PETITION TO LIST YELLOW-CEDAR, *CALLITROPSIS NOOTKATENSIS*, UNDER THE ENDANGERED SPECIES ACT

Photo Credit: Walter Siegmund

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GREATER SOUTHEAST ALASKA CONSERVTION COMMUNITY, PETITIONER
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JUNE 24, 2014

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Pursuant to Section 4(b) of the Endangered Species Act (ESA), 16 U.S.C. §1533(b), Section 553(3) of the Administrative Procedures Act, 5 U.S.C. § 553(e), and 50 C.F.R. § 424.14(a), the Center for Biological Diversity, the Boat Company, Greater Southeast Alaska Conservation Community (GSACC), and Greenpeace (collectively "Petitioners") hereby petition the Secretary of the Interior, through the United States Fish and Wildlife Service ("USFWS"), to list the Yellow-cedar tree, *Callitropsis nootkatensis,* as a threatened or endangered species.

The Center for Biological Diversity works through science, law, and policy to secure a future for all species, great or small, hovering on the brink of extinction. The Center has 775,000 members throughout Alaska and the United States. The Center and its members are concerned with the conservation of imperiled species, including the yellow-cedar tree, and the effective implementation of the ESA.

The Boat Company is a nonprofit educational and charitable organization with a 35-year history of offering wilderness cruises in southeast Alaska, helping to build a strong constituency for wildlife and wildlands conservation through personal experience.

GSACC's mission is to defend and promote the biological integrity of Southeast Alaska's terrestrial, freshwater, and marine ecosystems for the benefit of current and future generations.

Greenpeace is the leading independent campaigning organization that uses peaceful protest and creative communication to expose global environmental problems and to promote solutions that are essential to a green and peaceful future.

USFWS has jurisdiction over this petition. This petition sets in motion a specific process, placing definite response requirements on USFWS. Specifically, USFWS must issue an initial finding as to whether the petition "presents substantial scientific or commercial information indicating that the petitioned action may be warranted." 16 U.S.C. § 1533(b)(3)(A). USFWS must make this initial finding "[t]o the maximum extent practicable, within 90 days after receiving the petition." *Id*. Petitioners need not demonstrate that a listing *is* warranted; rather, Petitioners must only present information demonstrating that such listing *may* be warranted. While Petitioners believe that the best available science demonstrates that listing the yellow-cedar tree as endangered *is* in fact warranted, there can be no reasonable dispute that the available information indicates that listing the species as either threatened or endangered *may* be warranted. As such, USFWS must promptly make a positive initial finding on the petition and commence a status review as required by 16 U.S.C. § 1533(b)(3)(B).

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EXECUTIVE SUMMARY

Yellow-cedar is suffering massive and unprecedented decline as the climate changes and warms with increasing anthropogenic greenhouse gas emissions. Across over 500,000 acres in southeast Alaska, over 70% of yellow-cedar trees are dead because of climate-change-induced root freezing injury. By the middle of this century, yellow-cedar will only exist in scattered fragments of its former range, and is likely to be extinct in 100 years. Unsustainable old-growth logging practices that target healthy yellow-cedar in southeast Alaska and British Columbia contribute to yellow-cedar's rapid slide toward extinction.

Absent both drastic reductions in greenhouse gas emissions and a ban on all live-logging removals, yellow-cedar will continue to suffer widespread decline. Current regulatory mechanisms are inadequate to address the rising greenhouse gas emissions that threaten yellow-cedar. Regulatory mechanisms governing old-growth logging are similarly inadequate to protect this vulnerable tree species, and are often focused on commercial exploitation of the species rather than protection. Given its precarious status and the uncertainty surrounding future impacts of climate change throughout its range, yellow-cedar cannot withstand any level of live-tree logging, and is need of immediate protection under the Endangered Species Act.

Yellow-cedar plays an important ecological, economic and cultural role in southeast Alaska and coastal British Columbia. As physically massive, long-lived components of the ecosystem, the trees define forest structure, alter microclimates, affect soil chemistry, and, through respiration, mass, and chemical composition, greatly influence ecosystem processes, such as carbon cycling and decomposition. The native people of the region have long valued yellow-cedar's honey-colored, aromatic wood for its strength, straight grain, and decay resistance, and use it in cultural and medicinal applications. The timber industry places high economic value on yellow-cedar, which has long been the most commercially valuable wood in Alaska. Yellow-cedar is important to wildlife, as a browse species for brown bears and Sitka deer, and as habitat for a wide range of forest species, including flying squirrels, bats, and nesting birds. Downed yellow-cedars and snags provide important structural habitat along waterways for anadromous and freshwater fish species, including salmon.

Yellow-cedar distribution is climate dependent. During the snowy, cool and wet period of the Little Ice Age, from about 1500 to 1850 AD, yellow-cedar at lower elevations and at wet, cool sites thrived, due to the tree's unique ability to access nitrates early in spring with a network of fine roots. Unfortunately, this shallow root system also makes the tree more vulnerable to reduced snow pack as the climate rapidly warms with anthropogenic greenhouse gas emissions. This causes a loss of soil-insulating snow pack, earlier springs, and spring freezing events during the vulnerable period after the snow is gone and when the soil has thawed, resulting in root-freezing injury. As a result, yellow-cedar at lower elevations in southeast Alaska, continue to suffer drastic decline due to inadequate snowpack, and early spring freeze-thaw events. In addition to the 600,000 acres of trees already affected in the United States and Canada, decline is likely to spread to higher elevation sites, and to more southerly latitudes as the climate continues to warm. Migration to more suitable sites at higher elevation is limited by the tree's specific habitat needs and extremely low rate of regeneration, and the lack of suitable areas for long-term

growth, especially if climate change continues to accelerate at its current pace. Researchers have recorded next no natural regeneration at sites with yellow-cedar decline.

Despite their decline, yellow-cedar trees are one of the primary targets of the old-growth logging industry in southeast Alaska. The timber industry is putting a great deal of pressure on remaining yellow-cedars because the wood has a high value in foreign markets. In fact, red cedar and yellow-cedar trees drive the layout of most major timber sales in the Tongass National Forest. Without cedars present, most timber sales are economically unviable.

As a long-lived tree that reproduces very slowly, with poor competitive ability, and with a nutrient acquisition strategy (shallow fine roots, and early de-hardening) that results in deadly root-freezing injury as the climate warms, yellow-cedar is unable to naturally adapt to a rapidly changing climate. There is no evidence that enough genetic variability exists within the species to allow a percentage of trees resistant to climate change to survive and repopulate. The devastating effects of climate change on this species, combined with unsustainable logging that directly targets yellow-cedar, will lead to its extinction. Yellow-cedar is unlikely to survive this century unless the species is protected under the Endangered Species Act.

I. NATURAL HISTORY, CULTURAL IMPORTANCE, AND ECONOMICS OF THE YELLOW-CEDAR

A. TAXONOMY AND NAMING

Although there is controversy among scientists as to what to call this species, this petition uses the most updated and widely accepted scientific (*Callitropsis nootkatensis*) and common names (yellow-cedar), as described in more detail below.

1. Taxonomic Nomenclature

When first described in 1824, yellow-cedar was placed in the *Cupressus* genus, and then transferred to *Chamaecyparis* in 1842 (Little et al. 2004). In 1865 botanist Orsted created the monotypic genus *Callitropsis* specifically for the tree then known as *Chamaecyaparis nootkatensis*, based on unique cone structure, but at the time this did not gain approval in the scientific community (Russell 2012).

Thus, the species remained solidly in the *Chamaecyaparis* genus until the discovery of a species of related conifer in Vietnam, *Xanthocyparis vietnamensis* (Farjon and Hiep), which indicated that yellow-cedar is more closely related to the cypress family, Cupressoideae, than the cedar family (Gadek et al. 2000, Little et al. 2004, Little 2006, Harrington 2010, Russell 2012). Further evidence, including information from molecular markers, coupled with the taxonomic rules for assigning scientific names, all give compelling support for using the scientific nomenclature *Callitropsis nootkatensis* (Russell 2012). We will use the scientific name *Callitropsis nootkatensis* in this petition.

2. Common Name

Like the scientific name, the common name for yellow-cedar is also variable, but subject to less vigorous debate. Yellow-cedar is the most frequently used common name for this species, and is widely accepted in both Canada and the United States (Harrington 2010). We have retained the hyphen in the common name, despite its somewhat outdated usage to denote a false cedar (Russell 2012). Although recent scientific information places the yellow-cedar in the cypress family, meaning yellow cypress may be the most appropriate common name, this has not been widely adopted. Other common names include Nootka cedar, Sitka cedar, Sitka cypress, Nootka false cypress, and Alaska cedar or Alaska yellow-cedar (Harrington 2010, Russell 2012).

B. CULTURAL AND ECONOMIC IMPORTANCE

1. Cultural Importance

Yellow-cedar is of immense cultural importance to the native peoples of Alaska and Canada (Stewart 1995), who value its honey-colored, aromatic wood for its strength, straight grain, and decay resistance (Hennon et al. 2007). Alaska Native and First Nations people carved yellow-cedar trunks into totem poles (Figure 1), and used the wood for canoe paddles, dishes, masks and bows, while the fibrous inner bark was woven into baskets, hats, mats, blankets and clothing (Turner et al. 2007, Turner *in* Harrington 2010). Yellow-cedar was also used in a variety of medicinal applications, and played a central role in native peoples' culture, ceremonies, and spiritual belief systems (Stewart 1995). Historically, native people often partially harvested yellow-cedar wood or bark, which was accomplished without killing the tree. These culturally modified trees are found in many parts of the yellow-cedar's range, and are useful for dating and anthropogenic studies (Turner *in* Harrington 2010). Commercial logging and decline has limited the availability of yellow-cedar for cultural purposes in many areas (Turner *in* Harrington 2010).

Figure 1: Yellow-cedar totem pole in front of a Haida longhouse. Image Source: http://www.csindy.com/blogs/IndyBlog/

2. Economic Importance

With natural durability and superior wood characteristics, yellow-cedar is commercially prized, and on a per-unit-volume basis, the most valuable tree species in Alaska (Hennon et al. 2007). From 2005 to 2010, the value of yellow-cedar was nearly three times that of the next most valuable tree species in southeastern Alaska, Sitka spruce (Beier 2011). Currently, Western redcedar is the second most valuable tree species to yellow-cedar, and timber sales are driven by the economics of cedar sales. Yellow-cedar comprises a relatively small percent of harvest, but brings high prices at market, primarily as an export. There is great pressure on this tree resource, especially as many stands are now composed of dead and dying trees.

Most yellow-cedar wood is exported to Asian markets, primarily in Japan, where it is used for home construction, ceremonial boxes, and restoration of temples and shrines (Kelsey et al. 2005, Gaston and Eastin *in* Harrington 2010). The wood is popular decking material in the United States, where it is also used for boat building, saunas, musical instruments, carving, window frames and greenhouse construction (Gaston and Eastin *in* Harrington 2010).
In addition to the harvest of live trees, salvaging of dead standing yellow-cedar also provides wood for these markets, as wood from yellow-cedar snags remains viable for up to a century (Kelsey et al. 2005, Hennon et al. 2007).

Yellow-cedar's slow rate of growth and poor reproductive success has limited its use in tree plantations (Ritland et al. 2001). Recent evidence suggests that the species may be a suitable candidate for commercial plantations or reforestation in areas when ecological conditions are carefully chosen, although long-term studies on commercial plantation viability are not available (Kooistra et al. *in* Harrington 2010). Because yellow-cedar is not naturally competitive at many sites, young replanted trees would have to be carefully nurtured to viability, with deer-exclusion, addition of needed nutrients to the soil, and elimination of competing tree species. Yellow-cedar growth can also be encouraged through planting and thinning in areas determined suitable for long-term survival as the climate warms. Generally, these sites are at high elevation with adequate spring snowpack and well drained soils (Lamb and Wurtz 2009).

C. BIOLOGY, LIFECYCLE, AND ECOLOGICAL ROLE

1. Lifecycle

Yellow-cedar is one of the longest-lived and slowest growing trees in the western United States and Canada, routinely living over 1,000 years, with very narrow annual growth rings compared to other species of trees (Ritland et al. 2001). The amount of yearly growth is tightly linked to climatic conditions (Laroque and Smith 1999). Reaching over 44 meters in height, with a trunk diameter of up to one meter, the yellow-cedar is covered in shaggy, gray, fibrous bark, with drooping soft-green foliage that sheds snow (Figure 2). The largest yellow-cedar was recorded in Mount Rainier National Park, with a diameter at breast height of 2.43 m and a height of 40.2 m (Harris 1970). Some researchers have reported that yellow-cedar may live as long as 3,500 years, while others indicate a maximum age of 1,824 years (Harris 1990, Pojar and MacKinnon 1994). The longevity of yellow-cedar is related to its ecological strategy of defense, and the production of antifungal and antibacterial nootkatin and chamic acids, which together provide the tree with resistance to both disease and insect infestation (Barton 1976, Harris 1990, Hennon et al. 1990b). As a result, yellow-cedar has a low mortality and long life span once mature, but less energy is devoted to reproduction and growth.

Figure 2: Largest living yellow-cedar on Vancouver Island. Photo credit: B. DeBaie.

Yellow-cedar's unique heartwood chemistry with natural anti-fungal and bacterial agents delays decay or rotting of the wood, leaving snags of dead trees standing for up to a century (Barton 1976). This allows for large-scale mapping of areas of yellow-cedar decline, because stands of dead trees are relatively easy to find via remote sensing, especially via aircraft overflights (Hennon and Wittweb 2013). Dead standing trees also provide incentive for the salvage of viable and lucrative wood for market. Issues with permitting and types of harvest have limited such activities to date (Harrington et al. 2010).

2. Reproduction and Genetics

a. Sexual Reproduction

Yellow-cedar has low reproductive potential, due to low pollen viability, poor recruitment rate, and a long natural reproductive cycle (Harris 1990, Hak and Russell 2004, Massah et al. 2010). Yellow-cedar has an extended, three-year natural reproductive cycle, meaning there are often at least four years between good seed crops (Harris 1990, Ritland et al. 2001, Hennon et al. 2006). Some researchers suggest that yellow-cedar cones take two years to develop as an adaptation to the short growing season at high elevations (El-Kassaby et al. 1991).

During year one of yellow-cedar's three-year reproductive cycle, yellow-cedar forms pollen and seed cone buds. Pollination and fertilization occurs in the spring or early summer of the second year of cone development (El-Kassaby et al. 1991). Yellow-cedar seeds mature and disperse in autumn of the third year (Ritland et al. 2001). The tree is monecious, with male and female reproductive organs in the same plant, and appears to utilize outcrossing (Ritland et al. 2001). Seeds have limited dispersal, of less than 120 m, and wind is critical for pollen and seed dispersal (Thompson et al. 2008). Mature yellow cedars produce hundreds of pollen and seed cones, increasing the incidence of self-fertilization, and inbreeding is relatively high within the species. As a result of the above factors, successful sexual reproduction is limited, as indicated by few young seedlings at many sites, and poor regeneration capacity (Hak and Russell 2004). The abundance of young seedlings at a site is directly correlated with the live basal area of yellow-cedar trees, with older trees critical to successful reproduction (Hennon and Shaw 1997).

b. Asexual Reproduction

At marginal sites, yellow-cedar utilizes a form of vegetative reproduction called "layering," where low-lying branches produce adventitious roots. This type of reproduction mainly occurs at boggy sites and in rocky soils at high elevations (Zobel and Antos 1986). Layering may also occur at avalanche and landslide sites. Seedlings produced by layering often form dense, genetically similar thickets at the edges of poor habitat (Zobel and Antos 1986, Ritland et al. 2001). Layering is relatively uncommon in closed-canopy forests and well-drained sites where trees grow to massive heights and thus lower limbs are farther from the ground (West Coast Region Ministry of Natural Resource Operations 2011).

c. Genetic Structure and Diversity

Yellow-cedar is able to survive in a wide range of ecological conditions, which promotes genetic plasticity (Harris 1990, Russell 1993), resulting in a high level of genetic diversity among yellow-cedar populations, with significant genetic differences among populations of yellow-cedar (Ritland et al. 2001). This genetic structure is based on several factors (Harrington 2010, Russell and Krakowski 2012). First, the species has a core range covering over 20 degrees latitude or 1,000 km of coastal North America, and occupies different ecological niches across this range, from bogs at sea level in southeast Alaska, to rocky high elevation peaks in Oregon and Washington, to dry montane areas in the Siskiyou Mountains of Northern California and Southern Oregon. The wide variety of environments puts diverse selective pressures on different populations, resulting in genetic variation. Second, as discussed in greater detail in the two sections above, low rates of natural regeneration and frequent use of layering mean there is reduced gene flow among disjunct populations of yellow-cedar. Finally, the range of yellow-cedar is not continuous, due to yellow-cedar's adaptations to specific niche environments. Yellow-cedar is especially fragmented in the southern half of its range (see distribution map in Section I.D, Figure 6). These geographic isolations contribute to among-population variation in yellow-cedar (Ritland et al. 2001). While populations of yellow-cedars are genetically distinct, they do not appear to have different levels of inbreeding or to be more homozygous.

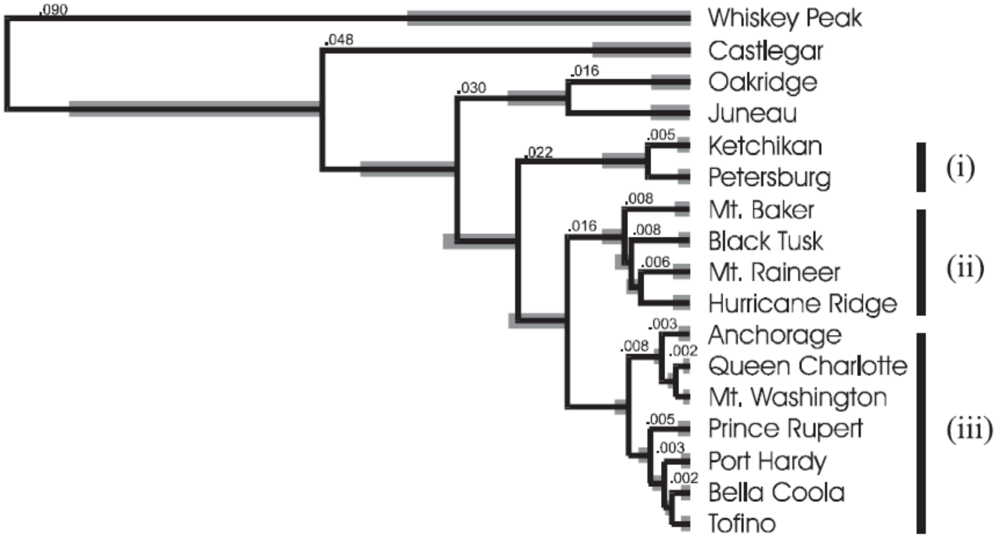


Figure 3: Dendrogram showing genetic distances among the yellow-cedar populations. Distances between clusters indicate relatedness. Source: Ritland et al. 2001.

The genetic structure of yellow-cedar is still poorly understood. Yellow-cedar appears to be divided into three major genetic groups: (i) Ketchikan and Petersburg; (ii) Mount Baker, Black Tusk, Mount Rainier, and Hurricane Ridge; and (iii) Anchorage, Queen Charlotte, Mount Washington, Prince Rupert, Port Hardy, Bella Coola, and Tofino (Figure 3; Ritland et al. 2001). Ritland (2001) believes that the geographic structure of populations reflects separate glacial refugia, with the biotic refugia of the Queen Charlotte Islands during the last ice age accounting for group (c). Group (b) is accounted for as the refugia south of glaciated areas. Each group had varying levels of inbreeding and heterozygosity.

3. Ecological Value of Yellow-cedar

a. *Introduction*

Trees are a foundation species in forested ecosystems and play an important role in many ecological processes. Trees define forest structure, alter microclimates, and through respiration, mass and chemical composition, greatly influence ecosystem processes, such as carbon cycling and decomposition. Long-lived trees like yellow-cedar play an important role in many aspects of forest ecology.

Yellow-cedar occupies harsh sites with poorly drained soils, often on the edges of bogs, where nutrient supplies are low. In these very wet, rocky or acidic areas, few other tree species are able to survive, and there is little competition (Figure 4). Thus, by channeling relatively few resources into growth and reproduction, yellow-cedar outlives competitors (Hennon and Shaw 1997). Yellow-cedar is also adapted to survive in avalanche zones, due to the snow-shedding properties of its needles (Zobel and Antos 1986, Harris 1990).

