites (MSRM, DFO), coastal hatcheries (MSRM), and industrial/treatment facilities (DLCD, WDNR, MSRM, DFO). Coastal structures have been mapped as point and linear features and attributed to the same spatial data as the shoreline conservation targets. Log transfer sites and tenure data have been mapped as either points or polygons illustrating their general location. The point data were attributed to the shoreline features (e.g., a log transfer site was associated with a linear shoreline segment). Where tenures and log transfer sites were represented as point data they were included in the shoreline impact analysis; where they were represented as areal extents they were included in the adjacency analysis (described in the next section). For both analyses the impact scores were the same. Point locations of coastal facilities were included in the analysis where they were within 500 meters from shore.

We then calculated a shoreline cost within both shoreline AUs (linear-based) and nearshore AUs (nested grids). For shoreline AUs we determined a base cost of 435 meters, or the mean shoreline length across the ecoregion. If all shoreline impacts occurred in an AU the total shoreline cost would add up to twice the base cost, or 870 meters (Table 6.3). An alternative approach would be to classify the shoreline into length classes and assign higher scores to longer segments. We decided to assign every shoreline unit the same base cost because we could not make the assumption that longer stretches of beach have more impacts (e.g., small rocky coves could be heavily developed while long sandy beaches could have relatively little impact across its entire length). For nearshore AUs, we used AU size (400 hectares) as the base cost.

The shoreline cost was calculated for each AU with the equation:

Shoreline cost = base cost + (base cost * cumulative impact scores)

Table 6.3 Shoreline impacts, relative impact scores and associated costs

Shoreline impacts	Impact scores	Base cost	Shoreline costs
Bulkhead high	0.25	435	108.75
Bulkhead low	0.15	435	65.25
Finfish tenure	0.35	435	152.25
Shellfish tenure high	0.3	435	130.5
Shellfish tenure low	0.2	435	87
Hatcheries [1]	0.15	435	65.25
Facilities	0.25	435	108.75
Log transfer sites	0.35	435	152.25
Total	**2**		**870**

[1] Due to limitations in the data, only hatcheries in British Columbia were included in the analysis.

6.3.5.2 Adjacent terrestrial, freshwater, and marine factors

Estuaries have long been recognized as the confluence of a freshwater source and the marine environment (MacKenzie and Moran 2004), but there is a growing amount of attention in the scientific literature regarding the concept of a marine riparian zone across the entire coastal environment (e.g., Desbonnet et al. 1994, Lemieux et al. 2004, Levings and Jamieson 2001, NRC 2002). In their manuscript, Brennan and Culverwell (unpublished) define the marine riparian as “riparian systems located in those areas on or by land bordering a wetland, stream, lake, tidewater, or other body of water that constitute the interface between terrestrial and aquatic ecosystems.” The health and integrity of the nearshore ecosystem is significantly influenced by the character of the land adjacent to marine shorelines and the transport mechanisms from both the degree of freshwater flow and tidal flooding.

Commercial and residential development along our coasts is transforming land at an unprecedented rate. Coastal counties, which comprise just 17 percent of the land area nationwide, are now home to more than half of the U.S. population (Pew Oceans Commission 2003). And with another 25 million people living along the coast by 2015 (Beach 2002), our wetlands, estuaries, and other coastal habitats will continue to be strained. As mentioned above, coastal development adjacent to the shoreline is a major threat to the nearshore. Habitat destruction and the decline of coastal water quality resulting from upland development are a leading cause of species decline (e.g., Doyle et al. 2001).

Adjacent terrestrial and marine impacts were factored into the nearshore suitability index (Table 6.4). We will incorporate watershed and freshwater characteristics (e.g., drainage area, flow accumulation) in further iterations of the index. Similar to the costs assigned in the terrestrial suitability index, industry and urban areas were assigned a higher score than agriculture and early seral forests. Dredge disposal sites in Oregon and contamination sites in British Columbia were also included in the industrial category. Unlike the terrestrial suitability, however, where road density was calculated as a normalized cost per watershed area, we separated highways and railroads from other roads as higher cost. The length of road was not assigned a cost relative to the size of the AU, but was given an overall weight relative to other land use factors. In addition, we used adjacent marine impacts including the areal extent of finfish and shellfish tenures as well as log transfer sites in estuaries and embayments. These factors are listed under the shoreline impact table.

Table 6.4 Adjacency factors, relative impact scores, and associated costs

Adjacency or land use impacts	Impact scores	Base cost	Adjacency costs
Early Seral	0.05	435	21.75
Agriculture	0.15	435	65.25
Urban	0.25	435	108.75
Industrial	0.35	435	152.25
Roads/Secondary	0.15	435	65.25
Highways/Railroad	0.25	435	108.75
Total	**1.2**		**522**

Unlike the terrestrial suitability index that calculated different cost factors within watershed AUs, we designed a method of calculating the influence of adjacent land and water conditions that either directly or indirectly affect the shoreline. Adjacent lands were considered to be all watersheds (USGS HUCs, level 6 – the terrestrial AUs) that directly drain into the coastal zone. The adjacent waters were considered to be all nearshore waters within a 500 meter buffer of the coast.

The analysis of adjacency factors was done in the grid (i.e, raster) environment, where all data sets were transformed to grid cell data and assigned their relative impact scores.

Data sources included a combination of land use/land cover data (Vancouver Island 1:250,000 thematic map by BTM containing 19 classes including 3 seral stages; WDFW contained 10 classes with 3 seral stages; CLAMS covered Oregon, containing 4 seral stages; USGS 1:100,000 contained 4 classes, updated by Pacific Meridian Resources) and associated Estuary Plan Book data (DLCD), roads data (compiled by TNC Oregon), dredging disposal sites in the Estuary Plan Book (DLCD), aquatic lands designations from the aquatic ownership data (WDNR), fish and shellfish aquaculture sites (WDNR, MSRM, DFO), log transfer sites (MSRM, DFO), and contamination sites (DFO).

All impact factors were combined for each cell. We then assigned the relative impact scores to each factor and summed the impact scores for every cell to derive a new grid. The range of scores across all factors was from 0.05 to 0.85.

Since we were interested in the interaction between these costs and their association with the nearshore, we performed a moving window average to evaluate all cells in the coastal watersheds as they entered the coastal zone. We used a circular neighborhood with radius roughly 250 meters, or 17 cells wide based on a 30 meter cell size (510 meters). The mean value is assigned to the grid cell at the center of the analysis window.

The last step was to calculate a single cost value per AU. We did this for both shoreline (linear) and nearshore (areal) AUs. The cost was the mean value of all grid cells in the AU. The adjacency cost was calculated as:

Adjacency cost = base cost + (base cost * mean of impact scores)

For nearshore AUs, we used AU size (400 hectares) as the base cost; for shoreline AUs we used mean length (435 meters).

6.3.5.3 Management designations across all environments

We recognize that assigning relative values to management designations in the marine environment according to their level of protection is more difficult than on land. This difficulty arises because there are often multiple factors to consider including what is being protected, what portion of the marine environment is actually within designated boundaries, and what uses are allowable. For instance, the Olympic Coast National Marine Sanctuary (OCNMS or sanctuary) was designated in 1994 as part of the federal National Marine Sanctuary System. The area was recognized for its extraordinary beauty and rich biological diversity, as a marine area deserving of enhanced protection and preservation (OCNMS Advisory Council 2003). OCNMS covers approximately 8,550 square kilometers of the outer coast of Washington, stretching north from the Copalis River around Cape Flattery to Koitlah Point, approximately 4 nautical miles into the Strait of Juan de Fuca. OCNMS was established as a multiple use marine protected area, with mandates for resource protection, research, and education, but with relatively few restrictions on human activities. Activities prohibited by sanctuary regulations include overflights below 2,000 feet within 1 nautical mile of the coast or national wildlife refuge islands, oil exploration and drilling, extraction of ocean minerals, alteration of the seafloor with the exception of traditional fishing practices, and discharge and deposit of materials. The marine conservation working group’s final report for the sanctuary (OCNMS Advisory Council 2003) recognizes that although existing regulations do provide a level of protection to meet the sanctuary’s mission of ecosystem-wide conservation of ecological and historic resources, activities such as gathering of intertidal resources and bottom trawling continue to occur at levels that are poorly documented or in ways that might contribute to habitat degradation. This, along with state and tribal jurisdiction and rights within the sanctuary, further complicate an assessment of marine protection (see Chapter 5).

Among the three terms of the overall suitability index we scored the shoreline impacts highest followed by adjacency impacts and management impacts. We used the work of the Gap Analysis Program as a baseline for scoring management status (see Cassidy et al. 1997, Kagan et al. 1999). We assumed that protected and natural area categories receive less human impact and are managed for biodiversity relative to areas designated as pubic resources or private lands (Table 6.5). The protected areas category included marine protected areas in British Columbia, the National Marine Sanctuary, National Wildlife Refuges, National Estuarine Research Reserves, National Parks, Wilderness areas, and Nature Conservancy preserves. The natural areas category included state, provincial, and county parks, marine gardens, and research reserves. Other public lands designated for multiple-use were given a higher score, but ranked lower than all private lands. The public lands category included National Forest Service, Bureau of Land Management, British Columbia Crown Lands, and designated public tidelands and bedlands. We assumed that private industrial lands, commercial industry, or areas projected for industrial development represented the highest potential impact. Private lands including tribal reservations, oyster tracts, and urban areas were given a slightly lower score (private lands/urban).

Table 6.5 Management Impacts, impact scores, and associated costs

Management Impact	Impact scores	Base cost	Management costs
Protected areas	0.01	435	4.35
Natural areas	0.05	435	21.75
Public\multiple use areas	0.15	435	65.25
Private lands\urban	0.25	435	108.75
Private lands\industrial	0.35	435	152.25
Total	**0.81**		**352.35**

For each AU, we summarized the management impact scores in a manner very similar to how we dealt with the adjacency impact factors. The combinations of management imopact factors were then summed for each grid cell. The range of total weights across all factors was from .01 to 0.6.

In a similar fashion to computing the adjacency costs, we did a moving window average with a circular window with radius roughly 250 meters). The next step was to calculate a single mean management impact score for each shore and nearshore AU. Lastly, the management impact was calculated as:

Management cost = base cost + (base cost * mean of management impact scores)

For nearshore AUs we used the grid size (400 hectares) as the base cost; for shoreline AUs we used mean length (435 meters).

The final step of the suitability analysis was to combine shoreline, adjacency, and management costs to produce an overall cost per AU. Up to this point we had constructed stand alone costs to test the sensitivity of site selection for each category. After a preliminary assessment, we combined all three categories in a single index. The formula to calculate the overall index was:

Overall suitability index = base coast + shoreline costs + adjacency costs + management costs

The range of the suitability index was 435 to 923 for shoreline AUs, and 400 to 752 for the nearshore units. Initially we designed three scenarios for the overall index. The first assigned all AUs equally using either the shoreline or nearshore base cost. The second scenario is illustrated in the explanation of methods and scores above. We also conducted a third scenario that increased the range of scores across all factors to see how site selection would be affected. After testing these scenarios we determined that the scores and process described above validated conditions on the ground and in the water, and that site selection was more accurately represented using the second scenario. This scenario best supported the optimization of the least area needed to meet the conservation goals for all targets.

Chapter 7 – Prioritization of Assessment Units

7.1 Introduction

A conservation portfolio could serve as a conservation plan to be implemented over time by nongovernmental organizations, government agencies and private land owners. In reality, though, an entire portfolio cannot be protected immediately and some conservation areas in the portfolio may never be protected (Meir et al. 2004). Limited resources and other social or economic considerations may make protection of the entire portfolio impractical. This inescapable situation can be addressed two ways. First, we should narrow our immediate attention to the most important conservation areas within the portfolio. This can be facilitated by prioritizing conservation areas. Second, we should provide organizations, agencies and land owners with 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 inform everyone about their options for conservation.

The prioritization of potential conservation areas is an essential element of conservation planning (Margules and Pressey 2000). The importance of prioritization is made evident by the extensive research conducted to develop better prioritization techniques (e.g., Margules and Usher 1981, Anselin et al. 1989, Kershaw et al. 1995, Pressey et al. 1996, Freitag and Van Jaarsveld 1997, Benayas et al. 2003). Consequently, many different techniques are available for addressing the problem of prioritization. None are obviously better than the rest. We used two different techniques – an optimal site selection algorithm and a scatterplot – that together yielded four indices (irreplaceability, utility, and two Euclidean distances) each indicating relative priorities.

Irreplaceability and conservation utility scores were generated for the integrated realms (terrestrial, freshwater, and estuary) and for the terrestrial realm alone. A sensitivity analysis was done for only the terrestrial realm. The terrestrial realm was done separately because: (1) the terrestrial data have a greater influence on the portfolio than the freshwater data; (2) terrestrial environments and species have been more thoroughly studied, and therefore, our assumptions about terrestrial biodiversity are more robust than for estuary or freshwater biodiversity; and (3) the terrestrial portfolio has the greatest potential influence on land use planning and policy decisions affecting private lands as land ownership is a key determinant in land management.

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

7.2 Methods

7.2.1 Irreplaceability

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, Stewart et al. 2003). However, the original operational definition was given 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.

Simulated annealing is a stochastic heuristic search for the global minimum of an objective function. Since it is stochastic, or random, simulated annealing can arrive at different answers for a single optimization problem. The algorithm may not converge on the optimal solution, i.e., the global minimum, but it will find local minima that are nearly as good as the global minimum (McDonnell et al. 2002). The random search of simulated annealing enables it to find multiple nearly-optimal solutions, and an AU may belong to many different nearly-optimal solutions.

The number of simulated annealing solutions that include a particular AU is a good indication of that AU's irreplaceability. This is the assumption made by Andelman and Willig (2002) and Leslie et al. (2003) for their irreplaceability index. The index of Andelman and Willig (2002) was:

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

where H 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. H_j have values between 0 and 1, and are obtained from a 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 irreplaceablity scores. The fact that some AUs go from zero irreplaceabilty to a positive irreplaceability demonstrates a shortcoming of Willig and Andelman's index – at low representation levels, some AUs are shown as having no value for biodiversity conservation. We created an index for relative irreplaceabilty that addresses this shortcoming. Our comprehensive irreplaceability index for AU_j was defined as:

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

where H_{jk} are relative irreplaceability values as defined in equation (2) and m is the number of representation levels used in the site selection algorithm. I_j have values between 0 and 1. Each H_{jk} is relative irreplaceability at a particular representation level. We ran SITES at ten representation levels. 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. We too had the selection algorithm minimize the total area of selected AUs. That is, the "cost" of each AU was its area. Consequently, efficiency is indirectly incorporated into our estimates of irreplaceability.

7.2.1.1 Conservation Utility

We expanded upon the concept of irreplaceability with *conservation utility*, a term coined by Rumsey et al. (2004). Conservation utility is defined by equation (2), but the selection frequency is generated with the AU costs incorporating a suitability index. To create a map of conservation utility scores, AU "cost" reflects practical aspects of conservation – current land uses, current management practices, habitat condition, etc. (see section 6.5). In effect, conservation utility is a function of both biodiversity value and the likelihood of successful conservation.

