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Draft Terrestrial Ecosystems Resource Assessment

Tongass National Forest Plan Revision

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Cover Photo: Alpine Vegetation by Rick Turner.

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Introduction

Diverse terrestrial ecosystems exhibiting high ecological integrity have the capacity to provide people and communities with ecosystem services and multiple uses that provide a range of social, economic, and ecological benefits for the present and into the future. These benefits include habitat for fish, wildlife, and plant communities, sustainable economic use of natural resources, and opportunities for recreational, spiritual, educational, and cultural benefits.

The Tongass constitutes a substantial part of one of the largest temperate rainforests on Earth. Covering millions of acres and thousands of islands, it is largely intact, remaining free from the widescale mortality caused by many of the abiotic and biotic factors, such as uncharacteristic wildfire and insects and disease, that are negatively affecting ecosystems in national forests of the contiguous United States. Many of the ecosystems on the Tongass remain largely unaffected by direct management activities.

The 2012 Planning Rule contains specific requirements for assessing the integrity of terrestrial and aquatic ecosystems (36 CFR 219.6(b)). It also directs that forest land management plans must provide components, including standards and guidelines, to maintain or restore ecological integrity of terrestrial and aquatic ecosystems and watersheds (36 CFR 219.8(a)).

In the current Forest Plan, a land allocation process is used in which all areas of the Tongass National Forest (the plan area) are allocated to various Land Use Designations (LUDs) based on emphasized objectives or uses. Some LUD allocations represent congressionally designated areas, such as Wilderness, and these areas must be managed in accordance with the congressional legislation that designated the area. Other LUD allocations are for development of resources, and these areas are managed in accordance with LUD direction. In the timber production LUD for instance, goals are focused on wood production and managing lands for sustained long-term timber yields and LUD direction allows roads to be built and commercial timber to be harvested while protecting other resources. Approximately 35 percent of the Tongass National Forest is currently within designated Wilderness, and an additional 45 percent is within various 'natural setting' land use designations, leaving the remaining 20 percent allocated as development land use designations.

As heard from the 2024 Assessment Engagement, most people's vision for the Tongass centered around healthy, functioning terrestrial and aquatic ecosystems. Important management considerations included: freshwater sources, fish and wildlife habitats, maintaining intact systems, and sustainability. People were concerned with development, pollution and climate change impacting fisheries and watersheds.

Indigenous Knowledge of Ecosystems

The indigenous knowledge systems, or "ways of knowing", include deep observation of the environment over thousands of years. This includes perpetuating and utilization of ancestral knowledge through stories/language, place names, harvesting practices, seasonal migrations, relationships, value systems and behaviors.

A key element to the building of this knowledge system is the underlying values that represent indigenous people's relation to all beings within their homelands. Both the indigenous people's relation to and shared spirit of place with everything in their homelands leads to a deep respect and curiosity to understand and learn about all things within an environment or ecosystem. A critical element to stewardship of environmental systems for indigenous people is the understanding that they are an integral part of their environment and building relationships with all beings is key to fully understanding how a system maintains balance.

An important value that ties to ecosystem study and stewardship is the value of balance, reciprocity and respect, introduced in the Tongass as an Indigenous Place assessment section. Tribes recognize that Forest Service ecosystem research and stewardship would be enhanced by working with Tribes to utilize this key value of balance, along with Tribal "ways of knowing" and observation to improve monitoring and stewardship efforts.

Having a cross-cultural recognition of biological and cultural health as two sides of the same entity: place, will be a key for success. Environmental health and communal health were never separate in Tlingit place consciousness (Thornton and Sivaramakrishnan 2011, p196). "Taking care" of places and communities meant never going "against nature" and instead cultivating places through respectful engagement with their constituent beings as a means of promoting biocultural health (Thornton and Sivaramakrishnan 2011, p196).

Expanding the focus on cultural and community health with forest and ecosystem health will create a more holistic framework for creating progress and enhancing stewardship of ecosystems.

Scope and Scale of Assessment

The scope for this assessment includes terrestrial ecosystems that occur on both public and private lands within the administrative boundary of the Tongass National Forest. The scale of this assessment is the administrative boundary of the Tongass National Forest because it comprises most of the land in Southeast Alaska.

Large-scale ecosystem classifications are used to help provide insight into spatial variation of ecological conditions across the Tongass. For this assessment, the ecological subsections of Southeast Alaska (Nowacki et al. 2001) were used to stratify the landscape. Ecological subsections are mid-level ecosystems included as part of the National Hierarchical Framework of Ecological Units, which describes and defines the process for delineating landscapes at various spatial scales (Cleland et al. 1997). The primary factors for subsection delineation are physiography, lithology, and surface geology, along with geomorphic processes, soil groups, subregional climate, and potential natural vegetation (Nowacki et al. 2001). For the purposes of this assessment, the 73 ecological subsections occurring on the Tongass National Forest were combined into 11 higher level groups based on broad similarities in landform and geologic characteristics (Figure 1). This stratification provides a basis for assessing differences in ecological drivers and stressors across the plan area, and their effects on overall ecosystem integrity.

This assessment first introduces the 11 major ecosystem types that will be discussed. It then presents the major ecosystem drivers and stressors across the Tongass National Forest. Finally, it describes each ecosystem type, its status and trends, and impact of the drivers and stressors to that specific ecosystem.

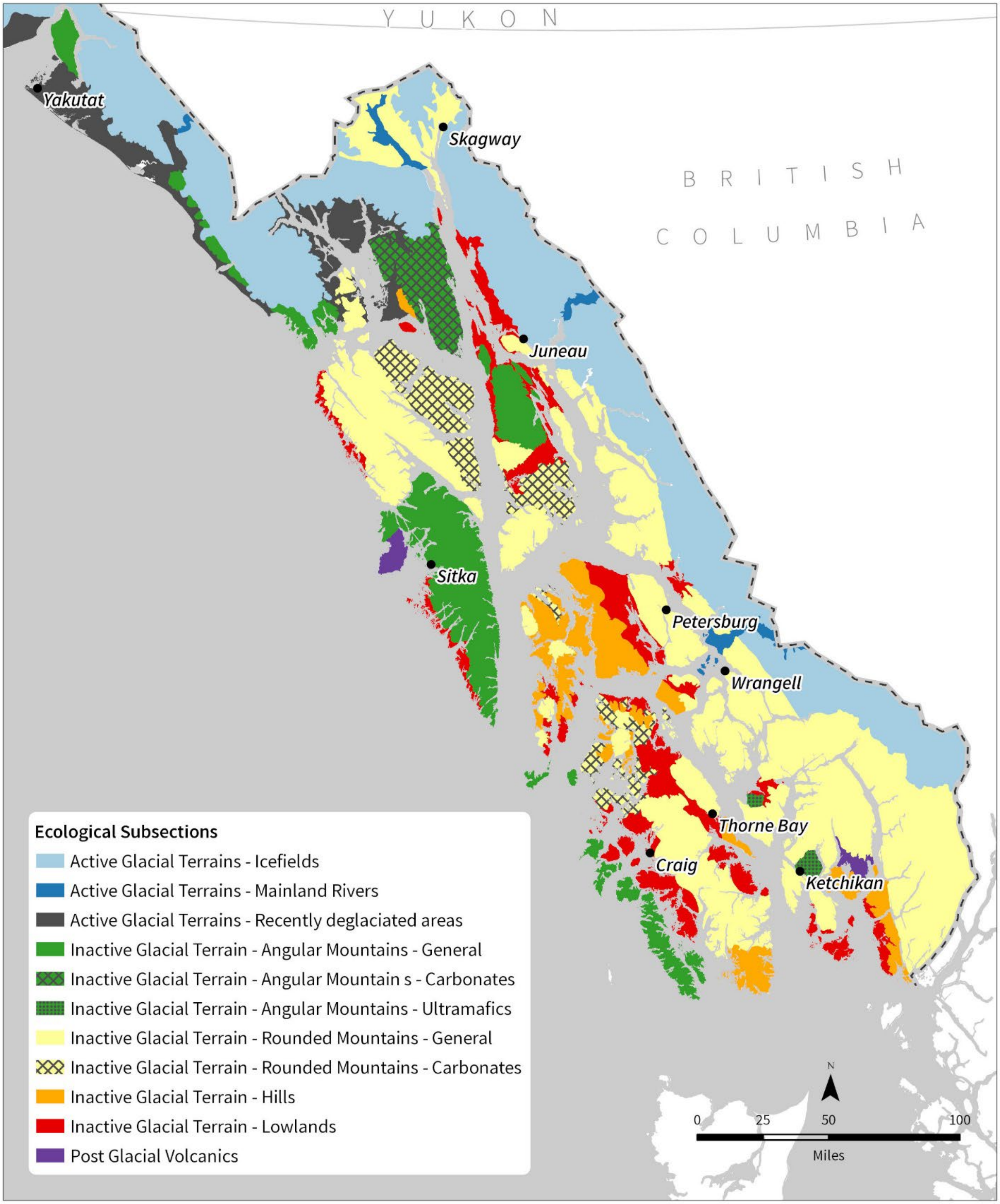

Figure 1. Map of ecological subsection groups in Southeast Alaska.

Terrestrial Ecosystem Classifications and Assessment Criteria

According to the 2012 Planning Rule, an ecosystem is a spatially explicit, relatively homogeneous unit of the Earth that includes all interacting organisms and elements of the abiotic environment within its boundaries (36 CFR 219.19). For this assessment, terrestrial ecosystems are organized into four major groups based on broad similarity of physical site conditions and vegetation (Table 1). These major groups are divided further into discreet ecosystems based on their species composition, structure, function, and connectivity. These ecosystems were assessed for current status and future trends in ecological integrity. Ecological integrity is the quality or condition of an ecosystem when its dominant ecological characteristics (for example, composition, structure, function, connectivity, and species composition and diversity) occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence (36 CFR 219.19).

Estimates of ecosystem acreage in the plan area were derived from multiple existing GIS data sets, including the Tongass Size-Density model and Riparian Management Areas (Forest), National Wetlands Inventory (Wetlands), and Cover Type (Alpine and Subalpine, Well Drained Non-Forest). Because of differences in mapping criteria among the various data sets used, acreages are approximations to the nearest 1,000 acres, and their sum does not equal the total land area of the Tongass National Forest. Areas that are currently mapped as barren land cover such as unvegetated rock, glaciers, permanent snowfields, and open freshwater, are not included in the terrestrial ecosystem acreage estimates. The Tongass National Forest is currently in the process of completing a new forest-wide existing vegetation map that will be used in subsequent phases of forest plan development.

Table 1. Terrestrial Ecosystems of the Tongass National Forest.

Ecosystem Group	Ecosystem	Approximate acres
Alpine and Subalpine	Alpine Vegetation	514,000
	Subalpine Forest	875,000
Forest	Well Drained Forest	3,477,000[1]
	Poorly Drained Forest	1,129,000[1]
	Riparian Forest	396,000[1]
Wetlands	Forested Wetlands	1,927,000
	Tidal Wetlands	63,000
	Non-Forested Wetlands	1,265,000
Mesic Non-Forest	Shrublands	1,638,000
	Meadows	16,000
Other Land Cover[2]		4,887,000

[1] Young growth forest stands (approximately 558,000 acres of both natural and harvest origin), while discussed in later sections of this assessment, are not included in the forest ecosystem acreages because of lack of available information on stand conditions prior to harvest or natural disturbance.
2 Includes rock, ice/snowfield, open freshwater, urban/agricultural, and other barren, non-terrestrial, or modified land cover types.

Ecosystem Integrity Assessment Criteria

For each ecosystem, key characteristics, drivers, and stressors were determined, and other relevant information was compiled to qualitatively assess the status and projected trends in ecosystem integrity (Table 2). The following criteria were developed to facilitate ecosystem integrity assessments (Greg Hayward pers. comm.) and were used to assign integrity levels to each ecosystem:

- **High Ecological Integrity**: If the ecosystem remains on current trajectory it is expected to continue delivering major functions and services including supporting biodiversity and productivity expected for this ecosystem without human interference. Drivers, stressors, and key ecosystem characteristics exhibit the range of variation that was common in the past.
- **Moderate Ecological Integrity:** If the ecosystem remains on current trajectory it is expected to deliver major functions and services including supporting biodiversity and productivity at a reduced level relative to expectations for this ecosystem. One or more drivers, stressors, and key ecosystem characteristics are compromised in a way that disrupts disturbance regimes or characteristics of the system. However, compromised features are not those that determine the identity of this system or significant characteristics are only modestly compromised. Drivers, stressors, and key ecosystem characteristics exhibit a range of variation that was not common in the past but well within the range that results in resilience.
- **Low Ecological Integrity**: If the ecosystem remains on current trajectory it is expected to deliver some major functions and services including supporting a portion of the biodiversity and productivity at a reduced level relative to expectations for this ecosystem, if no restorative intervention is implemented. One or more drivers, stressors, and key ecosystem characteristics are significantly compromised. However, compromised features are not those that determine the identity of this system. Drivers, stressors, and key ecosystem characteristics exhibit a range of variation that was not common in the past but within the range and resilience is possible.
- **Poor Ecological Integrity**: The ecosystem currently is (or is trending toward) experiencing a type-change or is incapable of delivering major functions and services including supporting biodiversity and productivity expected for this ecosystem type without herculean human intervention and maintenance. Drivers, stressors, and key ecosystem characteristics exhibit a range of variation rarely or never exhibited in the past.

As seen below and described in further sections of this document, several ecosystems are assessed as supporting high ecological integrity. The rationale for this includes a lack of evidence that natural disturbances such as wind events, fire, insects, and disease occur at operationally significant higher or lower rates or severities than what occurred historically. These historically significant disturbances help ensure that the ecosystem composition, structure, function, and connectivity are operating normally (similar to long-term patterns) over multiple spatial and temporal scales, leading to high ecological integrity. While on some national forests in the US, ecosystem structure and composition has departed from historical conditions and ecological integrity is compromised due to factors such as fire suppression and changes in the fire regime, this generally isn't the case on the Tongass National Forest. One exception is yellow-cedar decline given yellow-cedar is typically a long-lived species and increased mortality of yellow-cedar in Alaska began in the late 1880s.

Table 2 . Ecological Integrity of ecosystem groups on Tongass National Forest.

Ecosystem Group	Ecosystem	Ecological Integrity (Current Status)
Alpine and Subalpine	Alpine Vegetation	Moderate
	Subalpine Forest	High
Forest	Well Drained Forest	Low to High[1]
	Poorly Drained Forest	Moderate to High
	Riparian Forest	Low to High
Wetland	Forested Wetland	High
	Non-Forested Wetland	High
	Tidal Wetland	Moderate
Mesic Non-Forest	Shrublands	High
	Meadows	High

Major Ecosystem Drivers / Stressors and Current Management Direction

This section addresses major ecosystem drivers and stressors that affect many, or most ecosystems across the Tongass National Forest. It also discusses the current management direction related to those drivers and stressors. In the following sections, the specific importance of these drivers and stressors for each ecosystem will be discussed.