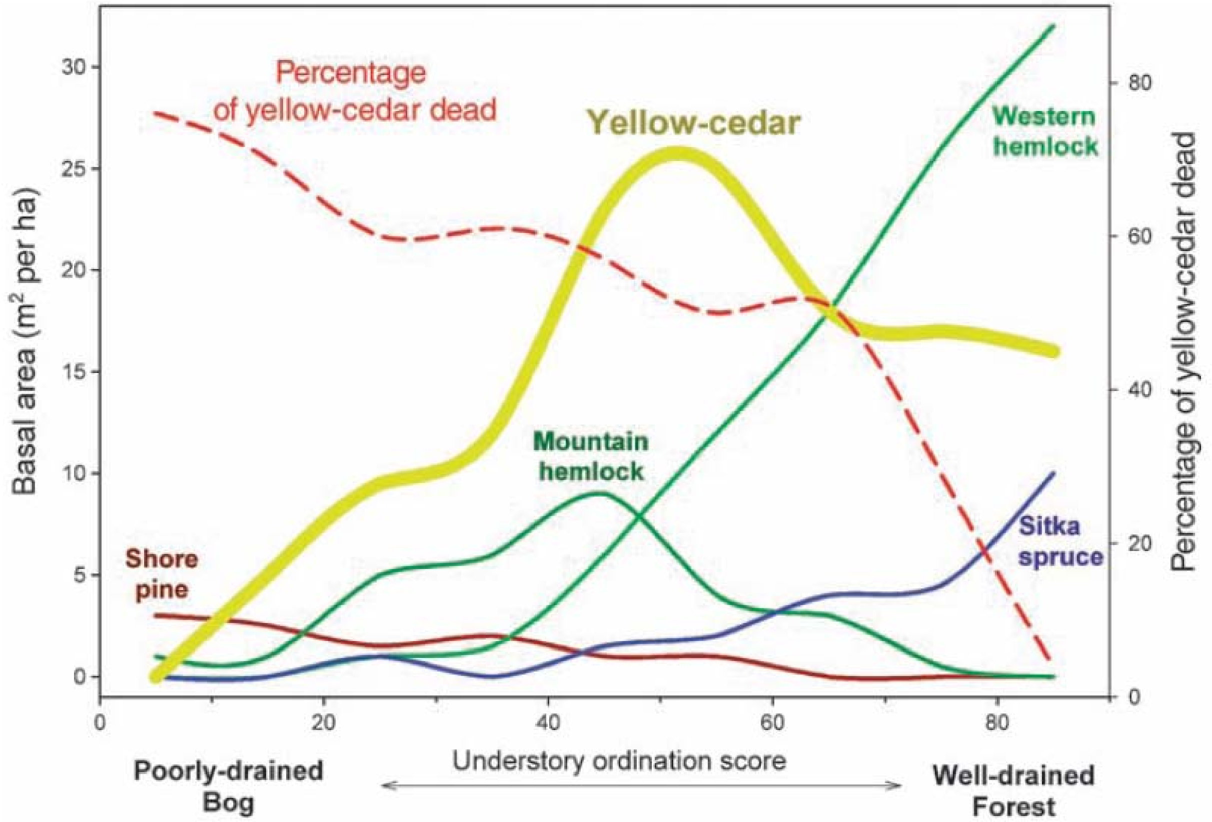


Figure 4: Yellow-cedar's optimum niche and yellow-cedar mortality along the soil-drainage gradient. The percentage of dead yellow-cedar reveals a threshold of drainage beyond which yellow-cedar is healthy but outcompeted by faster-growing tree species. Source: Hennon et al. 2012.

Based on its ecological strategy, yellow-cedar is primarily found in moist, nutrient-poor soils, where biotic competition is low, inhabiting boggy settings with more acidic soil toward the northern edge of its range in southeast Alaska and northern British Columbia. Yellow-cedar can be found in mixed-species forests at low elevation along with western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*) and other species including lodgepole pine (*Pinus contorta*), mountain hemlock (*Tsuga mertensiana*), Pacific silver fir (*Abies amabilis*), and Sitka spruce (*Picea sitchensis*).

b. *Wildlife Interactions: Sitka Deer and Brown Bear*

Yellow-cedar is an important browse species for Sitka black-tailed deer or Sitka deer (*Odocoileus hemionus sitkensis*) and Alaska brown bears (*Ursus arctos*) (Hennon et al. 2012). Alaska brown bears gnaw on yellow-cedar trunks in the spring in order to access the soft under-bark layer, the phloem, which is high in fructose. Basal scars from either brown bears or native Alaskans were evident on over 49% of the yellow-cedars on Chichagof and Baranof Islands (Hennon et al. 1990a), and in some stands the majority of yellow-cedar have basal scars from bear feeding (ADNR 2000).

Yellow-cedar provides critical thermal and refuge cover for Sitka deer, other large ungulates, and small mammals (Walters 1991). In a study of 34 Queen Charlotte goshawk (*Accipiter gentilis laing*) nest trees, four percent were yellow-cedar (Flatten et al. 2002). Keen's myotis (*Myotis keenii*) females, preferred cedar (redcedar and yellow-cedar combined) for roosting trees, which comprised 87% of roosts used by the bats in one study (Boland et al. 2009). Female bats roosted in cedars significantly more than expected, based on their availability (Boland et al. 2009). Yellow-cedar comprise important habitat for Keen's myotis, which is a poorly known species with limited range.

Hennon et al. (2012) hypothesize that yellow-cedar trees were able to regenerate prolifically during the Little Ice Age, in part because heavy snow kept populations of Sitka deer in check (White et al. 2009). Snow may reduce winter browsing by deer. The extirpation or decline of natural predators, including the Alexander Archipelago wolf (*Canis lupus ligoni*), may result in rapid population growth of Sitka deer. Deer may exert cascading effects on small mammals, birds and invertebrates, both by competing directly with them for the same resources, and by indirectly modifying the composition and physical nature of habitats (Baltzinger et al. 2009). Habitat protection is the most important aspect of deer management in southeastern Alaska (Hanley et al. 1989). Thus, yellow-cedar, Sitka deer, and large predators such as the Alexander Archipelago wolf, form an important community, vital to the forests of southeast Alaska. A loss of yellow-cedar has cascading negative impacts on this important ecosystem.

c. Carbon Balance

In southeast Alaska and British Columbia, tree mortality along the Gulf of Alaska, where forests contain a significant source of carbon, can potentially impact the climatic balance of the region (McKinley et al. 2011). Loss of forest habitat will accelerate the climate changes that are already imperiling the habitat of yellow-cedar, possibly shifting the balance from forests as a net carbon sink to forest as a source of atmospheric carbon, further accelerating climate change (Figure 5). The net contribution of a forest to the atmospheric greenhouse gas balance is the result of a combination of factors including uptake of CO_2 by photosynthesis, release of CO_2 by respiration, release of CO_2, CH_4 and N_20 by disturbance, and transfer of carbon to forest products (e.g., the timber industry) (Houghton et al. 1997). A loss of living trees also exerts strong feedbacks on the local and regional climate by altering surface albedo and thus energy exchange between land surface and the atmosphere. Even small increases in albedo due to tree loss could result in increasing climate warming because of the high amount of energy available in these systems (Rotenberg and Yakir 2011). Changes in hydrology are also likely, as a loss of trees may increase surface evaporation, but decrease the amount of water released through the leaves and needles of a tree (transpiration; Adams et al. 2010)

Currently, forests of the United States absorb and store about 16% of the CO_2 emitted by fossil fuel burning in the country each year (Joyce et al. 2014). The carbon stored in United States' forests right now is equal to about 25 years of the country's anthropogenic greenhouse gas emissions, under current rates. This amount of carbon storage is likely to drop drastically with tree die-offs and with changing habitat caused by climate change.

Because of their important role in the carbon cycle, it is important that forest management practices and policy decisions consider the importance of forests as carbon sinks when making decisions. Forest management strategies that increase the average carbon storage and uptake by forests and reduce disturbance to tree species may include: altering tree planting and harvest strategies through species-specific selection and timing; considering genetic variation; managing for reduced stand densities (reduced wildfire risk); reducing other stressors such as poor air quality; using forest management practices to minimize stress from drought; and developing regional-focused strategies to mitigate impacts to ecosystem functions (Joyce et al. 2014).

Large-scale die-backs of the forest, such as those occurring with yellow-cedar decline, reduce carbon sequestration and contribute to warming in the Pacific Northwest and entire subarctic region (Lamb and Wurtz 2009). Forests play an important role in the United States and global carbon cycle, and carbon sequestered in forests and timber products offsets 12-19% of fossil fuel emissions in the United States (Ryan et al. 2010), with long-lived, old-growth trees especially important for carbon sequestration (Stephenson et al. 2014).

In Canada, climate related die-offs of pine forests resulted in carbon emissions of an estimated 990 megatons of CO_2 over a 20-year period, reducing carbon sinks by 270 megatons. This die-off was equivalent to 5 years of Canada's annual emissions from the transportation sector (Anderegg et al. 2011), and influenced Canada climate change policy.

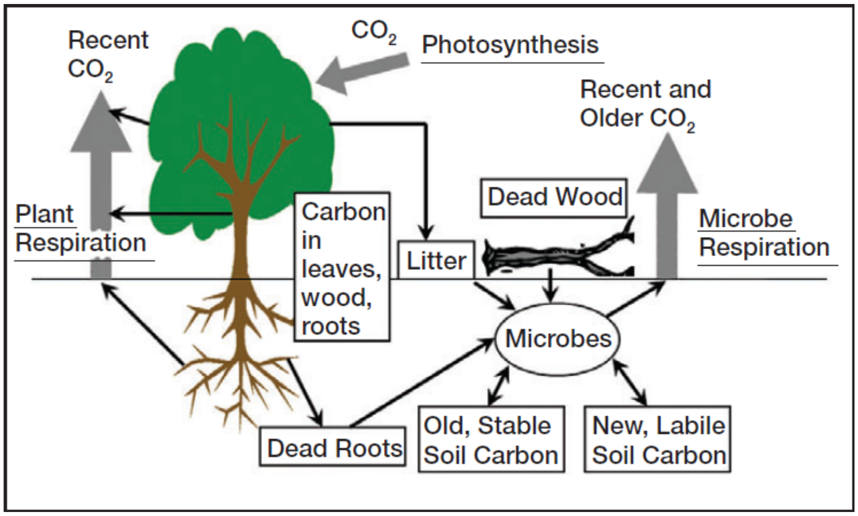


Figure 5: Flows of carbon from the atmosphere to the soils and back. Carbon is stored mostly in live and dead wood as forests grow. Source: Ryan et al. 2010.

Loss of these large, old-growth trees continues to radically transform the landscape, which will alter biodiversity, soil chemistry, undercover growth, ecosystem function and services, and land-atmosphere interactions such as carbon sequestration (Anderegg et al. 2011). Thus, the loss of yellow-cedar could exacerbate (or already is exacerbating) impacts of climate change and warming on the species by disrupting the carbon balance. Long-lived trees take up an especially significant amount of carbon dioxide, increasing the importance of yellow-cedar as a thriving part of the ecosystem (Stephenson et al. 2014). Future forest management may significantly contribute to reducing future greenhouse gas concentrations in the atmosphere, as recognized in the Kyoto Protocol for 2008- 2012. It is important that living yellow-cedar be protected, to preserve their role in the carbon cycle.

d. Landslides

Yellow-cedars also reduce landslide risk and increase productivity of the landslides that do occur. Both cedar decline and timber harvest increase landslide activity, with timber harvest resulting in a 2-fold to 10-fold increase, while in areas with cedar decline landslide risk increases by 3.8 times (Johnson 2013). Following tree death, either by decline or forest harvest, there is a loss of soil cohesion and decreased root strength. Decreased tree canopy interception and reduced transpiration reduces the shear strength of soil, which is associated with increased soil saturation (Johnson 2013). Most landslides occur after the majority of yellow-cedars at a site have been dead for more than 50 years, while landslides typically occur less than 5 years after timber harvest, with 50% of landslides occurring within a year at clearcut sites (Johnson 2013).

Landslides at sites with old-growth, where yellow-cedar snags remain standing, are more ecologically beneficial. Ecological benefits are especially important for anadromous fish habitat, because landslides from areas with standing dead yellow-cedar contain more woody debris that provides structure to streams, and are an important part of fish habitat. Thus, while site conditions that result in landslides are similar at both harvested sites and sites with yellow-cedar decline, the timing and ecological consequences are very different. (Johnson 2013).

D. DISTRIBUTION AND PREFERRED HABITAT

Yellow-cedar is primarily a coastal species, and occurs from the Siskiyou Mountains of northern California to Prince William Sound, Alaska, with isolated interior stands in southeastern British Columbia and central Oregon (Figure 6; Harris 1990). While primarily found in areas with a wet maritime climate, yellow-cedar also occurs on dry locations in the southern parts of its range, and can survive under a wide range of marginal conditions due to a combination of slow growth, a unique fine-root system, reproduction by layering, and an inherent biotic resistance to natural stressors. On a small scale, the yellow-cedar niche is mostly controlled by an affinity for wet or acidic soils at sites where most other tree species are not competitive (Krajina 1969).

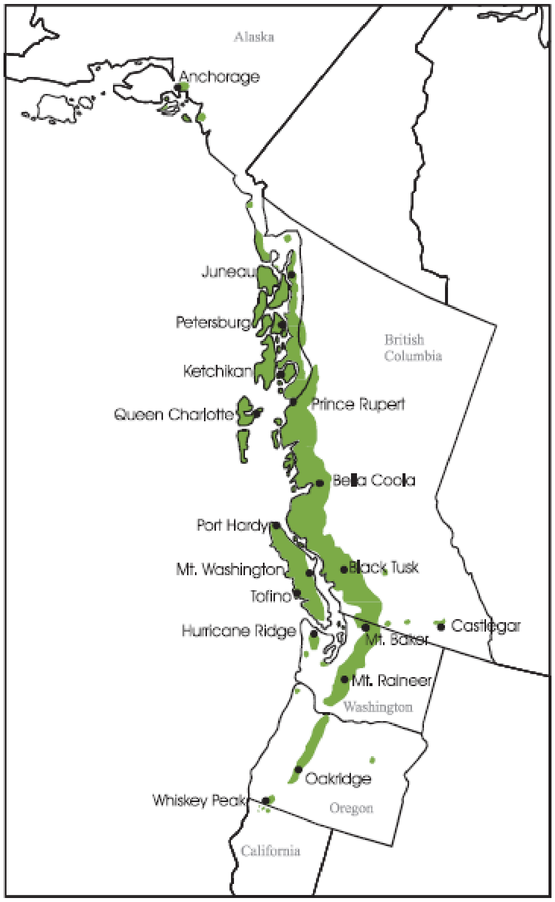


Figure 6: Distribution of yellow-cedar in green. Source: Ritland et al. 2001.

Yellow-cedar is widely distributed and locally abundant in the coastal mountains of southeastern Alaska and British Columbia. Southeast Alaska has a cool, moist climate, with annual precipitation of 150 to 500 cm. Winters are moderate, with occasional brief cold snaps. Summers have few prolonged dry periods, and lightning is rare. Thus, fire does not currently play a role in forest structure and succession (Harris 1990). Common disturbances include windfall and landslides, with disease and insects also playing a relatively small role in mortality. The poorly drained soils preferred by yellow-cedar are highly organic and shallow to deep. These soils are found on sites with gentle slopes.

Old-growth forests of western hemlock (*Tsuga meterophylla*) and Sitka spruce (*Picea sitchensis*) dominate the region, accounting for 89% of commercial timber volume (Deal 2009). Yellow-cedar, western redcedar (*Tsuga plicata*), mountain hemlock (*Tsuga mertensiana*), and shore pine (*Pinus contorta* var *contorta*) are relatively minor forest components, with yellow-cedar accounting for just 4-9% of the commercial timber volume (Hutchinson and LaBau 1975, Wilson 2002). As discussed in this petition, the high market value and special wood qualities of yellow-cedar makes it a sought-after and commercially important tree species, despite its relative scarceness.

In southeast Alaska and northern British Columbia and Washington, yellow-cedar is found in bogs or rocky ridges, where it can form dense thickets through layering. Yellow-cedar is found at middle to higher elevations in the southern portions of southeast Alaska, extending to treeline, where it can form krummholz and tree islands. North of a latitude of 55 degrees, the tree is restricted to a more limited elevation range from sea level to just 150 m in some locations (Hennon et al. 2005, Lesher and Henderson *in* Harrington 2010). The 55 degree latitude line also marks the northern extent of western redcedar, a species often found in association with yellow-cedar (D'Amore et al. 2009).

In the western United States, yellow-cedar is common on the slopes of Mount Rainier, but occurs infrequently south of the mountain, and is locally common to the mountain peaks of the central Oregon Cascades (Figure 7; Zobel and Antos 1986). South of Mount Jefferson, the species is absent from the high Cascades, with a few disjunct locations in the Siskiyou Mountains of northern California and southern Oregon, and one occurrence in the Aldrich Mountains, east of the Oregon Cascades (Ritland et al. 2001).

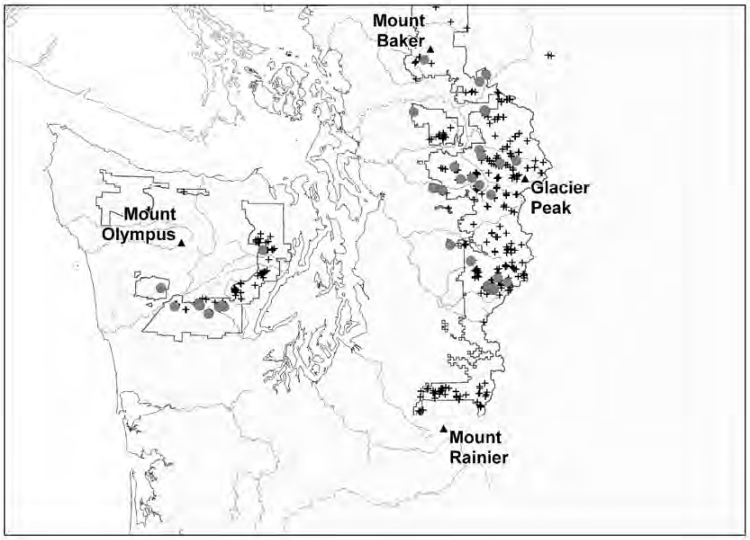


Figure 7: Yellow-cedar distribution in Washington Source: (Lesher and Handerson *in* Harrington 2010).

South of Mount Rainier, yellow-cedar occupies a variety of sites, including boggy and wet areas, and dry rocky ridges (Lesher and Handerson *in* Harrington 2010). In the Siskiyou Mountains, yellow-cedar forms shrubby thickets on marginal sites that are rocky or very wet. In the Aldrich Mountains, yellow-cedar occurs in one isolated location at the head of a sheltered, north-facing drainage (Zobel and Antos 1986).

II. CONSERVATION STATUS: YELLOW-CEDAR DECLINE

A. INTRODUCTION

For the past three decades yellow-cedar has precipitously declined. This population collapse, called "yellow-cedar decline" is caused by a warming and changing climate. Specifically, shifts in the timing and frequency of freeze-thaw events during February and March, and reduced snow cover, causes freezing injury to the tree's shallow fine roots, resulting in death (Figure 7).

Over the past decade, widespread tree die-offs due to climate change have been reported globally (Allen 2009). These mortality events drastically transform the landscape, affecting biodiversity, ecosystem functions and services, and land-atmosphere interaction, and lead to increased fire risk (Anderegg et al. 2011). Over the past thirty years, tree mortality rates in the western United States have more than doubled (Adams et al. 2010). Rising temperatures drive elevation shifts, increasing mortality at lower altitudes and latitudes, and pushing tree species uphill into smaller geographic ranges (Lenoir et al. 2008, Allen 2009). Because trees do not easily migrate or shift distribution to more suitable habitats when conditions in their environment change and become deadly or suboptimal, many tree species will be pushed to extinction as climate change progresses (Bunnell and Kremsater 2012).

Yellow-cedar decline is the most severe forest die-off ever recorded in North America (Ostry et al. 2011, Hennon et al. 2012), and has greatly altered forest dynamics in southeast Alaska. Because yellow-cedar is extremely decay-resistant, snags remain standing for 80 to 100 years, which allows for long-term study and reconstruction of cedar population dynamics (Figure 8). Mapping to date indicates that yellow-cedar decline occurs across more than 500,000 acres in southeast Alaska, primarily on sites from sea level up to 300 m in elevation (Lamb and Wurtz 2009, Hennon and Wittweb 2013). Decline extends 150 km south from the Alaska border into British Columbia onto an additional 124,000 acres at elevations up to 1,000 m (Westfall and Ebata 2012, Hennon et al. 2012). Yellow-cedar decline is concentrated at lower elevations in the northern parts of the tree's range, but extends to higher elevations and to warmer, southerly slope aspects at southern latitudes (Wooton and Klinkenberg 2011).

In stands affected by yellow-cedar decline in southeast Alaska, over 70% of yellow-cedar trees are dead (D'Amore and Hennon 2006, pers. comm. Lauren Oakes 2014), with complete mortality recorded at some sites. Mortality is more severe at locations with relatively wet soils, decreasing or loss of snow cover, southerly slope aspect, and gentle gradient (Snyder and Lundquist 2007). The number of trees suffering from active mortality continues to increase at many locations, indicating that the yellow-cedar decline is expanding in area and intensity at sites where many trees have already died (Snyder and Lundquist 2007). This also indicates that the rapid pace of human-caused climate change may be exacerbating an already serious dieback.

