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Coastal Alaska's Forest Resources, 2004–2013: Ten-Year Forest Inventory and Analysis Report

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Technical Editors

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Cover photo: A Forest Inventory and Analysis crew navigates to a plot on Prince of Wales Island in southeast Alaska. Photo by S. Ellison.

Coastal Alaska's Forest Resources, 2004–2013: Ten-Year Forest Inventory and Analysis Report

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Abstract

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This report highlights key findings from the most recent 10-year survey of Forest Inventory and Analysis (FIA) data collected across southeast and south-central Alaska and represents the first full remeasurement of all forest plots in the coastal Alaska inventory unit. Estimates of forest area, stand age, volume, aboveground biomass, and carbon are provided across ownerships, forest types, and species throughout the region. Of the 54 million ac in the inventory unit, approximately 15 million ac (28 percent) were considered forest land, most of which is managed by Tongass National Forest in southeast Alaska. Western hemlock (*Tsuga heterophylla)*, mountain hemlock (*T. mertensiana),* Alaska yellow-cedar (*Callitropsis nootkatensis)*, and Sitka spruce (*Picea sitchensis)* forest types dominate the region, together accounting for 75 percent of total forest area and 86 percent of total aboveground biomass. Understory vegetation was dominated by oval leaf blueberry, rusty menziesia, and bunchberry dogwood, while nonforest areas were dominated by tall and dwarf shrub community types characterized by Sitka alder (*Alnus viridis* ssp. *sinuata*), salmonberry (*Rubus spectabilis*), and sweet gale (*Myrica gale*). Over the 10-year remeasurement cycle (1995–2003 to 2004–2013), net change in forest volume was mostly positive, with the exception of privately owned lands, where timber removals exceeded growth. Among softwood species, only lodgepole pine (*Pinus contorta)* (also known as shore pine) displayed a net loss in biomass, while mountain hemlock, Sitka spruce, western redcedar *(Thuja plicata)*, and all hardwood species exhibited a net increase in biomass. Mortality rate was highest for white spruce (*P. glauca)*, likely driven by a large spruce bark beetle outbreak in the late 1990s. However, white spruce also experienced a higher growth rate than other softwood species, perhaps reflecting a growth release among survivors of the beetle attack. This report serves as an updated version to the forest attribute data summarized by Barrett and Christensen (2011) and provides important insight into forest resources for land managers, industry, and researchers.

Keywords: Biomass, carbon, coastal Alaska, FIA, invasive plants, timber industry, understory vegetation, volume.

Key Forest Inventory and Analysis Statistics, Coastal Alaska, 2004–2013

- Number of forested plots measured by FIA crews (2004–2013): 2,227
- Largest tree (diameter at breast height): 96.6 inches, Sitka spruce
- Tallest tree: 223 ft, Sitka spruce
- Estimated forest area: 15.3 million ac
- Estimated live tree volume: 56.9 billion ft^3
- Estimated boardfoot volume (Scribner rule) on timberland: 141.6 billion ft
- Estimated aboveground dry biomass in live trees: 1.4 billion tons
- Estimated aboveground carbon in live trees: 620 million Mg
- Average annual net increase in biomass: 1.4 million tons per year

Contents

Background

Introduction to Forest Inventory and Analysis

The U.S. Forest Service (USFS) Forest Inventory and Analysis (FIA) program is responsible for monitoring the status and trends of all public and private forests in the United States and U.S.-affiliated Pacific Islands. Established by the McSweeney-McNary Forest Research Act of 1928 with the vision of instituting a national survey to monitor the nation's timber resources, FIA has evolved several times over the program's history. Most recently, the program underwent major restructuring in 1998, guided by the Agriculture Research, Extension, and Education Reform Act (i.e., the Farm Bill). The new legislation mandated that 20 percent of all plots be measured annually in every state using a nationally standardized set of core measurements, with statewide summaries reported no more than every 5 years. Western states were later granted an exemption and implemented a 10 percent sampling rate owing to the additional cost associated with the remoteness and ruggedness of the region (particularly coastal Alaska). With a spatially and temporally robust sampling design, FIA provides land managers, researchers, and the general public with detailed estimates of forest resources with the goal of advanced understanding of forest ecology and improving resource management strategies.

Forest Inventory and Analysis in Coastal Alaska

Alaska's forests extend from the Brooks Range in the north to the rainforests of southeast Alaska—a range of nearly 13 degrees of latitude. Owing to the complexity of implementing an annual inventory cycle throughout the vast and diverse forests in Alaska, the statewide FIA program has been separated into interior and coastal inventory units. The interior units primarily consist of boreal forest land between the Brooks and Chugach Ranges and from the Canadian border to the broad Yukon-Kuskokwim River delta. The coastal inventory unit encompasses the forests of the southern portion of the state, stretching nearly 1,200 mi from Kodiak Island to the Canadian border in southeast Alaska (fig. 1). For the purposes of this report, coastal Alaska refers to lands within the inventory unit boundary and not the entire geographic shoreline of Alaska.

The forests of south-central and southeast Alaska are an important source of cultural, economic, ecological, and aesthetic value to the region. Alaska Natives have lived in the region for more than 10,000 years, establishing a rich and diverse culture that is intimately linked with the land (Dixon et al. 1997). The large tree species and productive forests have supported a timber industry for more than 100 years, providing lumber and fuelwood around the world.

Common FIA Terminology

What is a tree?

The U.S. Forest Service defines a tree as a woody perennial plant, usually with a single well-defined stem carrying a crown, with a minimum height of 15 ft at maturity. Tally trees are all live and standing dead trees (snags) in accessible forest land or measurable nonforest land condition classes.

What is a snag?

The term "snag" is synonymous with "standing dead tree." To qualify as a snag, dead trees must be at least 5.0 inches in diameter at breast height, have a bole that has an unbroken actual length of at least 4.5 ft, and lean less than 45 degrees from vertical.

What is a forest?

Forests come in many shapes and sizes, varying from complex and species diverse to monoculture plantations. For most data summarized in this report, the FIA program defines a forest as currently or formerly (within 30 years) at least 10 percent stocked by trees of any size and not currently developed for nonforest use. Forests must be at least 1 ac in size with a minimum width of 120 ft. A modified definition was adopted in 2012 that defines forest as at least 10 percent canopy cover (instead of stocking).

What is a forest type?

Most forests contain multiple tree species but are grouped into a single forest type. Forest type usually describes the species with the plurality of non-overtopped live trees (Example: Sitka spruce or aspen forest type).

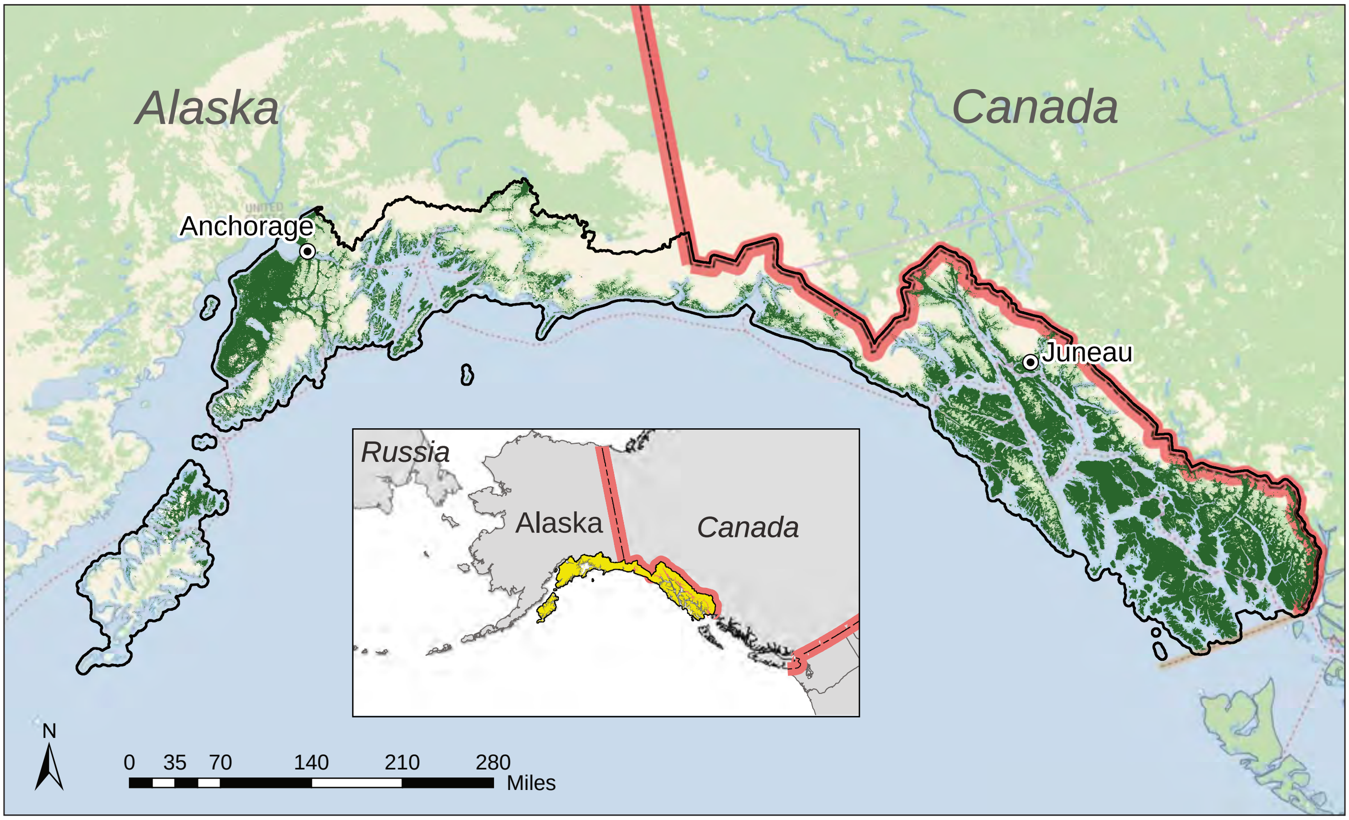

Figure 1—The coastal inventory unit (black outline; yellow shading in inset) with estimated forest land in green.

The majestic fjords and old-growth forests continue to draw thousands of visitors to Chugach and Tongass National Forests, also providing a revenue source for local communities. World-class opportunities for wildlife viewing, hunting, and recreation are abundant throughout the region. The forests of coastal Alaska are also intricately linked with anadromous salmon and the commercial fishery that depends on a productive population. The tall, complex canopy created by streamside trees and shrubs provides shade that moderates stream temperature, influencing growth and embryo development (Brett 1995) and the timing of life history events such as spawning, foraging, and smolting (Fraser et al. 1993, Quinn 2005). Forests also contribute down woody material to stream channels, which alters the structural characteristics of salmon habitat by slowing water velocity, enabling easier upstream travel by adults, and increasing the quality of spawning habitat (Harmon et al. 1986). In return, the annual influx of salmon provides a major source of marine-derived nitrogen in the form of salmon carcasses to riparian plants, stimulating growth among nutrient-limited species (Gende et al. 2002, Helfield and Naiman 2001) and creating a tightly coupled feedback loop between salmon and forest productivity. In short, the forest ecosystems in coastal Alaska offer unique opportunities and benefits to a wide array of users and reveal the complexity of managing and researching forest resources in the region.

The coastal inventory unit is uniquely positioned across two distinct ecological provinces, representing six ecological sections (fig. 2). Ecological sections (ecosections) are large ecosystems distinguished by common geography, climate, vegetation, and disturbance regimes across the landscape and comprise more broadly defined ecological provinces (Nowacki et al. 2002). Most of the inventory unit falls within the Coastal Rainforest Ecological Province, with the exception of plots located on the western Kenai Peninsula where the Cook Inlet Basin ecosection represents the Alaska Range Transition Province. Ecosections within the Coastal Rainforest Province are broadly characterized by relatively warm annual temperatures and high annual precipitation, whereas ecosections within the Alaska Range Transition Province are cooler and much drier in comparison (fig. 3). The difference in climate between

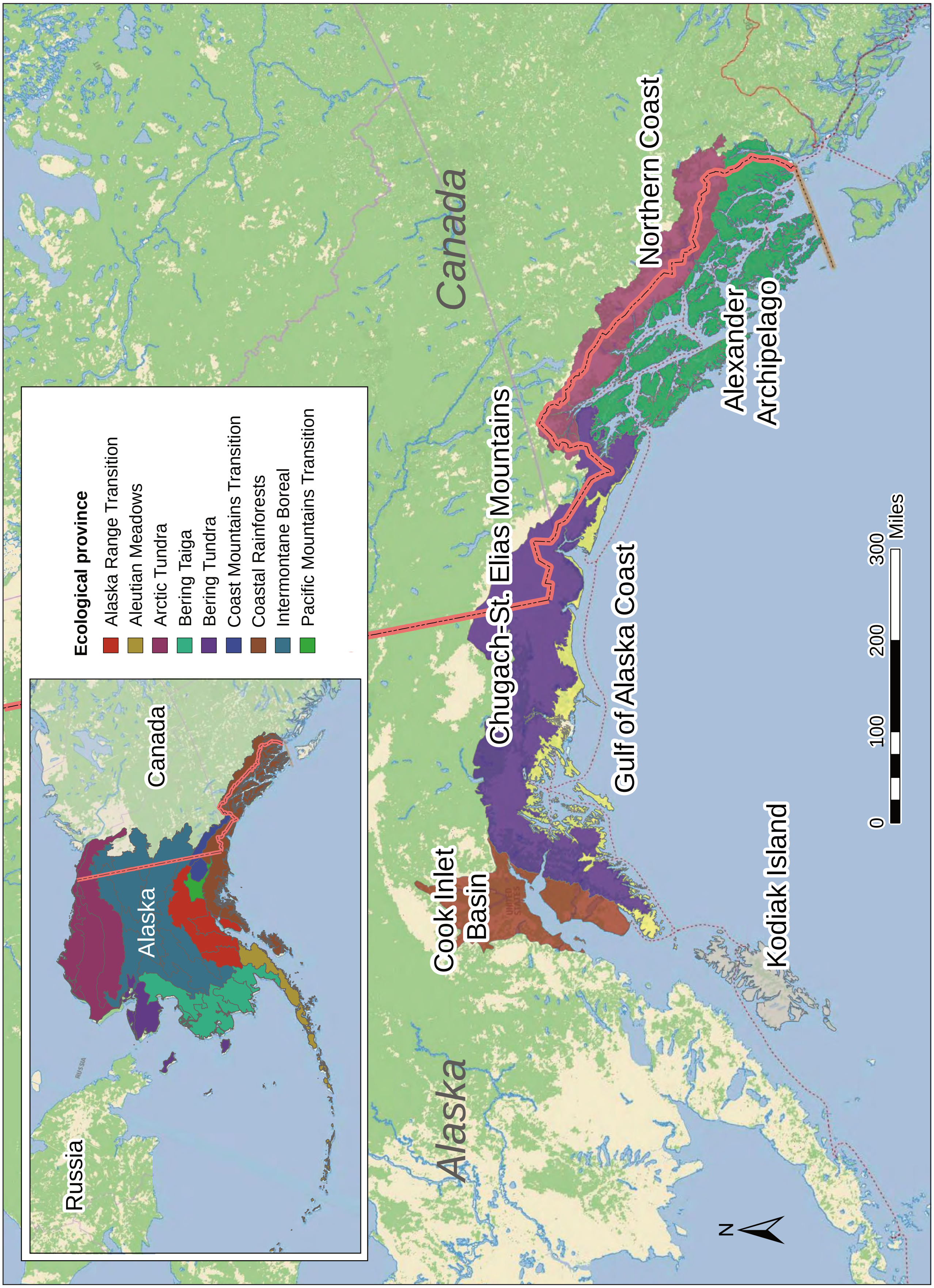

Figure 2—Ecological sections (ecosections) within the coastal inventory unit. The inset map shows the broader ecological provinces throughout Alaska.

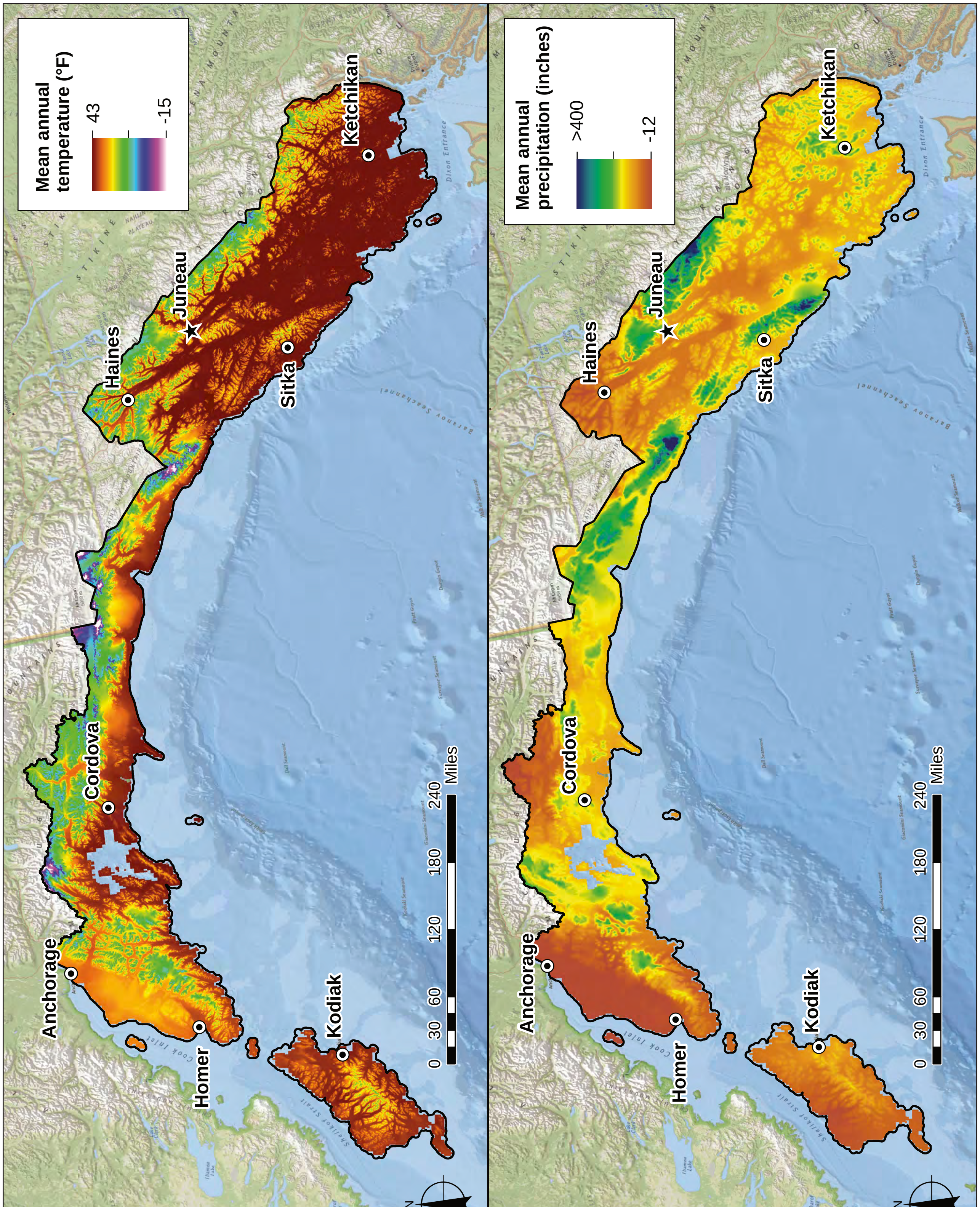

Figure 3—(A) Mean annual temperature and (B) mean annual precipitation for the climate normal period 1981–2010. Data were obtained through the PRISM Climate Group, Oregon State University (http://prism.oregonstate.edu) using a high-resolution digital elevation model and monthly gridded climate data to provide locally downscaled climate normal surfaces (Daly et al. 2008).

provinces is an important driver of plant community composition, disturbance, and growth. The climate of the Coastal Rainforest Province supports extensive old-growth forests dominated by western hemlock (*Tsuga heterophylla)*, Alaska yellow-cedar (*Callitropsis nootkatensis),* Sitka spruce (*Picea sitchensis)*, and mountain hemlock (*T. mertensiana)* at higher elevations (fig. 4). In contrast, the western Kenai Peninsula lies in the transition zone between the coastal rainforest and boreal forest, where conditions are more favorable for aspen (*Populus tremuloides)*, paper birch (*Betula neoalaskana)*, white spruce (*Picea glauca),* and black spruce (*P. mariana)*—species that dominate the vast forests of interior Alaska.

Annual FIA measurements were implemented in coastal Alaska in 2004 at a resolution of one plot installed every 6,000 ac, per FIA protocol. Prior to 2004, a periodic inventory was completed throughout the region, beginning in 1995. Aligning periodic and annual inventory data to detect change in Alaska's forests represents a major challenge because of sampling and protocol changes. For example, annual plots in coastal Alaska were allocated to each of 10 measurement years by selecting them at random from within hexagons across the entire sampling area, whereas periodic plots were installed beginning in southeast Alaska in 1995 and gradually extended to the south-central region in 2003. Additionally, definitions for forest and tree have evolved and the location of the microplot (where saplings 1 to 5 inches in diameter at breast height [d.b.h.] are measured) was relocated away from subplot center to minimize trampling in the annual inventory. These differences were reconciled by limiting analyses of change to plots that were forested at both time periods and trees that were larger

Figure 4—(A) Forest Inventory and Analysis crews battle steep terrain and (B) sometimes encounter unusual trees while collecting data in coastal Alaska.

than 5 inches d.b.h. at the time of initial measurement. The result includes remeasurement data from 2,023 plots and represents the most recent comprehensive analysis of changes in forest volume and biomass throughout southeast and south-central Alaska.

In addition to the remeasurement analysis, this report summarizes data collected from 2,535 plots located throughout the coastal inventory unit during the 2004–2013 field seasons (table 1). Of the plots visited by an FIA crew, 2,227 had at least one accessible forest land condition present on the plot (fig. 5). The remainder of the visited plots were wholly nonforest on national forest lands, which were measured to support management planning. Estimates provided here represent a revised assessment of forest trends and status for the region (e.g., Barrett and Christensen 2011) for the period 2004 through 2013. Importantly, FIA has never inventoried plots within Glacier Bay National Park and, with the exception of 2005, FIA has not sampled land within wilderness and wilderness study areas in the Tongass and Chugach National Forests to preserve the wild nature of these areas. In

Table 1—Total number of accessible, inaccessible, and field-sampled plots, coastal Alaska, 2004–2013

Plots	Number
Accessible:	
Forest land	2,227
Nonforest land	5,862
Total	8,089
Inaccessible:	
Denied access	23
Hazardous	46
Skipped	16
Other	1,193
Total	1,278
Field sampled plots:	
Forest	2,227
Nonforest	308
Total	2,535

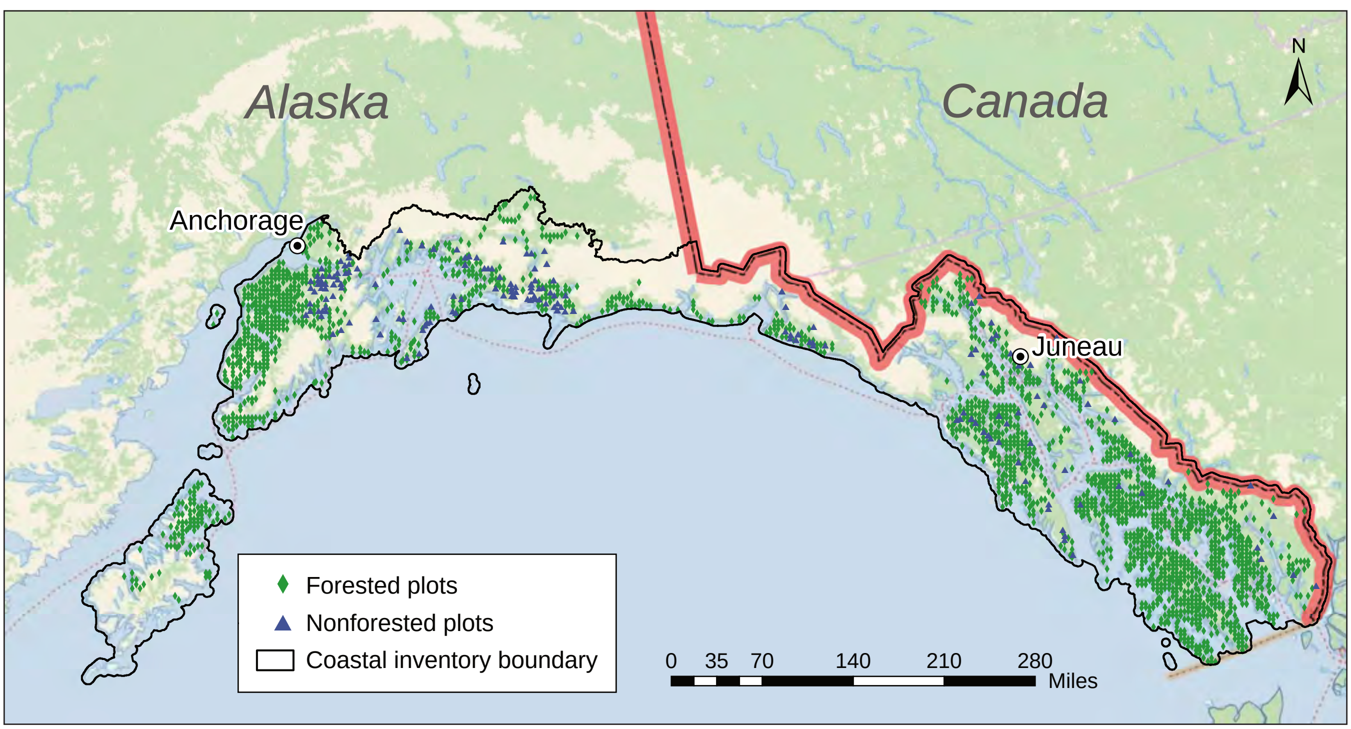

Figure 5—Approximate plot locations for forest and nonforest plots in coastal Alaska, 2004–2013. The inventory boundary is outlined in black. Areas without symbols represent glaciated regions or locations where Forest Inventory and Analysis has been denied access.

total, approximately 7.7 million ac were excluded from sampling, representing roughly 25 percent of the land area within the coastal inventory unit boundary. Thus, estimates of change (i.e., growth, removals, and mortality) do not include data from inventories conducted on these lands. Additionally, the reduced sample size in USFS wilderness and wilderness study area lands creates greater sampling error of current forest attributes (e.g., composition, volume, biomass, etc.) for estimates that include those areas. Summary statistics were generated using the methods of Bechtold and Patterson (2005) and are compiled in a series of tables in appendix 1 (https://www.fs.fed.us/pnw/pubs/pnw_gtr979-supplement1.pdf) and in appendix 2 (https://www.fs.fed.us/pnw/pubs/pnw_gtr979-supplement2.pdf). Data collection methods and analysis for forest and nonforest plots can be found in appendix 3 and online at https://www.fs.fed.us/pnw/rma/fia-topics/documentation/field-manuals/index.php.

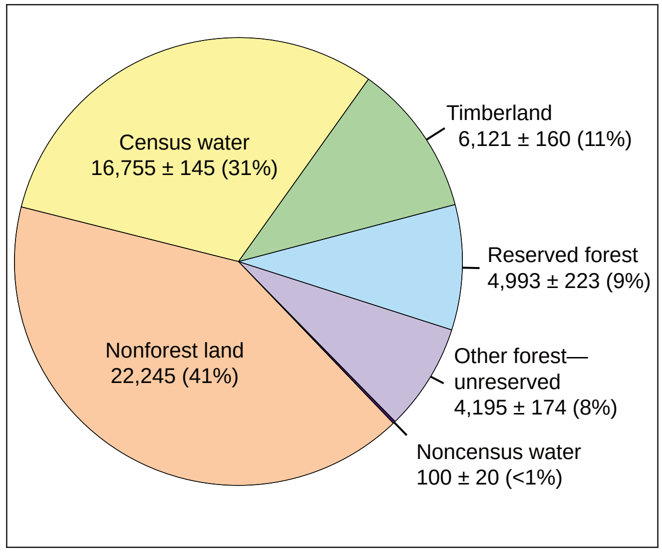

Figure 6—Area of land and water by land status in the coastal Alaska inventory unit, 2004–2013. Values are in thousand acres (±1 standard error) and percentage of total acres.

Forest Resources of Coastal Alaska

Forest Area

Much of south-central and southeast Alaska is characterized by vast glaciers, tall peaks, narrow fjords, and steep terrain, with dense forests and understory vegetation carpeting the lower elevations. Indeed, most of the area in coastal Alaska is defined by FIA as nonforest and census water (fig. 6). Of the 54.4 million ac in the coastal inventory unit (including noncensus and census water), forest land covers approximately 15.3 million ac and is divided almost evenly among timberland, other forest land, and reserved forest land (see sidebar for definitions). Forest land is predominantly located in southeast Alaska (~11 million ac; 72 percent of the coastal inventory unit), with 3.0 (± 0.16) million ac found in the Prince of Wales–Hyder Census Area. The Kenai Peninsula Borough contains a majority of forest land in south-central Alaska (~2.2 ± 0.07 million ac), followed by the Valdez-Cordova Census Area (~1.3 ± 0.16 million ac). Across the entire inventory unit, in total 8.9 (± 0.27) million ac are considered timberland or productive reserved forests (capable of producing >20 ft^3 of wood per acre per year at culmination of mean annual increment). The majority (~71 percent) of forest land in the inventory unit is under USFS management (fig.

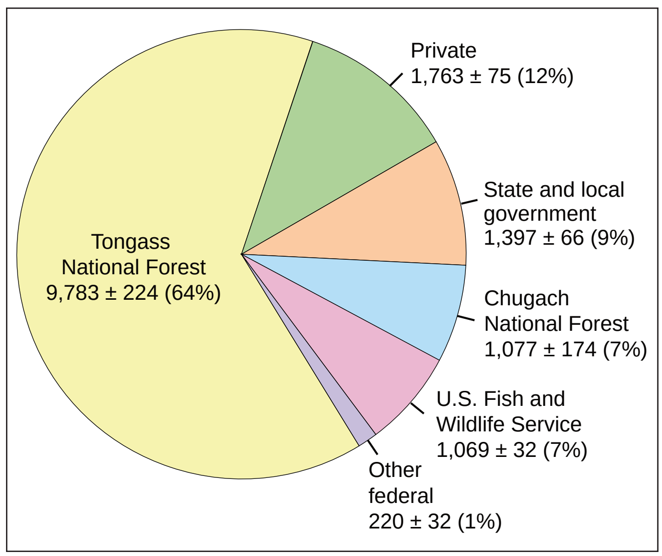

Figure 7—Forest area by ownership in the coastal Alaska inventory unit, 2004–2013. Values are thousands of acres (±1 standard error) and percentage of total forest land.

7), followed by private owners (1.8 ± 0.07 million ac; ~12 percent), state and local governments (1.4 ± 0.06 million ac; ~9 percent) and other federal agencies (1.3 ± 0.05 million ac; ~8 percent). The U.S. Fish and Wildlife Service manages about 1 million ac of forest land, primarily within the Kenai National Wildlife Refuge (fig. 8). Land managed

What Are the Differences Among Timberland, Other Forest Land, and Reserved Forest Land?

Forests can be classified into three main categories based on their productivity and level of management:

- Timberland is unreserved forested land producing or capable of producing at least 20 ft^3 of wood per acre per year.
- Other forest land is less productive (not capable of producing 20 ft^3 of wood per acre per year).
- Reserved forest is permanently protected from management for the production of wood products through statute. Examples include national parks, wilderness areas, and state parks. Timber harvest can occur in some areas for habitat or recreational purposes, but is incidental.

by the USFS includes the Tongass National Forest in southeast Alaska (9.8 ± 0.2 million ac; 64 percent) and Chugach National Forest in south-central Alaska (1.1 ± 0.2 million ac; 7 percent). These are the largest and second largest national forests in the nation, respectively. Thus, much of the forest land in coastal Alaska can be found in one of two national forests. See sections "Alaska's National Forests" and "U.S. Fish and Wildlife Service Forest Resources" below for more details about the forest attributes of these areas.