7.2.1.2 Representation Levels

Each representation level corresponds to a different degree of risk for species extinction. Although we cannot estimate the actual degree of risk, we do know that risk is not a linear function of representation. It is roughly logarithmic.

Coarse Filter

We based the assumption that there is a logarithmic relationship between the risk of species extinction and the amount of habitat on the species-area curve. The species-area curve is arguably the most thoroughly established quantitative relationship in all of ecology (Connor 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 says 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 of the study. Most values lie between 0.15 and 0.35 (Wilson 1992). An oft cited rule-of-thumb for z's value is called Darlington's Rule (MacArthur and Wilson 1967, Morrison et al. 1998). The rule states that a doubling of species occurs for every 10 fold increase in area, hence $z = \log(2)$ or 0.301. We used this relationship to derive representation levels that roughly correspond to equal increments of biodiversity – i.e., each increase in coarse filter area captured an additional 10% of species .

Fine Filter

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:

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

where pr(P) is the persistence probability of each isolated population and n is the number of populations. This equation says, in effect, that the first population (i.e., occurrence) is more important than the second population and much more important than the tenth population. That is, the function exhibits diminishing returns as the number of occurrences increases. According to this relationship, if we want representation levels to correspond to equal degrees of risk, then fine filter representation levels should not increase linearly but logarithmically. However, the above equation won't work for our purposes. We don't know pr(P).

Luckily another relationship was available to us – the criteria used by natural heritage programs to rank species. These criteria indicate the degree of imperilment, i.e., the risk of extinction, and follow a logarithmic relationship. For instance, one criterion relates the number of occurrences to degree of imperilment (Master et al. 2003; unpublished report). We used this and other such criteria to develop fine filter representation levels. The representation levels are explained more fully in Appendix 7B.

7.2.1.3 Running the Selection Algorithm

SITES produces an output that is equivalent to nH_j, i.e., the number of times an AU was selected out of n replicates. We ran 25 replicates at each representation level. Hence, the product m * n equaled 250 for both irreplaceability and conservation utility. For the integrated analysis, the boundary modifier (BM) was set to 0.1 to link the layers in vertical stacking (see section 8.3). For the terrestrial only analysis, BM was set to zero. When BM is set to zero, neighboring AUs have no influence on the selection frequency of an AU. A more detailed explanation of running the SITES for site prioritization is given in Appendix 6A.

7.2.2 Irreplaceability versus Vulnerability Scatterplot

The irreplaceability versus vulnerability scatterplot was first used by Pressey et al. (1996, as described by Margules and Pressey 2000) and was also recently used by Noss et al. (2002) and Lawler et al. (2003). These studies plotted irreplaceability versus vulnerability for a large number of potential conservation areas. We plotted irreplaceability versus vulnerability for every AU. 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, Stewart et al. 2003). Our definition of irreplaceability (see Section 7.1.1) is similar to those of Andelman and Willig (2002) and Leslie et al. (2003). We used the irreplaceability scores from the integrated terrestrial and freshwater analysis.

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. Our suitability index incorporated factors that reflected both current habitat conditions and management. Therefore, for the purposes of prioritization, we assumed that our suitability index could also be used as a vulnerability index. Recall that the cost index was the weighted geometric mean of AU area and suitability. For the vulnerability index we used only the suitability. 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 scatterplots into four quadrants which correspond to priority categories: high irreplaceability, high vulnerablity (Q1); high irreplaceability, low vulnerability (Q2); low irreplaceability, low vulnerability (Q3) and low irreplaceability, high vulnerability (Q4). Potential conservation areas in Q1 were considered the highest priority. Potential areas in Q3 were the lowest priority. Quadrants Q2 and Q3 were moderate priorities. 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 scatterplot into quadrants is to assign AUs to priority categories. But the scatterplot can be divided other ways as well. We utilized four others. First, as done by Lawler et al. (2003), we divided the scatterplot into 16 sub-quadrants using the quartile values for irreplaceability and vulnerability. Each sub-quadrant corresponds to a priority category.

The assessment covered 2442 AUs. Hence, roughly 611 AUs fell into each quadrant of the scatterplot, and average number of AUs in each sub-quadrant was 153. For the purposes of directing conservation action, this may be far too many AUs per category. We were most interested in the small number AUs with the highest irreplaceability and the highest vulnerability. For that reason, we divided the scatterplot at the 99.5, 99, 98, 96, 92, and 84 percentiles for both irreplaceability and vulnerability. This created 36 cells in upper right-hand corner of the scatterplot.

The third and fourth ways for subdividing the scatterplot were based on Iso-euclidean distance contours. In theory, the highest priority possible is an AU with both irreplaceability and vulnerability equal to 100. Assuming that the qualities of irreplaceability and vulnerability are equally important for determining AU priorities, the distance between an AU and the upper right-hand corner of the scatterplot would determine its priority for conservation. This distance is calculated with the equation:

$$D = [(100 - I)^2 + (100 - V)^2]^{1/2}$$

where I is irreplaceability, V is vulnerability, and D is the Euclidean distance of an AU from the point (100, 100). Our contours corresponded to percentiles – 0.5, 1, 2, 4, and 8 percent of AUs.

Some might argue that the highest priorities for conservation should be the AUs with the highest irreplaceability and the lowest vulnerability. These AUs have high biological value and are places where conservation will most likely succeed. Following this strategy, the distance between an AU and the upper left-hand corner of the scatterplot would determine its priority for conservation. This distance is calculated with the equation:

$$D = [(100 - I)^2 + V^2]^{1/2}$$

The assumption that irreplaceability and vulnerability are equally important does not hold over the entire scatterplot. For instance, two AUs situated at (100, 1) and (1, 100) are the same distance from the (100, 100) corner of the scatterplot, but certainly the AU at (1, 100) should be a much higher priority. However, in the immediate vicinity of the (100, 100) or (0, 100) corners, the Euclidean distance can be a useful index to sort out priorities. Incidentally, the divisions used by Margules and Pressey (2000) and Noss et al (2002) to divide their scatterplots into quadrants imply that irreplaceability and vulnerability are equally important. Lacking a strong rationale for favoring either axis we followed their convention.

7.2.3 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, pp. 59-61). Sensitivity analysis serves two main purposes: (1) to measure how much influence each parameter has on the model output; and (2) to evaluate the effects of poor parameter estimates or weak assumptions (Caswell 1989). Through a sensitivity analysis, we can ascertain the robustness of our results and judge how much confidence we should have in our conclusions.

The selection algorithm input with the greatest uncertainty is the cost index. The cost index is not a statistical model – variable selection and parameter estimates for the index were based on professional judgment. For this reason, our sensitivity analysis focused on the index. Other assessments have incorporated a cost index or something similar in an optimal site selection algorithm (Davis et al. 1996, Nantel et al. 1998, Stoms et al. 1998, Davis et al. 1999, Lawler et al. 2003). Only Davis et al. (1996) and Stoms et al. (1998) investigated the sensitivity of site selection to changes in their index.

We explored sensitivity to the cost index 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. A more detailed explanation of the sensitivity analysis is given in Appendix 7B.

7.3 Results

7.3.1 Irreplaceability and Conservation Utility

7.3.1.1 Terrestrial Only Analysis

The irreplaceability and utility maps for the terrestrial only analysis are shown in Maps 7.1 and 7.2. The irreplaceability and utility scores can be displayed two ways: (1) the distribution of nonzero scores divided into deciles (10% quantiles); and (2) range of nonzero scores divided into 10 equal intervals. Deciles answer the question, where are the AUs with a selection frequency, or score, in the top 10 percent of all AUs. Equal intervals answer the question where are the AUs with a score greater than 90. The maps show deciles. By coincidence, the number of AUs in the top decile and with a score greater than 90 is about equal, 9.1 and 9.2 percent of AUs had a score greater than 90 for irreplaceability and utility, respectively.

AUs with scores equal to 100 are those selected in every replicate at every representation level. Seven percent of AUs had a utility score of 100, 7.1 percent had an irreplaceability score of 100 (Table 7.1), and 6.5 percent of AUs had both scores equal to 100. This large overlap between utility and irreplaceability at the highest possible score is evident in Figures 7A.1 and 7A.2 (Appendix 7A).

At the lowest representation level, the best solutions for irreplaceability and utility consisted of 270 and 252 AUs, respectively. Perfect scores were attained by 83 percent of the irreplaceability best solution and 85 percent of the utility best solution. The large proportion of AUs with scores equal to 100 demonstrates how little flexibility existed even at the lowest representation level. That is, rare targets could only be captured at particular AUs.

The median and mean of irreplaceability scores (i.e., 24, 34) are larger than those of utility scores (i.e., 11, 28). When the cost of AUs is equal to area (i.e., irreplaceability), the selection algorithm prefers smaller AUs. A preference for smaller AUs means that more AUs must be selected to meet the coarse filter representation levels. As expected, the total area of best solutions for irreplaceability is less than the total area of best solutions for utility, but more AUs are needed for irreplaceability solutions. Because the algorithm selects more AUs for irreplaceability solutions than for utility solutions, *I* and G are larger for irreplaceability. More comparisons between irreplaceability and utility are described in Appendix 7A.

7.3.1.2 Integrated Analysis

Recall that the data inputs to the selection algorithm consisted of three different layers: terrestrial, freshwater class 1, and freshwater classes 2 and 3. AU boundaries for terrestrial and freshwater class 1 were the same HUC watersheds. Irreplaceability and utility scores were computed for every AU in each layer. To calculate single scores for each HUC, we added the scores for terrestrial and freshwater class 1 AUs and normalized the combined scores across all AUs to 100. Some freshwater class 1 AUs contained no occurrences and these AUs were never selected by the algorithm. Irreplaceability and utility scores for the corresponding terrestrial AU were normalized to 100. The irreplaceability and utility maps for the integrated analysis are shown in maps 7.3 and 7.4.

If all AUs in every layer are viewed as separate AUs, then certain results are very similar to those of the terrestrial only analysis (Table 7.1, Figure 7A.2). The percentage of AUs with high irreplaceability and utility scores and the distribution of scores are about the same as those from the terrestrial analysis. However, when terrestrial and freshwater scores are combined then the proportion of AUs with high scores is much reduced (Figure 7A.3 in Appendix 7A).

Table 7.1 Percentage of AUs with high irreplaceability and conservation utility scores. "No data" AUs are those that had no freshwater target data.

	Selection Frequency	Terrestrial Analysis	Integrated Analysis				
			All AUs All Layers	Terrestrial AUs, Terrestrial Layer	Class 1 AUs; Freshwater Layer	Combined Terrestrial/ Freshwater; Include No Data AUs	Combined Terrestrial/ Freshwater; Exclude No Data AUs
Number of AUs		2707	5343	2707	2123	2707	2123
Utility	100 %	7.0	7.8	7.2	6.7	1.3	0.6
	≥ 95 %	8.3	8.8	8.1	7.4	2.0	1.2
Irreplaceability	100 %	7.1	7.9	7.4	6.5	1.9	1.0
	≥ 95 %	8.5	9.1	8.7	7.4	2.5	1.6

7.3.2 Irreplaceability versus Vulnerability Scatterplot

The assessment covered 2442 AUs. Hence, roughly 611 AUs fell into each quadrant of the scatterplot. The quartiles defining the sub-quadrants are given in Table 7.2. The average number of AUs in each sub-quadrant was 153 but ranged from 112 to 202. The scatterplot is shown in Figure 7A.4 (Appendix 7A).

The scatterplot shows a very high density of AUs in the region below the third quartiles of irreplaceability and vulnerability. In effect, AUs in each of these sub-quadrants are very similar and are not distinct enough to warrant different priorities. AU density in the scatterplot decreases as irreplaceability and vulnerability increase. This separation of AUs suggests real differences in AU priorities.

Four sub-quadrants contain AUs with irreplaceability scores in the top quartile. These four quadrants contain 608 AUs – far too many to be useful for prioritization. The 36 cells based on the 99.5, 99, 98, 96, 92, and 84 percentiles for both irreplaceability and vulnerability contain 102 AUs, a more manageable number. How these AUs are distributed among cells is shown in Table 7.3.

The distribution of AUs relative to iso-Euclidean distance contours is shown in Figures 7A.5 and 7A.6 (Appendix 7A). Many of those AUs closest to the upper right-hand corner of the scatterplot have only modest irreplaceability scores (Table 7.4). Some of these AUs have rather low utility scores because according to the suitability index they are a relatively poor choice for conserving biodiversity. For the same reason, utility is usually lower than irreplaceability for these AUs. In constrast, AUs closest to the upper left-hand corner of the scatterplot have high scores for both irreplaceability and utility (Table 7.5).

Table 7.2. Summary statistics for irreplaceability and vulnerability. The variance was excluded because the distributions were highly skewed.

Index	Minimum	1st quartile	Median	Mean	3rd quartile	Maximum
Irreplaceability	0	15.0	24.4	31.3	42.5	100
Vulnerability	0	7.9	12.5	16.6	22.5	100

Table 7.3. Irreplaceability versus vulnerability percentile matrix.
Matrix shows the number of AUs in each irreplaceability versus vulnerability percentile category. Values for vulnerability and irreplaceability at each percentile are shown in parentheses.

Percentile for Irreplaceability	Percentile for Vulnerability						Total
	84 (28.0)	92 (36.7)	96 (41.1)	98 (46.2)	99 (52.0)	99.5 (61.2)	
99.5 (100)	--	--	--	--	--	--	--
99 (100)	2	3	1	1	0	0	7
98 (95.0)	3	0	0	0	0	0	3
96 (76.5)	4	2	1	1	1	1	10
92 (62.8)	11	7	5	2	0	1	26
84 (53.5)	15	19	10	4	3	5	56
Total	**35**	**31**	**17**	**8**	**4**	**7**	**102**

Table 7.4. Assessment units within the 0.5 percentile for Euclidean distance from the (100,100) scatterplot corner.
AUs ordered by irreplaceability score. Irreplaceability and utility scores are from the integrated freshwater and terrestrial analysis.

AU Number	AU Name	Irreplaceability	Vulnerability	Euclidean Distance	Utility
1902	Orveas Bay	100	51.5	48.5	100
1701	Chemainus River	100	42.6	57.4	100
1383	Qualicum River	100	39.9	60.1	100
1656	Chemainus River	100	39.5	60.5	98.4
2391	Camp Creek	84.4	66.6	36.9	71.0
2394	Chehalis River, lower	81.2	48.9	54.5	75.8
1274	Stamp River	73.6	59.4	48.4	73.8
2473	Hazeldell	62.8	68.2	49.0	57.4
1903	Sooke River	60.0	79.2	45.1	35.2
1303	Qualicum River	58.0	62.8	56.1	55.5
2484	Longview	56.0	94.1	44.4	30.0
2588	Rock Creek/Tualatin River	55.2	90.2	45.9	55.0
2573	Clackamas River	55.0	95.7	45.2	55.0
Mean		75.9	64.5	50.2	69.8
Standard Deviation		18.5	19.5	6.8	23.5

Table 7.5. Assessment units within the 0.5 percentile for Euclidean distance from the (0,100) scatterplot corner.
AUs ordered by irreplaceability score. Irreplaceability and utility scores are from the integrated freshwater and terrestrial analysis.