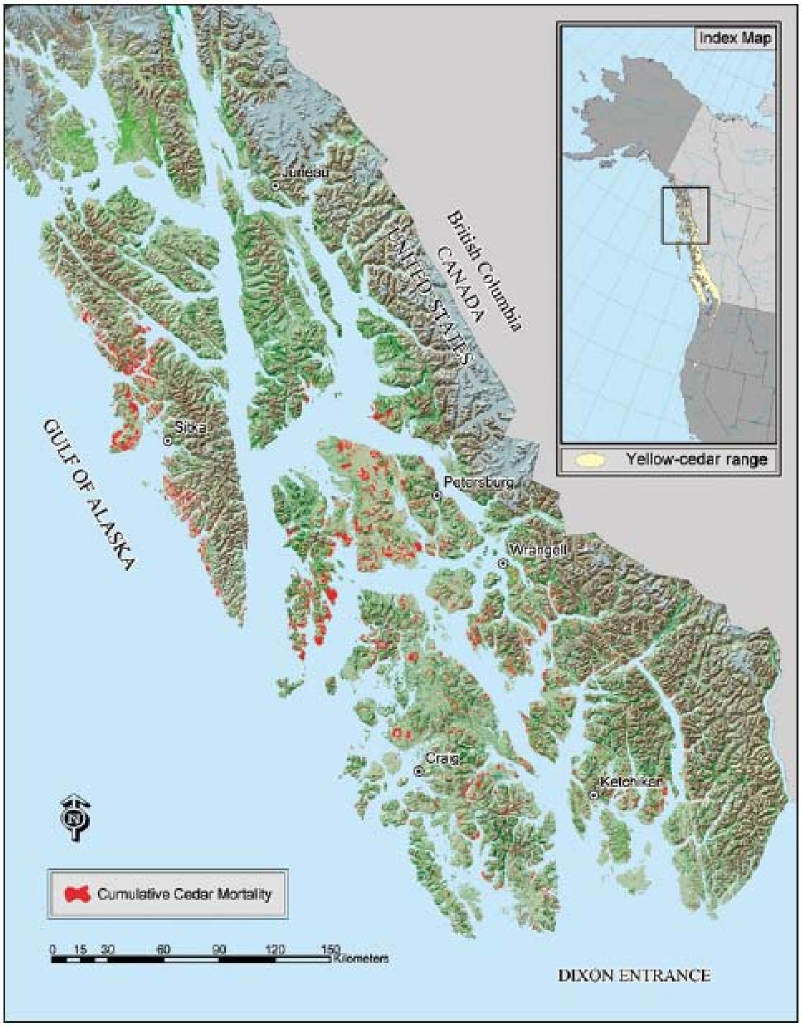


Figure 8: Distribution of yellow-cedar decline in southeast Alaska and inset map of the natural range of yellow-cedar. Figure from Hennon et al. 2005.

Yellow-cedar decline has been intensively studied for over 30 years. After all likely biotic factors were researched and rejected, researchers focused their attention on abiotic reasons for decline by investigating two primary questions: (1) what change in the environment triggered decline, and (2) what physiological features or other factors make yellow-cedar uniquely vulnerable to decline. To date, the best scientific information indicates that yellow-cedar decline is due to a unique combination of physiological features and environmental change—namely a warming climate due to anthropogenic greenhouse gases—which is discussed in more detail in Part II of this petition.

Researchers have determined that the warming climate, which leads to slight shifts in freeze-thaw patterns, is the root-cause of freezing injury and yellow-cedar decline. Decreasing snow cover is a key factor linked to decline, and provides for a fairly simple mapping tool to predict and model future decline patterns (Hennon et al. 1990a, 2008, 2012). Affected trees exhibit dieback symptoms that progress from initial root injury to subsequent crown death, and eventually to tree death (Hennon and Shaw 1997).

Yellow-cedar's unique physiology, which makes it well adapted to cool, snowy habitats, and to marginal habitats, also makes is susceptible to root freezing injury as the climate warms. Yellow-cedar has a shallow fine root system, early dehardening, and extensive uptake of nitrogen and calcium in early spring, along with a propensity for growth in saturated soils. These traits make the tree more prone to freezing injury with shifts in the freeze-thaw cycle, especially when freezing temperatures penetrate the soil surface layer, where the trees' shallow fine-roots grow.

Based on over 30 years of research, scientists have developed an interactive causation pathway that includes the physiological and abiotic factors for decline, the basis of which is fine-root death (Figure 9). Separate studies, as detailed in the upper right corner of Figure 9, contributed to this figure, by investigating the many interactions along the causation pathway that leads to yellow-cedar decline, including hydrology, canopy cover, air and soil temperatures, snowpack, yellow-cedar phenology, and freezing injury to seedlings and mature trees (Hennon et al. 2012).

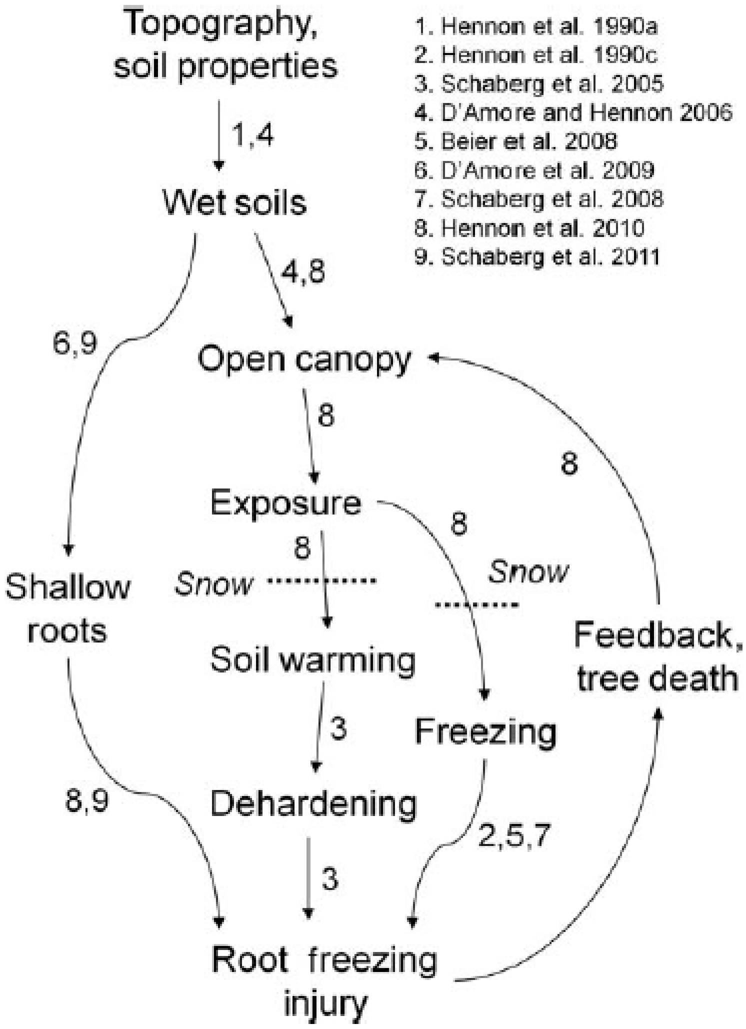


Figure 9: Cascading factors that contribute to yellow-cedar decline, culminating the fine-root mortality and tree death. The mitigating role of snow cover is shown. Tree death is a feedback that can expose adjacent trees to great fluctuation in microclimate, thereby creating conditions for local spread of this

forest decline. In the original document, numbers refer to the studies on interacting factors. Source: Hennon et al. 2012.

Tree death primarily occurs in areas where yellow-cedar was formerly well adapted with a competitive advantage over other tree species due to marginal site conditions, such as bogs. The spreading mortality of yellow-cedar indicates that the tree has been pushed beyond a critical level of biological tolerance over a large area (D'Amore and Hennon 2006). Climate change-caused warming soil and air temperatures and decreasing snow cover are strongly linked to yellow-cedar decline.

Researchers have mapped yellow-cedar decline across an extensive portion of southeast Alaska, especially from the western Chichagof and Baranof Islands to the Ketchikan area. Starting with broad aerial surveys that mapped areas with dead trees, researchers used finer-scale mapping to identify landscape features and other factors such as snow cover, slope, elevation, and aspect that together play a role in yellow-cedar decline. Recent mortality has been most dramatic on the outer and southern coast of Chichagof Island, indicating a northward spread of mortality, which is consistent with the climatic patterns that trigger mortality, especially decreasing snowpack and warmer spring temperatures, combined with intermittent freezing events (Mulvey and Lamb 2012).

B. PHYSIOLOGICAL FACTORS RELATED TO DECLINE: ROOT-FREEZING OF YELLOW-CEDAR

Yellow-cedar's fine roots are relatively shallow and have certain properties that make them more vulnerable to cold temperatures and freezing injury than other conifers. This is due to adaptations that allow yellow-cedar trees to better access nutrients such as nitrogen and calcium, especially at marginal sites such as bogs (Daniels et al. 2011, Schaberg et al. 2011). The high proportion of yellow-cedar's fine roots found in the upper soil levels (less than 7.5 cm) is an important factor predisposing the tree to freezing injury (Schaberg et al. 2011). Yellow-cedar roots near the soil surface are vulnerable to injury when temperatures drop just below freezing (-5 degrees C). Soils commonly drop to temperatures below the threshold for fine-root injury at depths less than 7.5 cm, but such conditions are less common at depths of 15 cm (Schaberg et al. 2011).

The combination of limited cold tolerance, early dehardening and shallow rooting contributes to the unique sensitivity of yellow-cedar trees to freezing injury and decline (Hennon et al. 2012).

1. Spring and Winter Dehardening

Yellow-cedar roots are fully dehardened in March, while other conifer species' roots continue to deharden into May (Hennon et al. 2012). Researchers believe the spring dehardening of yellow-cedar roots is thermoregulated to track microbial activity in late winter, associated with the surge in available nitrogen that occurs during freeze-thaw periods at this time (Schaberg et al. 2005). Tree species that co-occur with yellow-cedar regulate dehardening and growth by photoperiod, and also maintain fewer shallow roots, making them less vulnerable to spring freezes (Hennon & Shaw, 1994).

A study comparing cold hardiness of yellow-cedar and western hemlock at various elevations found that yellow-cedar was much more sensitive to cold temperatures in spring. From winter to spring, yellow-cedar trees dehardened almost 13 °C more than western hemlock (Schaberg et al. 2005, Hennon et al. 2012). This study found that low- and mid-elevation stands of yellow-cedar were less cold hardy than trees growing above 130 m in elevation, consistent with observed trends in yellow-cedar decline.

A study comparing cold hardiness of yellow-cedar with four other coniferous species growing near Ketchikan had similar findings. The roots of all conifer species showed a typical pattern of increasing cold hardiness from November to January, decreasing hardiness from January to March, and a continued reduction in cold hardiness from March to May (Figure 10). Compared to the other species, yellow-cedar developed minimal winter hardiness, and was fully dehardened by March. Particularly notable was the yellow-cedars trees' reduced mid-winter cold hardiness, at a time when air temperatures were lowest, and prior to consistent spring warming (Schaberg et al. 2011). In January, the difference in cold hardiness between yellow-cedar and other cedar species was just 1.6 degrees C, but this small difference may be important. This is because the threshold in freezing tolerance is close to the temperature of -5 degrees C reached in soils in southeast Alaska when there is no insulating snow cover (D'Amore and Hennon 2006, Hennon et al. 2010). Thus, just a small difference in cold hardiness may mean the difference between fine-root death due to freezing injury, and no cold damage.

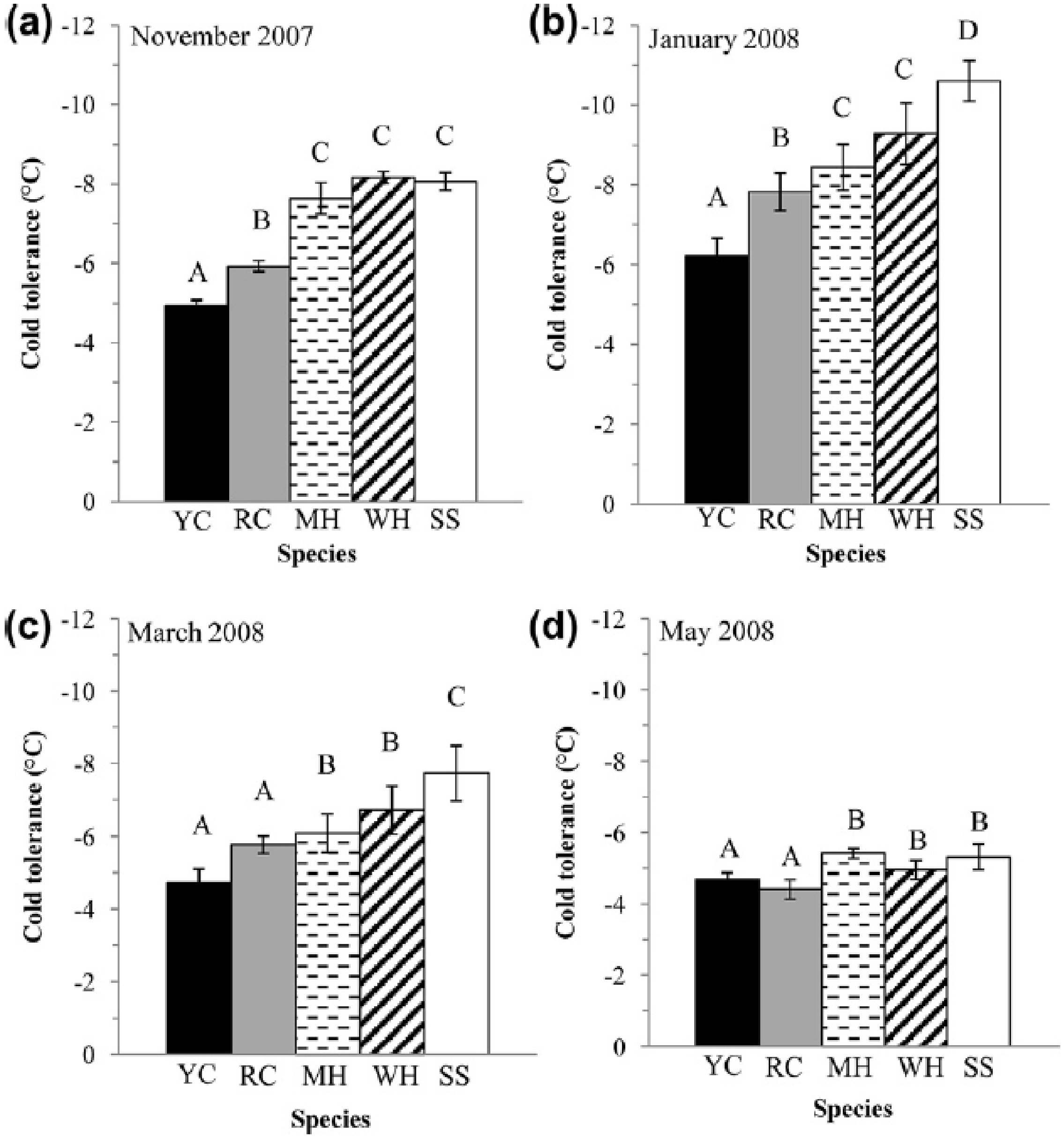


Figure 10: Difference in mean cold tolerance of fine roots of yellow-cedar (YC), western redcedar (RC), mountain hemlock (MH), western hemlock (WH), and Sitka spruce (SS) growing together in Ketchikan, Alaska, and assessed on four dates: (a) November 2007, (b) January 2008, (c) March 2008, and (d) May 2008. Per sampling date, treatment means with different letters are significantly different. Source Schaberg 2011.

These results indicate that freezing damage to yellow-cedar trees is influenced by early dehardening which, for yellow-cedar starts as early as January, and continues through late winter and early spring.

2. Nutrient Acquisition Strategies

Yellow-cedar root systems are especially vulnerable to changes in climate because they are shallow—a characteristic that is essential for the trees to take up nutrients. Yellow-cedar trees rely on the linked uptake of nitrate anions with calcium cations to exploit shallow, rich sources of nitrogen (D'Amore et al. 2009). In order to accommodate this nutrient uptake, yellow-cedar trees have a high proportion of shallow fine roots, early spring dehardening and root activation, and exceptionally high levels of calcium in their tissues (Oliver and Hennon 2013). Scientists theorize that this method of calcium-nitrate cycle from soil to tree, and the resulting interactions with yellow-cedar physiology, plays a crucial role in yellow-cedar decline (Figure 11).

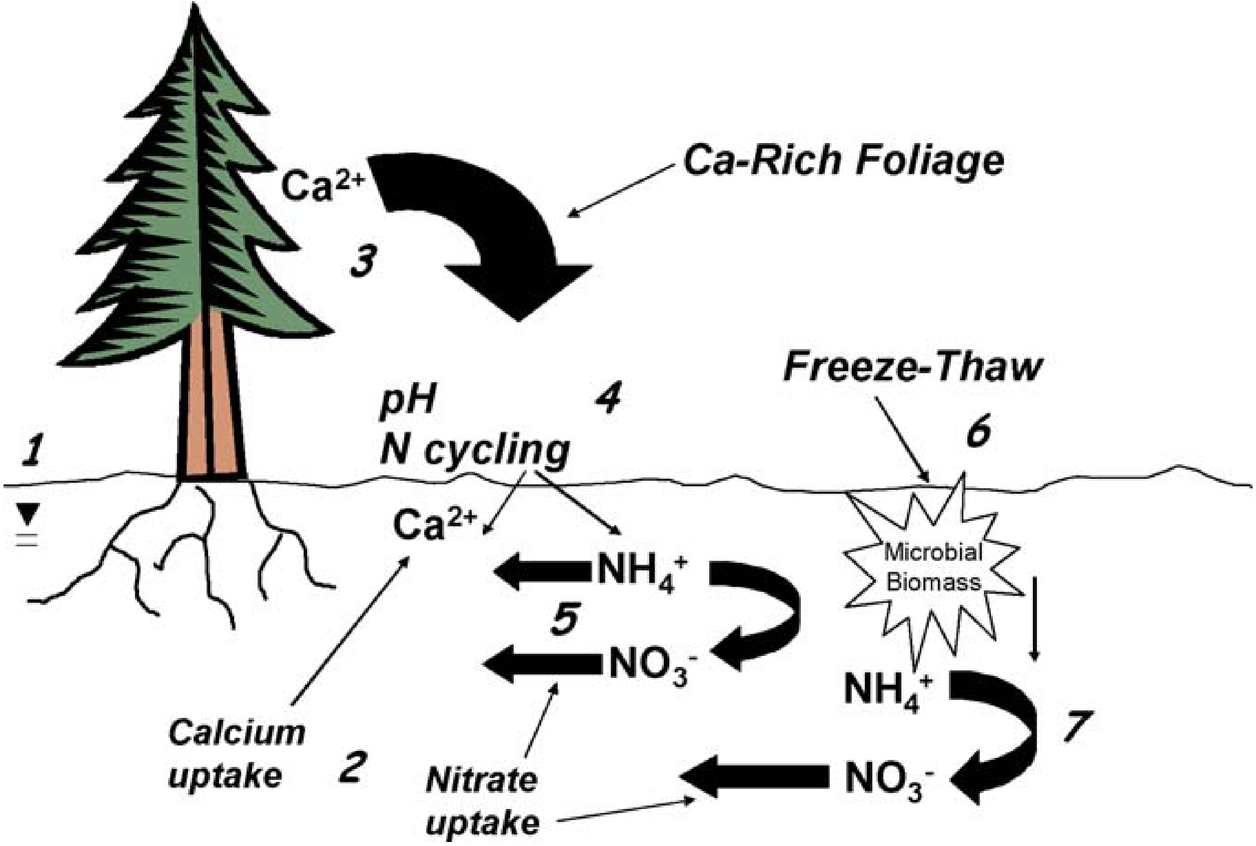


Figure 11: Model for the hypothesis of cedar calcium (Ca) and nitrogen (N) cycling in forests of the Pacific Northwest. (1) Cedars grow in wet soils with low N; (2) cedars assimilate NO3- as a nitrogen source, but must also assimilate Ca as a counter ion to balance cellular pH and osmotic pressure; (3) Ca-enriched foliage falls to the forest floor during senescence, and decomposition consumes H+; (4) increased pH enhances N turnover including nitrification in the forest floor; (5) mineralization and nitrification provide a low, but persistent supply of N to the plant along with Ca available near the soil surface; (6) spring freeze-thaw leads to the release of microbial biomass N that is nitrified; and (7) early spring dehardening and fine-root activity of cedars coincides with the N released by freeze-thaw events.

The shallow-rooting system utilized by yellow-cedar may allow the trees to be more competitive by utilizing nitrate as a source of nitrogen for growth. The acquisition of nitrogen is difficult in saturated soils where yellow-cedar often grows, due to lower mineralization rates and competition from microbial communities and bryophytes. In such areas, nitrogen availability is regulated by the ability of a tree to acquire nitrogen that has been mineralized through organic matter decomposition or microbial biomass turnover (D'Amore et al. 2009). This type of nitrogen is often available during spring freeze-thaw events in bogs and forested wetlands, and can be utilized by the tree if cedar roots are active at the time, through early dehardening and an extensive fine root system.

High concentrations of calcium also play a role in yellow-cedar's ability to uptake nitrogen. Yellow-cedar accumulates a high level of calcium in its tissues. This high level of calcium, an ion which contains two positive charges, allows yellow-cedar roots to associate with negatively charged ions in the soil, especially nitrate (D'Amore et al. 2009).

When the roots remain insulated by snow, early dehardening allows the tree to immediately utilize the spring flush of nitrogen for growth. However, this strategy comes at a cost. Adaptations to increase tolerance of marginal habitats, and allow for increased uptake of nitrogen and calcium from soils, especially during early spring, make yellow-cedar uniquely vulnerable to root freezing and decline (D'Amore and Hennon 2006, Daniels et al. 2011).