Forest Composition

Coniferous (softwood) forest types covered the largest share of forested area in coastal Alaska (13.9 ± 0.2 million ac; ~91 percent), while deciduous (hardwood) forest types accounted for just over 1 million ac (fig. 9). The two hemlock forest types (western hemlock and mountain hemlock) dominated the inventory unit, followed by Alaska

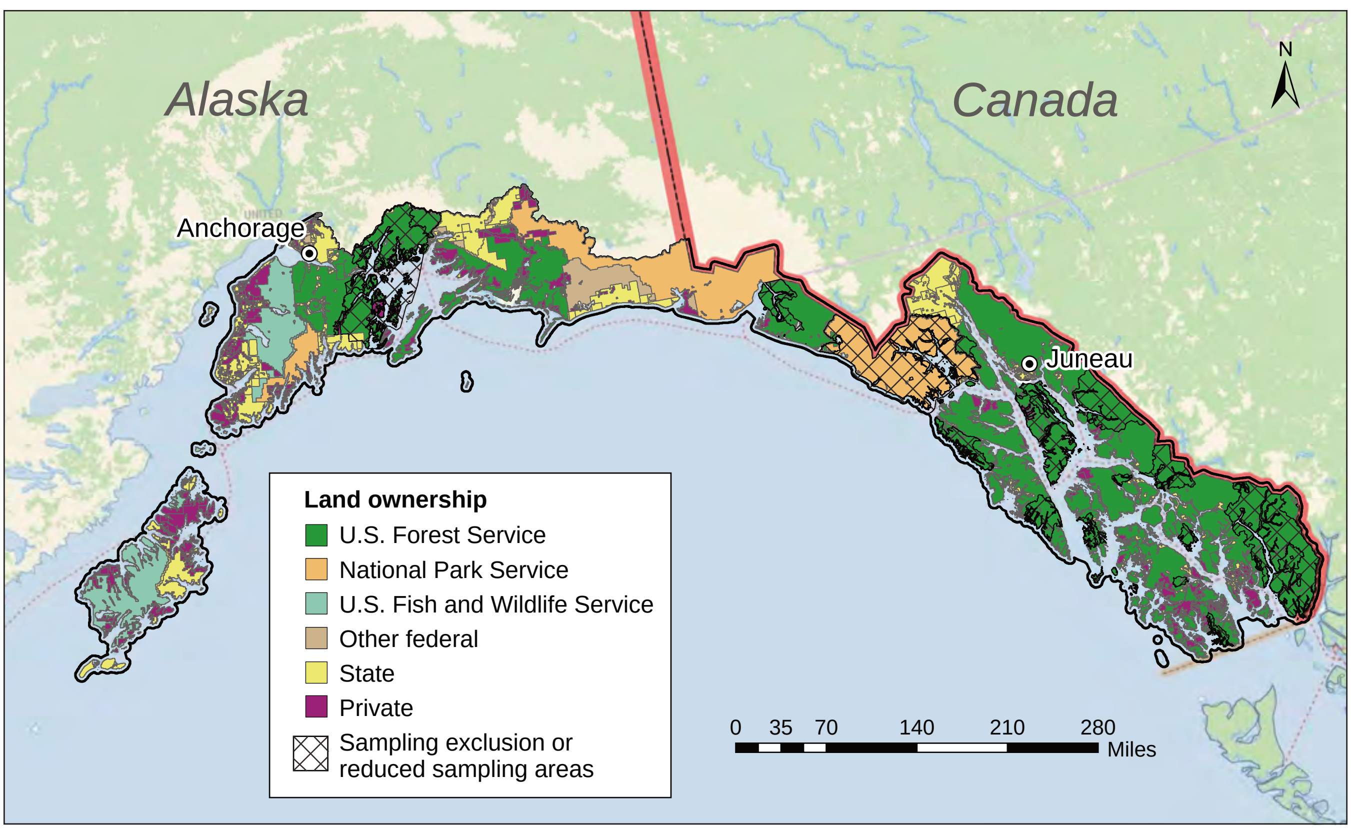

Figure 8—Land ownership throughout the coastal Alaska inventory unit. Private landowners include individuals and corporate entities. Cross-hatched areas represent portions of the region where Forest Inventory and Analysis has been denied access for all or a portion of the 2004–2013 measurement period.

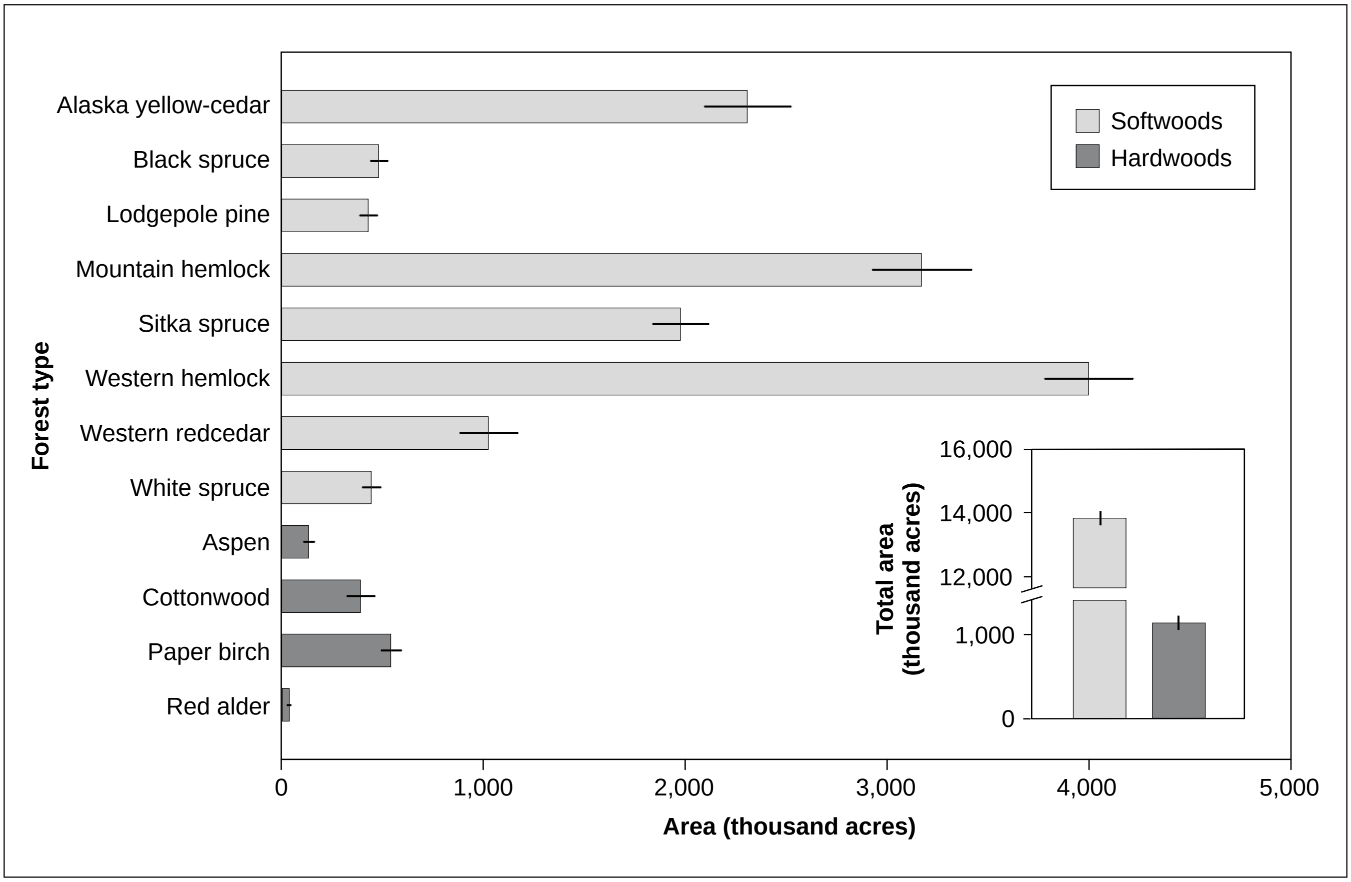

Figure 9—Area of forest land among forest types in the coastal Alaska inventory unit, 2004–2013. Inset shows total forest area for the broad forest types (softwood and hardwood). Note break in the y axis of inset graph. Bars represent the mean, and error bars are ±1 standard error.

yellow-cedar and Sitka spruce. Together, these four forest types accounted for about 75 percent of total forest area throughout the entire inventory unit. There were sharp differences in forest composition among ecological sections. Western hemlock and Alaska yellow-cedar dominated the Alexander Archipelago ecological section—the southernmost ecosection—but were found in much lower abundance or completely absent in the northern ecosections Cook Inlet Basin and Chugach–St. Elias (fig. 10), although Alaska yellow-cedar has been noted in small areas of Prince William Sound (Harris 1990). Additionally, western redcedar (*Thuja plicata)* and lodgepole pine, also known as shore pine (*Pinus contorta)*, were limited to the Alexander Archipelago ecosection. In contrast, mountain hemlock (fig. 11) and Sitka spruce forest types can be found in many of the ecosections in coastal Alaska, reflecting the broad geographic range of these species. The Cook Inlet Basin ecosection represents the southern transition to Alaska's boreal forest and is dominated by a mixture of black and white spruce forest types along with aspen and paper birch, species that are poorly represented in ecosections outside the Alaska Range Transition Province. Importantly, estimates of forest composition in Cook Inlet Basin were limited to plots located on the western Kenai Peninsula and do not include the Susitna River basin. Data collected from this region will be included in FIA plot production as part of the Susitna–Copper Interior inventory unit beginning in 2019. These data will be used to update ecosection summaries in subsequent reports.

Coastal Alaska softwood forest types displayed a distinctly older age distribution, particularly among the dominant forest types, Alaska yellow-cedar, mountain

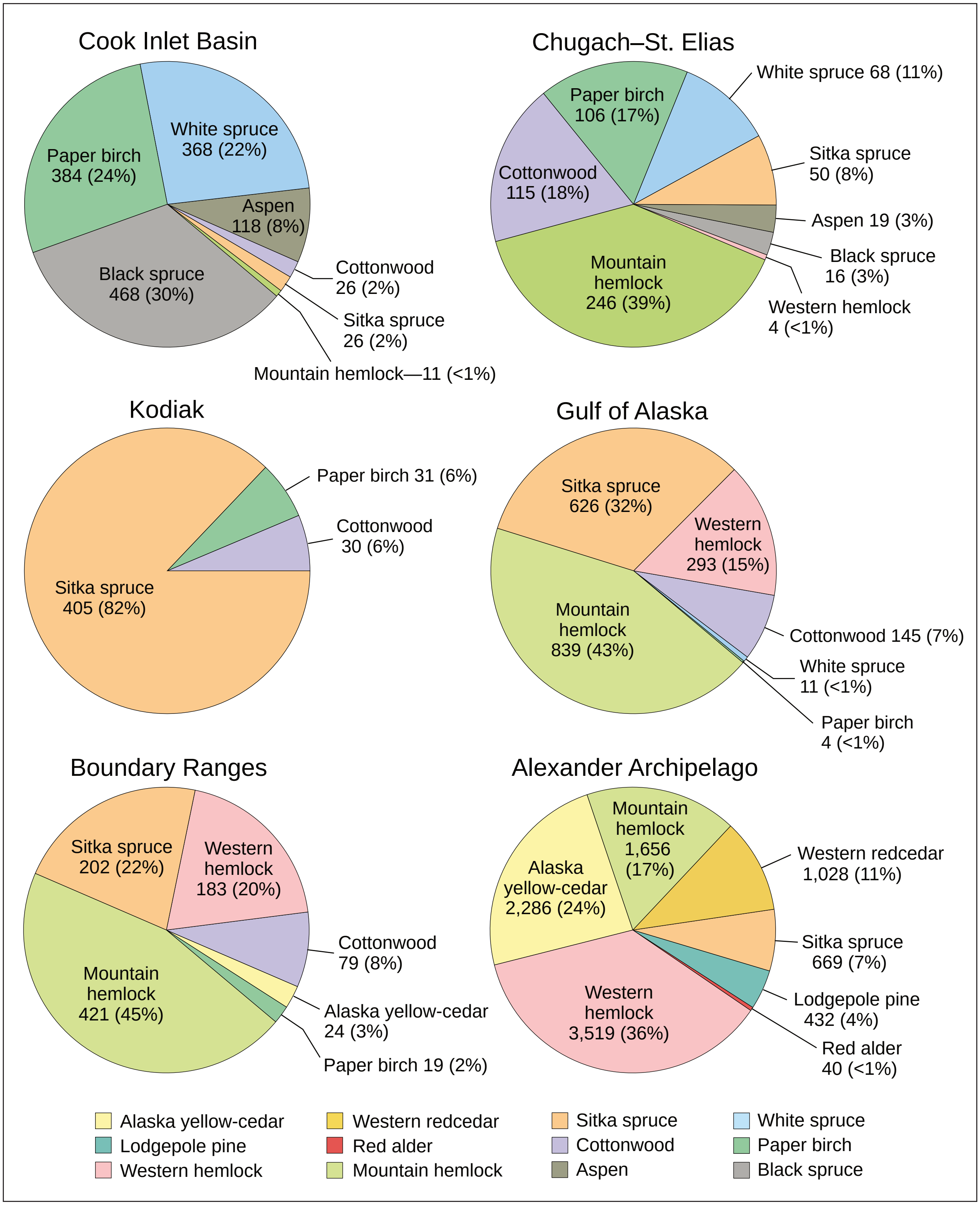

Figure 10—Area of forest land by forest type within each ecosection found in the coastal Alaska inventory unit. Values represent the mean and percentage of total forest area within each ecosection.

S. Ellison

Figure 11—A Forest Inventory and Analysis field crew installs a plot within a mountain hemlock forest on Prince of Wales Island in the southern portion of the Tongass National Forest.

hemlock, Sitka spruce, and western hemlock (fig. 12). A majority of these species were at least 200 years old and are typical of old-growth, primary forests. The advanced age of the most common softwood forests also represents the lack of widespread and recurring stand-replacing fire events owing to the cool maritime climate. Windthrow is the dominant disturbance in southeast Alaska forests, the scale and severity of which are influenced by landscape patterns, forest age, and structure (Kramer et al. 2001). This contrasts with forest types that characterize the Kenai Peninsula in south-central Alaska, where a majority of black and white spruce forests are less than 100 years old and have been subject to widespread, repeated disturbance events such as fire and spruce bark beetle (*Dendroctonus rufipennis* Kirby) outbreaks (Berg and Anderson 2006, Berg et al. 2006). Depending on the timing and severity of fire damage, this type of disturbance tends to promote the initial establishment and growth of grasses (e.g., *Calamagrostis*) and hardwood forest types (e.g., aspen and birch) by providing additional light to these shade-intolerant species and a seedbed favorable for germination (Johnstone et al. 2004). In general, hardwood forests are much younger than most coniferous forests, which likely reflects these species' life history of higher growth rates and shorter lifespans.

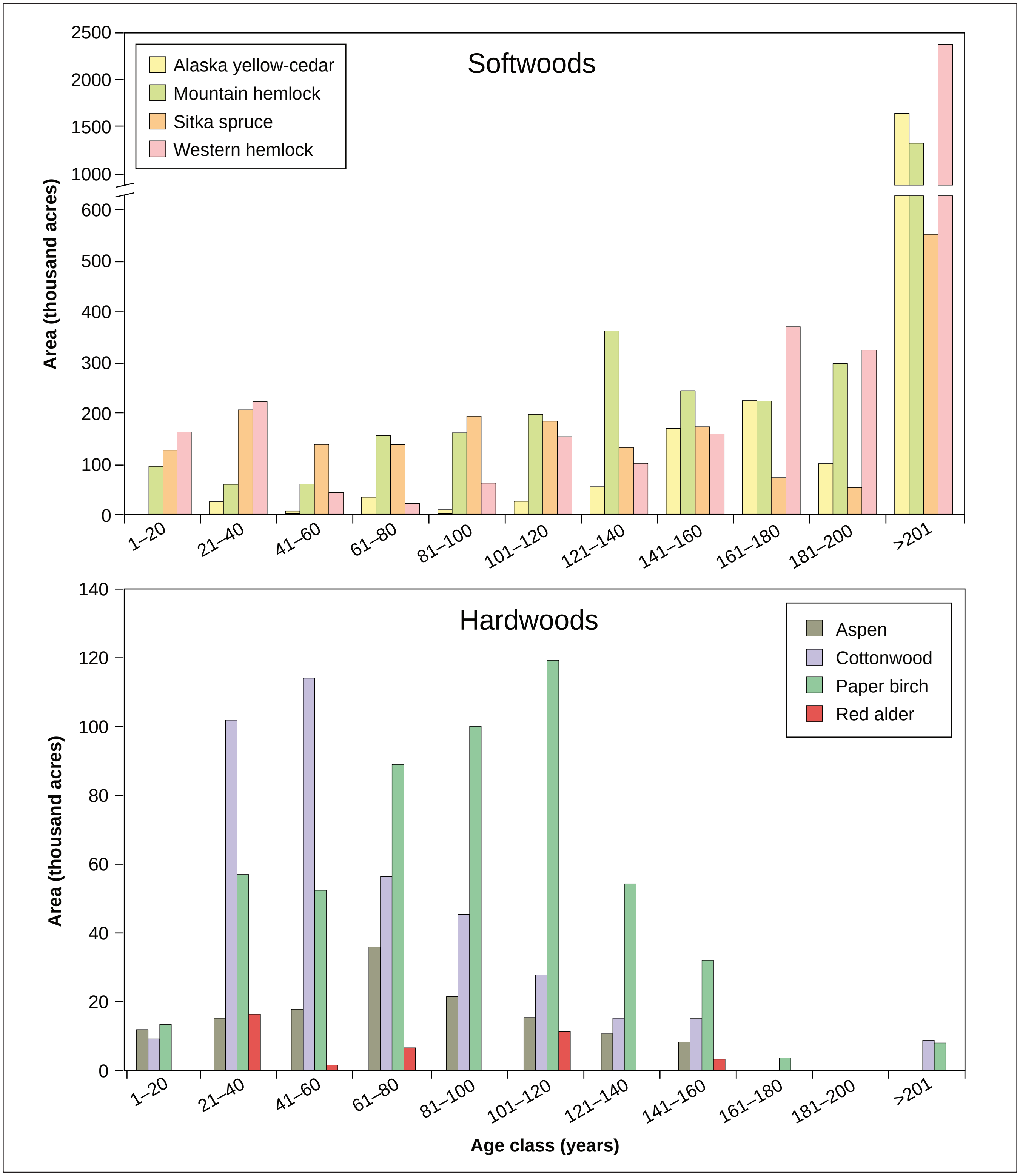

Figure 12—Area of forest types within 20-year age classifications for the four most abundant (by area) softwood and hardwood forest types in coastal Alaska, 2004–2013. See table A1-5 for a complete list of forest types. Note the difference in scale between softwood and hardwoods. Vertical bars represent the mean. Error bars have been omitted for clarity.

Forest Health Conditions Throughout Coastal Alaska[1]

Spruce aphids (*Elatobium abietinum* Walker) are non-native insects and the most common pest detected in southeast Alaska, with a range that has expanded in the coastal forest from 1998 to 2013 (figs. 13 and 14). Spruce aphid damage was detected by aerial survey in 2005 in Prince William Sound but not noticed there again until 2016. Spruce aphid was first found on the Kenai Peninsula in 2007 but not again until 2015, when a severe outbreak began. Populations are limited by cold winter temperatures and may continue to expand in range with a warming climate. Typically, aphid feeding in coastal environments results in decreased growth and vigor but rarely causes mortality.

Spruce bark beetle (*Dendroctonus rufipennis* Kirby) is considered one of the most destructive pests in Alaskan forests, but causes less mortality in coastal forests than in drier inland forests. Spruce bark beetle can attack standing trees in response to a disturbance (such as windthrow or landslides) or if the environmental conditions are ideal (a drier summer). In southeast Alaska, areas of spruce bark beetle damage are typically limited to small pockets of 100 ac or less. Notably higher spruce bark beetle activity occurred in 2008, with damage detected between Haines-Skagway and Petersburg. The Kenai Peninsula experienced a massive spruce bark beetle outbreak during the 1990s that spanned 1.2 million ac and affected about 50 percent of the forested land. Following the outbreak, spruce bark beetle activity decreased substantially but remains present. The western balsam bark beetle (*Dryocoetes confusus* Swaine) is active in coastal forests and is responsible for killing subalpine fir (*Abies lasiocarpa*) near Skagway.

The western blackheaded budworm, (*Acleris gloverana* Walsingham) and hemlock sawfly (*Neodiprion tsugae* Middleton) were once considered the most significant forest pests in coastal Alaska. Hemlock sawflies feed on older foliage, whereas western blackheaded budworms feed in the buds and new growth. Outbreaks of these two pests together can result in mortality; however, there has not been a significant outbreak of either since the 1980s. A sizable hemlock sawfly outbreak occurred in 2010 and continued until 2012; about 25,000 ac of defoliation were mapped by aerial survey during this outbreak, with the highest affected acreage south of Mitkof Island. A notable outbreak of western blackheaded budworm occurred in 2007 with 1,400 ac mapped in Prince William Sound.

Two nonnative insects became established in coastal Alaska between 2004 and 2013. The green alder sawfly (*Monsoma pulveratum* Retzius) was found in Sitka in 2013 and has been found feeding on red alder (*Alnus rubra)* throughout southeast Alaska. The European yellow underwing (*Noctua pronuba* L.) is a generalist feeder on many agricultural and ornamental plants. It was first found in Haines in 2005 and has been found throughout southeast Alaska, although the impacts of these two nonnative pests in coastal forests have been minimal. The highly invasive Asian gypsy moth (*Lymantria dispar asiatica* Vnukovskij) has been intercepted on vessels coming into southeast Alaska on multiple occasions but thus far has not become established.

Yellow-cedar decline continues to affect trees on low-snow sites, especially the outer coast of Chichagof Island between Peril Strait and Yakobi Island. The decline was observed in young-growth (30 to 40 years old) stands for the first time on Zarembo Island in 2012 and to a lesser extent on Kupreanof, Mitkof, and Wrangell Islands. Thinning on wet sites may increase decline risk by exposing stands to greater soil temperature fluctuation (Hennon et al. 2016).

Hemlock dwarf mistletoe (*Arceuthobium* spp.) and stem decays are leading causes of disease in coastal forests and play important roles in gap dynamics, wildlife habitat, nutrient cycling, and forest structure and composition. Cull studies from the 1950s and 1970s found that about one-third of old-growth timber

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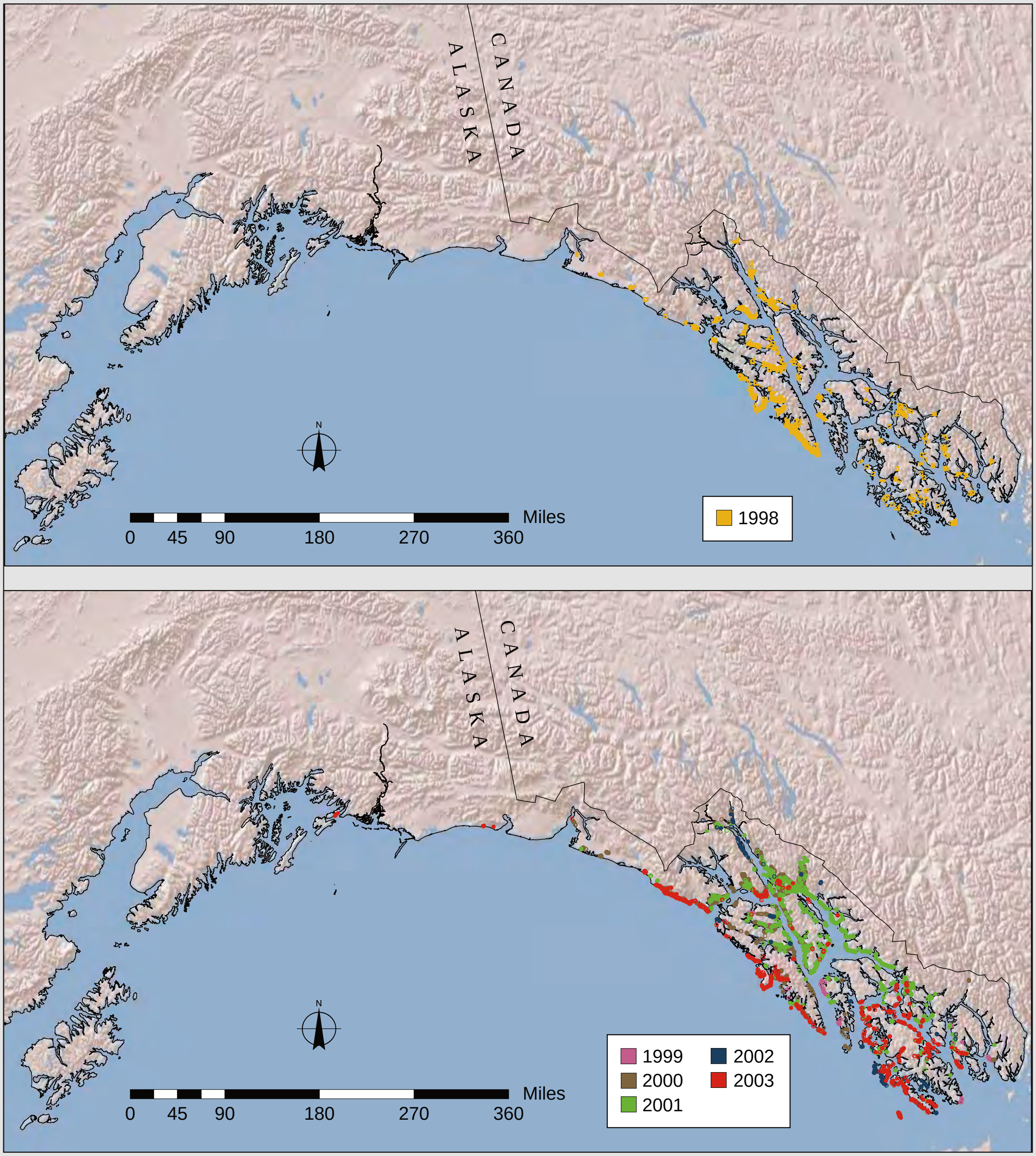

Figure 13—Distribution of spruce aphid damage (A) from 1998 through 2003, and (B) from 2004 through 2016, detected during aerial surveys throughout southeast and south-central Alaska.

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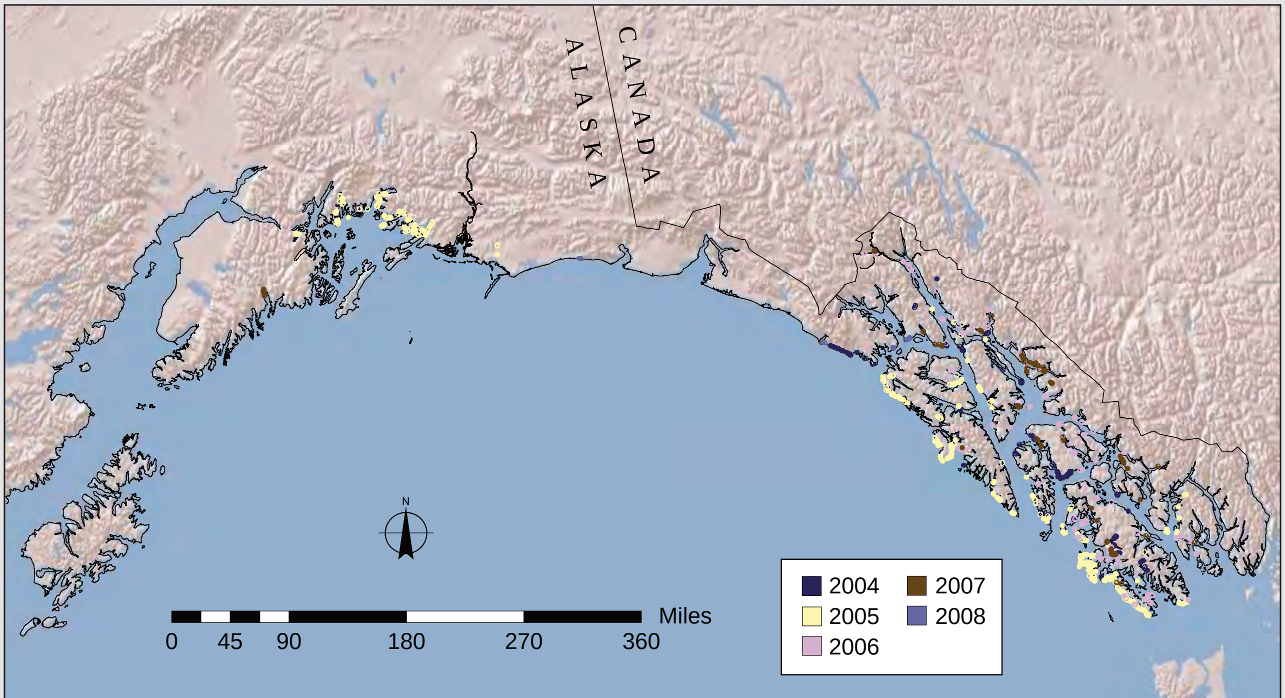

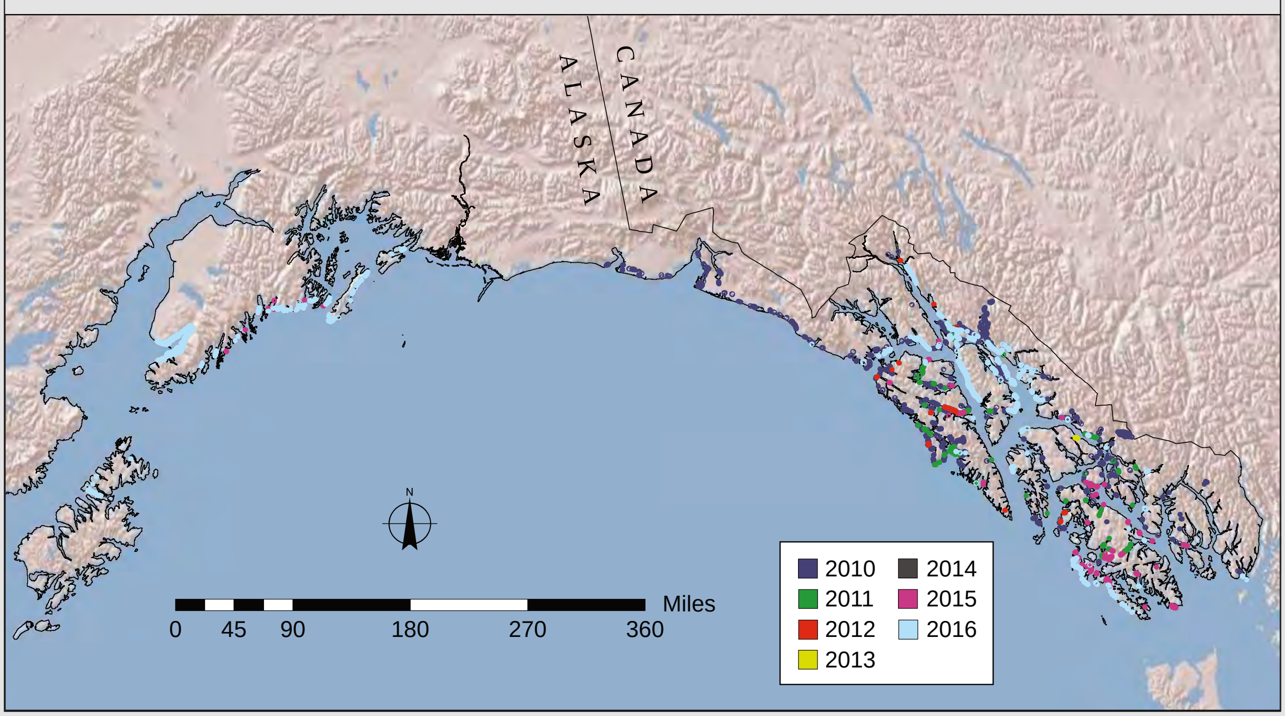

Figure 13—Continued.

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E. Graham

E. Graham

Figure 14—Spruce aphids are the most common pest in southeast Alaska, causing severe defoliation (inset photo).

is defective, mostly from stem decays (Farr et al. 1976, Kimmey 1956). Hemlock canker outbreaks began on Prince of Wales Island in 2011–2012 and have now been mapped along more than 70 mi of roadside forest and other locations throughout southeast Alaska. The outbreak has also caused mortality of crop trees in managed stands near the main outbreak area. Although the causal fungus is under investigation, potential pathogens include *Discocainea treleasei*, *Ophiostoma piceae*, *Pezicula livida*, and *Sirococcus tsugae*.

Dothistroma needle blight is a pine foliage disease that occurs throughout the range of lodgepole pine in Alaska. Around 2009–2010, an outbreak began near Gustavus that has now been mapped on 11,000 cumulative ac and caused significant tree mortality. Severe disease has also been noted near Haines, Klukwan, and Skagway. This native disease has caused unprecedented damage in lodgepole pine plantations in British Columbia since the early 2000s (Woods et al. 2005), with the increase linked to warmer August minimum temperatures and greater spring precipitation (Welsh et al. 2014).

