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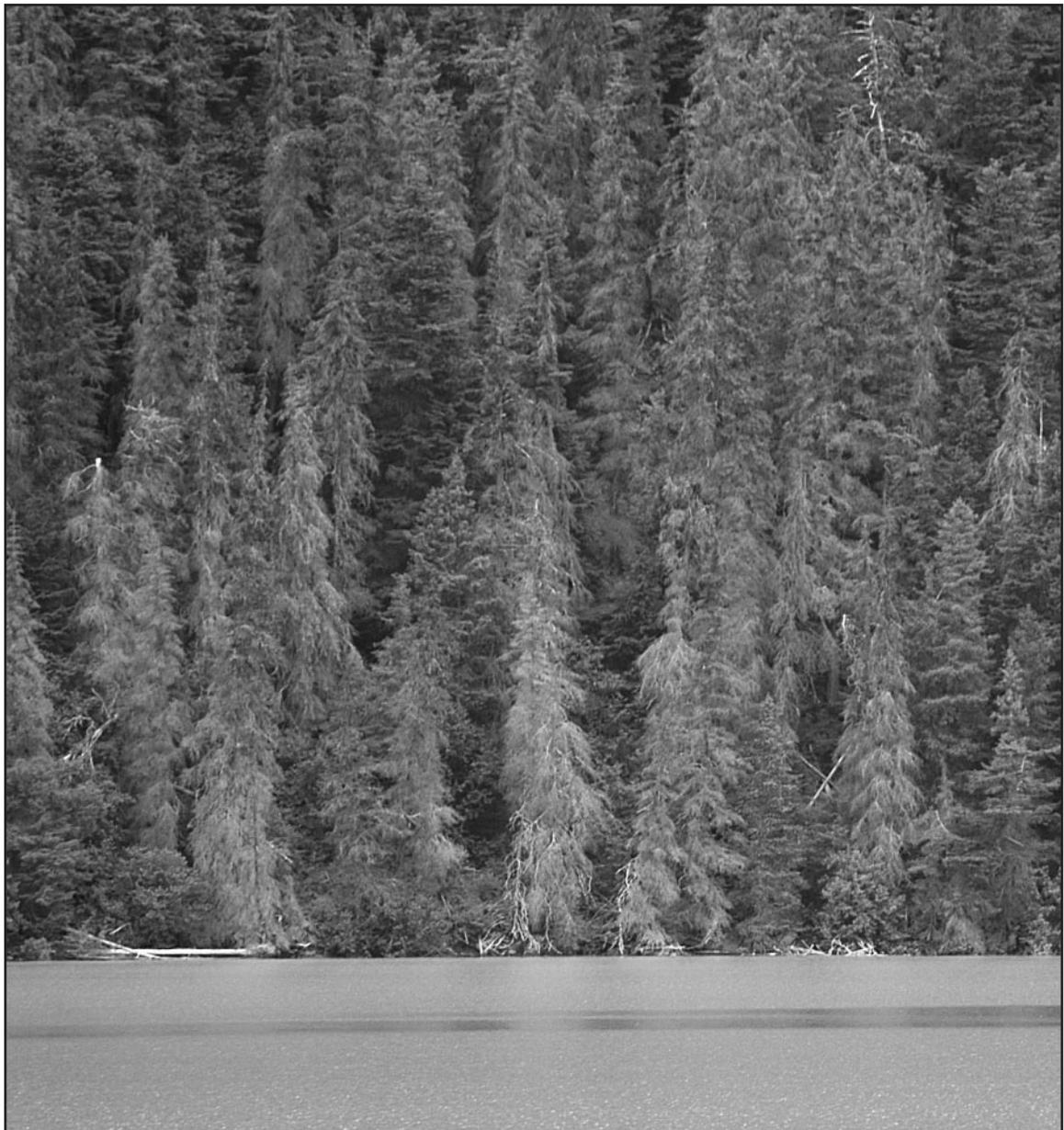
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Changes in Downed and Dead Woody Material Following a Spruce Beetle Outbreak on the Kenai Peninsula, Alaska

Bethany Schulz



Author

Bethany Schulz is a research forester, Forestry Sciences Laboratory, 3301 C Street, Suite 200, Anchorage, AK 99503.