C. MAPPING AND EVALUATING RISK FACTORS FOR YELLOW-CEDAR DECLINE

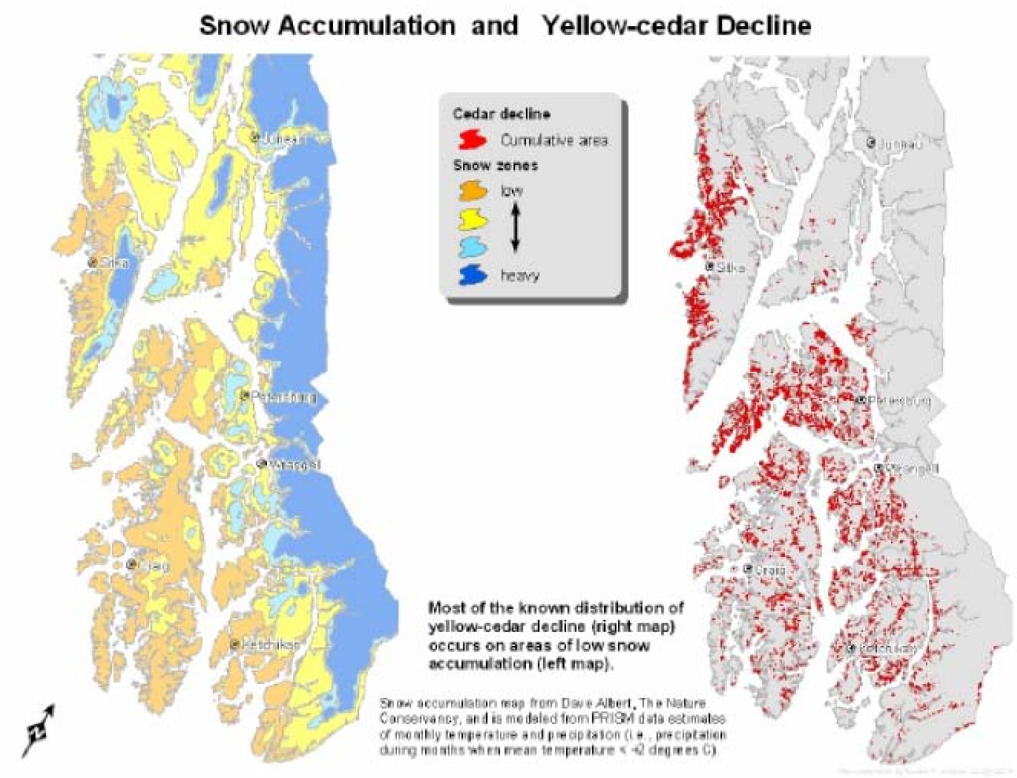
Researchers first determined the onset and trends of yellow-cedar decline based on aerial photographs, historical written observations, and various methods of dating time of death for standing snags (Hennon et al. 1990a). Although yellow-cedars began declining in the 1880s, at the end of the Little Ice Age, studies indicate that the decline accelerated at most sites during the second half of the 20th century, peaking during the 1980s. Progressive mortality continues in declining forests, with the oldest snags found in the wettest soils, and dying trees typically found around the perimeter of recently dead trees, or in better drained soils (for illustration of this, see Figure 12, below). The slow spread of tree death occurs along a hydrologic gradient, with trees in wetter soils affected first (D'Amore and Hennon 2006).

In order to investigate the climate-related causation behind yellow-cedar decline, and to determine future suitability of sites for yellow-cedar regeneration or planting, researchers have investigated the link between various landscape and climatic features and yellow-cedar decline, and also mapped yellow-cedar decline and different abiotic factors at three different spatial scales. The species' highly rot-resistant wood provides a unique opportunity to map and investigate long-term trends in yellow-cedar decline. Site-specific details were obtained from on-ground studies or more detailed mapping of landscape features.

1. Yellow-cedar Decline and Climate: Regional Snow-Cover and Temperature

Researchers used aerial photographs to develop a complete distribution map of yellow-cedar decline in Alaska (see Figure 12 and Figure 8, above). The resulting map depicts more than 500,000 acres of dead and dying yellow-cedar forest at a total of over 2,500 locations (Wittwer 2004), and is useful for determining broad trends connecting yellow-cedar decline to climate change, or for targeting areas to conduct more detailed site-studies. Early on, when biotic causes for decline were still being explored, Hennon and Shaw (1994) used a similar regional-scale map to demonstrate that forest decline aligned with warmer average winter temperatures, an early indication that climate change was linked to yellow-cedar decline.

Regional-scale maps are also used to link snow depth to yellow-cedar decline. Dave Albert of The Nature Conservancy developed the snow accumulation model, derived from PRISM data estimates of monthly temperature and precipitation. The model found close association between the occurrence of yellow-cedar decline and the lowest snow accumulation zone (Figure 12; Hennon et al. 2006). Further discussion of this snow-accumulation model is found in Part III of this petition.



Most of the known distribution of yellow-cedar decline (right map) occurs on areas of low snow accumulation (left map).

Snow accumulation map from Dave Albert, The Nature Conservancy, and is modeled from PRISM data estimates of monthly temperature and precipitation (i.e., precipitation during months when mean temperature < +2 degrees C).

Figure 12: Map depicting snow levels (left) and the occurrence of yellow-cedar decline (right). Note the close association between decline and low snow accumulation. Snow fall amount ranges from heavy (dark blue- light blue) to low (yellow-orange). Map at right depicts areas of yellow-cedar decline in red. Snow zone map was developed by Dave Albert of the Nature Conservancy using PRISM data estimates of temperature and precipitation. Cedar decline map based on Forest Service aerial surveys. Source Hennon et al. 2006.

Currently, the there are no broad-scale regional maps of yellow-cedar decline in British Columbia, where tree death typically occurs in bands from 300 to 400 m in elevation (Hennon et al. 2005). The British Columbia Forest Service is working toward mapping the southern extent of yellow-cedar mortality, and is cooperating with the United States Forest Service to compile a map of yellow-cedar decline throughout its range (Hennon et al. 2005).

2. Yellow-cedar Decline and Landscape Features: Slope, Aspect, Elevation

Researchers associated yellow-cedar decline with various landscape features, including slope, aspect and elevation, using infrared photographs to delineate polygons of yellow-cedar decline. Maps completed to date include those of Peril Strait and adjacent areas of Baranof and Chichagof Islands, and southern Kruzof Island (Figure 13). These maps can be overlayed with climate features such as snow cover or soil saturation. Very few maps have been compiled from areas above 300 m (Hennon et al. 2008). While yellow-cedar decline occurs at all slope aspects across elevation zones, decline is more prevalent at lower elevations and at warm, southerly aspects (D'Amore and Hennon, 2006).

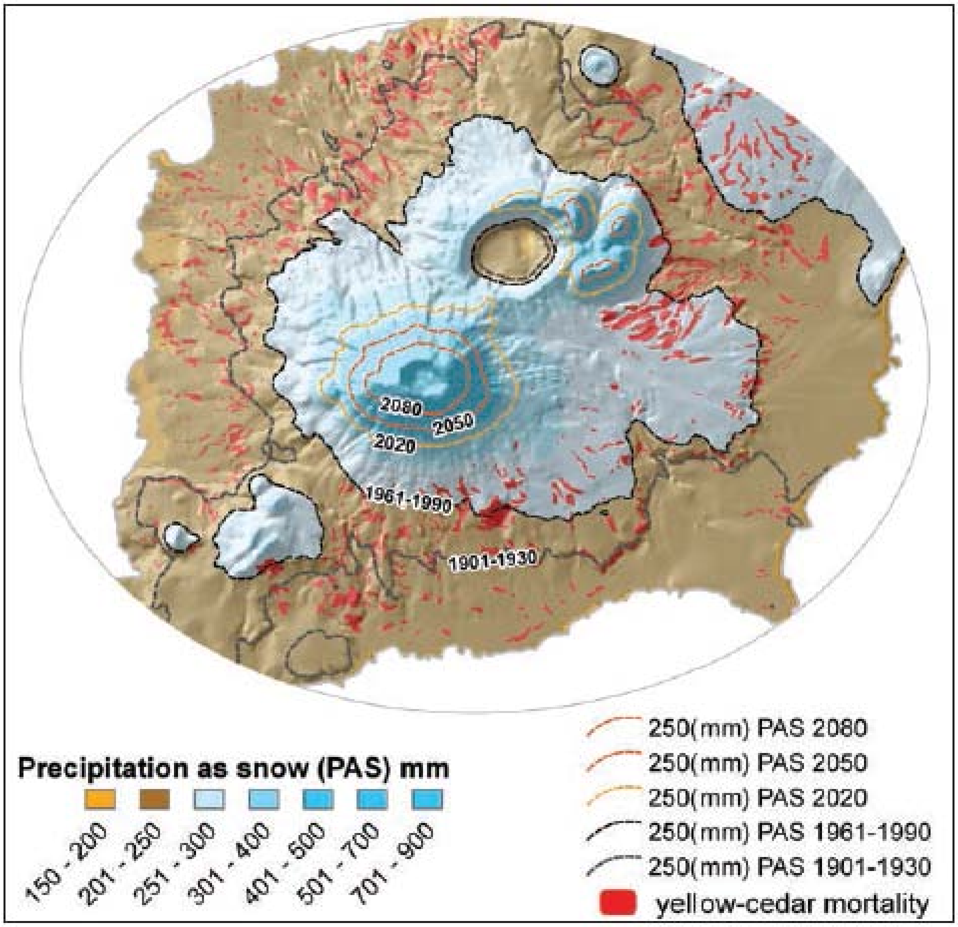


Figure 13: The distribution of yellow-cedar decline on Mount Edgecumbe near Sitka, Alaska, mapped from 1998 color photography. The annual precipitation of snow between 1961 and 1990 is shown with colors indicating the values above (gray, protects yellow-cedar) or below (dark gray, inadequate) the threshold of 250 mm of annual precipitation as snow. Forecasts for this modeled snow threshold are indicated by dashed lines.

Mount Edgecumbe on Kruzof Island near Sitka is a dormant volcano with radial symmetry and even slope gradients, and is the site of extensive mapping (Figure 13). Open-canopy forests with abundant yellow-cedar extend from sea level close to timberline. These features control confounding factors, and have allowed researchers to isolate the influence of elevation and aspect on yellow-cedar decline. Results from Mount Edgecumbe studies are discussed in more detail in Section III, because they show that a lack of spring snow is one of the most important factors leading to yellow-cedar decline.

3. Yellow-cedar Decline and Site-specific Conditions: Canopy Cover, Snow Cover, Air and Soil Temperature, Hydrology, and Soil Chemistry

Detailed site-specific, small-scale studies, and resulting maps were designed to increase researchers' understanding of how forest conditions vary among areas with and without yellow-cedar decline. Researchers created maps based on 100 m grids of vegetation plots at two small watersheds, Goose Cove on Baranof Island, and Poison Cove on Chichagof Island (Hennon et al. 2008). On-ground studies investigated the association between live and dead trees and different environmental variables, including hydrology (Figures 14 and 15), soil chemistry, canopy cover, air and soil temperature, and snow (D'Amore and Hennon 2006).

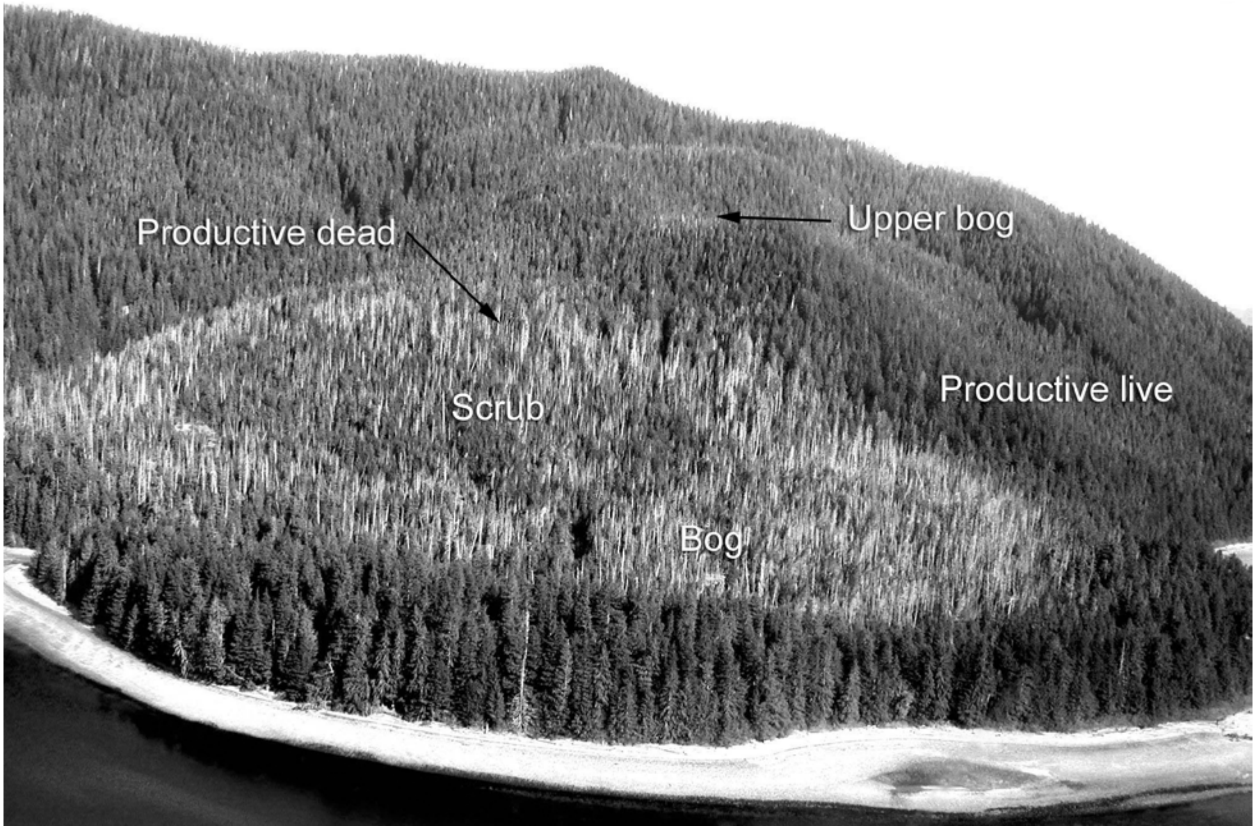


Figure 14: The Poison Cove study site illustrating an area of intense yellow-cedar decline. Note the circular area of decline, with dead trees on the inside and dead and dying trees on the perimeter. This inside-out trend in decline is related to a hydrologic gradient, where cedar in wetter soils suffer decline first, followed by those on the outer edges. Source: D'Amore and Hennon 2006.

In order to collect accurate, targeted, site-specific data, researchers used automated snow cameras to record daily snow measurements. Soil temperature monitors were also included at some sites in order to map the association between soil temperature and snow depth.

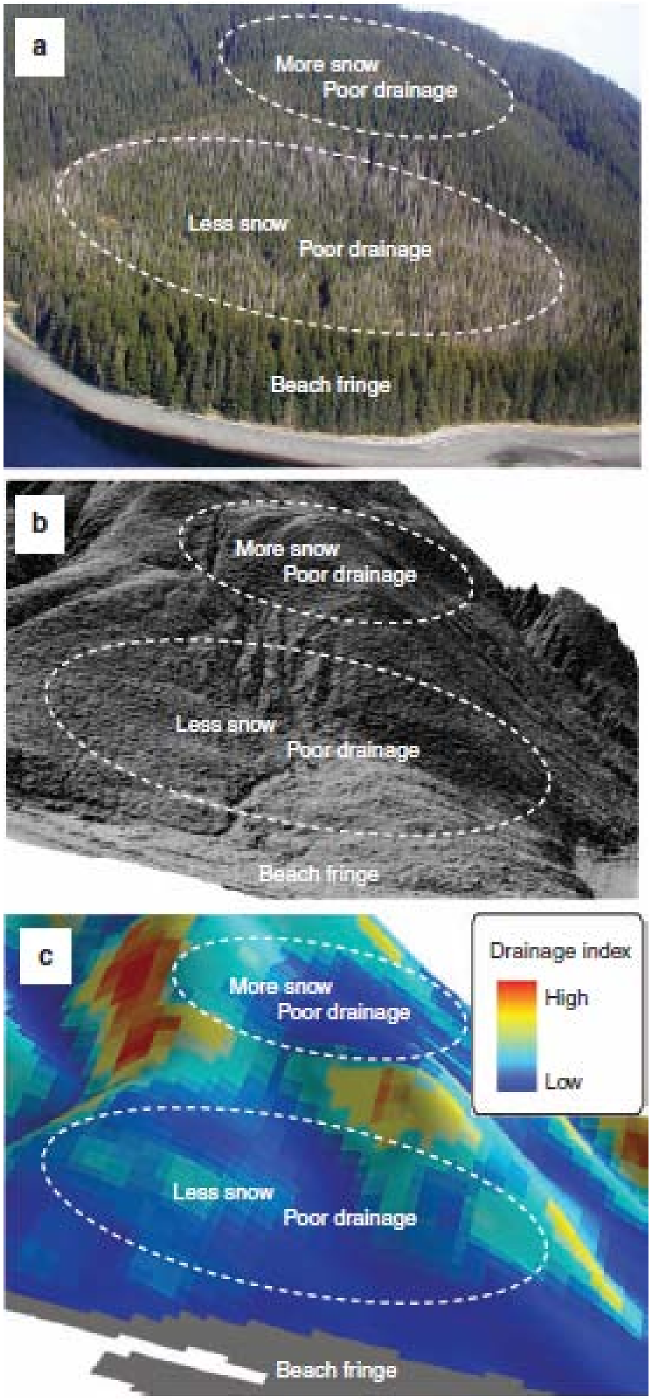


Figure 15: (a) Patch of dead and dying yellow-cedar and the surrounding forest. (b) LIDAR (light detection and ranging)- derived high-resolution digital elevation terrain model. (c) Drainage classes at Poison Cove watershed, Chichagof Island, Alaska. Yellow-cedar has died in the less-snow, poor-drainage areas, but trees remain alive in the more-snow, poor-drainage area at slightly higher elevation that has

evidence of snowpack persisting later in the spring, which protects shallow roots from freezing injury. Source: Hennon et al. 2012.

When the maps of dead/dying and live cedar are overlayed with site-specific landscape variables, the results clearly indicate once again the determining role of snow in protecting yellow-cedar from freezing injury. For example, measurements of snow pack at the Poison Cove study site find that live, non-declining yellow-cedar are protected by a thick layer of snow through April and occasionally into May (Figure 15), while yellow-cedar at a similar site where snow cover was no longer present were suffering decline.

This research was useful for associating yellow-cedar decline with environmental factors, but has also proven useful for predicting future trends in yellow-cedar decline, and determining where active-management might be most effective. Further discussion occurs in Part III and Part IV of this petition.

III. YELLOW-CEDAR MUST BE LISTED AS THREATENED OR ENDANGERED UNDER THE ESA

Under the ESA, a species is “endangered” if it is “in danger of extinction throughout all or a significant portion of its range.” 16 U.S.C. § 1531(6). A species is “threatened” if it is “likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.” 16 U.S.C. § 1531(20). In determining whether a species is threatened or endangered, USFWS must consider these five listing factors:

> (A) the present or threatened destruction, modification, or curtailment of its habitat or range;
>
> (B) overutilization for commercial, recreational, scientific, or educational purposes;
>
> (C) disease or predation;
>
> (D) the inadequacy of existing regulatory mechanisms;
>
> (E) other natural or manmade factors affecting its continued existence.
>
> (16 U.S.C. § 1533(a)(1)(A)-(E); 50 C.F.R. § 424.11(c)(1) - (5).)

This section describes threats to the yellow-cedar tree in the context of the five listing factors and demonstrates that the yellow-cedar is in danger of extinction within all or a significant portion of its range, or will be in the foreseeable future. The primary threat to yellow-cedar trees is the destruction and modification of habitat from greenhouse-gas-driven climate change. Adding to this threat is the current overutilization of yellow-cedar by the old-growth timber industry in southeast Alaska. Physiological and ecological attributes of yellow-cedar make it extremely unlikely that the species can adapt to changing habitats or migrate to new ones, and existing regulatory mechanisms are inadequate to address threats from greenhouse gas emissions and from unsustainable logging.

A. THE PRESENT OR THREATENED DESTRUCTION, MODIFICATION, OR CURTAILMENT OF HABITAT OR RANGE

Climate change is driving the fine-root death that results in yellow-cedar decline (Oliver and Hennon 2013, Hennon et al. 2012). Anthropogenic greenhouse gas emissions are rapidly altering the climate of southeast Alaska and coastal British Columbia, causing progressively widespread yellow-cedar decline. Due to climate change, scientists project that the frequency of occurrence of yellow-cedar trees will decrease by as much as 75% by 2085 (Hamann and Wang 2006).

Yellow-cedar decline is the result of freezing injury to the tree's fine roots when soils drop below the tree's physiological cold tolerance threshold during periods of low snow cover, during spring freeze-thaw cycles, in areas where the soils are wet, or where a lack of canopy cover creates a microclimate that encourages penetration of freezing temperatures into the soil surface.

Climate change will increase the intensity and spread of yellow-cedar decline that is caused by spring freezing injury through three primary mechanisms: (1) increased and earlier spring freezing events, (2) warmer winters leading to reduced snow cover, and (3) variations in soil drainage.

1. The Earth's Changing Climate

Human activities continue to release massive amounts of greenhouse gases into the atmosphere, primarily through the burning of fossil fuels, cement manufacturing and deforestation, with the rate of emissions increasing by 3% each year, well above that predicted under most climate scenarios (Hansen et al. 2013).

The last twenty years have been the warmest period in the entire global instrumental temperature record. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) concludes that most of the observed global temperature increase since the mid-20th century is due to increases in anthropogenic greenhouse gas concentrations.

Plant health is predicted to suffer under climate change through a variety of mechanisms, from accelerated pathogen evolution and northward spread of pathogens, to increasing abiotic stress due to mismatches between biota of an ecosystem and the climate, such as earlier springs and changes in freeze-thaw cycles (Ahanger et al. 2013).

Anthropogenic greenhouse gases are projected to result in air temperature warming of more than 3 degrees C by 2100, while temperature increases of just 1.5 – 2.5 degrees C are projected to result in significant ecological consequences (IPCC 2011). The rate of climate change projected to occur over the next century is an order of magnitude greater than the average rate occurring since the last glacial maximum. Many species of plants and animals will be incapable of successfully tracking and adapting to such changes through migration to more suitable habitats (Spittlehouse 2008, Aitken et al. 2008).

Species that will be the most vulnerable to climate change will be those that are large and long-lived, with specialized habitats, limited mobility, and low regeneration rates (Lenoir et al. 2008).