Spruce bud blight, caused by three different fungi (*Gemmamyces piceae*, *Dichomera gemmicola*, and a species of *Camarosporium*), was detected in 2013 on several spruce species on the Kenai Peninsula and has since been detected from Homer to Fairbanks. It is thought to be native to central Asia and represents the first detection in the United States. Research by Forest Service Forest Health Protection scientists and collaborators with the University of Nevada is currently underway to learn more about this disease and its native/nonnative status.

Forest Volume, Biomass, and Carbon

Volume, biomass, and carbon (C) are commonly used to assess forest structure and improve our understanding of forest productivity and ecosystem services. Regional allometric equations for each species in the inventory (see app. 3) are applied to tree height and diameter data collected by FIA field crews (fig. 15). Volume and biomass are then extrapolated across the entire forest, and C is assumed to comprise approximately 50 percent of forest biomass (Chapin et al. 2002, Fahey et al. 2005). Here, total volume, biomass, and C of living and standing dead trees (snags) are summarized for the coastal inventory unit.

Volume—

Total net volume of wood in live trees (≥5 inches d.b.h.) in the inventory unit was nearly 57 billion ft^3, most of which (43.8 ± 1.6 billion ft^3; ~77 percent) was found on land managed by the USFS within Tongass National Forest (fig. 16). Across all ownerships, about 53 percent (30.1 ± 1.1 billion ft^3) was considered timberland, whereas unproductive forests (reserved and unreserved status) accounted for about 23 percent (12.9 ± 1.0 billion ft^3). Among forest types, western hemlock contained the highest total volume and volume of live trees per acre (fig. 17). The next most voluminous forest types per acre were Sitka spruce (5,718 ± 350 ft^3 ac^{-1}) and western redcedar

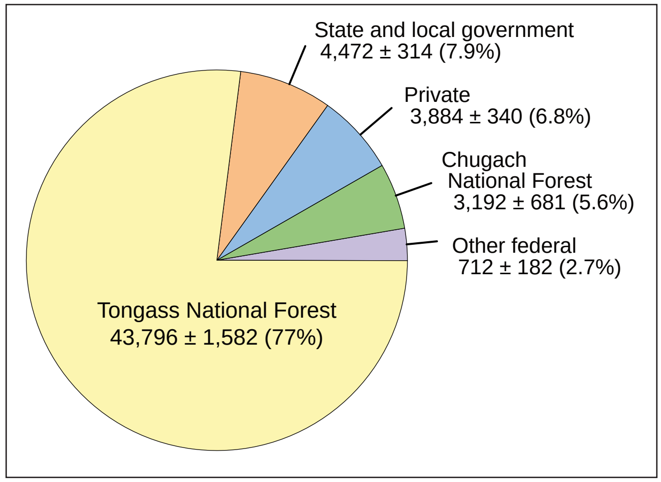

Figure 16—Net volume of live trees across ownership groups. Values are in million cubic feet (±1 standard error) and percentage of total volume.

M. Ausman

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Figure 15—Forest Inventory and Analysis crews measure (A) western redcedar and (B) Sitka spruce in southeast Alaska. Measurements of diameter and height are used to calculate forest volume, biomass, and carbon.

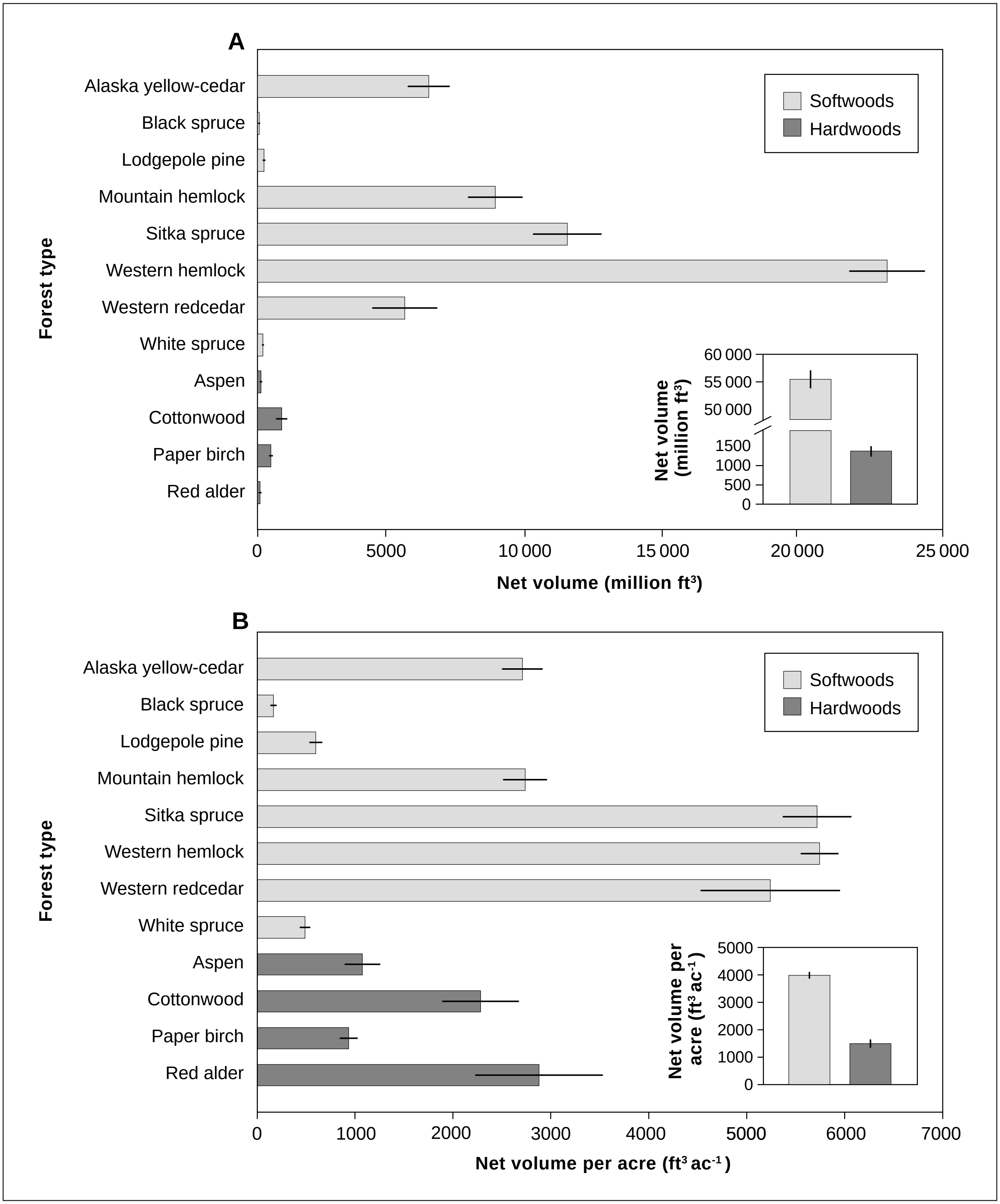

Figure 17—(A) Total net volume and (B) average net volume per acre of live trees (≥1 inch diameter at breast height) across forest types in coastal Alaska. Inset graphs compare softwood and hardwood forest types. Note y axis break in inset graph of panel A. Error bars are ±1 standard error.

(5,240 ± 711 ft^3 ac^{-1}), despite these forests accounting for the fourth and fifth most common forest types by area, respectively (fig. 9). Although the hardwood forest types comprised a very small portion of overall forest volume, all four hardwood forest types had greater average volume of live trees per acre than the generally smaller stature and less productive black spruce and lodgepole pine forests.

Estimates of young-growth volume provide useful insight into coastal Alaska forests that are commercially important as the Forest Service transitions to primarily young-growth timber harvest (USDA FS 2016). Defined here as stands younger than 150 years old (Hutchison 1968), young-growth forests often include the most vigorously growing trees that may be regenerating from previous harvest or site disturbance. Overall, volume of young-growth trees accounted for about 22 percent (12.6 ± 1.1 billion ft^3) of total live tree volume across the inventory unit (fig. 18). Although the total volume of young-growth trees was highest in Tongass National Forest, the **proportion** of net volume of young-growth trees relative to the net volume of all live trees was highest among other federal land managers (about 79 percent), which includes land managed by the Fish and Wildlife Service on the Kenai Peninsula. This region experienced widespread mortality from fire and spruce beetle in recent decades and now appears to be dominated by regeneration of a younger cohort of individuals. Young-growth volume comprised about 51 percent and 49 percent, respectively, among state and local governments and private landowners. This contrasts with a much lower proportion (~15 percent) of young-growth volume on Tongass National Forest lands. The higher proportion among private landowners likely reflects more intensive management for timber production, whereas harvesting tends to be more limited in the Chugach and Tongass National Forests.

Further refining volume data to growing stock trees (trees that meet minimum merchantability standards, larger than 5 inches d.b.h. and excluding rough and rotten cull), growing on timberland provides a detailed examination of merchantable wood resources among ownerships and size classes (fig. 19). Total volume of these high-quality trees was approximately 7.8 (± 0.5) billion cubic feet, with most

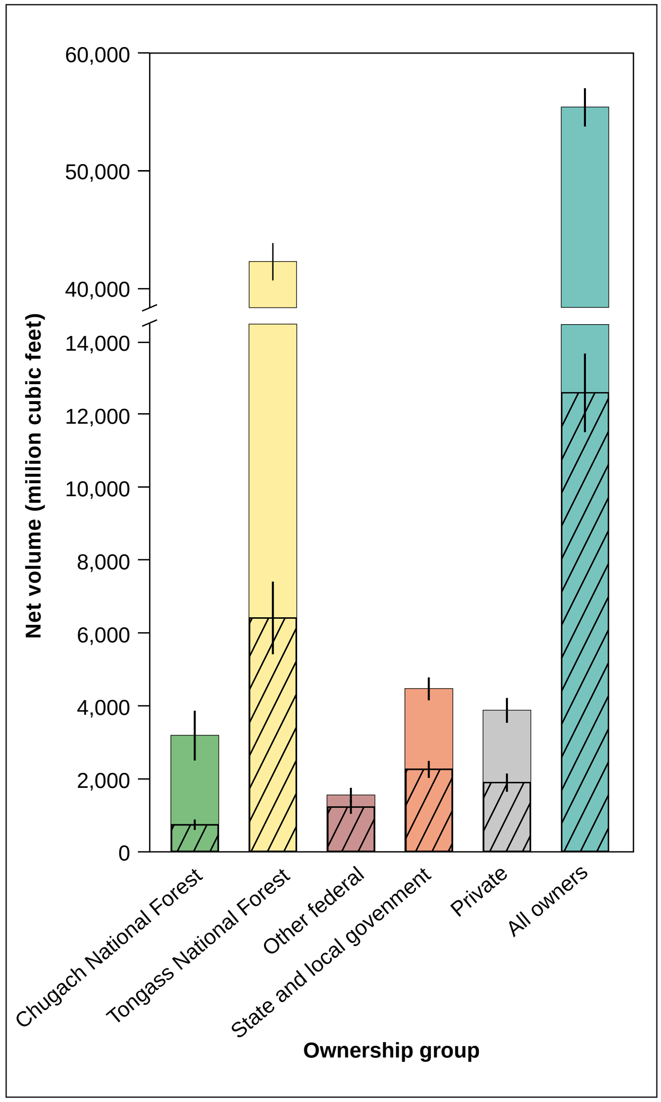

Figure 18—Total net volume of live trees (≥1 inch diameter at breast height) among ownership groups. Hatched portions represent the volume of live trees considered young growth (<150 years old). Error bars are ±1 standard error.

growing stock, young-growth volume found on Tongass National Forest land (3.3 ± 0.4 billion ft^3; 43 percent), while state and local governments and private landowners manage 24 and 23 percent, respectively. Across all ownerships, most of the volume of growing stock, young-growth trees was found among trees 10.1 to 20.0 inches d.b.h. (fig. 19B). Collectively, Sitka spruce and western hemlock growing-stock trees comprised 54 and 29 percent, respectively, of total young-growth volume (fig. 20), which may reflect post-harvest (or post-disturbance) regeneration of these

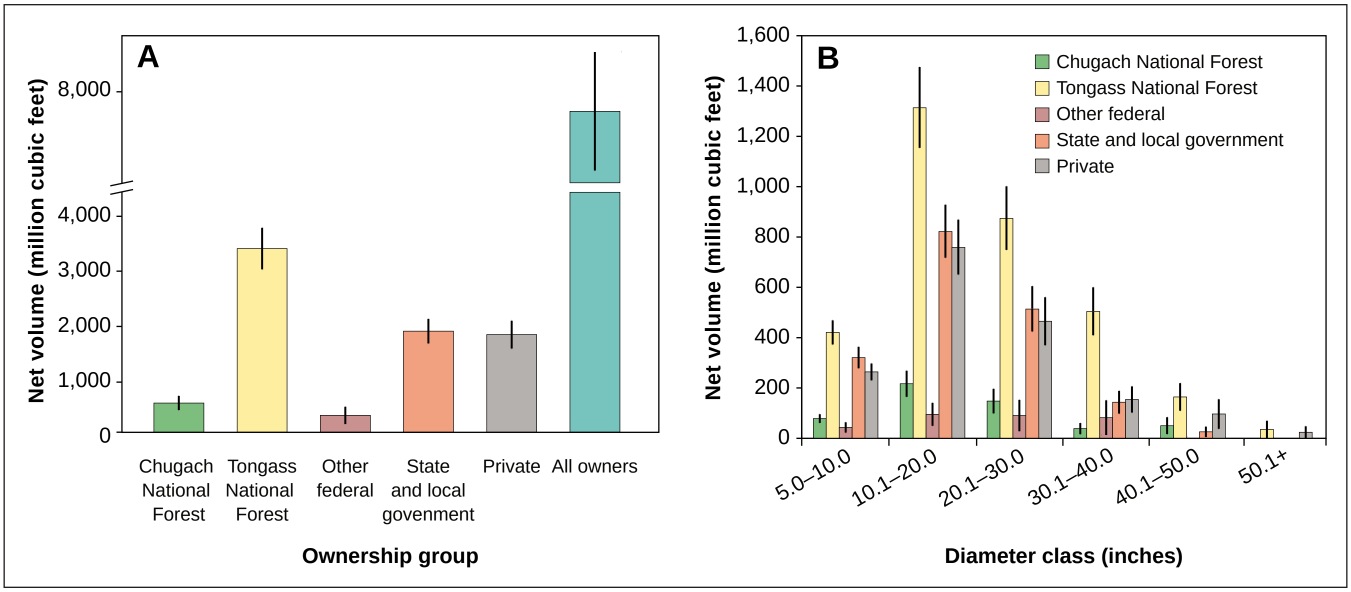

Figure 19—Net volume of (A) young-growth (<150 years old), growing stock trees on timberland among ownership groups and (B) across diameter classes in coastal Alaska. Growing stock includes trees that meet merchantability standards and excludes rough and rotten cull individuals. Error bars are ±1 standard error.

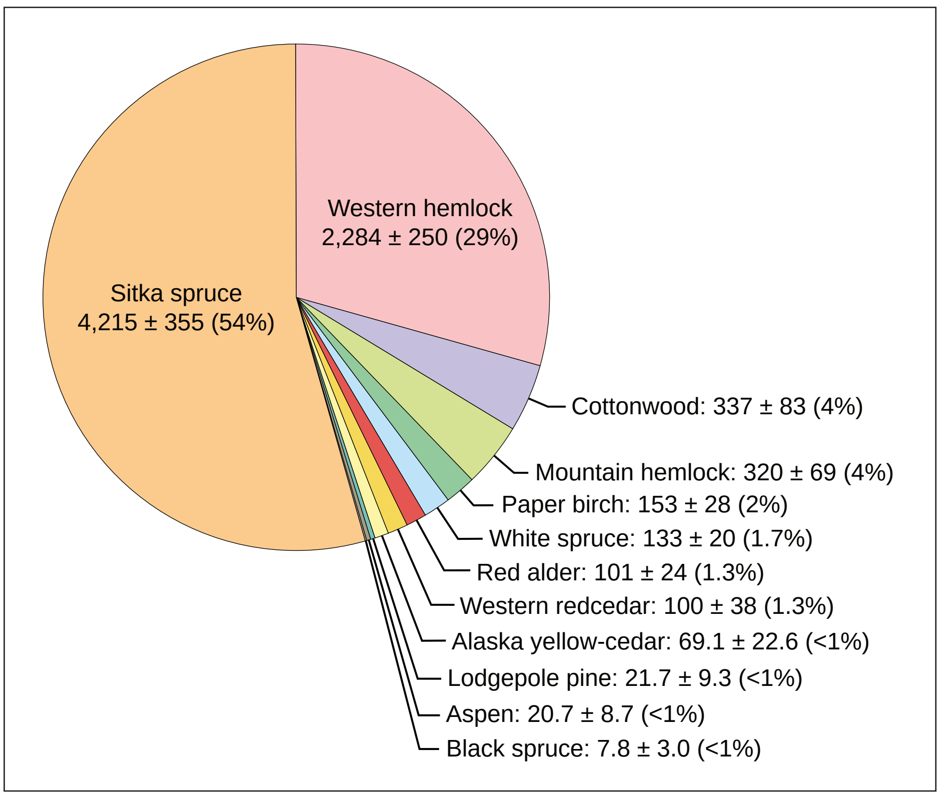

Figure 20—Net volume of young-growth (<150 years old), growing-stock trees on timberland among species in coastal Alaska. Growing stock includes trees that meet merchantability standards and excludes rough and rotten cull individuals. Values are in million cubic feet (±1 standard error) and percentage of total volume.

commercially important species (see "Forest Products" section below). Although mountain hemlock and Alaska yellow-cedar comprised approximately 15 and 10 percent, respectively, of total live tree volume throughout the inventory unit (fig. 17), higher quality trees (i.e., growing stock, young-growth) of both species accounted for less than 5 percent of young-growth volume.

Biomass—

Estimates of aboveground forest biomass provide an opportunity to examine landscape heterogeneity of long-term trends in net primary productivity. The accumulation of biomass is largely influenced by climate, topography, disturbance, and biotic factors such as herbivory and forest pests (Schlesinger 1997). Coastal Alaska contains approximately 1.37 billion tons of aboveground live tree biomass (≥1 inch d.b.h.), with an additional 217 million tons of snag biomass (≥5 inches d.b.h.). Biomass is most dense in the southernmost portions of the inventory unit (fig. 21), where large old-growth Alaska yellow-cedar, western hemlock, and Sitka spruce forests dominate the landscape. Like tree volume and forest area, most of the forest biomass in coastal Alaska is under USFS management (~82 percent), with state and local governments (~7 percent) and private (~7 percent) ownership responsible for managing most of the remaining forest biomass.

Almost all aboveground biomass in coastal Alaska is found in softwood forest types, with western hemlock forests contributing more than twice the biomass of any other forest type (fig. 22A). Western hemlock forests also contain the highest amount of biomass in live trees on an areal basis (139 ± 4.7 tons ac^{-1}), while Sitka spruce and western redcedar forests contribute nearly equal amounts (fig. 22B). Standing dead trees (snags) are an important component of forest ecosystems as they provide important habitat for birds, mammals, and invertebrates. Snag biomass comprised the greatest proportion of total biomass (living plus standing dead) in the white spruce forest types (~36 percent), more than twice the overall average (~14 percent). The high percentage of dead biomass among white spruce forest types likely reflects the high mortality following a widespread spruce bark beetle outbreak in the late 1990s (Berg et al. 2006).

Among the hardwood forest types, red alder forests contain the greatest biomass per acre (fig. 22B). This is likely due to a dense concentration of this species in the southernmost region of the inventory unit, where just 40,000 ac of red alder forest were estimated. Red alder is a pioneer species that requires abundant sunlight and quickly colonizes disturbed soils, creating dense stands of young, fast-growing individuals (Harrington 1990). Indeed, at least one plot in the inventory unit experienced regular flooding, and another was harvested 2 years prior to the inventory measurement, likely leading to favorable growing conditions for this species.

Carbon—

Aboveground forest C data provide important insight into the distribution of C pools among owners, tree species and stand ages, and can be used to inform management decisions regarding the preservation of existing C stocks. Importantly, estimates of C mass provided here are limited to aboveground live trees and snags (live trees ≥1 inch d.b.h.; standing dead trees ≥5 inches d.b.h.) in forested ecosystems. However, a recent analysis of the 1995–2003 FIA coastal Alaska inventory data indicated that down woody material, though not included in this report, contain an estimated 10.3 percent of aboveground C stores (Yatskov 2016). Although estimates vary and uncertainty is substantial among forest types in southeast Alaska (Mishra and Riley 2012), up to 70 percent of total ecosystem carbon can be found in soil organic matter, particularly areas with muskegs that contain deep organic horizons (Johnson et al. 2011, Leighty et al. 2006). Nevertheless, estimates provided by FIA represent a rigorous assessment of the aboveground live tree and snag C pools across a variety of forest types and ecoregions and in response to forest management (Barrett 2014).

Approximately 620 million Mg (683.4 million tons) of C were stored in the aboveground portion of live trees throughout coastal Alaska, with an additional 98 million Mg (108 million tons) stored in standing dead trees (fig. 23A). More than 77 percent of total aboveground live tree C mass was found on the Tongass National Forest (478 ± 17 million Mg C [527 ± 18.7 million tons C]). Additionally, C mass of live and standing dead trees per hectare on Tongass

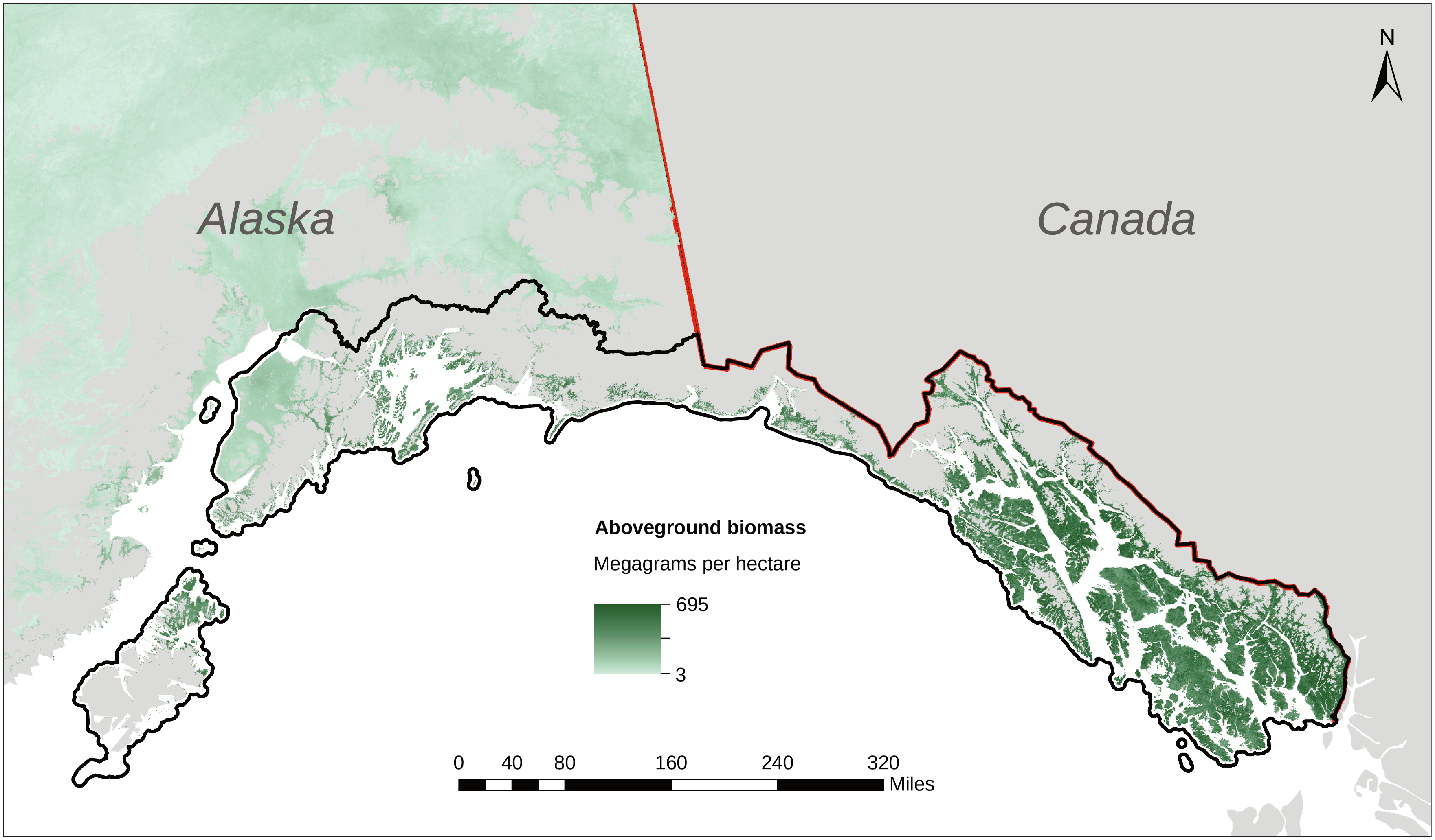

Figure 21—Spatial distribution of aboveground tree biomass throughout coastal Alaska. Plot-level biomass data were modeled as a function of several geospatial layers. Data are available online: https://data.fs.usda.gov/geodata/rastergateway/biomass/.

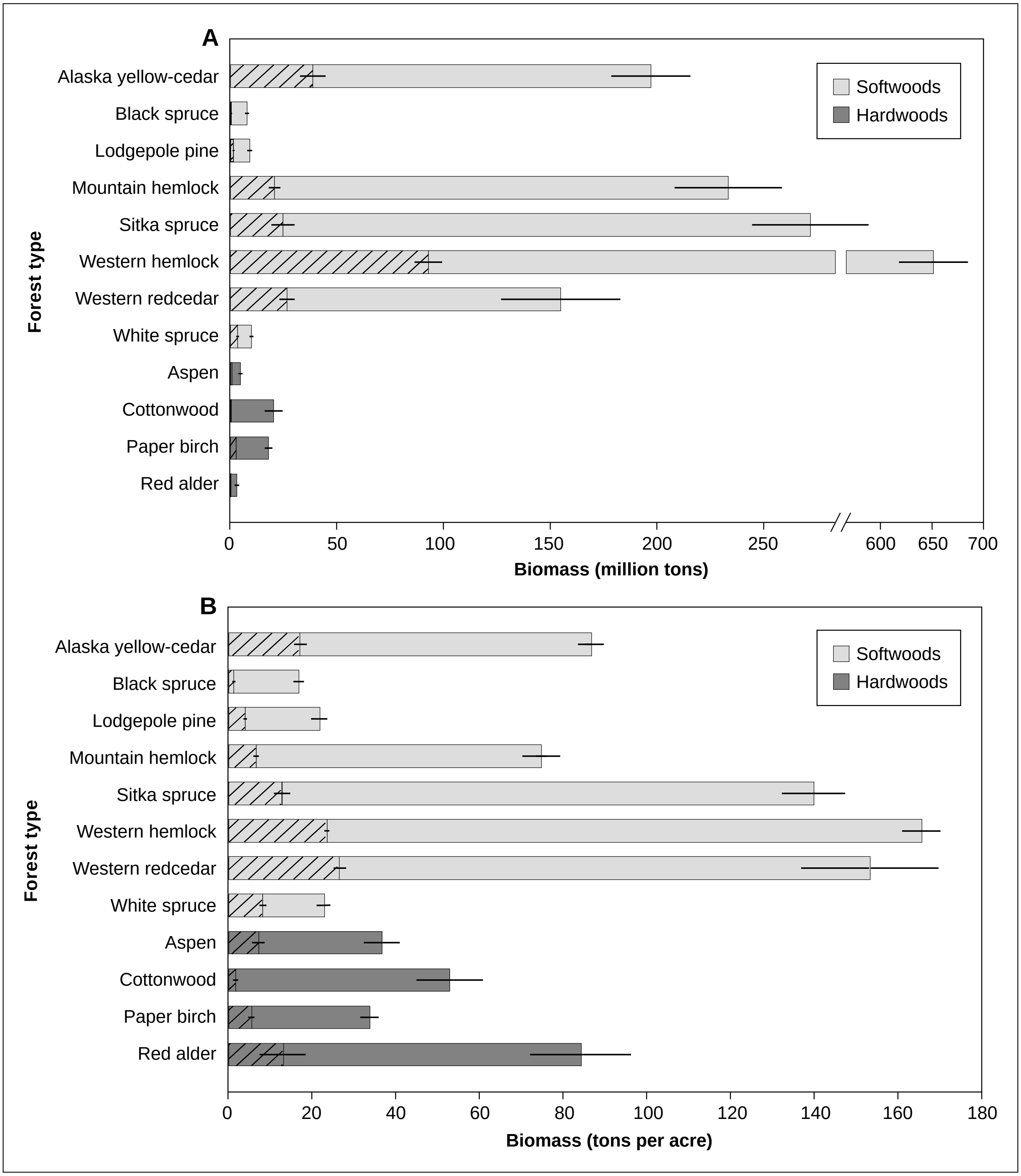

Figure 22—(A) Total aboveground tree biomass and (B) average tree biomass per acre among softwood and hardwood forest types in coastal Alaska. Solid colors represent live tree biomass (≥1 inch diameter at breast height [d.b.h.]). Hatched lines represent the portion of biomass in standing dead trees (≥5 inches d.b.h.). Error bars are ± 1 standard error.

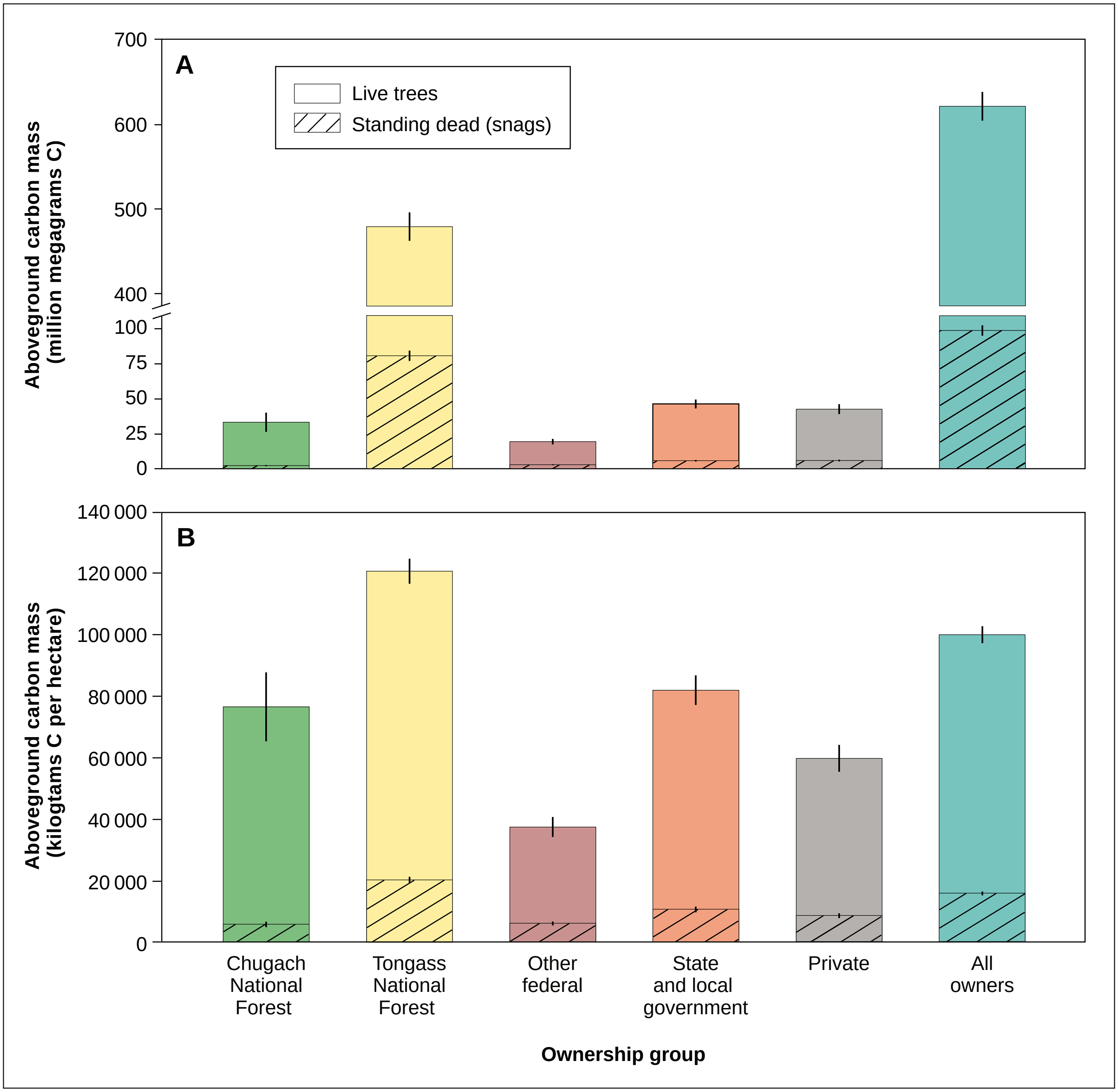

Figure 23—(A) Total aboveground tree carbon mass and (B) average carbon mass per hectare among landowners in coastal Alaska. Live trees (≥1 inch diameter at breast height [d.b.h.]) carbon mass is shown in the solid portion of each bar, while standing dead (≥5 inch d.b.h.) carbon mass is represented in hatched portion. Note the break in the y-axis in panel A for scale. Error bars are ±1 standard error.