AU Number	AU Name	Irreplaceability	Vulnerability	Euclidean Distance	Utility
2966	Island in BC	100	1.0	1.0	100
1650	Island in BC	100	1.0	1.0	100
2957	Island in Oregon	100	1.0	1.0	100
1135	Stamp River	100	4.3	4.3	100
239	Marble River	100	1.8	1.8	55
1939	Cape Alava	100	2.5	2.5	100
1709	Tzartus Island	100	3.1	3.1	100
1426	Island in BC	100	3.1	3.1	100
2945	Long Island, Willapa Bay	100	3.5	3.5	100
54	Frisherman river	100	3.8	3.8	100
571	Checleset Bay	99.6	4.3	4.4	100
2155	Saghalie Creek	98.6	2.5	2.8	74.6
1681	Island in BC	96	1.0	4.1	100
Mean		99.6	2.5	2.8	94.6
Standard Deviation		1.1	1.2	1.2	13.3

7.3.3 Sensitivity Analysis

Changes to cost index parameters result in changes in AU utility scores (Figure 7B.1, Appendix 7B). A linear regression shows a significant ($p < 0.0001$) but weak relationship ($r^2 = 0.20$) between change in cost index and change in utility scores – as the AU cost decreases the utility score increases. A regression which includes only AUs with significant change in AU value (according to the contingency table analysis) shows a stronger relationship: $r^2 = 0.32$. For 15 percent of AUs the relationship between change in utility and change in cost did not follow the general trend. That is, cost increased and utility increased, or cost decreased and utility decreased. This counter-intuitive result occurs because AU selection is based on relative cost. An AU's cost and utility can both decrease if many AUs with the same targets have a much greater cost decrease.

Parameters a and b, which control the influence of AU suitability relative to AU area, had the largest effect on conservation utility scores. For all incremental changes to parameters a, b, c, d, and e, changes to parameter a (and b) resulted in the largest changes to various similarity measures (see Appendix 7B). Amongst the parameters d, e, and f, equal incremental changes in parameter value resulted in about the same result for each similarity measure but changes to e usually had a smaller effect on the original utility map than the same change to d or f (Appendix 7B: Figures 7B.2, 7B.3, and 7B.4). The differences between the original utility map and the altered map were minor for all parameter changes except one: b + 0.75.

According to the similarity measures there was little overall difference between the original and altered utility maps. However, many individual AUs did change (Figure 7B.5) and some showed statistically significant changes in utility. A plus or minus 0.25 change in parameters a or b caused 47% of AUs (n=2707) to change utility scores, but only 7.8 percent of AUs had a statistically significant change (Figure 7B.6). When b was changed by 0.75 (a=0, b=1), over three-quarters of AUs change utility score and nearly half (45.8%) had a statistically significant change. Utility scores were much less sensitive to changes in parameters d, e, and f (Figure 7B.7). For the biggest changes in d, e, and f (± 0.3), between 33.4 and 39.0 AUs changed utility score, but only between 1.2 and 6.4 percent had significant changes. Utility scores were least sensitive to changes in e.

Changes in utility due to changes in the cost index can also be examined spatially. We examined a pair of maps that showed changes in utility in response to changing parameter a (and b) plus and minus 0.25. As expected, changes to AU utility were of opposite sign on these two maps in most cases (55%). The objective function of the selection algorithm has two terms – one dealing with AU cost and one dealing with target representation. The maps showed AU sensitivity to the former term. Many AUs (28%) had no change in utility on either map. These AUs are insensitive to this degree of change in a because the targets were the main drivers for selection of these AUs. In Washington, AUs that change utility are mainly concentrated on the Olympic Peninsula. There are two reasons for this. First, survey effort in Olympic National Park and surrounding wilderness areas is uniformly low. Hence, from an ecological perspective, most of these AUs appear to be about the same. Second, suitability index data are also rather uniform across the Park and wilderness areas. Consequently, the main distinction among AUs is area and so changing parameter a (and b) causes noticeable changes in conservation utility. In short, for these AUs the cost term of the objective function is dominating the target representation term. Similar but opposite reasoning explain why some AUs did not change utility scores to this degree of change in parameter a (and b).

More results are presented in Appendices 7A and7B.

7.4 Discussion

We used two different techniques – an optimal site selection algorithm and a scatterplot – that together yielded four indices (irreplaceability, utility, two Euclidean distances). Both techniques incorporate a notion of efficiency. Irreplaceability minimizes the area and utility minimizes the cost of AUs needed to meet representation levels. The ordinate of the scatterplot is irreplaceability, and therefore, the plot also incorporates efficiency.

How should our 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. Think of the first representation level as the amount of biodiversity to be captured in an initial set of reserves, the second level as a 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 together, the result specifies the most efficient sequence of AU protection that will eventually capture 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.

Using irreplaceabilty or utility AUs can be ranked along a single dimension. The rankings derived from these two indices tend to be similar for many AUs, especially the most important AUs. The two indices give different perspectives on prioritization, and the combination of perspective gives a richer view on AU priorities. The irreplaceability versus vulnerability scatterplot can be used to rank AUs along two dimensions. The vulnerability axis is most useful when AUs have similar scores for irreplaceability. Forty-seven AUs had irreplaceability scores equal to 100 and 68 AUs had irreplaceability scores of 95 or greater. The scatterplot enabled us to make some distinctions among these AUs.

Priorities for conservation depend on the strategy one decides to pursue. Those who favor action at more highly threatened and higher value sites, would look to quadrant Q1 of the scatterplot or the distance from the (100, 100) corner for their highest priorities. Others may believe a more efficient conservation strategy would direct resources toward AUs in Q2 or close to the (0,100) corner of the scatterplot. These are AUs with high ecological value but with lower vulnerability, and therefore, presumably a better chance of successful conservation. Regardless of ones strategy, we recommend that all four prioritization indices should be used to when planning conservation actions. One should not interpret minor differences between potential conservation areas as significant. The sub-quadrant and the iso-Euclidean distance contour in which an AU lies are the proper level of precision when assigning priorities to AUs.

The prioritization methods can be used by decision makers who are thinking about conservation at ecoregional scales. The rough priorities portrayed in the scatterplot are useful at an ecoregional scale, but the information underlying the prioritization is not accurate or precise enough to support prioritization within much smaller parts of the ecoregion. At these smaller scales, such as a single county, the job of prioritizing among potential conservation areas must be informed by a more complete understanding of biodiversity value, local threats, monetary costs, and opportunities. Keep in mind that relative biological value is sometimes determined by relative survey effort. Poorly surveyed areas with high biodiversity may not be accurately represented in this analysis. Users should take this prioritization as a beginning, and adjust it as they look more closely at a particular area's biodiversity, vulnerability, and the practical issues of conservation costs and opportunities.

Our prioritization results are based on the best available data for targets species, target communities, ecological systems, and factors in the suitability (a.k.a., vulnerablity) index. However, the factors included in the suitability index were severely limited by the types of GIS data that were available. We had no ecoregion-wide GIS data for several factors that should be considered when prioritizing places to conserve biodiversity such as invasive species locations, land acquisition costs, county land use zoning, etc. Other factors which are just as important but difficult to quantify are local attitudes toward conservation, opportunities for partnerships, the prospect for funding, etc. In short, while the results of our prioritization are useful, they solve just one piece of a complicated puzzle. The results for the entire ecoregion are available on CD.

7.4.1 Irreplaceability and Utility

The selection algorithm generates a set of AUs corresponding to a local minimum of the objective function. AUs are included in a solution because they serve to minimize the objective function. Therefore, AUs with high utility or high irreplaceability scores are those that (1) contain one or more rare targets, (2) contain a large number of target occurrences, and (3) have a low relative cost. AUs with scores at or near 100 are those that were selected in every replicate of every representation level. To be chosen in every replicate the AU must be unique. That is, the AU contained target occurrences that were found in no other AU, contained a substantially larger number of occurrences than other AUs, or contained targets and had a substantially lower cost than other AUs.

The preceding paragraph explains a surprising result of the analysis. Most AUs in the Olympic National Park, which protect some of the last remaining temperate old-growth rain forests in the United States, had lower utility and irreplaceability scores than AUs in southwestern Washington, which consist mostly of privately-owned, intensively-managed forest with very little old-growth. There are two reasons for this, one proximal and one ultimate. First, the proximal reason is that the target occurrence and suitability index data are rather uniform across the park. Hence, the AUs are essentially interchangeable and very few have a high selection frequency. In contrast, some AUs in southwest Washington stand out as unique because of rare targets or a very high number of target occurrences. Second, the ultimate reason is occurrence data. Private forest managers have funded wildlife surveys throughout southwest Washington, in particular for amphibians. The data density in Olympic National Park is much lower. More surveys in the park might show more heterogeneity among AUs with respect to target occurrences.

A similar but opposite pattern is seen on Vancouver Island. Very few AUs on the Island have high utility or irreplaceablity scores; they are essentially interchangeable. They appear to be interchangeable because very few surveys have been done on lands which are leased by timber companies. One cluster of AUs with high scores is located in Strathcona Provincial Park. In this park a small number of AUs contain alpine and sub-alpine communities found nowhere else on Vancouver Island. These rare communities have been intensively surveyed.

The results on Vancouver Island and in Washington State call into question the reliability of utility and irreplaceability scores. These AU scores were strongly influenced by the uneven spatial distribution of survey effort. No or low survey effort may be effectively equivalent to false negatives. That is, according to the data, a species does not exist in an AU when it actually does exist there. As a consequence, the utility and irreplaceability scores do not reflect reality, and we may be missing some places important for biodiversity conservation. One approach 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 we did not use predictive models. First, we did not have any reasonably accurate species-specific habitat models. The ones available to us, (e.g., Cassidy et al. 1997), have low spatial precision and untested accuracy. Second, we did not have the resources needed to develop our own models for a large number of vertebrate species. Third, species-specific habitat models have both false negatives and false positives. False positive errors are a major concern. We don't want to select places for conservation where the species of concern don't actually exist. Given our limited resources for conservation action, the prevailing opinion in the scientific literature is that the false negatives inherent to survey data are less troubling than the false positives of habitat models. Freitag and Van Jaarsveld (1996) and Araujo and Williams (2000) recommend using only occurrence data because of the potential for false positives in habitat models. Loiselle et al. (2003) recommend that species-specific habitat models be used cautiously. Given the lack of readily available models of proven accuracy and our incapacity to develop our own models, we believed the most cautious approach was to use occurrence data (with the exception of marbled murrelets on Vancouver Island).

The integrated portfolio combines freshwater, terrestrial, and estuary AUs through a technique known as vertical stacking. Unlike the terrestrial only analysis, the boundary modifier (BM) parameter was greater then zero, and therefore, AUs were selected not only for their biodiversity value and suitability but also for their adjacency to other AUs. With BM greater than zero the algorithm will select larger contiguous areas, which, in theory, are better for biodiversity conservation. On the other hand, the reasons for AU selection (biodiversity value or AU adjacency) are obscured. The scores for freshwater class 1 AUs and terrestrial AUs were combined to yield a single utility score and single irreplaceability score for each AU. One result was that fewer AUs had scores of 100 relative to the terrestrial only analysis. This should help to further prioritize AUs. AUs that score high for both freshwater and terrestrial should be higher priorities for conservation. When combining the scores for freshwater class 1 and terrestrial AUs we weighted them equally. One could argue that terrestrial AUs should be weighted more heavily because most of the terrestrial data are empirical (i.e., occurrences) as opposed to modeled (i.e., freshwater macrohabitat types). The subjective assignment of weights through expert judgment is one shortcoming of our methods that must be addressed through the development of more rigorous methods and the collection of more empirical data.

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. 2004), and it assumes that land area is the sole consideration for efficient conservation. Utility incorporates other factors that can effect efficient conservation such as land management status and current condition. Many AUs attained scores of 100 for both utility and irreplaceability. A statistical comparison of utility and irreplaceability scores showed that differences between them at high scores were less than differences at low scores (see Appendix 7A). These results demonstrate that for scores at or near 100 the cost had little influence on selection frequency; occurrence data drove the results.

More importantly, it demonstrated that the results are robust. Under two different assumptions about efficiency (area versus suitability), the highest priority AUs were nearly identical.

Utility and irreplaceability scores were significantly different for many individual AUs at the middle and low end of the utility score range. 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 an AU can be distinguished from other AUs because conservation there will be cheaper or more successful, then that AU should be a higher priority for action. For these AUs, the utility score should be used for prioritization.

7.4.2 Sensitivity Analysis

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 individual AUs do change and some exhibit significant changes. The number of AUs that change depends of which index parameter is changed and the amount of change to that parameter. Of the five index parameters, a and b (which are complementary) have the biggest effect on utility.

We investigated the sensitivity of the utility map to changes in the cost index because of our uncertainty about the index. The variable selection and parameter estimates for the index were based on professional judgment. The results of the sensitivity analysis have two implications for conservation planning. First, highest priority AUs (about ranks 1 through 10; the top 218 AUs) are rather robust to changes in the suitability index. Therefore, regardless of the uncertainties in the cost index, we can be confident about the most highly ranked AUs. These AUs were selected mainly for their relative biological value, not relative cost. For similar reasons, the lowest ranked AUs (rank less than about 100), tend to be robust to changes in the cost index – they maintain a low rank because they have little relative biological value. Second, the utility of moderately ranked AUs (rank less than 10 and greater than 100; about 319 AUs), is sensitive to changes in the cost index. When choosing among AUs of moderate rank we must explore how our assumptions about cost and suitability affect rank.

Chapter 8 – Conservation Portfolio

This chapter presents the development of the 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. Several techniques of portfolio prioritization are reviewed and alternative conservation portfolios reflecting different conservation goals for targets are reviewed.

8.1 Portfolio Design Process

Successful conservation will entail choices about where we should and should not expend limited resources (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, we used an optimal site selection algorithm, called SITES, to help us create the portfolio. Optimal site selection analyzes the trade-offs between conservation values and conservation costs to arrive at an efficient set of conservation areas that satisfies conservation goals (Possingham et al. 2000; Cabeza and Moilanen 2001). The conservation value of a place is represented by the presence of target species, habitats, and ecological communities. The number of targets, condition of targets, and rarity of targets present at a particular place determines the conservation value of that place. However, large data sets showing the locations of species and habitat types are subject to error. To correct such errors, expert opinion is sought to critically review and modify draft portfolios. Portfolio creation took place in stages, making it an iterative process with expert knowledge balancing optimal reserve design.