Further, trees that have late sexual maturity, with small populations and fragmented ranges, are less likely to be able to adapt or migrate in response to climate change (Aitken et al. 2008).

2. Climate Change in Southeast Alaska and British Columbia

Warming associated with climate change is amplified in northern regions. Over the past 50 years, high-latitude regions have warmed more than any other region worldwide. Future increases are projected to continue to be proportionally greater at higher latitudes, with Alaska warming at least twice as much as the rest of the world during the 21st century (Kattsov and Kallen 2005). (Figure 16). Under current emissions scenarios, average annual temperatures in Alaska are projected to rise by an additional 1 to 2 degrees C by 2050, and another 3 to 4 degrees C by the end of the century. Even with substantial emission reductions, average temperatures in Alaska are projected to warm by 2 to 3 degrees C by the end of this century (Chapin et al. 2014).

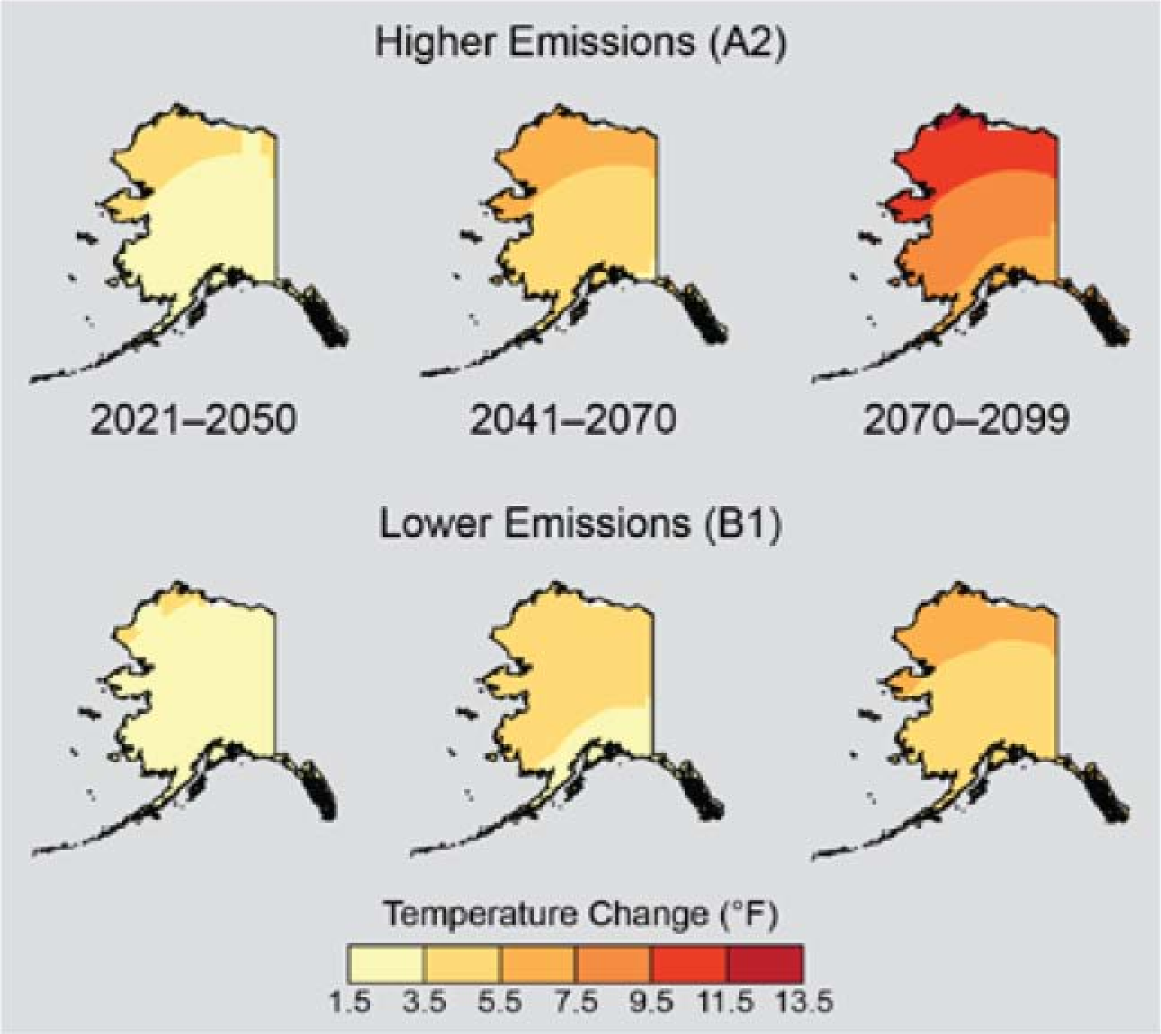


Figure 16: Northern latitudes are warming faster than temperate regions, and Alaska has already warmed much faster than the rest of the country. Maps show changes in temperature relative to 1971-1999, projected for Alaska in the early, middle, and late parts of the century, if heat trapping gas (GHG

emissions) continue to increase (higher emissions A2), or are substantially reduced (lower emissions, B1). Source: Chapin et al. 2014 as adapted from Steward et al. 2013.

Average precipitation in Alaska is projected to increase, but with increased evaporation actually reducing water availability for most of the state. As a result of these changes, the risk of wildfire and insect outbreaks will increase (Chapin et al. 2014).

Warming temperatures pose a serious threat to areas of Alaska where average temperatures are very close to freezing, as is the case in southeast Alaska. Here, a small change in temperature can have major impacts. Juneau's average winter temperature rose by 0.9-1.7 degrees C over the past 60 years (Figure 17; Kelly et al. 2007), with 2013 being the first year in which the average temperatures remained above freezing. January 2014 was the second warmest since 1944, while the average daily low of 33.5 degrees F was the warmest on record.

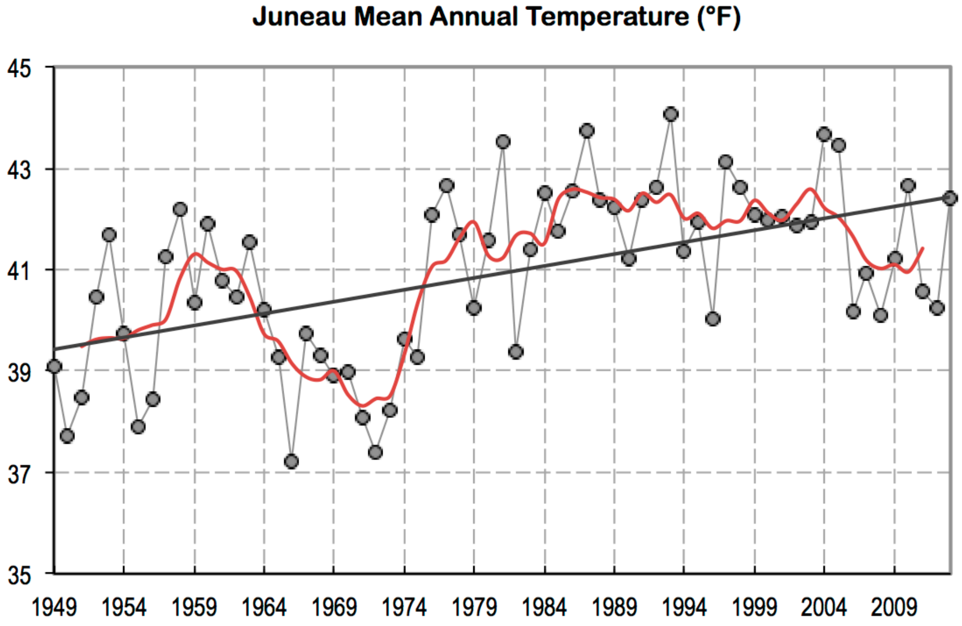


Figure 17: Mean annual temperature in Juneau from 1949 to 2013. Source: Alaska Climate Research Center

The reduction of the length of the snow season in Alaska (Liston and Hiemstra 2011) will impact timing of spring warm-up and periods of freeze thaw. The average winter snowfall at sea level in the City and Borough of Juneau decreased from 277 cm to 236 cm over the past 60 years. However, overall precipitation increased, with a shift to more rain. Average winter precipitation including rain and snow (reported as inches of liquid water), increased by 6.6 cm or more (Kelly et al. 2007). For example, precipitation in Juneau in January 2014 totaled 25.8 cm, nearly double the normal amount. This is a new record, but snowfall constituted only 11.9 cm, which is only 17% of the normal amount (Alaska Climate Research Center 2014).

Climate models predict that warming will continue under future greenhouse gas emissions scenarios. Overall, models predict that the city of Juneau will have warmer and wetter weather, especially in fall and winter. The IPCC predicts a temperature increase of 5.5 degrees C for southeast Alaska by the end of the 21st Century, accompanied by 50 to 70 fewer days below freezing per year (Kelly et al. 2007).

Climate change in British Columbia will follow a similar trend. Mean annual temperature and precipitation are expected to increase on average by as much as 4 degrees C, and by 16% respectively by the 2050s, with the largest temperature increase in coastal areas, where yellow-cedar decline is already occurring (Murdock and Spittlehouse 2011). As the climate of coastal British Columbia has warmed, there are fewer days with temperatures below freezing (Daniels et al. 2011). These above-average temperatures result in more rain than snow, a reduced snowpack and earlier snowmelt (Mote et al. 2005). The intensities and frequencies of extreme climatic events, such as late-winter thaws and freezes, have increased disproportionally relative to climatic means.

Studies show that yellow-cedar productivity is influenced by the maximum winter temperature, with cooler values resulting in the highest productivity (Russell and Krakowki *in* Harrington et al. 2010). Summer moisture, snowpack, and spring and autumn temperatures are also strong drivers of productivity, correlating with both growing season length and early and late frost damage to the fine root system.

Climate change will substantially increase the number of frost-free days in the forests of coastal Alaska and British Columbia (Meehl et al. 2004), with precipitation falling as rain rather than snow due to a small shift in temperatures that will push the average winter temperature above freezing. At low-elevation weather stations in southeast Alaska, temperatures have historically hovered just around freezing during the winter months (Beier et al. 2008). A shift to above-freezing winter temperatures will have widespread and major consequences for yellow-cedar.

3. Climate Change and Yellow-cedar Decline

Worldwide, tree distribution is primarily shaped by both climate and soil properties, and climate change is the driving factor behind the precipitous rate of yellow-cedar decline (Hennon et al. *in* Harrington 2010; Mathys et al. 2014).

Climate change affects a tree species in four major ways. First, it can significantly reduce the tree's capacity for growth and reproduction. Second, climate change can result in mismatches in climatic cues for physiological responses. This is one of the primary reasons for yellow-cedar die-off, where the timing of winter/spring dehardening of fine roots no longer corresponds with climate-associated snowcover and spring thaws. Thus, the tree is unable to adapt physiologically to shifts in the freeze-thaw cycle due to climate change. Third, climate change, such as warming and changes in precipitation that stress a tree species, may also favor the spread and growth of insect and fungal pathogens, with cumulatively lethal effect. Some examples of climate-dependent increase in disease and infestations are increased fungal pathogens and spruce beetle outbreaks. Finally, a changing climate increases the frequency and intensity of total area of forest fires (Bunnell and Kremsater 2012). Fire is not considered a concern for yellow-cedar throughout most of its range, but may threaten trees growing in the lower 48 states and in southern British Columbia.

The Forest Service has determined that over 70% of yellow-cedar trees have died in stands with yellow-cedar decline and that global warming over the next 100 years will greatly increase the area in which trees will suffer decline symptoms (Hennon et al. 2008, Forest Service 2013a). Long-lived conifers may be especially maladapted to a changing climate, and are unlikely to be able to simply move northward or upward with climate change, because soil formation at high latitudes and high altitudes is slow (Bunnell and Kremsater 2012). Additionally, because yellow-cedars are so long-lived, and very slow growing, projections for decline must be made for more than 100 years in the future. Fragmentation of the landscape due to timber harvest, human development, or road building may further prevent species adaptation and migration to more suitable regions as a response to climate change (Lenoir et al. 2008, Bunnell and Kremsater 2012).

As a tree that depends on exceptional longevity, resistance to pests, and adaptation to marginal site conditions, the yellow-cedar has little potential to move or adapt to rapidly changing climatic conditions. Historically, mature yellow-cedar trees have a very low mortality rate, and the widespread area of yellow-cedar decline means that the species is unlikely to survive into the species' biologically appropriate future if anthropogenic greenhouse gas emissions continue at their current rate. In fact, the tree is expected to suffer a 75% decrease in frequency by 2085 (Hamann and Wang 2006). This will be followed by a more gradual decline for remaining trees, where existing trees in some areas that remain suitable for a longer period of time will live out their lifespan but with little or no regeneration, resulting in slow but inevitable extirpation of the species. A catastrophic disease event, enabled by climate change, could result in additional precipitous declines in the future (Sturrock et al. 2011).

a. Reduced Snow Cover

A key threat to yellow-cedar habitat has been reduced snow cover accelerated by climate change. Snow insulates soil and acts as a buffer between freezing and thawed soil temperatures. The presence or absence of snow is closely linked to historical yellow-cedar distribution, and to current observations of yellow-cedar decline (also see Section II). When snow is not present, soil temperatures often drop below the lethal threshold (-5 degrees C) in the shallow-rooting zone for cedar (7. 5 cm depth) during late winter and early spring (Hennon et al. 2010). When snow is present, shallow soils retain a temperature just above freezing. Yellow-cedar decline and the original post-Holocene era distribution of yellow-cedar are linked to snow cover and drainage conditions (Figure 18). Clearly, the presence of snow is critical to preventing fine-root freezing injury.

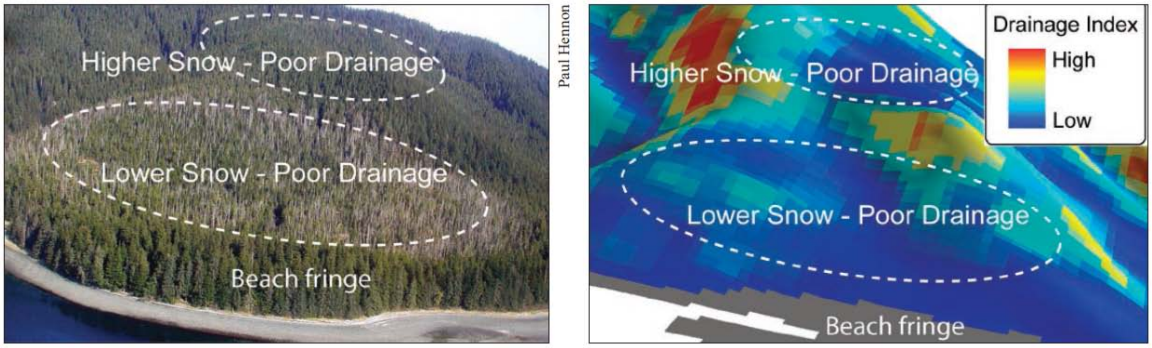


Figure 18: Drainage classes at Poison Cove watershed on Chichagof Island, Alaska. Yellow-cedar trees have died in the areas with less snow and poor drainage. Trees remain living in areas with more snow and poor drainage at slightly higher elevation where the snowpack persists later in the spring and protects shallow roots from lethal freezing injury. Source: Oliver and Hennon 2013.

Research finds that snow protects yellow-cedar from decline by delaying the dehardening process and/or protecting fine shallow roots from freezing. As little as several centimeters of snow may be all that is required to buffer the soil temperature enough to prevent root injury. In a study investigating the effects of simulated snow cover on yellow-cedar roots, Schaberg et al. 2008 found that the roots of yellow-cedar seedlings could tolerate soil temperatures down to -5 °C. When soil temperatures fell below this threshold on plots without simulated snow, roots were severely injured and seedlings died (Figure 19; Schaberg et al. 2008).

Figure 19: Insulating presence of snow protects seedlings from freezing injury. Blocks of seedlings on the left and middle were protected by perlite to mimic snow. These seedlings remained healthy because soil temperatures never dropped below -5 degrees C. Seedlings on the right were unprotected and the soil dropped below the temperature threshold of mortality. Source: Forest Service at http://www.fs.usda.gov/detail/r10/forest-grasslandhealth/?cid=fsbdev2_038760

Thus, reliable snow cover from February through March or April allows yellow-cedar to survive a period of potential vulnerability during spring freezing episodes. A loss of snow cover during these time periods makes the trees vulnerable to freezing injury and death. When snow is present after the last hard freeze in the spring, this provides protection for yellow-cedars from root injury.

A lack of insulating snowpack in spring can explain the broad spatial distribution of yellow-cedar decline on the landscape (Figure 19; Hennon et al. 2008). In areas in which the level of snow cover is insufficient to protect roots from freezing injury, suitable habitat for yellow-cedar is limited to moderately- to well-drained soils where roots can penetrate to deeper soil horizons and thus avoid freezing injury. In areas with adequate snow cover yellow-cedar trees can continue to survive at poorly drained sites, unless they are outcompeted.

Normally, snowpack insulates fine roots from extreme cold. When snowpack is absent, freeze events are fatal to the unprotected roots of yellow-cedar. Snow, and reduced snow cover, has a major influence on yellow-cedar health and decline (Figures 19 and 20). Snow can be modeled at the regional or small island spatial scale. Mapping of temperature/snowpack and topographic layers clearly demonstrate that warming temperatures—and snowpack—are critical factors in yellow-cedar decline.

In western North America, regional warming resulting in decreased snowpack and consequent increased drought stress appears to be the dominant cause of increasing tree mortality, especially of large trees. In a long-term study from 1977 to 2007, van Mantgem et al. (2009) found that a temperature increase of 1 °C across the coast of British Columbia was enough to significantly reduce winter snowpack, causing earlier snow melt and increasing the duration of summer droughts in the region (van Mantgem et al. 2009). As discussed in great detail throughout this petition, the current consensus of the scientific community is that yellow-cedar decline is a direct result of regional climate change, specifically loss of snow cover and fine root freezing (Beier et al. 2008). Figure 20 illustrates the link between snow cover and yellow-cedar decline, with areas of red indicating yellow-cedar mortality.

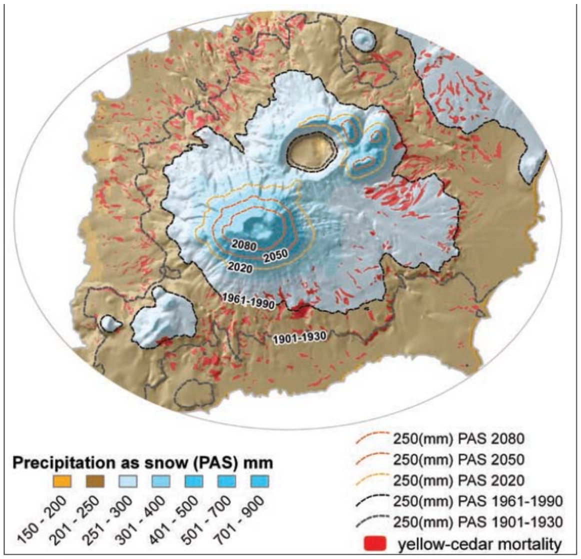


Figure 20: The distribution of yellow-cedar decline on Mount Edgecumbe near Sitka, Alaska, is mapped from color infrared photography. The annual precipitation as snow between 1961 and 1990 is shown with colors indicating the values above (gray, protects yellow-cedar) or below (dark gray, inadequate) the threshold of 10 inches of annual precipitation as snow. Forecasts for this modeled snow threshold are indicated by dashed lines. Source: Dustin Wittwer *in* Oliver and Hennon 2013.

Figure 21 below projects snow decline in the future, and how a loss of snow-cover may impact yellow-cedar. This figure demonstrates that yellow-cedar will decline significantly under future climate change scenarios, occupying very little of its current range and even less of the range it once occupied in the late 1880s and early 1900s. By the year 2080, yellow-cedar will be restricted to just fragments of suitable habitat.

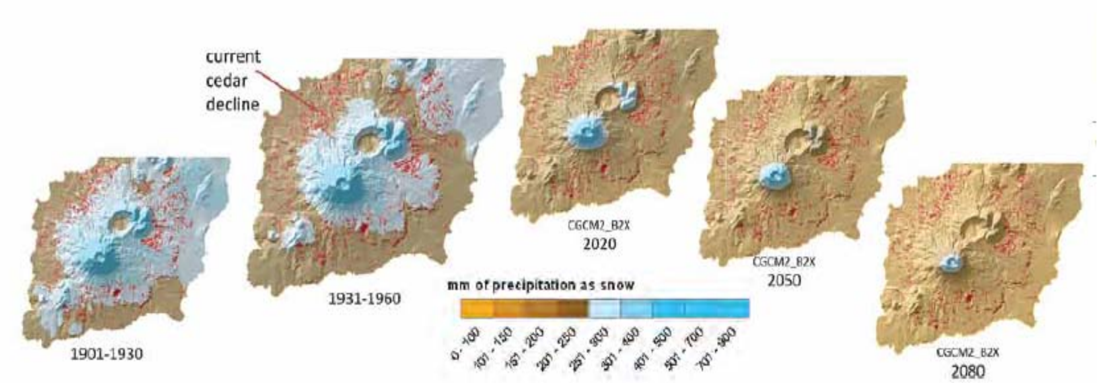


Figure 21: Past and projected (CGMC2 B2 scenario shown here) annual snow accumulation using PRISM data, with downscaling by an elevational adjustment (Wang and others 2006). Light blue zones represent sufficient snow to protect cedar from spring freezing injury (annual precipitation as snow = 2500 mm); current areas of cedar decline mapped from aerial photographs are shown in red. Note the abundance of habitat protected by snow (shades of blue) in the early 1900s and progressive shrinking of habitat through this sequence, to being nearly absent by 2080. Data sources: PRISM Group, Oregon State University; IPCC 2001. Source: Hennon and Wittweb 2013.

b. Soil Type and Drainage

In southeast Alaska, slope and soil properties, including peat accumulations, produce gradients of soil drainage that are largely responsible for driving forest productivity. Topography, moisture, elevation, and humus quality are the primary environmental variables that determine species composition in the forest of southeast Alaska (Ver Hoef et al. 1988). Forest types in the area range from large-stature, closed canopy forests on well drained soils to stunted, open canopy forests on saturated organic soils (Ver Hoef et al. 1988).