Windthrow

Wind is the dominant natural disturbance encountered in Southeast Alaska forests (Harris and Farrar 1974). Wind disturbance events range from small-scale events (gap disturbance) to large-scale events (catastrophic disturbance), with affected areas generally ranging from 1 up to 1,000 acres (Nowacki and Kramer 1998). Small-scale events occur on a frequent basis and generally affect less than 15 percent of the forest stand canopy, with diseased or standing dead snags more likely to be damaged (Nowacki and Kramer 1998, Hennon and McClellan 2003). Large-scale windthrow is generally caused by infrequent major storms and has blown down entire stands in the past, resulting in even-aged structure in the subsequent tree regeneration (Nowacki and Kramer 1998).

Current management direction requires special consideration in the design of harvest units adjacent to LUDs or other areas that limit or prohibit timber harvest activities. Where the chance of windthrow in adjacent stands is increased by timber harvest, measures are taken to contain the windthrow within the LUD where timber harvest is allowed (USDA 2016a). Reasonable Assurance of Windfirmness (RAW) buffers are managed areas designed to contain windthrow within the area where timber harvest is allowed. It is used to protect Riparian Management Areas and adjacent stands (USDA 2016a).

[1] As described in sections below, ecological integrity for well drained, poorly drained, and riparian forest differs based on past management.

Landslides

Landslides dominate soil movement processes on steep forest lands in Southeast Alaska. A forest-wide inventory to identify, delineate, and digitize all landslides was initiated in 2001. The first phase of the landslide inventory to map all landslides in development land use designations and other areas where soil mapping exists was completed in 2012 (USDA 2016a). Details regarding the landslide inventory can be found in the Geology and Geologic Hazards Assessment section.

Landslides can remove vegetation and soil in the head scarp, and can cover vegetation at the toe slope. These disturbances are part of the natural disturbance regime on the Tongass National Forest, and are an important part of creating vegetation and ecosystem heterogeneity. Where roads, timber harvest, or other management activities contribute to landslides, effects may be outside of the natural range of variation.

Current management direction to minimize landslide risk includes preventing activities such as rock quarries and timber harvest on areas of high landslide risk, avoiding timber harvest or other ground-disturbing activities on steep slopes or on certain soil substrates, and conducting slope stability reviews before activities. Alaska Region Best Management Practices (BMPs) also include recommendations regarding slope stability and landslides. Further information on direction regarding landslides can be found in the Tongass Forest Plan Revision Geologic Hazards Assessment section.

Insects and Disease

Common defoliator insects in Southeast Alaska include western blackheaded budworm (*Acleris gloverana*), hemlock sawfly (*Neodiprion tsugae*), and spruce aphid (*Elatobium abietinum*). While extensive outbreaks have occurred, associated widespread tree mortality has not been documented in Southeast Alaska (Holsten et al. 2008, E. Graham, personal communication). Spruce beetle infestations can occur in forests containing Sitka spruce, but widespread tree mortality is not as common as it is in Southcentral Alaska. Notable tree diseases on the Tongass include cedar leaf blight, hemlock dwarf mistletoe, *Dothistroma* needle blight, western gall rust, and spruce needle blights and rusts (Dubois et al. 2022). Insects and disease that affect vegetation are also discussed in the Drivers, Stressors and Climate Change assessment.

Current management direction is to survey and inventory visible outbreaks annually and to implement insect and disease management measures to protect the watershed and adjacent resources consistent with Land Use Designation objectives (USDA 2016a).

Timber Harvest

The Tongass contains vast acreages of large, old growth forest that is valued for its timber resource. Timber harvest has been a primary human disturbance on the forest, with industrial scale timber harvest occurring from the 1950s through the 1990s, and lower levels before and after those time periods. Past timber harvest occurred on about 4% of the forested area (productive and unproductive) and 8% of the productive old-growth forest[2] on the Tongass

[2] Productive old growth (POG) is defined in the 2016 Tongass Forest Plan as old-growth forest capable of producing at least 20 cubic feet of wood fiber per acre per year or having greater than 8,000 board feet per acre.

(USDA Forest Service 2016b). The earliest harvests occurred in highly productive forests on moderate slopes near waterways, since those areas had easier access by loggers and their equipment. Harvested logs were often rafted up for water transport to sawmills. In many areas, trees were harvested along stream reaches containing anadromous species such as salmon, with impacts that are still evident today. These impacts include channel widening, undercut bank density, large instream wood density, and pool size (Moore et al. 2024).

Since the completion of the 1997 Forest Plan, timber harvest on the Tongass has steadily decreased (USDA Forest Service 2024b). This has been due to a downturn in the timber industry as well as an emphasis by the USDA on reducing harvest in old-growth forest and transitioning to harvesting primarily in young-growth forest.

Young Growth Management

The 2016 Tongass Forest Plan Amendment provides guidance for transitioning from timber harvest primarily in productive old growth forests to a more economically, socially, and ecologically sustainable timber program by accelerating the transition from old growth to young growth forest management (from 32 years under the 2008 Forest Plan to 16 years) while maintaining a viable local timber industry. More details on current timber management direction can be found in the Timber Assessment section.

The Southeast Alaska Sustainability Strategy (SASS) sought to further accelerate the transition to primarily young-growth timber management. It called for an immediate end to large scale old-growth timber harvest and focus of resources toward restoration, recreation, climate resiliency, and young-growth transition.

Old-Growth Forest Management

In Southeast Alaska, old growth forests are generally considered to be greater than 150 years old and characterized by: multiple canopy layers; an interspersion of trees of multiple age classes; the presence of snags, decadent trees, and fallen trees; presence of forbs; and variation in the amounts and distribution of live trees (Capp et al. 1992). Approximately 5,000,000 acres of the Tongass is classified as productive old growth forest (USDA 2016b). Old growth forests have been the focus of past timber harvest in the region (USDA 2016b).

The Tongass Old Growth Conservation Strategy was developed to maintain the integrity of the old growth forest ecosystem, and thereby conserve biodiversity across the Forest, by retaining intact, largely undisturbed forested habitat. This strategy, initially included in the 1997 Forest Plan, was reviewed and amended for incorporation into the 2008 and 2016 forest plan amendments. The Strategy includes a system of large, medium, and small old-growth reserves, a network of old-growth corridors connecting the medium and large reserves, and a series of standards and guidelines that provide additional protection for species and species groups with conservation needs not fully addressed by the reserve system alone (Berkley et al. 2024).

Climate Change

Climate change is currently influencing and is likely to continue affecting the integrity of terrestrial ecosystems on the Tongass in future decades. Although predicting the scope and scale of future impacts is challenging, climate change may eventually compromise the ability of some of these ecosystems to provide important ecological services (Halofsky et al. DRAFT). The assessments of terrestrial ecosystems in this report summarize the ecological services that are provided by each ecosystem on the Tongass.

Further information on climate change and trends in carbon stocks on the Tongass can be found in the Drivers, Stressors, and Climate Change Assessment and Carbon Stocks Assessment sections.

Other than coordinating with other Forest Service units and the National Park Service in air climate change inventory, monitoring, and modeling efforts, no management standards or guidelines specific to addressing or mitigating the effects of climate change are included in the current Forest Plan.

Yellow-Cedar Decline

Extensive, long-term mortality of yellow-cedar within its natural range, known as yellow-cedar decline, is has been documented in Southeast Alaska for at least 100 years, as climate has warmed since the end of the Little Ice Age. These areas of widespread mortality have cumulatively affected over 500,000 acres of forest in Southeast Alaska. Research suggests that climate change plays a key role in the increased rate of mortality, specifically frost damage to the species' shallow roots on moist sites due to low winter temperatures combined with a reduced protective snowpack (Hennon et al. 2016, Halofsky et al. DRAFT).

Current management direction for silvicultural examinations and prescriptions is to consider regenerating and maintaining a mix of dominant overstory tree species, including yellow-cedar where appropriate for the site, to provide for the diversity of future stands and to augment the future availability of forested habitats used by other wildlife and plant species (USDA 2016a).

Major Ecosystem Drivers / Stressors and Current Management Direction

Alpine Vegetation

Key Takeaways

- Ecological integrity is currently moderate due to observed impacts from climate change and is trending toward lower ecological integrity.
- The key driver influencing the alpine ecosystem is persistent snowpack.
- The main stressor is climate change, with warming temperatures predicted as well as shifts in winter precipitation from snow to rain resulting in decreased snow accumulation.

Ecosystem Description

The alpine zone on the Tongass National Forest usually lies above 2,500 to 3,000 feet, though this is variable across the Forest and may be as low as 2,000 feet. It occupies the highest elevations, above tree line. Alpine areas occur in active glacier terrain icefields, angular mountain, and rounded mountain ecological subsection groups. Alpine areas are an important source of meltwater and sediments to lower elevation ecosystems. They are also botanically significant; for example, carbonate geology in alpine areas is associated with well developed karst which is habitat for some rare plant species on the Tongass National Forest. There is variation across the ecological subsections, with alpine areas on sedimentary and carbonate geologic formations often having significant amounts of bare rock, where soils are too thin to support vegetation. On mafic and ultramafic geology (rocks with high iron and magnesium content with low nutrient levels), the forest-alpine transition zone occurs at lower elevations compared to other bedrock.

Alpine vegetation or tundra occurs above the tree line and consists mainly of herbaceous and dwarf shrub species. While tall-statured shrubs such as Sitka alder (*Alnus viridis* ssp. *Sinuate)* and salmonberry (*Rubus spectabilis*) occasionally occur in alpine sites, they are generally confined to lower-elevation subalpine sites (Boggs et al. 2010). Plant community composition can vary by elevation, soil type, drainage, and exposure. In Southeast Alaska, heavy winter snowpack generally protects vegetation from the freeze-thaw cycles. Cold winter temperatures, wind scour, and desiccation can limit plant growth and survival in alpine environments (Halofsky et al. DRAFT). In summer, cool, rainy conditions also contrast with the often harsh, dry growing season conditions common in other alpine zones, so many species found at mid-elevation sites and even at sea level may occur in the alpine as shorter statured individuals (Jaques 1973).

Alpine areas occur across the entire Tongass National Forest, though they may be more common in the northern portion of the Forest. Estimating the acreage of the alpine ecosystem on the Tongass is not straightforward given how the lower elevation limit for this ecosystem varies by latitude, with elevation decreasing from south to north. Also adding to the complexity is that vegetated areas are often intermixed with barren rock, snow, and ice. High elevation areas with alpine vegetation cover approximately 514,000 acres, while barren areas of rock, and permanent ice and snow are approximately 4 million acres in extent (USDA 2008). More than 90 percent of high elevation land on the Tongass National Forest is currently in Wilderness and Natural Setting LUD groups and have little disturbance from management or other human activities.

Figure 2. Photo of alpine vegetation. Photo taken by Rick Turner, U.S. Forest Service.

Ecosystem Drivers and Stressors

Snowpack

The most important driver in this ecosystem is persistent snowpack. Slow-melting snowpack, along with rain, provides continuous moisture throughout the growing season. Persistent snowpack also protects low-stature alpine vegetation from severe winter temperatures and wind, which prevents trees and tall shrubs from establishing and thus maintains the extent of alpine plant communities.

Wind

Wind exposure is among the strongest determinants of species composition in the alpine zone. Low-stature, wind-tolerant species such as cushion and mat-forming plants tend to occur on exposed sites with less snowpack while dwarf shrubs, forbs, grasses, sedges, and some lichen tundra communities often occur in less exposed areas where a persistent snowpack buffers vegetation from wind and frost damage (Halofsky et al. DRAFT).

Avalanches and Soil Movement

Other drivers in this ecosystem include snow avalanches in steeper areas, soil movement due to freeze/thaw cycles, and soil creep. Soil creep is slow-motion movement of soil downslope under the influence of gravity, also known as mass wasting. In the alpine it is usually caused by alternating freezing, thawing, wetting, and drying of soil material.

Climate Change

The main stressor in this ecosystem is climate change. As described in Halofsky et al. (DRAFT), warming temperatures are predicted as well as increases in precipitation, shifts in winter precipitation from snow to rain, and decreases in snow accumulation. Areas under 1000 m (3280 ft) are expected to have the largest decreases in snow accumulations, and areas above 1500 m (4921 ft) are expected to have smaller decreases in snow-to-rain fraction and remain snow dominated. A greater fraction of precipitation falling as rain instead of snow would result in less water stored in the snowpack, a shorter duration of snow cover, and greater wintertime runoff (Halofsky et al. DRAFT).

Disturbance processes and vegetation community composition are tightly coupled with climate conditions. Projected changes in winter precipitation type and amount will shift soil water recharge to earlier in the season and result in lower soil moisture during a lengthening growing season. Increases in growing season temperature will raise the demand for water by vegetation even as available soil moisture declines. Increases in precipitation will not be able to fully compensate for the shift from snow to rain in winter nor degree of warming that is projected (Halofsky et al. DRAFT).

Models of climate impacts to alpine tundra vegetation in Southeast Alaska are lacking. As described more fully in Halofsky et al. (DRAFT), models for other parts of Alaska and adjacent Canadian provinces generally project losses of arctic tundra due to the advancement of large-stature woody plants and associated communities into tundra systems dominated by low-stature plants. They also show predictions for global shrub line and tree line advances as a result of decreased snow depth and persistence, lengthening of the growing season, and mismatches in the phenology of plants and their pollinators.

Additionally, glacial recession and the melting of high-elevation snowfields lead to the emergence of additional land area that may eventually be capable of supporting vegetation. However, many alpine areas in the Tongass NF do not have glaciers, and some are relatively isolated from other alpine vegetation. As trees and tall shrubs continue to advance in elevation, herb and dwarf shrub-dominated alpine communities may reduce in area due to slower migration to higher elevations. The rate of loss of alpine habitat is likely to increase in the coming decades and affect alpine-dependent wildlife by decreasing the area of vegetated habitat available to them and by increasing the difficulty of movement between smaller and more isolated alpine areas. The loss of permanent ice and snow is quite evident in Southeast Alaska, as well is changes in vegetative cover in the alpine zone. For example, using the Landscape Change Monitoring System (LCMS) to examine changes over a 30-year period, glacier retreat was observed for several glaciers including Leconte, Dawes, South Sawyer, and North Sawyer, as well as an increase in vegetated habitat in those areas (Gregg Dunn pers. comm.).

In summary, expected changes in the alpine ecosystem given future climate change include some increases in vegetated areas in the alpine due to deglaciation and loss of snow and ice, and some decreases in extent due to encroachment of tall shrubs and trees. Rates of colonization of new areas may not occur at the same rate as loss of current habitat. Some species that rely on persistent snowpack and consistent moisture may be negatively affected; however, other species may benefit from a longer growing season. Given how persistent snowpack and snowmelt in the alpine ecosystem supports the flow of lower-elevation streams and their essential ecological processes and elements, associated hydrological changes are expected in lower-elevation ecosystems.