The portfolio creation process for the Pacific Northwest Coast Ecoregion occurred on three parallel tracks and took place in stages with intermediate stages resulting in portfolios that were specific to three environmental realms: terrestrial, freshwater and marine. Previous chapters discuss conservation targets existing within these realms. These three realm-specific portfolios were integrated into a final single portfolio.

8.1.1 Terrestrial Portfolio

The terrestrial conservation portfolio was developed using the SITES optimal site selection algorithm (see Chapter 6 for a description of the tool). The terrestrial portfolio identified a set of assessment units (AUs) that met conservation goals for all terrestrial conservation targets in a way that minimized portfolio costs. 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 2). A number of fine filter targets that were initially identified were not included in the final SITES analysis. Targets were omitted from the analysis due to data limitations including insufficient or lack of occurrence data, incomplete range of occurrence data or obsolete records. A complete list of targets and their use in the SITES analysis is detailed in Appendix 8E.

The draft terrestrial portfolio used the “best solution” provided by the SITES algorithm. The best solution can be characterized as the most efficient solution based on the suitability and size of selected AUs. The best solution met most of the SITES goals set for the conservation targets and did so in a least cost configuration of AUs. One drawback to SITES is that it does not deal with connectivity. Consequently, the best solution may exclude some AUs that create an ecologically superior portfolio with higher connectivity. The best solution also may exclude AUs that contain considerable biodiversity but are considered too costly. Portfolio review was the avenue we used to address these and other deficiencies of the site selection algorithm.

The terrestrial portfolio is shown in Map 8.1. The portfolio covers 3,226,000 ha, 39 % of the assessment area. The core team conducted very little review of the stand alone terrestrial portfolio because without consideration of freshwater and marine biodiversity, it is very incomplete in terms of capturing the biodiversity of the ecoregion.

The terrestrial portfolio analysis utilized conservation goals set by the target subteams that were then transcribed to SITES goals as required by the algorithm. In many cases, especially for fine filter targets, the SITES goals are lower than the conservation goals. Hence, though the draft terrestrial portfolio meets SITES goals, it often does not meet conservation goals for some targets. This deficiency was partly corrected by experts who added more AUs to the portfolio that contained more occurrences of target species.

8.1.2 Freshwater Portfolio

The assessment of freshwater biodiversity utilizes a different set of geographies than the ecoregion; it is based on ecological drainage units (EDU) that overlap ecoregion boundaries (see Chapter 3). Ideally, the freshwater portfolio is developed independently from the terrestrial and marine portfolios, expert reviewed, and then integrated with the other portfolios. The freshwater portfolios for EDUs that intersect Washington were reviewed separately by experts. The freshwater portfolios for EDUs in Oregon and British Columbia, on the other hand, were reviewed in conjunction with the integrated portfolio that is discussed later in the chapter. In British Columbia, the EDUs and freshwater ecosystem classification are undergoing an update by the Nature Conservancy of Canada as part of developing a freshwater classification scheme for the entire province (Ciruna and Butterfield 2005)

The freshwater portfolio, like the terrestrial portfolio is an intermediate product whose primary purpose is to be used in developing the integrated conservation portfolio. The freshwater portfolio consists of several distinct groups of conservation targets (see Chapter 3). The components include fine filter targets, mostly salmonid species, and coarse filter targets that are represented by freshwater systems. For purpose of analysis, the freshwater systems are viewed as two groups or GIS layers, Class 1 systems that are characterized by headwaters and small streams, and Class 2 and 3 systems that are characterized by large streams and medium rivers, respectively. These layers come into play more in the portfolio integration that is described in Chapter 8.3.

The freshwater portfolio is shown in Map 8.2. The portfolio covers 2,576,000 ha, 32 % of the ecoregion.

8.1.3 Nearshore Marine Portfolio

In the development of the nearshore marine portfolio we utilized a decision support tool called MARXAN. Similar to SITES, MARXAN helps create an efficient conservation portfolio by minimizing the total “cost” or unsuitability of selected sites while meeting conservation goals. See Appendix 6A for more details about MARXAN.

Marine technical teams designed an analytical framework to evaluate the different MARXAN solutions by varying specific parameters and testing those analyses within a structured review process (Figure 8.1). Sensitivity analyses (tiers 1 - 3) were conducted to see how different sets of conservation targets, variations in the suitability index, and spatial formats of AUs affected the portfolio. Tier 4 was designed to vary conservation goals across all targets and the amount of shared boundary (the clumping or boundary modifier) between AUs. Tier 5 incorporated expert review recommendations into the various algorithmic solutions to complete the final draft nearshore marine portfolio. This portfolio was then integrated with terrestrial and freshwater portfolios to form land/sea conservation areas.

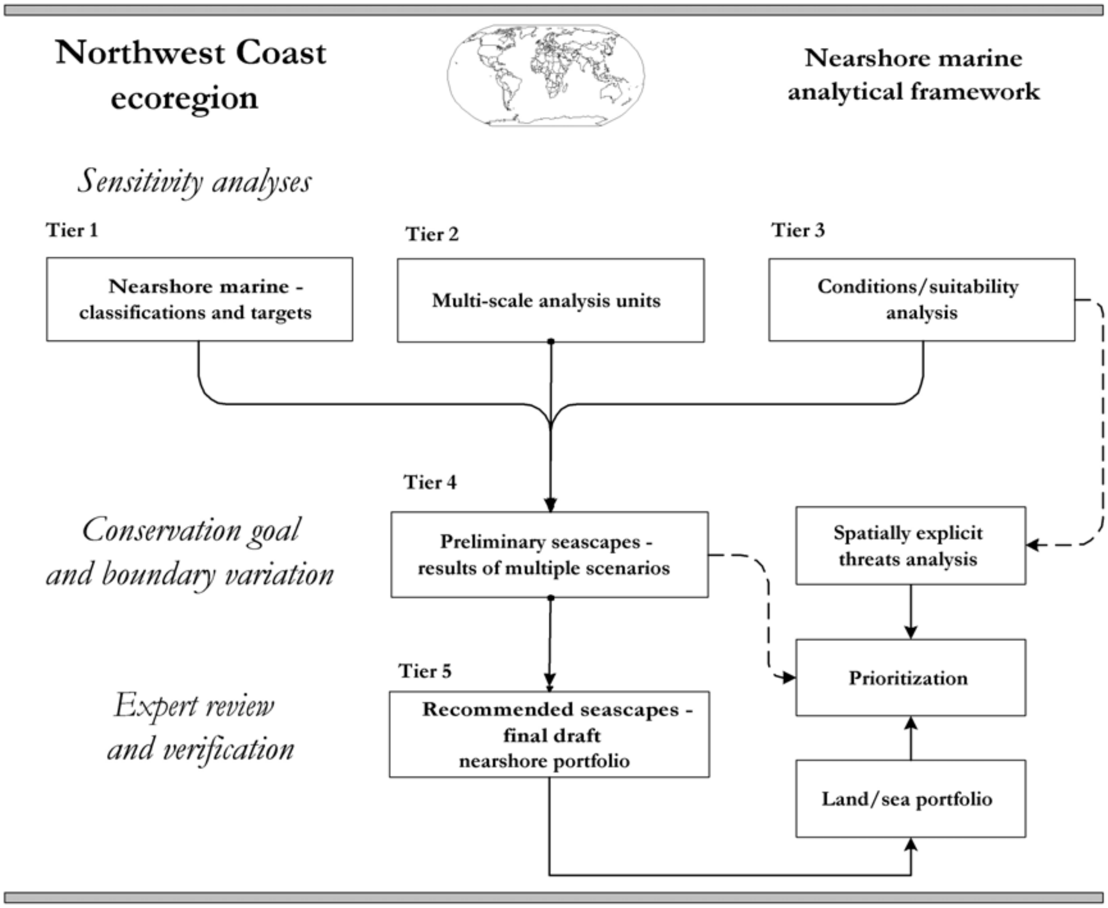


FIGURE 8.1 THE ANALYTICAL FRAMEWORK DESIGNED TO BUILD A CONSERVATION PORTFOLIO OF THE NEARSHORE AND INTEGRATE IT WITH TERRESTRIAL AND FRESHWATER PORTFOLIOS

We ran several different scenarios to calculate an irreplaceability index for the marineAUs. A scenario corresponds to a set of MARXAN input parameters, including the desired number of solutions and the degree of AU clumping. One of the main outputs of MARXAN, called "summed solutions", adds all of the solutions from a scenario together. The summed solutions output reports how often each AU was selected for a given scenario. This information can be used as an irreplaceability index (Leslie et al. 2003, Warman et al. 2004). A "sum of summed solution," or multiple scenarios added together, has also been referred to as an irreplaceability index. Summing these scenarios allowed us to vary specific MARXAN parameters and track how often each AU was selected. We used these scenarios as part of Tier 4 of our analytical framework

The nearshore marine portion of the ecoregion followed the methods of Rumsey et al. (2004). We varied the goals across targets (goal ranges of 10 - 30%, 20 - 40%, and 30 - 50%) and degree of clumping (boundary modifier = 0.01,0 .05, 0.125) to produce an irreplaceability map (Maps 8.3a, b, c). We used the irreplaceability map to help construct the portfolio. Irreplaceability scores ranged from 1 to 900 (9 scenarios run 100 times each) for AUs that were chosen in at least one solution. The distribution of scores (Figure 8.2) reveals a wide disparity in the relative importance of AUs. The lowest 20% of scores (chosen 1 to 181 times) consisted of 1,317 AUs (64% of all AUs). The highest 20% of scores (chosen 721 to 900 times), the most irreplaceable AUs, consisted of 177 units (9% of all AUs). We deemed AUs with scores greater than the 721 as the core group of units needed in the final portfolio. Irreplaceability scores were informed decisions about portfolio construction around this core group of AUs. It is generally thought that assessment units chosen more than 50% of the time are essential for efficiently meeting biodiversity goals (from Hugh Possingham's explanation of MARXAN - http://www.ecology.uq.edu.au/index.html?page=20882). Sites that are rarely selected can be ignored.

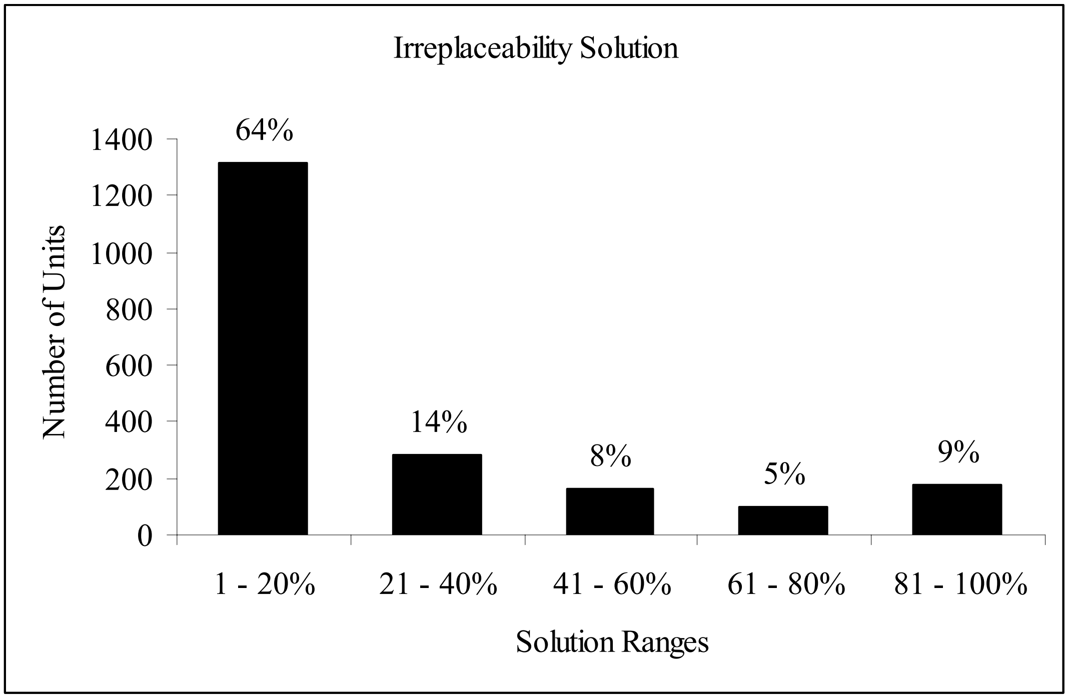


FIGURE 8.2 DISTRIBUTION OF IRREPLACEABILITY SCORES FROM THE MARINE NEARSHORE ANALYSIS.

Total number of AUs was 2,042 units.

MARXAN also produces a "best solution" which is the most optimal run in the scenario. The scenario for the best solution here used the 0.01 boundary modifier and the 20 - 40% goal range (Maps 8.4a, b, c). This single solution was compared to both the irreplaceability map and expert review by marine technical teams in constructing the initial nearshore portfolio. The distribution of irreplaceability scores for AUs in the best solution are shown in Figure 8.3. Of the 425 units in the best solution, 167 (39%) were in the highest 20% of the irreplaceability score range. On the other end of the range, the 36 units (8%) in the lowest 20% of the range and the 66 units (16%) in the next highest 20% of the range were considered replaceable. Doing this evaluation for the expert review process helped focus our attention on the highest priority conservation sites in the nearshore environment.

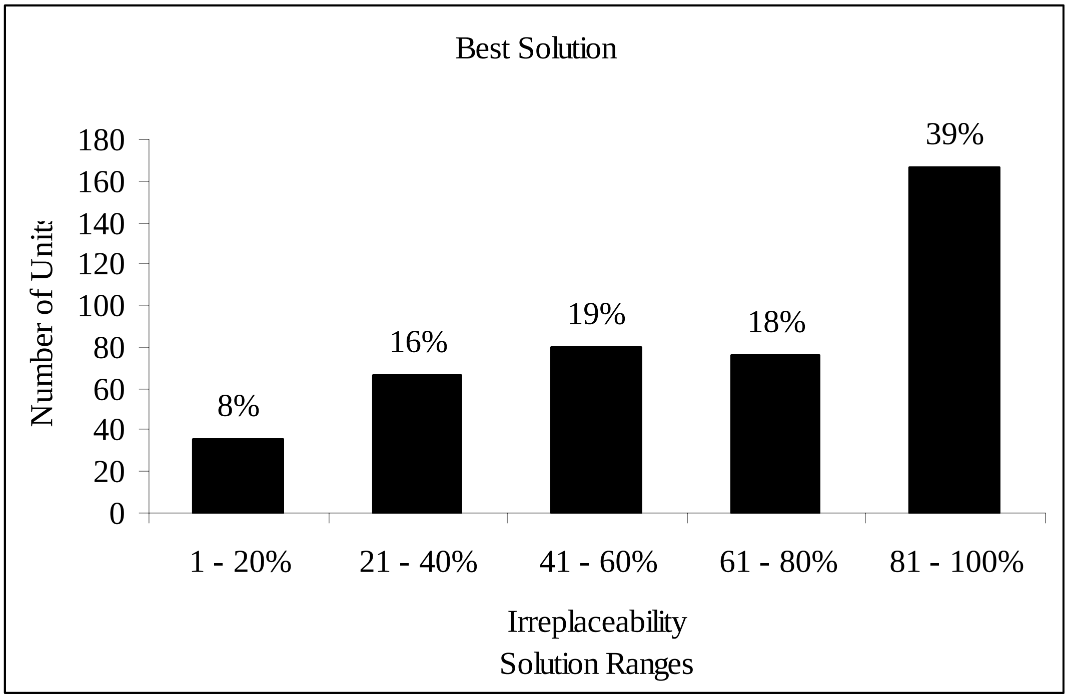


FIGURE 8.3 DISTRIBUTION OF IRREPLACEABILITY SCORES FOR AUS IN THE BEST SOLUTION FROM THE MARINE NEARSHORE ANALYSIS.

