TIDEWATER TO TIMBERLINE, FOREST TO STEPPE: NATURAL HISTORY OF THE GREATER NORTH CASCADES ECOSYSTEM

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WHAT IS THE GREATER NORTH CASCADES ECOSYSTEM?

The Greater North Cascades Ecosystem (GNCE) is one of the finest expressions on the North American continent of nature's beauty and diversity. The Ecosystem ranges from shell-studded tidewater bays along Puget Sound, to one of the world's densest ancient forests, an enclosed damp world of towering trees and green of every hue. These ancient lowland forests give way with increasing elevation to colder, sparser montane forests, which at their upper limits are reduced to twisted, dwarf timberline trees, and finally to the land above all trees, where dazzling meadows of alpine wildflowers emerge from snow for only a few weeks a year. The North Cascades are rugged mountains, with precipitous crags climbing high above deep dark valleys. Their dominant characteristics are water, ice, jagged peaks, near-vertical cirque headwalls and steep glacial valleys. Indeed, the North Cascades contain most of the glaciers of the United States outside of Alaska. These are steep mountains--often ascending more than 5,000 feet from valley to summit. This amazing elevational gradient makes other mountains seem gentle by comparison. From the Cascade Crest, a stark world of sheer rock walls, glaciers, and permanent snowfields, the Ecosystem stretches eastward into the rainshadow forests of spruce and pine, until finally reaching the airy light of the vast sagebrush steppe. This land of Raven and Salmon, Bear and Wolf, remains a realm of insistent beauty and enormous ecological diversity, one of the wildest intact ecosystems remaining in the world.

Precisely defining ecosystem boundaries is an impossible task. In nature, boundaries are seldom as precise as we like to believe. Boundaries at any level are somewhat arbitrary and misleading. Ecotones, the “edges” between ecosystems, always involve an interfingering of habitats. Even in those ecotones where distinctions seem sharpest—such as at the meeting of aquatic and terrestrial ecosystems—there is major and essential interchange between the two worlds. Ultimately our human predilection toward marking boundaries is founded on our own need for order and convenience more than on ecological or topographical reality. Nevertheless, boundaries can serve an important function in planning and in communication.

Thus, in defining the Greater North Cascades Ecosystem (GNCE) and its constituent zones we attempt to draw boundary lines in deference to what is really *there*: plant communities, animal habitats, topographic features, geologic structures, and river drainages. We acknowledge that any attempt to define and categorize the infinite diversity of wild nature necessitates arbitrary choices and oversimplification. We have tried to follow nature's boundary indicators, as described above, as accurately as possible.

Human political boundaries all too often lack any relationship to landscape realities. It is clear that nature reserve boundaries based on purely political reasoning are doomed to fail at protecting the very attributes they were intended to protect (Newmark 1985).

Although watersheds are sometimes used in attempts to define bioregions, in this work we have chosen to use major rivers as Ecosystem boundaries; in the rugged, vertical world of the North Cascades the low corridors provided by major rivers are a greater aberration on the landscape, and generally serve as natural dividing lines. As mentioned above, any arbitrary map-line must be taken with a few grains of salt; our boundary definitions are merely intended to clarify of what we speak.

The GNCE stretches eastward from Puget Sound to the Okanogan and Columbia Rivers, and from Snoqualmie Pass northward to the Fraser and Thompson Rivers. This spectacular region of coastal plain, rich lowland valleys, dense forests, spectacular mountain peaks, and arid shrub-steppe habitats encompasses approximately 28,000 square miles (74,000 square kilometers). The close proximity of the moist,marine ecosystem of Puget Sound to the west and the dry, continental Rocky Mountains to the east is essential to an understanding of the GNCE. The mutual influence of the maritime weather system and the mountains provides the climatic framework for ecological diversity throughout the region. Drainages west of the Cascade Crest flow directly to saltwater; drainages to the east flow to the Columbia River before ultimately making their passages to the sea.

Elevations in the GNCE range from sea-level at Puget Sound to 10,778 feet at Mount Baker. It is characteristic of the North Cascades that these two vastly different places are separated by only 30 miles. The highest peaks are the only two volcanoes in the region: Mount Baker and Glacier Peak (10,541 feet). The highest non-volcanic peaks range from 8,000 to 9,500 feet.

The largest watercourse in the GNCE is the Columbia River, which gathers together all the waters of the eastern slope and empties directly into the Pacific Ocean along the Washington-Oregon border. Watersheds west of the crest drain directly into the inland marine waters of Puget Sound and the Strait of Georgia. The largest of these west-slope rivers are the Skagit and the Fraser, the latter of which, with the Thompson River, is the only river to bisect the North Cascades, and thus serve as a low corridor connecting its dramatically different east and west sides.

The American portion of the GNCE comprises one of the most intact wildlands in the contiguous United States. The heart of this area lies under public management as North Cascades National Park, Ross Lake and Lake Chelan National Recreation Areas, Mount Baker-Snoqualmie, Okanogan, and Wenatchee National Forests, and the Glacier Peak, Pasayten, Mount Baker, Chelan-Sawtooth, Boulder River, Noisy-Diobsud, Alpine Lakes, and Henry M. Jackson Wilderness Areas. North of the international border much of the land is designated as Manning and Cathedral Provincial Parks, the Skagit and Cascade Recreation Areas, and in Provincial (Crown) Forests.

PHYSICAL SETTING

Weather and Climate

Although not exceedingly high by some standards, the North Cascades present a formidable obstacle to moisture-laden storm winds moving eastward from the North Pacific. Their proximity to the ocean, where wet weather systems originate, makes them imposing and influential mountains indeed. Due to the earth's rotation and resulting global air circulation patterns, weather moves across the North American continent from west to east. The GNCE, therefore, lies exactly upon the leading edge of the continent: whatever moisture is picked up from the North Pacific and moved landward strikes the western slope of the North Cascades first. This collision of moist air and coastal mountain has a dramatic impact on both.