Other Stressors

Other stressors are minor, localized, and of short duration in comparison to the effects of climate change and include communication sites, mining, and recreational use. Communication sites and radio repeaters are often found on high-elevation mountain tops. The 2016 Forest Plan (Appendix E, Table E-1) lists approved communications sites on the Tongass National Forest. Of the 76 communication sites, more than half (48) are located at 2000 ft elevation or higher. While some sites are being converted to solar power, many sites have large quantities of fuel stored on site that serve a heating, ventilation, or electrical system.

Current mining sites include Greens Creek on Admiralty Island, Kensington Gold Mine north of Juneau, as well as other existing locations. Greens Creek and Kensington are subsurface mines, but exploratory drilling occurs on the surface and often within the alpine ecosystem. Potential future mining sites include the Bokan Mountain and Niblack sites on the southern end of Prince of Wales Island. At Bokan, a potential rare earth mine, there is active exploration but no mining plan of operations. Mining-related impacts include the development of roads, water use, and potential discharge of sediment and hazardous substances such as heavy metals to streams.

Recreational use in the alpine zone includes activities such as hunting, helicopter tours to the Juneau icefield or other glaciers, heli-skiing near Cordova and Yakutat, icefield sled dog camps, and travel via high elevation roads and trails, such as Dude Mountain and Harbor Mountain near Ketchikan and Sitka. This recreational use generally has low or no direct impact on alpine vegetation, but can affect wildlife.

Ecosystem Services

A variety of ecosystem services are tied to the alpine ecosystem.

- Persistent snowpack in the alpine ecosystem provides important source water for lower elevation streams and helps sustain essential ecological processes and elements, including healthy salmon populations.
- Wildlife common to these environments include ptarmigan, raptors, passerine birds, hoary marmots, small mammals, black and brown bears, deer, mountain goats, wolverine, and insects and other invertebrates. As stated in Halofsky et al. (DRAFT), while some wildlife species use

rocky areas and more sparse vegetation created by glacial retreat and recession, vegetated alpine supports more alpine-dependent wildlife species.

- Supports subsistence through foraging for berries and deer hunting.
- Provides high scenic value and support associated tourism.
- Provides habitat for rare plants, including Eschscholtz's little nightmare (*Aphragmus eschscholtzianus*), Spatulate moonwort (*Botrychium spathulatum*), Macoun's thistle (*Cirsium edule* var. *macounii*), and Calder's lovage (*Ligusticum calderi)* (USDA 2016b, Table 3.7-1).

Status and Trends

The ecological integrity of the alpine ecosystem is rated as moderate, given observed impacts from climate change, in particular the observed increase in average air temperature and decrease in permanent snow and ice (Table 3). Future trends are expected to include increased temperatures, reductions in snow and ice will eventually lead to a shift in hydrologic flow and increased stream temperatures in alpine-sourced watersheds (Halofsky et al. DRAFT).

Table 3. **Alpine Vegetation ecosystem ecological integrity levels.**

Terrestrial Ecosystem	Ecological Integrity	Vulnerability to Stressors
Alpine Vegetation	Moderate	High

Lower elevations may be affected by compromises in ecological integrity in the alpine zone. The restoration potential of alpine vegetation is low, because there are likely few options for reversing this current trend or increasing the resilience of existing habitats. Retreat of glaciers and snowfields may provide additional areas for alpine vegetation to grow, but this would be highly dependent on local site conditions and may not keep pace with the rate of loss of habitat at the current lower elevation limit of this ecosystem.

The current Tongass monitoring plan does not include monitoring changes in the condition or extent of alpine areas. General trends in associated ecosystem services, such as berry production and rare plant habitat, are generally unknown. Given the potential for rapid changes due to climate change, monitoring of alpine areas should be considered as an addition to the revised plan, including but not limited to, continued monitoring of alpine habitat and glacier retreat. Additional monitoring could help inform future management decisions in these areas.

Subalpine Forest

Key Takeaways

- The ecological integrity of the subalpine forest is currently high, but climate change will likely have some impact on the integrity of this ecosystem.
- In response to warmer temperatures and less precipitation falling as snow, elevational and latitudinal distribution of mountain hemlock is expected to shift upward and northward,

respectively, although there may be a substantial lag time in species response to climatic changes. Future rates of contraction and expansion of mountain hemlock-dominated stands are uncertain.

- The loss of mountain hemlock in lower-elevation subalpine sites and the potential expansion of western hemlock and Sitka spruce into these areas is likely to be determined by both climate trends and local site conditions, including soil properties.

Figure 3. Photo of subalpine forest. Photo taken by Rick Turner, U.S. Forest Service.

Ecosystem Description

Subalpine forests occupy the area between the low- to mid-elevation forests and the non-forested alpine areas found at the highest elevations of Southeast Alaska (Halofsky et al. DRAFT). It generally ranges from 1,500 ft to 3,000 ft in elevation (DeMeo et al. 1992). Subalpine forests are found in ecological subsections consisting mainly of angular mountains and rounded mountains. They are not found on lowlands and only infrequently on hills (Nowacki et al. 2001).

The location of the subalpine climatic zone depends strongly upon latitude and topography; it tends to occur at lower elevations in more northern portions of Southeast Alaska, on more north-facing slopes, and in the interior portion of islands in the region (Martin et al. 1995; DeMeo et al. 1992). The subalpine zone has both later snowmelt and shorter growing seasons than lower elevations due to colder average temperatures. Subalpine forests tend to have both lower canopy cover and productivity than lower-elevation forests.

Subalpine forests in Southeast Alaska are usually dominated by mountain hemlock, although Sitka spruce can range from co-occurring to codominant in some stands, particularly those with history of soil disturbance (Martin et al. 1995; DeMeo et al. 1992; Boggs et al. 2010). Western hemlock or yellow-cedar may also co-occur with mountain hemlock in stands at the lower-elevation edge of the subalpine band, and subalpine fir may be present at some locations (mostly on the mainland) in the southern portion of Southeast Alaska. Shrub- and herb-dominated vegetation often intergrade with subalpine forest, with these mosaics of vegetation types becoming more common near the upper elevational limit of the subalpine zone, near the tree line.

Ecosystem Drivers and Stressors

Wind

Wind is a strong determinant of species composition in the subalpine ecosystem. Wind exposure and associated snow depth/persistence are among the strongest determinants of species composition in subalpine communities (Halofsky et al. DRAFT). Dwarf tree growth forms such as krummholz as well as lower-stature, species such as cushion and mat-forming plants tend to occur on exposed sites with less persistent snow accumulation.

Snowpack

Snowpack, along with rain, provides consistently moist soil that is necessary for growth of subalpine vegetation. Effects of persistent snowpack in subalpine forest are similar to those in the alpine zone: cold temperatures result in later snow melt and reduced growing season; snowpack insulates tree roots and understory plants from winter sub-freezing temperatures, and it helps protect trees from storm wind damage.

Landslides and Avalanches

Landslides, avalanches, and other soil movement are common, with some stands becoming mosaics of raised areas and depressions. On landslide scarps, poor soil development and continued instability can yield soils with reduced available nutrients to support tree growth (DeMeo et al. 1992).

Climate Change

The main stressor in this ecosystem is climate change. As described in Halofsky et al. (DRAFT), warming temperatures are predicted as well as increases in precipitation, shifts in winter precipitation from snow to rain, and decreases in snow accumulation.

Halofsky et al. (DRAFT) state that climatically suitable habitat for mountain hemlock is projected to decline across temperate rainforests of the Pacific Northwest, and that in Southeast Alaska the elevational distribution and potentially the prevalence of mountain hemlock climate is anticipated to be substantially altered. There is potential for low-elevation dieback of subalpine vegetation including mountain hemlock, but this may be compensated for by expansion of subalpine forests into higher-elevation sites historically occupied by alpine tundra communities.

Studies examining the potential effects of climate change on mountain hemlock growth have not found certain predictions. The loss of mountain hemlock in lower-elevation subalpine sites and the potential expansion of western hemlock and Sitka spruce into these areas is likely to be jointly determined by both climate and local conditions including soil properties.

Communication Sites

While not as prevalent as they are in the alpine areas, some communication sites are located at subalpine elevations. The Tongass Forest Plan (USDA 2016b, Appendix E, Table E-1), lists approved communications sites on the Tongass National Forest and only 22 percent (17 of the 76 communication sites) are found at elevations less than 1500 ft. The footprint of these sites is relatively small. While these sites are being shifted to solar power, many of them have large quantities of fuel stored on site for powering the electrical, heating, and ventilation systems.

Timber harvest

Timber harvest is not a major stressor in this type. Subalpine areas have not been targeted for timber harvest because they are generally less productive and have a lower wood volume per acre than lower-elevation forests, and they are also more difficult to access with harvesting equipment.

Ecosystem Services

- Subalpine forests are heavily used by wildlife species, including mountain goat and Sitka deer forage habitat in the summer and fall, and denning areas for brown bears in the winter (DeMeo et al. 1992).
- The subalpine zone is the upper limit for many wildlife species such as marten and endemic small mammals that are common in lower elevation forested areas, and it is the lower elevational limit for alpine-associated species such as ptarmigan and marmot.
- Subalpine forests provide habitat for rare plants, including Eschscholtz's little nightmare (*Aphragmus eschscholtzianus*) and Calder's lovage (*Ligusticum calderi*) (USDA Forest Service 2016b).
- Yellow-cedar is often found at the lower elevational limit of this ecosystem (1,500 – 2,000 feet) (DeMeo et al. 1992). As discussed in Halofsky et al. (DRAFT) and other assessment sections, yellow-cedar is a particularly important tree species in Southeast Alaska from cultural and commercial standpoints.
- Subalpine fir (*Abies lasiocarpa*) is present in some locations in this ecosystem in the southern portion of the Tongass, which is the northern edge of its range in Alaska.

Status and Trends

The ecological integrity of subalpine forests is currently high, but climate change will likely have some impact on this ecosystem in the future (Table 4). There is currently uncertainty whether that impact will be positive or negative. In response to warmer temperatures and less precipitation falling as snow, elevational and latitudinal distribution of mountain hemlock is expected to shift upward and northward, respectively, although there may be a substantial lag time in species response to climatic changes (Halofsky et al. DRAFT).

Table 4. **Subalpine forest ecosystem ecological integrity levels.**

Terrestrial Ecosystem	Ecological Integrity	Vulnerability to Stressors
Subalpine Forest	High	Low – changes could be positive and negative

Well Drained Forest

Key Takeaways

- Well drained forests exhibit overall high ecological integrity because it is generally unaffected by frequent large-scale or catastrophic natural disturbances, and human disturbances such as timber harvest have occurred on a relatively small portion of this ecosystems, with a current trend toward less harvest, particularly in old-growth stands.
- Young-growth stands resulting from timber harvest and that have been pre-commercially thinned have moderate integrity with the level of integrity increasing with time post-thinning. Unthinned, young-growth stands may have low to moderate integrity but are expected to trend towards high integrity with little management intervention needed.
- The key ecosystem drivers are frequent small-scale disturbances from windthrow, landslides, and insect and disease infestation that create small openings in the forest canopy (gap-phase dynamics).
- The main stressors are warming temperatures, and shifts in the amount and type of winter precipitation (from snow to rain) and decreases in snow accumulation due to climate change.

Ecosystem Description

Approximately 60 percent (about 10 million acres) of the Tongass National Forest consists of forest land (including harvested acres). Of this, approximately 5.5 million acres are considered productive forest land, with ‘productive’ defined as land having greater than 8,000 board feet per acre of standing volume. The remaining forest area (about 4.4 million acres) is considered unproductive because it does not meet these criteria (USDA 2016b).

Well drained forests are productive and do not contain hydric soils. They primarily occupy the hillslopes between the riparian valley bottoms and the subalpine forests. There are approximately 3.5 million acres of unharvested, well drained forest on the Tongass. The dominant tree species is western hemlock, with Sitka spruce much less abundant but which can be the dominant in some areas. Both western redcedar and yellow-cedar are components of the well-drained forest. Western redcedar is generally found in the lower elevations, with its northern range limit in the central Tongass National Forest near Petersburg. Yellow-cedar is found in the higher elevations in the southern half of the forest and at lower elevations in the northern half (Halofsky et al. DRAFT).

Figure 4. Photo of well drained forest. Photo taken by Tongass Ecology Staff, U.S. Forest Service.

Ecosystem Drivers and Stressors

Disturbances

Frequent fine-scale, low-intensity disturbances, generally caused by wind but also by landslides and localized insect and disease infestations, are the most common natural disturbance type across the coastal regions of Southeast Alaska (Alaback 1984) and typically results in the formation of small canopy gaps from tree fall. Gap creation and subsequent regeneration provides continual forest canopy regeneration in this ecosystem (Nowaki and Kramer 1998).

Wildfire is uncommon in forests of Southeast Alaska. Fire history studies in coastal British Columbia, Canada, found that fire intervals exceed 1,000 years in maritime forests at similar latitudes. Cultural burning has occurred for millennia, at local scales, to clear vegetation around villages and transportation corridors, and improve production of important plant species such edible and medicinal plants and cedar (Halofsky et al. DRAFT).

Past Timber harvest

Past timber harvest targeted highly productive forest stands, leading to a disproportionate loss of the old-growth stands of well drained forest (USDA 2016a). Young growth stands, after harvest, exhibit less complexity in stand structure, understory plant diversity, and presence of snags and down woody debris.

Intermediate treatments (precommercial thinning) can interrupt or accelerate stand succession of structural stages. Harvested well-drained forests that are precommercially thinned exhibit higher integrity sooner than unthinned stands, tending to reach late successional structure more quickly as precommercial thinning substantially increases residual tree growth (Newton and Cole 2012) Currently there are approximately 180,000 acres of unthinned young growth. Photos below show unthinned forest and thinned forest at two sites at the northern end (Figure 5, Figure 6) and southern end (Figure 7, Figure 8) of the Tongass.

Figure 5. Photo of unthinned forest at Lemon Creek near Juneau. Forest is approximately 55 years old. Photo taken by Kellen Nelson, U.S. Forest Service.

Figure 6. Photo of thinned forest at Lemon Creek near Juneau. Forest is approximately 55 years old. Thinning and pruning occurred 30 years ago at age 25. Photo taken by Kellen Nelson, U.S. Forest Service.

Figure 7. Photo of unthinned forest at Staney Creek on Prince of Wales Island. Forest is 40-50 years old. Photo taken by Kellen Nelson, U.S. Forest Service.

Figure 8. Photo of thinned forest at Staney Creek on Prince of Wales Island. Forest is 40-50 years old. Thinning occurred 15 years earlier, at age 25-35 years. Photo taken by Kellen Nelson, U.S. Forest Service.

Climate Change

Climate change is becoming a key stressor in this ecosystem. Historically, natural disturbance has been frequent, widespread, but mostly of low intensity. Warmer and drier conditions at lower elevations and latitudes may lead to changes in environmental factors that help regulate seed germination, establishment, and tree recruitment (Halofsky et al. DRAFT). It may lead to a higher level of stress on mature trees, increasing their vulnerability to insect and disease outbreaks (Halofsky et al. DRAFT). At the higher elevations and latitudes, growth rates may be increased, and some species may expand vegetation cover and species range (Halofsky et al. DRAFT).