Total number of AUs equals 425 units.

8.2 Expert Review of Draft Portfolio

Expert review of automated portfolios is an absolute necessity to ensure that ecological realities are reflected by the portfolio. The output of the SITES and MARXAN algorithms are only as good as the empirical data used in the analyses. Experts are needed to compensate for errors in or lack of data. Experts removed AUs that should not be in the portfolio (e.g., data showed habitat present but it had been destroyed) or added AUs that should be in the portfolio (e.g., occurrence of a species present but not recorded in the data).

Expert review of draft products was an essential part of the assessment process and took place at several stages of the project (e.g., target identification, setting goals, etc.). Expert reviews also served to introduce many stakeholders to the ecoregional assessment process and the anticipated products of the project. These review sessions were conducted for a combined terrestrial/freshwater portfolio and the marine portfolio.

Reviews of the draft portfolios were conducted on a state or province basis with experts gathered together in forums of 15-20 individuals, and where necessary, in individual or small-group sessions. The reviews began with an overview of the assessment process and were followed with a presentation of the draft portfolio before comments were solicited on what was presented. Comments were recorded and reviewer comment forms were also distributed to attendees so they could write additional comments and forward them to us after the review.

Expert review comments were divided into three general types that were each dealt with differently. One general group of comments dealt with input data and included both questions about the sources of such data as well as recommendations for inclusion of new and/or updated data. If possible, comments regarding data were incorporated into the analyses when they pointed us to additional or higher-quality data or they provided expert correction of input data. A second type of review comments were generally classified as recommendations to assessment methods including changes to the suitability index. Some of these comments were incorporated to improve the current analysis (e.g., dropping the use of hatchery data in the freshwater suitability index); others were beyond the capacity or scope of the current iteration and were recorded for later reference in a section on “lessons learned” (Chapter 9), or were recommendations the core team did not concur with. All comments were recorded for future reference (Appendix 8B).

The final type of comments received in peer reviews were those that were specific to the draft portfolio and reflected reviewer’s concurrence with the draft or recommendations for inclusion or exclusion of particular assessment units (HUC6/third order watersheds or nearshore grids). Recommended modifications to the draft portfolio were assessed on an individual comment-by-comment basis by members of the core team with careful consideration being given to the expertise of the reviewer relative to the recommendation. The addition or subtraction of assessment units in the draft portfolio depended on our confidence in related data, the contribution that the suggestions made to connectivity in the portfolio, and whether the comment addressed assessment unit condition. In general, if we had low confidence in the data for a particular conservation target or assessment unit we were more inclined to incorporate portfolio modification recommendations from expert reviewers. For instance, when we heard from experts with on-the-ground knowledge that an assessment unit was degraded to the extent that it compromised the viability of the targets present there, we would consider dropping the unit from the draft portfolio. The expert reviews enabled us test the portfolio against expert knowledge, thus ensuring that our results were valid recommendations of priority conservation areas.

8.2.1 Draft Portfolio Modifications

The final draft portfolio was examined planning unit by planning unit. Comments from expert review were applied and some units were dropped and others added (Appendix 8B). Areas identified as Urban Growth Boundaries for cities and towns within the ecoregion were taken out of the portfolio and then in a few cases, we modified those resulting boundaries to include a target which otherwise would have fallen outside the portfolio. We also dropped the HUC6/third order units which were entirely within the eastern buffer (or WPG ecoregion) as they had already been considered in another ecoregional assessment (Floberg et al. 2004). The selected units in the buffer between other ecoregions were reconciled with adjoining portfolios. The selected class 2 and 3 freshwater systems were similarly examined. The resulting HUC6 footprint, all currently protected areas (GAP 1 or 2), together with the selected reaches corresponding to the class 2 and 3 freshwater polygons, formed our final terrestrial/freshwater "portfolio

8.2.2 Marine Portfolio Review and Modifications

Marine portfolio reviews of the draft marine analysis took place in Washington and Oregon. In addition to the portfolio reviews there were several meetings held in each state as well as the province during the data collection phase of the marine assessment. These meetings not only provided data resources but they also reviewed target lists, methods and recommended specific coastal locations within the ecoregion.

In parallel with the nearshore analysis, the terrestrial/freshwater analysis included estuaries and marine shoreline AUs. This analysis identified estuaries at different scales than the rectangular AUs (irregularly-shaped estuary polygons versus 400-hectare squares). In addition, the estuary polygons were analyzed along with the HUC 6 watersheds in order to find efficiencies of site selection between coastal watersheds and their adjoining estuaries. We compared terrestrial/freshwater analysis with the nearshore and estuary analysis prior to the expert review process. Overall, there was considerable agreement between them, particularly with regards to selected estuaries. The square assessment units of the nearshore analysis often provided a more spatially explicit selection of estuaries and where appropriate delineated specific sections within larger estuaries. These methods were integrated into a single layer of estuarine sites for the final portfolio. We used both estuarine selection methods in building the integrated portfolio.

8.3 Portfolio Integration

As specified in an earlier chapter (Chapter 6) the basic method used to develop the conservation portfolio involves creating separate portfolios for a terrestrial solution, a freshwater solution and a marine solution. These different solutions were then “integrated” to produce the overall conservation portfolio. Integration of portfolios from different realms can be achieved in multiple ways that have differing results as discussed below.

8.3.1 Terrestrial/Freshwater Portfolio Integration

The simplest "integration" method would be to overlay portfolio maps and look for places where the portfolios overlap. Areas of overlap between realms would represent higher priority sites as more targets would be captured at those sites. However, this simple approach may not be as efficient as we would like. The approach we used was intended to improve the efficiency of the integrated portfolio.

The target groups (terrestrial and class 1, class 2, and class 3 freshwater systems) were combined in a single SITES analysis using a "vertical integration" technique (Appendix 8A). Each group corresponded to a separate layer. The boundaries between layers were represented by the areal overlap of AUs. The SITES analysis was run on this amalgamated dataset, and the "best" output was decomposed into its constituent layers to compare back to the stand-alone portfolios. The area of overlap between the terrestrial and freshwater portfolios was measured, as well as the "cost" of each layer in the solution. The “boundaries” between the layers were increased by 20%, and SITES was run again. At each iteration, the layers were decomposed, measured, boundaries increased and a new SITES run was performed.

As the values of the boundaries between layers increased, the area of overlap between layers also increased, while the "costs" of the constituent solutions remained fairly flat. The solutions within each group were shifting to allow targets, for which multiple combinations of assessment units at similar costs could meet goals, to accommodate integration.

This iterative process was repeated until the "costs" of one of the solution layers began to sharply increase (see Appendix 8A). The run previous to that increase was then used to identify the "core", the area of overlap between the terrestrial and freshwater solutions (Map 8.5). The "core" is those areas where both freshwater and terrestrial targets are efficiently captured, with the bias reduced from "pinch-point" targets. Estuaries, shore-zones and class 2 and 3 freshwater systems were excluded from the "core", but were influential in the overall selection of those planning units in SITES. The total contribution of the core was compared to the final portfolio after all analyses were complete. The core covers 39% of the total portfolio footprint, captures 42% of its targets, yet only accounts for 30% of its cost. This core formed the backbone of our integrated portfolio, a suite of assessment units with highly representative samples of freshwater and terrestrial targets at a reasonable cost.

The next step was the final combined SITES analysis. All freshwater and terrestrial HUC6 targets were attributed to a single AU layer. The costs for that layer were the averages of the sums of the freshwater and terrestrial suitability indices. The class 2 and 3 freshwater systems were "stacked" on this base layer during the final SITES analysis.

The core was locked into the solution, as well as the planning units with at least 70% of their area in protected status. These protected areas were locked in to make sure the targets contained in the existing protected area network were counted towards the goals.

The SITES algorithm was run on this final dataset (10 runs, 10,000,000 iterations each, boundary modifier 0.03) with the output of each individual run being saved. All ten solutions were examined to find the one solution with the smallest total cost, the best integration with the class 2 and 3 freshwater systems, and the highest overall coincidence with expert review comments. The output chosen as the basis for the final portfolio was not the "best" according to SITES, but definitely was the best fit for these criteria.

8.3.2 Integration of Terrestrial/Freshwater Portfolio with Marine Portfolio

The integration of the terrestrial/freshwater portfolio with the marine portfolio utilized the method of simply merging the separate portfolios, noting where there was overlap or agreement but not excluding anything that had been identified in one or the other portfolio delineation efforts. This approach was adopted because of the many challenges faced – the different types of assessment units used in the efforts, the different character of the conservation targets, particularly the coarse filter targets, and the duplication of targets in each effort, such as estuarine habitats.

8.3.3 Addition of Special Occurrences to the Final Portfolio

There was one significant addition to the final portfolio that could be termed a special occurrence. The southern end of the ecoregion abuts the Northern California Coast ecoregion for which the California office of The Nature Conservancy recently completed a conservation assessment. That assessment stopped at the Oregon-California border, leaving a small portion of Oregon outside of a formal assessment process. Upon consultation with experts a priority conservation area, Chetco River, was added to the portfolio, and another existing site, Cape Ferrelo, was extended along the coast to encompass the entire HUC6 watershed that previously had been clipped to the ecoregion boundary. The Chetco River portfolio site consists of two HUC6 watersheds and is immediately adjacent to the Kalmiopsis portfolio site identified in the Klamath Mountains ecoregional conservation assessment (Vander Schaaf et al. 2004).

8.4 Portfolio Sites

The conservation portfolio for the Pacific Northwest Coast ecoregion is most accurately defined as a collection of AUs (HUC6/third order watersheds, freshwater systems, and marine grid cells) that best meet the conservation goals for the targets in the ecoregion. These assessment units are then grouped into larger landscapes called priority conservation areas or portfolio sites. No attempt was made to refine site boundaries to a greater degree than was afforded by the original assessment units used in the project other than larger urban areas were excluded from portfolio sites using Land Use-Land Cover GIS data (NLCD 1992).

Portfolio sites often comprise larger watersheds but they can also be small, managed areas such as Research Natural Areas that may not have their surrounded HUC6 watershed unit included in the portfolio. Priority conservation areas also may be comprised of larger river systems such as Class 2 or Class 3 streams that have been selected to conserve freshwater systems and/or fisheries related conservation targets (see Chapter 3 for discussion of Freshwater Targets). When priority conservation areas only include these defined Class 2 or 3 streams without any surrounding HUC6 assessment units the portfolio site is characterized as a buffered stream reach 100 m in width.

Another type of priority conservation area that is distinct from the HUC6/third order watershed-derived portfolio sites is found in the marine portfolio (see Section 8.1.3 above) and is defined as a marine assessment unit or collection of such units that are 400 ha in size (individual cells). In some cases the marine priority conservation areas overlap with selected HUC6/third order assessment units along the coast, identifying specific sections of shoreline along coastal watersheds. In this instance we merged selected marine areas within coastal watersheds, but counted the marine grid units towards our conservation goals. In other cases there is no overlap and the marine selected areas act as stand alone portfolio sites. These are usually offshore rocks where there is no adjoining watershed. The marine portfolio also selected several estuaries that were not selected in the terrestrial/freshwater integrated portfolio. These are also considered as stand alone portfolio sites.

8.4.1 Portfolio Results

The conservation portfolio for the Pacific Northwest Coast ecoregion covered 3,623,451 ha or 45% of land and waters of the assessment area (Maps 8.6 and 8.6a, b, c). (The marine portion of the ecoregion is not included in the total ecoregion area.) The conservation portfolio is comprised of terrestrial and freshwater lands and waters as well as nearshore, intertidal and shallow subtidal marine lands. There were four conservation sites, totaling 1047 ha, that were identified solely for their freshwater conservation targets. Before integration there were 162 coastal marine sites identified in the portfolio, covering 400,000 hectares. After integration the majority of these sites were joined with an adjacent terrestrial site; there were only 20 conservation sites, totaling 13,970 ha, identified solely for their marine conservation targets. The portfolio included a considerable area of land already managed for conservation that covered 898,634 ha. These conserved sites often formed core areas within larger watersheds identified in the assessment.

The conservation portfolio includes 164 priority conservation areas that vary widely in size. Not surprisingly the largest sites, Olympic National Park (420,442 ha) and Strathcona (320,906 ha), are dominated by large publicly protected landscape sites. Many of the smaller priority conservation areas such as Myrtle Island RNA (9 ha) and Copalis Rocks NWR (12 ha) are also publicly protected areas as well. Portfolio conservation areas are listed in Appendix 8C. Site summary descriptions containing basic site parameters as well as listing the conservation targets present in the site are detailed in Appendix 8D.

Many of the smallest priority conservation areas were selected to conserve established protected areas (see Chapter 5) and they often contain only a few conservation targets. This is in contrast with the largest priority conservation areas that were complete landscapes, often comprising several watersheds and including a plethora of target species as well as representative terrestrial and freshwater systems. Both types of conservation areas are critical to protecting the representative biodiversity in the ecoregion but their roles in such conservation may differ considerably. Smaller sites may contain isolated occurrences of rare species or special habitats that are important for maintaining genetic diversity. Larger sites often contain the best examples of functional land and seascapes that may contribute to biodiversity conservation by maintaining ecological processes that are essential for ecosystem resiliency. Larger sites are also better suited to be adaptable to climate change and other large scale events that affect biodiversity.

The conservation portfolio is fairly evenly divided between the states and province with only slightly a larger percentage of it located in British Columbia (Vancouver Island) and Washington (Table 8.1). These minor differences can be attributed to the two largest portfolio sites being located in these regions. Another perspective on the conservation portfolio is with regards to how it is distributed among the ecological sections of the ecoregion (Tables 8.3, 8.4). The portfolio occupies over half of some sections because of large existing blocks of publicly protected land. Length of shoreline is also a good measure for evaluating and summarizing the size of the conservation portfolio (Table 8.2). The amount captured includes man-made and undefined shoreline units.