National Forest lands exceeded that of other owners (fig. 23B). On a per-hectare basis, across all ownerships, the average concentration of C in live trees in coastal Alaska was approximately 100 000 kg C ha^{-1} (44.6 tons C ac^{-1}), higher than the most recent 10-year estimate (2002–2011) from Washington state (~93 000 kg C ha^{-1} [41.5 tons C ac^{-1}]). Carbon mass in standing dead trees accounted for approximately 14 percent of total standing tree C (live plus dead) across all ownerships and varied between 7.1 percent in Chugach National Forest (~5800 kg C ha^{-1} [2.6 tons C ac^{-1}]) and 14.4 percent in Tongass National Forest (~20 000 kg C ha^{-1} [8.9 tons C ac^{-1}]). The amount of carbon in standing dead trees is an integral component of forest ecosystem dynamics as these trees represent a C pool available for decomposition and are not actively photosynthesizing.

Among tree species in coastal Alaska, western hemlock accounted for more than one-third (36 percent) of the aboveground live tree C pool (fig. 24). Sitka spruce accounted for more than one-fourth of the pool (26 percent), while mountain hemlock and Alaska yellow-cedar contributed 15 percent and 11 percent, respectively, to total live tree aboveground C mass. The distribution of C within stand ages of these four dominant species revealed a strong trend toward a higher concentration of C in stands older than 200 years (fig. 25). Thus, more than 54 percent of aboveground live tree C mass in coastal Alaska was found in the oldest stands of four tree species. This detailed analysis of C in coastal Alaska's

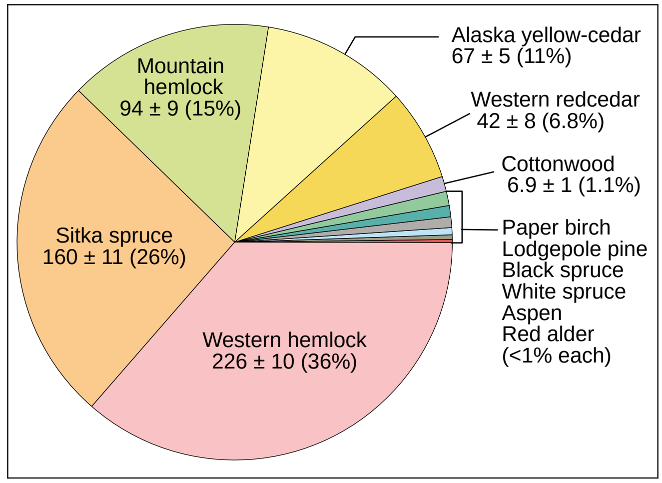

Figure 24—Distribution of aboveground live tree (≥1 inch diameter at breast height) carbon mass among species in coastal Alaska. Values are in million Mg C (±1 standard error) and percentage of total carbon mass (~620 million Mg C) throughout the inventory unit.

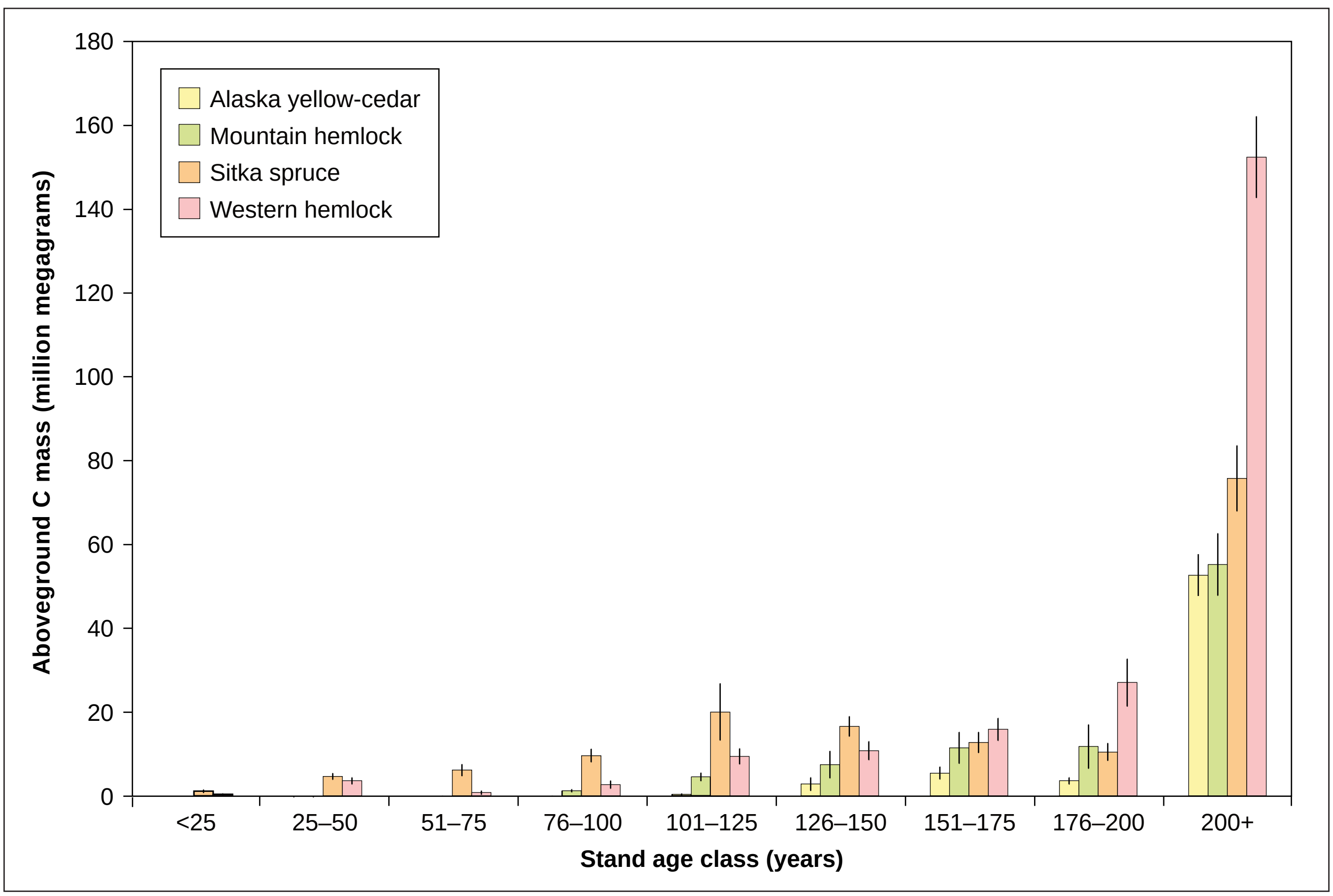

Figure 25—Aboveground carbon (C) mass (million Mg C) in live trees (≥1.0 inch diameter at breast height) among Alaska yellow-cedar, mountain hemlock, Sitka spruce, and western hemlock in coastal Alaska grouped into 25-year stand age classes. Species were selected based on their areal dominance and contribution to total C pool throughout the inventory unit. Error bars are ±1 standard error.

forests could be used to inform management decisions regarding possible market-based C offsets in an effort to mitigate climate change impacts. For example, the total amount of aboveground C stored in live trees in coastal Alaska, were it to be emitted to the atmosphere as CO_2, would roughly equal emissions from nearly 487 million passenger vehicles driven in a single year (USEPA 2017), almost double the amount of all registered vehicles in the United States in 2004 when this inventory began (USDOT BTS 2015). The forests of south-central and southeast Alaska are a key component of the global climate cycle as they provide the vital ecosystem service of storing a vast amount of C in relatively stable and long-lived individual trees (fig. 26).

Alaska's National Forests

The coastal inventory unit is dominated by the only two national forests in Alaska. Chugach National Forest covers 5.4 million ac between Turnagain Arm in the west and Cape Suckling to the southeast and is the second largest national forest in the United States. Encompassing nearly 17 million ac, Tongass National Forest is the nation's largest, stretching from Yakutat in the north to the Canadian border in the southeast (fig. 27). About 1 million ac of forest land are estimated within the Chugach National Forest, nearly 70 percent of which were identified as mountain hemlock forests, with Sitka spruce and western hemlock forests comprising most of the remaining forest area (fig. 28). Forest types were more evenly distributed in the Tongass National Forest. Of the 9.8 million ac of forest land estimated within the Tongass, western hemlock forests were most common

M. Ausman

Figure 26—A forested valley with rocky, snow-covered peaks near Haines, Alaska.

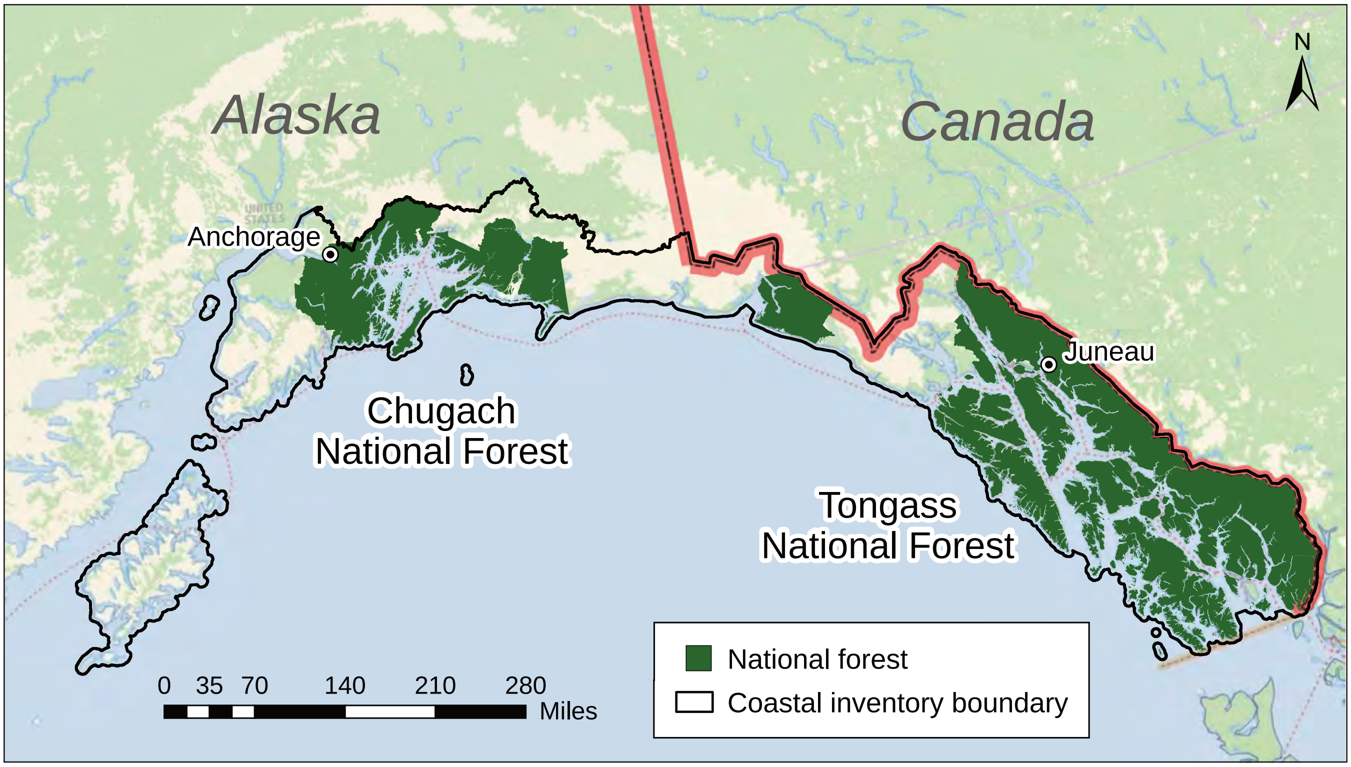

Figure 27—Map of Chugach and Tongass National Forests outlined by the coastal Alaska inventory unit.

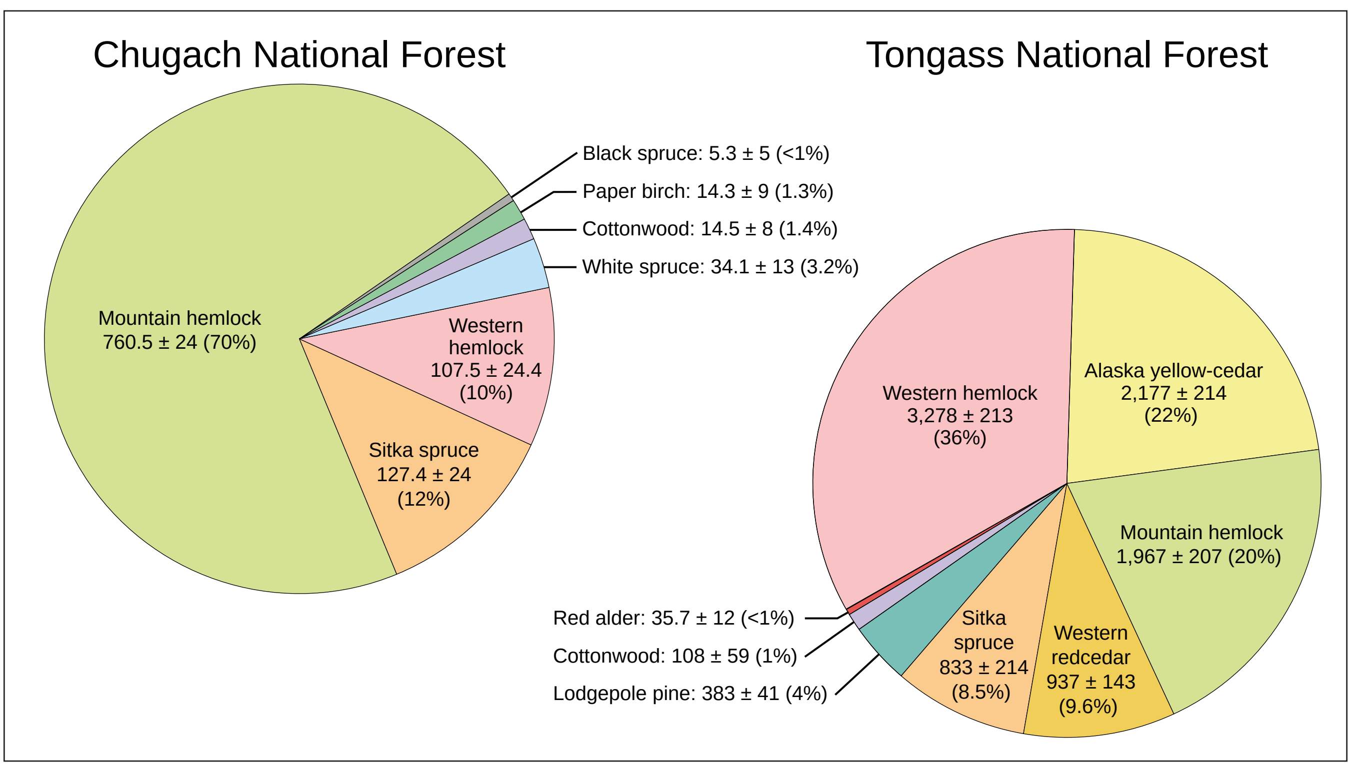

Figure 28—Distribution of forest type area within the Chugach and Tongass National Forests. Values are in thousands of acres (±1 SE) and percentage of total area in each forest.

(~36 percent), followed by Alaska yellow-cedar (~22 percent) and mountain hemlock (~20 percent). Lodgepole pine is found only in Tongass, whereas black and white spruce are limited to small areas in the Chugach.

Forests within the Tongass and Chugach National Forests represent a significant portion of regional biomass and provide the critical ecosystem service of C sequestration. Of the nearly 1.37 billion tons of aboveground live tree biomass in the inventory unit, about 1 billion tons (77 percent) were found within the Tongass alone. Nearly 600 million Mg of C are stored in live trees and snags in Chugach and Tongass National Forests, most of which is sequestered in the Tongass, where old-growth forest types characterize the region. For comparison, the total amount of live tree C in Alaska's two national forests is similar to the live tree C stored in all 11 of the national forests in Oregon combined.

U.S. Fish and Wildlife Service Forest Resources

The U.S. Fish and Wildlife Service manages about 1 million ac of forest land within the coastal inventory unit. Most of this forest land is found within the Kenai National Wildlife Refuge (Kenai NWR), a 1.9-million-ac refuge south of Anchorage (fig. 29). Kodiak National Wildlife Refuge also falls within the inventory unit and consists of approximately 72,000 ac of forest land. Forests of the Kenai NWR are representative of the northern boreal biome, dominated by black spruce in the lowland regions with white spruce, paper birch, and aspen occupying drier locations (fig. 30). The 378,000 ac of black spruce forest type in the Kenai NWR comprised approximately 78 percent of all black spruce forest area throughout the entire inventory unit. Similarly, 76 percent of aspen forests in the inventory unit are managed within the Kenai NWR.

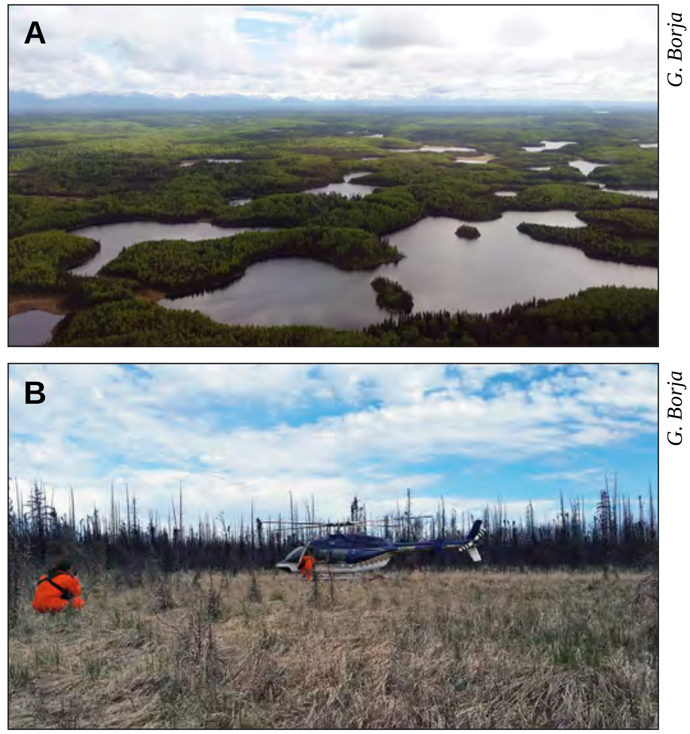

Figure 29—(A) A typical landscape view of the Kenai Peninsula. Much of the area is managed by the Kenai National Wildlife Refuge and is dominated by white and black spruce forests, like that pictured in the background of panel B.

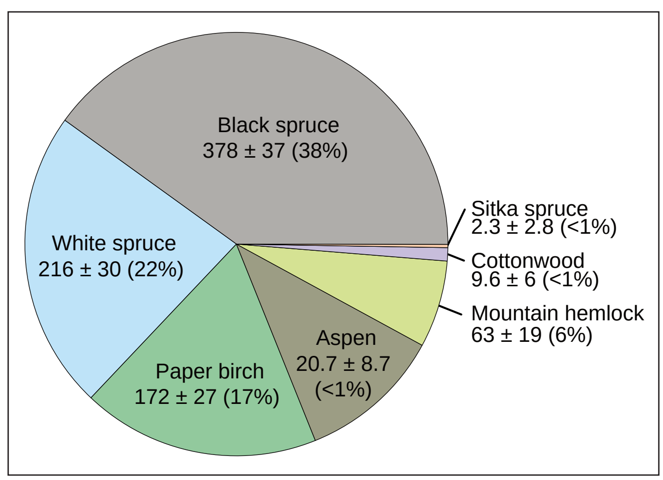

Figure 30—Area of forest types within the Kenai National Wildlife Refuge. Values are in thousands of acres (±1 standard error) and percentage of total acreage within the refuge. Note that area estimates of Sitka spruce forest are derived from a single plot inventoried in 2013.

Average Annual Growth, Removals, and Mortality

Plot remeasurement is a key strength of the FIA program that allows industry leaders, private citizens, land managers, and researchers to gain insight into broad patterns and trends in changing forest resources. Understanding trends in forest growth, removals, and mortality (GRM) is critical

Warm Summer Nights and the Decline of Shore Pine Growth in Southeast Alaska[2]

Shore pine, which is a subspecies of lodgepole pine, was a widespread and dominant tree species in southeast Alaska during the early Holocene. At present, the distribution of shore pine in Alaska is restricted to coastal bogs and fens, likely by competition with Sitka spruce and western hemlock. Monitoring of permanent plots as part of the U.S. Forest Service Forest Inventory and Analysis (FIA) program revealed a statistically significant 4.6 percent decline in live aboveground biomass of shore pine in coastal Alaska between the remeasurement periods of 1995–2003 and 2004–2008. The apparent loss of shore pine is concerning, because its presence adds a vertical dimension to coastal wetlands, which are the richest plant communities of the coastal temperate rainforest in Alaska. In this study, we examined the shore pine tree-ring record from a newly established plot network throughout southeast Alaska and explored climate-growth relationships.

We found a steep decline in shore pine growth from the early 1960s to the present (fig. 31). Random forest regression revealed a strong correlation between the decline in shore pine growth and the rise in growing season diurnal minimum air temperature. Warm summer nights, cool daytime temperatures, and a reduced diurnal temperature range are associated with greater cloud cover in southeast Alaska. This suite of conditions could lead to unfavorable tree carbon budgets (reduced daytime photosynthesis and greater nighttime respiration) or could favor infection by foliar pathogens, such as Dothistroma needle blight, which was observed within our plot network and has recently caused widespread tree mortality on lodgepole pine plantations in British Columbia (Woods et al. 2005). The well-publicized decline of yellow-cedar forest in southeast Alaska has

Continued on next page

[2] **Sullivan, P.F.; Mulvey, R.L.; Brownlee, A.; Barrett, T.M.; Pattison, R.R. 2015.** Warm summer nights and the growth decline of shore pine in Southeast Alaska. Environmental Research Letters. 10: 124007.

to maintaining sustainable harvest levels and detecting impacts from pests, climate change, or abiotic disturbance events such as wildfire or windthrow. This report summarizes GRM estimates from 2,023 plots originally installed in 1995–2003 and remeasured between 2004 and 2013. A notable caveat to GRM estimates here is the lack of data from USFS wilderness and wilderness study areas, where FIA only sampled plots in 2005, precluding any estimates of change from these lands.

There are several other important limitations to GRM estimates from coastal Alaska resulting from protocol changes between inventories. Briefly, the most consequential differences were changes to the definition of forest, the location of d.b.h. measurements on leaning trees, and the location of the microplot where saplings were measured. To reconcile these differences, only plots that met the forest definition of the second inventory were considered, and only trees that were within the subplot boundary in both inventories were included. This precluded any estimate of change in forest area. Finally, trees smaller than 5 inches d.b.h. were excluded to account for the relocation of the microplot. The latter rule resulted in the exclusion of nearly 66 percent of all black spruce trees in the sample, creating a sample of larger individuals. Thus, current estimates of growth do not include the smallest cohort of black spruce and should be interpreted with much caution when applying these data to the entire population. The same 5-inch rule resulted in the exclusion of less than 15 percent of the sample among all other species, with the exception of paper birch, which was reduced by 20 percent. However, trees <5 inches d.b.h. contribute only to biomass estimates and are excluded from merchantable and sawtimber volume. Despite these limitations, the estimates provided here were generated from a large sample of more than 71,000 trees, offering robust insight into the trends in growth, removals, and mortality among owners

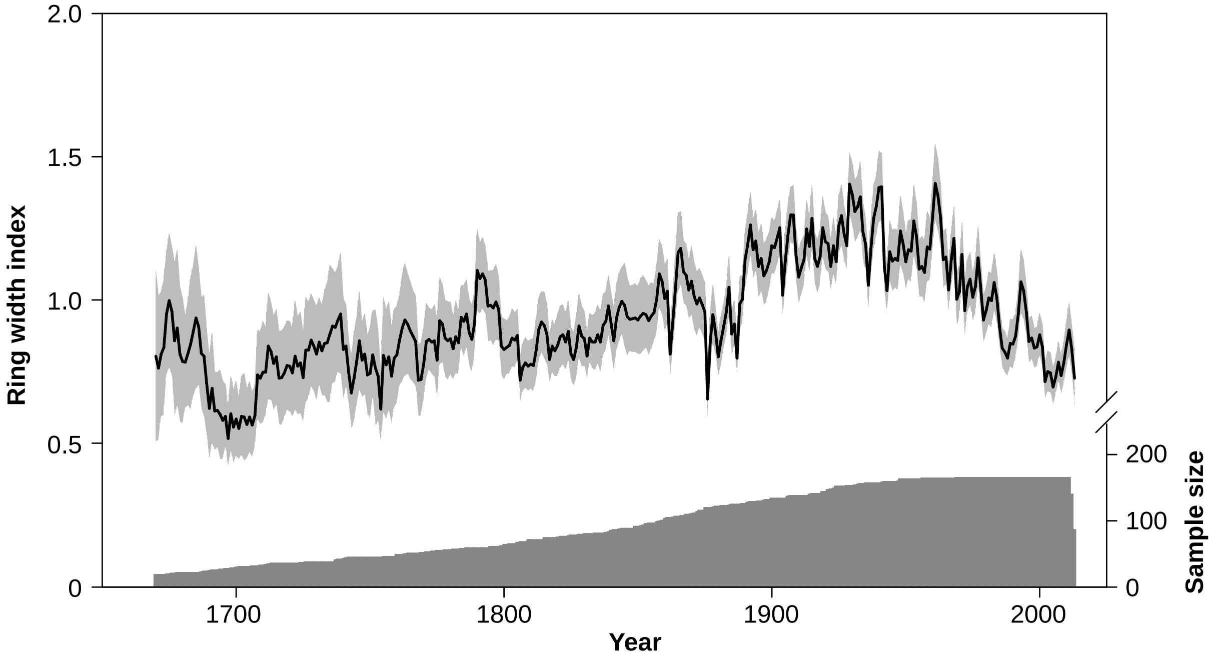

Figure 31—Shore pine chronology for the period with an expressed population signal >0.85. The gray shading indicates the 95 percent confidence limits, while the number of trees contributing data is indicated at the bottom of the panel (Sullivan et al. 2015).

largely been attributed to freezing injury to shallow fine roots, as a result of a diminished winter snowpack (Hennon et al. 2012). Shore pine occupies even wetter habitats than yellow-cedar and likely maintains a shallow fine root network, but the sensitivity of shore pine roots to freezing injury is unknown. We found some evidence that warm winters with a shallow or ephemeral snowpack were associated with reduced shore pine growth, but these variables ranked much lower in importance than mean growing season diurnal minimum air temperature. Further, there is no evidence from our plot network nor the FIA plot network that shore pine dieback or mortality are concentrated at lower elevations or farther south, where the winter snowpack is more ephemeral. Although we cannot exclude the possibility that freezing injury to fine roots may be contributing to mortality and declining growth of shore pine, our results suggest that shore pine growth decline may be driven by a different suite of mechanisms than yellow-cedar decline. Further field study will be necessary to identify the proximal cause(s) of the shore pine growth decline. In the meantime, we anticipate continuation of this concerning trend.

and species throughout the region. Future remeasurement cycles will include all live trees greater than 1 inch d.b.h. from the same microplot and will provide greater confidence in whole population estimates.

Across the entire inventory unit and all ownership categories, total growth (net volume) exceeded mortality and removals, resulting in an annual net increase of ~78 (± 27.3) million ft^3 $year^{-1}$ on forest land (fig. 32) and ~51.3 (± 26.1) million ft^3 $year^{-1}$ on timberland over the remeasurement period (trees >5 in d.b.h.). On average, net change was positive among all ownerships, with the exception of private landowners, for whom mortality and removals exceeded growth, resulting in an average net loss in volume on forest land of -24.3 million ft^3 $year^{-1}$. Because the Tongass National Forest is the largest forest ownership, annual growth and mortality was much higher than for other owners, with approximately 58 percent of gross growth (226.6 ± 11.1 million ft^3 $year^{-1}$) and 67 percent of total

Common Definitions of Growth, Removals, and Mortality Estimates

Average annual gross growth—The change in volume (or biomass) of all live trees between time periods divided by the number of years between remeasurement. Includes survivor growth (G_s), ingrowth (I), growth on ingrowth (G_I), reversion growth (G_R), mortality growth (G_M), and cut growth (G_C).

Average annual mortality—The loss of volume (or biomass) owing to a change in tree status from live to dead between time periods divided by the number of years between remeasurement.

Average annual removals—The loss of volume (or biomass) owing to a change in trees status from live to dead or removed by silvicultural applications between time periods divided by the number of years between remeasurement.

Average annual net growth—Annual gross growth less annual mortality.

Average annual net change—Annual net growth less annual removals.

Average annual net growth rate—Average annual net growth, divided by the live tree volume (or biomass) at the time of initial measurement.

Average annual net mortality rate—Average annual mortality, divided by the live tree volume (or biomass) at the time of initial measurement.

G_s—The growth on trees tallied at time (t) that survive until $t + 1$.

I—The volume of trees at the time they grew across the 5-inch diameter at breast height (d.b.h.) minimum threshold between time t and $t + 1$.

G_I—The growth on trees between the time they grow across the 5-inch-d.b.h. minimum threshold and time $t + 1$.

G_R—The growth of reversion trees from the midpoint of the measurement inverval to time $t + 1$. Tree size at the midpoint is modeled from tree size at time $t + 1$. Includes subsequent growth on ingrowth trees that achieve the minimum 5-inch-d.b.h. threshold after reversion.

G_M—the growth of trees that died from natural causes between time t and the midpoint of the measurement interval. Tree size at the midpoint is modeled from tree size at time t. Includes subsequent growth on ingrowth trees that achieve the 5-inch-d.b.h. threshold prior to mortality.

G_C—the growth of cut trees between time t and the midpoint of the measurement interval. Tree size at the midpoint is modeled from tree size at time t. Includes subsequent growth on ingrowth trees that achieve the minimum 5-inch-d.b.h. threshold prior to being cut.

For greater detail, see Bechtold and Patterson (2005).

mortality (154.6 ± 13.5 million ft^3 $year^{-1}$) across all owners on forest land (tables 2 and 5). However, annual net change **per acre** (7.0 ± 2.9 ft^3 ac^{-1} $year^{-1}$) on the Tongass was similar to the overall average (6.8 ± 2.3 ft^3 ac^{-1} $year^{-1}$) (tables 3 and 4). The majority (63 percent) of tree volume removed from coastal Alaska forests occurred on private land (54.0 ± 15.1 million ft^3 $year^{-1}$), where much of the timber harvest occurs (see "Forest Products" section below). Timber harvests on the Tongass National Forest comprised a sizable portion of removals from publicly managed forests (25.6 ± 9.4 million ft^3 $year^{-1}$; 30 percent of all removals), whereas the volume of removals on land managed by other public owners represented less than 10 percent of all removals.