Warmer winters and drier summers could lead to insect outbreaks that may be more robust and longer lasting, possibly leading to widespread mortality. Shifts in climatic envelopes may also cause a corresponding shift in the geographic range of outbreaks. Globally, forest dynamics are changing because of climate change-driven exacerbation of chronic stressors such as rising temperature and increasing transient disturbances, including wildfire, drought, windthrow, biotic attack, and land-use change. (McDowell, N., et al. 2020). Although the fire regime is not expected to shift substantially from its current low frequency and intensity, an increase in drought conditions during the growing season could lead to increased fuel flammability under extreme conditions (Halofsky et al. DRAFT). A decrease in snowpack persistence has been noted as the probable cause of yellow-cedar decline, a climatic phenomenon that has led to extensive mortality in yellow-cedar. It is predicted that western hemlock may expand into the sites once occupied by yellow-cedar (Hennon et al. 2016). An increase in soil saturation during intense rain events will likely lead to associated increases in landslides throughout the region. Landslides can facilitate the establishment of invasive species that prefer disturbed sites. Landslides can also affect a change in species composition and succession with the establishment of alder immediately following a landslide (Halofsky et al. DRAFT).

Ecosystem Services

- Downed wood and snags within well-drained forests are important as favorable habitat for snag-dependent wildlife species such as marten and woodpeckers. Even-aged timber management has decreased the amount of downed wood and snags present in harvested stands.
- Understory vegetation within well-drained forests is used by deer as a food source. The amount of understory vegetation in even-aged young-growth stands is reduced temporarily as the stand moves through the stem exclusion successional stage.
- Western redcedar and Sitka spruce are important tree species in Southeast Alaska from economic standpoints. Old growth timber is highly prized, economically valuable, and is used to produce a variety of specialty products, such as piano wood and guitar tops, that can be shipped worldwide. Dimensional lumber is also created from tight-grained and/or decay resistant trees. Young growth forests will become increasingly important for forest products such as dimensional lumber and log cabin kits.
- In both actively managed and undisturbed areas, well-drained forests are important to residents of the region for access to free use trees, firewood, fishing and hunting related activities, and for non-timber forest products such as berries and mushrooms. Free-use sawtimber and firewood opportunities provided by 36 CFR 223.10 that allows bona fide settlers, miners, residents, and prospectors for materials in Alaska to take green or dead timber from the National Forests in Alaska for personal use, but not for sale, free of charge.
- Western redcedar and yellow-cedar are particularly important tree species in Southeast Alaska for cultural uses. Cedars are less abundant in this ecosystem than in the less productive poorly drained forest ecosystem, but grow in a more desirable form for large cultural items, such as dugout canoes and totem poles.
- Provides habitat for deer and other forest-dependent wildlife, including wolves and other furbearing mammals.
- Many forest-dependent plant and fungi species are important subsistence foods and sources for traditional medicine. It also provides habitat for rare plants such as Alaska rein orchid (Piperia unalascensis).
- Old growth, coastal rain forest connects with the aesthetic and spiritual values of many people. The Tongass is highly valued from this perspective as the most intact rainforest in the world (Cutler and Johnson 2019). Because this ecosystem generally contains the largest trees, this is where much past timber harvest occurred and therefore where many roads were originally constructed for timber harvest. These roads are now used to access recreation, food harvest, and

other uses. Therefore, areas with previous timber harvest are some of the more accessible areas of the Tongass.

- Many Southeast Alaska communities are turning to tourism for economic opportunities. Tourists often visit the Tongass to enjoy the scenery, particularly from waterways used by cruise ships and other boats. These productive forests with large trees are considered highly scenic by many.

Status and Trends

Unharvested well drained forests (approximately 3,477,000 acres) currently exhibit high ecological integrity. In some areas however, past timber harvest has resulted in some reduction of heterogeneity in structure, tree ages, understory plants and presence of snags and/or decaying wood. Young-growth stands that have been pre-commercially thinned have moderate integrity with the level of integrity increasing from time post thinning. Unthinned young growth stands may have low to moderate integrity but are expected to continue to trend towards high integrity with little management intervention needed (Table 5).

Table 5. **Well drained forest ecosystem ecological integrity levels.**

Terrestrial Ecosystem: Well drained Forest	Ecological Integrity	Vulnerability to Stressors
Well drained forest, unharvested	high	moderate
Well drained young growth forest, thinned	moderate	low
Well drained young growth forest, unthinned	low	moderate

Well-drained forests are generally unaffected by large-scale catastrophic disturbances on a frequent basis. Stands that do experience disturbance tend to recover without management intervention and follow predictable successional stages of structural development to reach current forest conditions. Intermediate treatments (precommercial thinning) can interrupt or accelerate stand succession of structural stages. Of the 10 million acres of the forested portion of the Tongass National Forest, around 430,000 acres have ever been harvested (logged). Harvest was intensive from the mid-1950s through the late 1990s. Approximately one half of the harvest has occurred on the southern third of the Tongass, and most of the oldest harvests are located on Prince of Wales Island (USDA 2024b). Very low levels of harvest have occurred from the early 2000s through the present.

In previously harvested areas, stands are occupied by young-growth forest (also called second growth), which are almost entirely even-aged stands. The most common post-harvest treatment is a precommercial thin, generally between the stand ages of 20-30 years after harvest. A precommercial thinning creates larger spaces between healthy trees. Removing the inter-tree competition allows the remaining trees to grow faster, become more windfirm and disease resistant, while also allowing more sunlight to reach the forest floor which increases understory vegetation development. The Tongass did not use precommercial thinning as a silvicultural tool until the late 1970s; before then, the importance of precommercial thinning to meet multiple objectives was not recognized. Therefore, the oldest harvested stands generally have remained un-thinned after the regeneration harvest. Un-thinned stands exhibit less understory and stand structural heterogeneity than unharvested stands but are expected to proceed through structural succession without management assistance. Harvested stands that are pre-commercially thinned exhibit higher structural integrity sooner than unthinned stands and tend to reach later structural stages more quickly because tree growth increases substantially (Newton and Cole 2012).

Forests transition from the mature to old-growth forest as surviving long-lived species come to dominate the stand. Old forest stands are structurally complex and multi-aged with irregularly spaced large trees, snags, and downed wood. These stands exhibit increased structural complexity over those in the mature forest stage. This structural complexity supports a diverse understory of forbs, ferns, and shrubs. Red alder may be present in niche locations with disturbed soils or high light availability. Old forest stands are maintained via continual recruitment through gap-phase mortality and regeneration dynamics.

Poorly Drained Forest

Key Takeaways

- Poorly drained forests exhibit overall high ecological integrity. This ecosystem is considered fairly stable as it is generally unaffected by large-scale catastrophic disturbances on a frequent or regular basis. However, the extent of the ranges of both yellow-cedar and western redcedar may change drastically due to climate change.
- Young growth stands that have been precommercially thinned have moderate integrity with the level of integrity increasing with time post-thinning. Unthinned, young-growth stands may have low to moderate integrity but are expected to continue to trend towards high integrity with little management intervention needed.
- The key ecosystem driver is poor drainage which results in overly saturated soils and low productivity.
- The main stressor is warming temperatures and shifts in winter precipitation from snow to rain and decreases in snow accumulation due to climate change.

Ecosystem Description

The poorly drained forests of the plan area are forests that grow on hydric soils. They are low to moderately productive forests that are associated with wet, poorly and somewhat poorly drained land types. Canopy closure, texture, and structure tends to be variable and patchy (USDA 2016a). These ecosystems are generally located on the edges of muskegs, broken mountain slopes and on plateaus (USDA 2016a). These ecosystems often occur as a transition zone between the very poorly drained wetlands of the lowlands to the well drained forests located on the hills and mountain slopes (Krosse 2024).

The poorly drained forested ecosystem is comprised of mixed conifers consisting of western hemlock, Sitka spruce, shore pine, mountain hemlock, the rare pacific yew, and often with a high component yellow-cedar and/or western red cedar (Krosse 2024). The cedars commonly occur in poorly drained forest because of their greater tolerance to soil saturation (Halofsky et al. DRAFT). Yellow-cedar is more competitive due to the open canopies and higher light availability in poorly drained stands, but they tend to be stunted or shrubby in form (Harris and Farr 1974; Halofsky et al. DRAFT) and are more susceptible to freezing conditions that cause root damage (Hennon et al. 2016). Structurally, the poorly drained forests have multiple canopy layers, with canopy closure ranging from open forest to moderately closed forest, trees can range in size and spacing is variable (Krosse 2024; USDA Forest Service, 2016a).

The understories of stands containing western redcedar and yellow-cedar are often dominated by blueberry (DeMeo et al. 1992; Martin et al. 1995). Skunk cabbage (Lysichiton amercanus), salal (Gaultheria shallon), deer cabbage (Nephrophyllidium crista-galli), and/or copperbush (Elliotia pyroliflora) may also be common depending upon the topographic position, canopy cover, and drainage status of a site.

Figure 9. Photo of poorly drained forest. Photo taken by Tongass Ecology Staff, U.S. Forest Service.

Ecosystem Drivers and Stressors

Soil drainage

The lack of drainage is key driver in this ecosystem. The soils are often overly saturated, and sites are less productive than well drained forests. Soils within this ecosystem are formed from the organic parent material overlaying compact glacial till or bedrock (Krosse 2024). Poorly drained forests are located near the edge of wetlands, but with sufficient drainage to support a forest overstory (Krosse 2024).

Climate change

Growing-season, soil saturation, and light influence the persistence of this ecosystem (Krosse, 2024). Climate change will likely increase moisture deficit during the growing season and lead to warmer winters. Conversely, climate change predictions include an increase in overall precipitation amounts, rain-on-snow events, and the incidence of atmospheric rivers (Halofsky et al. DRAFT).

Warmer winters and drier summers could lead to insect outbreaks that may be more robust and longer lasting, leading to widespread mortality. Globally, forest ecosystem dynamics in general are changing due to increasing transient disturbances, including wildfire, drought, windthrow, biotic attack, and land-use change. (McDowell et al. 2020). A decrease in snowpack persistence has been noted as the probable cause of yellow-cedar decline. It is predicted that western hemlock may expand into the sites once occupied by yellow-cedar (Hennon et al. 2016).

The increase in soil saturation from increased intensity of precipitation events will likely lead to associated increases in landslides throughout the region. Landslides can facilitate the establishment of invasive species that prefer disturbed sites. Landslides can also affect a change in species composition and succession with the establishment of alder immediately following a landslide (Halofsky et al. DRAFT).

While climate change may lead to a potential expansion of latitudinal or elevational distributions of western redcedar and Alaska yellow-cedar, there are also potentially challenges for these species. Perhaps the greatest threat to yellow-cedar resulting from climate change is an expansion in the extent and severity of yellow-cedar decline (Halofsky et al. DRAFT). The Washington State Department of Natural Resources (2022) noted that redcedar is exhibiting dieback that appears to be caused by extreme heat and drought events. Although Southeast Alaska is anticipated to experience greater precipitation with a changing climate, there may be increased water deficits in some portions of the region that may yield drought conditions that could result in similar dieback if these events become sufficiently severe (Halofsky et al. DRAFT).

Ecosystem Services

- Understory plants are important for dietary, cultural, or medicinal values for forest users (Halofsky et al. DRAFT). Berries, including red huckleberries (*Vaccinium parviflorum*), blueberries (*Vaccinium* spp.), and high-bush cranberries (*Viburnum dentatum*) are harvested in poorly drained forest ecosystems.

- The poorly drained forest ecosystem is an area of high terrestrial species diversity, for both plants and animals. Specifically, redcedar stands within this ecosystem provide habitat for lesser round-leaved orchid (*Plantanthera orbiculata),* a rare forest plant (Krosse 2024).

- Both western redcedar and yellow-cedar are particularly important tree species in Southeast Alaska from cultural and commercial standpoints. The bark of both species is harvested for use in weaving baskets, blankets, mats, hats, and clothing, and the roots and branches are also used in basket weaving and cordage production (Turner et al. 2009). Large western redcedar are prized for their characteristics that make them valuable for construction of totem poles and dugout canoes.

- Poorly drained forests retain and slow down high-water flows and provide a source of groundwater during dry periods (DeMeo et al. 1992; Krosse 2024).

- Provides important habitat for wildlife. During the spring and fall, it provides transitional habitat for both Sitka blacktail deer and bear. Subsistence hunters tend to hunt for bear in the spring and Sitka black tail deer in the fall within this ecosystem.

Status and Trends

Poorly drained forests in the plan area (approximately 1,130,000 acres) currently exhibit high ecological integrity. They have experienced timber harvest, but with fewer acres logged than in well drained forests. Past timber harvest has resulted in localized reduction of heterogeneity in structure, tree ages, understory plants and presence of snags and decaying wood, although the stem exclusion stage may not be as pronounced, nor last as long as it does in well drained forests (USDA 2014). Young growth stands resulting from timber harvest that have been precommercially thinned have moderate integrity with the level of integrity increasing from time post-thinning (Table 6). Unthinned young growth also have moderate integrity but are expected to continue to trend towards high integrity with little management intervention needed (Table 3).

Table 6. **Poorly drained forest ecosystem ecological integrity levels.**

Terrestrial Ecosystem: Poorly drained Forest	Ecological Integrity	Vulnerability
Poorly drained forest, unharvested	high	moderate
Poorly drained young growth forest, thinned	moderate	low
Poorly drained young growth forest, unthinned	moderate	low

Overall, poorly drained forests in Southeast Alaska exhibit high ecological integrity. This ecosystem is considered stable and are not prone to large-scale catastrophic disturbances or large-scale wind events due to the position on the landscape. Past disturbances have occurred primarily as a result of road construction (USDA 2016a) and past timber harvest. Stands that do experience disturbance tend to recover without management intervention, and they also tend to have a shorter stem exclusion successional stage, sometimes skipping it altogether (USDA 2014) due to the lower density of trees and higher understory diversity. Intermediate treatments (precommercial thinning) can improve herbaceous plant growth within young growth stands as the density of trees is less and the diversity of the understory is higher (USDA 2014).

Riparian Forest

Key Takeaways

- Riparian forests exhibit high overall ecological integrity. This ecosystem is highly adaptive and resilient to the dynamic nature of the ecosystem.
- Unharvested riparian forested ecosystems have high ecological integrity. Young riparian forests that have been precommercially thinned have moderate integrity with the level of integrity increasing from time post thinning. Unthinned, young riparian forested ecosystems may have low integrity but are expected to continue to trend towards high integrity with little management intervention needed.

- The key ecosystem driver is hydrogeomorphic processes such as floods that move water, sediment, and large woody debris from the uplands of the riparian forest ecosystems through the area into the stream channel.
- The key ecosystem stressor is climate change, including changes in amount of precipitation and temperature.

Ecosystem Description

The U.S. Forest Service defines riparian areas as complex three-dimensional transition zones between terrestrial and aquatic ecosystem (USDA 2016b). The riparian ecosystem experiences constant change with highly variable vegetation communities (Halofsky et al. DRAFT).