Table 8.1 Distribution of the conservation portfolio within the assessment area by political jurisdiction

State/Province	Total Area (ha)	Portfolio Area (ha)	Percent of State/Province
British Columbia	3,123,600	1,449,000	46
Washington	2,194,200	989,200	46
Oregon	2,852,500	1,126,600	39
Total	8,170,300	3,564,800	44

Table 8.2 Length of shoreline captured in the conservation portfolio, by political jurisdiction

State/Province	Total Shoreline Length (m)	Portfolio Shoreline Length (m)	Percent of State/Province
British Columbia	5,934,200	1,988,100	34
Washington	1,054,500	681,700	65
Oregon	2,031,400	1,036,000	51
Total	9,020,200	3,705,800	41

Table 8.3 Distribution of the conservation portfolio within the assessment area by ecological section

Ecological Section	Section Area (ha)	Portfolio Area (ha)	Percent of Section
Nahwitti Lowlands	251,900	128,800	51
North Isle Mtns	532,600	274,700	52
Lee Isle Mtns	1,116,100	481,400	43
Windward Isle Mtns	1,181,600	563,300	48
Olympics	1,107,500	598,000	54
Willapa Hills	1,562,800	581,700	37
Coast Range	2,374,000	935,900	39
Total	8,171,600	3,563,800	44

Table 8.4 Distribution of shoreline captured in the conservation portfolio by marine ecosection

Marine Ecosection	Ecosection Shoreline Length (m)	Portfolio Shoreline Length (m)	Percent of Ecosection
Cape Arago North	1,620,000	823,900	51
Cape Arago South	397,300	198,600	50
Juan de Fuca Strait	274,800	142,600	52
Johnstone_Strait	212,500	108,200	51
Pt Grenville North	256,100	118,300	46
Pt Grenville South	705,200	514,200	73
QC Sound	65,700	38,900	59
QC Strait	188,800	108,900	58
VI Shelf	5,299,600	1,652,200	31
Total	9,019,900	3,705,700	41

8.4.2 Conservation Goals Assessment

One way to measure the performance of the portfolio is to analyze how well the conservation targets met their conservation goals (see Chapter 2, 3 & 4 for targets and goals description). Results for groups of targets are summarized in Table 8.5. A complete assessment of how well each conservation target met its goals within each of the ecoregional sections is included in Appendix 8E.[1]

Table 8.5 Conservation targets captured in the integrated conservation portfolio.

Target Group	number of targets analyzed	number of targets with goals	number meeting conservation goals	percent meeting conservation goals
Ecological Systems	25	25	24	96
Freshwater Systems	408	388	324	84
WA wetlands	19	19	19	100
OR wetlands	20	20	19	95
Mineral Springs	1	1	1	100
Vascular Plants	60	59	5	8
Nonvascular Plants	11	11	0	0
Mammals	16	8	4	50
Birds	19	15	9	60
Herptiles	13	12	11	92
Fish, freshwater	66	61	51	84
Insects	16	11	3	27
Mollusks	10	8	4	50
Estuary Habitat	24	24	23	96
Subtidal Habitat	4	4	4	100
Estuary Shoreline	57	57	57	100
Coastal Shoreline	61	61	50	82
Marine Mammals	2	2	2	100
Seabirds	12	12	11	92
Fish, marine	3	3	3	100
Marine Invertebrates	1	1	1	100
Marine Shorebird areas	3	3	3	100
Shorebird Concentration Area	1	1	1	100

Conservation goals for terrestrial coarse filter targets were nearly fully met in the portfolio with the exception of the ponderosa pine woodland ecological system, a peripheral system to the PNW Coast ecoregion, which has a very minor representation in the ecoregion (less than 2,000 ha), and is much more prominent in adjacent ecoregions.

Freshwater systems were well captured with the exception of a number of systems that were reach-level macrohabitats on Vancouver Island. Fewer fine filter targets met their conservation goals because often there were insufficient numbers of target occurrences available in the

[1] We actually examined this performance measure with respect to both conservation goals and SITES goals. Conservation goals relate to the number of individuals or hectares of habitat required to maintain a target over time and SITES goals were the actual inputs to the SITES algorithm. Whenever possible, both goals were the same. There were two situations when the SITES goals did not equal our conservation goals. First, where insufficient occurrences of a target remain in the ecoregion to meet a conservation goal, we set the SITES goal to 100 percent in order to select all remaining occurrences. Second, where we had more than enough occurrences of a target but many were of questionable viability or integrity, we adjusted the SITES goals to select only the occurrences that were presumably viable. The SITES goals results are reported in Appendix 8E.

ecoregion. It is instructive to note that several taxa groups did reasonably well at meeting conservation goals including herptiles (92 %) and fishes (84%). Several other groups had approximately half of their targets meet conservation goals; these groups were birds (60 %), mammals (50 %) and mollusks (50 %). A number of species in these groups have been listed as Survey & Manage Species under the U.S. Northwest Forest Plan (USDA 1994a, 1994b) and have benefited from more survey effort than non-listed species generally receive.

Species groups that fared poorly with regards to meeting conservation goals include vascular plants (8 %), nonvascular plants (0 %) and insects (27 %). It is interesting to note that a far smaller percentage of vascular plant targets for the Pacific Northwest Coast Ecoregional Assessment are also taxa listed under the Survey & Manage Species list referred to above. One reason plant targets seemed to do poorly in terms of meeting conservation goals was that a very high proportion of plant targets were used in the actual analysis (50 of 60 targets). Many of these plant targets had just barely enough data to be included in the analysis but not enough to meet the conservation goals. This is in direct contrast to the terrestrial animal targets where nearly one-third of the targets did not have sufficient data to be included in the SITES analysis.

Estuary, subtidal, and estuary shoreline habitat types all met their conservation goals. Coastal shoreline targets (82% met) did least well among marine target groups but a closer look at this group of targets shows that most of these targets are represented within 80% of their stated conservation goals in the portfolio. All marine fine filter targets met their goals except seabirds. Of all the target groups used in the assessment, comprehensive location information for marine species represented the largest data gaps.

8.5 Portfolio Prioritization

The conservation portfolio consists of 165 sites that vary considerably in their contributions to biodiversity conservation and their suitability to being conserved in a practical manner. One issue that every ecoregional assessment deals with is the relative importance of portfolio sites. Different organizations and agencies have different perspectives on how relative importance should be determined. For example, some may prioritize based on a combination of overall biodiversity, viability of the site, and the leverage potential of conservation actions taken there. Others may define priorities based more on meeting the greatest number of conservation goals at a given site irregardless of the site's suitability for conservation. Still others may be more concerned about which sites have the greatest threats or are most vulnerable. Each of these approaches will yield different results regarding prioritization of the portfolio.

We explored a number of techniques to estimate both biodiversity value and threats to biodiversity in order to prioritize conservation sites. We have not reported on most of these attempts but through these efforts we formed some basic generalizations about site prioritization. First, larger sites may appear to be more valuable than smaller sites simply because they tend to contain more biodiversity. To account for this we added some area-weighted factors to our prioritization ranking. Second, existing protected areas have a tendency to be highly ranked, often due to increased survey effort on these sites and their focus on rare, endemic species. Third, GIS data limitations preclude quantitative analysis of some well known threats such as invasive species and human population growth. Fourth, conservation leverage, especially leverage relative to other sites across an entire ecoregion, defies objective analysis. "Leverage" is the ability for actions at a single site to promote or encourage similar actions at other sites. Fifth, reducing biodiversity value and threats to numeric scores has drawbacks, and hence, these scores should be used only as guidelines for setting priorities. Other considerations such as opportunity and leverage as well as the political will to work at a site all affect future decisions to take conservation action at a given place.

8.5.1 Conservation Value

In assessing the biodiversity value of the portfolio sites we began by considering irreplaceability as defined in Chapter 7, as a point of departure. An irreplaceability index was used to prioritize all 2707 terrestrial assessment units. We eventually decided against using irreplaceability as an indicator of biodiversity value, however, as it placed too great a weight on rarity and less weight on representation of targets and richness. The index we settled on for biodiversity value reflects both richness and representation. It is expressed as the percent of each target goal that is met at a site summed for all targets present at the site. It can be thought of as target richness weighted by how much the amount of each target present contributes to the conservation goal. We evaluated the U.S. sites separately from the BC sites as there was a considerably different target base for Vancouver Island, particularly with regards to coarse filter freshwater communities. The biodiversity score was computed only for sites comprised of HUC6 assessment units and for protected areas, none of the solely marine or freshwater sites were ranked. Results for the prioritization analysis are included in Appendices 8F and 8G.

8.5.2 Vulnerability

We attempted to construct a vulnerability (or threats) index for the ecoregion using a variety of factors including projected human population growth, land use, land cover, and fire condition class but the results were less than satisfying (see Appendix 8H for a discussion of this work). However, we could still readily assess vulnerability because there had been a considerable effort expended at deriving a suitability index for use in the SITES algorithm (see Chapter 6). A calculation for vulnerability was developed in Chapter 7 with vulnerability being defined as the suitability index as expressed on an assessment unit basis without the area of the assessment unit involved in the calculation.

We computed the vulnerability value for a portfolio site by averaging the suitability values for each assessment unit in the site and then normalized the resulting scores. Again, scores were calculated separately for U.S. sites and BC sites to recognize the great differences in types of data available. Managed area sites such as ACECs and RNAs that are typically considerably smaller in area than the HUC6 they are found in had the suitability scores for the HUC6 ascribed to them. This can be an inaccurate portrayal of their actual conservation suitability given that their protected status would make them highly suitable (low vulnerability score). Hence, those vulnerability scores are inadequate for the purposes of ranking managed area portfolio sites. We did not attempt to adjust scores for managed area portfolio sites but rather have added a footnote to indicate that these sites are actually more suitable than their scores portray. The normalized scores are displayed in Appendix 8F for all portfolio sites.

8.5.3 Portfolio Prioritization Discussion

The normalized scores for biodiversity value and vulnerability provide a means to prioritize the portfolio on each of these factors. Appendix 8F shows the individual scores for each of the terrestrial/freshwater portfolio sites that were evaluated. Estuaries were included in this evaluation where there was an adjoining terrestrial site but strictly marine-based sites were not included. Some ready observations made from the results can be offered. First, a few of the portfolio sites that fall at either end of the spectrum of either biodiversity value or vulnerability are surprising to persons who have a sense of priority areas in the ecoregion. Yaquina Bay had the highest estimated biodiversity value, which was quite surprising. Its high value is likely due to it containing at least one target that is restricted to only one or two occurrences and it also has a high number of estuarine shoreline targets. Conversely some sites with very low biodiversity value estimates, many of which are small National Wildlife Refuges, are known to be important sites for wildlife but because of their small size they often contribute very little to protecting coarse filter targets and contain a limited number of occurrences of species as well. In terms of vulnerability, sites that reportedly have very low vulnerability appear to be small, existing protected areas such as offshore rocks managed by U.S. Fish & Wildlife Service. The site with the highest vulnerability, Forest Park outside of Portland, Oregon, clearly has high threats related to urbanization.

Dividing the sites into quartiles for each value shows that the upper quartile of sites regarding biodiversity value includes many well known biodiversity hotspots such as Cascade Head-

Salmon River, Mt. Townsend and Boistfort as well as some surprises like Yaquina Bay, Quillayute-Sol Duc River, Cape Sebastian-Hunter Creek, Fanno Meadows and Cape Lookout-Sand Lake. Sites with the greatest vulnerability or threats include Forest Park, Castle Rock, Boistfort, Long Beach Peninsula, Chehalis River, Yaquina Bay and Clatsop Plains-Necanicum River. It should be noted that Boistfort and Yaquina Bay rank high in biodiversity and vulnerability.

These scores can be graphed to show how biodiversity and vulnerability values relate to each other in order to determine site priorities in the ecoregion (Figure 8.4). It is of interest to look at site priorities from two perspectives, low vulnerability-high biodiversity value sites and high vulnerability-high biodiversity value sites. Low vulnerability sites might be seen as “low hanging fruit” that have much value and are relatively easy to protect, while high vulnerability sites might be viewed emergency situations where biodiversity value will be lost forever if action is not taken soon. As in Chapter 7, we computed the Euclidean distance for all sites from both the low and high vulnerability perspective (Appendix 8F) and have mapped the top quartile of sites in each case (Map 8.7). To portray these results we removed sites that are protected areas since their vulnerability values generally equal zero. The top quartile sites for each perspective are listed in Appendix 8G. The Euclidean distance values (low values are “best” for both the low and the high vulnerability perspectives) give a comprehensive view of site priorities for the ecoregion within the limitations of the existing data.

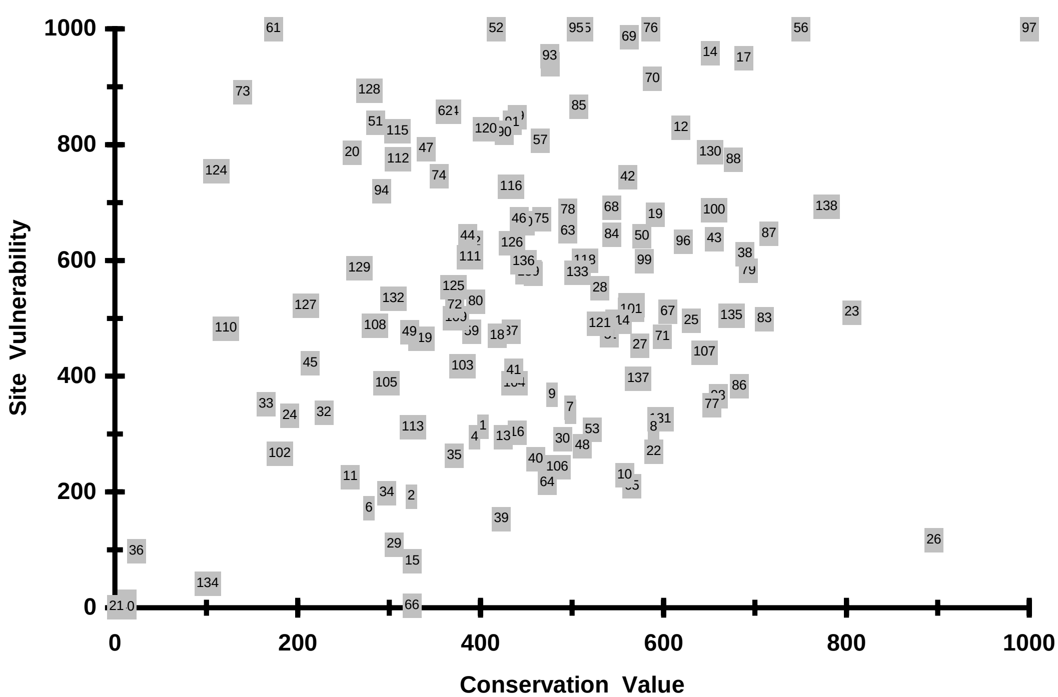


FIGURE 8.4. RELATIVE PRIORITIES FOR PORTFOLIO SITES SHOWN BY PLOTTING VULNERABILITY VERSUS CONSERVATION VALUE.

Numbers refer to particular sites.