As water vapor cools it approaches the dewpoint—that point at which vapor condenses to liquid. And as every mountain hiker knows, air is cooler at higher elevations. Moving eastward from the ocean, air masses must abruptly lift themselves over the North Cascades to continue on their eastward journey. In doing so they cool to the dewpoint and convert to rain or snow. As a result, most of the moisture in the ocean-born clouds falls almost immediately on western slopes of the North Cascades; air masses are dramatically drier by the time they reach the eastern slopes. Average annual precipitation on the western side of the range averages 110 inches (including up to 46 feet of snow). The Pasayten Wilderness Area, in the eastern "rainshadow" of the crest, receives an average of only 12 inches (Harris and Tuttle 1983). Much of the precipitation on the western side of the mountains falls as snow, with as much as 46 feet accumulating over a winter. Snow often begins to fall in September and persists through July.

One of the most conspicuous aspects of the North Cascades—the abundance of glaciers—is the direct result of this heavy orographic (mountain-influenced) precipitation. When winter snow accumulation consistently exceeds summer melting and evaporation, the snow compacts and recrystallizes into ice. The immense weight of ice accumulated over many years causes the ice to move downhill. This *movement* of ice distinguishes a glacier from a permanent but non-moving snowfield. Deep cracks in the ice, called crevasses, are evidence of this movement.

As glacial ice moves, it functions much like a huge sheet of sandpaper, scouring rocks, widening valleys, and leaving behind jagged ridges and spire-like peaks. The western portion of the North Cascades is a classic glaciated landscape. Wide U-shaped valleys prevail over the typical V-shaped valleys formed by river erosion. Textbook examples of glacial landforms abound here: spectacular spire-like horn peaks, jagged aretes, and cirques with steep headwalls.

As a result of all this glacial erosion, in addition to the dramatic uplift of the range, the local topographic relief (elevational distance between highest and lowest points in an area) is greater here than anywhere else in the coterminous United States. For example: the upper 6,000 feet of Mt. Goode's 9,200 foot stature rises in just 1.6 horizontal miles;

the upper 5,000 feet of Johannesburg Mountain jut up in one horizontal mile; the west face of Eldorado Peak rises 6,400 feet in two horizontal miles above the Marble Creek valley (Beckey 1977). Because the erosional cycles of the North Cascades are well advanced, major drainage valleys are typically relatively level except for their upper few miles, which are quite steep.

The GNCE hosts the densest concentration of glaciers in the contiguous United States. There are well over 500 active glaciers in just the American portion of the Ecosystem. Virtually all of the present glaciers lie west of the Cascade Crest, but past glacial activity has dramatically altered the landscape of the entire GNCE .

Glaciers advance and retreat in response to changing climatic conditions. Modern glaciers are only remnants of the ice that once covered the North Cascades. In ages past, glaciers were more extensive and reached much lower elevations than they do today. Within the past two to three million years, a cool, wet climate created large alpine glaciers that flowed down the valleys from the high peaks. Episodes of alpine glaciation occurred repeatedly, most recently about 20,000 years ago. The present landscape of the North Cascades was carved during that time, known as the Pleistocene. The North Cascades are known for their extensive alpine glaciation, and the many high cirque basins connected by sheer and twisted aretes bear witness to the mighty rivers of ice that carved them.

Geology and Landforms

The powers that raise mountains are folding, faulting, and volcanism. These powers of uplift are balanced by the erosional forces of water and glaciers, that literally tear down the mountains. Glaciation is especially prominent in the North Cascades. The craggy summits of the high peaks and the deep U-shaped valleys are both due to glacial erosion. The North Cascades represents one of the most complex geologic systems in the world. Rocks have been heavily metamorphosed as heat and pressure—sometimes 7000 times normal atmospheric pressure—have altered their chemical and physical structure. Different geologic systems often interfinger within small local areas, adding to the structural complexity. The North Cascades is one of the fastest rising mountain ranges in the world. If it were not for the tremendous erosive posers of water and ice, its peaks would be several miles high. Much of this dynamism is a function of large-scale plate tectonic movements. This entire region was once a free-floating continent somewhere in the Pacific before ramming up against North America and being accreted onto the continent (Alt and Hyndman 1984).

The North Cascades were built over hundreds of millions of years by the accumulation of sediments deposited in ancient seas, by the collision of tectonic plates and the metamorphism produced by the collision, and finally, by the upwelling of molten magma and the rising of bedrock that displaced the ocean to the west. The mountains we see today have resulted from the recent uplift of the ancient rocks and erosion of the surface of the land. The volcanoes are a spectacular and last-minute addition to the story. In the past few million years the uplift in the northern end of the range has continued.

Volcanism, glaciation, and stream erosion continue to play the major roles in creating the landscape.

The central crystalline core of the North Cascades consists of the oldest and most severely metamorphosed rocks in the range, mostly over 60 million years old. Snoqualmie Pass provides a clear demarcation between the northern and central Cascades: to the north, rocks are primarily crystalline and metamorphic, to the south, primarily younger volcanic and sedimentary rocks are found overlaying the deeper metamorphic rocks. In the North Cascades intensive erosion has scoured away the volcanic layer. (Easterbrook and Rahm 1970, McKee 1972).