Riparian forests and associated vegetation are shaped by stream processes, the productivity of the site, disturbances, microclimates, and landforms (Halofsky et al. DRAFT) and is often associated with stream terraces and alluvial fans (Krosse 2024). Riparian forests are highly sensitive to the hydrologic regime and ecological function of the corresponding aquatic resource (USDA 2016b). The overstory canopy is comprised of large, widely spaced Sitka spruce, western hemlock, red alder, with black cottonwood trees often occurring near the large stream and river systems of the mainland (Halofsky et al. DRAFT; Krosse 2024). The understory consists of a variety of shrubs, seedlings, forbs, ferns, mosses, lichens and liverworts. Riparian forests allow for terrestrial and aquatic species diversity by contributing leaf litter to the forest floor, and in nearby stream systems, snags, and downed large woody debris (Halofsky et al. DRAFT; Krosse 2024). Within the flood plains and alluvial fans associated with riparian forests, downed large wood provides nurse logs for tree seedling establishment, while also retaining sediment and acting as a filter (USDA Forest Service, 2016b). Red alder typically serves as the pioneer species of stand development in the riparian forest ecosystems following disturbance. This species fixes nitrogen, adds organic material to the soil, and allows sufficient light to penetrate through the canopy to allow conifers such as Sitka spruce and western hemlock to germinate and eventually transition the stand to a more diverse mix of conifers and deciduous species (Krosse 2024).

Figure 10. Photo of riparian spruce forest. Photo taken by Tongass Ecology Staff, U.S. Forest Service.

Ecosystem Drivers and Stressors

Stream processes

Various stream processes such as floods move water, sediment, and large woody debris from the uplands of the riparian forest ecosystems through the area into the stream channels and are key processes in this ecosystem (Wilford 2011). Other disturbances such as landslides, that effect vegetative cover and runoff, could have also have a direct impact (Wilford 2011) on these ecosystems. Riparian forest vegetation helps to stabilize slopes, and changes to this vegetation can influence water storage and alter the timing and amount of water reaching streams and the ocean (Halofsky et al. DRAFT).

Timber harvest

Human activities such as timber harvest, road building, and water pollution can have a negative effect on the riparian forest ecosystem integrity (Halofsky et al. DRAFT). Timber harvest in uplands may affect riparian forests through erosion and slumping of hill slopes following harvest, which may lead to alterations in sediment transport upstream of the ecosystem (USDA 2016a).

Climate change

Climate change is a key stressor in this ecosystem. It is expected that with the change from less snow and more rainfall, there will be a shift in vegetative communities in the riparian forest due to reduced soil moisture and lower stream flows (Halofsky et al. DRAFT). Riparian forest vegetation may also become more vulnerable to frost damage with less snow cover. Growing seasons may also be lengthier, allowing for improved growth rates and transpiration of riparian vegetation.

Ecosystem Services

- Riparian forest vegetation reduces soil erosion, maintains stream bank stability, and filter sediment and contaminants from slope runoff and stream flooding (Halofsky et al. DRAFT).
- Provides habitat for both terrestrial and aquatic wildlife. Large woody debris from riparian forests helps improve cover to pool ratio, pool riffles, and other habitat features, and also help to maintain stream bank, channel, and floodplain integrity (USDA 2016b).
- Helps to maintain and restore optimum water temperatures for aquatic species (USDA 2016a).
- Provides opportunities for sport and subsistence fishing and hunting.
- Aesthetic and spiritual values: Old, coastal rain forest connects with spiritual values of many people. The Tongass is highly valued as being the most intact rainforest in the world (Cutler and Johnson 2019).
- Many local communities are turning to tourism for economic opportunities, which often rely on forest system roads originally constructed for timber harvest. Many tourists visit the Forest to enjoy the scenery, particularly from waterways used by cruise ships and other boats. These productive forests with large trees are highly scenic.
- Carbon sequestration: Riparian forest ecosystems often are comprised of large and mature trees and have a high component of organic material on the forest floor, providing for carbon storage (USDA 2016a).

Status and Trends

Riparian forest ecosystems (approximately 396,000 acres) exhibit overall high ecological integrity. This ecosystem is highly adaptive and exhibits high resilience to the dynamic nature of the ecosystem. The ever-changing dynamic leads to riparian forest ecosystems to having low risk of loss which sustains the integrity of the ecosystem. From the 1950s to the 1990s, past timber harvest impacted the riparian forest ecosystem by harvesting timber to the streambanks (Halofsky et al. DRAFT). Unthinned, young-growth stands may have low integrity but are expected to continue to trend towards high integrity with little management intervention needed (Table 7).

Table 7. **Riparian forest ecosystem ecological integrity levels.**

Terrestrial Ecosystem: Riparian Forest	Ecological Integrity	Vulnerability
Riparian Forest, unharvested	high	Moderate
Riparian young-growth forest, thinned	moderate	Moderate
Riparian young-growth forest, unthinned	low	moderate

Restoration activities on the Tongass have primarily focused on in-stream restoration to improve aquatic habitat and bank stabilization, but they also often include improving riparian forest vegetation by precommercially thinning trees, and activities upland, such as restoring or decommissioning roads, improvements to road drainage structures, and upland vegetation restoration (USDA 2016b).

Forested and Non-Forested Wetlands

Key Takeaways

- Forested and non-forested wetlands exhibit high ecosystem integrity due to their wide distribution across latitude, landforms, geology, parent material, and elevation.
- Soil drainage and hydrology is the main driver for these ecosystems, with level of soil saturation a factor in the species composition of a particular wetland.
- Climate change is the main stressor due to warming temperatures and changing precipitation patterns. Although it is expected that these ecosystems will persist, there uncertainty regarding changes in species composition.

Ecosystem Description

The U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (Corps) jointly define wetlands as "those areas that are inundated or saturated by surface or groundwater with a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." Non-tidal wetlands are found at a variety of elevations, from sea level to above tree line. For the purposes of this assessment, alpine areas including wetlands are covered in the alpine vegetation section.

Forested and non-forested wetlands are exclusively freshwater-influenced, non-tidal ecosystems, while tidal wetlands are influenced by tides and the presence of brackish and saltwater. Non-tidal wetlands occur in low-lying or gently sloping terrain that retains rainfall or captures groundwater flow saturating the soils. This saturation gives rise to organic soils, or mineral soils with deep organic accumulation. The groundwater within these wetlands is often highly acidic and nutrient poor, and their productivity is correspondingly low (McClellan et al. 2003).

Together, forested and non-forested wetlands cover approximately 3,192,000 acres on the Tongass National Forest and may be found from sea level to subalpine elevations. The U.S. Fish and Wildlife Service's (USFWS) National Wetlands Inventory (NWI) has mapped wetlands on the Tongass National Forest based on aerial photo interpretation and limited ground verification (Cowardin et al., 1979, USDA 2016b). They include all non-tidal wetlands dominated by trees, shrubs, persistent emergent plants, mosses or lichens, and all such wetlands where salinity due to ocean-derived salts is below 0.5 percent. Palustrine wetland classes on the Tongass National Forest include emergent wetlands, scrub-shrub wetlands, forested wetlands, and other palustrine classes. Classes are described in 2016 Forest Plan EIS (USDA 2016b). Palustrine wetlands are the most common freshwater wetland on the Tongass. The most common type of palustrine wetland are peatlands, known colloquially as 'muskeg,' which is often a complex system of raised and blanket bogs, open pools, forested wetlands, and poor fens (McClellan et al. 2003). Palustrine wetlands also include the vegetated wetlands traditionally referred to as marshes, swamps, fens, and wet meadows. They vary by plant species composition, water chemistry, soil moisture regime or flooding, and soil nutrient availability (MacKenzie and Moran 2004).

Forested and non-forested wetlands across similar landforms and soils, but forested wetlands differ mainly due to the presence of an open tree canopy. According to the Forest Service Handbook (1909.12), forest land includes land at least 10 percent occupied by forest trees of any size or formerly having had such tree cover and not currently developed for non-forest uses, and many wetland sites meet that threshold (Bechtold and Patterson 2005). A diverse range of plant species, including grasses and forbs, occur across all the wetland classes. Several rare plants such as mountain lady's slipper (*Cypripedium montanum*), Calder's lovage (*Ligusticum calderi),* Alaska rein orchid (*Piperia unalascensis),* and lesser round-leaved orchid (*Platanthera orbiculata)* may occur in either forested or non-forested non-tidal wetlands (USDA 2016b).


Figure 11. Photo of a forested wetland on Prince of Wales Island. Photo taken by Rick Turner, U.S. Forest Service.

Figure 12. Photo of a non-forested wetland on Yakutat Ranger District. Photo taken by Rick Turner, U.S. Forest Service.

Ecosystem Drivers and Stressors

Soil drainage and hydrology

Wetlands are reliant on soil saturation, groundwater flow, or other water sources. Anything that affects these water sources, including excess rainfall or not enough rainfall (drought), would also affect these ecosystems. Seasonal fluctuations in the water table are common, with summer draw down and high water tables during spring melt.

Wetlands vary by the type of water they receive. Wetlands in landscape positions receiving groundwater or surface flow from upslope tend to be richer in nutrients than those that only receive rainfall (Mackenzie and Moran 2004). Different plant communities occur on a continuum or gradient that aligns with soil drainage and slope hydrology.

Most forested and non-forested wetlands have deep organic soils, or thick organic layers on top of mineral layers. The saturated conditions reduce decomposition rates, giving rise to organic soil accumulations. Forested wetlands tend to have shallower organic or mineral soils compared to non-forested wetlands. However, they do occur on deep soils with high soil organic matter (Hartshorn et al. 2003). The gradient from well drained forest to forested wetland follows soil drainage and flow patterns in the landscape. Wetland complexes may have non-forest vegetation in low, saturated areas and trees along surface streams where drainage is slightly improved.

Freshwater wetlands are generally very stable ecosystems. According to pollen studies, some wetlands have persisted for thousands of years. They are considered by some as climax communities, because site conditions get wetter as organic matter builds up and stores more water. Non-forested wetlands occur almost exclusively on deep, organic soils that process groundwater. They don't have water-holding capacity so they rely on landscape position and consistent inputs from rainfall to retain saturation. These deep organic soils are a source of soil carbon that far exceeds well drained forests (Hartshorn et al. 2003) (Stewart et al. 2024).

Non-forested wetlands also include beaver ponds, and many of them may be considered fens. Beavers dam and impound small streams, sometimes for decades, creating overwintering habitat for coho salmon. When these areas eventually fail, the sediments left behind become productive riparian habitat and fertile ground for new fens or forests.

Fens are a specific type of wetland, or a feature within wetlands. Since fens require mineral-rich water, any changes to the flow that maintains them will alter their composition. Calcareous fens rely on very specific source waters with underlying carbonate geology, so any change to the source or the flow of these waters will alter the species composition.

Climate change

Climate change is the main stressor for all non-tidal wetlands. Climate change is anticipated to change temperature and precipitation across the Tongass National Forest. Since these ecosystems are driven by hydrology, any climate change-related shifts in precipitation will affect these ecosystems to some degree (Halofsky et al. DRAFT). However, these systems occur across broad latitudinal, geologic, and geophysical gradients. They are remarkably similar across the landscape due to the strong driver of soil saturation and the accumulation of soil organic matter.

Higher temperatures as measured and predicted in climate change models will have a varied impact on the plant communities. Some species will flourish under warmer temperatures while others will struggle. The species composition may change over time but deep, saturated organic soils will likely persist across the plan area.

Drought occasionally occurs in Southeast Alaska, though it is uncommon. The persistence and duration of droughty periods can affect these systems that depend on constant inputs of flow or rainfall to persist. Prolonged dry periods in the growing season may shift the species composition and favor some species that are less reliant on saturated soil conditions. Since these areas store an enormous amount of soil organic carbon (SOC), drying may release carbon from these sites (Stewart et al. 2024).

Infrastructure development

Any developments, such as roads, utility projects, and mines, that are located on wetlands can impair their function in the immediate vicinity (within a few meters) of the development (Landwehr 2007). Roads constructed across a drainage can re-route water away from a wetland on a widespread scale, or it may just impact areas adjacent to roads where there is greater drainage (USDA 2016a). The Tongass Forest Plan provides direction for management activities in wetlands through its standards and guidelines, which includes following Best Management Practices, the Clean Water Act, and Army Corps of Engineers and EPA guidance regarding wetlands.

Both forested and non-forested wetlands are sometimes filled in for development purposes. They often occur on flat or gently sloping areas, so they can be vulnerable to development when near a town or village. The communities of Petersburg and Wrangell are built on filled-in wetlands.

Large renewable energy projects like hydropower dams changes the way streams flow, which changes adjacent water tables that support wetlands. This would mainly affect riparian-associated wetlands where the elevational gradient of the high-potential hydropower stream reaches is steep, so the effects are probably limited to the valley bottoms far below the dams.

Recreational use

Recreational activities often impact these areas because both forested and non-forested wetlands have open terrain that allows potential access by off highway vehicles (OHVs). The low bearing strength of the soils in these wetlands leads to severe rutting, with the potential of OHVs getting stuck. The impacts can be severe but usually do not extend outside of the immediate damaged area.

Invasive species

Some invasive plant species such as reed canarygrass (Phalaris arundinacea) and orange hawkweed (Hieracium aurantiacum) can infest non-tidal wetlands. Some of the more acidic areas, such as ombrotrophic bogs are apparently less susceptible to infestation than the less acidic wetlands. In Petersburg, invasive plants on road prisms have been observed moving into adjacent wetlands.

Ecosystem Services

- Wetlands are a key component in carbon flux. (D'Amore et al. 2015). They can be a carbon sink, or a source of carbon emissions, depending on whether they stay wet or dry out.
- Provides water storage during low flow (for all wetlands) and maintenance of stream baseflow.
- Functions as snow storage. Open wetlands, including open-canopy forested wetlands accumulate more snow than forests and hold it into the spring.
- Provides subsistence opportunities, including foraging for various edible berries.
- Provides wildlife habitat, including spring, summer, and fall deer forage.
- Pollinators may use wetlands as foraging habitat depending on the type of wetland and whether it has a lot of flowering plants or not.
- Has high amphibian usage compared to other ecosystems.
- Provides rearing and overwintering habitat for salmon when connected to anadromous streams, including beaver ponds.
- Provides scenic and recreational value from open spots in an otherwise very densely vegetated landscape.
- May have rare, unique, and diverse plant and animal communities. Karst fens are listed as a plant community of conservation concern in Alaska by the Alaska Center for Conservation Science (Boggs et al. 2019). Vegetation in karst fens is quite different from surrounding acidic peatlands.

Yellow lady's slipper (*Cypripedium parviflorum* var. *pubescens*) is one rare plant that occurs in karst fen communities.

- They may also provide productive forage for wildlife because of the lush, accessible and nutritious vegetation.