One debate that often occurs when prioritizing sites is whether to focus efforts on high value/high vulnerability sites or to work on sites that have high value but much lower vulnerability. The high vulnerability sites may be lost forever unless action is taken soon, but the lower vulnerability sites may have greater long-term potential for successful conservation. This dilemma is often complicated even further by conservation opportunities that may be more closely associated with highly vulnerable sites. In addition, the potential leverage that a site may offer in terms of promoting additional conservation at other sites is also a consideration and can be a primary determinant in prioritizing conservation actions. These factors of conservation opportunity and leverage are very difficult to project in an objective fashion and have been left out of our prioritization schemes. They remain, though, key considerations that agencies and conservation organizations must take into account as they focus their collective energies.

8.6 Alternative Portfolios

The size of the conservation portfolio is mainly determined by the goals – the larger the goals, the larger the portfolio. For this reason, goal setting is possibly the most critical step in creating a portfolio.

For this ecological assessment, conservation goals were set that reflected a high likelihood of target species survival and properly 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 insufficient scientifically established methodology 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, similar to other ecoregional assessments (Marshall et al. 2000, Neely et al. 2001, Rumsey et al. 2003, Floberg et al. 2004) based largely on the work of Comer (2003).

8.6.1 Methods

Risk is related to the amount of habitat or the number of occurrences that are protected in the portfolio, more habitat and occurrences yields less 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. We simply multiplied all mid-risk goals by 0.5 but the goals could not be less than 1 for targets with occurrence goals, less than 40 ha for targets with area goals (if the maximum available was less then 40 ha, then the goal equaled the maximum), or less than 4 km for targets with linear goals. For the lower risk, the goals were increased. We simply multiplied all goals by 1.5 but the goals could not exceed the maximum available.

We created higher and lower risk alternative portfolios that were derived from the mid-risk alternative. The alternative portfolios are nested. That is, all 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. The SITES algorithm has a feature for locking AUs into or out of the optimal solution. To create a nested higher risk portfolio, we locked out all AUs that were not in the mid-risk portfolio. This limited the algorithm's selection space to only the mid-risk portfolio. To create a nested lower risk portfolio, we locked in all AUs that were in the mid-risk portfolio. 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 integrated target list (terrestrial, freshwater, estuary) and with the same boundary modifier and target penalty factors as those used for the mid-risk portfolio.

8.6.2 Results

The lower and higher risk portfolios are depicted on Map 8.8. These portfolios nest with the mid-risk portfolio. The number of AUs in the higher risk portfolio is roughly half the mid-risk portfolio for the terrestrial, estuary, and class 2 and 3 freshwater systems (Table 8.6). The number of AUs in the lower risk portfolio averages out to be about 1.5 times the mid-risk portfolio. All three alternatives captured more public land than private land, but the ratio of public to private land was greatest for the mid-risk portfolio. The mid-risk portfolio had 79 percent more private land than the higher-risk portfolio and the lower risk portfolio had about 74 percent more private land than mid-risk.

Table 8.6 Percent of all AUs in ecoregion captured by each of the alternative portfolios

AU type	percent of AUs selected			total AUs available
	higher risk	mid-risk	lower risk	
terrestrial	14	28	50	2707
estuary	26	52	60	317
class 2 and 3 freshwater systems	14	24	35	196

8.6.3 Discussion

The three alternative portfolios represent different tolerances of risk to biodiversity loss with the low risk portfolio covering the largest geographic area and the high risk the smallest. The three portfolios also are an acknowledgment of the uncertainty of how much is enough to conserve for the survival of biodiversity. Finally, the three goal levels illustrate that there are a range of policy options for biodiversity conservation. It is important to realize that because of our uncertainty, any portfolio's absolute risk to the loss of biodiversity is unknown and the actual risk might be higher or lower than stated here.

Chapter 9 – Assessment Products, Assessment Uncertainties, and Future Assessments

9.1 Assessment Products

The Pacific Northwest Coast Ecoregional Assessment generated a number of products that are useful for conservation planning, decision making, and priority setting. 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 that should be useful to groups asking specific questions regarding threats, freshwater and marine conservation, and conservation site priorities.

The data that have been compiled and developed for this assessment have broad utility. These data are especially useful because they are in a GIS format and have undergone intensive review to correct data errors. They are accessible for other analyses addressing different conservation-related questions. SITES could be used to reanalyze the data using subsets of the biological data, different suitability indices, or different goals thereby tailoring the products to the needs of various users.

The conservation portfolios depict a set of conservation areas that most efficiently meet a specific set of conservation goals defined for the ecoregion (see Chapter 8). 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 species and plant communities associated with low-elevation, old-growth coniferous forests. Second, some of these areas are the last large, relatively undisturbed landscapes in the ecoregion. Many of these places are parks or wilderness areas. Large areas are especially important to wide-ranging extant species such as black bear, bobcat, spotted owls, goshawks, and species that could be re-introduced such as the fisher. These areas currently make irreplaceable contributions to conserving ecoregional biodiversity and possess significant potential for the maintenance of landscape-scale ecological processes. Third, wherever possible, the portfolios identify areas that are most promising for successful conservation. This assessment used a suitability index to map the relative likelihood of successful conservation across the ecoregion. The suitability index was a quantitative expression of several well-accepted principles of conservation biology: (1) large areas of habitat are better than small areas; (2) habitat areas close together are better than areas far apart; and (3) areas with low habitat fragmentation area better than areas with high fragmentation. The suitability index also relied on two intuitive assumptions, first, that existing public land is more suitable for conservation than private land; and second, rural areas are more suitable for conservation than urban areas. Application of these principles and assumptions guided site selection toward existing public lands and away from private land, and toward rural areas with low habitat fragmentation and away from urban areas.

The irreplaceability maps depict a prioritization of all assessment units (AUs). One type of irreplaceability map, conservation utility, is based on the both relative irreplaceability and relative suitability of AUs (see Chapter 7). This map is a prioritization of all assessment units (AUs) based on their relative biological value and relative suitability. It can be used to guide ecoregion-level conservation action and can inform smaller scale conservation decisions as well. A sensitivity analysis of the terrestrial utility map showed that the ranking of highest ranked AUs was robust to changing assumptions about AU suitability.

Ancillary products developed for this assessment have proven to be useful for a number of specific needs of the assessment partners, as well as other entities. For example, cataloging and assessing threats to the biodiversity conservation at an ecoregional basis is a growing interest to private and public entities. Freshwater aquatic and marine portfolios are important parts of the overall assessment that have garnered attention in their respective fields, both for their results as well as for the development of analytical tools that they utilized. Conservation site prioritization provides insights for guiding short-term conservation action.

The alternative portfolios are intended as an illustration of how the conservation areas change based on different goal levels for species and ecosystems. Deciding which alternative is most appropriate is ultimately a decision for society to make based on the best available science and value-based policy decisions. These particular alternatives were selected to bracket the scientific uncertainty in the relationship between changes in biodiversity associated with different amounts of landscape fragmentation and loss.

9.1.1 Uses for the Assessment

The PNW Coast ecoregional assessment was prepared to support conservation of the entire ecoregion's biodiversity. It provides information for decisions and activities that occur at an ecoregional scale: establishing regional priorities for conservation action, coordinating programs for species or habitats that cross political boundaries, and evaluating the regional importance of any particular place. The conservation portfolios and the irreplaceability maps are each suitable for particular applications while the conservation datasets have broad applicability to a variety of users.

The mid-risk conservation portfolio will be used by The Nature Conservancy and Nature Conservancy of Canada to drive priorities for site-based work and for identifying priority investments in "multi-site" strategies that conserve portfolio sites through policy, education, research, and other approaches. Likewise, planners, natural resource agencies and local land trusts can use this portfolio to understand the ecoregional significance of local portfolio sites and to coordinate their actions with these organizations and others. However, WDFW does not advocate the use of a particular portfolio. WDFW acknowledges the importance of setting conservation goals, which is a key step for developing a portfolio, however, WDFW is obligated to consult with the public before establishing goals for how much biodiversity is important to protect. Therefore, WDFW will use the irreplaceability maps to guide their State Comprehensive Wildlife Conservation Strategy (SCWCS) and to inform land use planning by county governments. The irreplaceability maps are useful for assessing the relative importance of all assessment units, recognizing their limitations regarding a lack of expert review and the uncertainty regarding which goal level is significant.

9.1.2 Caveats for Using the Assessment

- 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 our natural landscape. They should be managed to maintain their own special values. Furthermore, due to their large size, high priority AUs and conservation portfolio sites may include areas unsuited for conservation. We expect that local planners armed with more complete information and higher resolution data will develop refined boundaries for these sites. The author organizations – The Nature Conservancy, Nature Conservancy of Canada, and Washington Department of Fish and Wildlife – are eager to work directly with local planners to explore the use of the assessment and make progress toward practical conservation strategies for high priority areas. The Nature Conservancy is actively developing Conservation Action Plans for its highest priority sites based on the PNW Coast ecoregional assessment.

- This assessment has no regulatory authority. It is simply a guide to help inform conservation decision-making across the 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, governments, and other community members.

- Some high priority conservation areas described in this assessment may accommodate multiple uses and are not intended to become parks or nature reserves set aside from economic activity. While some areas may warrant such protection, others will accommodate various activities as determined by landowners, local communities and appropriate agencies.

- 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. However, the assessment's results should not be used as the sole guide for siting restoration projects. A reliable assessment of restoration priorities would require a different approach than the one we have presented. AUs and portfolio sites were selected for the habitats and species that exist there now, not for their restoration potential.

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

9.2 Assessment Uncertainties

All conservation assessments possess some degree of uncertainty. In general, uncertainty increases as the areal extent of the assessment increases and as the number of species covered by the assessment increases. Hence, an ecoregional assessment, which covers a huge area and a large number of species, has many uncertainties. The two main causes of uncertainty were data gaps and analytical shortcomings. A great many of these uncertainties can be ameliorated if users remember the geographic scale of the analysis (~1:100,000). Expert review of the mid-risk portfolio product addresses some of the uncertainties.

9.2.1 Data Gaps

- There were a number of targets for which the desired **occurrence data** did not exist. For example, location data for native freshwater species is sparse, except for salmonids. The same is true for many terrestrial invertebrate species. As a result, most of the ecoregion's biodiversity must be represented through the surrogate of coarse-filter habitat types or ecological systems, freshwater aquatic systems and marine shorezone and intertidal habitats. Similarly, biodiversity information in some portions of the ecoregion is less well developed than in others. On Vancouver Island, the density of species occurrence data is much less than in the Washington and Oregon due in part to lack of survey effort.

  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 we did not use predictive models. First, we did not have any reasonably accurate species-specific habitat models. The ones available to us, (e.g., Cassidy et al. 1997), have low spatial precision and untested accuracy. Second, we did not have the resources needed to develop our own models for a large number of vertebrate species. Third, species-specific habitat models have both false negatives and false positives. False positive errors are a major concern. We don't want to select places for conservation where the species we're concerned about don't actually exist. The prevailing opinion in the scientific literature is that false negatives inherent to 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) recommend using only occurrence data because of the potential for false positives in habitat models. Loiselle (2003) recommends that species-specific habitat models be used cautiously. Given the lack of readily available models of proven accuracy and our incapacity to develop our own models, we believed the most cautious approach was to only use occurrence data (with the exception of marbled murrelets on Vancouver Island).

- We constructed a **vegetation map** by piecing together landcover 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 tested across the ecoregion. However, there were a number of positive responses from reviewers for the vegetation map that gave us confidence that is accurately reflected the 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 more or less restricted by sectional boundaries.

- The **marine datasets** used in this assessment were considerably less robust than the terrestrial and freshwater datasets, hence the marine analysis results are less certain. While we made great advances in compiling marine data and we were careful with its use in this assessment, the reality of the poor state and general lack of availability of nearshore marine data translates into greater uncertainty in these results. To address this we relied extensively on expert review of results and we generally were conservative with conservation goals for marine targets.

- A number of steps in the analysis rely heavily on **expert opinion**: target selection, the suitability index, threats index, and review of the portfolio. Although a number of problems are associated with the use of expert opinion (Tversky and Kahneman 1974, Coughlan and Armour 1992, Cleaves 1994), such as imperfect knowledge and motivational biases, expert opinion provides a significant net benefit as experts fill in data gaps or address errors in analysis with knowledge gained from on-the-ground experience. Experts also supplanted shortcomings in the methodology such as addressing issues regarding the maintenance of connectivity in the conservation portfolio, something that the optimization algorithm was unable to accomplish. One of our major products, the irreplaceability maps, were not subjected to expert review.

9.2.2 Main Analytical Shortcomings

- The **size of the AUs** (HUC 6 and HUC 7 drainage units in Washington and Oregon, and third order watersheds in BC) causes a high degree of spatial imprecision. This problem is most acute when an AU is selected for only a single occurrence. In that case, the large AU size obscures where the occurrence is located (although this information is captured in the underlying data) and most of the AU may contribute little toward biodiversity conservation which lowers efficiency.

- We invented a method called **"vertical stacking"** (see Appendix 8A) that enabled us to integrate terrestrial, freshwater and nearshore marine realms in SITES. Compared to other ways of integrating the three realms, vertical stacking should yield a more efficient solution, however we're uncertain how much efficiency was gained using the vertical stacking technique. Furthermore, vertical stacking requires subjective decisions about how strongly the realms should be linked through the boundary modifier parameter.

9.2.3 Recommended Future Enhancements

From the data gaps and analytical shortcomings mentioned throughout this report, the following correctives emerged as the highest priorities:

- This assessment did not make a full accounting of **existing protected lands**. While nearly all public and some private nature reserves were included in our GIS data, future assessments would be strengthened by assembling complete spatial information on land management status, including land trust properties, wetland reserve conservation easements, and other types of conservation easements. This data has yet to be compiled within most geopolitical units.

- The **freshwater assessment** includes assessments for 7 ecological drainage units (regional watersheds) that intersect the ecoregion. The analyses varied considerably among ecological drainage units in depth of expert input on such matters as watershed condition and importance. The most pressing need is a comprehensive and coordinated approach to bringing much more species occurrence data into the analysis.

- We lacked **reliable data on occurrences** and occurrence condition for many imperiled and rare species and plant communities in the ecoregion. As a broad strategy for filling this data gap, new survey efforts should focus on finding additional occurrences of these targets and documenting the condition of known occurrences. Some of the occurrence data that we assembled was deemed out-dated. Surveys of these sites could add considerably to the overall dataset. Finally, many species that were included on the initial target lists because they were presumed to exist in the ecoregion had no reliable observations nor had they benefited from any surveys; these species in particular need attention.

- The **vegetation map** developed for this assessment could be improved upon by: 1) quantitative evaluation of map accuracy for all system types and seral stages through ground-truthing, especially where the map was developed with restricted plot data and 2) remapping of types that are found to be least accurate.