Historically, yellow-cedar has preferred wet soils, typically reaching its greatest abundance here relative to other trees (Hennon et al. 2008). The wet soils in yellow-cedar habitat were probably present several thousand years before the start of yellow-cedar decline, when cool and wet climatic conditions along the Pacific coast facilitated extensive peat development (Heusser et al. 1985). The cool, moist climate during the late Holocene created the bog and forested wetlands that favored the establishment of yellow-cedar, which was competitive at those sites due to its fine-root system's ability to access nitrogen (D'Amore et al. 2009). Open canopy conditions on boggy sites created a more extreme microclimate, allowing for greater warming during late winter and early spring, but also meaning that during cold temperatures, freezing conditions were able to penetrate more deeply into the soil (Hennon et al. 2010).

Variations in soil drainage play a critical role in yellow-cedar decline and health, and are also influenced by precipitation changes due to climate change. Current yellow-cedar decline is most strongly associated with trees growing on wetter soils, with a soil saturation threshold found to separate living and dead forests (Figure 22). Past a certain threshold, soils become more favorable to other tree species, which outcompete yellow-cedar for growth and space. Thus, as the climate warms, the specialized niche of soils where yellow-cedar is able to survive freezing, but still competitive with other tree species, becomes increasingly rare.

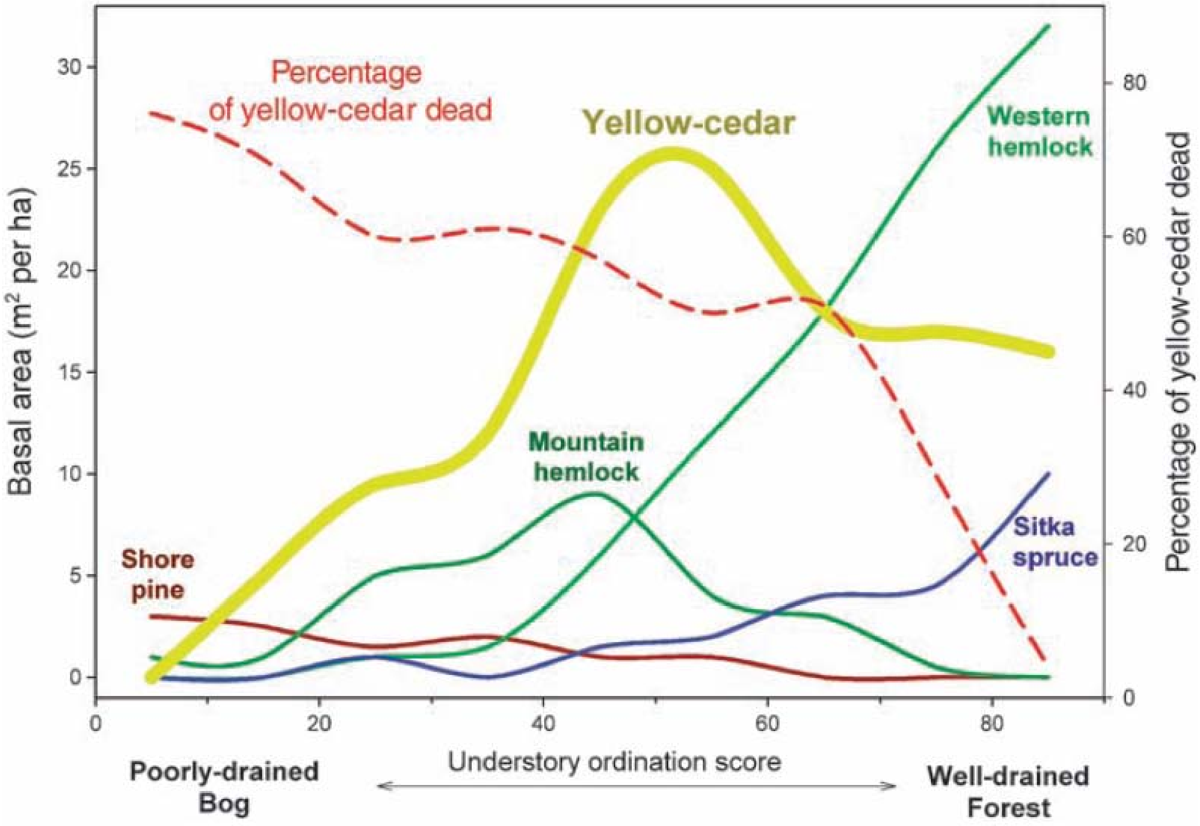


Figure 22: Yellow-cedars' optimum edaphic (soil-related) niche and the occurrence of yellow-cedar mortality along the soil-drainage gradient. The percentage of dead yellow-cedar basal area reveals an apparent threshold of drainage, beyond which yellow-cedar is healthy but outcompeted by faster-growing tree species. Source: Hennon et al. 2012.

The link between site drainage and yellow-cedar decline was noted early in aerial photographs compiled from 1927, 1948, 1965 and 1976, that show the peripheral boundaries of yellow-cedar mortality expanding over a 60-year period at all sites (Hennon et al. 1990). Mortality spread from poorly-drained sites to sites with better drainage, generally upslope (Wooton and Klinkenberg 2011).

Microclimate changes due to reduced canopy cover play an important role in decline. Tree growth rates, standing biomass of live trees, and canopy cover are all reduced in wet soils, due to less nutrient cycling and more shallow rooting depth (D'Amore and Hennon 2006). Hennon et al. (2010) found that estimated canopy cover at a site was highly correlated to basal area of live trees for all species along a soil drainage gradient. Reduced canopy cover was associated with more extreme microclimates on the ground, exacerbating extreme highs and lows in temperature. As more yellow-cedar trees die, canopy cover decreases, further increasing the high-low temperature extremes on the ground that promote yellow-cedar decline.

Thus, there is a tight feedback related to wet soils and yellow cedar decline. In wet soils with historically little canopy cover, the lack of canopy cover causes small shifts in microclimate that lead to yellow cedar decline, resulting in further reduced canopy and the outward spread of yellow-cedar decline (Hennon et al. 2010). This can be visualized in Figure 15, which shows the typical inward-out spread of yellow cedar decline at a wet, low-elevation site.

Soil type and drainage should be introduced into models at the fine spatial scale. Yellow-cedar trees are primarily found in an area called the Marine West Coast Forest, the most productive forested zone in the Pacific Northwest, with high annual precipitation. Temperate coastal forests contain soils that vary from infertile, well drained shallow soils to nutrient-rich bogs with high organic matter content (Mathys et al. 2014). Yellow-cedar in well-drained soils appears resilient to decline, even when snow-cover is inadequate for yellow-cedar growing in wet soils, although competition with other tree species may limit the tree's establishment. Yellow-cedar decline is more severe and more strongly linked to snow cover at wet and boggy sites.

c. Analogous Species: Yellow Birch

In a similar well-documented climate-related decline, extensive dieback due to climate change has also been recorded for yellow birch (*Betula alleghaniensis* Britt.) in the Northeastern United States. Yellow birch decline occurs due to changing spring conditions, where prolonged winter thaws are followed by sharp freezing temperatures, which result in fine-root damage and tree death. Yellow birch decline has resulted in a 19% loss of the growing stock of the tree in North America (Ward and Stephens 1997), with major economic losses. As with yellow-cedar, yellow birch has a shallow fine root system, and is especially vulnerable to freezing injury when snow cover is absent or inadequate (Bourque et al. 2005). Also, similar to yellow-cedar, dieback first began in the northern parts of the tree's range, with up to 95% of trees affected (Bourque et al. 2005). Another economically and culturally important tree of northeastern North America, sugar maple (*Acer saccharum*), is projected to decline by over 90% by 2100 due to climate change (Iverson and Prasad 2001).

These species show that there is strong precedent for a climate-change link to extensive tree death, especially for tree species found at high altitude, northern, and/or marginal habitats, where a competitive strategy of shallow fine-roots and early dehardening are used to take advantage of early spring nutrient uptake. This type of strategy also makes trees especially vulnerable to reduced snow cover. Like yellow-cedar, yellow-birch shows few signs of adaptation or migration in response to climate change.

4. Projected Range-wide Decline of Yellow-cedar

a. *Current Decline*

Yellow-cedar decline in Alaska occurs most intensely at lower elevations and on wetter soils, with little decline above about 200 m (Hennon and Wittweb 2013). Meso-scale mapping shows a correlation between decline and slope aspect, with yellow-cedar decline occurring at higher elevations on warmer southerly aspects (Hennon and others 2010, Lamb and Wurtz 2009), and decline is more strongly associated with gentle slopes compared to steep slopes (D'Amore and Hennon 2006, D'Amore and others 2009). Decline is strongly associated with snowpack, soil and air temperatures, and wetter soils.

b. *Modeling and Projecting Yellow-cedar Decline*

Most climate change scenarios predict a dramatic reduction in yellow-cedar range. The response of vegetation to climate change is likely to be complicated with varying outcomes; however, generally species' ranges are expected to shift northward and upward in elevation to cooler areas, with recent studies documenting these patterns (Aitken et al. 2008, Lenoir et al. 2008). This shift may be difficult if higher elevation soils or conditions are not appropriate for yellow-cedar, which requires a highly specialized ecological niche to survive. Thus, models based merely on future "climatic envelopes" do not adequately assess the future survival of the species, but merely provide a rough projection of the future.

Snowpack and drainage are the two controlling factors to determine landscape suitability for yellow-cedar, and are essential factors to developing management strategies for long-term conservation of yellow-cedar (Oliver and Hennon 2013). Indeed, there is a close association between yellow-cedar decline and the lowest snow accumulation zone (Schaberg et al. 2008, Hennon et al. 2010, Oliver and Hennon 2013). Mapping shows that there is massive projected range-wide decline by 2080, as projected snow cover greatly declines (Oliver and Hennon 2013).

Climate change is likely to proceed at a pace that exceeds the ability of yellow-cedar to regenerate at more suitable locations. For example, Hamann and Wang developed a model based on climatic factors alone, which predicts a 75% decline in the frequency of yellow-cedar by the year 2085 (Figure 23), and matches the results of the PRISM snow-accumulation model (Hamann and Wang 2006). The authors of this study note that modeling is based merely on climate profiles, and does not consider other important factors for the establishment of yellow-cedar such as adequate snow cover, acidic or boggy soils, soil drainage, and complications to regeneration such as Sitka deer browsing, or competition with other tree species. As such, it is more useful for predicting how rapidly the climate in areas where yellow-cedar are now living will change to the point of initiating yellow-cedar decline, than for predicting where yellow-cedar may regenerate in the future.

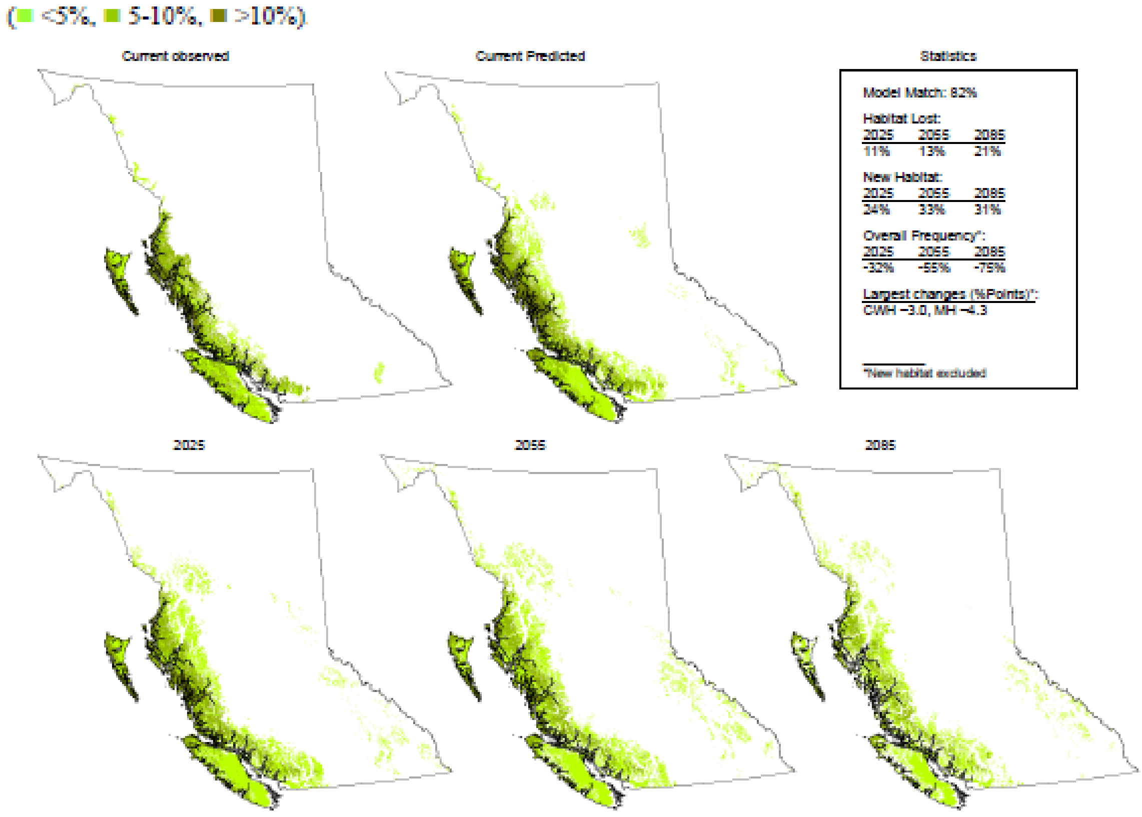


Figure 23: Observed and predicted frequency for yellow-cedar. “Model Match” is the correctly predicted habitat, based on current climate (1961-1990 normals) as a percentage of the observed species range. “Habitat Loss” is the area predicted as unsuitable habitat for the species under climate change as a proportion of the total current habitat. “New Habitat” is the area predicted as suitable habitat under climate change, where the species is currently not present. The authors of this study note that a species is unlikely to colonize most of this area within a few decades. “Overall Frequency” is a weighted average of predicted frequency changes where the species is already present. This excludes new habitat areas, as it is unlikely that yellow-cedar will colonize most of this area. Source: Hamann and Wang 2006.

5. Habitat Threats Summary

Greenhouse-gas-driven climate change is causing significant and widespread changes to yellow-cedar habitat throughout its range. The species cannot adapt to these rapid changes, is as apparent from its current decline. Thus, yellow-cedar is in danger of extinction throughout all or a significant portion of its range as a result of habitat modification.

B. OVERUTILIZATION OF THE SPECIES FOR COMMERCIAL, RECREATIONAL, SCIENTIFIC, OR EDUCATIONAL PURPOSES

Logging threatens the continued survival of yellow-cedar, particularly because it targets long-lived trees that may be able to withstand climate change impacts while greenhouse gas emissions are reduced. These trees would provide an important source of genetic material for future regeneration of the species. In the 2008 Tongass Land Management Plant (TLMP), the Forest Service developed an integrated old-growth conservation strategy of large, medium, and small reserves to protect and maintain old-growth habitat in southeast Alaska. The goal was to maintain the mix of habitats at different spatial scales capable of supporting the full range of naturally occurring flora, fauna, and ecological processes (Forest Service 2008). However, the large scale and rapid loss of yellow-cedar trees in landscapes that are protected from timber harvest demonstrates the inadequacy of current measures in the TLMP to protect cedar habitat types from climate change (Hennon et al. 2008). Moreover, healthy yellow-cedar trees continue to be logged in disproportionally high numbers under current management. Approximately 274,377 total acres, or 10% of the Tongass National Forest is expected to be subject to timber harvest in the next 100 years (Johnson 2013). There is great pressure on yellow-cedar for timber harvest due to the wood's desirable characteristics and high value at market (Figure 25; Green et al. 2002). Yellow-cedar constitutes just 9% of the growing stock on unreserved national forest land in southeast Alaska (van Hees and Mead 2005), yet it accounts for a disproportionately high percentage of timber harvest. This "high-grading" of yellow-cedar is unsustainable and is accelerating the species' decline, and limiting any chance of future recovery.

1. The Tongass National Forest Timber Sale Program Targets Areas with Yellow-Cedar for Large Timber Sales

Western redcedar and yellow-cedar drive the layout of most major timber sales in the Tongass (Carstensen and Christensen 2008, Forest Service 2008) because of their higher economic value, as shown in Figure 25 below. From 2010 through 2013, the average Forest Service sale price for yellow-cedar was $140.23 per thousand board feet (MBF). Western redcedar is the second most valuable species, with an average sale value of $116.21 per MBF from 2010-2013 (Carstensen and Christensen 2008, Forest Service 2008, Forest Service Cut and Sold Reports FY 2010-2013 2013). For comparison, western hemlock sold for a mere $3.76 per MBF. These price differentials are significant because Congress has prohibited the Alaska Region of the Forest Service from advertising deficit timber sales,[1] which has greatly reduced the Tongass National Forest's ability to sell timber (Housely et al. 2007). As a result, timber sale planners often target yellow-cedar for removal because it is the only species that generates positive appraisals across the Tongass National Forest (Housely et al. 2007). Conversely, western hemlock, which comprises roughly half the volume in an average Tongass National Forest timber stand, is not worth the cost of cutting (Housely et al. 2007).

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[1] *See, e.g.* FY 2003 Interior and Related Agencies Appropriations Act, § 318, PL 108-7; Consolidation Appropriations Act of 2012, PL 112-74; 125 STAT 1042, § 414 ("No timber sale in Alaska's Region 10 shall be advertised if the indicated rate is deficit").

A significant factor that increases the value of yellow-cedar is a Congressional exemption from the domestic processing requirements that apply to other Tongass National Forest tree species. This exemption allows timber operators to freely export unprocessed Alaska yellow-cedar trees to foreign purchasers.[2] Timber markets favor unprocessed raw log exports, and Tongass National Forest timber sale purchasers are likely to export as much as they can.[3] The Forest Service acknowledges that the premium value for yellow-cedar and the Congressional export authorization ensure that yellow-cedar always has the highest value in a timber sale (Wilson 2002). Thus, because of the prohibition on deficit sale advertisements and the particularly high value of yellow cedar for raw log export markets, Tongass National Forest timber sales must target a combination of western redcedar and yellow-cedar in order to generate positively appraised timber sales.

This dynamic leads to yellow-cedar trees being disproportionately logged, in a strategy dubbed "high-grading." In 2002 and 2006, the Forest Service evaluated the amount of cedar scheduled for removal in timber sales in response to public concerns about high-grading yellow-cedar and western redcedar (Wilson 2002). The report estimated that although yellow-cedar comprised only 9.7% of the net volume of growing stock on timberlands and western redcedar comprised only 5.9%, the agency was removing 19.6% of each species (Wilson 2002).

The agency provided several interrelated explanations for the higher levels of cedar harvest. First, the report indicated that the agency was high-grading both cedar species on a geographic scale because timber harvest was occurring primarily (94% of the volume) in the southern portion of the Tongass National Forest, where there is a higher percentage of both cedar species (Wilson 2002). In the northern Tongass, yellow-cedar comprises 7% of the net volume of growing stock and there is no western red cedar, while yellow-cedar comprises 13.7% of the net volume of growing stock in the central Tongass and 9.5% in the southern Tongass (Wilson 2002). In 2007, the agency conducted an economic analysis of timber sales that illustrated that the Tongass National Forest needed to target a combination of redcedar and yellow-cedar on the southern and central Tongass in order to generate positively appraised timber sales (Housely et al. 2007). Since that time, nine of the ten largest Tongass National Forest timber sales have been planned by southern and central Tongass ranger districts.

Second, the report indicated that the agency was high-grading both cedar species at a finer scale because timber sale planners were selecting project areas with higher than average cedar components, or designating the removal of a greater proportion of cedar than naturally occurred within a project area in order to address timber sale economics concerns (Wilson 2002). For example, many of the largest timber sales occur in the Thorne Bay Ranger District, which is located within the southern Tongass inventory area where yellow cedar-comprises 9.5% of net volume of growing stock (Wilson 2002). The two largest timber projects implemented by the Tongass National Forest over the past five years – the 2009 Logjam Timber Project and 2013 Big Thorne Project – also occur within the Thorne Bay Ranger District. The species composition for the Logjam project was comprised of 11% yellow-cedar and 34% of both cedar species (Sheets 2009). Logjam Timber Project cutting units specifically targeted healthy yellow-cedar

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[2] *See, e.g.* FY 2003 Interior and Related Agencies Appropriations Act, § 318, PL 108-7;

[3] USDA Forest Service. 2012. Tonka Project Final Environmental Impact Statement, Volume I at 3-16-17. Tongass National Forest, Petersburg Ranger District. R10-MB0705c. Ketchikan, AK: Alaska Region. March 2012.

stands occurring in areas of adequate soil drainage where cedar decline is less likely to occur (Forest Service 2009a). For the 2013 Big Thorne Project, the project area species composition was comprised of 17% Alaska yellow-cedar and 28% of both cedar species (Forest Service 2013b).

