Fuels Treatment Demonstration Sites in the Boreal Forests of Interior Alaska

Written for the Joint Fire Science Program

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July 2005

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INTRODUCTION

Nationally, the wildland fire threat to homes is increasing, and is often referred to as the wildland-urban interface (W-UI) fire problem (Cohen 2000). The increase in the W-UI fire problem is a result of a major population increase in or adjacent to forested areas (Davis 1990). Alaska is no exception to this trend. Wildland fire is the dominant disturbance agent of the boreal forest of Alaska (Juday et al. 1998), which covers about 114 million ac. (46.2 million ha) of the southcentral and interior regions of the state (LaBau and Van Hess 1990). Currently, about 80% of the population of Alaska resides in communities potentially at risk from wildland fire, with dispersed and suburban settlements being especially at risk (Berman et al. 1999).

Alaska's increasing W-UI fire problem is primarily due to settlement patterns and settlement policy that began in the 1970s. The following discussion regarding Alaska's changing settlement patterns and policy is summarized from Berman et al. (1999).

> Large-scale dispersed settlement in Alaska is a recent occurrence. Traditionally, Native people, trappers, and miners lived in or adjacent to forests. These populations, however, were highly mobile, and seasonal homes were concentrated in villages or in isolated camps and cabins that existed in very low densities. As a result, wildfire damage to property was relatively small. Since the 1970s, however, a different settlement pattern came into being as a result of government policies. State and local governments have disposed of hundreds of thousands of acres of land transferred to the state from the federal government under the Alaska Statehood Act. These same governments have built a network of roads into rural areas, thereby making the disposed land accessible to the public. The result has been an increased proliferation of dispersed settlement in forested areas at risk from wildland fire.
>
> While large-scale land disposals expanded non-Native rural and suburban settlement in Alaska, other state and federal programs altered Native villages into permanent communities with significantly more infrastructure. Schools, bulk fuel storage facilities, public utilities, airports, and other community facilities were built in hundreds of communities state-wide, including at least 60 communities in the boreal forest regions of interior and southcentral Alaska. If a wildfire enters one of these Native communities, the resulting damage of public facilities and concentrated homes will be vastly greater than it would have been a generation ago.
>
> In the absence of major shifts in policy regarding public provision of transportation facilities and other infrastructure in rural and suburban areas, it is expected there will be further expansion of dispersed settlement and entrenchment of villages in forested areas at risk from fire. This settlement pattern will most certainly result in increased damage from a typical fire.

Because dispersed and isolated settlements are more difficult and costly to protect (Berman et al. 1999), it is expected that in the future more infrastructure will be damaged by wildland fire and the cost of fire protection to infrastructure will increase. Two recent examples illustrate this point. The Miller's Reach Fire of 1996 burned about 37,000 acres of forested land with extensive suburban and vacation home development in southcentral Alaska. The fire destroyed 454 structures, including about 200 homes (Nash and Duffy 1997 cited in Berman et al. 1999). The total direct cost of the Miller's Reach Fire was estimated at $80 million (Nash and Duffy 1997 cited in Berman et al. 1999), and is considered to be the most destructive fire ever to occur in Alaska. The Donnelly Flats fire of 1999 burned 47,000 acres, forced the evacuation of Fort

Greeley Army Base, and threatened a TransAlaska Pipeline pump station. Interestingly, although Fort Greeley was evacuated, a firebreak prevented the destruction of its residential areas.

As the frequency and cost of fires in the W-UI increase, the need for fuels reduction techniques for the purpose of creating defensible space increases with them. Fuels (both dead and living organic matter) control fire unless weather is extreme (Schmoldt et al. 1999), so creating defensible space is a proactive way to reduce the fire risk[1] and hazard[2] around settlements. Fire fighting agencies in interior and southcentral Alaska have been implementing fuels reduction programs, such as installation of firebreaks and shaded fuel breaks around settlements. To our knowledge, however, the effectiveness of these programs has not been monitored anywhere in the state, so comparison of various fuels reduction techniques is not possible.

The objective of project was to develop the first fuels treatment demonstration sites—in the form of shaded fuel breaks—in the boreal forests of interior Alaska. The sites allow for the comparison of the effectiveness, environmental effects, and cost of four different fuels treatments in black spruce (*Picea mariana*) stands located on floodplains. The demonstration sites are available to officials, resource management professionals, and interested publics for a minimum of seven years. Having access to the sites will allow people to visually compare the differences of the various fuels treatments.

SITE DESCRIPTIONS

Three demonstration sites (i.e. three replicates) were created in the Tanana River watershed in interior Alaska (Figure 1). The Fort Wainwright Site (FWW) near Fairbanks is located on land

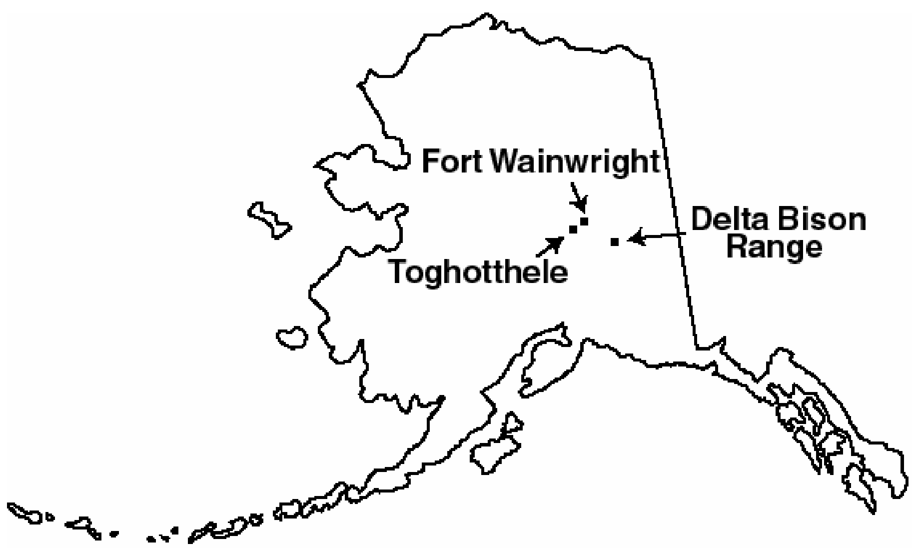


Figure 1. Locations of black spruce fuels treatment demonstration sites in interior Alaska.

owned by the Federal government under the jurisdiction of the US Army. The Toghotthele Site (Tog) is located about 45 miles southwest of Fairbanks near the village of Nenana. The Toghotthele Corporation is the Native village corporation of the village of Nenana. The Delta

[1] Risk is the likelihood of an ignition (Sapsis 1999).
[2] Hazard relates to potential fire behavior that results from the interaction of fuel, topography, and weather (Sapsis 1999).

Bison Range Site (DBR) is located about 130 miles southeast of Fairbanks, and about 30 miles southeast of the town of Delta. The Delta Bison Range is jointly managed by the Alaska Department of Fish and Game and the Alaska Department of Natural Resources, Division of Mining, Land, and Water.

FWW and Tog were installed during the summer of 2001, but due to permitting delays DBR was installed during the summer of 2002. Treatments on FWW were applied by the Alaska Fire Service. Tanana Chiefs Conference foresters treated the Tog site. Treatments on the DBR Site were applied by Alaska Division of Forestry.

SITE INSTALLATION AND MONITORING PROTOCOL

Each demonstration site consisted of five one-acre fuels treatment blocks located within a black spruce stand. Each block was randomly assigned to receive one of the five fuels treatments described below. Block corners were marked with PVC stakes and metal tags. The center of each block also was staked and labeled and its geographic coordinates were determined using a hand-held GPS (Global Positioning System). An informational sign was posted at each site (Figure 2).

Figure 2. Information sign describing the intent of the fuels treatment demonstration project at the Toghotthele Site.

The five fuels treatments were:

- Treatment 1 (8x8)—Thin trees to 8 ft x 8 ft spacing (i.e. 680 trees/ac) and remove slash from the site;
- Treatment 2 (10x10)—Thin trees to 10 ft x 10 ft spacing (i.e. 435 trees/ac) and remove slash from the site;

- Treatment 3 (8x8P)—Same as Treatment 1 except residual trees are pruned with a chainsaw to increase the ladder fuel height[3];
- Treatment 4 (10x10P)—Same as Treatment 2 except residual trees are pruned with the addition of pruning the residual standing trees to increase ladder fuel height.
- Treatment 5 (Control)—No trees were cut or pruned.

Costs of performing the fuels treatments were documented for each site.

Data were collected within each treatment block, including the control block, before the shaded fuel breaks were created (i.e. pre-treatment). In the treatment blocks where the fuel breaks were created, post-treatment data were collected the same season. Two-year post-treatment data were collected for all treatment blocks, including the control blocks.