Abstract

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The forests of the Kenai Peninsula, Alaska, underwent a major spruce beetle (*Dendroctonus rufipennis* (Kirby)) outbreak in the 1990s. A repeated inventory of forest resources was designed to assess the effects of the resulting widespread mortality of spruce trees, the dominant component of the Kenai forests. Downed woody materials, fuel heights, and moss depths were recorded during each inventory. Changes in downed and dead woody materials are summarized by forest type and harvest activity, compiled by fuel timelag classes. Fuel heights, fine fuels, and sound large fuels increased between 1987 and 2000. Moss depths and rotten large fuels decreased. Harvested white spruce (*Picea glauca* (Moench) Voss) showed the greatest increase of fine fuel classes.

Keywords: Downed woody material, fuels, inventory, Kenai Peninsula, Alaska, spruce beetle outbreak.

Summary

The forests of the Kenai Peninsula, Alaska, have changed dramatically over the past two decades as a result of a major spruce beetle (*Dendroctonus rufipennis* (Kirby)) outbreak that peaked in the mid-1990s. A repeated inventory of forest resources was designed to assess the effects of the resulting widespread mortality of spruce trees, the dominant component of the Kenai forests. Downed woody materials, fuel heights, and moss depths were recorded during each inventory. Changes in downed and dead woody materials are summarized by forest type and harvest activity, compiled by fuel timelag classes. Descriptions of changes in fuel loads can assist managers in prescribing fuel treatments. Land managers are especially concerned with fuel load conditions in areas within the wildland-urban interface. Fuel heights, fine fuels, and sound large fuels increased between 1987 and 2000. Moss depths and rotten large fuels decreased. Harvested white spruce (*Picea glauca* (Moench) Voss) showed the greatest increase of fine fuel classes.

Introduction

Forests of the Kenai Peninsula have changed dramatically over the past two decades as a result of a major spruce bark beetle (*Dendroctonus rufipennis* (Kirby)) outbreak (Wittwer 2003). An inventory was conducted in 1987 by the USDA Forest Service, Pacific Northwest Research Station (PNW), Forest Inventory and Analysis (FIA) Program to assess the impact of the spruce beetle on the forest resources of the Kenai Peninsula (van Hees and Larson 1991). The plots were remeasured over a 2-year period (1999 and 2000) after the spruce bark beetles had affected most of these stands. One set of measurements included downed and dead woody materials.

Descriptions of changes in fuel loads can assist managers in prescribing fuels treatments on affected sites. Land managers are concerned with reducing fuel loads and altering fuel profiles in areas within the wildland-urban interface. These areas are of high priority because of increased risk of human-caused ignitions and the number of lives and structures potentially jeopardized by a wildfire. Many of these areas have been targeted for fuel-reduction treatments funded by millions of dollars of federal grants (Kenai Peninsula Borough 2002). The objective of this initial analysis is to describe the changes in the downed and dead woody material fuel loading by forest type and harvest activity.

Study Area

Results are summarized in tons per acre by fuel timelag classes to best describe downed wood as fuel for wildfires. Fuel classes reflect the rate at which wood particles respond to changes in air temperature and relative humidity. This, in turn, relates to how “ready” the pieces are to burn, depending on recent past and present atmospheric conditions. Small pieces lose and gain moisture more quickly than large pieces owing to higher surface-area-to-volume ratios and are more likely to be consumed by fire over a wide range of burning conditions. Small size classes will ignite more readily, are considered to be “flashy” fuels and fire carriers, and will increase the fire spread rate. Larger pieces are more difficult to ignite, and if they do burn, are more likely to smolder for much longer than to support flames. Rotten and sound wood burn at different rates and are distinguished in downed wood inventories (Miller 1994).