Changes in biomass differed among species in the inventory unit and provide insight into trends in forest growth and mortality throughout the region. All species showed an average net increase in biomass (i.e., gross growth minus removals and mortality), with the exception of Alaska yellow-cedar and lodgepole pine (fig. 33). When limited to net growth (i.e., gross growth minus mortality), only lodgepole pine displayed a slightly negative trend. Thus, the net overall reduction in Alaska yellow-cedar biomass appears to be largely influenced by removals, as gross growth (420 ± 39 thousand tons $year^{-1}$) was similar to mortality (404 ± 60 thousand tons $year^{-1}$), resulting in effectively no change in biomass among trees larger than

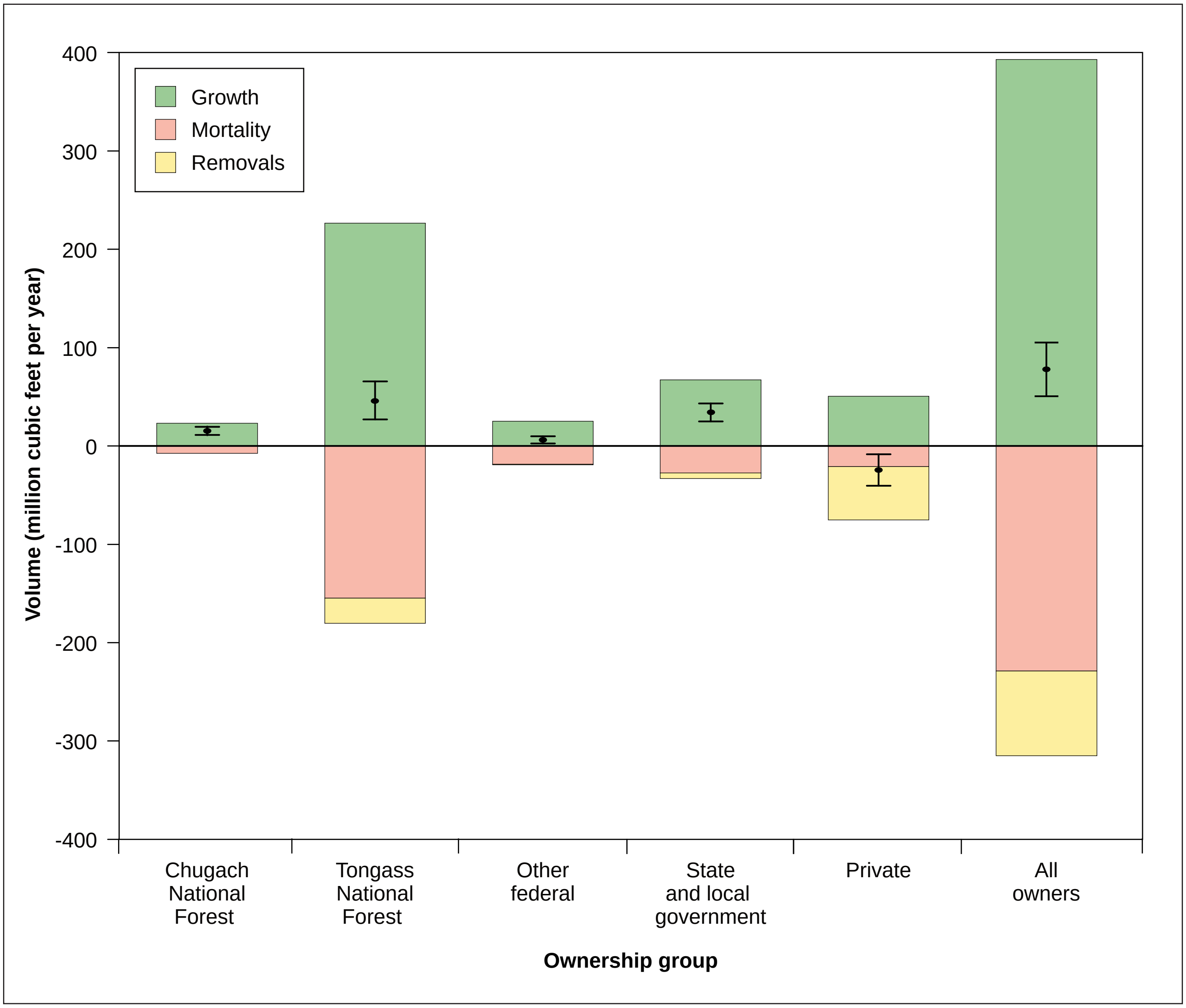

Figure 32—Average annual volume of growth, mortality, and removals among owners in coastal Alaska for the periods of 1995–2003 and 2004–2013. Includes all trees ≥5 inches diameter at breast height during the initial plot visit. Solid circles represent net change (±1 standard error).

5 inches d.b.h (17 ± 72 thousand tons year^{-1}). The health and productivity of Alaska yellow-cedar is an active area of research in southeast Alaska, with many studies indicating that the species is experiencing widespread decline, possibly because of freezing damage to roots in response to reduced snowpack at low elevations as the climate warms (Buma et al. 2017; Hennon et al. 2012, 2016). Although identifying the drivers of Alaska yellow-cedar growth were beyond the scope of this report, Barrett and Pattison (2016) analyzed nearly the same FIA data and concluded that there has been no change in Alaska yellow-cedar basal area in recent decades in coastal Alaska (but see Bidlack et al. 2017). Importantly, the remeasurement data used here represent a relatively short window into the long-term tree growth trends of this long-lived species. In addition, this analysis does not include national forest wilderness and Glacier Bay National Park forest land, where FIA was prevented from resampling.

The net loss of lodgepole pine biomass might have been driven, in part, by reduced photosynthesis resulting from cloudy daytime conditions and greater nighttime respiration as summer nights have warmed since the 1960s, thus creating

Table 2—Average annual volume (million cubic feet) of growth, removals, and mortality per year, coastal Alaska, 1995–2003 to 2004–2013

	Ownership group											
	USDA Forest Service											
	Chugach National Forest		Tongass National Forest		Other federal		State and local government		Private		All owners	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
	Million cubic feet per year											
Timberland[a]												
Growth	16.9	3.5	164.6	11.1	4.2	1.7	55.1	6.3	44.4	4.1	285.1	13.6
Mortality	5.7	2	106.7	12.6	1.2	0.7	23.9	5.4	17.8	3.7	155.3	14.3
Removals	—	—	21.5	9.1	—	—	5.5	5.5	51.5	15	78.5	18.4
Net change	11.2	3.8	36.4	18.3	3	1.1	25.6	9	-24.9	15.8	51.3	26.1
Forest land[b]												
Growth	23.3	3.5	226.6	11.1	25.2	2.6	67.3	6.4	50.7	4.2	393.1	13.7
Mortality	7.5	2.3	154.6	13.5	18.5	3.6	27.4	5.5	21	3.8	229	15.6
Removals	0.4	0.4	25.6	9.4	0.5	0.4	5.7	5.5	54	15.1	86.1	18.6
Net change	15.4	4.1	46.4	19.4	6.3	3.6	34.2	9.2	-24.3	16	78	27.3

Note: Totals may be off because of rounding; data are subject to sampling error; SE = standard error; — = not available.

[a] Includes all live trees ≥5 inches in diameter at breast height (d.b.h.) during the initial plot visit and capable of producing 20 ft^3 ac^{-1} yr^{-1}.

[b] Includes all live trees ≥5 inches d.b.h. during the initial plot visit, consisting of growing stock, rough cull, and rotten cull tree classes.

Table 3—Average annual volume (cubic feet) of growth, removals, and mortality per acre per year, coastal Alaska, 1995–2003 to 2004–2013

	Ownership group											
	USDA Forest Service											
	Chugach National Forest		Tongass National Forest		Other federal		State and local government		Private		All owners	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
	Cubic feet per acre per year											
Timberland[a]												
Growth	55.6	10.2	48.8	2.9	55.7	15.3	57.2	5.1	34.9	2.6	47.6	2
Mortality	18.7	6.6	31.7	3.6	15.9	8.3	24.8	5.4	14	2.8	26	2.3
Removals	—	—	6.4	2.7	—	—	5.7	5.7	40.5	11.7	13.1	3.1
Net change	36.9	11.9	10.8	5.4	39.8	8.5	26.6	9.1	-19.5	12.4	8.6	4.4
Forest land[b]												
Growth	34.1	5.5	28.9	1.8	18.9	1.8	41.2	4.3	24.6	2.4	29	1.3
Mortality	9.6	3.2	18.4	1.8	13.7	2.8	13.4	3.2	9.7	1.9	15.5	1.2
Removals	0	0	3.5	1.4	—	—	3.9	3.8	28	7.9	6.7	1.5
Net change	24.5	6.3	7	2.9	5.3	2.8	23.9	6.3	-13.1	9	6.8	2.3

Note: Totals may be off because of rounding; data are subject to sampling error; SE = standard error; — = not available.

[a] Includes all live trees ≥ 5 inches in diameter at breast height (d.b.h.) during the initial plot visit and capable of producing 20 ft^3 ac^{-1} yr^{-1}.

[b] Includes all live trees ≥ 5 inches d.b.h. during the initial plot visit, consisting of growing stock, rough cull, and rotten cull tree classes.

Table 4—Average annual biomass (tons) of growth, removals, and mortality per acre per year, coastal Alaska, 1995–2003 to 2004–2013

	Ownership group											
	USDA Forest Service											
	Chugach National Forest		Tongass National Forest		Other federal		State and local government		Private		All owners	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
	Tons per acre per year											
Timberland[a]												
Growth	2,310.80	504.7	2,092.90	131.3	2,450.00	608.9	2,461.30	189	1,561.30	107.9	2,054.60	87.7
Mortality	768.5	275.1	1,457.50	174.3	642.8	329.1	1,083.10	242.1	596.4	115.8	1,169.00	109.8
Removals	—	—	282.4	119.6	—	—	269	265.3	1,717.50	499	567.7	133.5
Net change	1,542.30	563.4	353.1	250.7	1,807.20	360.3	1,109.30	402	-752.7	528.9	317.9	194.6
Forest land[b]												
Growth	1,515.70	254.9	1,419.10	72.9	927.4	80.8	2,039.80	147.1	1,265.40	85.1	1,424.00	49.6
Mortality	492.8	149.2	1,044.30	96.1	664	123.2	831.6	166.8	511.1	85.7	868.1	61.6
Removals	24.9	28.8	167.8	62.3	18.6	18.6	185.8	178.1	1,286.40	361	314.5	68.3
Net change	998	294.7	207	132.9	244.8	125.2	1,022.40	277	-532.1	381.9	241.4	102.7

Note: Totals may be off because of rounding; data are subject to sampling error; SE = standard error; — = not available.
[a] Includes all live trees ≥ 5 inches in diameter at breast height (d.b.h.) during the initial plot visit and capable of producing 20 ft^3 ac^{-1} yr^{-1}.
[b] Includes all live trees ≥ 5 inches d.b.h. during the initial plot visit, consisting of growing stock, rough cull, and rotten cull tree classes.

Table 5—Average annual biomass (thousand tons) of growth, removals, and mortality per year, coastal Alaska, 1995–2003 to 2004–2013

	Ownership group											
	USDA National Forest											
	Chugach National Forest		Tongass National Forest		Other federal		State and local government		Private		All owners	
	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
	Thousand tons per year											
Timberland[a]												
Growth	350	84	3,527	249	92	35	1,185	123	994	87	6,148	299
Mortality	116	42	2,456	304	24	14	521	121	380	77	3,498	337
Removals	—	—	476	202	—	—	129	128	1,093	321	1,699	400
Net change	234	89	595	423	68	24	534	198	-479	337	951	583
Forest land[b]												
Growth	485	85	4,778	250	586	57	1,465	124	1,128	89	8,442	299
Mortality	158	48	3,516	325	420	78	597	122	455	79	5,146	366
Removals	8	9	565	210	12	11	133	128	1,146	322	1,864	405
Net change	319	96	697	447	155	80	734	202	-474	340	1,431	610

Note: Totals may be off because of rounding; data are subject to sampling error; SE = standard error; — = not available.
[a] Includes all live trees ≥ 5 inches in diameter at breast height (d.b.h.) during the initial plot visit and capable of producing 20 ft3 ac^{-1} yr^{-1}.
[b] Includes all live trees ≥ 5 inches d.b.h. during the initial plot visit, consisting of growing stock, rough cull, and rotten cull tree classes.

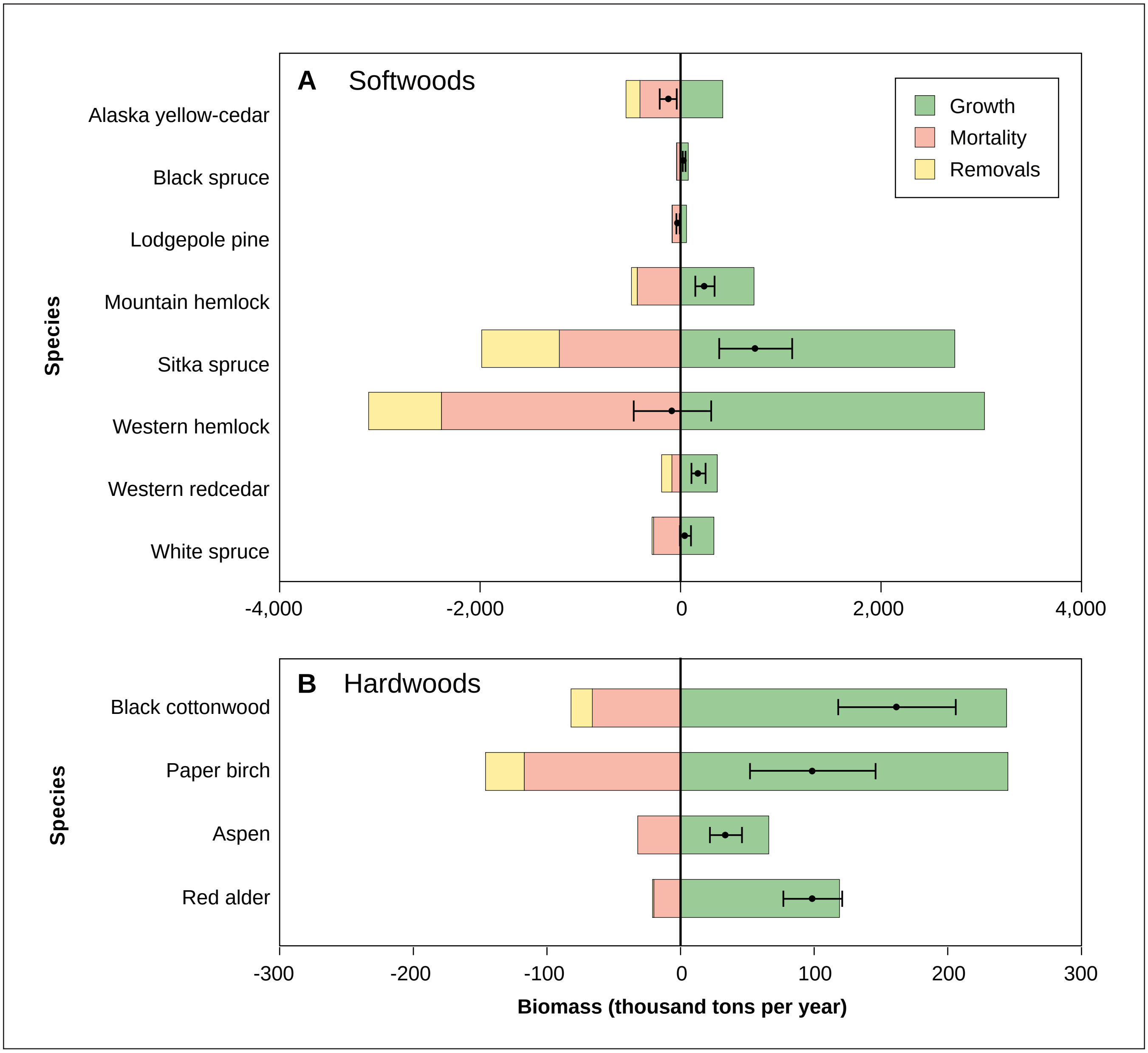

Figure 33—Average annual biomass of growth, mortality, and removals for (A) softwood and (B) hardwood species in coastal Alaska for the periods of 1995–2003 and 2004–2013. Includes all trees ≥5 inches in diameter at breast height during the initial plot visit. Solid circles represent net change (±1 standard error). Note the difference in scale between softwoods and hardwoods.

net negative carbon budgets (Sullivan et al. 2015) (see sidebar on page 29). The foliar pathogen Dothistroma needle blight also likely contributed to the decline in lodgepole pine biomass. Although a relatively minor species throughout the inventory unit, continued reduction in lodgepole pine biomass could alter the structure of coastal Alaska forests, particularly wetland communities where the species is commonly found.

Western hemlock biomass was nearly unchanged between the two measurement periods (fig. 33), as net change ranged between -837 and 677 thousand tons per year (95 percent confidence interval). When removals were excluded, this species experienced a net increase in biomass of 646 ± 309 thousand tons per year. Mortality biomass was notably higher for western hemlock compared with other softwood species in southeast Alaska, although the mortality **rate** was near the average of all species. Western hemlock mortality is largely driven by hemlock dwarf mistletoe (*Arceuthobium tsugense* (Rosendhal) G.N. Jones), a parasitic plant that can cause branch proliferations and bole deformities, and can serve as a vector for decay fungi (USDA FS 2015). In addition to natural mortality, other causes of western hemlock mortality include porcupine girdling and an aggressive, annual hemlock canker that can cause synchronized, widespread mortality among smaller individuals (fig. 34). Although western hemlock forest biomass was relatively stable, Sitka spruce experienced a significant increase in biomass during the 10-year window of this analysis (fig. 34). Such a large increase in the growth of Sitka spruce, which contributes approximately one-fourth of aboveground C mass in the inventory, has important implications for regional C cycle dynamics that may favor landscape-scale carbon dioxide uptake, should growth continue to increase. Future remeasurement cycles and analysis will help elucidate long-term growth trends and drivers of biomass production in these commercially and ecologically important species.

On average, hardwood species experienced much higher net growth rates (expressed as the difference between gross growth and mortality divided by the biomass at the time of initial measurement) than softwood species in coastal Alaska (fig. 35A). Red alder stands, in particular, accrued biomass at a relative rate of nearly 5 percent annually, more than twice the rate of any other species in the inventory unit. Rapid growth rate is a notable characteristic of this early successional species, which also forms important symbiosis with N-fixing bacteria (Bormann and Gordon 1984). White spruce experienced very high mortality rates between the periods of 1995–2003 and 2004–2013 (fig. 35B) likely due, in part, to a widespread outbreak of spruce

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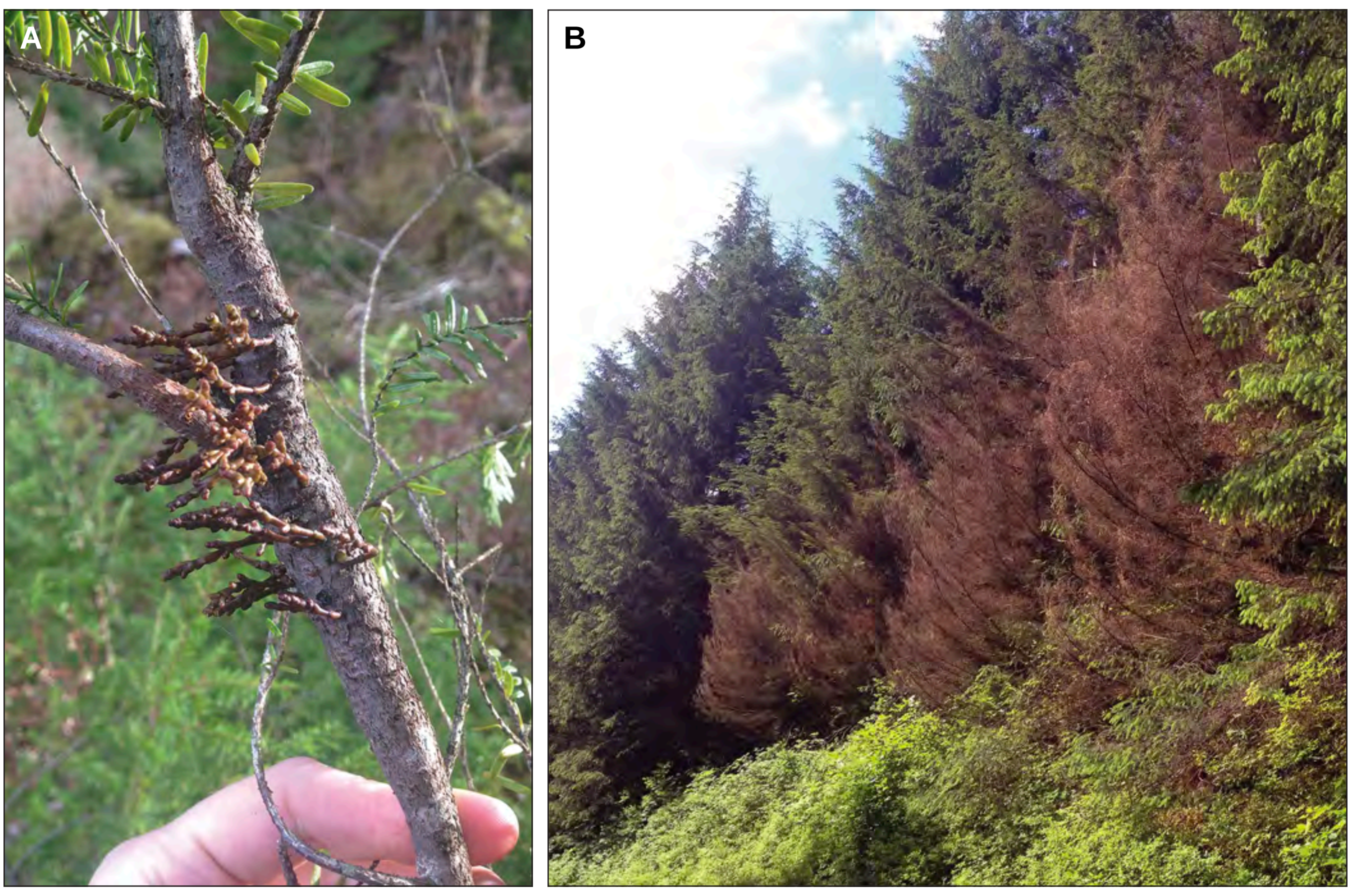


Figure 34—(A) Hemlock dwarf mistletoe and (B) damage caused by hemlock canker are important drivers of mortality in western hemlock forests in coastal Alaska.

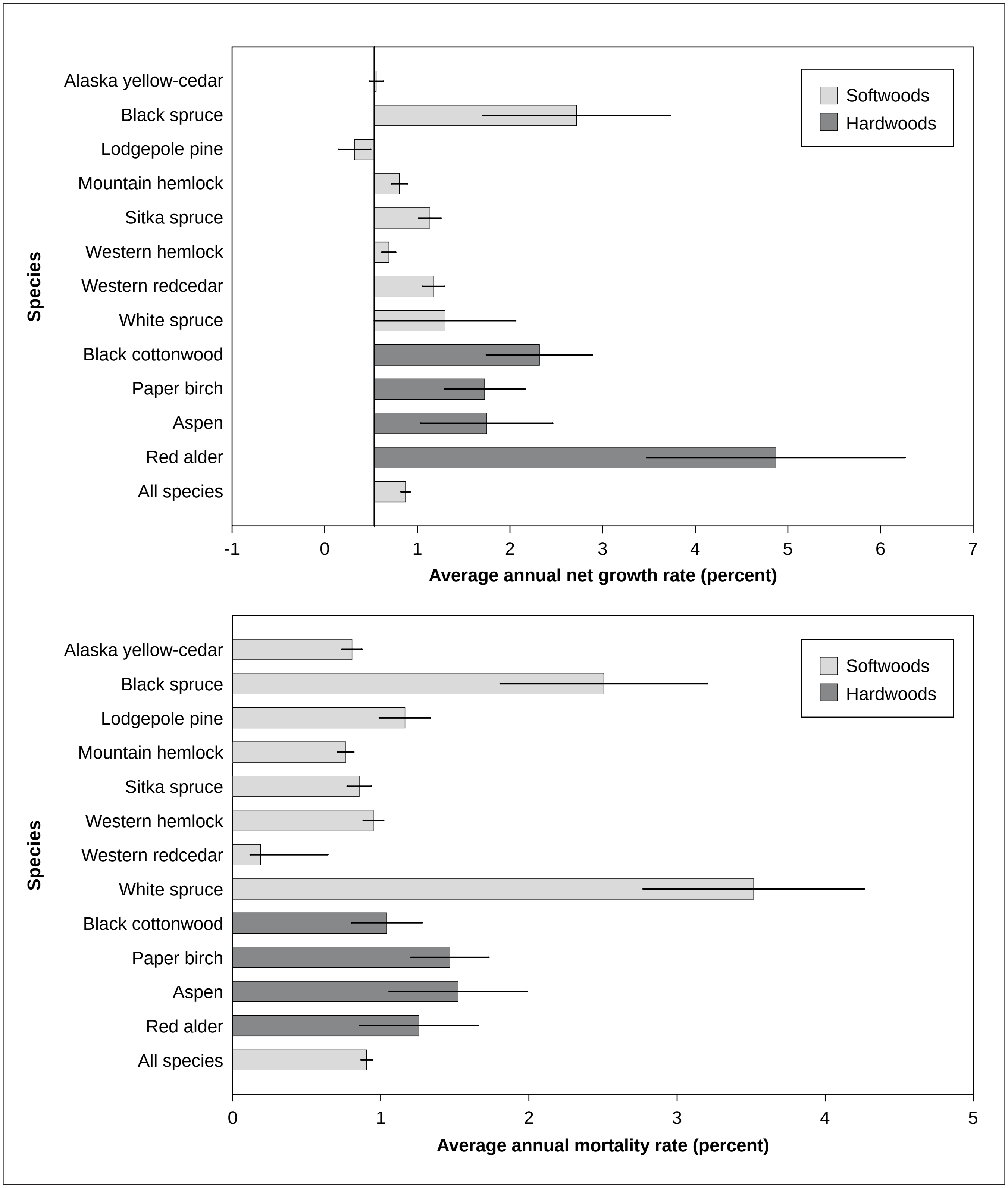


Figure 35—Average annual (A) net growth rate and (B) mortality rate of each species in coastal Alaska. Data are presented as the relative change in forest biomass between the periods of 1995–2003 and 2004–2013 for all trees ≥5 inches diameter at breast height (d.b.h.) during the initial plot visit. The very high growth and mortality rates for black spruce are likely an artifact of excluding trees <5 inches d.b.h., approximately 66 percent of the sample. Thus, caution is urged when interpreting black spruce values.

bark beetle, which affected nearly 1.2 million ac on the Kenai Peninsula in the late 1990s. Conversely, white spruce also experienced the highest growth rate among softwood species (fig. 35A), if black spruce is ignored because of data limitations (see above). This apparent contradiction may represent a growth release among survivors following the bark beetle outbreak. Spruce bark beetles are known to attack slow-growing, mature individuals by boring into the inner bark or phloem layers. Mortality of canopy-dominant individuals can result in reduced competition for light, water, and nutrients among younger individuals (Berg et al. 2006), a trend that may be evident in the remeasurement data here. The substantial range in annual net growth rate of white spruce (0.09 to 1.9 percent; 95 percent confidence interval) may reflect the variability in growth among younger individuals and older survivors.

Figure 36—Small sawmill operation and residue pile in southeast Alaska, June 2016.

Forest Products[3]

Removals for Timber Products

Quantifying timber volume harvested from the forest inventory provides an important indicator of the sustainability of timber harvest levels. Timber harvest exceeding net growth for extended periods could indicate overharvesting and a decreasing future forest inventory. Conversely, growth or mortality rates greatly exceeding harvest could signal a need for increased vegetation management to facilitate forest health (e.g., decreased risks of tree mortality, insect outbreaks, or wildfire). Timber harvest can come from two sources: growing-stock trees (portions of live, commercial-grade tree species meeting specified standards), or dead trees and other sources that are not growing stock (e.g., tree limbs and tops). Wood removed for commercial purposes is categorized as either timber products harvested for processing by wood product manufacturers or logging residue (i.e., volume cut or killed but not utilized) (fig. 36). Harvest data are based on Bureau of Business and Economic Research surveys of Alaska's primary forest products facilities operating during 2005 and 2011 (Berg et al. 2014, Halbrook et al. 2009) and U.S. Energy Information Administration data for residential fuelwood consumption (USDOE EIA 2016). Importantly, timber harvest data are based on operating years and therefore differ from the 10-year moving window analysis provided by FIA. More detailed timber products data for Alaska and other states are available from FIA's Timber Products Output (TPO) website at http://www.fs.usda.gov/srsfia.php/tpo_2009/tpo_rpa_int1.php.

Harvest from timberlands in Alaska declined substantially between 2005 and 2011. Total harvest exceeded 88.4 million ft^3 (MMCF) in 2005 and consisted of 62 MMCF of roundwood products and 26.4 MMCF of logging residue (fig. 37A). By 2011, total harvest in Alaska had decreased by almost 41 percent to approximately 52.3 MMCF, 37.4 MMCF in roundwood products, and nearly 14.9 MMCF in logging residue. Harvest for total industrial wood products (excluding fuelwood) were 44 percent less in 2011 compared to 2005. Growing stock material accounted for approximately 75 percent of total timber harvest in both 2005 and 2011. During both years, growing stock harvest was the leading source for all industrial timber products and more than 60 percent of logging residue harvest (fig. 37B). Harvest of industrial products decreased from 2005 to 2011, and logging residue also declined from both growing stock (47 percent

[3] Authors: Kate C. Marcille, Erik C. Berg, and Todd A. Morgan, Bureau of Business and Economic Research, University of Montana.

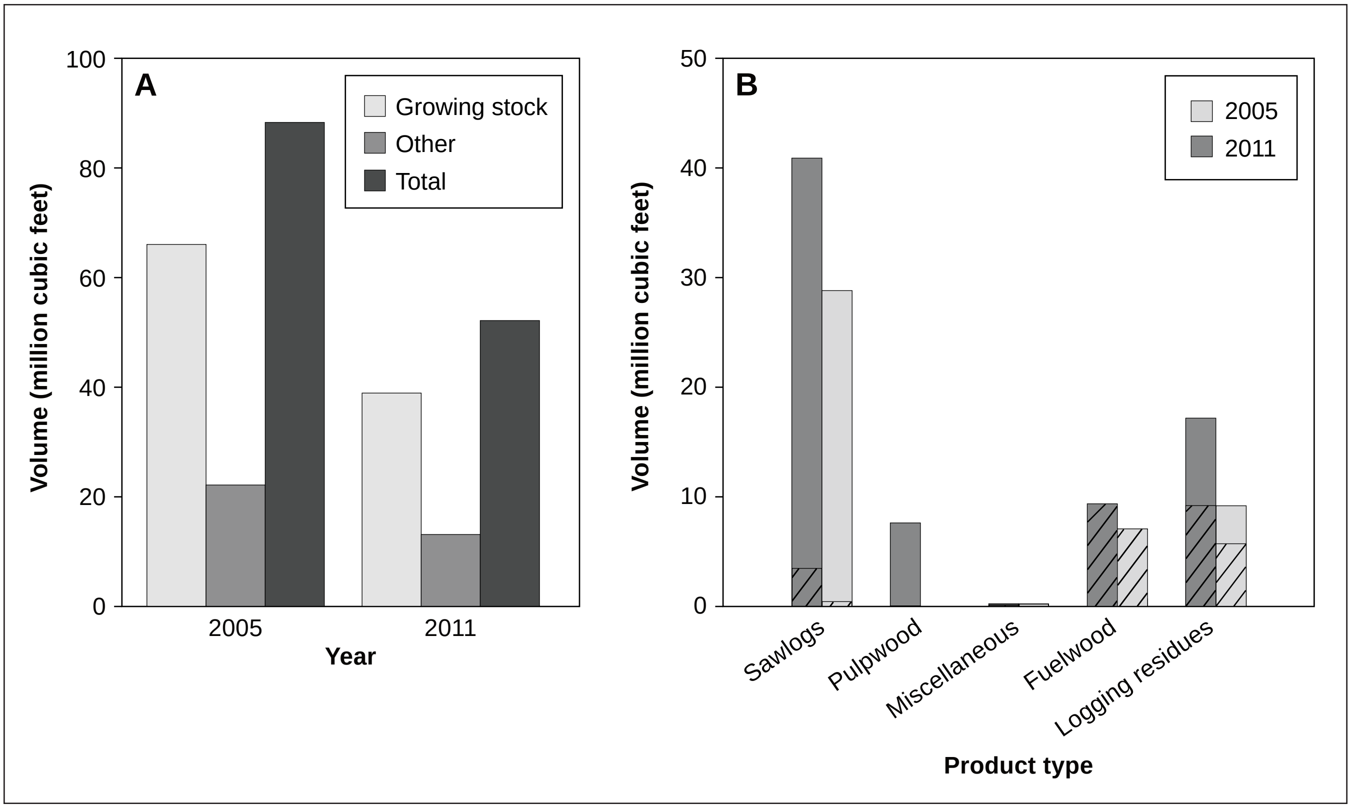


Figure 37—Volume of removals by (A) source material and (B) product type in 2005 and 2011 survey years. Sawlogs, pulpwood, and miscellaneous products are considered roundwood products. Hatched portion of bars in panel B represents a source other than growing stock trees used for each product type.

reduction) and non-growing stock (38 percent reduction) sources. The proportion of harvest for timber products relative to logging residue remained relatively consistent between survey years.