Within each treatment block, data were collected within 5 systematically dispersed clusters of measurement plots, lines, and pits (Figure 3). Plot corners and the ends of sample lines were marked with PVC stakes and labeled with aluminum tags. One set of measurement plots, lines, and pits was located at the center of each treatment block. The center for each of the four other measurement clusters were located 80 ft. from the center of the treatment blocks, along the diagonal from the center to each corner.

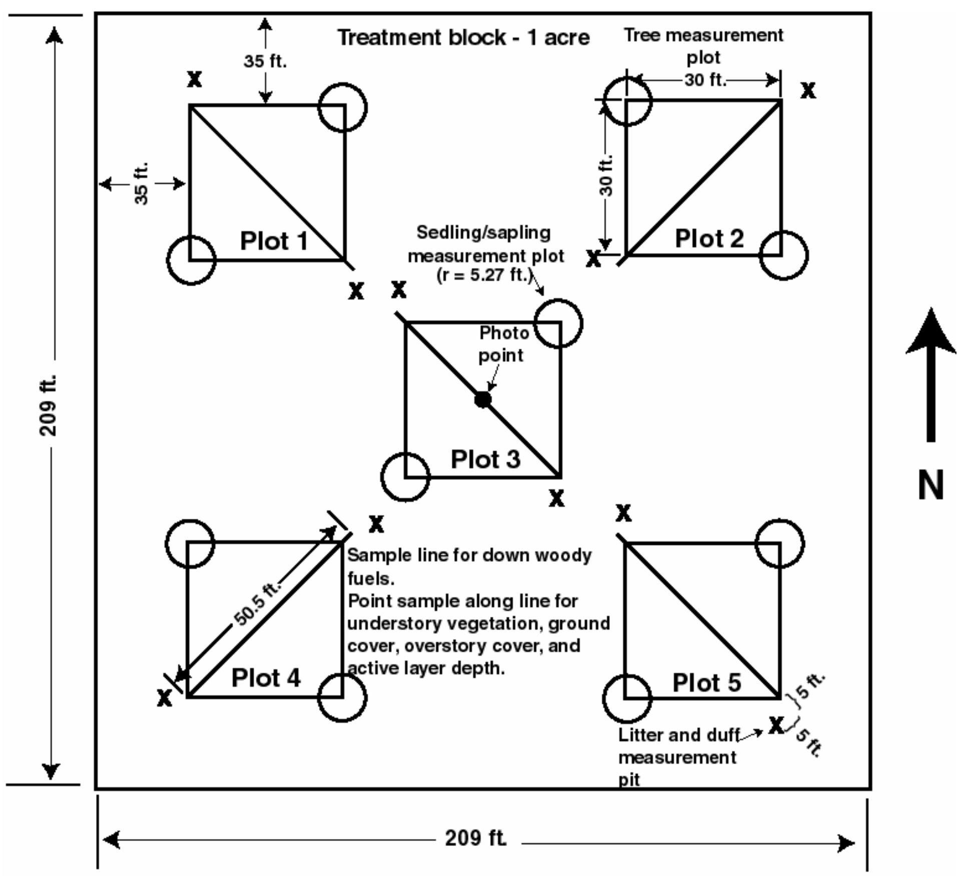


Figure 3. Measurement plot layout for fuels treatment demonstration sites (not drawn to scale).

A cluster of measurement plots, lines, and pits consisted on a tree (d.b.h.[4] ≥1 in.) measurement plot, two seedling (d.b.h. <1 in.) measurement plots, a sample line, and two duff

[3] Ladder fuel height is the height of the lowest live or dead branch that can carry fire into a tree crown (Ottmar and Vihnanek 1998).
[4] D.b.h. refers to diameter at breast height, which is measured at 4.5 ft. above the root collar of a tree.

measurement pits. In total, therefore, there were five tree measurement plots, 10 seedling measurement plots, five sample lines, and 10 litter and duff measurement pits.

Tree measurements were recorded within square, 0.02 ac. (30 ft. x 30 ft.) plots. The edges of the tree measurement plots were aligned parallel with the edges of the treatment and control plots. Seedling measurements were recorded within circular, 0.002 ac. Plots (radius = 5.27 ft.). Seedling measurement plots were centered at the northeast and southwest corners of the tree measurement plots. Down woody fuels, understory vegetation and ground cover, overstory cover, and active layer[5] depth were measured along 55 ft. sample lines that extended diagonally through the tree measurement plots. Data were only recorded along the first 50 ft. of each sample line. Litter and duff measurement pits were located five feet from the ends of, and five feet to the side of, the sample lines.

Pre-treatment data collection consisted of the following:

- In tree measurement plots, species and d.b.h. class were recorded for every live and dead stem. The four d.b.h. classes were: ≤ 2 in., 2.1–4.0 in., 4.1–9.0 in., and >9 in.
- In seedling measurement plots, live and dead stems were tallied separately by tree species.
- Along the sample lines, point samples were taken for understory vegetation and ground cover at one foot increments for a total of 50 points along each line. At each point, understory shrubs, herbs, and forbs were recoded by species. Ground cover was recorded as being moss, lichen, bare duff, mineral soil, litter, or woody debris.
- Along the sample lines, point samples were taken for overstory tree cover and active layer depth at 5 ft. increments for a total of 10 points along each line.
- Along the sample lines, line intersect sampling was used to record down woody fuels. One hr. fuels and ten hr. fuels were tallied within the first six ft. of each sample line. One hundred hr. fuels were tallied within the first 12 ft. of each sample line. Both solid and rotten 1000 hr. fuels were tallied along the entire 50 ft. of each sample line. The four down woody fuel classes were:
  - 1 hr. — ≤0.25 in. diameter at the plane of intersection with the sample line;
  - 10 hr. — >0.25 in. and ≤1.0 in. diameter;
  - 100 hr. — >1.0 in. and ≤3.0 in. diameter;
  - 1000 hr. — >3.0 in. diameter.
- In litter and duff measurement pits, depths of litter, lichen, live moss, dead moss, upper duff, and lower duff were recorded.

Post-treatment data were collected the same season in all treatment blocks where shaded fuel breaks were created. Post-treatment data collected consisted of re-measuring the tree measurement plots, seedling measurement plots, overstory tree cover, and down woody fuels.

In addition to the above mentioned post-treatment data collection, individual trees were tagged and measured in each tree measurement plot, including those in the control treatment blocks. Within each tree measurement plot, up to five trees in three d.b.h. classes (≤2 in., 2.1–4.0 in., and >4.0 in.) nearest the plot center were tagged. The following data were collected for each tagged tree: species, d.b.h., total height, height to live crown[6], and ladder fuel height. A d.b.h. line was painted on each tree after it was measured.

In addition to data collection, pre-treatment and post-treatment photographs were taken in the four cardinal directions from the center of each treatment and control block. A 35mm camera

[5] The active layer is the layer of soil over permafrost that seasonally thaws.
[6] Height to live crown is the height to the lowest living branch of the main tree crown.

equipped with a 24mm lens was mounted on a 4.5 ft. tall tripod that was placed over each center stake. The camera was leveled both horizontally and vertically.

Active layer depths could not be compared among sites using the pre-treatment and the same year post-treatment active layer depths because they were taken at different time periods during the summer months. To allow for among site comparisons, active layer depths were re-measured at all sites about the middle of September of the same year the shaded fuel breaks were created. Measuring the active layer depth during this period, when maximum active layer depth is achieved, allowed for among site comparisons, because all of the measurements were taken during the same time period.

Two-year post-treatment data were collected in all treatment blocks, including the control blocks, and included re-measurement of the tree measurement plots, seedling measurement plots, understory vegetation and ground cover, overstory tree cover, active layer depth, down woody fuels, and individual tagged trees. In addition, two-year post-treatment photographs were taken, and active layer depths were once more re-measured during mid-September so that among site comparisons could be made.

Data logging weather stations (Figure 4) were installed at each demonstration site for a summer to monitor treatment effects on microclimate variables that influence fire behavior.

Figure 4. Weather station being installed in the control block at the Fort Wainwright Site.

Paired, synchronized recording weather stations were placed in the center of the control and the center of the 10Px10P treatment at FWW (2002), DBR (2003) and Tog (2004). Measured microclimate variables were temperature, relative humidity, wind speed, solar radiation and precipitation (only in the 10Px10P treatment block). Measuring microclimate differences in this way allowed for the comparison between treatment and control in the same site, but not among sites because the microclimate data were collected during different years at the three sites.

Fire behavior was modeled for treatment and control sites using NEXUS (http://fire.org/nexus). NEXUS 2.0 is crown fire hazard analysis software that links separate models of surface and crown fire behavior to compute indices of relative crown fire potential. NEXUS was designed to compare crown fire potential for different stands, and to compare the effects of alternative fuel treatments on crown fire potential.