RESULTING ECOSYSTEM DIVERSITY

Plant Communities

Due to the topographic and climatic diversity described above, there is a concordant diversity of ecosystems in the GNCE. This is a rich and varied landscape—a tapestry woven of geography, climate, topography, and the interactions of living communities of plants and animals. Although gradations are gradual rather than abrupt, on a macro scale the vegetation of the GNCE can be seen as consisting of eight major zones: six forest zones, each named for the dominant climax tree species, the land above timberline, which is actually a mosaic of many different closely spaced and interwoven plant assemblages, and the sagebrush-steppe, or semi-desert, of the eastern edges of the Ecosystem. From west to east, these vegetation zones are: 1) Douglas-fir-western hemlock (*Pseudotsuga menziesii-Tsuga heterophylla)* forest; 2) Pacific silver fir-western hemlock (*Abies amabalis-Tsuga heterophylla)* forest; 3) mountain hemlock (*Tsuga mertensiana)* forest; 4) the complex mosaic of communities above timberline; 5) subalpine fir-Englemann spruce (*Abies lasiocarpa-Picea englemannii*) forest; 6) interior Douglas-fir (*Pseudotsuga menziesii*) forest; 7) ponderosa pine (*Pinus ponderosa*) forest; and 8) sagebrush steppe.

The forests of the western slope of the Cascades are unique among the temperate forests of the world, because of both the size and the longevity of their constituent trees (Franklin and Dyrness 1973, Franklin 1988). The almost total dominance of coniferous species is exceptional; in most other moist temperate forests of the world hardwoods are the dominant lifeform, while here conifers are a thousand times more abundant than hardwoods (Kuchler 1946). The dominance of evergreeen conifers is due to both the evolutionary history in the area since the Miocene, and to the present climate of mild wet winters alternating with dry summers. The mildness of winter and the drought stress of the summer growing season both favor evergreens—which can photosynthesize during winter--over deciduous hardwoods, which are more dependent on the summer growing season (Franklin and Dyrness 1973). These forests, which are part of a band of forests which stretch from northern California to British Columbia, also are exceptional for the sheer volume of plant matter produced: they exhibit the greatest accumulation of biomass of any forests in the world (Franklin 1988). Although some other forest ecosystems have higher annual productivity rates, the longevity and sustained height growth of the dominant conifer species in the GNCE lead to exceptional accumulations of biomass—sheer abundance of living matter.

Ranging from sea-level up to elevations of 700-1000 m. is the Douglas-fir—western hemlock (*Pseudotsuga menziesii-Tsuga heterophylla*) forest zone (Franklin 1988; referred to as the *Tsuga heterophylla* Zone by Franklin and Dyrness 1973). This is the major forest complex of the western slope of the Cascades, the now famous "old growth" or "ancient" forest so steeped in political controversy. "Old-growth" Douglas -fir forests are characterized by several structural features: large trees, large snags, and large fallen logs on land and in streams. These forests have abundant nitrogen-fixing epiphytes, and are very efficient at retaining nutrients (Franklin et al. 1981, Franklin and Spies 1984, USFS 1986). Critical functions within the forest are carried out through complex interrelationships. For example, mycorrhizal fungi, upon which giant conifers depend, are dependent upon small rodents for spore dispersal (Maser et al. 1978). In a very real sense, tiny mice and some of the largest trees in the world are co-dependent. More and more, ecologists are beginning to understand the critical roles played by fallen logs and standing snags in nutrient cycling and provision of wildlife habitat (Maser and Trappe 1984, Franklin et al. 1981, Maser 19 , Norse 1990, Ervin 1989).

Douglas-fir typically dominates young forests, due to its greater sun-tolerance, faster growth rate, and hardy seedlings, while western hemlock eventually dominates where major disturbance, such as fire or clearcutting, has been absent. The dominance of hemlock typically takes about four to six centuries to become established; individual Douglas-fir trees may persist up to 1000 years (Franklin 1988), and often predominate in stature and abundance over the climax hemlock. There are many variants of the *Pseudotsuga menziesii-Tsuga heterophylla* forest, depending on local moisture conditions. Where conditions are relatively dry, understory is characterized by salal (*Gaultheria shallon*), while the wetter end of the spectrum tends to have an understory of sword fern (*Polystichum munitum*). On very wet sites, giant western redcedar (*Thuja plicata*) may dominate locally. The most prominent example of this is Big Beaver Creek valley, home to one of the largest remaining western redcedar forests in the world.

Natural disturbance factors—wildfire and wind—have played essential roles in maintaining the structure of these forests since long before Euro-americans entered the picture. Westside cascade forests have always had large, intense, but infrequent forest fires. These periodic fires—less frequent than those of the Sierra Nevada or Rocky Mountains—are thought to be a key factor contributing to the wide variety of age classes present in old-growth Douglas-fir forests. Wind has also been an important instrument of natural forest disturbance. Pathogens, such as insect outbreaks, have generally not been as important here as in many other types of western coniferous forests (Franklin 1988).

The greatest force of forest disturbance today is not fire nor wind, but Homo *sapiens*. Most of the habitat along the western margin of the GNCE has been altered by logging, agriculture and urbanization. When the first white settlers arrived in the western portion of the GNCE, they saw something quite different than we see today. Almost all of the landscape from tidewater to timberline was covered by dense ancient forest; only remnants remain today. Today clear-cutting is the most common agent of disturbance of *Pseudotsuga menziesii-Tsuga heterophylla* forests. The effects of clear-cutting on forest succession patterns are significantly different from those of natural wildfire. After clear-cutting, soil erosion is increased, nutrient pathways are altered, and wildlife habitats, such as snags and fallen logs, are removed (Franklin 1988).