The distribution of timber harvest across public and private (including Native Corporation) forest ownerships shifted between 2005 and 2011. The decrease in total harvest for timber products was mirrored by declining trends observed across all land ownerships. Timber harvest for industrial timber products from private forest lands decreased by 47 percent from 2005 to 2011, and harvest for industrial products from USFS land decreased approximately 30 percent. In 2005, approximately 61 percent of industrial products harvested in Alaska came from private lands. By 2011, this proportion had slightly decreased to around 58 percent. Conversely, public lands represented an increased proportion of total timber harvest by 2011, with Forest Service industrial product harvest increasing from 17 to 21 percent, while other public lands, including Alaska Division of Forestry, University of Alaska, and Mental Health Trust lands, remained at 22 percent.

Alaska's Timber Industry

The geographic sources of Alaska's timber harvest can be divided into five resource areas: southeast, south-central, interior, western, and far north (fig. 38). The southeast resource area was the predominant source of industrial product removals in both 2005 and 2011, despite a proportional decrease from 74 percent of the harvest in 2005 to just under 60 percent in 2011. Conversely, the combined harvest contribution of south-central and western Alaska increased over the same period, from almost 25 percent of the harvest volume in 2005 to nearly 37 percent in 2011. Much of this expansion in south-central and western Alaska resulted from increased Native Corporation harvest on and around Kodiak Island (Alexander 2012).

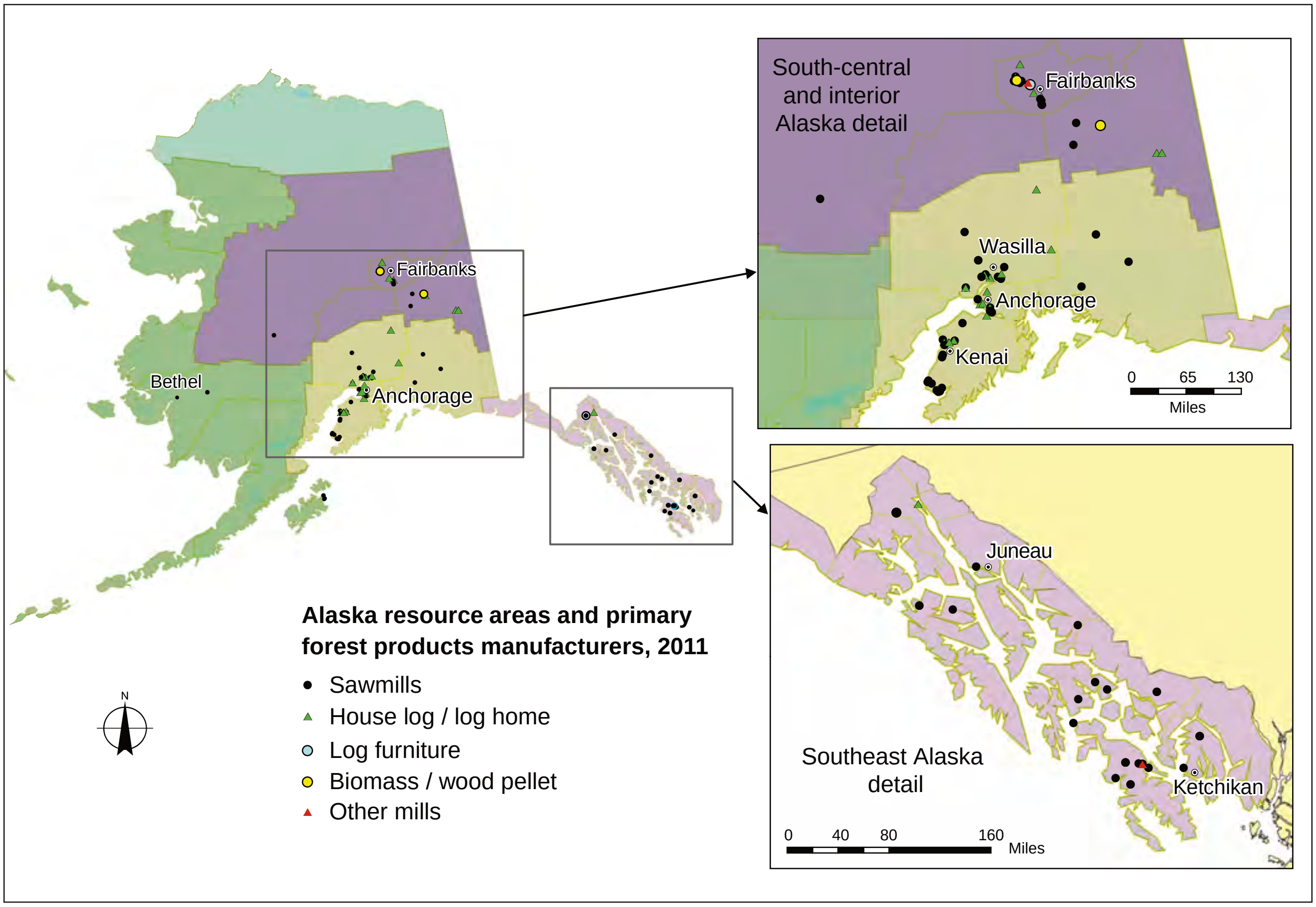


Figure 38—Alaska's forest resource areas and active primary manufacturers, 2011.

The volume of timber received by Alaska mills differs from the harvest volume because logs can be exported out of state. Exports of sawlogs and chipped roundwood, primarily to Pacific Rim countries such as China, accounted for a large percentage of timber harvest volume in Alaska. In 2005 and 2011, Alaska was a net exporter of timber with 83.4 percent and 87 percent, respectively, of the total timber harvest exported for processing (Halbrook et al. 2009). In 2005, Alaska facilities received almost 45 million board feet, Scribner (MMBF) (about 18 percent of the harvest) and in 2011, facilities received 23.3 MMBF (13 percent of the harvest) (fig. 39). The majority of timber harvested on private and Native Corporation land is exported, thus leaving Alaska mills highly dependent upon publicly supplied timber. The expansion of the log export markets in 2011 likely decreased the proportion of statewide timber harvest received by Alaska mills.

During 2005, approximately 268.2 MMBF) Scribner (about 52.6 million ft^3) of commercial timber products—excluding residential fuelwood—were harvested (Halbrook et al. 2009). By 2011, the harvest level for industrial timber products had fallen to 175.3 MMBF (Berg et al. 2014). Although overall harvest levels declined, the proportion of harvested volume coming from private and Native Corporation lands increased between 2005 (60.7 percent) and 2011 (73 percent) (Berg et al. 2014, Halbrook et al. 2009). Strong global demand for logs, particularly from Pacific Rim countries, continued to drive harvest operations across Native Corporation and other private timberlands.

There were major differences between species harvested for sawlogs, which accounted for 74 percent of timber received by Alaska facilities. In 2005, western hemlock accounted for more than 52 percent of the timber volume received by Alaska facilities (fig. 40), followed by

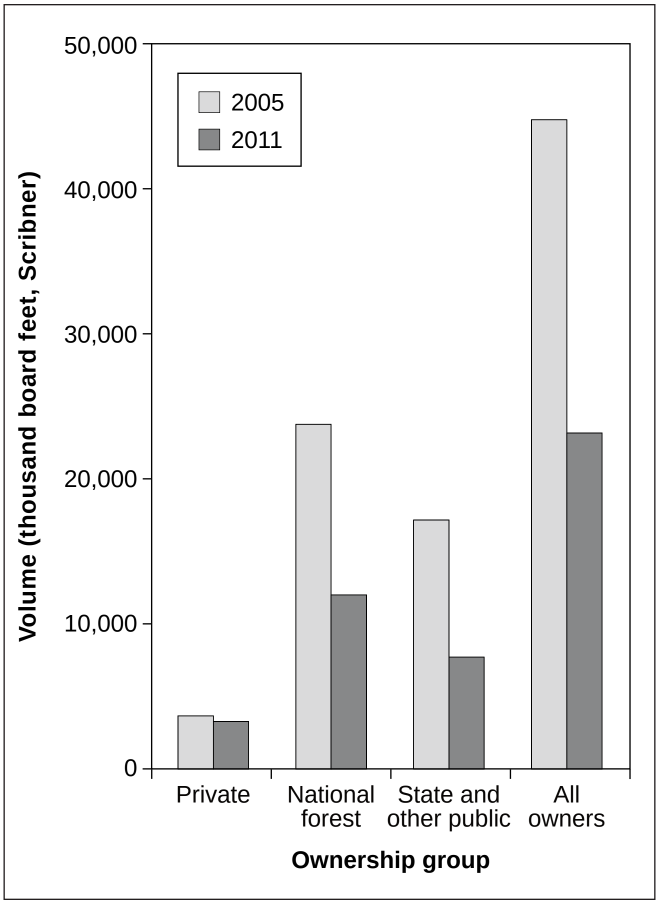


Figure 39—Timber volume received by Alaska facilities by ownership group. Data represent all timber products, including sawlogs, house logs, fuelwood, furniture, tonewood, novelty items, and cedar products (Berg et al. 2014).

Sitka spruce (24 percent). However, by 2011, white spruce accounted for the most timber volume received by mills (26.5 percent), closely followed by western redcedar (24.4 percent) and Sitka spruce (22 percent). The sharp decline in western hemlock timber reflects reductions in southeast Alaska mill operations as well as the closure or idling of several mills that predominately processed western hemlock and Sitka spruce in 2005.

Forest Understory and Nonforest Vegetation[4]

Understory and nonforest vegetation are important features of coastal Alaska ecosystems, providing habitat and forage for birds and mammals and contributing to biogeochemical and energy cycles (fig. 41). Vegetation profile protocols are aimed at quantifying understory vegetation among growth habits (shrub, forb, and grasslike), forest types and percentage cover of the most abundant species across all plots (see app. 3 for detailed methods). Nonforest vegetation is summarized by dominance type—a classification system that defines a plant community as it would be seen from overhead. Plot totals are summarized by year, forest, and nonforest conditions in table A1-49.

[4] Author: Bethany Schulz, research ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Anchorage, Alaska.

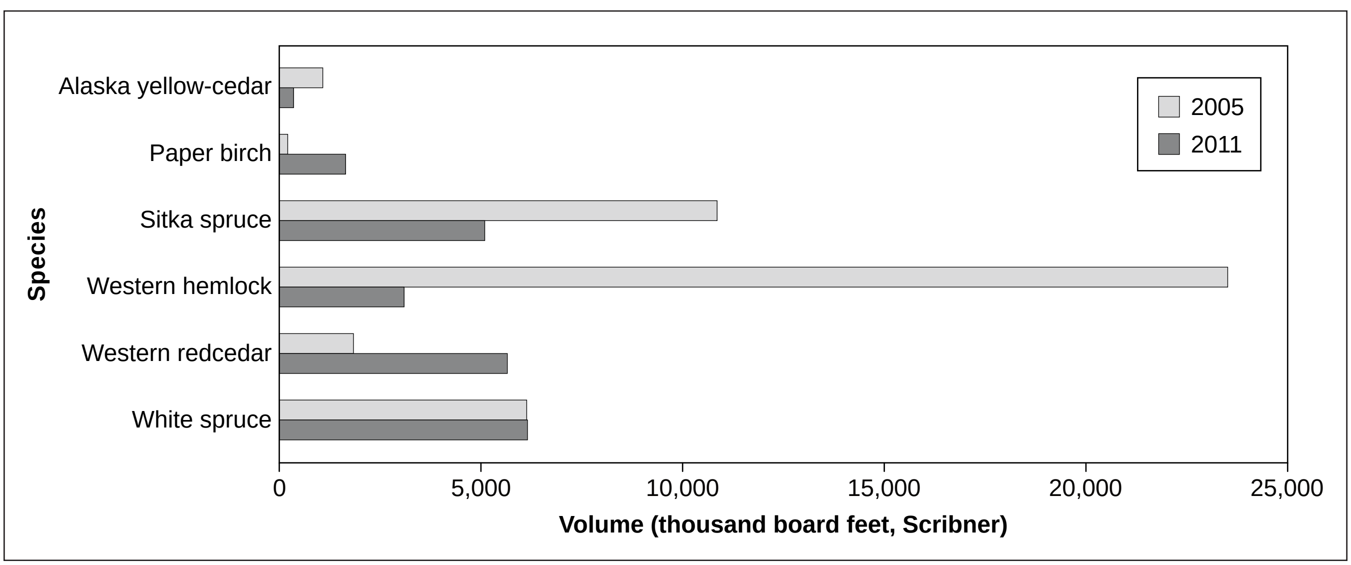


Figure 40—Timber volume of sawlogs (thousand board feet, Scribner) received by species in 2005 and 2011.

G. Dean

Figure 41—A Forest Inventory and Analysis field crew member navigates the dense understory on Kuiu Island in southeast Alaska. Devil's club (*Oplopanax horridus*) is the dominant vegetation in the foreground.

Vegetation Structure of Forest Lands

The distribution of growth habits was similar between reserved and unreserved forest lands. However, there was a significantly ($P < 0.05$) higher percentage of forbs on reserved lands (fig. 42). Higher canopy cover by forbs in reserved forests is indicative of older stands with more overstory canopy gaps in the coastal rainforest, as well as younger stands with canopies prone to disturbance in the boreal transition of Kenai Peninsula. When comparing growth habits among forest types (fig. 43), shrubs generally covered a higher percentage than forbs and grasslike plants. Forb cover was greatest in Alaska yellow-cedar forests, followed by cottonwood (*Populus* spp.), mountain hemlock, and white spruce forests. White spruce forests and lodgepole pine forests had significantly more grasslike cover than all other forest types except paper birch. White spruce stands recovering from a spruce bark beetle outbreak had high cover of bluejoint (*Calamagrostis canadensis*), particularly in the Kenai Lowland, where this species increased more than 10 percent following widespread spruce mortality (Boucher and Mead 2006). Lodgepole pine forests tended to include a variety of wetland

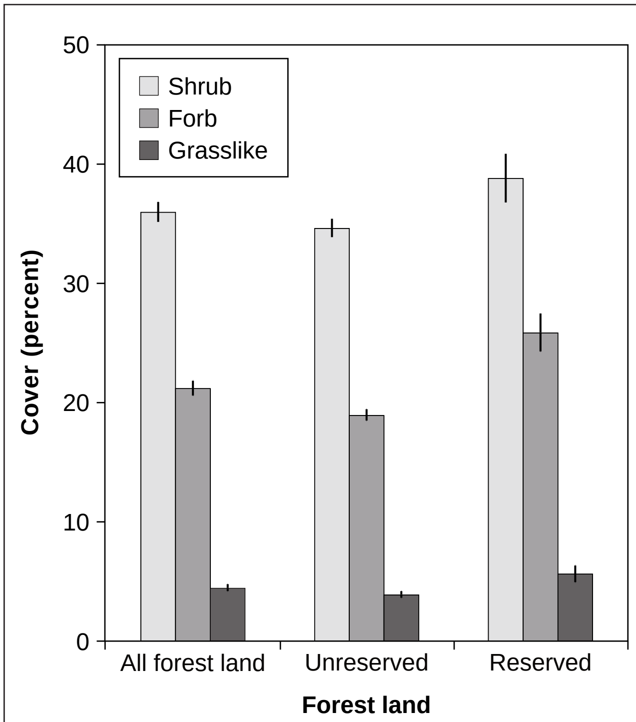


Figure 42—Average percentage cover of shrubs, forbs, and grasslike plants on all forest land, unreserved and reserved land conditions. Error bars are ±1 standard error.

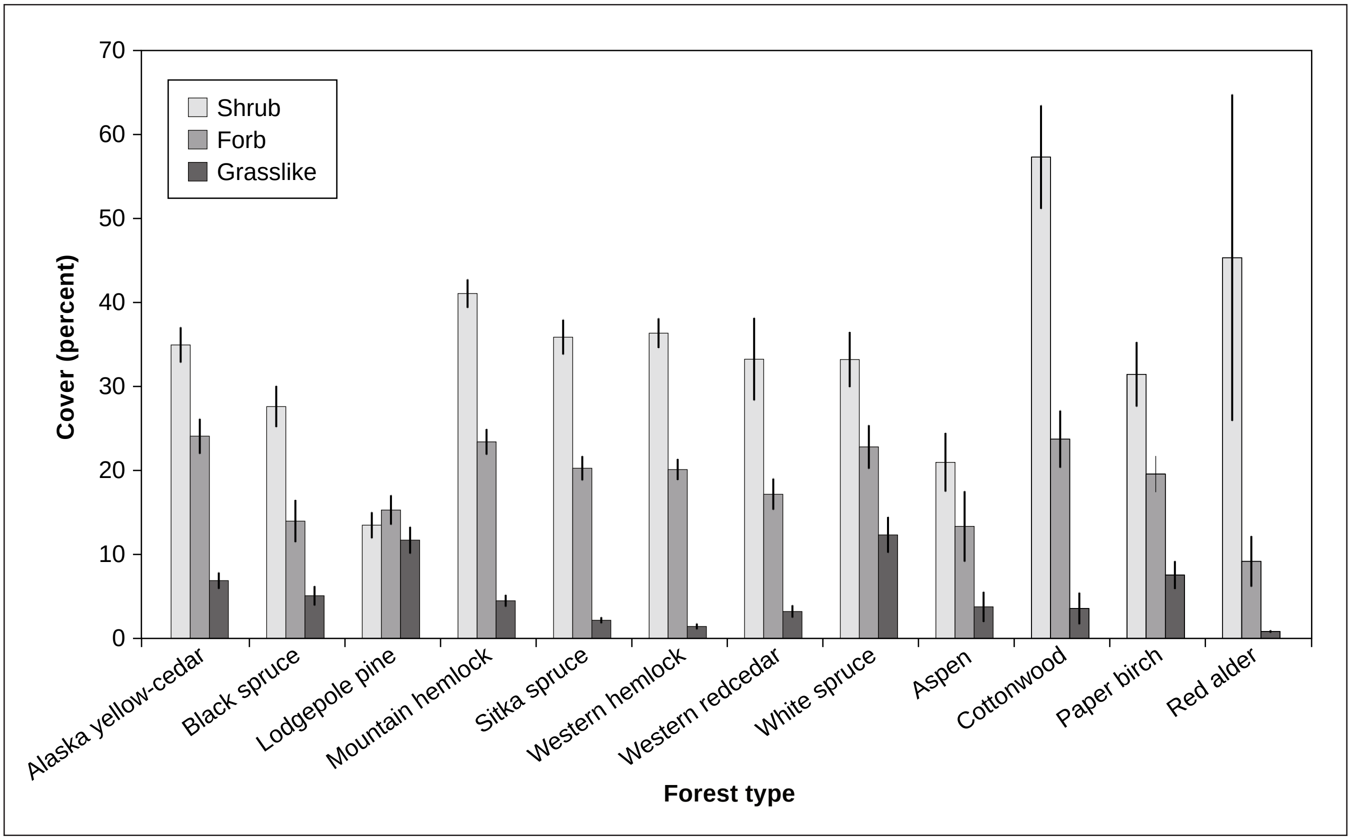


Figure 43—Average percentage cover of shrubs, forbs, and grasslike plants within each forest type. Error bars are ±1 standard error.

species, such as tall cottongrass (*Eriophorum angustifolium*), manyflower sedge (*Carex pluriflora*), and tufted bulrush (*Trichophorum cespitosum*), reflecting the habitat lodgepole pine forests generally occupy in southeast Alaska.

Species on Forest Land

Oval-leaf blueberry (*Vaccinium ovalifolium*) was by far the most abundant understory species within the coastal Alaska inventory unit (fig. 44) and serves as an important forage species for wildlife and humans alike (fig. 45). Rusty menziesia (*Menziesia ferruginea*) was the second most common species and is indicative of high light exposure and acidic, nutrient-poor soils. Many other species indicate various environmental conditions or have characteristics important to wildlife or stand structure definitions. For example, Sitka alder (*Alnus viridis* ssp. *sinuata*) is a large woody plant that occupies disturbed sites and forms a tight symbiotic relationship with nitrogen-fixing bacteria. Comparing the distribution of the top 30 species between reserved status, cover was significantly ($P < 0.05$) higher on reserved lands for deer fern (*Blechnum spicant*), lingonberry (*V. vitis-idaea*), and red huckleberry (*V. parvifolium*). Deer fern is a strong indicator of acidic, nutrient-poor conditions and is one of the most common species in western redcedar, mountain hemlock, and Alaska yellow-cedar forests. Lingonberry occurs most often in black spruce stands, a majority of which (21 of 30 plots) fall into reserved status lands on the Kenai National Wildlife Refuge. Red huckleberry has a limited distribution that overlaps with both western redcedar and several tracts of USFS wilderness.

Species by Forest Type

The most commonly recorded abundant species on each forest type often indicate distinct habitat features and provide insight into the variety of habitats among and within forest types. For instance, bunchberry dogwood (*Cornus canadensis*) was among the most abundant species on 10 of 12 forest types, western oakfern (*Gymnocarpium dryopteris*) was found on 8 of 12 forest types, and rusty menziesia and oval-leaf blueberry were found on 7 of 12 forest types. Some understory species are unique to particular forest types.

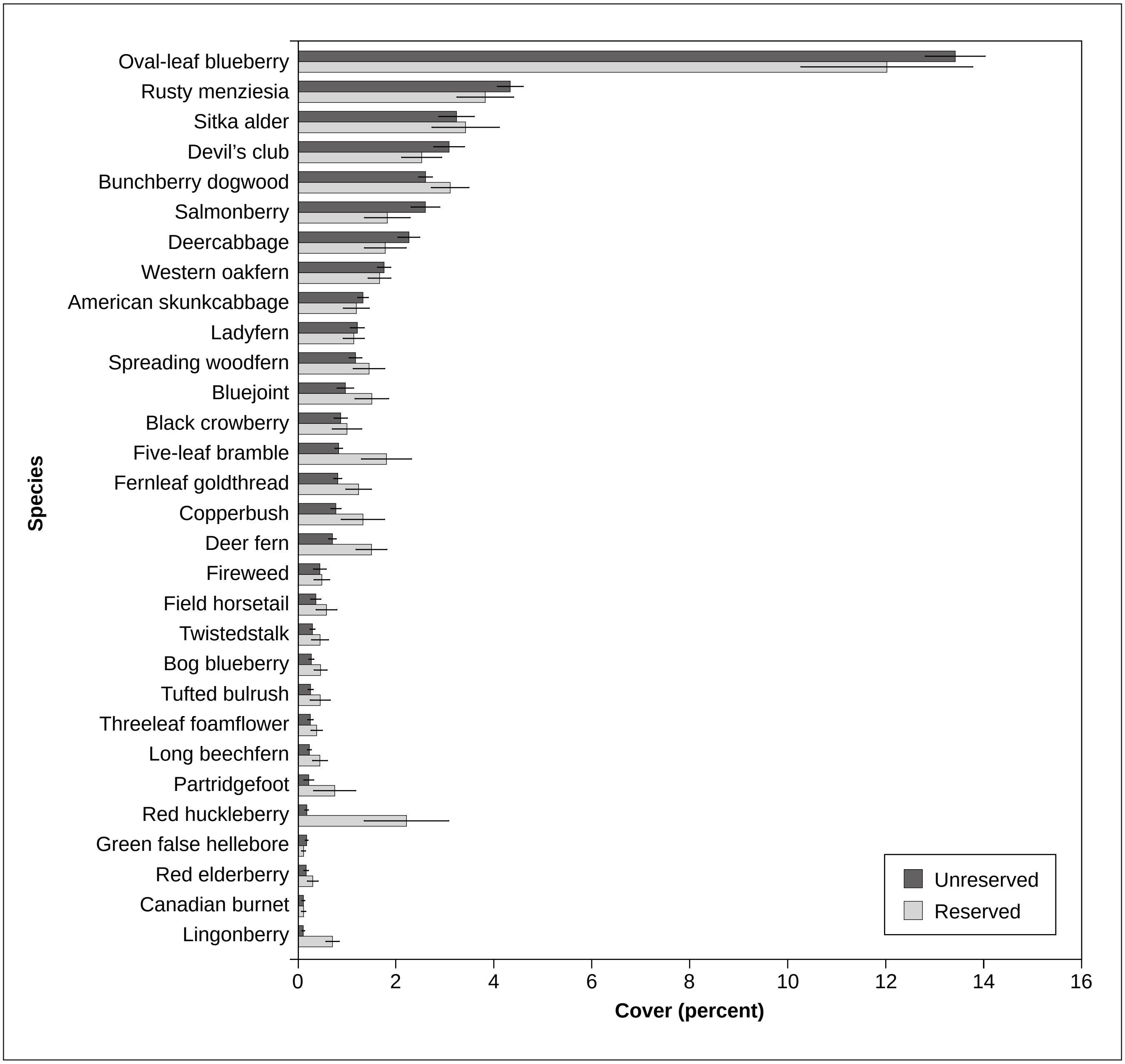


Figure 44—Average percentage cover of understory species on all forest land. Error bars are ±1 standard error.

K. Mohatt

Figure 45—Oval-leaf blueberry (*Vaccinium ovalifolium*), is the dominant understory species in coastal Alaska. This type of tall-shrub understory vegetation is an important structural and functional component of coastal forests.

Indeed, the most abundant commonly recorded species for black spruce, paper birch, and aspen include many species that are common to interior Alaska (e.g., lingonberry, dwarf birch [*Betula nana*], prickly rose [*Rosa acicularis*], and highbush cranberry [*Viburnum edule*]). These species are restricted to the Cook Inlet Basin Section and are not frequently found within the Coastal Rainforest Province that encompasses the majority of the inventory unit.

In Alaska yellow-cedar forests, understory species indicate the cool, moist habitats that allow yellow-cedar to compete with other tree species. Species most common to lodgepole pine include indicators of nutrient-poor, poorly-drained soils. This forest type has the greatest proportion of plots in a hydric physiographic class. Mountain hemlock stands include species common to a wide variety of site conditions, including the ubiquitous oval leaf blueberry, the cold site-indicator deercabbage (*Nephrophyllidium crista-galli*), and species indicating site disturbance and nutrient-rich conditions, such as Sitka alder and common ladyfern (*Athyrium filix-femina*). Sitka spruce stands commonly included species indicative of disturbance, ample moisture, and nutrients (e.g., devil's club [*Oplopanax horridus*], Sitka alder, common ladyfern, and salmonberry [*Rubus spectabilis*]).

Vegetation on Nonforest Lands

Species found on nonforest lands are summarized by their presence among dominance types (fig. 46). The most common species for most dominance types are shown in table A2-55, along with the constancy (proportion of plots where recorded) and average cover where recorded. Many species found in the tall shrub type indicate nutrient-rich,

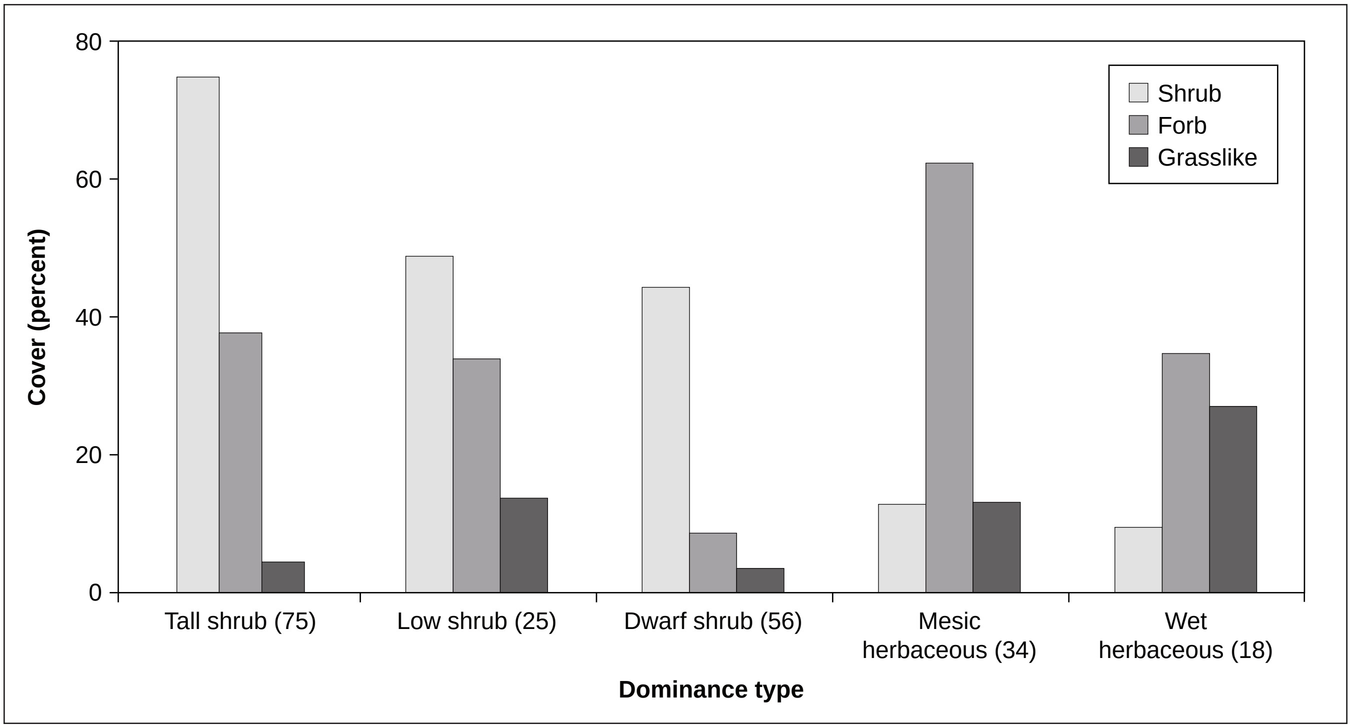


Figure 46—Average percentage cover of shrubs, forbs, and grasslike plants on nonforest dominance types. Numbers in parentheses represent the number of plots sampled from each dominance type.

moist soils and site disturbance, including Sitka alder and salmonberry. Low shrub types can occupy both wetland or nonwetland conditions, and the most common species include four obligate wetland species: sweet gale, buckbean (*Menyanthes trifoliata*), purple marshlocks (*Comarum palustre*), and deercabbage. The most common species in the dwarf shrub type are frequently found in subalpine and alpine zones. Mesic herbaceous types represent a wide variety of communities, as expressed with relatively low constancies for the most abundant species. The most common species in the wet herbaceous type include six obligate wetland species: buckbean, purple marshlocks, sweet gale, tall cottongrass, western waterhemlock (*Cicuta douglasii*), and manyflower sedge (*Carex pluriflora*).

Just as the status of "forest" covers a wide variety of structures and species composition, "nonforest" includes a diversity of plant communities (fig. 47). Woody shrubs comprise the majority of understory biomass in forests (Johnson et al. 2017), yet several species are not currently included in the FIA tree tally list. Sitka alder is one of the most common understory and nonforest species and is capable of growing to tree size (>5 inches d.b.h.). Incorporating nonforest vegetation in this analysis emphasizes the importance of the tall shrub dominance type, strengthening the argument to capture additional measurements of large shrubs and nontally tree species to account for their contribution to landscape biomass and carbon.

Invasive Plants[5]

Nonnative plants can displace native vegetation, degrade wildlife habitat, and negatively affect human health, the economy, and the environment. Factors such as geographic isolation and harsh winters have generally protected Alaska from large-scale invasions. However, some of the most harmful weeds of the contiguous United States have begun to grow and spread in Alaska. In addition, some introduced species that are not problematic elsewhere have demonstrated high invasiveness in Alaska (Carlson et al. 2008). Although

[5] Author: Bethany Schulz.