RESULTS AND DISCUSSION

Trees and Seedlings

Prior to treatment, average total live tree densities ranged from 3566 to 5337 trees/acre, with the vast majority (95.4 to 100.0%) being comprised of black spruce. Average total dead tree densities ranged from 642 to 1120 trees/acre (Table 1). As a result of treatment, reductions of average total live tree densities ranged from 3037 to 4834 trees/acre (79 to 91% reduction), and reductions of average dead tree densities ranged from 632 to 949 trees/acre (98 to 100% reduction). The level of overall tree density reduction was positively associated with pre-treatment tree density. Post-treatment tree densities in 11 of 12 treatment blocks exceeded target tree densities. For this reason, we recommend that tree thinning crews be given tree spacing guidelines that are greater than the actual target tree spacings. Prior to treatment, average overstory cover values ranged from 40.0 to 53.3% (Table 2). As a result of treatment, reductions of average overstory cover values ranged from 18.0 to 39.3%.

Table 1. Average tree density (per acre).

		≤ 2" DBH		2.1-4" DBH		4.1-9" DBH		> 9" DBH	
Treatment	**Time period**	**Total live**	**Total dead**	**Total live**	**Total dead**	**Total live**	**Total dead**	**Total live**	**Total dead**
8X8	Pre-Treatment	3475	594	810	48	71	0	0	0
	0 Yr. Post-Treatment	323	10	313	0	52	0	0	0
	2 Yr. Post-Treatment	316	19	307	0	52	0	0	0
8X8P	Pre-Treatment	2898	687	1045	113	116	10	0	3
	0 Yr. Post-Treatment	294	6	487	3	58	0	0	0
	2 Yr. Post-Treatment	310	3	500	6	68	0	0	0
10X10	Pre-Treatment	4250	678	1026	35	61	3	0	0
	0 Yr. Post-Treatment	142	0	313	0	48	0	0	0
	2 Yr. Post-Treatment	165	3	287	0	48	0	0	0
10X10P	Pre-Treatment	2472	839	942	97	152	13	0	0
	0 Yr. Post-Treatment	119	0	297	0	113	0	0	0
	2 Yr. Post-Treatment	132	3	281	0	113	0	0	0
Control	Pre-Treatment	3059	1000	1039	110	87	10	0	0
	0 Yr. Post-Treatment	3059	1000	1039	110	87	10	0	0
	2 Yr. Post-Treatment	3520	820	1104	103	77	16	0	0

Table 2. Average overstory cover (%).

Treatment	Time period	Overstory cover	No Cover
8X8	Pre-Treatment	53.3	46.7
	0 Yr. Post-Treatment	20.0	80.0
	2 Yr. Post-Treatment	18.7	81.3
8X8P	Pre-Treatment	42.0	58.0
	0 Yr. Post-Treatment	24.0	76.0
	2 Yr. Post-Treatment	20.7	79.3
10X10	Pre-Treatment	51.3	48.7
	0 Yr. Post-Treatment	12.0	88.0
	2 Yr. Post-Treatment	12.0	88.0
10X10P	Pre-Treatment	40.0	60.0
	0 Yr. Post-Treatment	20.7	79.3
	2 Yr. Post-Treatment	18.0	82.0
Control	Pre-Treatment	46.0	54.0
	0 Yr. Post-Treatment	46.0	54.0
	2 Yr. Post-Treatment	47.3	52.7

Prior to treatment, average total live seedling densities ranged from 5083 to 7600 seedlings/acre, the vast majority (96.4 to 100.0%) of which were black spruce. Average total dead seedling densities ranged from 250 to 633 seedlings/acre (Table 3). As a result of treatment, reductions of average total live seedling densities ranged from 1366 to 3050 seedlings/acre (21.6 to 43.3% reduction), and reductions of average dead seedling densities ranged from 183 to 450 seedlings/acre (58.9 to 86.8% reduction). Treatment did not reduce seedlings densities to the same extent as it did tree densities because only the tallest seedlings were removed during treatment.

Table 3. Average seedling density (per acre).

		Picea mariana		*Picea glauca*		*Larix laricina*		*Betula papyrifera*	
Treatment	**Time period**	**Live**	**Dead**	**Live**	**Dead**	**Live**	**Dead**	**Live**	**Dead**
8X8	Pre-Treatment	4900	633	0	0	0	0	183	0
	0 Yr. Post-Treatment	3717	183	0	0	0	0	0	0
	2 Yr. Post-Treatment	2567	667	0	0	0	0	750	17
8X8P	Pre-Treatment	6400	250	0	0	17	0	0	0
	0 Yr. Post-Treatment	5017	33	17	0	0	0	0	0
	2 Yr. Post-Treatment	4117	767	0	0	0	0	0	0
10X10	Pre-Treatment	7050	567	0	0	0	0	0	0
	0 Yr. Post-Treatment	4000	233	0	0	0	0	0	0
	2 Yr. Post-Treatment	3383	617	0	0	17	0	0	0

Table 3 continued. Average seedling density (per acre).

		Picea mariana		*Picea glauca*		*Larix laricina*		*Betula papyrifera*	
Treatment	**Time period**	**Live**	**Dead**	**Live**	**Dead**	**Live**	**Dead**	**Live**	**Dead**
10X10P	Pre-Treatment	5350	300	0	0	0	0	0	0
	0 Yr. Post-Treatment	3733	117	0	0	0	0	0	0
	2 Yr. Post-Treatment	2933	483	17	0	0	0	0	0
Control	Pre-Treatment	7600	467	0	0	0	0	0	0
	0 Yr. Post-Treatment	7600	467	0	0	0	0	0	0
	2 Yr. Post-Treatment	8617	617	0	0	0	0	0	0

Understory Vegetation and Ground Cover

Before treatment, the Ericaceous shrubs, lowbush cranberry (*Vaccinium vitis-idaea*) and Labrador tea (*Ledum palustre*), were the most common understory plants among all treatment blocks and together represented from 68.2 to 79.4% of understory vegetation cover (Table 4). Grasses and sedges (Poaceae, *Calamagrostis canadensis*, *Carex* spp.) also were common understory plants, and combined, averaged from 23.4 to34.1% of understory vegetation cover prior to treatment.

Two years after treatment, lowbush cranberry and Labrador tea were still the most common understory plants (Table 4). However, average cover values decreased in all treatment blocks, including the control. Lowbush cranberry decreased 5.1 to 12.4%, and Labrador tea decreased 3.1 to 7.2%. *Calamagrostis canadensis* also decreased (2.9 to 10.7%) in all treatment blocks. The other common understory vegetation increased in some treatment blocks and decreased in others. As a group, however, the grasses and sedges decreased 4.3 to 18.6% in all treatment blocks, with the greatest decrease occurring in the control blocks.

Live feather mosses were the most common pre-treatment ground cover, and averaged between 55.7 to 66.0% (Table 5). No dead feather moss ground cover was recorded in the pre-treatment measurements. Litter was the second most common pre-treatment ground cover, with average values ranging from 16.9 to 28.5%. After treatment, live feather moss cover decreased in all treatments blocks, including the controls, with reductions ranging from 28.0 to 34.9%. At the same time, dead moss cover increased in the range of 21.1 to 27.5% in all but the control blocks. Post treatment litter cover also increased in all treatment blocks, with average values ranging from 1.9 to 14.4%. Mosses other than the feather mosses increased 2.5 to 8.0% after treatment.

The overall decrease in common understory plants in all treatment blocks, including the controls, suggests that general environmental conditions such as climate may have influenced understory plant dynamics more than localized treatment effects due to tree thinning and slash removal. Treatment effects were more pronounced in the ground cover layer, with tree thinning and slash removal apparently resulting in mortality of live feather mosses while simultaneously resulting in increases in dead mosses, litter, and mosses other than feather mosses.

Table 4. Average cover values (%) for the most common understory plants.

Treatment	**Time period**	***Vaccinium vitis-idaea***	***Ledum palustre***	**Family Poaceae**	***Calamagrostis canadensis***	***Carex* species**	***Equisetum scirpoides***
8X8	**Pre-Treatment**	39.2	32.7	13.9	8.7	0.8	3.7
	2 Yr. Post-Treatment	34.1	29.6	6.1	0.5	12.5	3.5
	Change	-5.1	-3.1	-7.7	-8.1	11.7	-0.3

Table 4 continued. Average cover values (%) for the most common understory plants.

Treatment	Time period	*Vaccinium vitis-idaea*	*Ledum palustre*	Family Poaceae	*Calamagrostis canadensis*	*Carex* species	*Equisetum scirpoides*
8X8P	**Pre-Treatment**	42.9	35.2	7.7	10.5	11.9	13.9
	2 Yr. Post-Treatment	37.5	28.0	12.5	5.2	6.9	7.9
	Change	-5.5	-7.2	4.8	-5.3	-4.9	-6.0
10X10	**Pre-Treatment**	41.3	26.9	6.7	12.4	13.5	8.0
	2 Yr. Post-Treatment	28.9	22.7	5.6	1.7	12.9	2.5
	Change	-12.4	-4.3	-1.1	-10.7	-0.5	-5.5
10X10P	**Pre-Treatment**	46.7	32.7	18.8	6.3	2.1	5.2
	2 Yr. Post-Treatment	35.9	25.9	7.7	1.1	11.2	0.9
	Change	-10.8	-6.8	-11.1	-5.2	9.1	-4.3
Control	**Pre-Treatment**	43.2	29.9	11.1	6.3	16.7	14.3
	2 Yr. Post-Treatment	32.5	23.7	7.9	3.3	4.3	8.0
	Change	-10.7	-6.1	-3.2	-2.9	-12.4	-6.3

Table 5. Average ground cover values (%) for the most common ground cover types.