Status and Trends

The ecosystem integrity of forested and non-forested wetlands is high (Table 8) although there is some uncertainty in how climate change will affect them. There are opportunities for both expansion and loss noted in the Tongass climate change vulnerability assessment (Halofsky et al. DRAFT). They may shift location with climate change but are currently resilient across a variety of temperature and microclimate regimes. With climate models showing decreased rainfall in some places while increasing in others, it is expected that this ecosystem will persist, although their plant communities may shift. For example, between 1995 and 2008 the USFS Forest Inventory and Analysis program found a 4.6% decrease in shore pine biomass. This correlates to increased air temperatures during the growing season (Halofsky et al. DRAFT). Several hypotheses exist to explain this decline including climate change, and further research is needed to determine the cause.

Table 8. **Forested and Non-forested wetlands ecosystem ecological integrity levels.**

Terrestrial Ecosystem	Ecological Integrity	Vulnerability
Forested and Non-Forested wetlands	High	Low

Since fens occupy niche places on the landscape their integrity depends on how the immediate landscape is affected. Although there is uncertainty about fens, due to lack of information, there is more data available for calcareous fens. In general they are rare but fairly stable with not many stressors beyond those common to other wetlands. Fens may be more vulnerable to changes in soil pH, but their extent and condition is not expected to change in the short or long term.

Tidal Wetlands

Key Takeaways

- The ecological integrity of the tidal wetlands is currently moderate due to the current and anticipated impacts from climate change.
- The main stressor for the tidal wetlands ecosystem is climate change-induced increases in air and ocean temperatures, and increased storm frequency or intensity.

Ecosystem Description

Tidal wetlands are found at sea level and they include both marine and estuarine environments and are the result of both marine and freshwater influences. Marine influences include daily tidal fluctuations, maritime storms, wave splash, periodic saltwater inundation, and wave or surf carving. Freshwater influences include flow and sediment deposition. In many cases, the formation of these coastal landforms is modified by isostatic rebound (general land mass uplift after glacial recession), tectonics (e.g. tectonic uplift), and longshore transport (USDA 1996).

Estuarine and marine environments differ by water regime. Both estuarine and marine wetlands are subject to diurnal and seasonal tidal flooding but in estuarine wetlands the sea water is diluted with freshwater derived from land drainage (Cowardin et al. 1979). Marine wetlands are those areas of high energy coastline where habitats are exposed to waves and currents of open oceans. They are rocky, sparsely vegetated, or with vegetation heavily influenced by salt spray (Cowardin et al. 1979).

Estuaries can be classified by physical or hydrological parameters such as water depth and volume, tide height, tidal prism volume, freshwater inflow rates, salinity, and temperature (Engle et al. 2007). This classification of estuaries can be used by natural resource managers to describe and inventory coastal systems, understand stressor impacts, predict which systems are most sensitive to stressors, and manage and protect coastal resources.

The landward extent of an estuary is the limit of salt intolerant vegetation, and the seaward extent is a stream's delta at mean low water. Sedges and grasses dominate these areas with Lyngbyei sedge (*Carex lyngbyei*) in landward, less saline locations, and spike rush (*Eleocharis* spp.) or alkali grass (*Puccinellia* spp.) in the more saline locations seaward. Unvegetated or sparsely vegetated mud flats characterize the low intertidal zones (Shepard 1995, Turner 2010). Habitat for Henderson's checkermallow (*Sidalcea hendersonii*), rare plant that has been documented on the Tongass National Forest, includes tidal flats and estuaries (USDA 2016a).

Figure 13. Photo of a tidal wetland on the Wrangell Ranger District. Photo taken by Rick Turner, U.S. Forest Service.

Ecosystem Drivers and Stressors

Stream flow

Estuarine tidal wetlands are dependent on the upland (terrestrial) hydrologic regime, and their size is typically correlated with the size of the drainage area. Most stream flow depends on rain, snowmelt or high elevation summer melt (which include snow and/or ice). Large estuarine deltas occur at the mouth of the Stikine and other transboundary rivers and along the outlets of many of the fjords on the mainland (Nowacki et al. 2001). Stream flow also affects the size and extent of the brackish water environment that characterizes estuaries. Small streams have less freshwater input, so saltwater-tolerant species dominate. Large streams have more freshwater, so areas of lower or mixed salinity are larger. Stream flow brings additional supplies of minerals and improves oxygenation (MacKenzie and Moran 2004). This increases the species richness of the plant and animal communities in estuaries.

Any changes to freshwater quantity or quality affects estuaries. Forest management and road building in the uplands doesn’t directly affect these estuaries; however, indirect changes in peak flows and temperature has the potential to alter sensitive estuarine communities.

Ocean exposure

Along the Gulf of Alaska coastline, the dominant process of tidal wetland formation is longshore drift. This is notable along the Yakutat forelands and south towards the inner sea channels (Shepard 1995). Wave action and tidal inundation are the dominant processes affecting the protected marine waters of Southeast Alaska.

Tidal action

The degree of tidal flooding, which is closely related to height above the mean tide level, is an important gradient. Large diurnal tidal fluctuations affect the extent of flooding in estuaries and other tidal wetlands, which influences plant community composition. Where high volumes of fresh water are delivered to estuarine environments, communities change along a gradient from where freshwater influences predominate (usually within the tidal reaches of the river) to where freshwater inputs are minimal (MacKenzie and Moran 2004).

Changes to wave action, tides, or stream flow will affect the structure and function of these ecosystems. Estuaries rely on constant inputs of sediment from streams to build and maintain the substrate. Sedge marsh vegetation is excellent at trapping fine sediments and settling them, providing habitat for other plants and animals and stabilizing stream flows, sediment transport, and filtering water.

Isostatic rebound

Landforms of Southeast Alaska are not static, and uplift through isostatic rebound as glaciers recede occurs at differential rates in different locations. These uplifts gradually raise tidal flats, causing them to disconnect from saltwater influence and transition to other ecosystem types such as freshwater wetlands.

Climate change

Climate change is the main stressor for tidal wetlands. Stream and ocean temperatures are driven by air temperature, which is projected to increase annually and seasonally across Southeast Alaska (Halofsky et al. DRAFT). Changes to stream flow, flow seasonality, or existing flow patterns affected by climate change would change these tidal wetlands. Increased storm frequency or intensity resulting from higher sea water temperature could increase wave action and produce storm surges which can erode tidal wetlands faster than sediment deposition rates can replenish them.

Southeast Alaska has experienced periodic drought, and the frequency and intensity of water deficit, is projected to increase in some areas which is an indicator of plant stress (Halofsky et al. DRAFT). Estuarine systems rely on consistent inputs of freshwater stream flow and are not adapted to withstand prolonged drought. Alterations of stream flow or temperature can affect vegetation patterns, fish, and any creature feeding on these organisms.

Sea level rise is not expected to substantially affect tidal wetlands in Southeast Alaska (Halofsky et al. DRAFT). Land rising due to isostatic rebound will likely offset any rise in sea level and will likely outpace it in northern portions of the Tongass National Forest as glaciers continue to recede.

Past timber harvest

Timber harvest adjacent to streams and estuaries has occurred in the past (USDA 2016a). Since passage of the Tongass Timber Reform Act and completion of the 1997 Forest Plan, timber harvests have been restricted in areas adjacent to tidal wetlands. Prior timber harvests and road construction near wetlands are recovering and are trending toward higher ecological function.

Dams

Dams mostly return water back to the creek after going through the hydropower facility or hatchery, although all dams affect flow timing. Water drawn for municipal water supplies do not return the water to the creek. The timing of water storage or release can affect rates of freshwater input to tidal wetlands in estuaries.

Urban development

Cities, towns and villages in Southeast Alaska are often located near tidal marshes, since that is where much of the flat, buildable land is located. Tidal marshes are sometimes filled in to provide areas for infrastructure, such as the airport in Juneau. The city of Craig used to be on an island, but they filled in between two islands with a road which interrupts saltwater flow between the two islands. This type of development is usually on land immediately surrounding towns and village that is not managed by the Forest Service. An exception is marine access facilities that provided for water transport of harvested logs. These areas can be indirectly impacted by urban development by events such as oil spills.

Transboundary mines

Mines use freshwater to dilute mine effluents, and mine tailings are often stored in close proximity to stream systems. The history of mine spills implies some risk of future negative effects on stream, estuarine and marine water quality.

Invasive species

There are large infestations of invasive plants in some tidal wetlands, including brass buttons (*Cotula coronopifolia*) in intertidal areas around Petersburg. Some invasive species that haven’t yet been recorded on the Tongass National Forest could gain a foothold, especially as the climate warms. There is an unofficial Tongass invasive plant watch list that lists with several potentially invasive species, some of which are specific to tidal wetlands habitat.

European green crab (*Carcinus maenas*) is a potential threat to this ecosystem. It has recently been recorded around Annette Island in the south end of the plan area. Studies have shown that the presence of this species leads to loss of eelgrass beds (Grason et al. 2018, Howard et al. 2019).

Ecosystem Services

- Buffer for storm surges, shoreline protection.
- Traps sediment so it doesn't end up in the saltwater.
- Captures carbon and nutrient flux from uplands.
- Provides subsistence and recreational fishing, hunting, foraging, and wildlife-watching opportunities.
- Specific wetland plant species support fish and wildlife communities, with sedges serving as nutritious forage in the spring for deer and for bears coming out of hibernation.
- Provides forage and habitat for small fish and invertebrates such as clams.
- Provides rearing habitat for salmon – especially coho.
- Provides a staging area for migrating shorebirds and waterfowl.

Status and Trends

Tidal wetlands have a moderate ecological integrity rating (Table 9) because of their vulnerability to the future effects of climate change, and the ways they are already changing under increased ocean and stream temperatures (Halofsky et al. DRAFT). Most of these areas have not been substantially altered by timber harvest, road construction, or other infrastructure on Forest Service lands, but privately owned coastal areas have been substantially altered.

Table 9. **Tidal wetlands ecosystem ecological integrity levels.**

Terrestrial Ecosystem	Ecological Integrity	Vulnerability
Tidal Wetlands	Moderate	High

Tidal wetlands are vulnerable ocean and water temperature increases, changes in pH, and shifts in hydrologic regime. Mean air temperature has already risen (Halofsky et al. DRAFT) and so have ocean and freshwater temperatures. Changes in air and water temperature can shift the energy flow through food webs and potentially decrease the capacity of these ecosystems to provide habitat for salmon and everything that feeds on salmon (Halofsky et al. DRAFT).

Shrublands

Key Takeaways

- This ecosystem currently exhibits high integrity. It occurs from sea level up to the subalpine zone and mainly in areas that have frequent disturbance such as steep slopes and other areas with potential for recurring avalanches or landslides.

- The main ecosystem drivers are well drained soils and frequent disturbance such as avalanches and landslides.
- Climate change is the main stressor for mesic shrublands. There is uncertainty regarding the type and amount of change, with both loss and gain possible.

Ecosystem Description

Mesic shrublands occur in areas of frequent disturbance, from sea level up to the subalpine tree line. They occur on moist but well drained soils in various physical settings. In the subalpine zone, steep mountain slopes can produce frequent snow avalanches or landslides that interrupt development of a tree canopy. Upper avalanche slopes typically have a slope angle of at least 70 percent, but lower slopes and run-out zones can be much less steep (NatureServe 2024). Soils are often shallow, with little or no profile development, and are underlain by colluvium and glacial till. Tree seedlings and saplings may be abundant on some slopes but do not develop into a forest overstory canopy due to the frequent disturbance. Well drained shrublands can also occur on well drained river floodplain and glacial outwash gravel bars and can be maintained by disturbance from frequent flooding, but if disturbance becomes less frequent or ceases, it will eventually be replaced by forest vegetation as the tree canopy closes.

Sitka alder (*Alnus viridis* ssp. *sinuata*) is typically the dominant species, but salmonberry (*Rubus spectabilis*) may be codominant. Copperbush (*Elliottia pyroliflora*) can also dominate in higher subalpine environments. Other shrubs present may include red elderberry (*Sambucus racemosa*), feltleaf willow (*Salix alaxensis*), Barclay willow (*S. barclayi*), and devil's club (*Oplopanax horridus*). On portions of the Yakutat Foreland, crabapple (*Malus fusca*) may be a co-dominant (Shepherd 1995). For this assessment, shrublands that occur on lowland sites, such as old lakebeds, drained beaver ponds, wet depressions, and the edges of peatlands and tidal marshes with poorly drained or saturated soils, are considered part of the non-forested wetland ecosystem.

Shrublands are more extensive on northern portions of the Tongass and closer to the mainland than they are further south and on the seaward islands. The northern and mainland areas generally have a higher abundance of angular mountains and steep slopes that are subject to more frequent disturbance from snow avalanches and landslides, which are the main drivers that perpetuate shrubland vegetation. Land exposed by deglaciation may also become dominated by shrublands, especially on well drained glacial till substrates (Chapin et al. 1994). Although these areas will likely succeed to black cottonwood or Sitka spruce forest, the lack of soil development and nutrient availability can inhibit tree growth for many decades, and shrublands can persist indefinitely on deglaciated sites that are subject to frequent disturbance such as avalanches or landslides.

Figure 14. Photo of a shrubland. Photo taken by Rick Turner, U.S. Forest Service.

Ecosystem Drivers and Stressors

Snowpack and avalanches

At subalpine elevations, mesic shrublands are maintained by a heavy snowpack and frequent avalanches initiating on steep slopes. Shrubs are generally resilient to this frequent disturbance due to their extensive rootsystem and multi-stemmed, flexible growth form, but forest canopy growth is effectively inhibited.

Landslides

Like avalanches, landslides provide suitable conditions for the growth and maintenance of shrublands. On infrequent landslides, shrubland vegetation may be successional to the re-establishment of a previous forest canopy, but these shrublands can be perpetuated in areas subject to frequently recurring land or rock slides that prevent encroachment by trees.

Insects and disease

Several insects are known to attack alder and willow, including defoliators, wood borers, and bark beetles, as well as diseases and decays (Holsten et al. 2008). Although individual plants or small patches of vegetation are often affected, large-scale outbreaks and mortality are uncommon. However, drought stress caused by changes in precipitation patterns due to climate change may heighten the susceptibility of some shrublands to insect or disease attack and result in increased associated damage (Halofsky et al. DRAFT).

Herbivores

Moose heavily browse alder and willow shrublands (MacCracken et al. 1997), especially in winter when tall shrubs such as alder and willow can often be accessed in areas of deep snow. Browsing by moose and other herbivores may help maintain shrublands by cropping it which can encourage re-sprouting.

Climate change

Climate change is expected to increase average temperatures and decrease precipitation occurring as snow, which will likely result in less frequent avalanches on some sites. This may allow trees to encroach due to less frequent disturbance. Conversely, increased precipitation in the form of rain along with more frequent intense rain events may increase the frequency of landslides in some areas, which would create and maintain additional habitat for shrub vegetation to grow. In addition, warming temperatures may result in the expansion of tall shrubs into areas that are currently occupied by alpine vegetation (Halofsky et al. DRAFT).