The Kenai Peninsula is in south-central Alaska and is bordered by Cook Inlet on the west and Prince William Sound on the east (fig.1). Total land area is approximately 5.2 million acres, about 1.9 million acres of which are forested. Of the forested acres, about 25 percent (482 thousand acres) are considered timberland. Percentage of forest type on forested land and timberlands is given in table 1. Across the Kenai, the ranges for Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and white spruce (*Picea glauca* (Moench) Voss) overlap and the hybrid Lutz spruce (*Picea x lutzii* Little) occurs. Because Lutz spruce has characteristics that range between those of Sitka and white spruce making it difficult to distinguish among the three types of spruce, but not between white and Sitka spruce, inventory crews were instructed to identify trees as either white or Sitka spruce.

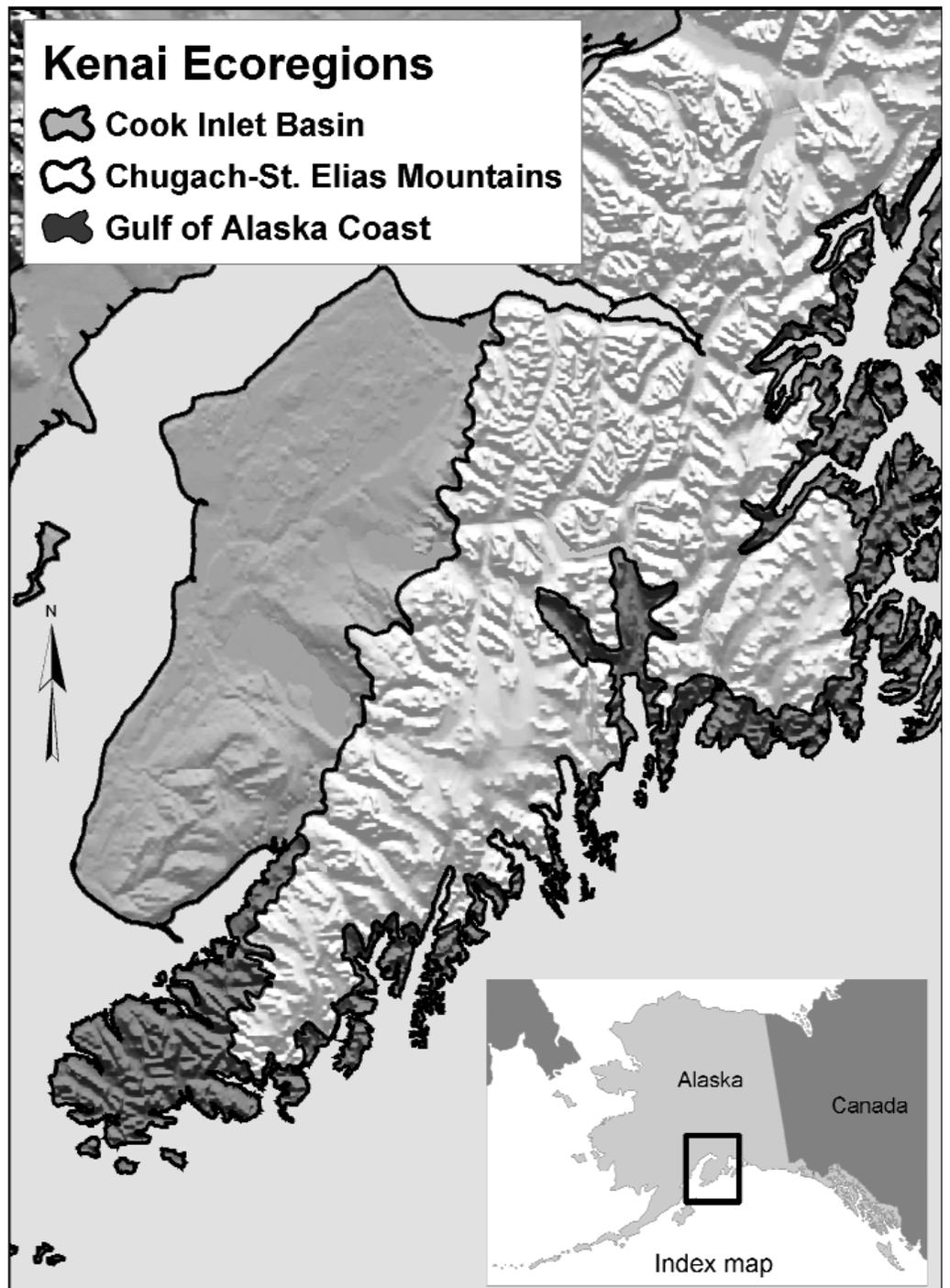


Figure 1—The Kenai Peninsula, Alaska, with ecoregions. (Map by Dustin Wittwer)

Table 1—Percentage of forest types by forested land and timberland on the Kenai Peninsula

Forest type	Percentage of forested land (1.9 million acres)	Percentage of timberland (482 thousand acres)
Aspen (<i>Populus</i> spp.)	0.3	1.2
Birch (<i>Betula papyrifera</i> Marsh.)	8	28
Black spruce (<i>Picea mariana</i> (Mill.) B.S.P.)	2	1.2
Cottonwood (<i>Populus</i> spp.)	.15	.6
Mountain hemlock (<i>Tsuga mertensiana</i> Bong. Carr.)	3.5	9
Sitka spruce	4	12
White spruce	19	46
Unclassified	62	2

Source: van Hees and Larson 1991.

The peninsula includes portions of three distinct ecoregions: the Cook Inlet Basin, the Chugach-St. Elias Mountains, and the Gulf of Alaska Coast (Nowacki and others 2001). The three ecoregions are distinguished by geological and climatic differences that are quite dramatic from east to west. The Cook Inlet Basin ecoregion conditions and forests are similar to those of interior Alaska. The Chugach-St. Elias Mountain ecoregion includes ice fields and rugged mountaintops as well as temperate forested valleys. Conditions and forests within the Gulf of Alaska