Treatment	Time period	Exposed duff layer	Dead moss	Feather moss species	Litter	Leaf lichen species	Other moss	Reindeer lichen species	Sphagnum moss species
8X8	**Pre-Treatment**	0.8	0.0	64.8	28.5	5.5	0.3	4.5	1.6
	2 Yr. Post-Treatment	1.5	21.1	36.8	30.7	2.3	4.3	4.3	1.2
	Change	0.7	21.1	-28.0	2.1	-3.2	4.0	-0.3	-0.4
8X8P	**Pre-Treatment**	0.5	0.0	55.7	27.9	6.8	0.9	8.1	4.9
	2 Yr. Post-Treatment	0.7	27.5	20.8	40.7	2.1	3.5	7.3	3.9
	Change	0.1	27.5	-34.9	12.8	-4.7	2.5	-0.8	-1.1
10X10	**Pre-Treatment**	0.5	0.0	64.9	28.1	7.9	0.0	4.1	2.7
	2 Yr. Post-Treatment	3.3	24.7	27.9	30.0	4.8	8.0	4.1	2.7
	Change	2.8	24.7	-37.1	1.9	-3.1	8.0	0.0	0.0
10X10P	**Pre-Treatment**	0.1	0.0	66.0	21.5	5.3	0.8	7.1	2.7
	2 Yr. Post-Treatment	1.1	24.9	29.3	32.1	2.0	6.7	7.9	1.7
	Change	0.9	24.9	-36.7	10.7	-3.3	5.9	0.8	-0.9
Control	**Pre-Treatment**	0.8	0.0	65.5	16.9	5.2	0.4	7.1	5.3
	2 Yr. Post-Treatment	0.0	0.0	42.1	31.3	12.4	4.7	7.7	2.3
	Change	-0.8	0.0	-23.3	14.4	7.2	4.3	0.7	-3.1

Duff and Active Layer Depths

Pre-treatment duff layer depths were similar across all treatment blocks, with total duff thicknesses ranging 10.2 to 12.4 inches (Table 6). The upper duff was the thickest layer in all treatment blocks, ranging from 3.2 to 4.1 inches. Litter and lichen were the thinnest duff layers, with both layers ranging from 0.1 to 0.4 inches. Post-treatment duff measurements were not recorded, due to concerns that impacts of trampling from tree thinning and slash removal would confound any possible treatment effects on duff layer depths.

Table 6. Average pre-treatment duff layer depths (inches), including partially frozen layers.

Treatment	Litter	Lichen	Live moss	Dead moss	Upper duff	Lower duff	Total
8X8	0.4	0.2	2.3	2.6	4.1	2.8	12.4
8X8P	0.1	0.1	2.0	2.3	3.5	3.2	11.2
10x10	0.4	0.1	2.4	2.5	3.4	2.8	11.5
10X10P	0.1	0.4	1.8	2.5	3.2	2.3	10.2
Control	0.1	0.3	1.6	3.2	3.3	2.9	11.3

The active layer, which is the layer of soil over permafrost that seasonally thaws, is very sensitive to the current year’s summer temperatures. Because the DBR Site was installed one year after the FWW and Tog Sites, initial temperatures were not the same among all three sites. For this reason, we did not compare actual active layer depths among sites, but we instead compared relative differences in active layer depths among sites (Table 7).

Relative increases in active layer depth, as well as variations in active layer depths, were greater in the fuel reduction treatment blocks than in the control blocks. Among fuel reduction treatment blocks, the greatest relative increases in active layer depth and in active layer variation were in the 10X10 and 10X10P treatment blocks. Based on these results, average active layer depth and variation increases as the level of fuel reduction (i.e. tree thinning and slash removal) increases. Active layer depths are expected to continue to increase over time.

Table 7. Average difference in September active layer depth between year 2 post-treatment and year 0 post-treatment time periods. Difference values show increases in active layer depth during a two year period.

Treatment	Average difference (%)	St. Dev. (% difference)
8X8	10.8	4.2
8X8P	10.4	5.0
10X10	19.6	8.5
10X10P	16.0	6.1
Control	6.1	1.0

Down Woody Fuel Load

Average pre-treatment total down woody fuel load ranged from 1.53 to 4.69 tons/acre. (Table 8). Treatment activities resulted in post-treatment fuel load reductions that ranged from a 35.3% reduction in the 10X10P treatment to a 63.3% reduction in the 10X10 treatment. The greatest reductions in the total average down woody fuel loading were in the two non-pruning treatments—63.3% in the 10X10 treatment and 60.8% reduction in the 8X8 treatment. This observation is most likely due to increased fine fuel loading from the pruning of residual trees in the two pruning treatments. Average 1-hr. fuel loads increased for all four fuel reduction treatments due to these fine fuels breaking off standing trees during tree thinning, and breaking off slash as it was removed from the treatment blocks. However, greater amounts of 1-hr. fuels, which are too small to remove once they are broken from branches and tree boles, were created in the two pruning treatments when residual trees were pruned in order to increase ladder fuel height.

Table 8. Average down woody fuel load (tons/acre).

	1-hr			10-hr			100-hr			1000-hr		
Treatment	**Pre**	**Post**	**Change**	**Pre**	**Post**	**Change**	**Pre**	**Post**	**Change**	**Pre**	**Post**	**Change**
8X8	0.25	0.34	0.09	0.97	0.90	-0.07	0.70	0.23	-0.47	2.77	0.37	-2.40
8X8P	0.16	0.50	0.33	0.43	0.63	0.20	0.80	0.23	-0.57	0.80	0.00	0.80
10X10	0.23	0.42	0.19	0.47	0.50	0.03	0.00	0.07	0.07	2.00	0.00	-2.00
10X10P	0.13	0.42	0.29	0.47	0.43	-0.03	0.40	0.07	-0.33	0.53	0.07	-0.46
Control	0.13	-	-	0.80	-	-	0.70	-	-	0.60	-	-

Microclimate

At the suggestion of fire behavior experts we consulted during the initial stages of the project, we decided to compare microclimate between the 10X10P treatment and the control block at each demonstration site. It was suggested that increases in temperature, reductions in relative humidity (RH), and increases in wind speed in the fuel reduction treatments would increase fire rates of spread and intensity and offset any potential value in shaded fuel breaks. This information is important to State, Federal and private landowners who have already created a number of operational shaded fuel breaks which are presumed to provided a measure of protection.

Microclimate data were averaged over 1 hour increments. At the DBR Site, wind data were recorded from June 6 until September 19, 2003 for a total of 2514 hours. Temperature and relative humidity data were recorded from June 6 until July 23, 2003 for a total of 1122 hours. Microclimate data were recorded at the FWW Site from June 21 until August 16, 2002 for a total of 1347 hours. These data were recorded at the Tog Site from June 4 until August 12, 2004 for a total of 1649 hours.

Noticeable cycles of temperature differences between the 10X10P treatment and the control existed at all three demonstration sites (Figures 5, 6, and 7). Average temperatures in the 10X10P treatment blocks were greater than in the control blocks for portions of the day, but not for the entire day. Patterns were similar at the FWW and Tog Sites, where average temperatures in the 10X10P treatment were greater than in the control block during a portion of the evening, starting about 2100 hours, and into the morning hours, until about 900 hours (Figures 5 and 7). A similar, but less obvious pattern was observed at the DBR Site (Figure 6). Temperatures in the 10X10P treatment exceeded temperatures in the control blocks from 24.1 to 38.6% of the time (Table 9). Temperatures in the 10X10P treatment were less than those in the control block for roughly a third of the time (30.8 to 37.3%) at each of the demonstration sites. Maximum and minimum temperatures were similar between the 10X10P treatment and the control block at each site (Table 9).

Figure 5. Average temperature differences between the 10X10P treatment block and the control block over an entire day at the Fort Wainwright Site.