What were once considered signs of "decadence"—snags and fallen logs—are increasingly being recognized as key elements in the rich, interconnected world of ancient forest diversity. After a large Douglas-fir dies, it can remain standing as a snag for up to a century. A variety of insects—carpenter ants, termites, and beetles—eat the wood, and are in turn eaten by pileated, white-headed, and three-toed woodpeckers, who depend upon the snag for nest sites. Large snags also provide day roosts for brown bats (Thomas 1988). Downed logs provide runways for woodrats, substrate for western hemlock seedlings, and moist habitat for a variety of amphibians. Ensatina salamanders live in piles of bark which accumulate at the base of snags (Aubrey et al. 1988), while Olympic salamanders and tailed frogs breed in the small streams which run clear and cold (Bury and Corn 1988). Western red-backed voles are common in these ancient forest communities, but found nowhere else in the world (Corn et al. 1988). In the Skagit River watershed, over 53 species (39 birds and 14 mammals) use dead, standing and fallen trees for nesting cavities and for feeding. To a careful observer, it becomes quickly apparent that the fabric of the "decadent" ancient forest has an infinitely more complex weave than previously assumed.

Water is an essential element of the North Cascades. Especially on the west side, one is seldom away from the sound of moving water. The margins of dozens of streams, rivers, and lakes all harbor slightly different plant communities than live in the adjacent forests. Black cottonwood (*Populus trichocarpa*), red alder (*Alnus rubr*a), and western redcedar all frequent these riparian zones, which are even more moist than the surrounding forest. These special habitats often create narrow ribbons of deciduous woodland through the realm of tall conifers. Lakes are found in all forest zones, from lowlands to above timberline.

As one moves eastward and upward, these ancient forests of Douglas-fir, western hemlock, and western red cedar (the *Pseudotsuga menziesii-Tsuga heterophylla* forest type) begin to give way gradually to middle-elevation forests of Pacific silver fir and western hemlock, the *Abies amabalis- Tsuga heterophylla* forest type (Franklin 1988; equivalent to the *Abies amabalis* Zone of Franklin and Dyrness 1973). Cooler temperatures and permanent winter snowpack, along with the presence of Pacific silver fir as a climax species, distinguish this forest type from the lower elevation old-growth Douglas-fir—western hemlock forest. This montane forest type consists of a blend of temperate zone and subalpine species. Understories here are typically dominated by evergreen shrubs of the heath family, such as several species of huckleberries (*Vaccinium*). Western hemlock reproduces poorly towards the upper limit of its range, probably because its small seedlings get buried under snow-compressed litter (Thornburgh 1969). Thus, Pacific silver fir is the major climax species in this zone, although western hemlock often dominates local stands (Franklin 1988).

The incredibly steep relief and heavy snowpack of the North Cascades make avalanches a common occurrence. Avalanches leave remnant "tracks": long strips of open brushy vegetation in total contrast to the forest communities in which they are found. Douglas maple (*Acer glabrum*), Sitka alder (*Alnus sitchensis*), and many other shrubs compete vigorously for space and light. In early successional stages, avalanche tracks host meadows of tall wildflowers, such as lupines (*Lupinus latifolius*), valerians (*Valeriana sitchensis*), and false hellebore (*Veratrum viride*).

The coldest, snowiest forest zone in the GNCE, dominated by mountain hemlock (*Tsuga mertensiana*), lies above the *Abies amabalis- Tsuga heterophylla* forest. Mountain hemlock forests have deep and persistent winter snowpacks, sometimes as deep as 7.5 m. Mountain hemlock and Pacific silver fir co-dominate these forests . On moist sites Alaska yellow cedar (*Chamaecyparis nootkatensis*) may be present; an elevation gain of four or five thousand feet from sea level delivers similar environmental conditions to those of the southern Alaskan coast, several hundred miles north, where yellow cedar is common. The *Tsuga heterophylla* zone is typically divided into a lower subzone of closed canopy forest, and an upper ecotonal band of subalpine parklands, where forest islands interfinger with subalpine meadows. These beautiful parklands just below timberline are stunning, characteristic features of Northwest mountains, better developed here than anywhere in the world (Franklin 1988, Franklin and Dyrness 1973).

Timberline in the North Cascades lies at approximately 5,000 feet on the western slopes and rises on the east side to around 6,500 feet. Alpine timberline is a fascinating ecological mixing zone, with dramatic shifts in plant community structure occurring over very small areas. Stunted, wind-flagged trees, known as "krummholz" (German for "crooked wood"), are the uppermost outliers of upright tree growth. Krummholz is often composed of different species than the subalpine forest which grows just downslope. In the western North Cascades, krummholz tends to include subalpine fir (*Abies lasiocarpa*), although the subalpine forest is dominated by *Tsuga mertensiana*. In the eastern North Cascades *Abies lasiocarpa* is joined in the krummholz zone by Englemann spruce (*Picea engelmannii*), subalpine larch (*Larix lyalli*), and whitebark pine (*Pinus albicaulis*) (Douglas and Bliss 1977).

Timberline is caused by a complex interaction of ecological factors: topographic position, exposure to wind and frost, snow accumulation, soil moisture recharge, and solar radiation. The distribution of snow is a primary factor controlling the location of alpine timberline and the mosaic pattern of plant communities which lie above it. The depth of snow accumulation, and thus the duration of snowpack, influences soil moisture, soil temperature, and the length of the growing season. Sites which accumulate "too much" snow, such as basins and leeward slopes, have a late summer snowmelt, and thus a very short growing season. Additionally, the accumulation of heavy snow can cause direct physical damage to woody plants. On the other hand, sites which accumulate "too little" snow, such as ridgetops and windward slopes, are exposed to the full force of winter winds, have no insulation from dangerous winter frosts, and lack sufficient snowpack to recharge soil moisture. Thus these sites are susceptible to drought during the summer growing season (Fonda 1976, Canaday and Fonda 1974, Franklin et al. 1971, Evans and Fonda 1990).