- The marine portion of this assessment provides a starting point for marine conservation but supporting data in mostly not available yet and the modeling of **marine ecological systems** is still in its infancy. Data on substrates, bathymetry, salinity, currents, sea surface temperature, and productivity might be combined to create a more detailed model for nearshore ecological systems. More biological data are needed to test such a model. Ecosystem processes, such as those that take place within littoral cells, could be used in the delineation of ecological systems. Rare species data useful for the marine analysis was almost wholly absent and much needs to be learned about the marine realm before marine assessments can be as robust as their terrestrial counterparts.

- The process of **integrating terrestrial, freshwater and nearshore marine assessments** needs to be improved through validation of its resulting portfolios. Integration could also be improved by incorporating into the selection algorithm the ecological processes that link terrestrial, freshwater, and marine realms.

- When data or models are lacking, **expert opinion** is used to correct deficiencies. Future assessments should use elicitation techniques that reduce subjectivity and error in expert opinion solicitation (e.g., Saaty 1980). Expert review should be utilized more regularly throughout the assessment process.

- Future conservation portfolios could include some **measure of uncertainty** for the importance of each AU.

9.3 Future Ecoregional Assessments

This ecoregional assessment, like all conservation assessments, will require periodic updates. Some aspects of the assessment, such as the marine analysis, are being improved upon even as this report is drafted. Habitat, ownership, and land use patterns across the ecoregion will change, the abundance and spatial distribution of some species will change, our understanding of ecosystems will increase, analytical methods will improve, and occurrence data will become more comprehensive. Future iterations of the PNW Coast Ecoregional Assessment could be improved by incorporating some of the following concepts:

- Our assessment process was a scientific endeavor, largely disconnected from policy makers. While certain aspects of the assessment must remain purely scientific, the acceptance, and hence effectiveness, of the assessment will be greatly enhanced by involving citizens and stakeholders. With adequate funding ecoregional assessments can be done within a public process. For example, Rumsey et al. (2004) worked with stakeholders and decision makers on an ecoregional assessment in British Columbia.

- SITES, and other such algorithms, are decisions support tools. They can be used to support the actual decision makers. These tools are nearly interactive and with a modest increase in computer speed they will be fully interactive. 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, were made in an objective, transparent environment with quick exploration of alternatives.

- One of the original motivations for using site selection algorithms was the recognition that funds for conservation are limited (Pressey et al. 1993, Justus and Sarkar 2002). Therefore, cost-efficient reserve networks are essential for maximizing biodiversity conservation. Our cost index dealt with the economic cost of conservation in a superficial way. To fully inform policy makers the economic costs should be examined more closely. Others have called for a greater use of economics in conservation planning as well (Shogren et al. 1999, Hughey et al. 2003).

- Conservation biologists have recently realized that we need information that will enable us to respond effectively to a dynamic landscape (Meir et al. 2004, Christensen 2004). Portfolios tend to be large (25 to 35 percent of an ecoregion), so protecting the entire portfolio according to conventional conservation methods will take many years. So what happens to the effectiveness of a static portfolio if some sites are destroyed before they can be protected? What should be done if there is limited or no opportunity to protect portfolio sites but non-portfolio sites of somewhat lesser quality can be readily protected? We need to update portfolios and re-prioritize actions based on current status of the landscape and likely alterations of the landscape in the near future.

- We have long realized that identifying a conservation portfolio without defining the intended management of the conservation sites is inadequate in terms of what is needed for effective conservation at an ecoregional scale. The next iteration ecoregional assessment should begin to add in socio-economic factors so that they maybe included along with conservation targets. These may include high value farm or forest land or lands for recreation and urban development. This would enable the assessment to be more inclusive in terms of supporting human communities in the environment and would allow it to become a more comprehensive planning document.

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Glossary

Alternative Portfolios: higher and lower risk portfolios developed to illustrate a range of policy options for the conservation of an ecoregion's biodiversity.

Aquatic ecological systems: dynamic spatial assemblages of ecological communities that occur together in an aquatic landscape with similar geomorphological patterns, are tied together by similar ecological processes (e.g., hydrologic and nutrient regimes, access to floodplains and other lateral environments) or environmental gradients (e.g., temperature, chemical and habitat volume), and form a robust, cohesive and distinguishable unit on a hydrography map.

Assessment unit: the area-based polygon units used in the optimal site selection algorithm and attributed with the amount and quality of all targets located within them. These units are non-overlapping and cover the entire ecoregion.

Automated portfolio: a data-driven portfolio created by the SITES algorithm operating on spatial assessment units.

Base layer: a data layer in a GIS that contains basic information such as land ownership, rivers and streams, political boundaries, etc.

Biodiversity: the full range of natural variety and variability within and among organisms, and the ecological complexes in which they occur. This term encompasses multiple levels of organization, including genes, subspecies, species, communities, and ecological systems or ecosystems.

Candidate species: plants and animals that the U.S. Fish and Wildlife Service believe should be considered for status review. A status review may conclude that the species should be added to the federal list of threatened and endangered species.

Coarse filter: refers to the communities or ecological systems, which if protected in sufficient quantity should conserve the vast majority of species in the ecoregion.

Conservation target: (see target)

Core team: the interdisciplinary group that is accountable for the completion of the ecoregional assessment project.

Cost: a component of the SITES algorithm that encourages SITES to minimize the area of the portfolio by assigning a penalty to factors that negatively affect biodiversity, such as proximity to roads and development. A cost was assigned to each assessment unit in the ecoregion according to a suitability index.

Crosswalk: a comparison of two different vegetation classification systems and resolving the differences between them to form a common standard.

Disjunct: disjunct species have populations that are geographically isolated from each other.

Ecological drainage unit (EDU): aggregates of watersheds that share ecological characteristics. These watersheds have similar climate, hydrologic regime, physiography, and zoogeographic history.

Ecological integrity: the condition of an ecological community somewhat synonymous with ecosystem "health or viability." The ecological integrity of a community is governed primarily by three factors: demography of component species populations; internal processes and structures among these components; and intactness of landscape-level processes which sustain the community or system.

Ecological land unit (ELU): mapping units used in large-scale conservation assessment projects that are typically defined by two or more environmental variables such as elevation, geological type, and landform (e.g., cliff, valley bottom, summit). Biophysical or environmental analyses based on ELUs combined with land cover types and satellite imagery can be useful tools for predicting locations of communities or systems when field surveys are lacking.

Ecological system (see terrestrial ecological systems or aquatic ecological system).

Ecoregion: a relatively large area of land and water that contains assemblages of natural communities that are distinct from other geographic regions.

Element occurrence (EO): a term originating from the methodology of the Natural Heritage Network that refers to the location of a population of a species or example of an ecological community. For communities, these EOs represent a defined area that contains a characteristic species composition and structure.

Endangered species: any species which is in danger of extinction throughout all of its range; a species that is federally listed as Endangered by the U.S. Fish and Wildlife Service under the Endangered Species Act.

Endemic: species or communities that are largely restricted to an ecoregion (or small geographic area within an ecoregion), and depend entirely on this area for survival.

Extirpation: the extinction of a species or a group of organisms in a particular area.

Fine filter: species of concern or rare communities that complement the coarse filter, helping to ensure that the coarse filter strategy adequately captures the range of native species and ecological communities. Endangered or threatened, declining, vulnerable, wide-ranging, very rare, endemic, and keystone species are some criteria for fine filter.

Focal group: a collection of organisms related by taxonomic or functional similarities.

Fragmentation: the process by which habitats are increasingly subdivided into smaller units, resulting in increased insularity as well as losses of total habitat area.

GAP (National Gap Analysis Program): Gap analysis is a scientific method for identifying the degree to which native animal species and natural communities are represented in our protected lands. Those species and communities not adequately represented in the existing network of conservation lands constitute conservation "gaps." The purpose of the Gap Analysis Program (GAP) is to provide broad geographic information on the status of ordinary species (those not threatened with extinction or naturally rare) and their habitats in order to provide land managers, planners, scientists, and policy makers with the information they need to make better-informed decisions.

GAP status: the classification scheme or category that describes the relative degree of management or protection of specific geographic areas for the purpose of maintaining biodiversity. The goal is to assign each mapped land unit with categories of management or protection status, ranging from 1 (highest protection for maintenance of biodiversity) to 4 (no or unknown amount of protection).

GIS (Geographic Information System): a computerized system of organizing and analyzing spatially-explict data and information.

Global rank: an assessment of a biological element's relative imperilment and conservation status across its geographic distribution, ranging from G1 (critically imperiled) to G5 (secure). Assigned by the Natural Heritage Network, global ranks for species and communities are determined by the number of occurrences or total area of coverage (communities only), modified by other factors such as condition, historic trend in distribution or condition, vulnerability, and impacts.

Goal: in ecoregional assessments, a numerical value associated with a species or system that describes how many populations (for species targets) or how much area (for systems targets) the portfolio should include to represent each target, and how those target occurrences should be distributed across the ecoregion to better represent ecological diversity and hedge against local extirpations.

Ground truthing: assessing the accuracy of GIS data through field verification.

Historic species: species that were known to occupy an area, but most likely no longer exist in that area.

Impact: the combined concept of ecological stresses to a target and the sources of that stress to the target. Impacts are described in terms of severity and urgency.

Imperiled species: species that have a global rank of G1-G2 by Natural Heritage Programs/Conservation Data Centers. Regularly reviewed and updated by experts, these ranks take into account number of occurrences, quality and condition of occurrences, population size, range of distribution, impacts and protection status.

Integration: a portfolio assembly step whereby adjacent sites that contain high-quality occurrences of both nearshore marine, freshwater, and terrestrial targets are combined.

Irreplaceability: an index that indicates the conservation value of a potential conservation area. It is operationally defied as the percentage of alternative reserve systems in which a site occurs. When generating the irreplaceability values, a suitability index is not used.

Limited target: a geographically restricted species or community that occurs in the ecoregion and within a few other adjacent ecoregions.

Linear communities or systems: occur as linear strips and are often ecotonal between terrestrial and aquatic systems. Similar to small patch communities, linear communities occur in specific conditions, and the aggregate of all linear communities comprises only a small percentage of the natural vegetation of the ecoregion.

*Littoral cell: a g*eographic region of the coast, such as between two headlands, that is self-contained with respect to all sources and losses of beach sand.

Macrohabitats: units of streams and lakes that are similar with respect to their size, thermal, chemical, and hydrological regimes. Each macrohabitat type represents a different physical setting that correlates with patterns in freshwater biodiversity.

Matrix-forming systems or matrix communities: communities that form extensive and contiguous cover, occur on the most extensive landforms, and typically have wide ecological tolerances.

Minimum dynamic area: the smallest area necessary for a reserve or managed area to have a complete, natural disturbance regime in which discrete habitat patches may be colonized from other patches within the reserve.

Nearshore marine zone: the area of the marine environment extending from the supratidal area above the ordinary or mean high water line to the subtidal area. In the Willamette Valley-Puget Trough-Georgia Basin ecoregional assessment, the nearshore marine area extends below to -40 meters, because beyond that depth data were less available. This also approximates the photic zone, or depth of macrophytes. The WPG consists of 1,509,733 ha of nearshore marine zone.

Non-vascular plant: in this assessment, the term refers to ferns and fern allies.

Occurrence: spatially referenced locations of species, communities, or ecological systems. May be equivalent to Natural Heritage Program element occurrences, or may be more loosely defined locations delineated through the identification of areas by experts.

Partners in Flight: a cooperative program among U.S. federal, state, and local governments, philanthropic foundations, professional organizations, conservation groups, industry, the academic community, and private individuals, to foster conservation of migratory bird populations and their habitats in the Western hemisphere.

Peripheral: a species or community that only occurs near the edges of an ecoregion and is primarily located in other ecoregions.

Population: a group of individuals of a species living in a certain area that maintains some degree of reproductive isolation.

Portfolio: (see portfolio of sites)

Portfolio of sites: the identified and delineated suite of priority conservation areas that are considered the highest priorities for conservation in the ecoregion.

Reach: the length of a stream channel that is uniform with respect to discharge, depth, area and slope.

Sensitivity analysis: analysis done to determine what happens to model outputs in response to a systematic change of model inputs. Sensitivity analysis serves two main purposes: (1) to measure how much influence each parameter has on the model output; and (2) to evaluate the effects of poor parameter estimates or weak assumptions.

Seral: of, relating to, or constituting an ecological sere (a sere is a series of ecological communities formed in ecological succession).

Shoreline segments: nearshore marine elements of the integrated portfolio that are measured as linear features representing coarse filter targets.

SITES: software consisting of computerized algorithms specifically designed for The Nature Conservancy. SITES is an optimal site selection algorithm that selects conservation sites based on their biological value and suitability for conservation.

SITES goal: the goal adjusted for input to the SITES optimal site selection algorithm. SITES goals differed from goals (see “goal” definition) where there were not enough occurrences of a target in the ecoregion to meet the goal. In this case, the SITES goal was set to take all available occurrences in the ecoregion.

Small patch systems: communities or systems that form small discrete areas of vegetation cover and that are dependent upon specific local environmental conditions, such as hydric soil.

Subtidal area: the subtidal begins at approximately the mean lower low water line (zero feet elevation) to the –20 meter isobath.

Suitability Index: the likelihood of successful conservation at a particular place relative to other places in the ecoregion.
Supratidal area: area above the mean high water line, such as the top of a bluff or the extent of a saltmarsh in the upper intertidal; the upper limit of the nearshore marine zone.

Target: also called conservation target. An element of biodiversity selected as a focus for the conservation assessment. The three principle types of targets are species, ecological communities, and ecological systems.

Terrestrial ecological systems: dynamic spatial assemblages of ecological communities that 1) occur together on the landscape; 2) are tied together by similar ecological processes (e.g. fire, hydrology), underlying environmental features (e.g., soils, geology) or environmental gradients (e.g., elevation, hydrologically-related zones); and 3) form a robust, cohesive, and distinguishable unit on the ground. Ecological systems are characterized by both biotic and abiotic (environmental) components and can be terrestrial, aquatic, marine, or a combination of these.

Threatened species: any species that is likely to become an endangered species throughout all or a significant portion of its range; a species federally listed as Threatened by the U.S. Fish and Wildlife Service under the Endangered Species Act.

Urban Growth Area (UGA): an area designated, within which urban growth will be encouraged and outside of which growth can only occur if it is not urban in nature. Urban growth areas around cities are designated by the county in consultation with the cities; urban growth areas not associated with cities are designated by the county.

Utility (Conservation Utility): an index that indicates the conservation value of a potential conservation area. When generating conservation utility values, a suitability index is used.

Viability: the ability of a species to persist for many generations or an ecological community or system to persist over some time period. Primarily used to refer to species in this document.

Vulnerable: vulnerable species are usually abundant, may or may not be declining, but some aspect of their life history makes them especially vulnerable (e.g., migratory concentration or rare/endemic habitat).

Vulnerability: an index which reflects the relative likelihood that target species will be lost from an area

Widespread: a species or community typically found in the ecoregion, but common in several other ecoregions; the bulk of its distribution is elsewhere (or, the majority of the target occurrences exist in other ecoregions).