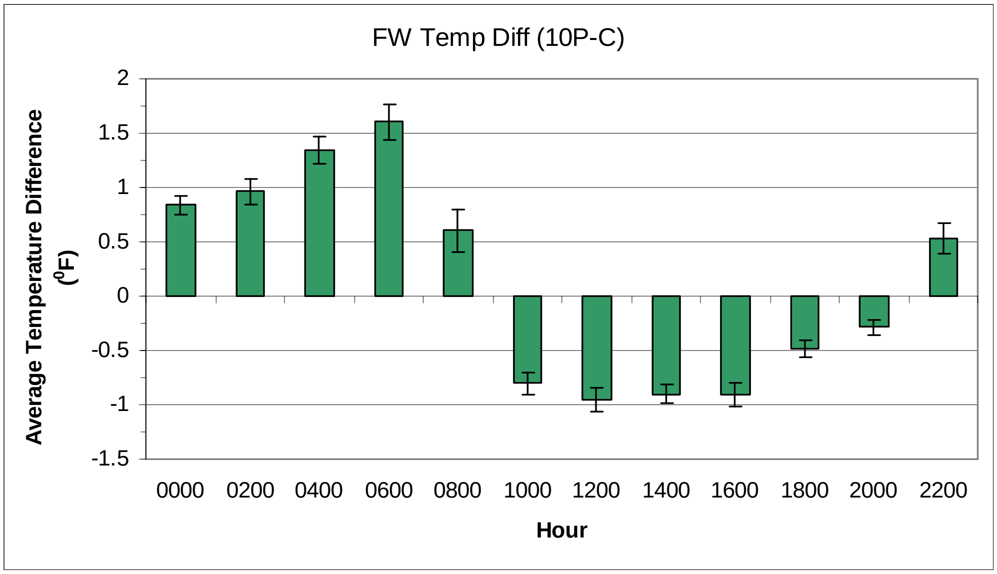


Figure 6. Average temperature differences between the 10X10P treatment block and the control block over an entire day at the Delta Bison Range Site.

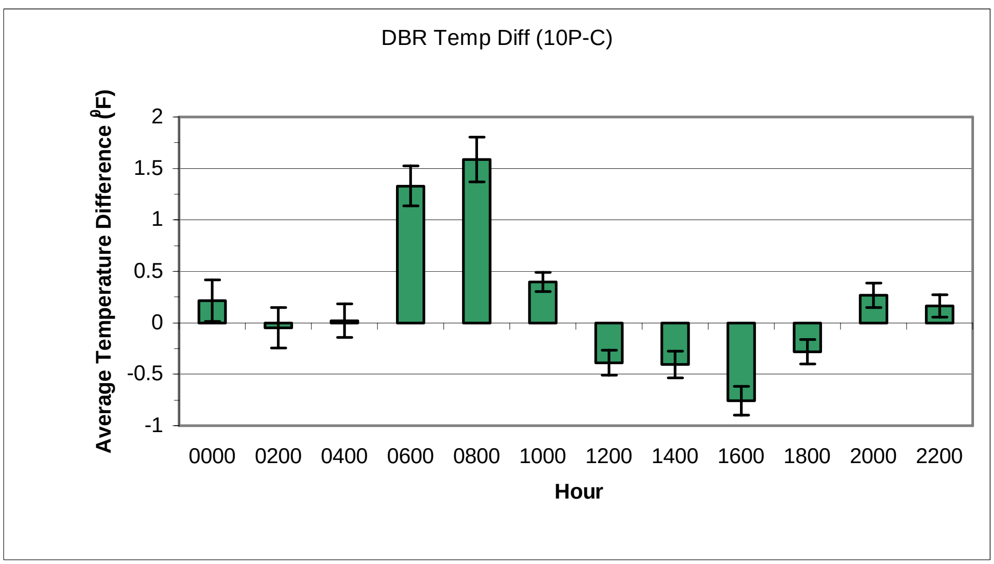


Figure 7. Average temperature differences between the 10X10P treatment block and the control block over an entire day at the Toghotthele Site.

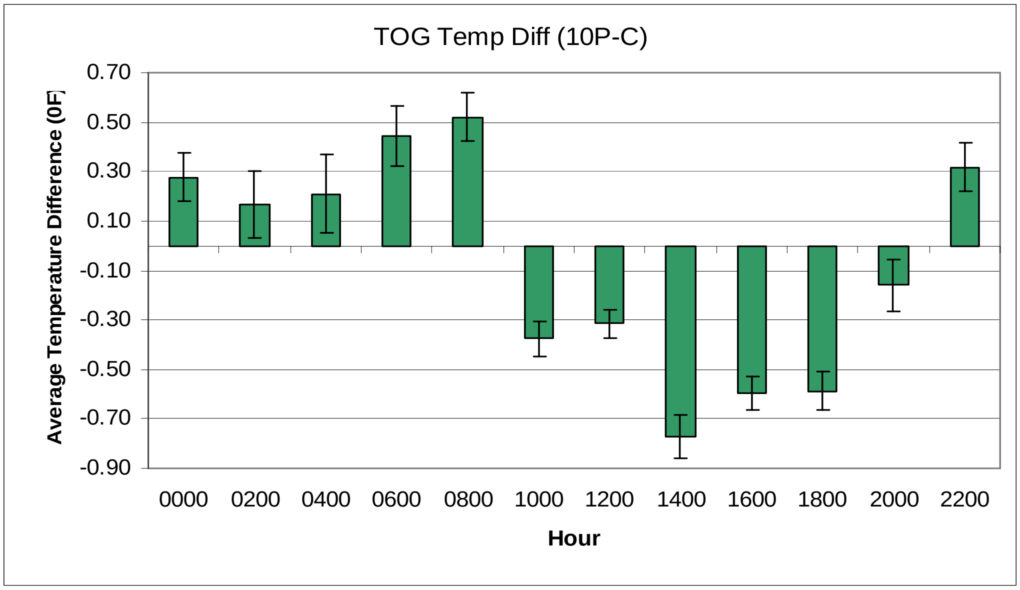


Table 9. Temperature (^{o}F) statistics.

	10X10P		Control		10X10P > Control (%)	10X10P < Control (%)	10X10P = Control (%)
Site	**Max**	**Min**	**Max**	**Min**			
Delta Bison Range	85.5	25.9	86.6	26.8	38.6	30.8	30.6
Fort Wainwright	85.8	25.9	87.3	25.1	37.6	35.6	26.8
Toghotthele	88.7	35.7	89.5	35.7	24.1	37.3	38.6

Unlike the temperature differences, average RH differences between the 10X10P treatment and the control blocks generally did not cycle between positive and negative values at the demonstration sites (Figures 8, 9, and 10). Average RH values were greater in the control block than in the 10X10P treatment block for all time periods at the Tog and DBR Sites (Figures 9 and 10). At the FWW Site, on the other hand, average RH was greater in the 10X10P treatment for most of the time periods (Figure 8). The amount of time that RH was greater in the 10X10P treatment than in the control block, and conversely, the amount of time that RH was less in the 10X10P treatment was similar between the DBR and the Tog Sites (Table 10). However, the proportions were reversed at the FWW Site. Maximum and minimum RH values were similar between the 10X10P treatment and the control at all three demonstration sites (Table 10).

Figure 8. Average relative humidity differences between the 10X10P treatment block and the control block over an entire day at the Fort Wainwright Site.

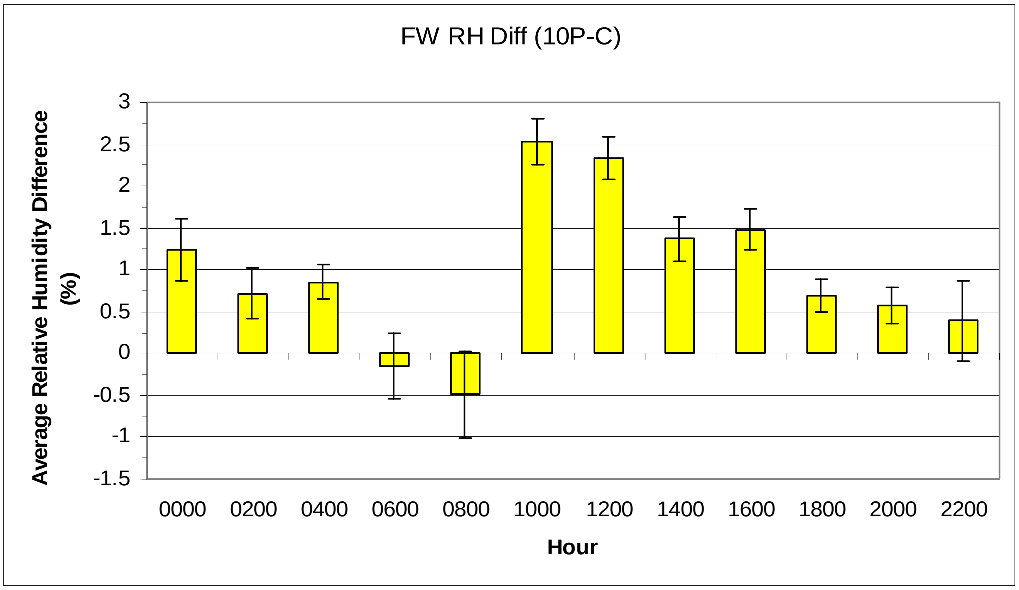


Figure 9. Average relative humidity differences between the 10X10P treatment block and the control block over an entire day at the Delta Bison Range Site.