Studies of plant communities above timberline in the North Cascades have found a complex mosaic of plant associations, growing in sweeps and patches in response to the ecological interactions described above. Twenty-four different plant community types have been described for this ecological checkerboard. These can be simplified into five broad categories (Douglas and Bliss 1977, Douglas 1972). Snowbed communities receive the greatest snow accumulation; the dwarf sedge (*Carex nigricans*) community, a low, mat-forming garden, is a widespread example of this type. Where late snowbanks are found, the mosaic of communities is condensed even further; in such a snowbank basin, miniature plant communities grow in concentric circles, corresponding to the progression of snowmelt through the summer (Billings and Bliss 1959). Mesic herb communities, such as that dominated by subalpine lupine (*Lupinus latifolius*), are the lushest, and generally the tallest, communities above timberline. There are several different types of dwarf shrub communities, typically dominated by members of the heath family (Ericaceae). This type includes the glorious heather meadows, so beloved—and so susceptible to damage—by North Cascades hikers. Red mountain-heather (*Phyllodoce empetriformes*), yellow mountain-heather (*P. glanduliflora*), and white mountain-heather (*Cassiope mertensiana*) all dominate extensive areas of the GNCE alpine world. There are also several types of dry graminoid (grasslike plant) communities. An easily recognized example is the showy sedge (*Carex spectabilis*) meadow. Lastly, there are fellfield communities, the sparsely vegetated areas composed largely of broken rock, such as are found near summits. In these high windswept areas the dominant life forms are lichens and small cushion plants: low-growing, prostrate masses of green with brightly colored flowers. On the most exposed summits, crustose lichens often represent the only growth. In the rugged, glacier-clad western North Cascades there is an entire world of rock, ice, and snow above all these community types, a world visited only briefly by insects, birds, and humans,

The alpine flora of the GNCE has affinities with many regions in Western North America; its strongest relationships are with the Arctic and the Rockies (Billings 1988). Those alpine sites on the western slope of the GNCE have floristic similarities with other coastal mountain ranges, while those to the east share more with the Rocky Mountains (Douglas and Bliss 1977).

The area above timberline is among the most delicate and easily damaged ecosystems in the world (Billings 1973). In the GNCE, the dwarf shrub communites in particular have suffered extensive damage from recreationists, due to the fragility of their brittle woody stems (see Chapter). Evolutionary adaptations which allow diminutive plants to withstand all the harshness of life above treeline do not serve as well against the rigors of vibram-soled boots, campfires, mining, and livestock. All these activities have had major impact on subalpine and alpine ecosystems in the GNCE. Human disturbance here has been very recent—the mountains' rugged nature discouraged visitors until this century—but profound and widespread.

The rainshadow effect of the Cascade Crest is dramatic. Standing on the Crest itself, one may have one foot in a sea of fog and clouds and the other in bright sun. This startling climatic difference affects more than hikers' spirits; as one descends from timberline toward the east, an immediate contrast can be seen in vegetation. Whereas the subalpine forests of the west side are largely composed of mountain hemlock, here on the east side the upper forests are dominated by subalpine fir, Englemann spruce, subalpine larch, and whitebark pine. The spruce-fir (*Picea-Abies)* forest community (the *Abies lasiocarpa* Zone of Franklin and Dyrness 1973) is dominant at high elevations throughout the Rocky Mountains, far to the east (Peet 1988). Thus, the rainshadow formed by the Cascades causes their east slopes to share more with the Rockies, several hundred miles distant, than with their own western slope, just a few miles away.

This Rocky Mountain affinity of the eastern slope can also be seen at lower elevations. Middle elevation forests of the eastern slope are dominated by Douglas-fir (*Pseudotsuga menziesii*) (the *Pseudotsuga menziesii* Zone of Franklin and Dyrness 1973 and the Interior Douglas-fir Zone of Krajina 1965). Here, Douglas-firs mix with lodgepole pine (*Pinus contorta*), ponderosa pine (*Pinus ponderosa)* , and western larch (*Larix occidentalis*) (Franklin and Dyrness 1973, Peet 1988). The lowest elevation forest of the eastern Cascades is the “classic” pine forest of the West, dominated by ponderosa pine (Peet 1988). The structure of ponderosa pine forests throughout the West have been dramatically changed since Euro-american settlement. Pre-settlement ponderosa forests were open woodlands, and tended to have a grassy understory rather than the shrub layer we find today. In addition, the size of the pines themselves were much larger. Fire suppression, livestock grazing, and logging have all contributed to this transformation (Peet 1988, Cooper 1960).

At the eastern margins of the GNCE, a second timberline is reached. This lower timberline is present because the climate becomes too arid to support forest growth (Arno 1984). Ponderosa pine forest gradually disappears along a decreasing moisture gradient, blending into the sagebrush steppe, a shrubby semi-desert dominated by *Artemisia spp.,* common throughout the Intermountain West (West 1988). The sagebrush steppe has also undergone drastic ecological revision since Euro-american settlement. Due to extensive livestock grazing and increased fire suppression, native perennial bunchgrasses, such as wheatgrasses (*Agropyron*) and fescues (*Festuca*), have been replaced by the Eurasian annual cheatgrass (*Bromus tectorum)* over millions of acres. Sagebrush increases in abundance under such conditions (West 1988). Thus, the abundance of shrubs has increased, while that of grasses has decreased, and the relative abundance of grass species has changed. Extensive agriculture near the eastern margin of the GNCE has eliminated native ecosystems altogether over large expanses.