Coast ecoregion are more similar to those of the coastal rain forests of southeast Alaska. Differences in annual precipitation between Seward to the east (about 68 inches) and Kenai to the west (about 19 inches) illustrate the contrasting conditions (Desert Research Institute 2002). The spruce bark beetle outbreak affected the white spruce in the Cook Inlet Basin and the Chugach-St. Elias Mountains ecoregions to a greater extent than it did the Sitka spruce on the Gulf of Alaska Coast ecoregion (Wittwer 2003).

Methods Sampling Design

A two-phase procedure was used to determine plot locations. In the first phase, 5,597 photopoints were systematically located on 1:60,000-scale high-altitude photographs of the Kenai Peninsula. Photointerpretation was used to classify the land class at each photopoint. Of the photopoints, 1,216 points were randomly selected for further examination; 130 photopoints were interpreted as timberland or likely to be timberland and selected for ground inspection. Timberland is defined as forest land capable of producing more than 20 cubic feet of industrial wood per acre per year at culmination of mean annual increment.

Ground plots were subsampled by a cluster of five subplots. From the first centrally located subplot, subplots were located 328 feet north, east, south, and west. Downed and dead woody material was inventoried along a 37-foot sampling plane 5.9 feet tall, running south to north and centered across each subplot at each location. Tally methods were based on Brown (1974); Waddell (2002) describes the use of Brown's method in forest inventories. Two measures of "duff" depth and fuel height were taken within the first 3.28 feet of the sample plane. For this inventory, duff was defined as the layer from the surface to the top of the decomposed organic layer; this equates to the depth of live moss and fibrous organic material. This measure will be called "moss" depth to avoid confusion with other definitions of "duff." Fuel height measured the highest dead fuel particle above the bottom of the litter layer along the sample plane.