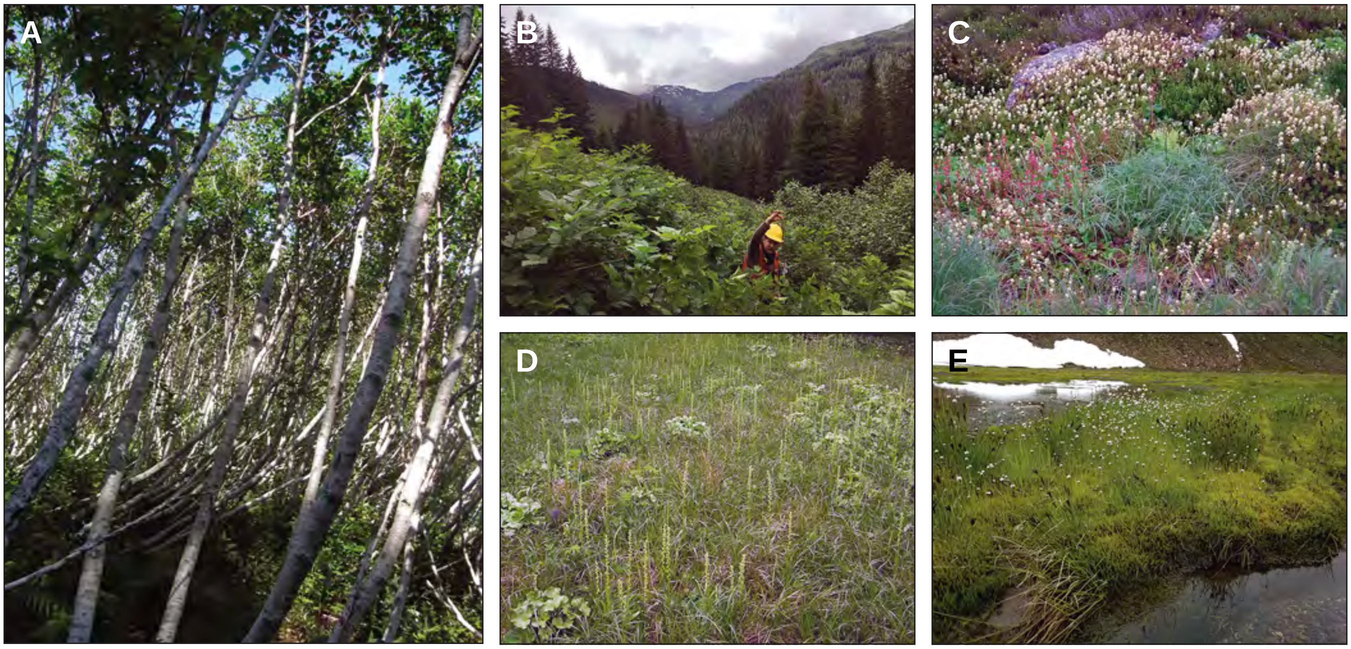


Figure 47—Examples of nonforest dominance types include (A) tall shrub, (B) low shrub, (C) dwarf shrub, (D) mesic herbaceous, and (E) wet herbaceous. Biomass can be quite high among tall shrub dominance types, particularly in Sitka alder stands shown in panel A.

most infestations occur around settlements and along travel corridors such as roads, trails, and waterways (Bella 2011, Carlson et al. 2008, Cortés-Burns et al. 2008, Spellman and Wurtz 2011), monitoring for these species throughout the coastal inventory unit provides valuable distribution information for land managers and invasive species researchers.

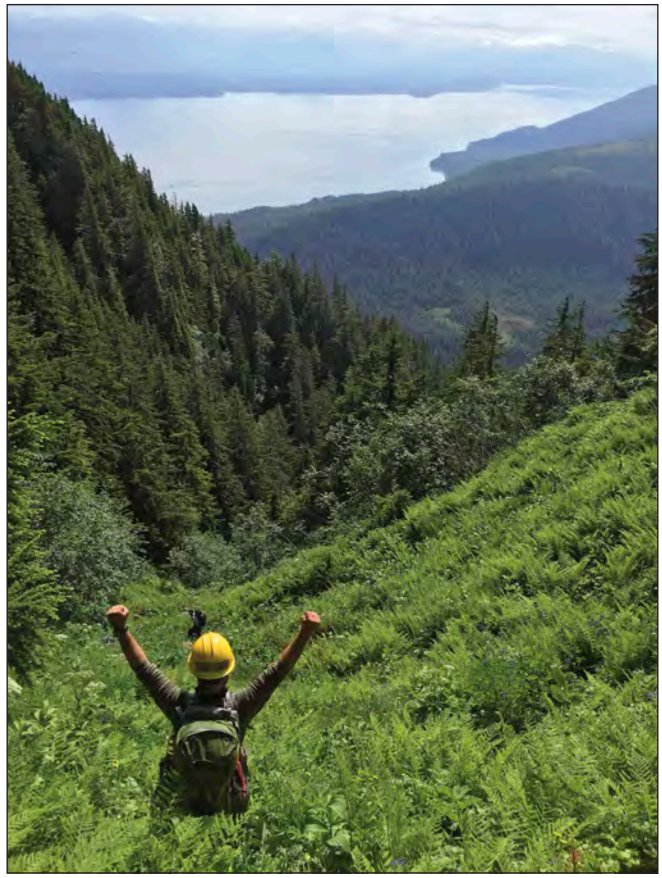
A total of 12 nonnative species were recorded on 18 plots between 2004 and 2013, representing less than 1 percent of all field-visited plots throughout the inventory unit. Of the 18 plots, 11 reported only one nonnative species. There were a total of 56 individual invasive species subplot records (some subplots had more than one species). The percentage of canopy cover of invasive species was low in general. The majority of records where cover exceeded 3 percent were in nonforested conditions with a present land use of “developed.”

Invasive species were present in a variety of forested conditions. Of the 18 plots, 7 had some nonforest conditions where invasive species were recorded, and 15 were less than 500 ft from a road. Two plots that were a mile or more from improved roads were occupied by a single species, reed canary grass, which was used to revegetate lands following timber harvesting. Previous plot records revealed that one plot had increased in distance from improved roads compared to an earlier plot visit, suggesting that the plot was near a logging road that was decommissioned between plot visits. The third plot greater than 500 ft from an improved road was a nonstocked plot, with minimal cover of white spruce and birch on the Kenai National Wildlife Refuge, where curly dock (*Rumex crispus*) was recorded. Curly dock seeds are small and easily transported by wind, water, or by attaching to clothing or fur, and is commonly found along the roadways of the Kenai Peninsula (AKEPIC 2018).

Although introduced and invasive plants are rare in Alaska’s remote forests, new species continue to arrive in the state. Monitoring forest inventory plots for invasive plant species helps land managers and researchers maintain awareness of changing species’ distributions and potential vectors for species transport, with important implications for policy development. In the case of remote plots, field crews have the potential to carry seeds from infested areas to pristine locations. Through extensive crew training, FIA strives to prevent spreading unwanted plants to avoid becoming part of the invasive species problem.

Conclusions

The forests of southeast and south-central Alaska hold important structural, functional, commercial, and cultural value throughout the region (fig. 48). Western hemlock, Sitka spruce, Alaska yellow-cedar, and mountain hemlock are the most common species in the inventory unit, together accounting for 75 percent of total forest area and 86 percent of total biomass. Much of coastal Alaska forest land is managed by the Forest Service within the 17-million-ac Tongass National Forest. The vast old-growth forests that occupy much of the inventory unit contain an enormous amount of C and play a vital role in regional C cycle processes. Understory vegetation was dominated by oval leaf blueberry, rusty menziesia, and bunchberry dogwood. Tall and dwarf shrub dominance types were the major communities in nonforest areas. Remeasurement analysis indicated that forest growth was positive or unchanged among most species in coastal Alaska, with the exception of lodgepole pine, which exhibited a net loss of biomass, potentially driven by climate and needle blight. Plot remeasurement data also provided insight into the forest growth dynamics of white spruce following the widespread spruce bark beetle outbreak in the late 1990s, with some evidence of a potential compensatory growth response among younger individuals following extensive mortality of dominant trees. Detecting trends in forest growth and changes in forest area is a major goal of the FIA program. By employing a spatially and temporally robust sampling protocol, FIA aims to provide updated estimates of forest resources to better inform the public, policymakers, and researchers of coastal Alaska's forest ecosystems.



G. Dean

Figure 48—Forest Inventory and Analysis crew members stop to enjoy a sunny day on Kupreanof Island in Tongass National Forest.

Selected Common and Scientific Plant Names

Life form	Common name	Scientific name
Trees:	Alaska paper birch[a]	*Betula neoalaskana* Sarg.
	Aspen, quaking aspen	*Populus tremuloides* Michx.
	Black spruce	*Picea mariana* (Mill.) Britton, Sterns & Poggenb.
	European bird cherry[b]	*Prunus padus* L.
	Lodgepole pine	*Pinus contorta* Douglas ex Loudon
	Lutz spruce[c]	*Picea × lutzii* Little
	Mountain hemlock	*Tsuga mertensiana* (Bong.) Carrière
	Pacific silver fir[d]	*Abies amabilis* (Douglas ex Loudon) Douglas ex Forbes
	Pacific yew[d]	*Taxus brevifolia* Nutt.
	Red alder	*Alnus rubra* Bong.
	Sitka spruce	*Picea sitchensis* (Bong.) Carrière
	Subalpine fir[d]	*Abies lasiocarpa* (Hook.) Nutt.
	Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
	Western redcedar	*Thuja plicata* Donn ex D. Don
	White spruce	*Picea glauca* (Moench) Voss
	Yellow-cedar, Alaska yellow-cedar	*Chamaecyparis nootkatensis* (D. Don) Spach a.k.a. *Callitropsis nootkatensis* (D. Don) Oerst. ex D.P. Little)
Shrubs:	American red raspberry	*Rubus ideaus* L.
	Black crowberry	*Empetrum nigrum* L.
	Bog Labrador tea	*Ledum groenlandicum* Oeder
	Bog laurel	*Kalmia polifolia* Wangenh.
	Common juniper	*Juniperus communis* L.
	Common snowberry	*Symphoricarpos albus* (L.) S.F. Blake
	Devil's club	*Oplopanax horridus* (Sm.) Miq.
	Hemlock dwarf mistletoe	*Arceuthobium* spp.
	Kinnikinnick	*Arctostaphylos uva-ursi* (L.) Spreng.
	Oval-leaf blueberry	*Vaccinium ovalifolium* Sm.
	Rusty menziesia	*Menziesia ferruginea* Sm.
	Salmonberry	*Rubus spectabilis* Pursh
	Sitka alder	*Alnus viridis* (Chaix) DC. ssp. *sinuata* (Regel) Á. Löve & D. Löve
	Sweetgale	*Myrica gale* L.
Forbs:	American skunkcabbage	*Lysichiton americanus* Hultén & St. John
	Bunchberry dogwood	*Cornus canadensis* L.
	Common ladyfern	*Athyrium filix-femina* (L.) Roth
	Green false hellebore	*Veratrum viride* Ait
	Deercabbage	*Nephrophyllidium crista-galli* (Menzies ex. Hook.) Gilg
	Fireweed	*Chamerion angustifolium* (L.) Holub.
	Spreading woodfern	*Dryopteris expansa* (C. Presl) Fraser-Jenkins &Jermy
	Threeleaf foamflower	*Tiarella trifoliata* L.
	Twistedstalk	*Streptopus lanceolatus* (Aiton) Reveal
	Western oakfern	*Gymnocarpium dryopteris* (L.) Newman
Graminoids:	Bluejoint	*Calamagrostis* canadensis (Michx.) P. Beauv.
	Rush	*Juncus* spp.
	Sedge	*Carex* spp.
	Tall cottongrass	*Eriophorum angustifolium* (Honckeny)

[a] Trees recorded as paper birch on the Kenai Peninsula are *Betula kenaica* in some taxonomies, but are not distinguished in this inventory.
[b] Included under "other hardwoods" in tables.
[c] Sitka spruce and white spruce can hybridize as Lutz spruce in areas of the Kenai Peninsula. Forest Inventory and Analysis field crew classify Lutz spruce to whichever of the two species it most resembles.
[d] Included under "other softwoods" in tables.

Metric Equivalents

When you know:	Multiply by:	To find:
Inches	2.54	Centimeters
Feet (ft)	0.3048	Meters
Miles (mi)	1.609	Kilometers
Acres (ac)	0.405	Hectares
Board feet	0.0024	Cubic meters
Cubic feet (ft^3)	0.0283	Cubic meters
Tons per acre	2.24	Megagrams per hectare

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Appendix 1: Summary Data Tables

The tables below represent the main summary of data used to compile this report, available online at https://www.fs.fed.us/pnw/pubs/pnw_gtr979-supplement1.pdf.

Area

Table A1-1—Area of sampled land and water, by land status and ownership group, coastal Alaska, 2004–2013

Table A1-2—Area of forest land, by borough/census area and land status, coastal Alaska, 2004–2013

Table A1-3—Area of forest land, by borough and ownership group, coastal Alaska, 2004–2013

Table A1-4—Area of forest land, by forest type, ownership group, and land status, coastal Alaska 2004–2013

Table A1-5—Area of forest land, by forest type and stand age class, coastal Alaska, 2004–2013

Table A1-6—Area of forest land, by ownership and land status, coastal Alaska, 2004–2013

Number of Live Trees

Table A1-7—Number of live trees on forest land, by borough and land status, coastal Alaska, 2004–2013.

Table A1-8—Number of live trees on forest land, by species and diameter class, coastal Alaska, 2004–2013.

Table A1-9—Number of dead trees on forest land, by species and diameter class, coastal Alaska, 2004–2013.

Table A1-10—Number of growing stock trees on timberland, by species and diameter class, coastal Alaska, 2004–2013.

Tree Volume

Table A1-11—Net volume of live trees on forest land, by ownership and land status, coastal Alaska, 2004–2013.

Table A1-12—Gross volume of dead trees on forest land, by ownership and land status, coastal Alaska, 2004–2013.

Table A1-13—Net cubic volume of live trees on forest land, by borough and land status, coastal Alaska, 2004–2013.

Table A1-14—Net volume of live trees on forest land, by forest type and stand size class, coastal Alaska, 2004–2013.

Table A1-15—Net volume of live trees on forest land, by forest type and ownership group, coastal Alaska, 2004–2013.

Table A1-16—Net volume of live trees on forest land, by species and diameter class, coastal Alaska, 2004–2013.

Table A1-17—Average net volume per acre of live trees on forest land, by forest type and stand age class, coastal Alaska, 2004–2013.

Table A1-18—Average gross volume per acre of dead trees on forest land, by forest type and stand age class, coastal Alaska, 2004–2013.

Table A1-19—Net volume of growing stock trees on timberland, by species and diameter class, coastal Alaska, 2004–2013.

Table A1-20—Net volume of growing stock trees on timberland, by species and ownership group, coastal Alaska, 2004–2013.

Biomass

Table A1-21—Aboveground biomass of live trees on forest land, by ownership and land status, coastal Alaska, 2004–2013.

Table A1-22—Aboveground biomass of live trees on forest land, by forest type and land status, coastal Alaska, 2004–2013.

Table A1-23—Aboveground biomass of dead trees on forest land, by ownership and land status, coastal Alaska, 2004–2013.

Table A1-24—Aboveground biomass of dead trees on forest land, by forest type and land status, coastal Alaska, 2004–2013.

Table A1-25—Aboveground biomass of live trees on forest land, by borough and land status, coastal Alaska, 2004–2013.

Table A1-26—Aboveground biomass of dead trees on forest land, by borough and land status, coastal Alaska, 2004–2013.

Table A1-27—Average aboveground biomass per acre of live trees on forest land, by forest type and ownership group, coastal Alaska, 2004–2013.

Table A1-28—Average aboveground biomass per acre of dead trees on forest land by forest type and ownership group, coastal Alaska, 2004–2013.

Table A1-29—Average aboveground biomass per acre of live trees on forest land, by forest type and stand size class, coastal Alaska, 2004–2013.

Table A1-30—Average aboveground biomass per acre of dead trees on forest land, by forest type and stand size class, coastal Alaska, 2004–2013.

Carbon

Table A1-31—Aboveground carbon mass of live trees on forest land, by ownership and land status, coastal Alaska, 2004–2013.

Table A1-32—Aboveground carbon mass of dead trees on forest land, by ownership and land status, coastal Alaska, 2004–2013.

Table A1-33—Average aboveground carbon mass per hectare of live trees on forest land, by forest type and ownership group, coastal Alaska, 2004–2013.

Table A1-34—Average aboveground carbon mass per hectare of dead trees on forest land, by forest type and ownership group, coastal Alaska, 2004–2013.

National Forests

Table A1-35—Area of forest land, by forest type within Chugach and Tongass National Forests, coastal Alaska, 2004–2013.

Table A1-36—Aboveground biomass of live trees on forest land, by national forest and land status, coastal Alaska, 2004–2013.

Table A1-37—Aboveground carbon mass of live trees on forest land, by national forest and land status, coastal Alaska, 2004–2013.

Table A1-38—Average aboveground biomass per acre of live trees on forest land, by national forest and land status, coastal Alaska, 2004–2013.

Table A1-39—Average aboveground carbon mass per hectare of live trees on forest land, by national forest and land status, coastal Alaska, 2004–2013.

Table A1-40—Average aboveground carbon mass per hectare of live trees on forest land, by forest type within each National Forest, coastal Alaska, 2004–2013.

Wildlife Refuges

Table A1-41—Area of forest land, by forest type within Kenai and Kodiak Wildlife Refuges, coastal Alaska, 2004–2013.

Table A1-42—Aboveground biomass of live trees on forest land within Kenai and Kodiak Wildlife Refuges, coastal Alaska, 2004–2013.

Table A1-43—Aboveground carbon mass of live trees on forest land within Kenai and Kodiak Wildlife Refuges, coastal Alaska, 2004–2013.

Timber Products Output

Table A1-44—Volume of removals by source of material and removal type, Alaska, 2005 and 2011.

Table A1-45—Volume of removals by ownership and removal type, Alaska 2005 and 2011.

Table A1-46—Proportion of removals by ownership and removal type, Alaska 2005 and 2011.

Table A1-47—Timber volume received by Alaska facilities by ownership class and product type, 2011 (Berg et al. 2014).

Table A1-48—Timber volume received by Alaska facilities by species and product type, 2011 (Berg et al. 2014).

Understory Vegetation

Table A1-49—Number of plots inventoried by plot condition and measurement year.

Table A1-50—Thirty most commonly recorded abundant species, indicator codes and average percent cover on all forest lands, coastal Alaska, 2004–2013.

Table A1-51—Number of plots within each forest type, separated by physiographic class category and elevation, coastal Alaska, 2004–2013.

Nonforest Vegetation

Table A1-52—Nonforest dominance type, description, number of plots and elevational bands, coastal Alaska, 2004–2013.

Invasive Plants

Table A1-53—Scientific and common names on invasive plants, the number of plots and subplots where recorded, invasive ranking, average percentage canopy cover, where present, and range of percentage canopy cover, coastal Alaska, 2004–2013.

Appendix 2: Summary Data Tables Available Online

Additional tables summarizing data used in this report can be found online at https://www.fs.fed.us/pnw/pubs/pnw_gtr979-supplement2.pdf

Area

Table A2-1—Area of forest land, by forest type and land status, coastal Alaska, 2004–2013

Table A2-2—Area of forest land, by forest type and site productivity class, coastal Alaska 2004–2013.

Table A2-3—Area of forest land, by forest type and stand size class, coastal Alaska, 2004–2013.

Table A2-4—Area of forest land by ecological section and land status, coastal Alaska, 2004–2013.

Table A2-5—Area of forest land by forest type and ecological section, coastal Alaska, 2004–2013.

Table A2-6—Area of forest land, by forest type and stand origin, coastal Alaska, 2004–2013.

Table A2-7—Area of timberland, by forest type and stand size class, coastal Alaska, 2004–2013.

Number of Live Trees

Table A2-8—Number of live trees on forest land, by forest type and ownership group, coastal Alaska, 2004–2013.

Table A2-9—Number of dead trees on forest land, by forest type and ownership group, coastal Alaska, 2004–2013.

Table A2-10—Average number of live trees per acre on forest land, by forest type and ownership group, coastal Alaska, 2004–2013.

Table A2-11—Average number of dead trees per acre on forest land, by forest type and ownership group, coastal Alaska, 2004–2013.

Volume

Table A2-12—Gross volume of dead trees on forest land, by forest type and stand size class, coastal Alaska, 2004–2013.

Table A2-13—Gross volume of dead trees on forest land, by forest type and ownership group, coastal Alaska, 2004–2013.

Table A2-14—Net volume of live trees on forest land, by species and ownership group, coastal Alaska, 2004–2013.

Table A2-15—Gross volume of dead trees on forest land, by species and ownership group, coastal Alaska, 2004–2013.

Table A2-16—Gross volume of dead trees on forest land, by species and diameter class, coastal Alaska, 2004–2013.

Table A2-17—Net volume of live trees on forest land, by forest type and stand origin, coastal Alaska, 2004–2013.

Table A2-18—Gross volume of dead trees on forest land, by forest type and stand origin, coastal Alaska, 2004–2013.

Table A2-19—Net volume of live trees on forest land, by forest type and stand age class, coastal Alaska, 2004–2013.

Table A2-20—Gross volume of dead trees on forest land, by forest type and stand age class, coastal Alaska, 2004–2013.

Table A2-21—Average net volume per acre of live trees on forest land, by forest type and stand size class, coastal Alaska, 2004–2013.

Table A2-22—Average net volume of live trees on forest land, by forest type and ownership group, coastal Alaska, 2004–2013.

Table A2-23—Average gross volume per acre of dead trees on forest land, by forest type and ownership group, coastal Alaska, 2004–2013.

Table A2-24—Net volume of growing stock trees on timberland, by species and diameter class, coastal Alaska, 2004–2013.

Table A2-25—Net cubic volume of sawtimber-sized trees on timberland, by species and ownership group, coastal Alaska, 2004–2013.

Table A2-26—Net boardfoot volume (Scribner rule) of sawtimber trees on timberland, by borough and ownership group, coastal Alaska, 2004–2013.

Table A2-27—Net boardfoot volume (Scribner rule) of sawtimber trees on timberland, by forest type and ownership group, coastal Alaska, 2004–2013.

Table A2-28—Net boardfoot volume (Scribner rule) of sawtimber trees on timberland, by forest type and stand size class, coastal Alaska, 2004–2013.

Table A2-29—Net boardfoot volume (Scribner rule) of sawtimber trees on timberland, by species and diameter class, coastal Alaska, 2004–2013.

Table A2-30—Net boardfoot volume (International ¼-inch rule) of sawtimber trees on timberland, by species and diameter class, coastal Alaska, 2004–2013.

Table A2-31—Net boardfoot volume (International ¼-inch rule) of sawtimber trees on timberland, by species and ownership group, coastal Alaska, 2004–2013.

Table A2-32—Average net boardfoot volume per acre (Scribner rule) of sawtimber trees on timberland, by forest type and ownership group, coastal Alaska, 2004–2013.

Table A2-33—Gross cubic volume of live trees on forest land, by costal region and land status, coastal Alaska, 2004–2013.

Table A2-34—Gross cubic volume of dead trees on forest land, by costal region and land status, coastal Alaska, 2004–2013.

Table A2-35—Net cubic volume of live trees on forest land, by coastal region and broad species group, coastal Alaska, 2004–2013.

Biomass

Table A2-36—Aboveground biomass of live trees on forest land, by forest type and ownership group, coastal Alaska, 2004–2013.

Table A2-37—Aboveground biomass of dead trees on forest land, by forest type and ownership group, coastal Alaska, 2004–2013.

Table A2-38—Aboveground biomass of live trees on forest land, by forest type and stand size class, coastal Alaska, 2004–2013.

Table A2-39—Aboveground biomass of dead trees on forest land, by forest type and stand size class, coastal Alaska, 2004–2013.

Table A2-40—Aboveground biomass of live trees on forest land, by forest type and stand age class, coastal Alaska 2004–2013.

Table A2-41—Aboveground biomass of dead trees on forest land, by forest type and stand age class, coastal Alaska, 2004–2013.

Table A2-42—Aboveground biomass of live trees on forest land, by species and diameter class, coastal Alaska, 2004–2013.

Table A2-43—Aboveground biomass of dead trees on forest land, by species and diameter class, coastal Alaska, 2004–2013.

Table A2-44—Aboveground green biomass of live trees on forest land, by forest type and land status, coastal Alaska, 2004–2013.

Table A2-45—Aboveground green weight biomass of live trees on forest land, by species and diameter class, coastal Alaska, 2004–2013.

Table A2-46—Average aboveground biomass per acre of live trees on forest land, by forest type and stand age class, coastal Alaska 2004–2013.

Table A2-47—Average aboveground biomass per acre of dead trees on forest land, by forest type and stand age class, coastal Alaska, 2004–2013.

Carbon

Table A2-48—Aboveground carbon mass of live trees on forest land by, forest type and ownership group, coastal Alaska, 2004–2013.

Table A2-49—Aboveground carbon mass of dead trees on forest land, by forest type group and ownership group, coastal Alaska, 2004–2013.

Table A2-50—Aboveground carbon mass of live trees on forest land, by forest type and stand size class, coastal Alaska, 2004–2013.

Table A2-51—Aboveground carbon mass of dead trees on forest land, by forest type group and stand size class, coastal Alaska, 2004–2013.

Table A2-52—Aboveground carbon mass of live trees on forest land, by species group and diameter class, coastal Alaska, 2004–2013.

Table A2-53—Aboveground carbon mass of dead trees on forest land, by species and diameter class, coastal Alaska, 2004–2013.

Understory Vegetation

Table A2-54—Ten most commonly recorded abundant species for each forest type, coastal Alaska, 2004–2013.

Nonforest Vegetation

Table A2-55—Constancy and average percent cover of species found within each dominance type, coastal Alaska, 2004–2013.

Invasive Plants

Table A2-56—Scientific and common names of invasive plants surveyed for in coastal Alaska, 2004–2013.

Appendix 3: Forest Inventory Methods and Design

The Annual Inventory

Since 2004, the Forest Inventory and Analysis (FIA) program in coastal Alaska has followed national FIA field sampling protocols. Each year, a random subsample of 10 percent of the plots in the inventory unit is measured, referred to as a panel. Because there are very few roads in the coastal Alaska region, most plots must be accessed by a helicopter/boat combination. Owing to limitations on the use of helicopters, Glacier Bay National Park and wilderness areas in the Chugach and Tongass National Forests are excluded from the inventory. With those exceptions, the plots measured in a single panel span all forest land in the inventory unit, including all public and privately owned forests.

Estimates of forest attributes made from a single panel are imprecise because one panel represents only 10 percent of the full inventory sample. More precise statistics are obtained by combining data from multiple panels. Estimates from sampled plots in the ten panels measured from 2004 to 2013 were combined to produce most of the statistics in this report. One extra panel of plots was collected and used for this report on the Kenai National Wildlife refuge. A single panel of plots measured in 2005 from the Chugach and Tongass National Forest wilderness and wilderness study areas was used for some summary estimates.

The FIA Program collects information in three phases. In phase 1, the area in the inventory unit is interpreted from remotely sensed imagery, classifying land into broad relatively homogenous groups called strata. In phase 2, field plots are measured for a variety of indicators that describe forest composition, structure, and the physical geography of the landscape. Phase 2 plots are spaced at approximate 3-mi intervals on a hexagonal grid throughout the forest. In phase 3, one of every 16 phase 2 field plots is visited and a variety of forest health measurements are collected.

Phase 1—

The purpose of phase 1 is to reduce the variance associated with estimates of various forest attributes. For the phase 1 interpretation of the coastal Alaska unit, FIA uses the National Land Cover Dataset 2001 (Homer et al. 2007) to stratify the land by forest, water, and nonforest and by canopy density class within forest land. We also incorporated an elevation grouping from digital elevation models (USGS 1999), broad ownership information from a variety of sources, and climate data representing a spatial model of 1961 through 1990 average annual temperature and precipitation (PRISM Climate Group 2002). The resulting strata are evaluated for each estimation unit, and collapsed as necessary to ensure that at least four plots are in each stratum. Stratified estimation is applied by assigning each plot to one of these collapsed strata and by calculating the area of each collapsed stratum in each estimation unit. The estimates from stratified data are usually more precise than those from unstratified estimates. Because of the statistical methods used, misclassification errors in the phase 1 data may cause imprecision but do not create bias in the estimators used. More information on sample design and estimators is available in Bechtold and Patterson (2005).

Phase 2—

Phase 2 plots are a systematic sample with a random component selected from the entire area within the inventory unit, including both land and water. Plots are visited in the field if an aerial photo indicates that they might contain forest. The plot installed at each forested phase 2 location is a cluster of four subplots spaced 120 ft apart (fig. A3-1). Subplot 1 is in the center, with subplots 2 through 4 uniformly distributed radially around it. Each point serves as the center of a 1/24-ac circular subplot used to sample all trees at least 5.0 inches in diameter at breast height (d.b.h.). A 1/300-ac microplot, with its center located just east of each subplot center, is used to sample trees 1.0 to 4.9 inches d.b.h., as well as seedlings (trees less than 1.0 inch d.b.h.).

Field crews delineate areas that are relatively homogenous using (1) reserved status, (2) owner group, (3) forest type, (4) stand size class, (5) regeneration status, and (6) tree density; these areas are described as condition classes. The process of delineating these condition classes on a fixed-radius plot is called mapping. All measured trees are assigned to the mapped condition class in which they are located. On phase 2 plots, crews assess physical characteristics such as slope, aspect, and elevation; stand characteristics such as age, size class, forest type, disturbance, site productivity,

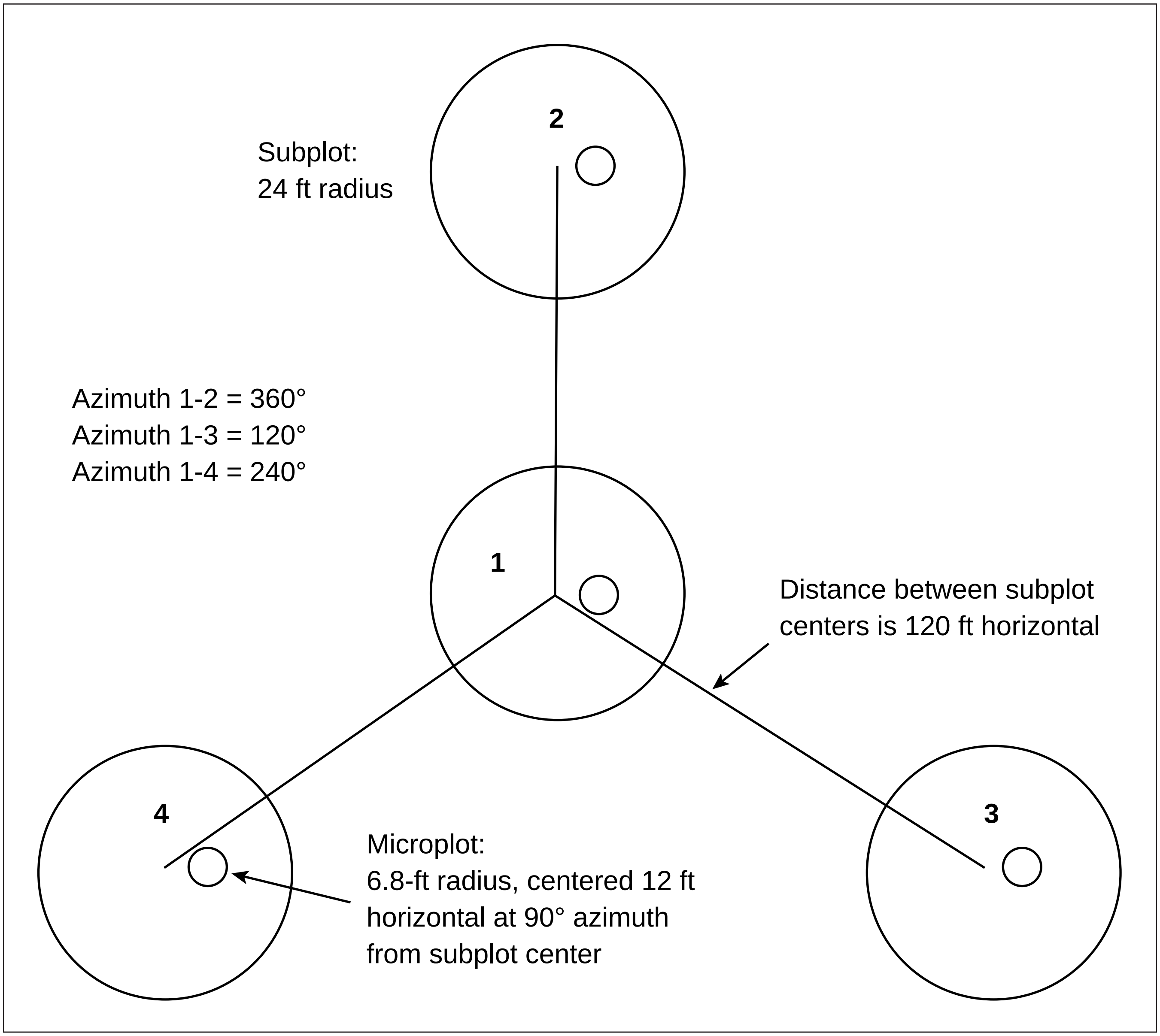

Figure A3-1—Plot layout diagram used in the coastal Alaska annual inventory (2004–2013).

and regeneration status; and tree characteristics such as tree species, diameter, height, and vertical crown dimensions. They also collect general descriptive information such as proximity to roads, and the geographic position of the plot in the larger landscape.