A vegetation transect of the GNCE from west to east demonstrates the enormous ecological impact of the Cascade rainshadow: the east side of the GNCE has more in common with the Great Basin and the Rocky Mountains than with the western slope of the Cascade range itself. While the western slope of the Cascades is much closer physically than the Rockies or the Great Basin, ecologically it is worlds apart. The climatic and topographic setting of the GNCE leads to an exceptional degree of environmental and biological diversity.

Animal Populations

The great diversity of vegetation in the GNCE sets the stage for a concordant diversity of animals. There are approximately 276 vertebrate wildlife species within the Skagit River Basin alone: 25 fishes, 17 amphibians, 10 reptiles, 73 mammals, and 174 birds (Weisberg 1991).

Due to their mobility, animals have the ability to range freely between vegetation zones. Some, however, have very precise habitat needs, and are found almost exclusively in a particular plant community type. Generalist species, such as ravens, are found in all habitats of the GNCE, from lowland ancient forest, to alpine fellfield, to sagebrush steppe. Other animals, such as the now-famous spotted owl, are much more particular about their choice of home. Closely related species of animals often sort themselves out into different elevational zones, just as closely related plants do. Four species of thrushes are common in the North Cascades. Swainson's thrush is found commonly in lowland coniferous forests, the hermit thrush is the archetypal dweller of subalpine forests, while the varied thrush and American robin are found throughout the entire range of coniferous forest zones. Two parnassian butterflies separate themselves according to elevation in a similar manner to the thrushes. The Clodius parnassian (*Parnassius clodius*)frequents the lowlands while Phoebus' parnassian (*P. phoebus*) lives at higher elevations.

Spotted owls (*Strix occidentalis*) are closely associated with dense coniferous forests of low and middle elevations on the western side of the Cascades (Forsman et al. 1984, Dawson et al. 1987). This includes the *Pseudotsuga menziesii-Tsuga heterophylla, Abies amabilis,* and *Tsuga mertensiana* forest community types. In an Oregon study, virtually all spotted owl nests discovered were in forest stands over one hundred years in age (Forsman et al. 1984). Feeding on flying squirrels and other small rodents, the each spotted owl pair needs at least 2,400 acres of ancient forest to survive (ref?). For years one of the great ornithological mysteries was the unknown nesting habitat of a small seabird, the marbled murrelet (*Brachyramphus marmoratus*). The mystery has begun to yield to naturalists' inquiries: surprisingly, this tiny, fish-eating seabird is also dependent on ancient Douglas-fir forests, nesting high in the giant conifers (*ref?*).

The larger lakes, including Ross Lake and Lake Chelan, host breeding populations of common loons (*Gavia immer*) and osprey . Common mergansers, large diving ducks, are frequently seen along rivers, as are great blue herons and spotted sandpipers. Harlequin ducks (*Histrionicus histrionicus*) breed in rushing mountain streams of the GNCE after wintering on saltwater bays and rocky coastlines of the Pacific.

The Skagit and Nooksack River systems, of the western GNCE, support the largest wintering bald eagle (*Haliaeetus leucocephalus*) populations in the contiguous United States. As many as 600 bald eagles feed along the winter waters of the Skagit and its tributaries. These eagles are winter residents; they arrive from coastal and northern breeding sites in late fall, reach a population peak in late January, and depart by early spring. Coming from as far away as Alaska and Montana, the eagles depend upon the spawning runs of chum salmon for livelihood throughout the winter. Eagles also depend on the adjacent forests; remaining patches of ancient forest near the rivers are used for communal night roosts, providing shelter and thermal advantage (roost sites are often 15^{o} F warmer than the surrounding forest).

The six species of Pacific salmon (chinook, coho, pink, sockeye, chum and steelhead) living in the rivers of the GNCE are not only the largest and most important predators in its aquatic ecosystems, they are also important indicators of their health. Salmon require cold, unpolluted water that is both high in dissolved oxygen and low in sediments. The Skagit River is the only large river system in the state that contains healthy populations of all five native salmon species. The life cycle of these salmonid fishes is one of nature's great miracles: individuals hatch in GNCE stream, make their way to the sea, then after several years of oceanic life, return to their natal stream sites, to breed and die. Only remnants of native salmonid populations survive; habitat destruction, dams, and overfishing have all taken their toll.

A number of mammals are commonly seen in the GNCE. The excited chatter of the Douglas squirrel, or chickaree (*Tamiasciurus hudsonicus*), is commonly heard from the high branches of ancient forest conifers. It nests in holes in dead trees and feeds primarily on conifer seeds and berries. Two subspecies of deer are found in the North Cascades: the mule deer on the east side and the blacktail deer west of the range. Interbreeding occurs between the two along the Cascade Crest, and various morphological gradations can be seen as a result. During the winter deer descend to the lowlands, where food is more abundant; in spring they follow the melting snow upward.

Black bears (*Ursus americanus*) are common throughout the North Cascades; they are observed most frequently in late summer when they ascend to feast on subalpine huckleberry meadows. North Cascades grizzly bears (*Ursus arctos horribilis*), classified as an threatened species, were once thought to be extirpated from the Ecosystem. Their presence here has been confirmed in recent years, however. Grizzlies prefer small meadows and openings in the forest for feeding. In the spring they frequent lower elevations and riparian areas, moving to the high country to feed in herbaceous meadows in the summer. Their diet consists of 90-95% vegetation, but includes insects, small mammals and carrion.