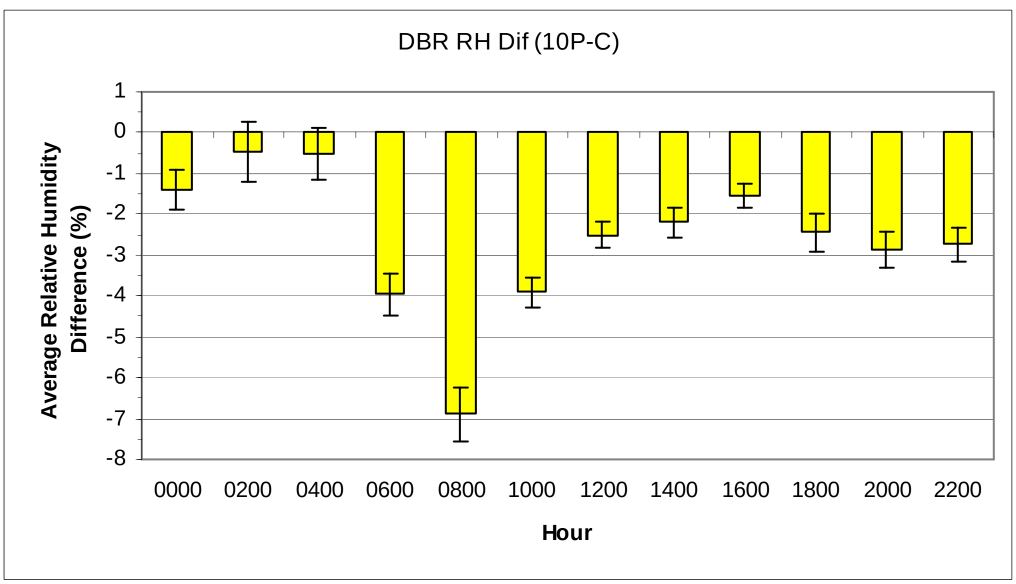


Figure 10. Average relative humidity differences between the 10X10P treatment block and the control block over an entire day at the Toghotthele Site.

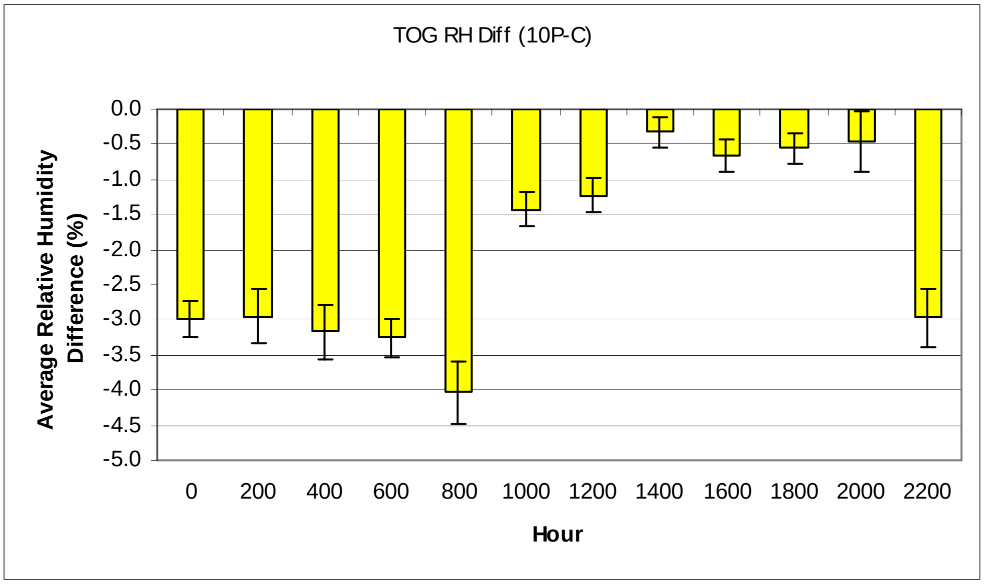


Table 10. Relative humidity (%) statistics.

	10X10P		Control		10X10P >	10X10P <	10X10P =
Site	**Max**	**Min**	**Max**	**Min**	**Control (%)**	**Control (%)**	**Control (%)**
Delta Bison Range	98.8	13.3	100.0	14.3	13.9	80.8	5.3
Fort Wainwright	100.0	19.5	98.5	19.0	71.0	22.6	6.4
Toghotthele	98.3	19.3	100.0	19.3	16.0	77.9	6.1

Average wind speeds were greater in the 10X10P treatments than in the control blocks at all three demonstration sites (Figures 11, 12, and 13), with average winds generally being >1.0 and <2.5 mph greater in the 10X10P treatments. Maximum wind speeds were always greater in the 10X10P treatments (Table 11). At all three demonstration sites, wind speeds in the 10X10P treatment always exceeded or were equal to (usually 0 mph) wind speeds in the control blocks (Table 11).

Table 11. Wind (mph) statistics.

	10X10P		Control		10X10P >	10X10P <	10X10P =
Site	**Max**	**Min**	**Max**	**Min**	**Control (%)**	**Control (%)**	**Control (%)**
Delta Bison Range	5.1	0.0	1.7	0.0	23.5	0.0	76.5
Fort Wainwright	5.1	0.0	3.4	0.0	33.4	0.0	66.6
Toghotthele	3.4	0.0	2.6	0.0	5.9	0.0	94.1

Figure 11. Average wind speed differences between the 10X10P treatment block and the control block over an entire day at the Fort Wainwright Site.

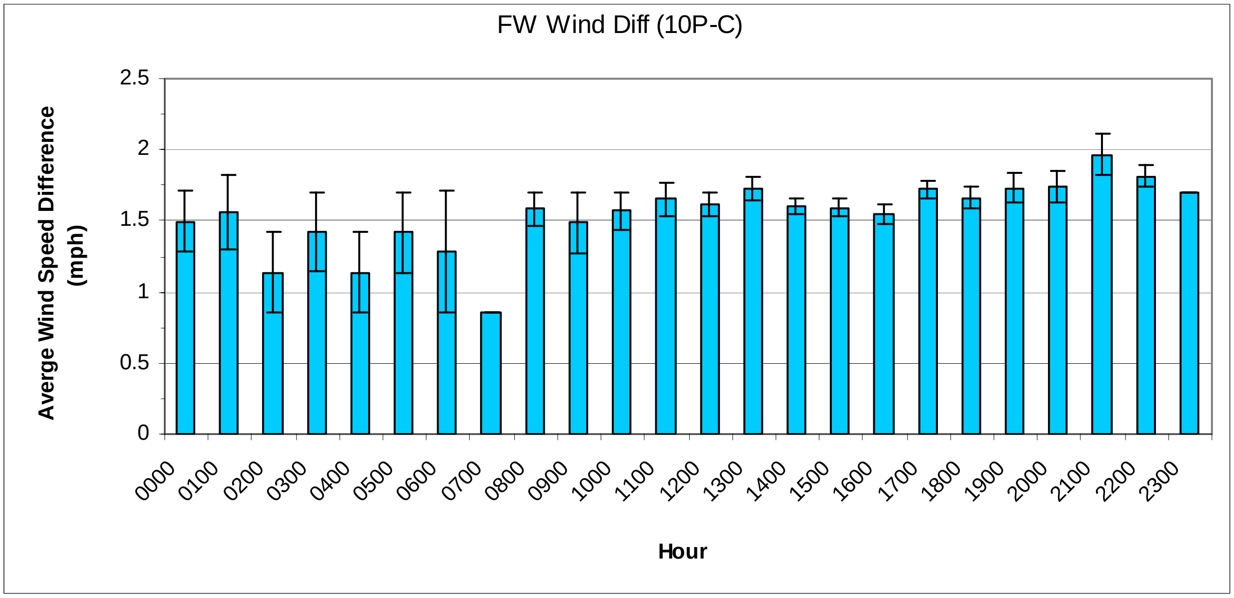


Figure 12. Average wind speed differences between the 10X10P treatment block and the control block over an entire day at the Delta Bison Range Site.