One- and ten-hour fuels (particles 0 to 0.23 inch and 0.23 to 0.98 inch in diameter, respectively) were tallied along the first 6.56 feet of the sample plane. One hundred-hour fuels (pieces 0.98 to 2.95 inches in diameter) were tallied along the first 13.12 feet of the sampling plane. Larger downed woody pieces were tallied by 1.18-inch size class along the entire sampling plane. The condition of larger pieces was recorded as sound or rotten. Sound pieces were defined as solid, not punky (a spongy condition caused by decay), and could not be kicked apart; rotten pieces were defined as soft, punky, and could be kicked apart through most of their diameter.

Data Summaries

Moss depths and fuel heights were averaged across all subplots for each plot. Tons per acre for each fuel size class were calculated as described in Brown (1974). Tons-per-acre estimates for each plot were determined by averaging individual subplot sums on each plot. Change was determined by subtracting 1987 plot summaries from the 1999-2000 plot summaries. Of the original 130 plots, one plot was not remeasured or replaced, one was in an area converted into a golf course where downed wood measurements were not collected during the revisit, and one had been harvested and cleared for agriculture, resulting in extreme values for some measures. Overall summaries included all plots ($n = 127$) regardless of how many subplots were remeasured or replaced with new subplots. New subplots were established when the original subplot could not be located. Summaries by forest type only included plots where all five of the original subplots were remeasured in the 1999-2000 survey ($n = 95$). Forest type for each plot was calculated from live-tree stocking recorded during the 1987 inventory.

Change Analysis

Changes across all plots were tested for significance by using the paired t-test, where the pairs are the average values of moss depth, fuel height, and tons per acre by fuel class for the 1987 and the 1999-2000 measurements for all plots ($n = 127$). The paired t-test also was used to test for significant changes within each forest type and harvested and nonharvested spruce plots. Only three forest types had enough plots to analyze: white spruce ($n = 48$), birch ($n = 26$), and mountain hemlock ($n = 13$). Of the white spruce plots used in this analysis, 10 had some level of harvest activity, and 38 were not harvested by the time of the 1999-2000 inventory. Differences in changes between the harvested and nonharvested plots were evaluated by using the Student's t-test.

Table 2—Average difference (change) between 1987 and 2000 inventories for moss depth, fuel height, and downed wood tonnage

Source	N	Fuel classes						
		Moss depth	Fuel height	1-hour	10-hour	100-hour	Sound 1,000-hour	Rotten 1,000-hour
		-----Inches-----		-----Tons per acre-----				
All plots	127	-2.06	3.00	0.17	0.38	0.23	4.75	-2.18
Birch	26	-1.68	2.55	-.02	.66	0	3.06	-1.0
Mountain hemlock	13	-2.25	.47	.12	.4	.04	2.16	-.79
White spruce	48	-2.38	3.94	.23	.46	.6	2.85	-.71
Nonharvested white spruce	38	-2.41	3.93	.19	.28	.38	3.02	-.75
Harvested white spruce	10	-2.30	3.54	.35	1.13	1.41	2.16	-.53

Note: Significant changes indicated by bold font. Significantly different changes between nonharvested and harvested white spruce plots are underlined.

Results

Changes across all plots and by forest type and harvest activity are summarized in table 2. Values in bold represent significant differences (change) between the 1987 and 2000 inventories (level of significance = 0.05). Significantly different changes between nonharvested and harvested white spruce stands are underlined.

When all plots are summarized without stratification by forest type, there are significant changes in all measures except the 100-hour fuel class. Fuel heights and 1-, 10-, and sound 1,000-hour fuel classes have increased, whereas moss depth and the rotten 1,000-hour fuel class have decreased.

All forest types showed a significant decrease in moss depth and sound 1,000-hour fuels. The white spruce forest type shows the largest number of significantly changed measures, including the 100-hour fuel class, but no significant difference in rotten 1,000-hour fuels.

Differences between white spruce plots that had some harvest activity were compared to nonharvested plots. The 10- and 100-hour fuels are significantly different, with more of these fine fuels on the harvested areas. Although sound 1,000-hour fuels increased more in the nonharvested stands, the difference was not significantly different from the increase in harvested areas.