There are several important but rarely seen predators living in the river valleys and montane forests. The marten (*Martes americana*) and the fisher (*M. pennanti*) are lean and graceful members of the weasel family that spend much time in the trees hunting insects, birds, and squirrels. The gray wolf once roamed throughout the GNCE. Due to heavy persecution and habitat loss, with a resultant decline in its favored prey, elk and deer, the wolf nearly disappeared from the Ecosystem, leading it to be classified as an Endangered species. An adaptable predator, recent evidence has documented breeding wolves in the Baker and Ross Lake areas. The bobcat (*Felis rufus*) and the mountain lion, (*F. concolor*) are both hunters in the mountain forests. Both are primarily nocturnal and roam widely throughout the mountains. The cougar preys mainly on deer; the smaller bobcat hunts birds and small mammals. At high elevations of the eastern Cascades, lynx (*F. lynx*) hunt for snowshoe hare (*Lepus americanus*) in lodgepole pine forests.

The land above timberline is home to a fascinating fauna. Birds are the most mobile animals and many commute daily to the land above the trees from roosting sites in the montane forests below. The reverse is done by black swifts who nest in small crevices in high cliffs, then fly many miles into the lowlands to catch insects and bring them back to their young. During long storms, metabolism of young birds slows down, enabling them to survive for extensive periods without food. Other birds spend most of their time in the alpine world. Rosy finches, small, gray, sparrowlike birds, are commonly found on the highest summits. They feed on seeds and small insects blown onto the snow. Horned larks and water pipits, two small songbirds, commonly inhabit subalpine meadows and alpine ridges. Both spend most of their time on the ground searching for insects to bring carry to the young who are carefully concealed in ground nests. These three species are among the few that actually breed above timberline—although they retreat to warmer regions in the winter. Many birds undertake a vertical migration, dropping to lower elevations for the winter instead of migrating south. The white-tailed ptarmigan is the only bird in North America that spends the entire year above timberline. Its feathered legs and snow-white plumage help it to survive the harsh winter conditions of the alpine zone.

Marmots and pikas are two of the most easily seen and heard alpine mammals. Hoary marmots (*Marmota caligata*) spend over half the year in hibernation under subalpine snowpack, then emerge in summer to engage in conspicuous courtship and feeding activities. The pika (*Ochotona princeps*), a small relative of the rabbit, remains active throughout the alpine winter, feeding on "hay piles" it busily cached the previous summer. The highest and most remote ridges are home to mountain goats. These uncommon residents of the high crags live well above timberline in the summer, retreating to the forest edges only when forced downward by severe winter storms. These skilled mountaineers of the animal world tread easily across the precipitous rock faces of the most rugged peaks. Even glaciers are not devoid of life. Threadlike ice worms live within the surface layers of frozen glacier ice. Carnivorous invertebrates, including several spiders, compete with rosy finches in stalking windblown insects on the ice.

While vertebrates are the most familiar and conspicuous animals to human eyes, they are not necessarily the most abundant or important. At least 3,400 species of arthropods ("joint-legged" animals, including insects, spiders, and mites)—and possibly as many as 8,000—live in westside ancient forests (Lattin 1990). Entomologists tell us that each time we take a step in these forests, our foot is supported by 120,000 arthropod legs! For this reason it may be that the <u>soil</u> of ancient forests has greater diversity than any other terrestrial ecosystem on earth (Moldenke 1990). Invertebrates can tell us much about ecosystem disturbance, as well. The arthropod community structure of westside forest canopy changes completely after logging; old-growth canopy is dominated by spiders and other predators, while second-growth forest canopy is dominated by herbivorous aphids (Schowalter 1989).

The human animal (*Homo sapiens*) has a clumped distribution pattern in the GNCE, being much more abundant around its perimeter, particularly in the coastal lowlands along the western margin. The densest concentrations of humans are at the Seattle-Everett megalopolis, in the southwestern corner of the Ecosystem, where approximately one and a half million of the species live year-round, and in the Vancouver metropolis (approximately half a million), at the Fraser River delta. Other sizable territories, feeding grounds, and lekking areas for the species include Mt. Vernon (13,000), at the Skagit River delta, and Bellingham (50,000), near the Nooksack River delta. Small human populations reach up river valleys on both sides of the range. Human population is sparser on the drier eastern side of the Ecosystem. The largest settlement here is Wenatchee (18,000), on the Columbia River.

Prior to Euro-american settlement, human populations existed at many of the same river mouths and other productive sites (see Chapter). European settlement of the Ecosystem has represented not only a change in genetic stock, but a quantum leap in population size of the human species here. This population explosion, as noted above, has been the driving force for drastic ecological transformations within the GNCE. In spite of these human-induced ecological changes, however, the GNCE remains remarkably intact, remarkably diverse, and remarkably wild.

LITERATURE CITED

Alt, D.D. and D.W. Hyndman. 1984. Roadside geology of Washington. Mountain Press Publishing, Missoula, MT.

Arno, S. 1984 . Timberline: mountain and arctic forest frontiers. The Mountaineers, Seattle.

Aubry, K., L. Jones, and P. Hall. 1988. Use of woody debris by Plethodontid salamanders in Douglas-fir forests in Washington. p. 32-37. In: Szarzo, Severson, and Patton, eds., Management of amphibians, reptiles, and small mammals in North America: Proceedings of a symposium. USDA-Forest Service, Gen. Tech. Rep. RM-166, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Beckey, F. 1977. Cascade alpine guide, Stevens Pass to Rainy Pass. The Mountaineers, Seattle.

Billings, W.D. 1973. Arctic and alpine vegetations: similarities, differences, and susceptibility to disturbance. BioScience 23: 697-704.

Billings, W.D. 1988. Alpine vegetation. p. 391-420. In: M.G. Barbour and W.D. Billings, eds., North American terrestrial vegetation. Cambridge University Press, Cambridge.

Billings, W.D. and L.C. Bliss. 1959. An alpine snowbank environment and its effects on vegetation, plant development, and productivity. Ecology 40: 388-397.