The FIA program measured 2,227 forested phase 2 plots in Alaska between 2004 and 2013. Estimates of tree biomass and other forest attributes were derived from tree measurements and classifications made at each plot. Volumes for individual tally trees were computed using published allometric equations for each of the major species in Alaska. Estimates of growth, removals, and mortality were determined from measurements taken at a subset of 2,023 forested plots that were also measured during the 1994 through 2003 periodic inventory.

Phase 3—
Some additional forest health measurements are collected on a subset (1/16) of phase 2 sample locations. At the phase 3 plots, measurements are taken on tree crowns, lichens, downed woody material, and understory vegetation, in

addition to the phase 2 variables. In total, 181 forested phase 3 plots were completed in the coastal Alaska inventory unit between 2004 and 2013. One forest health measurement, ozone injury, was monitored in 2004 and 2005 with four specially selected plots near Anchorage and Juneau; no ozone injury was detected. The relatively small number of phase 3 samples is intended to serve as a broad-scale detection monitoring system for forest health problems.

Core, core-optional, and regional variables—
Almost all of the FIA variables collected in Alaska are identical to those collected by FIA elsewhere in the United States—these are national "core" or "core optional" variables. Core optional, as the name suggests, are variables that are optional for any state but, if collected, must be collected using the standard national method. A small number of other variables are unique to PNW-FIA. These are "regional" variables and include such items as the species and cover of any invasive plants found on the plot and some variables used to help link measurements between the periodic and annual inventories (see below). The database and documentation of variables used in this report are available at: http://fiatools.fs.fed.us/fiadb-downloads/datamart.html. Field manuals can also be useful for understanding how variables were collected and are available at: www.fs.fed.us/pnw/rma/fia-topics/documentation/field-manuals/index.php.

Site index, volume, and biomass estimates—
Site index is used to measure potential productivity of forest land and to distinguish timberland from forest land. For Pacific silver fir, subalpine fir, Sitka spruce, western hemlock, and mountain hemlock (see "Selected Common and Scientific Plant Names") more than 200 years of age, site index curves from Hegyi et al. (1979) were used. For trees of these species less than 200 years old, a site index equation was fitted to data from Taylor (1934) using data from Payandeh (1974). For Alaska yellow-cedar, lodgepole pine, western redcedar, paper birch, aspen, and red alder, Hegyi et al. (1979) was used. For white spruce and black spruce, Farr (1967) was used. Volume equations used include Bracket (1973), DeMars (1996a and 1996b), Embry and Haack (1965), Larson and Winterberger (1988, 1990), and Bruce (1984). Application to individual trees differed depending on the height class and diameter class of the tree and type of volume (cubic foot, Scribner board foot, international board foot) estimated. For application to specific cases, contact the FIA office. Biomass calculations for tree species in coastal Alaska are derived from the following sources:

Species/tree type	Biomass citation
Seedlings	Alemdag (1984)
Aspen	Manning et al. (1984)
Balsam poplar	Singh (1984)
Birch	Alemdag (1984)
Black spruce	Manning et al. (1984)
Cottonwood	Singh (1984)
Lodgepole pine	Manning et al. (1984)
Mountain hemlock	Shaw (1979
Pacific silver fir	Krumlik and Kimmins (1973)
Red alder	Standish (1983)
Sitka spruce	Standish (1983)
Western hemlock	Shaw (1979
Wester redcedar	Shaw (1979
White spruce	Manning et al. (1984)
Alaska yellow-cedar	Standish (1983)

Access denied, hazardous, or inaccessible plots—
Although every effort was made to visit all field plots that were entirely or partially forested, some were not sampled for a variety of reasons. Field crews may have been unable to obtain permission from the landowner to access the plot ("denied access"). In coastal Alaska, it is common to have plots that are temporarily inaccessible owing to the presence of snow. Coastal Alaska also has many areas with extreme topography that can be very hazardous or impossible to reach, and plots in those areas will never be field measured. These kinds of missing data can introduce bias into the estimates if the nonsampled plots tend to be different from the entire population. The post-stratification approach outlined in Bechtold and Patterson (2005) removes nonsampled plots from the analysis. Estimates are adjusted for plots that are partially nonsampled by increasing the estimates by the nonsampled proportion within each stratum. To reduce the possible bias introduced by nonsampled plots, the phase 1 data are used to group plots similar in climate, vegetation, and ownership strata. The proportion of denied-access, hazardous, or inaccessible plots is significantly smaller for nonforest plots than for forested plots as field crews rarely

visit nonforested plots (however, see “Forest Understory and Nonforest Vegetation Methods” section below).

For the Chugach National Forest and Tongass National Forest wilderness and wilderness study areas, the 2004 panel of plots was used in some summary estimates. The process of stratification redistributed the 6.188 million unsampled ac to the sampled area, resulting in an estimate of 4.057 million forested ac and 5.806 million nonforested ac in the national forest wilderness areas. Because the ratio of plots to land area is very low (one plot per 58,000 ac), all estimates produced for the national forest wilderness are very imprecise, and these areas are excluded from most analyses.

Data processing—

The annual data used for this report are stored in the FIA National Information Management System (NIMS). It provides a means to input, edit, process, manage, and distribute FIA data. NIMS includes a process for data loading, a national set of edit checks to ensure data consistency, an error correction process, approved equations and algorithms, code to compile and compute calculated attributes, a table report generator, and routines to populate the presentation database. In addition, NIMS applies numerous algorithms and equations to calculate, stocking, forest type, stand size, volume, and biomass, and generates estimates and associated statistics based on the combined phase 1 and phase 2 information. Additional FIA statistical design and estimation techniques are further reviewed in Bechtold and Patterson (2005).

Statistical estimates—

Throughout this report, we have published standard errors (SE) for most of our estimates. These standard errors account for the fact that we measured only a small sample of the forest (thereby producing a sample-based estimate) and not the entire forest (which is the population parameter of interest). Because of small sample sizes or high variability within the population, some estimates can be very imprecise. The reader is encouraged to take the SE into account when drawing any inference. One way to consider this type of uncertainty is to construct confidence intervals. Customarily, 66- or 95-percent confidence intervals are used. A 95-percent confidence interval means that one can be 95 percent confident that the interval contains the true population parameter of interest.

It is relatively easy to construct approximate 66- or 95-percent confidence intervals by multiplying the SE by 1.0 (for 66-percent confidence intervals) or 1.96 (for 95-percent confidence intervals) and subtracting and adding this to the estimate itself. For example, in table A1-1, we estimated the total forest area in the coastal Alaska inventory unit to be 15.31 million ac, with a SE of 0.235 million ac. Thus, a 95-percent confidence interval for the total forest area ranges from 14.849 to 15.772 million ac.

The reader may want to assess whether or not two estimates are significantly different from each other. The statistically correct way to address this is to estimate the SE of the difference of two estimates and either construct a confidence interval or use the equivalent z-test. However, this requires the original inventory data. It is often reasonable to assume that two estimates are nearly uncorrelated. For example, plots usually belong to one and only one owner. The correlation between estimates for different owners will be very small. If both estimates are assumed to be nearly uncorrelated, the standard error of the difference can be estimated by

$$SE_{Difference} = \sqrt{SE^2_{\text{Estimate 1}} + SE^2_{\text{Estimate 2}}}$$

Using the SE of the difference, a confidence interval of the difference can be constructed with this method. However, if two estimates are based on data that occur on the same plot at the same time, the above equation should not be used. For example, table A1-16 contains estimates of tree volume by diameter class. If one wants to compare the volume of trees in the diameter class 9.0 to 10.9 d.b.h. with that of trees in the diameter class 21.0 to 22.9 d.b.h., the covariance between the estimates is not zero, and this equation should not be used. All estimates—means, totals and their associated SE—are based on the post-stratification methods described in detail by Bechtold and Patterson (2005).

Periodic Inventory

The periodic inventory (1995–2003) of southeast and south-central Alaska used the same plot layout as the annual inventory with the exception of the microplot used to measure trees less than 5 inches d.b.h. This microplot was located at subplot center in the periodic inventory and was offset in the annual inventory, resulting in no remeasurement information of trees less than 5 inches d.b.h. Unlike the annual inventory, the periodic inventory did not use a paneled system. Instead, data collection began in 1995 in southeast Alaska, and gradually moved northward, finishing in south-central Alaska in 2003. Although all estimates of change were converted to annual values before being used to calculate change, in general the time period between measurements was greater in southeast Alaska than in south-central Alaska.

There were also some differences in the sampling methods. Although both inventories used a spatially balanced design to locate samples, plots are located using hexagons in the current inventory but were located within a gridded area in the periodic inventory. This resulted in some of the periodic plots being dropped in the annual inventory and reduced the number of remeasured plots available for analysis. In addition, Kodiak Island was sampled at 50 percent intensity in the periodic inventory, resulting in less information about change for that area.

The forest-land definition changed between the periodic and annual inventories, as did a number of items affecting the definition of a tree. These changes in definition affected change estimates in several important ways. Afforestation (when nonforest land becomes forested) and deforestation (when forested land is converted to nonforest) are indistinguishable from procedural differences. This also means that real differences in carbon, biomass, numbers of trees, and other estimates produced from plots that were in both inventories are masked by procedural differences in the definition of forest land. We have attempted to reconcile these problems by limiting analysis to plots and portions of plots that were classified as forest in both inventories. Thus, reported change applies to land that was considered forest using one definition in 1995 through 2003 and using a different definition of forest land in 2004 through 2013. To develop an approximate estimate of land area reverting to or diverting from forest, an experienced field crew member reviewed each change between forest and nonforest that occurred at the center of each remeasured subplot to categorize whether the change had been caused by real or procedural differences. Although this allowed an approximation for forest area change, no attempt to quantify volume, biomass, forest type, or carbon change associated with reversions and diversions was possible.

Estimates produced from the periodic inventory data used in this report will differ slightly from those reported in van Hees (2003, 2005) for additional reasons. Errors in species identification or d.b.h. made at the first visit to the plot were often correctable at the second measurement. Additional errors found, such as missing data and misidentification of ownership or reserve status for a few plots and imprecise metric-to-U.S. conversions for small trees were also corrected before using the periodic data. A substantial change to the definition of forest type, and slight alterations to site index, volume, and biomass equations, were also made to match methods in the annual inventory. New information on boundaries and ownership was incorporated into the annual inventory.

Change calculation used the Beers and Miller (1964) method, which is the method currently used by the national FIA program. It fixes the inclusion probability of trees at time 1, or as they were measured in the periodic inventory. Change by ownership category, forest type, or site class are also reported by the category assigned in the periodic inventory. Because plots that were inaccessible during either the periodic or the annual inventory are not included in change calculations, the potential for bias from missing data is higher than for current (2004–2013) estimates.

Forest Understory and Nonforest Vegetation Methods

In 2011, the FIA program adopted national core optional protocols for collecting data on all growth habits of vascular vegetation (USDA FS 2010). The vegetation profile (VEG) includes an overall description of vegetation structure (cover by growth habit by height layer) and captures the percentage of canopy cover of the most abundant species by growth habit (up to four species per growth habit, if the species is present with at least a 3-percent canopy cover), with a height layer assigned to designate where the majority of foliage occurs. The U.S. Forest Service Pacific Northwest (PNW) Research Station Resource Monitoring and Assessment (RMA) program collects these data on all standard inventory plots and also includes all accessible nonforested plots with at least 10 percent vascular plant cover in Alaska Region national forests.

Several efforts to collect vegetation data have occurred within the 10-year cycle between 2004 and 2013. In 2005, permission was granted for FIA to access plots within designated wilderness and wilderness study areas in Alaska Region national forests with the caveat that data would be collected on both forest and nonforest plots or portions of plots within wilderness, including understory vegetation. Here, structure was recorded as total cover by growth habit and species were recorded if they occurred with at least 1 percent canopy cover. Total cover and cover by height class were recorded for each species. In 2010, the Chugach National Forest requested and funded vegetation profile data collection on all forest and nonforest lands within nonwilderness areas of the Chugach. The protocol used in 2010 had been established in Oregon and Washington, and although it was similar to the adapted core optional protocol in 2011, there were differences in assessing tree growth forms. In 2010, only seedlings of tally tree species were assessed. In 2011, the Tongass National Forest also requested and funded FIA data collection from nonforest plots in nonwilderness lands. FIA began this effort mid-cycle to record vegetation data, resulting in a smaller sample size than for the tree estimates in this report. Field guides for all protocol are available at https://www.fs.fed.us/pnw/rma/fia-topics/documentation/field-manuals/index.php.

Estimates of average percentage cover and standard error for the three growth habits (shrubs, forbs, and grass-like plants) and the most commonly recorded abundant species on forest lands were calculated following the standard ratio of means method (Bechtold and Patterson 2005). Confidence intervals (95 percent) and significant differences between groups were calculated as described in Barrett and Christensen (2011). A number of subplots/conditions had sufficient tree cover to classify as forested dominance types (i.e., >10 percent stocked). However, these conditions occurred in patches too small to be considered forest using FIA forest stand size (minimum 1 ac and >120 ft minimum width). Forested dominance types too small to be considered "forest" are referred to as "patches" to distinguish them from forestland results.

To summarize vegetation on nonforest lands, vegetation data were assigned a dominance type on each subplot classified as nonforest land. Dominance type is determined by the tallest growth habit and species occupying a plant community as would be seen from overhead with a canopy cover of at least 10 percent. Only subplots in a single "condition" were included, and any subplot with a portion of forest land was not included to simplify the analyses. Dominance types roughly followed several vegetation classification efforts, including Viereck et al. (1992) (levels II and III), DeVelice et al. (1999) (types), and Boggs et al. (2008) (landcover classes). Data are summarized as the average subplot total cover by each growth habit, the constancy (proportion of plots where each species was recorded) and average subplot cover (on subplots where the species was recorded) for the most commonly recorded abundant species for each dominance type. Methods to stratify these data beyond the very general "nonforest" status across the larger inventory unit are less sophisticated than data stratification from forested conditions. Thus, standard errors are omitted from nonforest estimates.

Invasive Plants

FIA began surveying for invasive species in 2005 in Alaska, and national core optional methods were officially established in 2011. Alaska's current list of targeted species is included in table A2-56 and is based on the most common known invasive plants in Alaska that may be present in forests. Most have been ranked for invasiveness using a system developed for natural areas of Alaska, based on ecological impacts, biological attributes, distribution, and control measures associated with each species (Carlson et al. 2008). There is no minimal cover limitation, so any listed species can be recorded if present in any amount. In both pre-core and core optional methods, each subplot was surveyed regardless of forested condition. Collections are encouraged of known or suspected invasive plants, especially in remote areas greater than ½ mi from an improved road.

Glossary

abiotic—Pertaining to nonliving factors such as temperature, moisture, and wind.

aerial photography—Imagery acquired from an aerial platform (typically aircraft or helicopter) by means of a specialized large-format camera with well-defined optical characteristics. The geometry of the aircraft orientation at the time of image acquisition is also recorded. The resultant photograph will be of known scale, positional accuracy, and precision. Aerial photography for natural resource use is usually either natural color or color-infrared, and is film based or acquired using digital electronic sensors.

artificial regeneration—An artificially regenerated stand is established by planting or artificial seeding.

aspect—Compass direction that a slope faces.

basal area—The cross-sectional area of a tree's trunk.

biodiversity—Variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequencies.

biomass—The aboveground weight of wood and bark in live trees 1.0 inch diameter at breast height and larger from the ground to the tip of the tree, excluding all foliage. The weight of wood and bark in lateral limbs, secondary limbs, and twigs under 0.5 inch in diameter at the point of occurrence on sapling-size trees is included in the measure, but on poletimber- and sawtimber-sized trees this material is excluded. Biomass is typically expressed as green or oven-dry weight in tons.

board foot—A volume measure of lumber 1 ft wide, 1 ft long, and 1 inch thick (12 in × 12 in × 1 in = 144 cubic inches).

bole—Trunk or main stem of a tree.

carbon mass—The estimated weight of carbon stored within wood tissues. On average, carbon mass values are about half of biomass values for trees, and are summarized as thousand tons or mean tons per acre.

carbon sequestration—Incorporation of carbon dioxide into permanent plant tissues.

coarse woody material—Down dead tree and shrub boles, large limbs, and other woody pieces that are severed from their original source of growth. Coarse woody material also includes dead trees that are supported by roots, severed from roots, or uprooted, and leaning >45 degrees from vertical.

corporate forest land—An ownership class of private forest lands owned by a company, corporation, legal partnership, investment firm, bank, timberland investment management organization, or real-estate investment trust.

crown—The part of a tree or woody plant bearing live branches or foliage.

crown dieback—Recent mortality of branches with fine twigs, which begins at the terminal portion of a branch and proceeds toward the trunk. Dieback is considered only when it occurs in the upper and outer portions of the tree.

current gross annual growth—The total growth of a given stand of trees, within a defined area, over the period of 1 year.

damage—Damage to trees caused by biotic agents such as insects, diseases, and animals or abiotic agents such as weather, fire, or mechanical equipment.

defoliation—Premature removal of foliage.

diameter at breast height (d.b.h.)—The diameter of a tree stem, located at 4.5 ft above the ground (breast height) on the uphill side of a tree. The point of diameter measurement may differ on abnormally formed trees.

diameter at root collar (d.r.c.)—The diameter of a tree (usually a woodland species), measured outside of the bark at the ground line or stem root collar.

dieback—Progressive dying from the extremity of any part of the plant. Dieback may or may not result in death of the entire plant (Helms 1998).

disturbance—Any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment (Helms 1998).

ecological region—A top-level scale in a hierarchical classification of ecological units subdivided on the basis of global, continental, and regional climatic regimes and broad physiography. Ecological regions (ecoregions) are further subdivided into domains, divisions, and provinces. The next level down in the hierarchy, subregion, is divided into ecological sections (ecosections) and subsections.

ecosection—A level in a hierarchical classification of ecological units for a geographic area delineated on the basis of similar climate, geomorphic processes, stratigraphy, geologic origin, topography, and drainage systems.

ecosystem—A spatially explicit, relatively homogeneous unit of the Earth that includes all interacting organisms and components of the abiotic environment within its boundaries. An ecosystem can be of any size: a log, a pond, a field, a forest, or the Earth's biosphere (Helms 1998).

elevation—Height above a fixed reference point, often the mean sea level.

erosion—The wearing away of the land surface by running water, wind, ice, or other geological agents.

federal forest land—An ownership class of public lands owned by the U.S. government.

fire regime—The characteristic frequency, extent, intensity, severity, and seasonality of fires within an ecosystem (Helms 1998).

fixed-radius plot—A circular sampled area with a specified radius in which all trees of a given size, shrubs, and other items, are tallied.

forb—A broad-leaved herbaceous plant, as distinguished from grasses, shrubs, and trees.

forest industry land—An ownership class of private lands owned by a company or an individual(s) operating a primary wood-processing plant.

forest land—Land that is currently or formerly (within 30 years) at least 10 percent stocked by trees of any size and not currently developed for nonforest use. Forests must be at least 1 ac in size with a minimum width of 120 ft. A modified definition was adopted in 2012 that defines forest as at least 10 percent canopy cover (instead of stocking).

forest type—A classification of forest land based on and named for the tree species that forms the plurality of non-overtopped live-tree stocking.

forest type group—A combination of forest types that share closely associated species or site requirements.

geospatial—The ccombination of spatial software and analytical methods with terrestrial or geographic datasets. Often used in conjunction with geographic information systems and geomatics.

graminoid—Grasses (family Gramineae or Poaceae) and grasslike plants such as sedges (family Cyperaceae) and rushes (family Juncaceae).

grassland—Land on which the vegetation is dominated by grasses, grasslike plants, or forbs.

greenhouse gas—A gas, such as carbon dioxide or methane, that contributes to potential climate change.

growing-stock—All live trees 5 inches diameter at breast height or larger that are considered merchantable in terms of sawlog length, and grade; excludes rough and rotten cull trees.

hardwood—Tree species belonging to the botanical subdivision Angiospermae, class Dicotyledonous, usually broad-leaved and deciduous.

increment borer—An auger-like instrument with a hollow bit and an extractor, used to extract thin radial cylinders of wood (increment cores) from trees having annual growth rings, to determine increment or age.

interpolation—A method of reallocating attribute data from one spatial representation to another. Kriging is a more complex example that allocates data from sample points to a surface.

invasive plant—Plants that are not native to the ecosystem under consideration and that cause or are likely to cause economic or environmental harm or harm to human, animal, or plant health.

lichen—An organism consisting of a fungus and an alga or cyanobacterium living in symbiotic association. Lichens look like masses of small, leafy, tufted or crust-like plants.

live trees—All living trees, including all size classes, all tree classes, and both commercial and noncommercial species for tree species listed in the Forest Inventory and Analysis field manual.

mean annual increment (MAI) at culmination—A measure of the productivity of forest land expressed as the average increase in cubic feet of wood volume per acre per year. For a given species and site index, the mean is based on the age at which the MAI culminates for fully stocked natural stands. The MAI is based on the site index of the plot.

mensuration—Determination of dimensions, form, weight, growth, volume, and age of trees, individually, or collectively, and of the dimensions of their products (Helms 1998).

mesic—Describes sites or habitats characterized by intermediate moisture conditions; i.e., neither decidedly wet nor dry.

microclimate—The climate of a small area, such as that under a plant or other cover, differing in extremes of temperature and moisture from the larger climate outside (Helms 1998).

MMBF—A million board feet of wood in logs or lumber.

model—(1) An abstract representation of objects and events from the real world for the purpose of simulating a process, predicting an outcome, or characterizing a phenomenon. (2) Geographic information system data representative of reality (e.g., spatial data models), including the arc-node, georelational model, rasters or grids, polygon, and triangular irregular networks (Helms 1998).

mortality—The death of trees from natural causes, or subsequent to incidents such as storms, wildfire, or insect and disease epidemics (Helms 1998).

municipal land—Land owned by municipalities or land leased by them for more than 50 years.

national forest lands—Federal lands that have been designated by executive order or statute as national forest or purchase units and other lands under the administration of the U.S. Department of Agriculture, Forest Service, including experimental areas and Bankhead-Jones Title III lands.

Native American lands—Tribal lands, and allotted lands held in trust by the federal government. American Indian lands are grouped with farmer-owned and miscellaneous private lands as other private lands.

native species—Plant species that were native to an American region prior to Euro-American settlement. For vascular plants, they are the species that are not present on the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) (2018) list of nonnative species (see **nonnative species**) (USDA NRCS 2018).

net primary production (NPP)—NPP represents the amount of chemical energy that is available to consumers in an ecosystem. It is the remaining energy from gross primary productivity discounting the loss of energy required by primary producers for respiration.

net volume—Gross volume less deductions for sound and rotten defects. Growing-stock net volume is gross volume (in cubic feet) less deductions for rot and missing bole sections on poletimber and sawtimber growing-stock trees. Sawtimber net volume is gross volume (in board feet) less deductions for rot, sweep, crook, missing bole sections, and other defects that affect the use of sawtimber trees for lumber (Azuma et al. 2004).

noncensus water—Lakes, reservoirs, ponds, and similar bodies of water 1.0 to 4.5 ac in size. Rivers, streams, canals, etc., 30 to 200 ft wide.

noncorporate forest land—Private forest land owned by nongovernmental conservation or natural resource organizations; unincorporated partnerships, associations, or clubs; individuals or families; or Americans Indians.

nonforest inclusion—An area that is not forested and is less than 1.0 ac and does not qualify as its own condition class (USDA FS 2006).

nonforest land—Land that does not support, or has never supported, forests, and lands formerly forested where use for timber management is precluded by development for other uses. Includes areas used for crops, improved pasture, residential areas, city parks, improved roads of any width and adjoining rights of way, power line clearings of any width, Census and noncensus water. If intermingled in forest areas, unimproved roads and nonforest strips must be more than 120 ft wide, and clearings, etc., more than 1 acre in size, to qualify as nonforest land.

nonnative species—Plant species that were introduced to America subsequent to Euro-American settlement. Nonnative vascular plants are present in the USDA PLANTS database (USDA NRCS 2018).

nonstocked areas—Timberland that is less than 10 percent stocked with live trees. Recent clearcuts scheduled for planting are classified as nonstocked area (Azuma et al. 2004).

nontimber forest products (NTFP)—Species harvested from forests for reasons other than production of timber commodities. Vascular plants, lichens, and fungi are the primary organisms included in NTFPs.

old-growth forest—Old-growth forest is differentiated from younger forest by its structure and composition, and often by its function. Old-growth stands are typified by the presence of large older trees; variety in tree species, sizes, and spacing; multiple canopy layers; high amounts of standing and down dead wood; and broken, deformed, or rotting tops, trunks, and roots (Franklin et al. 1986).

other forest—Forest land that is unproductive (land not capable of producing more than 20 cubic feet of wood per acre per year). In tables in which reserved and unreserved forest land are not broken out, "other forest" includes all reserved forest land as well as unproductive forest land.

other private forest lands—Lands in private ownership and not reported separately. These may include coal companies, land trusts, and other corporate private landowners.

overrun—Difference between the log scale of a shipment of timber and the actual volume of lumber obtained from it.

overstory—That portion of the trees, in a forest of more than one story, forming the uppermost canopy layer.

owner class—A variable that classifies land into categories of ownership. Current ownership classes are listed in the Forest Inventory and Analysis field manual.

owner group—A variable that combines owner classes into the following groups: Forest Service, other federal agency, state and local government, and private. Differing categories of owner group on a plot require different conditions.

ownership—A legal entity having an ownership interest in land, regardless of the number of people involved. An ownership may be an individual; a combination of persons; a legal entity such as corporation, partnership, club, or trust; or a public agency. An ownership has control of a parcel or group of parcels of land.

pathogen—An organism or virus directly capable of causing disease.

photointerpretation (aerial photography)—A process where points, or areas of interest on an aerial photograph are studied to determine information about land cover. The Forest Inventory and Analysis program uses photointerpretation to determine whether field plots are forested or not, the possible forest type and size class, and in analysis for land cover and land use changes.

productive forest land—Forest land that is producing or capable of producing in excess of 20 cubic feet per acre per year of wood at culmination of mean annual increment without regard to reserved status.

public land—An ownership group that includes all federal, state, county, and municipal land.

regeneration (artificial and natural)—The established progeny from a parent plant, seedlings or saplings existing in a stand, or the act of renewing tree cover by establishing young trees naturally or artificially. May be artificial (direct seeding or planting) or natural (natural seeding, coppice, or root suckers) (Adapted from Helms 1998).

remote sensing—Capture of information about the Earth from a distant vantage point. The term is often associated with satellite imagery but also applies to aerial photography, airborne digital sensors, ground-based detectors, and other devices.

reserved forest land—Land permanently reserved from management for the production of wood products by statute. Examples include national wilderness areas, national parks and monuments, and state parks.

richness—The number of different species in a given area, often referred to at the plot scale as alpha diversity and at the region scale as gamma diversity (USDA NRCS 2018).

riparian—Related to, living in, or associated with a wetland, such as the bank of a river or stream or the edge of a lake or tidewater. The riparian biotic community significantly influences and is influenced by the neighboring body of water (Helms 1998).

sampling error—Difference between a population value and a sample estimate that is attributable to the sample, as distinct from errors that result from bias in estimation, errors in observation, etc. Sampling error is measured as the standard error of the sample estimate (Helms 1998).

sapling—A live tree 1.0 to 4.9 inches in diameter.

sawlog—A log meeting minimum standards of diameter, length, and defect for manufacture into lumber or plywood. The definition includes logs with a minimum diameter outside bark for softwoods of 7 inches (9 inches for hardwoods) (Azuma et al. 2004).

sawtimber trees—Live softwood trees of commercial species at least 9.0 inches in diameter at breast height (d.b.h.) and live hardwood trees of commercial species at least 11.0 inches in d.b.h. At least 25 percent of the board foot volume in a sawtimber tree must be free from defect. Softwood trees must contain at least one 12-ft saw log with a top diameter of not less than 7 inches outside bark; hardwood trees must contain at least one 8-ft saw log with a top diameter of not less than 9 inches outside bark (Azuma et al. 2004).

scribner rule—The common board-foot log rule used to determine sawtimber volume. Scribner volume is estimated in terms of 32-ft logs for softwoods and 16-ft logs for hardwoods.

seedlings—Live trees <1.0 inch in diameter at breast height and at least 6 inches in height (softwoods) or 12 inches in height (hardwoods).

shrub—Perennial, multistemmed woody plant, usually less than 13 to 16 ft in height, although under certain environmental conditions shrubs may be single-stemmed or taller than 16 ft.

shrubland—A shrub-dominated vegetation type that does not qualify as forest.

slope—Measure of change in surface value over distance, expressed in degrees or as a percentage (Helms 1998).

snag—Standing dead tree ≥5 inches in diameter at breast height and ≥4.5 ft in length, with a lean of <45 degrees. Dead trees leaning more than 45 degrees are considered to be down woody material. Standing dead material shorter than 4.5 ft are considered stumps.

species group—A collection of species used for reporting purposes.

species turnover—A measure of difference in species composition among plots within an area (e.g., ecological section). Also known as beta diversity. Species turnover is calculated by dividing the total number of species in an area by the mean number of species per plot (USDA NRCS 2018).

specific gravity constants—Ratio of the density (weight per unit volume) of an object (such as wood) to the density of water at 4 °C (39.2 °F) (Helms 1998).

stand age—Average age of the live dominant and codominant trees in the predominant stand size class.

stand-size class—A classification of stands based on tree size. Large-diameter stands have the majority of trees at least 11.0 inches in diameter at breast height (d.b.h.) for hardwoods and 9.0 inches d.b.h. for softwoods; Medium-diameter stands have the majority of trees at least 5.0 inches d.b.h. but not as large as large-diameter trees, and small-diameter stands have the majority of trees less than 5.0 inches d.b.h.

state land—An ownership class of public lands owned by states or lands leased by states for more than 50 years.

stocked/nonstocked—In the Forest Inventory and Analsis program, a minimum stocking value of 10 percent live trees is required for accessible forest land.

stocking—(1) At the tree level, the density value assigned to a sampled tree (usually in terms of numbers of trees or basal area per acre), expressed as a percentage of the total tree density required to fully use the growth potential of the land. (2) At the stand level, the sum of the stocking values of all trees sampled (Bechtold and Patterson 2005).

stratification—A statistical tool used to reduce the variance of the attributes of interest by partitioning the population into homogenous strata (Bechtold and Patterson 2005).

succession—The gradual supplanting of one community of plants by another (Helms 1998).

surface fire—A fire that burns only surface fuels, such as litter, loose debris, and small vegetation (Helms 1998).

sustainability—The capacity of forests, ranging from stands to ecoregions, to maintain their health, productivity, diversity, and overall integrity in the long run, in the context of human activity and use (Helms 1998).

terrestrial—Of or relating to the Earth or its inhabitants; of or relating to land as distinct from air or water.

timberland—Forest land that is producing or capable of producing >20 cubic ft per acre per year of wood at culmination of mean annual increment. Timberland excludes reserved forest lands.

transect—A narrow sample strip or a measured line laid out through vegetation chosen for study (Helms 1998).

tree—A woody perennial plant, typically large, with a single well-defined stem carrying a more or less definite crown with a minimum height of 15 ft at maturity. For Forest Inventory and Analysis, any plant on the tree list in the current field manual is measured as a tree.

understory—All forest vegetation growing under an overstory (Helms 1998).

unproductive forest land—Forest land that is not capable of producing in excess of 20 cubic feet per acre per year of wood at culmination of mean annual increment without regard to reserved status.

unreserved forest land—Forest land that is not withdrawn from harvest by statute or administrative regulation. Includes forest lands that are not capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands.

vascular plant—A plant possessing a well-developed system of conducting tissue to transport water, mineral salts, and sugars.

wilderness—(1) According to the Wilderness Act of 1964, "a wilderness, in contrast with those areas where man and his works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain." (2) A roadless land legally classified as a component area of the National Wilderness Preservation System and managed to protect its qualities of naturalness, solitude, and opportunity for primitive recreation. Wilderness areas are usually of sufficient size to make maintenance in such a state feasible (Helms 1998).

wildfire—Any uncontained fire, other than prescribed fire, occurring on wildland. Synonym: wildland fire (Adapted from Helms 1998).

wildland—Land other than that dedicated for uses such as agriculture, urban, mining, or parks (Helms 1998).

wildland forest—A large continuous tract of forest with few or no developed structures on it. Delineated on aerial imagery for the purpose of detecting land use change. The Pacific Northwest Research Station Forest Inventory and Analysis program and the Oregon Department of Forestry jointly use a minimum of 640 ac containing fewer than five developed structures to designate wildland forest.

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