Figure 2 shows 1987 and 1999-2000 fuel summaries with mean standard errors by timelag class for mountain hemlock, birch, and nonharvested and harvested white spruce plots.

Discussion

Trends in all measurements across all plots are not surprising considering the changing forest conditions on the Kenai Peninsula.

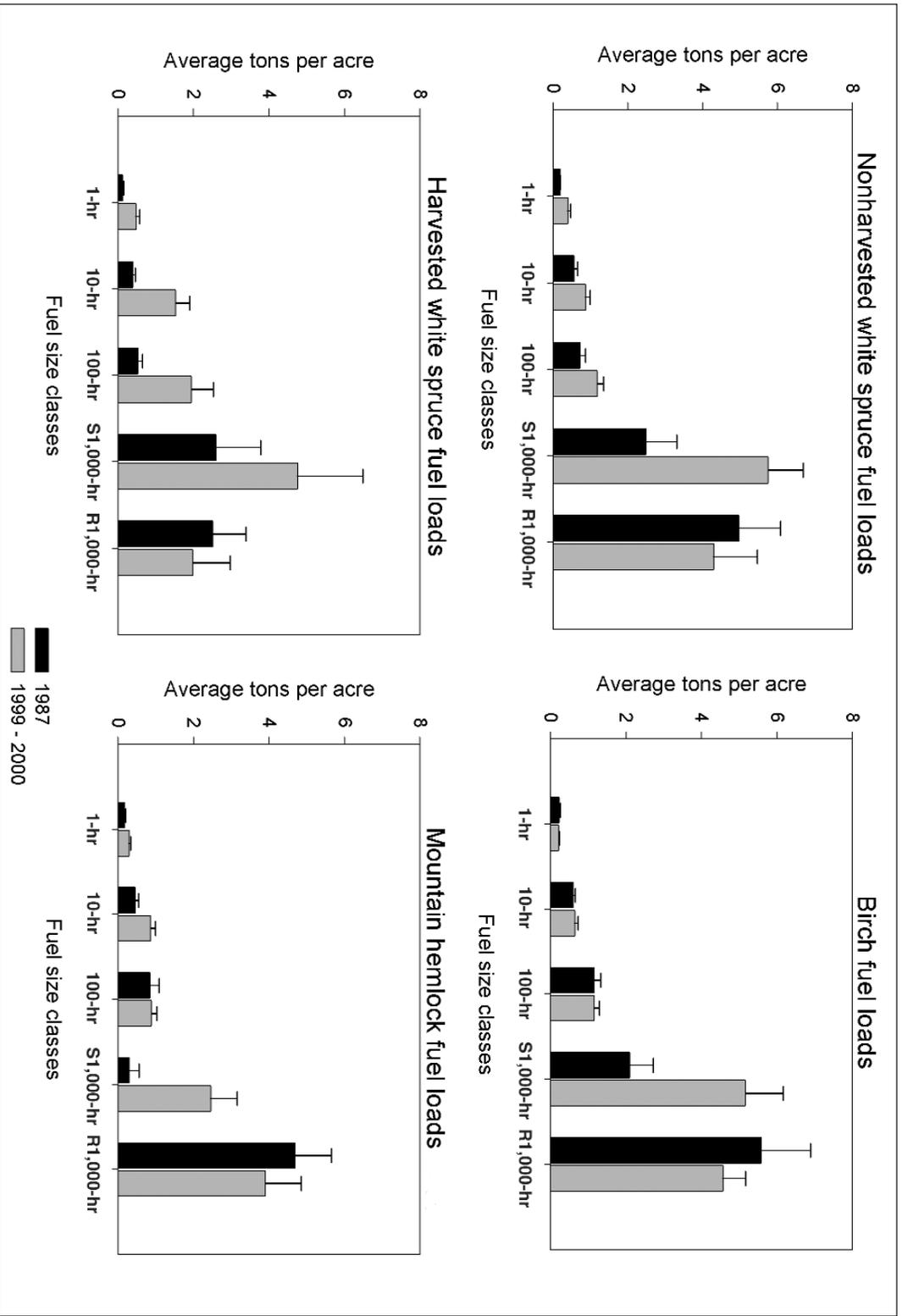


Figure 2—Average fuel load summaries with mean standard errors by size class for 1987 and 1999-2000 inventories.