Similarly, ongoing or planned projects in central Tongass ranger districts also occur in areas with disproportionately high levels of yellow-cedar and western redcedar (Myers et al. 2011). The pending Navy Timber Project occurs in a project area where the species composition consists of 17% yellow-cedar and 19% western redcedar (Forest Service 2009b). Yellow-cedar comprised 17.5% of the volume removed under the final decision for the 2011 Central Kupreanof Timber Project (Forest Service 2011a).

Thus, in the Tongass National Forest, in order to extract the economically valuable yellow-cedar, intact biological communities containing "junk" hemlock are destroyed just to remove a few individual yellow-cedar trees (Carstensen and Christensen 2008), creating ecosystem impacts beyond those to yellow-cedars themselves.

2. Commercial Logging Exacerbates Yellow-Cedar Decline

The large-scale clearcutting of old-growth yellow-cedar forests causes a conversion from yellow-cedar to other species in the newly regenerated stands (Forest Service 1999). In other words, once logged, yellow-cedar trees do not return. Western hemlock and Sitka spruce trees have faster growth rates and higher reproduction rates and thus out-compete yellow-cedar trees in regenerating stands (Hennon et al. 2012).

Deer browse compounds the poor natural regeneration because deer prefer yellow-cedar (Hanley et al. 1989, Stroh et al. 2008).[4] Stroh et al. studied the potential for western redcedar regeneration using deer exclusion studies and came to the conclusion that:

> [t]he likelihood that young, year-round palatable redcedars can escape deer browsing in an understory already severely depleted in resources for deer is understandably very limited. Our results indicate that any effort to restore redcedar generation in old-growth forest patches will need to achieve a significant reduction in deer abundance and maintain this reduction over a long period of time [Stroh et al. 2008].

In the Thorne Bay Ranger District's Logjam project area, regenerated and pre-commercially thinned stands showed a substantial decline in yellow-cedar composition and a large-scale conversion to hemlock-dominated forests after logging (Forest Service 2009a). Yellow-cedar comprises just 1% of the young growth stands in the Big Thorne Project area, and there is an ongoing conversion to spruce-dominated forests (Forest Service 2011b).

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[4] *See http://www.fs.fed.us/r10/spf/fhp/cedar/management.html; http://www.fs.fed.us/r10/spf/fhp/cedar/regen.html.*

Further, clearcutting transforms dense forested landscapes into large, open canopy gaps that exacerbate the freeze/thaw cycle responsible for yellow-cedar decline by creating conditions that cause more extreme temperature fluctuations:

> Air and soil temperatures respond primarily to exposure. Open canopies provide inlets for solar radiation that warm vegetation and the soil surface and also allow more rapid loss of energy at night. Dense forest canopies intercept solar radiation by shading during warm periods and insulate the loss of energy during cold periods, thus, creating buffered, less extreme temperature conditions. Soils located under open canopies warm more quickly in spring than the soils in dense canopies, as expressed by the rapid accumulation of soil degree days in the open canopy forest zones. The surface of these soils is also exposed to slightly colder night temperatures due to less insulation from the canopy [D'Amore and Hennon 2006].

Thus, logging not only permanently removes yellow-cedar from the ecosystem in areas where the trees are directly logged; it also exacerbates the climatic conditions that cause root-freezing injury and yellow-cedar decline. For this reason, all remaining living yellow-cedar should be protected from logging in order to: 1) conserve genetic diversity; 2) eliminate stressors related to timber harvest including changes in microclimates and soil chemistry; 3) avoid ecosystem changes such as deeper soil freezing due to loss of canopy cover, reduced snow-cover resulting in increased fine-root death, and changes in understory plants (Hennon et al. 2006, Oliver and Hennon 2013); and 4) prevent fragmentation of the landscape that may further hinder yellow-cedar adaptation and migration to more suitable regions as a response to climate change (Bunnell and Kremsater 2012). However, rather than protecting live yellow-cedar, current timber harvest practices on the Tongass selectively target these vulnerable trees. This overutilization of yellow-cedar for commercial purposes works in concert with climate change to put the species in danger of extinction throughout all or a significant portion of its range.

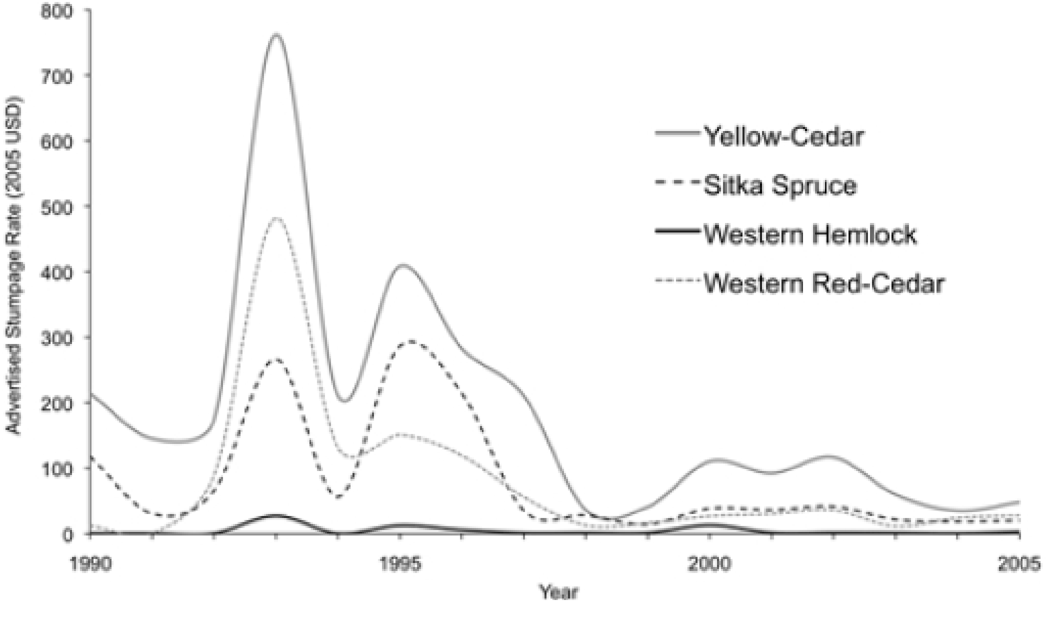

Figure 24: Mean advertised value of stumpage by species in Tongass National Forest timber sales from 1990-2005, in USD (not adjusted for inflation).

Unlike wood from live trees, which sells for high prices, wood from dead trees is rarely utilized, primarily going as firewood or to specialty niche markets including small-scale woodworkers, especially for musical instruments (Green et al. 2002). On the more than half-million acres where yellow-cedars are affected by widespread mortality, an average of 65% of the basal area of yellow-cedars are dead (Hennon et al. 1990). All ages of trees are affected. Managers and researchers suggest that salvage logging of dead yellow-cedar stands could be commercially valuable, help pay for ecological improvements, and direct harvest away from sites where yellow-cedars are not suffering from decline (Green et al. 2002, Donovan 2004, Beier 2011, Hennon and Wittweb 2013). Wood from dead yellow-cedars may be quite valuable, based on past sales (Figure 24 Hennon et al. 2012). However, salvage logging of yellow-cedar is rife with possible ecosystem problems (Mulvey and Lamb 2012) and is logistically difficult, generally involving helicopter-assisted harvest (Hennon et al. 2012).

C. DISEASE AND PREDATION

While yellow-cedar trees have strong resistance to most biotic pathogens, they may become more susceptible to disease under stress. The bright yellow color and strong aroma of yellow-cedar wood come from powerful natural biocides, including nootkatin (Barton 1976). The foliage also contains volatile leaf oils that may repel insect feeding (Cheng and von Rudloff 1970). Due to its natural defenses, at this time yellow-cedar has few serious problems with insect or fungal pests, although the paradigm shift in the occurrence of plant diseases due to climate change could increase the risk of healthy trees succumbing to what were once minor diseases.

During rigorous studies, biotic or contagious organism were ruled out as the primary cause of yellow-cedar decline (Hennon and Shaw 1997, Hennon et al. 2006). Researchers evaluated the following groups of organisms for their role in yellow-cedar decline, and ruled out each as a causative agent based on inoculation studies, or lack of association with affected tissues or areas of dying forests (Hennon et al. 2006): higher fungi (Hennon et al. 1990a, 1990b); oomycetes (Hennon et al. 2006); insects (Shaw 1985); nematodes (Hennon 1986); viruses and microplasmas (Hennon and McWilliams 1999); and bears (Hennon et al. 1990b).

Pathogens identified in diseased and dying yellow-cedar may play a small secondary role in yellow-cedar decline (Hennon et al. 1990b). While abiotic stresses are generally the root-cause of forest health problems, climate induced stressors are responsible for triggering many recent extensive forest insect and disease outbreaks (Allen 2009). Disease organisms often spread northward with climate change and tend to infect host trees that are already stressed by environmental factors (Sturrock et al. 2011). Some species of pathogens only impact a tree when it is stressed by other factors such as temperature extremes, or changes in the bioclimatic conditions. It is likely that the additive impacts of pathogens on tree species will increase in intensity with climate change, both independent of and in connection with fine-root freezing injury, the primary driver of yellow-cedar decline. When acting independently of climate effects, pathogens may affect yellow-cedar growing in sites where it is currently well-adapted, resulting in increased tree death and exacerbating currently observed climate impacts on the species (Ahanger et al. 2013). A review of the known pathogens leading to increased morbidity in yellow-cedar and their potential future impacts on yellow-cedar mortality follows.

1. Root Disease

Armillaria species cause root disease in many forests worldwide, primarily infecting conifers (Sturrock et al. 2011). Infection leads to wood decay, growth reduction and mortality. *Armillaria* root disease commonly affects dying yellow-cedars in stands of trees that are already suffering from yellow-cedar decline (Sturrock *in* Harrington et al. 2010). Thus, its role in decline is secondary to the primary abiotic process discussed in detail in Part II.A of this petition (Hennon et al. 1990b).

2. Fungus and Insects

A variety of fungal pests affect yellow-cedar, mostly targeting young trees, and generally not leading to tree mortality.

In a 2001 report, shoot blight of yellow-cedar regeneration remained at endemic levels in southeast Alaska (Wittwer 2004). The fungus that causes this disease is closely related to snow molds or blights and does not affect mature yellow-cedar trees. The terminal and lateral shoots of young trees (seedlings and saplings) become infected and die during late winter or early spring, with dieback extending as far as 10 to 20 cm from the tip of the shoot. Small seedlings of up to 0.5 m tall may be killed outright. The causal fungus is of the *Apostrasseria* genus but remains to be confirmed or identified to species levels.

More than a dozen different species of *Basidiomycetous* decay fungi have been identified on living yellow-cedar trees (Harrington 2010). All of the decay fungi-affected yellow-cedar trees can be categorized as causing either white rot or brown rot. White rot fungi digest all the components of wood tissue, including lignin, cellulose, and hemicellulose, and leave behind decayed wood. Brown rot fungi cannot digest lignin and leave behind brown crumbly wood decay that is mostly composed of modified lignin and may be resistant to further deterioration. Yellow-cedar trees are rarely killed by these fungi, although infected trees may have extensive internal decay without any visible external signs of rot (Harrington 2010).

More than 50 species of fungi were identified on dying or dead yellow cedar, but none were consistently related to yellow-cedar decline, while inoculation trials found that none of ten species of fungi killed unstressed seedlings.

Fungal decay is of greater concern for commercial wood products than for its impact on yellow-cedar survival. The ecological role of fungi in old-growth forests has not been the subject of extensive research. Researchers have observed old and decayed yellow-cedar with boles that snapped to create canopy gaps, indicating that decay fungi may be important mortality agents of old cedar trees that create small-scale disturbance in old-growth forests (Hennon et al. 2005).

Phloeosinius sp. (bark beetles) play a minor role in yellow-cedar mortality, and are frequently found on declining cedars, but they only attack trees that are already nearly dead or stressed due to other factors (Hennon and Shaw 1997). The beetles act as secondary damage agents to trees already stressed by freezing injury. Bark beetle outbreaks will move upward in latitude and elevation with climate change in the United States and Canada, and have already contributed to severe decline in tree species growing at elevation, including whitebark pine (*Pinus albicaulis*; Jessie et al. 2010).

3. Invasive Pathogens

Recent observations by researchers in Scotland and Argentina show that the pathogen *Phytophthora austrocedrae* may in the future significantly impact yellow-cedars in Alaska. This pathogen was first described as a new species in 2007, after it was isolated from dying Chilean cypress trees (*Austrocedrus chilensis*) located in Argentina, where it was destructive and presumed to be invasive. In 2011, the same pathogen was isolated from dying, cultivated yellow-cedars in Scotland. The pathogen's origin is unknown, as is the susceptibility of Alaska yellow-cedar to this pathogen, and whether this pathogen could survive Alaska's coastal rainforest environment. To date, there is no documentation of this pathogen being found in Alaska's soil or water, but it may pose a significant future risk (Mulvey and Lamb 2012).

4. Bears and Deer

Yellow-cedars, especially young saplings, are an important source of browse for Sitka deer, and adult trees are frequently damaged by Alaska brown bears (Hennon et al. 2012). Alaska brown bears gnaw on yellow-cedar trunks in the spring to access the soft under-bark layer, the phloem, which is high in fructose. As noted above, basal scars from either brown bears or Alaska Natives were evident on over 49% of the yellow-cedars on Chichagof and Baranof Islands (Hennon et al. 1990a), and in some stands the majority of yellow-cedars have basal scars from bear feeding (ADNR 2000). Brown bear damage to trees in Alaska and British Columbia creates open wounds that may allow for growth of destructive fungi (see Section III.A.1.b), but feeding by brown bears does not generally lead to mortality of yellow-cedar.

Saplings and young cedar may suffer high mortality due to browsing by Sitka deer. If proposed regeneration of yellow-cedar at long-term bioclimatically suitable sites is to be successful, managers must develop techniques to reduce Sitka deer grazing that leads to high levels of mortality (Hennon et al. 2009, 2012).

D. INADEQUACY OF EXISTING REGULATORY MECHANISMS

Existing regulatory mechanisms are woefully inadequate to curb the primary threats to yellow-cedar posed by anthropogenic greenhouse gas emissions and selective timber harvest, as discussed below. The strong links between the global carbon budget, energy and water cycles, and forest dynamics demonstrate that there is a critical need for the immediate implementation of regulatory mechanisms that will directly reduce the incidence of yellow-cedar decline.

1. Regulatory Mechanisms Addressing Greenhouse Gas Emissions and Climate Change are Inadequate

Greenhouse gas emissions pose a major threat to the continued existence of yellow-cedar trees through impacts from climate change, especially reduced snow cover and shifts in the freeze-thaw cycles in late winter and early spring that result in fine-root death of the trees. Regulatory mechanisms at the national and international level do not adequately protect yellow-cedar from these impacts, nor do they require the greenhouse gas emissions reductions necessary to protect yellow-cedar from extinction. As USFWS recognized when it listed the polar bear (*Ursus maritimus*) as a threatened species, while "there are some existing regulatory mechanisms to address anthropogenic causes of climate change . . . these mechanisms are not expected to be effective in counteracting the worldwide growth of greenhouse gas emissions within the foreseeable future." (Determination of Threatened Status for the Polar Bear (*Ursus maritiums*) Throughout Its Range, 73 Fed. Reg. 28212, 28241 (May 15, 2008)). Similarly, the National Marine Fisheries Service (NMFS) acknowledged in its 2012 *Management Report for 82 Corals Status Review under the Endangered Species Act* that no countries are reducing emissions enough to keep the increase in global temperature below 2 degrees C; and the top ten emitters, including the United States, are performing poorly or very poorly at meeting needed greenhouse gas reductions (NMFS 2012). No additional regulations have been implemented to adequately curb greenhouse gas emissions since USFWS's 2008 finding or NMFS's 2012 finding.

As detailed below, the continued failure of the U.S. government and the international community to implement effective and comprehensive greenhouse gas reduction measures places yellow-cedar at ever-increasing risk of extinction.

a. Global Greenhouse Gas Emissions are tracking the worst IPCC Emissions Scenario

The atmospheric concentration of CO_2 reached 400 parts per million (ppm) for the first time in human history in May 2013, compared to the pre-industrial concentration of ~280 ppm (Scripps Institution of Oceanography 2013). The current CO_2 concentration has not been exceeded during the past 800,000 years and likely not during the past 15 to 20 million years (Denman et al. 2007, Tripati et al. 2009). Atmospheric CO_2 emissions have risen particularly rapidly since the 2000s (Raupach et al. 2007, Friedlingstein et al. 2010). The global fossil fuel CO_2 emissions growth rate was 1.0% per year in the 1990s compared with 3.1% per year since 2000, and this growth rate has largely tracked or exceeded the most fossil-fuel-intensive emissions scenarios projected by the IPCC (A1FI and RCP 8.5) since 2000 (Raupach et al. 2007, Peters et al. 2012). The CO_2 emissions growth rate fell slightly in 2009 due largely to the global financial and economic crisis; however, the decrease was less than half of what was expected and was short-lived (Fiedlingstein et al. 2010). In 2013, global CO_2 emissions rose by the highest amount on record (http://www.esrl.noaa.gov/gmd/ccgg/trends/).

b. Greenhouse Gas Emissions Reductions Needed to Protect the Yellow-cedar

Recent international agreements have focused on a goal of limiting global temperature increase to 2°C above pre-industrial levels to "prevent dangerous anthropogenic interference with the climate system" as required by the United Nations Framework Convention on Climate Change

(UNFCCC 2012).[5] However, many studies demonstrate that a 2°C temperature increase above pre-industrial levels is well past the point where severe and irreversible impacts will occur (Smith et al. 2009).

Because a 2°C target would commit the world to serious harm, many climate scientists and governments have urged a target of 1.5°C to avoid dangerous climate change (Hansen et al. 2008, Rockström et al. 2009), which roughly corresponds to reducing the atmospheric CO_2 concentration to 350 ppm (Hare and Schaeffer 2009).[6] Limiting warming to 1.5°C has been called for by the Alliance of Small Island States, the Least Developed Countries, and Executive Secretary of the United Nations Framework Convention on Climate Change Christiana Figueres. As climate scientist Dr. James Hansen and colleagues concluded, “if humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO_2 will need to be reduced . . . to at most 350 ppm [equivalent to ~1.5°C], but likely less than that” (Hansen et al. 2008). This 350 ppm target must be achieved within decades to prevent dangerous tipping points and “the possibility of seeding irreversible catastrophic effects” (Hansen et al. 2008).

Reducing the atmospheric CO_2 concentrations to at most 350 ppm, and perhaps much lower (300 to 325 ppm CO_2) would help protect yellow-cedar from the threats of climate change, especially precipitation falling as rain rather than snow, and increased spring freeze/thaw cycles, that threaten the tree’s essential habitat and create conditions unsuitable for the tree’s continued survival.

c. U.S. Measures to Reduce Greenhouse Gas Emissions Are Insufficient

While existing domestic laws including the Clean Air Act, Energy Policy and Conservation Act, Clean Water Act, Endangered Species Act and others provide authority to executive branch agencies to require greenhouse gas emissions reductions from virtually all major sources in the United States, these agencies are either failing to implement or only partially implementing these laws for greenhouse gases. For example, the EPA has issued a rulemaking regulating greenhouse gas emissions from automobiles that will reduce greenhouse emissions emitted per vehicle mile traveled by passenger vehicles in the future; but because the improvements are modest, and more vehicles are projected to be driven more miles in the future, the rule will only slow the rate of increase somewhat compared to what it would be without the rule. EPA, Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule, 75 Fed. Reg. 25324 (May 7, 2010). Meanwhile the government concedes that emissions reductions for heavy-duty vehicles “are not sufficient by themselves to reduce total [heavy-duty] vehicle emissions below their 2005 levels by 2020.” NHTSA, Medium- and Heavy-Duty Fuel Efficiency Improvement Program – Final Environmental Impact Statement (June 2011). This means that the vehicle rule is far from achieving emissions goals agreed to by the United States in the Copenhagen Accord, which aim to keep global warming below 2°C.

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[5] The non-legally binding Cancún Agreement of 2010 and Copenhagen Accord of 2009 recognize the objective of limiting warming to 2°C above pre-industrial levels.

[6] An analysis of low emissions pathways found that only those that approach 350 ppm by 2100 have a reasonable probability (40–60%) of limiting warming to 1.5°C.

To date, the EPA has proposed to use the Clean Air Act's new source performance standard program to reduce greenhouse gas pollution from one stationary source, electric generating units (power plants), from both new and existing power plants. While there is enormous potential to reduce emissions through this program overall and through the power plants rule proposals in particular, the EPA's rules for new and existing plants are insufficiently stringent, increasing the nation's use of natural gas plants while failing to require meaningful emissions reductions from them, even though such reductions are readily achievable. The EPA admits that the proposed rule for new plants will not reduce emissions from these sources between now and 2022 compared to what would be expected without the rule. EPA. Standards of Performance for Greenhouse Gas Emissions from New Stationary Sources: Electric Utility Generating Units, 79 Fed. Reg. 1430 (Jan. 8, 2014). Indeed, in the rulemaking the EPA concedes that the rule for new power plants "will result in negligible CO_2 emission changes, quantified benefits, and costs by 2022." (Id. at 1495). The proposed rule for existing plants proposes to reduce existing power plant emissions 30 % below 2005 levels by 2030, which is equivalent to 7.7 % below 1990 levels, the base year for the international climate treaty, by 2030 (EPA. Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, EPA-HQ-OAR-2013-0602). However, according to the IPCC Fourth Assessment Report and other scientific studies, developed countries such as the United States must reduce their emissions 25 % to 40 % below 1990 levels by 2020 to have a medium chance of limiting warming to 2 degrees C (Gupta et al. 2007), meaning that this proposed rule falls far short of requiring emissions reductions needed to meet the internationally agreed-upon climate target and avoid dangerous climate impacts.