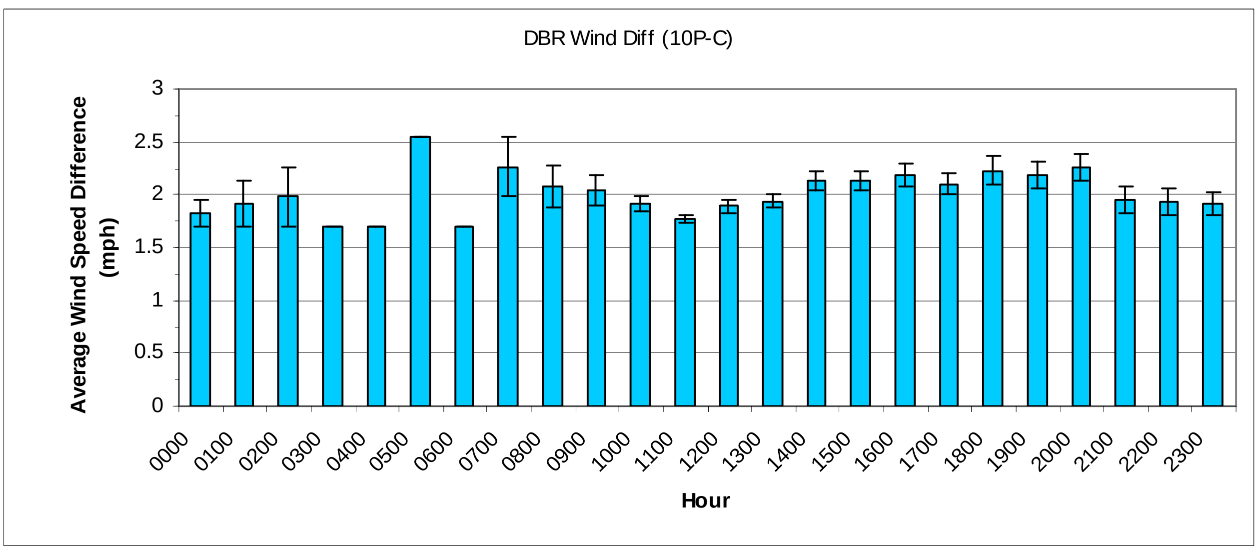
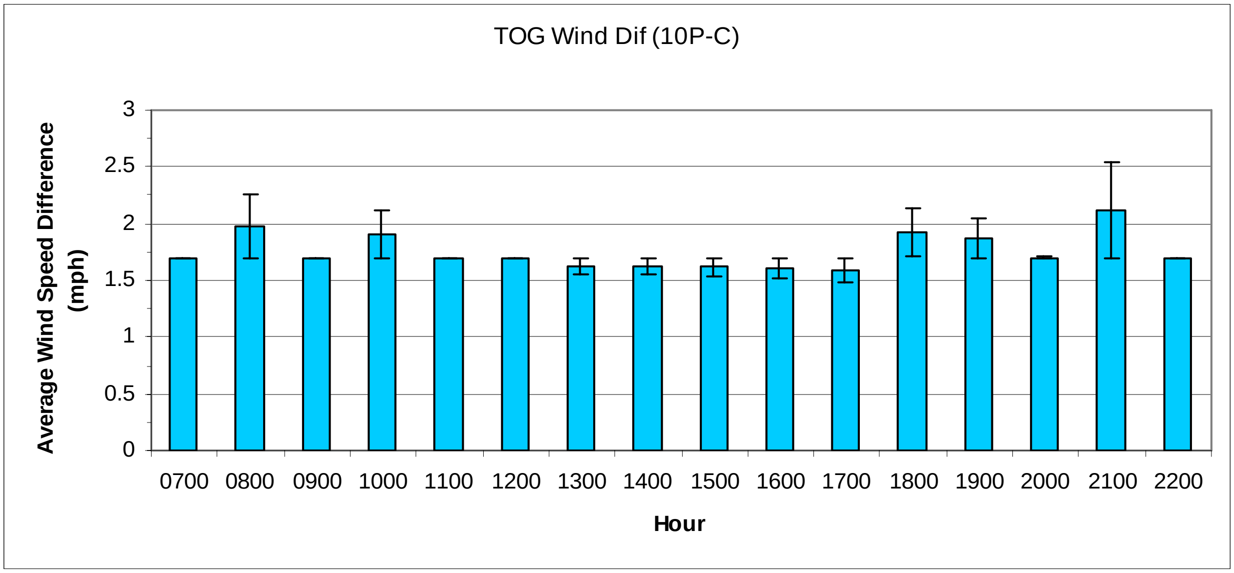


Figure 13. Average wind speed differences between the 10X10P treatment block and the control block over an entire day at the Toghotthele Site.



Fire Behavior

Crown bulk densities for the fire behavior inputs were computed by estimating crown mass (Table 12) from crown lengths and tree densities by size class and using conversion factors estimated for similar black spruce stands in Alaska (Barney and VanCleve 1973). The fraction of tree crown mass that would be expected to burn in frontal passage is generally the foliage and twigs less than 1/4". This fraction has been measured at approximately 42% of total crown mass for upland black spruce (Barney et al, 1978). This fraction of crown mass was multiplied by crown length to derive crown bulk density (Table 13) for input into NEXUS.

NEXUS was used to model crown fire potential, using a black spruce fuel model, in the 10X10P treatment block and control block at each of the three demonstration sites. Model inputs consisted of weather and fuels data. The model was used to simulate the 70th percentile (average summer day) and the 90th percentile (dry, windy) conditions. Historical weather data were used for model inputs for the control blocks. For the 10X10P treatment blocks, on site weather data obtained from the weather stations, were subtracted from historical weather data. The fuels data used in the model were those shown in Tables 13 and 14.

Table 12. Fuel loading—Crown mass, including foliage and twigs < ¼" (tons/ac).

	Ft. Wainwright				**Delta Bison Range**				**Toghotthele**			
	Diameter class (in)				**Diameter class (in)**				**Diameter class (in)**			
Treatment	**0-2**	**2-4**	**4-9**	**total**	**0-2**	**2-4**	**4-9**	**total**	**0-2**	**2-4**	**4-9**	**total**
8X8	0.43	0.55	1.45	2.44	0.09	2.11	1.79	3.99	0.10	1.12	1.49	2.70
8X8P	0.52	1.27	0.00	1.79	0.11	3.61	1.77	5.50	0.11	2.20	2.06	4.36
10X10	0.22	0.80	0.83	1.86	0.17	1.27	0.00	1.44	0.06	1.27	2.21	3.54
10X10P	0.21	0.72	1.08	2.01	0.12	1.63	1.71	3.46	0.05	1.38	4.92	6.36
Control	3.89	1.71	1.45	7.05	1.60	9.69	1.72	13.01	0.53	3.73	1.93	6.18

Table 13. Crown bulk density (foliage and twig < 1/4”) kg/m^3.

	Ft. Wainwright				Delta Bison Range				Toghotthele			
	Diameter class (in)				Diameter class (in)				Diameter class (in)			
Treatment	**0-2**	**2-4**	**4-9**	**total**	**0-2**	**2-4**	**4-9**	**total**	**0-2**	**2-4**	**4-9**	**total**
8x8	0.03	0.02	0.04	0.09	0.01	0.08	0.05	0.13	0.01	0.03	0.03	0.08
8x8 P	0.04	0.06	0.00	0.10	0.01	0.15	0.05	0.21	0.01	0.09	0.05	0.15
10x10	0.01	0.03	0.02	0.07	0.01	0.05	0.00	0.06	0.00	0.04	0.05	0.10
10x10 P	0.02	0.04	0.03	0.08	0.01	0.07	0.05	0.13	0.00	0.05	0.12	0.17
Control	0.26	0.07	0.03	0.36	0.10	0.32	0.04	0.46	0.04	0.14	0.05	0.23

Summary statistics of simulation outputs are presented for average summer fuel moisture conditions (Table 14) and for dry, windy conditions (Table 15). Passive crown fires are predicted for both the 10X10P and the control blocks for both weather conditions modeled, with the exception of the DBR control block. The fire spread rate is predicted to be greater in the 10X10P treatment versus the control block at all sites and for both weather conditions. However, the crown fraction that is burned, the heat per unit area, and the fireline intensity are expected to be less in all of the pruning treatments for both weather conditions.

Table 14. Summary of simulation outputs using average summer fuel moisture conditions (70th percentile weather). This table is from the draft report, “Fire Behavior Changes in Shaded Fuel Break Treatments,” being written by Esther Horschel, Randi Jandt, and Skip Thiesen.

Output	**10X10P**			**Control**		
	FWW	**DBR**	**Tog**	**FWW**	**DBR**	**Tog**
Type of fire, nominal	passive	passive	passive	passive	active	passive
Crown fraction burned, fraction	0.04	0.23	0.25	0.22	1.00	0.44
Spread rate, chains/hr	12.8	35.55	29.16	8.65	16.76	24.18
Heat per unit area, BTU/ft	1137	1327	1526	1583	6241	2182
Fireline intensity, BTU/ft	267	865	816	251	1918	967
Flamelength, feet	6	12	11.8	6.2	30.9	14.6
Effective midflame windspeed, mi/hr	5.1	9.5	8.2	3.5	3.6	6.6
Torching index, mi/hr	1.1	2.7	1.4	0	0	0.4
Crowning index, mi/hr	36.1	25.6	22.2	10.8	8.7	14.8
Surfacing index, mi/hr	36.1	25.6	22.2	10.8	8.7	14.8
Critical fireline intensity for crown fire initiation, BTU/ft	43	100	47	0	12	25
Critical flame length for crown fire initiation, ft	2.5	3.7	2.7	0	1.4	2
Critical spread rate for crown fire initiation, ch/hr	2.12	5.09	2.39	0	0.74	1.26
Critical avail. bulk density to sustain active crown fire, kg/m^3	0.85	0.37	0.43	1.11	0.53	0.48
Critical spread rate for sustained active crown fire, ch/hr	126.03	74.44	61.45	24.76	16.14	35.54
Critical open windspeed for active crown fire cessation*, mi/hr	2.5	2.4	2.5	2.5	2.5	2.5

*due to a too-high canopy base height

Table 15. Summary of simulation outputs using dry, windy conditions (90th percentile weather). This table is from the draft report, "Fire Behavior Changes in Shaded Fuel Break Treatments," being written by Esther Horschel, Randi Jandt, and Skip Thiesen.