Canaday, B.B. and R.W. Fonda. 1974. The influence of subalpine snowbanks on vegetation pattern, production, and phenology. Bull. Torrey Botanical Club 101: 340-350.

Cooper, C.F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. Ecol. Monographs 30: 129-164.

Dawson, W.R., J.D. Ligon, J.R. Murphy, J.P. Myers, D. Simberloff, and J. Verner. 1987. Report of the scientific advisory panel on the spotted owl. Condor 89: 205-229.

Douglas, G.W. 1972. Subalpine plant communities of the western North Cascades, Washington. Arc. Alp. Res. 4: 147-166.

Douglas, G.W. and L.C. Bliss. 1977. Alpine and high subalpine plant communities of the North Cascades Range, Washington and British Columbia. Ecol. Monographs 47: 113-150.

Easterbrook, D.J. and D.A. Rahm. 1970. Landforms of Washington. Western Washington State College. Bellingham.

Ervin, K. 1989. Fragile majesty: the battle for North America's last great forest. The Mountaineers, Seattle.

Evans, R.D. and R.W. Fonda. 1990. The influence of snow on subalpine meadow community pattern, North Cascades, Washington. Can. J. Bot. 68: 212-220.

Fonda, R.W. 1976. Ecology of alpine timberline in Olympic National Park. Proc. Conf. Sci. Res. Natl. Parks 1: 209-212.

Forsman, E.D., E.C. Meslow, and H.M. Wight. 1984. Distribution and biology of the spotted owl in Oregon. Wildlife Monographs 87: 1-64.

Franklin, J.F. 1988. Pacific Northwest forests. p. 104-130. In: M.G. Barbour and W.D. Billings, eds., North American terrestrial vegetation. Cambridge University Press, Cambridge.

Franklin, J.F. and C.T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA-Forest Service, General Tecnical Report PNW-8, Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Franklin, J.F., K. Cromack, Jr., W. Denison, A. McKee, C. Maser, J. Sedell, F. Swanson, and G. Juday. 1981. Ecological characteristics of old-growth Douglas-fir forests. USDA-Forest Service, Gen. Tech. Report PNW-118. Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Franklin, J.F. and T.A. Spies. 1984. Characteristics of old-growth Douglas-fir forests. p.10-16. In: New forests for a changing world, proceedings of the 1983 Society of American Foresters national convention. Society of American Foresters, Washington, DC.

Harris, A. and E. Tuttle. 1983. Geology of the national parks, third ed. Kendall/Hunt Publishing Co., Dubuque, Iowa.

Krajina, V.J. 1965. Biogeoclimatic zones and classification of British Columbia. p. 1-17. In: V.J. Krajina, ed., Ecology of western North America, Vol 1. Univ. of British Columbia Dept. of Botany, Vancouver.

Kuchler, A.W. 1946. The broadleaf deciduous forests of the Pacific Northwest. Ann. Assoc. Amer. Geogr. 36: 122-147.

Kuchler, A.W. 1970. Potential natural vegetation (map at scale 1:7,500,000). p. 90-91. In: The national atlas of the USA. US Government Printing Office, Washington, DC.

Lattin, J. 1990. Arthropod diversity in Northwest old-growth forests. Wings (Xerces Society), summer, p.7-10.

Maser, C. and J.M. Trappe (eds). 1984. The seen and unseen world of the fallen tree. USDA-Forest Service, Gen. Tech. Report PNW-164. Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Maser, C., J.M. Trappe, and R.A. Nussbaum. 1978. Fungal-small mammal interrelationships with emphasis on Oregon coniferous forests. Ecology 59: 799 -809.

McKee, B. 1972. Cascadia: The Geologic Evolution of the Pacific Northwest. McGraw-Hill. New York.

Moldenke, A. 1990. One hundred twenty thousand little legs. Wings (Xerces Society), summer, p. 11-14.

Newmark, W.D. 1985. Legal and biotic boundaries of western North American national parks: a problem of congruence. Biol. Conservation 33: 197-208.

Norse, E. 1990. Ancient forests of the Pacific Northwest. The Wilderness Society, Washington, D.C.

Peet, R.K. 1988. Forests of the Rocky Mountains. p. 63-101. In: M.G. Barbour and W.D. Billings, eds., North American terrestrial vegetation. Cambridge University Press, Cambridge.

Schowalter, T. 1989. Canopy arthropod community structure and herbivory in old-growth and regenerating forests in western Oregon. Can. J. For. Res. 19: 318 -322.

Thomas, D. 1988. The distribution of bats in defferent ages of Douglas-fir forests. J. Wildl. Mngmt. 52(4): 619-26.

Thornburgh, D.A. 1969. Dynamics of the true fir-hemlock forests of the west slope of the Washington Cascade Range. Ph.D. thesis, University of Washington, Seattle.

U.S. Forest Service (USFS). 1986. Interim definitions for old-growth Douglas-fir and mixed-conifer forests in the Pacific Northwest and California. USDA-Forest Service, Pacific Northwest Research Station, Research Note PNW-447. Portland, OR.

Wardle, P. 1974. Alpine timberlines. p.371-400. In: J.D. Ives and R.G. Barry, eds., Arctic and alpine environments. Methuen, London.

Weisberg, S. 1991. From the Mountains to the Sea: A Guide to the Skagit River Watershed. North Cascades Institute and Puget Sound Water Quality Authority. Sedro Woolley, WA.

West, N.E. 1988. Intermountain deserts, shrub steppes, and woodlands. p. 210-230. In: M.G. Barbour and W.D. Billings, eds., North American terrestrial vegetation. Cambridge University Press, Cambridge.

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