Ecosystem Services

- Well drained shrublands provide shelter and forage for many wildlife species, including browse for moose and other herbivores, winter foraging habitat for non-migratory birds, and nesting habitat for breeding birds. Because shrubland vegetation is dense, it provides concealment and shelter for almost any animal. They also can serve as corridors that facilitate movement of forest-dependent animals between forest stands.
- Provides subsistence and recreational foraging opportunities, including for edible berries such as salmonberry and gray currant which are often found in abundance in mesic shrublands.
- Shrubland growth in disturbed areas such as landslides or avalanche chutes helps to stabilize soils from further erosion, and alder can serve as a nitrogen fixer for soil development.

Status and Trend

Mesic shrublands currently exhibit high integrity (Table 10). This ecosystem may be vulnerable to climate change, but there is uncertainty in the type and direction of expected changes. In some areas there may be a loss of these shrublands where changes in temperature and precipitation reduce the frequency of avalanches, but there may also be a gain due to increased landslides and deglaciation. There could also be gains from expansion of this ecosystem into current alpine habitat as mean temperature rises. The rate of expansion will likely depend on complex interactions between long-term climate conditions, shorter-term weather regimes, and local site-level conditions such as topography, geology, and geomorphology (Halofsky et al. DRAFT).

Table 10. **Shrublands ecosystem ecological integrity levels.**

Terrestrial Ecosystem	Ecological Integrity	Vulnerability
Shrublands	High	Low – changes could be positive and negative

Meadows

Key Takeaways

- Well drained meadows are considered to have high ecological integrity. However, there is uncertainty regarding the effects of climate change on this ecosystem.
- The main ecosystem drivers are well drained, high-nutrient soils and lack of tree and shrubs due to frequent disturbance from avalanches, colluvial deposition from landslides, alluvial deposition from streams, persistent snowfields, and in the case of beach meadows, exposure to saltwater spray or occasional inundation.
- Stressors include infestation by invasive plants, damage from OHV and foot traffic, developments near towns and villages, and increased evapotranspiration rates and increased coastal beach erosion from stronger storms and waves due to climate change.

Ecosystem Description

Well drained meadows are relatively rare on the Tongass (approximately 16,000 acres) and usually occur as small inclusions at the edges of or within larger forested or wetland ecosystems. Although beach meadows may have similar structure and some overlapping species composition with other well drained meadows, they occur in different physical settings and some species are associated only with one type.

Beach meadows are located on coastal beaches, dunes, sand spits, and the outer edge of river deltas. Vegetation zonation in this system is related to exposure to saltwater inundation and spray and by disturbance frequency. Soils are usually well-drained sand deposits, although shallow depressions (dune slacks) may be poorly drained due to the deposition of fine-grained material during overflow events. The sandy soils may be periodically exposed to overwash from storm surges and exceptionally high tides, but they drain quickly, and precipitation rapidly leaches salt from the soil (Boggs 2000). Plant communities in beach meadows are dominated by grasses and forbs. Species composition is diverse and variable, and may include beach rye (*Leymis mollis*), Bering's tufted hairgrass (*Deschampsia beringensis*), cow parsnip (*Heracleum maximum*), marsh grass-of-parnassus (*Parnassia palustris*), boreal yarrow (*Achillea millefolium ssp. borealis*), beach strawberry (*Fragaria chiloensis*), bluejoint (*Calamagrostis canadensis*), and fireweed (*Chamerion angustifolium*).

Other well drained meadows are widely distributed on a variety of landforms and at varying elevations from near sea level to the subalpine zone. The main site characteristic is accumulation of deep, well drained, nutrient-rich soils through colluvial accumulation on slopes and sediment deposition on floodplains and stream levees. They commonly occur on frequently disturbed snow avalanche chutes or toe slopes of landslides. Other mesic meadows are located on well drained soils on inactive glacial outwash plains such as the Yakutat Forelands (Shepherd 1995), low-gradient stream levees and loess deposits in estuaries and alluvial floodplains of large rivers such as the Stikine and Taku (Turner 2010), or at subalpine sites that tend to retain snow and have a relatively short growing season. Plant communities consist of a diversity of forbs, graminoids, and ferns. Common species include kneeling angelica (*Angelica genuflexa*), bluejoint (*Calamagrostis canadensis*), fireweed (*Chamerion angustifolium*), false hellebore (*Veratrum viride*), lady fern (*Athyrium filix-femina*), and cow parsnip (*Heracleum maximum*).

Figure 15. Photo of a meadow on the Juneau Ranger District. Photo taken by Rick Turner, U.S. Forest Service.

Ecosystem Drivers and Stressors

Soil drainage, nutrients, and salinity

Important site characteristics of meadows are moist, well drained soils with high nutrient availability. Vegetation dynamics in dunes and beach meadows are also driven by salinity from salt spray and occasional seawater inundation, which typically decreases with distance from the shore.

Avalanches and landslides

Well drained soils that are non-forested are relatively rare on the Tongass. Factors that can inhibit growth of trees and shrubs include disturbances such as frequent avalanches or colluvial deposition from landslides or river sedimentation, lingering snowfields, or high soil salinity or salt spray exposure. Woody vegetation encroachment may also be prevented by competition from the robust herbaceous vegetation combined with a thick undecomposed litter layer, or an occasionally high water table (Shepherd 1995). Grazing by herbivores may also influence vegetation structure and composition.

Invasive species

Upper beach meadows are vulnerable to infestation by invasive species. Several invasive plants, including field mustard (Brassica rapa), hempnettle (Galeopsis tetrahit), field sowthistle (Sonchus arvensis), and black bindweed (Fallopia convolvulus), can establish and spread in these meadows, and several species are readily dispersed by air or carried by tidewater to other beaches.

Off-highway vehicle and foot traffic

Well drained meadows can be damaged or eroded by off-highway vehicle (OHV) use. Overuse by outfitters and guides or special use permittees can also trample vegetation in these areas. The damage is usually localized and of minor impact to overall ecosystem integrity. If OHV or visitor traffic ceases, tracks will tend to be recolonized by vegetation, as soils are generally not as susceptible to erosion as in wetter areas.

Urban development

Near towns and villages, mesic meadows are susceptible to development as they are often the only nearby land that is relatively level and well drained. Such development would not likely occur on lands managed by the Forest Service.

Climate change

Increased air temperatures and evapotranspiration due to climate change are expected to reduce soil moisture during the growing season (Halofsky et al. DRAFT), which in turn could affect the species composition and function of this ecosystem. Intensified storm events and the resulting storm surge and wave erosion could damage or erode beach meadows. A shift in precipitation type from snow to rain may reduce disturbance in avalanche chutes where well drained meadows are often found at higher elevations.

Ecosystem Services

- Provides habitat for plants that are considered rare or disjunct on the Tongass, including dune tansy (*Tanacetum camphoratum*) and several species of moonwort ferns (*Botrychium spathulatum, B. tunux, B. yaaxudakeit*) which occur in beach meadows.
- Well drained meadows are important for wildlife habitat, including grazing by herbivores and nesting for migratory birds.
- Provides subsistence and recreational foraging opportunities for berries including wild strawberry (*Fragaria chiloensis*) and nagoonberry (*Rubus arcticus*).

Status and Trend

Well drained meadows are considered to have high ecological integrity (Table 11) because most past impacts to this ecosystem have been minor. However, there is uncertainty regarding the effects of climate change on this ecosystem. Potential causes for loss of ecological integrity are changes to hydrologic and disturbance patterns related to climate change. Other stressors such as

OHV use, invasive species, and development are likely to have minor negative impacts to this ecosystem

Table 11. Meadows **ecosystem ecological integrity levels.**

Terrestrial Ecosystem	Ecological Integrity	Vulnerability
Meadows	high	Low

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References

Alaback, P. 1984. Secondary succession following logging in the Sitka spruce-western hemlock forests of southeast Alaska: Implications for wildlife management. Gen. Tech. Rep. PNW-173. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Albert, D. and J. Schoen. 2007. A conservation assessment for the coastal forests and mountains ecoregion of southeastern Alaska and the Tongass National Forest. Available at: https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/alaska/seak/era/cfm/Documents/2_Chapter_2.pdf

Audubon Alaska. 2016. ecological atlas of southeast Alaska. Available at: https://ak.audubon.org/sites/default/files/seak_atlas_144dpi.pdf

Barrett, T.M. 2014. Storage and flux of carbon in live trees, snags, and logs in the Chugach and Tongass National Forests. USDA-FS. General Technical Report PNW-GTR-889.

Bechtold, William A., Paul L. Patterson. 2005. The enhanced Forest Inventory and Analysis Program—national sampling design and estimation procedures. GTR SRS-80.

Berkley, E., S. Brockmann, P. Manlick, S. Markegard, and M. Mayville. 2024. Relevance and need for the Tongass Old-Growth Conservation Strategy: a forest plan revision pre-assessment. Unpublished technical report, USDA Forest Service, Tongass National Forest.

Boggs, K. 2000. Classification of community types, successional sequences, and landscapes of the Copper River Delta, Alaska. Gen Tech. Rep. PNW-GTR-469. Portland, OR: USDA Forest Service, Pacific Northwest Research Station.

Boggs, K., L. Flagstad, T. Boucher, M. Carlson, A. Steer, B. Bernard, M. Aisu, P. Lema, B. Heitz, and T. Kuo. 2019. Alaska ecosystems of conservation concern: biophysical settings and plant associations. Alaska Center for Conservation Science, University of Alaska, Anchorage.

Boggs, K., S. Klein, J. Grunblatt, T. Boucher, B. Koltum, M. Sturdy, and G. Streveler. 2010. Alpine and subalpine vegetation chronosequences following deglaciation in coastal Alaska. Arctic, Antarctic, and Alpine Research 42: 385–395.

Capp, J., B. Van Zee, P. Alaback, J. Boughton, M. Copenhagen, and J. Martic. 1992. Ecological definitions for old growth forest types in southeast Alaska. R10-TP-28. Juneau, AK: U.S. Department of Agriculture, Forest Service, Alaska Region.

Chapin III, S., L. Walker, C. Fastie, and L. Sharman. 1994. Mechanisms of primary succession following deglaciation at Glacier Bay, Alaska. Ecological Monographs. 64:149-175.

Cowardin, L., V. Carter, F. Golet, and E. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, FWS/OBS-79/31. Washington DC.

Cutler, A., and E. Johson. 2019. Drought in the world's largest temperate rainforest? USDA Forest Service, Office of Sustainability and Climate. 5 pp. Available at: https://www.usda.gov/media/blog/2019/07/17/drought-worlds-largest-temperate-rainforest

D'Amore, D., R. Edwards, and F. Biles. 2015. Biophysical controls on dissolved organic carbon concentrations of Alaskan coastal temperate rainforest streams. Aquatic Sciences 78:381–393.

DeMeo, T., J. Martin, and R. West. 1992. Forest plant association management guide: Ketchikan Area, Tongass National Forest. R10-MB-210.

Dubois, G., S. Brannoch, and E. Graham (Eds.). 2022. forest health conditions in Alaska - 2022. Anchorage, Alaska. U.S. Forest Service, Alaska Region. Publication R10-PR-48.

Engle, V.D., Kurtz, J.C., Smith, L.M. et al. A classification of U.S. estuaries based on physical and hydrologic attributes. 2007. Environ Monit Assess 129:397–412.

Grason, E., McDonald, S., Adams, J., litle, K., Apple, J., Pleus, A. 2017. Citizen science program detects range expansion of globally invasive European green crab in Washington State (USA). Management of Biological Invasives 9(1):39-47.

Halofsky, E., H. Prendeville, D. Peterson, and R. Parrish, Robert. eds. DRAFT. Climate change vulnerability and adaptation in the Tongass National Forest. Gen. Tech. Rep. PNW-GTR-XXX. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Harris, A. S, and W. A. Farr. 1974. The forest ecosystem of southeast Alaska: 7. Forest ecology and timber management. General Technical Report PNW-GTR-25. Portland, OR, USA.

Hartshorn, A., R. Southard, and C. Bledsoe. 2003. Structure and function of peatland-forest ecotones in southeastern Alaska. Soil Sci. Soc. Am. J. 67:1572–1581.

Howard, R., Francis, F., Cote, I., Therriaut, T. 2018. Habitat alteration by invasive European green crab (Carcinus maerias)causes eelgrass loss in British Columbia, Canada. Biological Invasives (2019) 21.3607-3618.

Hennon, P., C. McKenzie, D. D'Amore, D. Wittwer, R. Mulvey, M. Lamb, F. Biles, and R. Cronn. 2016. A climate adaptation strategy for conservation and management of yellow-cedar in Alaska. Gen. Tech. Rep. PNW-GTR-917. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Holsten, E., P. Hennon, L. Trummer, J. Kruse, M. Schultz, and J. Lundquist. 2008. Insects and diseases of Alaskan forests. USDA Forest Service: Alaska Region, State and Private Forestry, Forest Health Protection Publication Number R10-TP-140.

Jaques, D. 1973. Reconnaissance botany of alpine ecosystems on Prince of Wales Island, southeast Alaska. Masters Thesis, Oregon State University.

Krosse, P. 2024. Vegetation map-unit descriptions of Prince of Wales and Outer Islands, Tongass National Forest. Publication R10-FR-022, USDA Forest Service Alaska Region, Ketchikan, AK.

Landwehr, D. 2007. Implementation and effectiveness monitoring of wetland best management practices on the Tongass National Forest. Unpublished report, USDA Forest Service, Tongass National Forest, Ketchikan, AK.

MacKenzie, W., and J. Moran. 2004. Wetlands of British Columbia: a guide to identification. Res. Br., B.C. Min. For., Victoria, B.C. Land Manage. Handb. No. 52.

Manlick, P., M. Howe, J. Wen, J. Barnard, and K. Nelson. Manuscript in preparation. Forest thinning increases ungulate foraging habitat in historically logged forests.

Martin, J., S. Trull, W. Brady; R. West, and J. Downs. 1995. Forest plant association management guide, Chatham Area, Tongass National Forest. USDA Forest Service, Alaska Region, R10-TP- 57.

McClellan, M., T. Brock, and J. Baichtal. 2003. Calcareous fens in southeast Alaska. Pacific Northwest Research note PNW-RN-536.

McClellan, M. 2004. Development of silvicultural systems for maintaining old growth conditions in the temperate rainforest of southeast Alaska. Forest Snow and Landscape Research. 78:173–190.

McDowell, N., C. Allen, K. Anderson-Teixeira, B. Aukema, B. Bond-Lamberty, L. Chini, J. Clark, M. Dietze, C. Grossiord, A. Hanbury-Brown, G. Hurtt, R. Jackson, D. Johnson, L. Kueppers, J. Lichstein, K. Ogle, B. Poulter, T. Pugh, R. Seidl, M. Turner, M. Uriarte, A. Walker, and C. Xu. 2020. Pervasive shifts in forest dynamics in a changing world. Science, 368(6494), eaaz9463.

Moore J., R. Flitcroft, E. Tucker, K. Prussian, and S. Claeson, 2024. Same streams in a different forest? Investigations of forest harvest legacies and future trajectories across 30 years of stream habitat monitoring on the Tongass National Forest, Alaska. *PLoS One*, *19*(7), p.e0301723.