While full implementation of our flagship environmental laws, particularly the Clean Air Act, would provide an effective and comprehensive greenhouse gas reduction strategy, due to their non-implementation, existing domestic regulatory mechanisms must be considered inadequate to protect yellow-cedar from climate change

d. International Measures to Reduce Greenhouse Gas Emissions Are Inadequate

International initiatives are also currently inadequate to effectively address climate change. The United Nations Framework Convention on Climate Change, negotiated in 1992 at Rio de Janeiro, Brazil, provides the forum for the international negotiations. In the Framework Convention, signed and ratified by the United States, the world agreed to take the actions necessary to avoid dangerous climate change. Parties to the Convention also agreed as a matter of fairness that the world's rich, developed countries, having caused the vast majority of emissions responsible for the problem, would take the lead in solving it (Figure 25). It was not until the 1997 meeting in Kyoto, Japan, that the first concrete, legally binding agreement for reducing emissions was signed: the Kyoto Protocol. The Protocol requires the world's richest countries to reduce emissions an average of 5 percent below 1990 levels by 2012, while developing nations also take steps to reduce emissions without being subject to binding emissions targets as they continue to raise their standard of living. The United States has been a major barrier to progress in the international negotiations. After the Clinton administration extracted many concessions from the rest of the world in exchange for the United States signing on in Kyoto, the Senate rejected the equity principles behind the Convention, saying the United States should not agree to reduce its own emissions unless all other countries — regardless of their responsibility or ability — were similarly bound. Citing the same excuses, President George W. Bush repudiated the Kyoto Protocol entirely. Thus the United States is the only industrialized country in the world that has yet to ratify the Kyoto Protocol. The United States' negotiating team under both the George W. Bush and the Obama administrations has pursued two primary objectives in the international talks: to refuse any legally binding emissions reduction commitments until all other countries—but particularly China and India—do so, and to push back the date for a new agreement. Not surprisingly, the United States failed to meet its (never ratified) Kyoto pledge to reduce emissions to 7.2% below 1990 levels by 2012; to the contrary, U.S. emissions have increased by 10.5% since 1990 (EPA 2012).

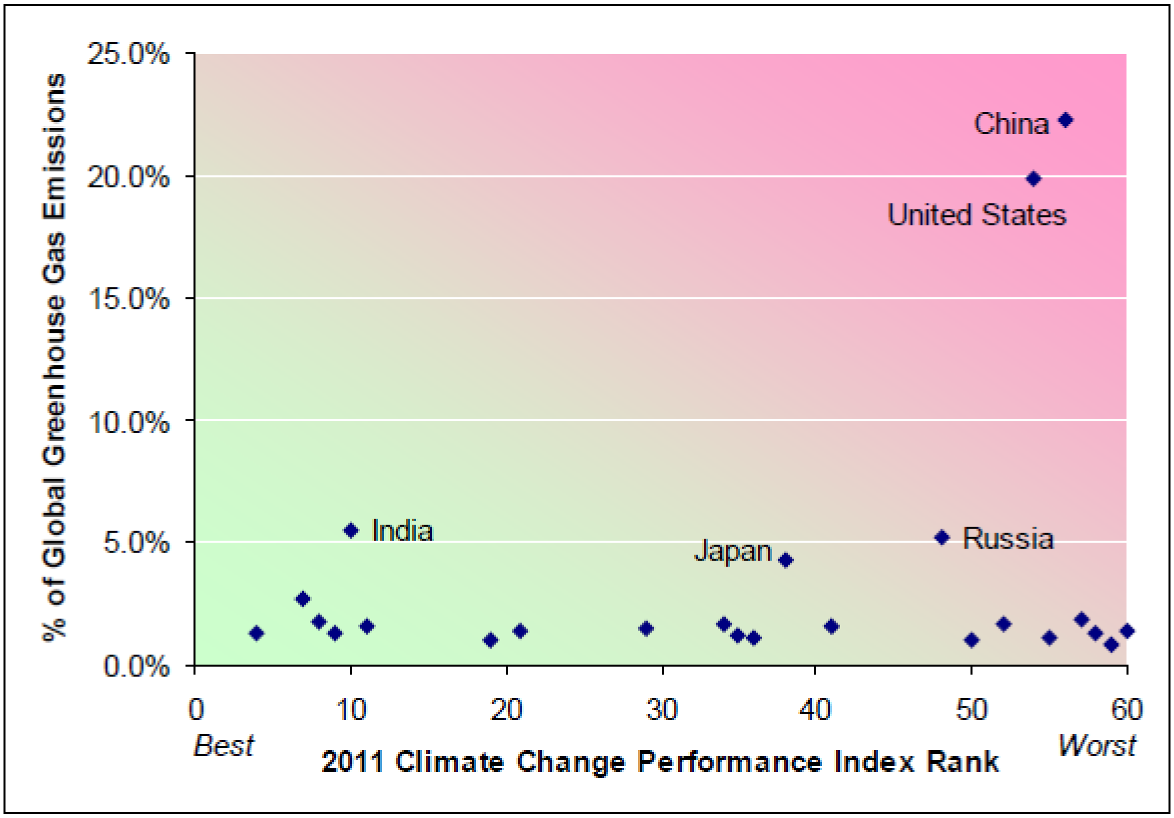

Figure 25: This figure is a qualitative illustration of which countries have the most potential to increase their positive impact on greenhouse gas emissions globally. The Climate Change Performance Index (CCPI) ranks the 60 emitting countries annually in various factors including emissions level, emission trend, and climate change policy. The United States and China are the top two greenhouse gas emitters, and were both ranked in the "very poor" category in the 2011 CCPI.

Moreover, the Kyoto Protocol's first commitment period only sets targets for action through 2012, and there is still no binding international agreement governing greenhouse gas emissions in the years beyond 2012. While the 2009 U.N. Climate Change Conference in Copenhagen called on countries to hold the increase in global temperature below 2°C (an inadequate target for avoiding dangerous climate change), the non-binding "Copenhagen Accord" that emerged from the conference, and the subsequent "Cancún Accords" of 2010 and "Durban Platform" of 2011 failed to enact binding regulations that limit emissions to reach this goal. Even if countries were to meet their Copenhagen and Cancún pledges, analyses have found that collective national pledges to cut greenhouse gas emissions are inadequate to achieve the 2°C target, and instead suggest emission scenarios leading to 2.5°C to 5°C warming (Rogelj et al. 2010, UNEP 2010, 2011). As of July 2013, many governments were not implementing the policies needed to meet their inadequate 2020 emission reduction pledges, making it more difficult to keep global temperature rise to 2°C and likely leading to a temperature rise of at least 3.5°C (USGCRP 2013). As noted in the NMFS Management Report, the United States has yet to issue regulations to limit greenhouse gas emissions in accordance with its pledge under the Copenhagen Accord (NMFS 2012).

2. Regulatory Mechanisms Addressing Management and Logging of Yellow-Cedar in the Face of Climate Change Are Inadequate

Existing forest management law in the United States contains inadequate regulatory mechanisms to protect yellow-cedar. Yellow-cedar is almost exclusively found on public lands and is therefore subject to the National Forest Management Act (NFMA), of 1976 16 U.S.C. §§ 1600, *et seq*., and the Healthy Forest Restoration Act (HFRA), 16 U.S.C. §§ 6501, *et seq*.

NFMA contains a mandate that the Forest Service adopt guidelines for the management of national forests that “provide for the diversity of plant and animal communities” and, in particular, provide for “steps to be taken to protect the diversity of tree species.” 16 U.S.C. § 1604 (g)(3)(B). Despite this specific language, this provision has not resulted in enforceable mandates to preserve yellow-cedar. To the contrary, in 2012 the Forest Service finalized new regulations that weakened measures to protect wildlife and water quality. Forest Service, National Forest System Land Management Planning, Final Rule, 77 Fed. Reg. 21162-21275 (April 9, 2012). The Forest Service explicitly recognized that there are “limits to the Agency’s authority and the inherent capability of the land.” *Id*. at 21175. Further, the Tongass National Forest interprets NFMA’s diversity provisions as procedural in nature, and insists that NFMA imposes no obligation to maintain any specified level of abundance or distribution of particular species (Forest Service 2009b).

NFMA also requires each national forest to develop management plans and periodically revise them. Plans are open to public review and comment. The 2008 Tongass Land Management Plan (TLMP) is part of NFMA. The 2008 TLMP requires the agency to monitor forest health and evaluate silvicultural prescriptions in light of future stand diversity, particularly overstory species such as yellow-cedar (Forest Service 2008). However, the TLMP contains no language to protect healthy yellow-cedar from timber harvest. There is no language in the TLMP that limits the agency from harvesting a particular volume of any species (Wilson 2002). Instead, the agency interprets the TLMP to allow for sales with a higher than average cedar component (Wilson 2002). This is because without these species present, the agency cannot generate an economically viable timber sale; indeed, the Tongass National Forest interprets its Forest Plan to require an emphasis on cedar in order to meet timber resource objectives and comply with its Standards and Guidelines (Wilson 2002).

The HFRA of 2003 was designed to reduce risk of forest fires, and does not mandate the conservation of yellow-cedar specifically, or the more general conservation of forest diversity.

Forest fires are rarely a problem in the temperate rain forests where the majority of yellow-cedar occurs.

The Forest Service has conducted extensive research on yellow-cedar decline and spearheaded research efforts into yellow-cedar decline, modeling, and recommendations for future yellow-cedar conservation (Forest Service 2013a). However, research has not equated to protective management practices, and extensive areas of healthy yellow-cedar continue to be subject to timber sales. Current Forest Service yellow-cedar research focuses on ecosystem effects of a loss of yellow-cedar from the landscape, and how shifts in forest communities will affect long-term management and conservation (Mulvey and Lamb 2012).

The Forest Service has also developed recommendations for yellow-cedar conservation, while recognizing the futility of conserving or restoring yellow-cedar in areas where it is now maladapted due to climate change, or will be maladapted in the future (Hennon et al. 2012). The Forest Service also has stated that it has plans to publish a yellow-cedar conservation plan, but details of when that may be released are not available. In general, Forest Service efforts to date have been focused on yellow-cedar research, and are not part of any national mandate. Any actions to protect yellow-cedar are still in the development stage and do not address greenhouse gas emissions. In short, existing regulatory mechanisms and efforts toward protecting yellow-cedars are not adequate to deal with existing threats to the species.

E. OTHER NATURAL OR MANMADE FACTORS AFFECTING ITS CONTINUED EXISTENCE

The potential for a tree species such as yellow-cedar to adapt, and thus survive changing climatic conditions in northwest North America through migration, is low. Hurdles to successful migration include the ability of a tree to produce and disperse seeds, and the difficultly in those seeds ending up in appropriate conditions for regeneration (Bunnell and Kremsater 2012). This is especially so for yellow-cedar. Yellow-cedar has historically occupied an extremely selective microhabitat, is generally not competitive with other tree species except under marginal conditions that pose additional obstacles to successful regeneration, has an extended life-history and long lifespan, has greatly contracted its range in the past due to climate change, and has a very low rate of regeneration.

Recent research suggests that yellow-cedar is significantly less likely to regenerate in forests affected by the dieback and that the loss of this species can dynamically rearrange the plant community. A recent site-specific study (Oakes et al., in review) found that yellow-cedar seedling and sapling abundance decreased in forests affected with widespread mortality from yellow-cedar decline. In these forests, yellow-cedar sapling occurrence decreased significantly from 0.56 in forests not affected by yellow-cedar decline, to 0.07. On average, dead yellow-cedar comprised 80% of the total (live and dead) yellow-cedar basal area in forests affected by the dieback, indicating that some individuals may still survive once the forests become affected. At this time, researchers do not understand if surviving yellow-cedar trees are superior genetically, or if they are growing with deeper roots on better microsites. Yellow-cedar decline may be more likely to affect smaller trees first, while death of larger trees occurs subsequently in a staggered process. Beier et al. (2008) found that surviving yellow-cedar trees in declining stands can produce larger growth rings, but with greater interannual variability after the onset of decline. Despite the survival of some individuals once a forest becomes affected, current scientific understanding documents significant losses of this species across all life stages (from reproduction to large trees) in areas affected by the dieback at low elevations, and yellow-cedar appears to be maladapted to areas affected for the foreseeable future. Yellow-cedar trees growing at higher elevations and to the north, where snowpack protects their roots from freezing injury, is helping to sustain the species in Alaska. Ongoing projections of snowfall in the future will predict the fate of these yellow-cedar populations.

Another major obstacle to natural regeneration of yellow-cedar a sites where yellow-cedar die-off has occurred is browsing by Sitka deer. As discussed earlier in this petition, Sitka deer selectively graze on yellow-cedar saplings. Where deer are present in any number, yellow-cedar are unlikely to survive.

There is no scientific evidence indicating that yellow-cedar will migrate to higher elevations or more suitable locations, as root-freezing injury kills off more trees at lower elevations. Yellow-cedar is adapted to a specific niche, dependent on wetter soil conditions, where it can outcompete other tree species. In addition to the barriers to natural migration, including low reproductive potential, it is likely that many other factors will come into play, limiting the trees ability to migrate. These include, lack of adequate soils at higher elevations, out-competition by other trees and understory plants due to yellow-cedar slow growth rate, and steeper slope aspects.

IV. CRITICAL HABITAT

The ESA mandates "to the maximum extent prudent and determinable," USFWS "shall, concurrently with making a determination . . . that a species is an endangered species or threatened species, designate any habitat of such species which is then considered to be critical habitat" 16 U.S.C. § 1533(a)(3)(A)(i); see also id. at § 1533(b)(6)(C). The ESA defines the term "critical habitat" to mean:

> i. the specific areas within the geographical area occupied by the species, at the time it is listed . . . on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and
> ii. specific areas outside the geographical area occupied by the species at the time it is listed . . . upon a determination by the Secretary that such areas are essential for the conservation of the species.

Id. at § 1532(5)(A).

The Center for Biological Diversity expects that USFWS will comply with this unambiguous mandate and designate critical habitat concurrently with the listing of yellow-cedar. Critical habitat must include suitable habitat from areas of the tree's natural range in southeast Alaska that are projected to be free from freezing injury due to climate change in the near future, are free from deer browsing, and are in areas where yellow-cedar will be able to survive over its entire 1,000-year-plus lifespan.

V. MANAGEMENT RECOMMENDATIONS

Climate change must be addressed in forest planning. Climate and landscape models can be used to evaluate how well specific conservation areas may meet their goals in the future and where widespread problems might develop as climate change continues. The Forest Service has no regulations in place to address rising greenhouse gas emissions and instead takes a reactive approach to management by monitoring and implementing "adaptive management" as needed. Yellow-cedar that is currently growing in zones where it is adapted, and where climate models show that it will continue to be adapted over the next hundred years, should not be subject to harvest. However, under the current TLMP, cedars in these areas are not explicitly protected. As Hamann and Wang state in their 2006 paper on the effects of climate change on tree species, "if currently observed climate trends continue or accelerate, major changes to management of natural resources will become necessary." With continued and rapidly accelerating climate change, implementation of management measures for yellow-cedar are currently not taking place quickly enough to protect the species or to ensure its long-term survival.

Active management to favor yellow-cedars is most likely to be successful in areas of south-facing, gentle sloped, well-drained soil, where yellow-cedar has continued to thrive and show resilience to climate change, even without adequate snow cover (Hennon et al. 2012). Active management would consist of favoring yellow-cedar through planting and thinning to expand yellow-cedar's realized niche, and protecting existing healthy stands of yellow-cedar from timber harvest. However, while small patches of this long-lived tree species may benefit from these measures, rapid changes in climate caused by continued greenhouse gas emissions, and the threat to the long-term survival of yellow-cedar, must be addressed through national and international regulations, not at the Forest Service management plan level.

Active management or restoration through human intervention is unlikely to be possible in many areas, due to the region's remoteness and inaccessibility, and instead a new community of plants will succeed to take the place of yellow-cedar (Hennon et al. 2012). As discussed in Hennon and Wittweb (2013), the zones where there will be adequate snow to protect against yellow-cedar decline are shrinking, even though currently healthy yellow-cedar occur in select areas (eg. south-facing slopes with gentle decline and adequate drainage) above 200 meters. "By 2080, only a small area near the cone of the volcano is predicted to have sufficient snow to protect yellow-cedar from root-freezing injury" (Hennon and Wittweb 2013).

Further efforts to restore, replant, or conserve yellow-cedar should be focused on the few sites where the species is likely to be well adapted for the next millennia, due to the tree's extreme longevity and the rapid die-off caused by small shifts in climate. Such sites will become increasingly rare and may disappear entirely over the next few hundred years. All modeling to date has only projected out to 2085, predicting massive declines, with yellow-cedar in Alaska only surviving at high elevations (Figure 21). Thus, active management is unlikely to meet with long-term success unless it is accompanied by a drastic reduction in greenhouse gas emissions, and an immediate end to timber harvest of living yellow-cedar. The following are a few actions that may allow some resiliency for yellow-cedar in the face of currently occurring climate change.

A. GENETIC CONSERVATION

In stands where a high percentage of yellow-cedar trees have died, the remaining trees may contain important genetic material for maintaining diversity in out-plantings (Oliver and Hennon 2013). While genetic studies are ongoing, genetic material from these trees should be collected and stored for possible future outplanting.

In Alaska there has been little research on the genetic structure of yellow-cedar, while somewhat more research has been conducted in British Columbia. Conservation of the genetic structure of yellow-cedar in the context of widespread and substantial decline must be investigated further (Hennon et al. *in* Harrington 2010). In order to conserve genetic structure, a genetics program that investigates breeding trees for late spring dehardening and for freezing resistance should be employed to potentially restore yellow-cedar in areas prone to decline now and in future.

B. SILVICULTURE AND REPLANTING

Yellow-cedar does not rapidly reproduce, and successful silviculture may require new and as yet unknown or untested techniques. Barriers to successful regeneration through planting include seed collection and germination, competing vegetation, browse by Sitka deer, and spring freezing injury. Reproduction through layering mainly occurs on boggy sites, where branches have contact with the ground. A planting trial for yellow-cedar began in 1986 on Etolin Island (Forest Service 2000). Results found that yellow-cedar can be regenerated on logged sites, when it is planted quickly following harvest. Another study near Ketchikan showed that rooted cuttings (stecklings) could substitute for seedlings (Hennon et al. 2009). Many aspects of yellow-cedar reproductive biology, and how to best achieve maximum yield through the use of seeds, seedlings, or layering, remain unknown. Further research must be conducted if yellow-cedar is to be successfully outplanted at suitable sites.

Planting yellow-cedar at suitable sites may be the best way to ensure that the tree does not go extinct. Modest climate warming across the natural range of yellow-cedar predicted by current general circulation models will likely result in increased productivity on sites with low hazard for yellow-cedar decline and improve performance of populations planted upward and northward of their origins (Russell and Krakowski 2012).

Silviculture of yellow-cedar in young-growth forest is poorly known, and needs more research and management attention, particularly in Alaska. Studies should include how best to dissuade Sitka deer from browsing on yellow-cedar saplings, such as the use of stock with genetically higher terpene concentrations. The ability of yellow-cedar to compete and maintain its canopy status in the long-term has also not been evaluated (Hennon et al. *in* Harrington 2010).

In addition, little is known about how to select an ideal site for yellow-cedar outplanting. Yellow-cedar utilizes calcium in a unique way to allow for competitive advantage at the fringes of bogs and other poorly drained soils. Yellow-cedar is able to alter nitrogen availability through this process, but this has not been field-tested (D'Amore et al. 2009). Selecting sites that are high in calcium, or adding calcium to the soil, may provide a competitive advantage to yellow-cedar.

C. SALVAGE LOGGING

There are no published long-term scientific studies on the ecological value of yellow-cedar snags (Mulvey and Lamb 2012, Oliver and Hennon 2013). Areas containing dead yellow-cedar trees may provide important wildlife habitat, for bats, raptors, songbirds, marten, flying squirrels, and other species, perhaps related to the extreme longevity and rot-resistance of standing trees (Hennon et al., 2007). While salvage logging of dead yellow-cedar is certainly preferable to harvest of ancient stands of living cedar, these areas are protected in many cases, because of yellow-cedar's propensity to occur on marginal, generally less productive sites (Green et al. 2002, Donovan 2004, Harrington 2010). These areas are often protected as existing wilderness or administratively protected lands (Oliver and Hennon 2013). However, as the yellow-cedar increases in price and demand, due to its rarity and unique wood qualities, dead yellow-cedar snags will likely be subject to harvest, and their ecological value must be taken into consideration.

VI. CONCLUSION

As demonstrated in this petition, yellow-cedar faces high magnitude and growing threats to its continued existence. Yellow-cedar decline is the most severe tree die-off ever reported in North America, and has been extensively studied for over 30 years, with scientists concluding that climate change is the leading cause. Yellow-cedar decline occurs over an expanding 600,000 acres in Alaska and British Columbia. Anthropogenic greenhouse gas emissions continue to rise at an unprecedented rate, leading to warmer springs, reduced snow cover, and a shift to average winter temperatures of above freezing throughout much of yellow-cedar's habitat.

Climate change threatens to severely reduce the suitable bioclimatic range for yellow-cedar, with a projected 75% decrease in population by 2085. Any measures to protect yellow-cedar trees that are currently well-adapted, or to plant yellow-cedar in currently suitable habitats, will eventually fail unless they are accompanied by drastic cuts in greenhouse gas emissions. Unless these cuts are made, yellow-cedar will suffer a rapid decline in population followed by a slower decline, ultimately leading to extinction. Additionally, failure to protect living stands of yellow-cedar from timber harvest reduces genetic diversity and further imperils the species. USFWS must promptly make a positive 90-day finding on this petition, initiate a status review, and expeditiously proceed toward listing and protection of this species.

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