Decreasing moss depths are significant in all forest types, indicating changing microclimates as stands “open up” after loss of the white spruce component. Changing microclimate conditions may include less shade, generally drier conditions, more grass, or any combination of these factors.

Fuel height is an important component in fire-behavior prediction exercises; higher fuel heights increase the risk of ground fires rising into tree crowns and becoming more difficult to control. Spruce bark beetle-killed trees have been documented to break or blow down after 5 to 10 years in some areas (Holsten and others 1995). On other portions of the Kenai Peninsula more prone to wind events, trees come down after a shorter period. Fuel heights would be expected to increase as dead trees fall. Although fuel heights increased in a statistically significant amount in white spruce stands, an increase of 3 to 4 inches is probably not significant in terms of fire behavior. I suggest that a different sampling method be devised to assess fuel heights in terms of fire behavior.

Fuel size class changes are also meaningful in predicting fire behavior. Increases in finer fuels increase risk of fire spread. Although larger fuels take more sustained heat to ignite than do finer fuels, they will smolder for long periods and are a source of reignition. Significant increases in all size classes except rotten 1,000-hour occurred in the white spruce type. Sound 1,000-hour fuels increased significantly in all types. Rotten 1,000-hour fuels did not change significantly in any forest type.

White spruce forest type results are, perhaps, of greatest interest because this is the most prevalent forest type on all forest lands on the Kenai Peninsula (van Hees and Larson 1991) and because white spruce is most affected by the spruce beetle outbreak. Some spruce plots are in stands that were the focus of salvage operations. These plots provided an opportunity to compare the rate of change between harvested and nonharvested areas. Note that the harvested areas inventoried were not specifically targeted for fuel-reduction treatment, and I cannot conclude from this study that the greater increase in fine fuels is a direct result of the harvest operations.

Removing dead and dying spruce is often the primary objective of fuel treatments; removing the trees that are likely to fall and create complex “jack-straw” fuel beds is important so that if fire occurs, firefighters can move about more easily and safely. Removal also reduces the amount of ladder fuels in the form of dead branches that can carry a ground fire into the canopy. Reducing fine fuels is also important to reduce fire spread potential. The results presented indicate fuel loads were still relatively high after salvage logging. These harvests were not designed as fuel-reduction treatments; to reduce fuel hazard, treatments specifically aimed at removing fine fuels (slash) are warranted.

Conclusion

This study has focused on downed wood as fuel for wildfire and documents the general increase of downed wood following the spruce beetle outbreak of the 1990s. Downed wood is only one element of a fuel profile, and predicting fire behavior involves many other factors. A more detailed analysis of the data collected for the Kenai spruce beetle inventory from a fuels perspective is underway. This research will incorporate changes in the understory vegetation, live and dead standing trees, and site characteristics such as ecoregion, elevation, stand size class, soil depth, and landform composition.

In the interim, managers can incorporate the finding that fine fuels have increased, especially in white spruce stands that have been salvage harvested. Fine fuels play a critical role in fire spread and can be detrimental in areas specifically treated to act as firebreaks. These fuel loads must be considered when prescribing fuel-reduction treatments.

Conversely, forest managers should keep in mind that dead and downed wood also plays an important role in forest ecosystem health. It stores carbon, provides locations for mycorrhizae, provides habitat for wildlife and insects, and contributes to site productivity through storage and cycling of nutrients and water. In south-central Alaska, decaying downed logs play an important role in forest regeneration by serving as nurse logs for seedlings.

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Metric Equivalents

When you know:	Multiply by:	To find:
Inches	2.54	Centimeters
Feet	.305	Meters
Cubic feet	.028	Cubic meters per hectare
Acres	.405	Hectares
Tons per acre	2.24	Tonnes per hectare

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