NatureServe. 2024. International terrestrial ecological systems. Accessed through NatureServe Explorer [web application], NatureServe, Arlington, Virginia. Available at: https://explorer.natureserve.org/

Newton, M., and L. Cole. 2012. Sitka spruce and western hemlock stand and tree growth 10 years after precommercial thinning in southeast Alaska. Western Journal of Applied Forestry 27: 5-11.

Nowacki, G., and M. Kramer, 1998. The effects of wind disturbance on temperate rain forest structure and dynamics of southeast Alaska. Gen. Tech. Rep. PNW-GTR-421. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Nowacki, G., M. Shepherd, P. Krosse, W. Pawuk, G. Fisher, J. Baichtal, D. Brew, E. Kissinger, and T. Brock. 2001. Ecological subsections of southeast Alaska and neighboring areas of Canada. Technical Publication R10-TP-75, USDA Forest Service, Alaska Region.

Shepherd, M. 1995. Plant community ecology and classification of the Yakutat Foreland, Alaska. Technical Report R10-TP-56. USDA Forest Service, Alaska Region.

Stewart, A., M. Halabisky, C. Babcock, D. Butman, D. D'Amore, and L. Moskal. 2024. Revealing the hidden carbon in forested wetland soils. Nature Communications (2024)15:726.

Thornton, T. & Sivaramakrishnan, K. (2011). Being and Place among the Tlingit. University of Washington Press.

Turner, N. 1979. Plants in British Columbia Indian technology. Handbook 38. Victoria, BC: British Columbia Provincial Museum.

Turner, N., Y. Ari, F. Berkes, I. Davidson-Hunt, Z. Ertug, and A. Miller. 2009. Cultural management of living trees: an international perspective. Journal of Ethnobotany 29:237-270.

Turner, R. 2010. Nonforested plant associations of the Stikine-Taku River Valleys and Stikine River Delta Ecological Subsections in southeastern Alaska. Publication R10-PR-023, USDA Forest Service, Alaska Region.

USDA Forest Service. 1996. Landforms of the Alaska Region classification guide. Unpublished report, USDA Forest Service, Alaska Region.

USDA Forest Service. 2008. Tongass land and resource management plan, final environmental impact statement plan amendment. R10-MB-603c.

USDA Forest Service. 2014. Tongass young growth management strategy, unpublished report, USDA Forest Service, Tongass National Forest, Ketchikan.

USDA Forest Service. 2016a. Tongass Land and Resource Management Plan. Forest Service Alaska Region, Tongass National Forest R10-MD-769j

USDA Forest Service. 2016b. Tongass National Forest land and resource management plan, final environmental impact statement plan amendment, volume I. R10-MB-769e. USDA Forest Service, Alaska Region, Juneau.

USDA Forest Service 2024a. Amendments to Land Management Plans to Address Old-Growth Forests Across the National Forest System, Draft Environmental Impact Statement. USDA Forest Service, Washington, DC

USDA Forest Service. 2024b. Natural Resource Manager - Forest Service Activities Tracking System (FACTS) database. USDA Forest Service. Accessed August, 2024.

Viereck, L., C. Dyrness, A. Batten, and K. Wenzlick. 1992. The Alaska vegetation classification. Gen. Tech. Rep. PNW-GTR-286. Portland, OR: USDA Forest Service, Pacific Northwest Research Station.

Washington State Department of Natural Resources. 2022. Forest health highlights in Washington - 2021: a summary of insect, disease, and other disturbance conditions affecting Washington's forests. Available at: dnr.wa.gov/publications/rp_fh_2021_forest_health_highlights.pdf

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Glossary

Adaptation

Adjustment in natural or human systems to a new or changing environment. Adaptation includes, but is not limited to, maintaining primary productivity and basic ecological functions such as energy flow; nutrient cycling and retention; soil development and retention; predation and herbivory; and natural disturbances. Adaptation occurs primarily by organisms altering their interactions with the physical environment and other organisms.

Adaptive Management

Adaptive management is the general framework encompassing the three phases of planning: assessment, plan development, and monitoring (36 CFR 219.5). This framework supports decision-making that meets management objectives while simultaneously accruing information to improve future management by adjusting the plan or plan implementation. Adaptive management is a structured, cyclical process for planning and decision-making in the face of uncertainty and changing conditions with feedback from monitoring, which includes using the planning process to actively test assumptions, track relevant conditions over time, and measure management effectiveness.

Alaska Native Corporation

One of the regional, urban, and village native corporations formed under the Alaska Native Claims Settlement Act of 1971 (36 CFR 219.19).

Assessment

For the purposes of the land management planning regulation at 36 CFR part 219 and this Handbook, an assessment is the identification and evaluation of existing information to support land management planning. Assessments are not decision-making documents, but provide current information on select topics relevant to the plan area, in the context of the broader landscape (36 CFR 219.19).

At-risk species

A term used in land management planning and this Handbook to refer to, collectively, the federally recognized threatened, endangered, proposed, and candidate species and species of conservation concern within a plan area.

Climate change adaptation

Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. This adaption includes initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Adaptation strategies include the following:

1. Building resistance to climate-related stressors.

2. Increasing ecosystem resilience by minimizing the severity of climate change impacts, reducing the vulnerability, and/or increasing the adaptive capacity of ecosystem elements.

3. Facilitating ecological transitions in response to changing environmental conditions.

Connectivity

Ecological conditions that exist at several spatial and temporal scales that provide landscape linkages that permit the exchange of flow, sediments, and nutrients; the daily and seasonal movements of animals within home ranges; the dispersal and genetic interchange between populations; and the long distance range shifts of species, such as in response to climate change (36 CFR 219.19).

Disturbance

Any relatively discrete event in time that disrupts ecosystem, watershed, community, or species population structure and/or function and changes resources, substrate availability, or the physical environment (36 CFR 219.19).

Drivers

System drivers include dominant ecological processes, disturbance regimes, and stressors, such as natural succession, wildland fire, invasive species, and climate change; and the ability of terrestrial and aquatic ecosystems on the plan area to adapt to change.

Disturbance regime

A description of the characteristic types of disturbance on a given landscape; the frequency, severity, and size distribution of these characteristic disturbance types; and their interactions (36 CFR 219.19).

Ecological conditions

The biological and physical environment that can affect the diversity of plant and animal communities, the persistence of native species, and the productive capacity of ecological systems. Ecological conditions include habitat and other influences on species and the environment. Examples of ecological conditions include the abundance and distribution of aquatic and terrestrial habitats, connectivity, roads and other structural developments, human uses, and invasive species (36 CFR 219.19).

Ecological integrity

The quality or condition of an ecosystem when its dominant ecological characteristics (for example, composition, structure, function, connectivity, and species composition and diversity) occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence (36 CFR 219.19).

Ecosystem

(36 CFR 219.19) A spatially explicit, relatively homogeneous unit of the Earth that includes all interacting organisms and elements of the abiotic environment within its boundaries. An ecosystem is commonly described in terms of its:

1. Composition. The biological elements within the different levels of biological organization, from genes and species to communities and ecosystems.

2. Structure. The organization and physical arrangement of biological elements such as, snags and down woody debris, vertical and horizontal distribution of vegetation, stream habitat complexity, landscape pattern, and connectivity.

3. Function. Ecological processes that sustain composition and structure, such as energy flow, nutrient cycling and retention, soil development and retention, predation and herbivory, and natural disturbances such as wind, fire, and floods.

4. Connectivity. See connectivity above.

Ecosystem diversity

The variety and relative extent of ecosystems (36 CFR 219.19).

Ecosystem services. Benefits people obtain from ecosystems, including:

1. Provisioning services, such as clean air and fresh water, energy, food, fuel, forage, wood products or fiber, and minerals;

2. Regulating services, such as long-term storage of carbon; climate regulation; water filtration, purification, and storage; soil stabilization; flood and drought control; and disease regulation;

3. Supporting services, such as pollination, seed dispersal, soil formation, and nutrient cycling; and

4. Cultural services, such as educational, aesthetic, spiritual, and cultural heritage values, recreational experiences, and tourism opportunities.

Even-aged stand

A stand of trees composed of a single age class (36 CFR 219.19).

Inherent capability of the plan area.

The ecological capacity or ecological potential of an area characterized by the interrelationship of its physical elements, its climatic regime, and natural disturbances (36 CFR 219.19).

Integrated resource management

Multiple use management that recognizes the interdependence of ecological resources and is based on the need for integrated consideration of ecological, social, and economic factors (36 CFR 219.19).

Karst

A type of topography that develops in areas underlain by soluble rocks, primarily limestone. Dissolution of the subsurface strata results in areas of well-developed, surface drainage that are sinkholes, collapsed channels, or caves.

Key ecosystem services

Ecosystem services provided by the plan area that are important in the broader landscape outside the plan area and are likely to be influenced by the land management plan.

Landscape

A defined area irrespective of ownership or other artificial boundaries, such as a spatial mosaic of terrestrial and aquatic ecosystems, landforms, and plant communities, repeated in similar form throughout such a defined area (36 CFR 219.19).

Maintain

In reference to an ecological condition: To keep in existence or continuance of the desired ecological condition in terms of its desired composition, structure, and processes. Depending upon the circumstance, ecological conditions may be maintained by active or passive management or both (36 CFR 219.19).

Mitigate

To avoid, minimize, rectify, reduce, or compensate the adverse environmental impacts associated with an action.

Monitoring

A systematic process of collecting information to evaluate effects of actions or changes in conditions or relationships (36 CFR 219.19).

Native species

An organism that was historically or is present in a particular ecosystem as a result of natural migratory or evolutionary processes and not as a result of an accidental or deliberate introduction into that ecosystem. An organism's presence and evolution (adaptation) in an area are determined by climate, soil, and other biotic and abiotic factors (36 CFR 219.19).

Natural range of variation (NRV)

The variation of ecological characteristics and processes over scales of time and space that are appropriate for a given management application. In contrast to the generality of historical ecology, the NRV concept focuses on a distilled subset of past ecological knowledge developed for use by resource managers; it represents an explicit effort to incorporate a past perspective into management and conservation decisions (adapted from Weins, J.A. et al., 2012). The pre-European influenced reference period considered should be sufficiently long, often several centuries, to include the full range of variation produced by dominant natural disturbance regimes such as fire and flooding and should also include short-term variation and cycles in climate. The NRV is a tool for assessing the ecological integrity and does not necessarily constitute a management target or desired condition. The NRV can help identify key structural, functional, compositional, and connectivity characteristics, for which plan components may be important for either maintenance or restoration of such ecological conditions.

Palustrine

Pertaining to low velocity, ponded environments. Examples are backwater sloughs, swamps, bogs, and muskeg ponds, as well as their outlet streams or any ponded environment. "Ponded" describes a condition in which free water covers the soil surface and is removed only by percolation, evaporation, or transpiration (USDA 2016a).

Productivity

The capacity of NFS lands and their ecological systems to provide the various renewable resources in certain amounts in perpetuity. For the purposes of the land management planning regulation at 36 CFR part 219 and this Handbook, productivity is an ecological term, not an economic term (36 CFR 219.19).

Resilience

The ability of an ecosystem and its component parts to absorb, or recover from the effects of disturbances through preservation, restoration, or improvement of its essential structures and functions and redundancy of ecological patterns across the landscape.

Restoration, ecological

The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Ecological restoration focuses on reestablishing the composition, structure, pattern, and ecological processes necessary to facilitate terrestrial and aquatic ecosystems sustainability, resilience, and health under current and future conditions (36 CFR 219.19).

Restoration, functional

Restoration of abiotic and biotic processes in degraded ecosystems. Functional restoration focuses on the underlying processes that may be degraded, regardless of the structural condition of the ecosystem. Functionally restored ecosystem may have a different structure and composition than the historical reference condition. As contrasted with ecological restoration that tends to seek historical reference condition, the functional restoration focuses on the dynamic processes that drive structural and compositional patterns. Functional restoration is the manipulation of interactions among process, structure, and composition in a degraded ecosystem to improve its operations. Functional restoration aims to restore functions and improve structures with a long-term goal of restoring interactions between function and structure. It may be, however, that a functionally restored system will look quite different than the reference condition in terms of structure and composition and these disparities cannot be easily corrected because some threshold of degradation has been crossed or the environmental drivers, such as climate, that influenced structural and (especially) compositional development have changed.

Restore

To renew by the process of restoration. See restoration (36 CFR 219.19).

Riparian Areas

Three-dimensional ecotones [the transition zone between two adjoining communities] of interaction that include terrestrial and aquatic ecosystems that extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally

Stressors

For the purposes of the land management planning regulation at 36 CFR part 219 and this Handbook, factors that may directly or indirectly degrade or impair ecosystem composition, structure, or ecological process in a manner that may impair its ecological integrity, such as an invasive species, loss of connectivity, or the disruption of a natural disturbance regime (36 CFR 219.19).

Substantive formal comments

Written comments submitted to, or oral comments recorded by, the Responsible Official or designee during an opportunity for public participation provided during the planning process (sections 219.4 and 219.16), and attributed to the individual or entity providing them. Comments are considered substantive when they are within the scope of the proposal, are specific to the proposal, have a direct relationship to the proposal, and include supporting reasons for the Responsible Official to consider (36 CFR 219.62).

Structure: See Ecosystems

Suitability of lands

A determination that specific lands within a plan area may be used, or not, for various multiple uses or activities, based on the desired conditions applicable to those lands. The suitability of lands determinations need not be made for every use or activity, but every plan must identify those lands that are not suitable for timber production.

Sustainability

The capability to meet the needs of the present generation without compromising the ability of future generations to meet their needs. For the purposes of the land management planning regulation at 36 CFR part 219 and this Handbook ‘‘ecological sustainability’’ refers to the capability of ecosystems to maintain ecological integrity; ‘‘economic sustainability’’ refers to the capability of society to produce and consume or otherwise benefit from goods and services including contributions to jobs and market and nonmarket benefits; and ‘‘social sustainability’’ refers to the capability of society to support the network of relationships, traditions, culture, and activities that connect people to the land and to one another, and support vibrant communities (36 CFR 219.19).

Timber harvest

The removal of trees for wood fiber use and other multiple use purposes (36 CFR 219.19).

Threatened Species

Any species that the Secretary of the Interior or the Secretary of Commerce has determined is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. Threatened species are listed at 50 CFR sections 17.11, 17.12, and 223.102.

Timber production

The purposeful growing, tending, harvesting, and regeneration of regulated crops of trees to be cut into logs, bolts, or other round sections for industrial or consumer use (36 CFR 219.19).

Watershed

A region or land area drained by a single stream, river, or drainage network; a drainage basin (36 CFR 219.19).

Watershed condition

The state of a watershed based on physical and biogeochemical characteristics and processes (36 CFR 219.19).

Wilderness

Any area of land designated by Congress as part of the National Wilderness Preservation System that was established in the Wilderness Act of 1964 (16 U.S.C. 1131–1136) (36 CFR 219.19).