Output	10X10P			Control		
	FWW	DBR	Tog	FWW	DBR	Tog
Type of fire, nominal	passive	passive	passive	passive	active	passive
Crown fraction burned, fraction	0.08	0.57	0.45	0.47	1.00	0.81
Spread rate, chains/hr	23.31	63.67	44.05	16.08	34.59	33.63
Heat per unit area, BTU/ft	1281	1763	1955	2219	6377	3162
Fireline intensity, BTU/ft	547	2058	1579	654	4044	1950
Flame length, feet	8.6	25	19.6	11.8	50.8	28
Effective midflame windspeed, mi/hr	6.8	11.2	9.3	4.3	6	6.2
Torching index, mi/hr	0.8	2.4	1.1	0	0	0.1
Crowning index, mi/hr	33.1	23.7	20.6	9.8	8.2	13.7
Surfacing index, mi/hr	33.1	23.7	20.6	9.8	8.2	13.7
Critical fireline intensity for crown fire initiation, BTU/ft	43	100	47	0	12	25
Critical flame length for crown fire initiation, feet	2.5	3.7	2.7	0	1.4	2
Critical spread rate for crown fire initiation, ch/hr	1.92	4.76	2.24	0	0.64	1.18
Critical avail. bulk density to sustain active crown fire, kg/m^3	0.53	0.19	0.28	0.65	0.26	0.30
Critical spread rate for sustained active crown fire, ch/hr	126.03	74.44	61.45	24.76	16.14	35.54
Critical open windspeed for active crown fire cessation*, mi/hr	2.5	2.5	2.5	2.5	2.5	2.5

*due to a too-high canopy base height

Hazard Fuels Treatment Costs

The cost of conducting hazard fuels reduction treatments was:

- FWW Site—$7650 ($1912.50/acre),
- Tog Site—$8389 ($2097.25), and
- DBR Site—$9280 ($2320/acre).

These costs reflect the cost of tree thinning and slash removal for four 1-acre treatment blocks at each demonstration site, but do not include the cost of slash burning.

Differences in treatment costs among sites were due to several factors, including differing pay scales of the work crews, differing levels of physical fitness among work crews, varying tree densities of treatment blocks, and varying accounting methods among the participating organizations (e.g. varying indirect rates).

Comparison of Planned Activities vs. Actual Accomplishments

Planned activities and deliverables from this project included:

- Creation of three hazard fuels treatment demonstration sites;
- Two annual progress reports (year 1 and 3);
- Presentation of project results at a national conference;
- Photographs of all treatment blocks, both pre-treatment and post-treatment, from fixed photo points;
- A final report in which the measured variables were to be used to determine fuel loading, to model fire behavior before and after the various fuels treatments, and to determination

the ecological effects of the fuels treatments. In addition, the cost of creating the shaded fuel breaks was to be determined;

- Writing a peer-reviewed article;
- Publication of a stereo photo series of the treatment and control blocks in collaborate with the USDA Forest Service, Pacific Northwest Research Station;
- Other information transfer activities including a visits to the demonstration sites with interested parties and presentation of results at other meetings for resource management professionals and other interested parties;

To date, the following activities have been accomplished:

- Creation of three hazard fuels treatment demonstration sites distributed near three different communities in the Tanana Valley in interior Alaska;
- Two poster presentations in lieu of two written annual reports;
- Project results were presented at an annual JFSP PI Workshop. The project budget only included funds for travel to one national meeting, and they were used to attend a mandatory PI workshop, in lieu of participation at another national conference;
- Pre-treatment and year 0 post-treatment photographs of all treatment blocks, and year 2 post-treatment photographs of the FWW and Tog treatment blocks. The year 2 post-treatment photographs of the DBR treatment blocks were not obtained during the summer of 2004 because of extreme smoke levels due to a record forest fire year. The photographs are currently being scanned onto a CD—a copy of the CD will be provided to the JFSP when it is available.
- This report is the planned final report in which the measured variables are used to determine fuel loading, to model fire behavior, and to determination the ecological effects of the fuels treatments. In addition, the cost of creating the shaded fuel breaks are presented. The modeling effort, however, is much less than originally planned. John McColgan, a fuels management specialist and co-PI on the initial proposal, was to perform the fire behavior modeling for this project. However, John transferred out of Alaska shortly after the proposal was submitted to the JFSP and we were unable to find a modeler to replace him. The modeling results reported here are those conducted by Esther Horschel, an undergraduate biology student at the University of Alaska Fairbanks, along with Randi Jandt and Skip Thiesen from the BLM Alaska Fire Service.
- Other information transfer activities have included:
    - Several field trips to the demonstration sites, including one for personnel from the Bureau of Indian Affairs and the National Interagency Fire Center,
    - Description of the project in the April 19, 2002 issue of BLM Snapshots, an annual report of BLM projects that support the National Fire Plan;
    - Description of the project in the June 2004 issue of the Council, a newspaper published by the Tanana Chiefs Conference and distributed to 40-43 (depending on the year) Native villages in interior Alaska;
    - Description of the project in “Summaries of Management and Research Activities Related to Alaska’s Boreal Forests,” which is a publication of the Alaska Northern Forest Cooperative (February 2004). The Alaska Northern Forest Cooperative is an organization that addresses forest management opportunities and challenges that are of mutual concern to forest managers, land owners, and scientists of Alaska’s boreal forests;

- Development of an informational brochure that will be distributed to users of the demonstration sites;
- Presentation of project results at the first annual Alaska Northern Forest Cooperative Symposium (September 2004) which was held in Fairbanks, Alaska;

A peer-reviewed publication is still an intended product of this project. However, it took four years to collect all of the data for a scheduled three year project. The manuscript, therefore, is still in progress. We anticipate that the manuscript will be ready for submission in the fall. Several of the co-authors are not currently available because of active participation in ongoing fire fighting efforts.

Publication of a stereo photo series of the treatment and control blocks in collaborate with the USDA Forest Service, Pacific Northwest Research Station is no longer an anticipated product. The PIs felt that the value of the stereo photos was limited. The funds budgeted for the publication of the photo series were used to purchase two data logging weather stations so that microclimate data could be obtained for a season at each demonstration site, as described in this report.

Several other projects were conducted, or are currently in progress, utilizing data collected for this project or by taking advantage of the existence of the hazard fuels treatment demonstration sites. Steve Thiesen (BLM Alaska Fire Service) modeled the effects of shaded fuel breaks on fire behavior using data obtained from the fuels treatment demonstration sites. His report, "An Analysis of Shaded Fuel Breaks on Fire Behavior," is BLM Alaska Fire Service Technical Fire Management Report 17, April 2003. A project on "Fuel and Duff Moisture Monitoring in 2002-2003," conducted by Randi Jandt (BLM Alaska Fire Service), Jennifer Allen (National Park Service), and Esther Horschel (Tetlin National Wildlife Refuge) utilized the FWW and DBR Sites (along with several others). A project on "Fire Behavior Changes in Shaded Fuel Break Treatments," being conducted by Esther Horschel, Randi Jandt, and Skip Thiesen, investigates the theoretical fire behavior using NEXUS at all three fuels treatment demonstration sites under dry, windy weather and average summer day conditions. This modeling effort is still in progress, but preliminary results have been discussed in this report. The NEXUS modeling effort is anticipated to be completed in September 2005. Finally, black spruce tree growth from all three demonstration sites is currently being analyzed by Dr. Glenn Juday from the University of Alaska Fairbanks as part of his climate change research program.

ACKNOWLEDGEMENTS

Funding for this project was provided by the Joint Fire Science Program, Tanana Chiefs Conference Forestry Program, BLM Alaska Fire Service, and the Alaska Department of Natural Resources Division of Forestry. Locations to install the fuels treatment demonstration sites were provided by the Toghotthele Corporation, US Army Alaska, and the Alaska Department of Natural Resources Division of Mining, Land, and Water. Many thanks to the tireless efforts of field assistants, especially Fabian Keirn and Jen Hrobak, in field data collection and summary. Esther Horschel, Steve Theisen and Skip Thiesen conducted analyses of fire behavior. Joe Scott (Systems for Environmental Management, Missoula) provided helpful advice on fire behavior inputs as the author of NEXUS 2.0.

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