1. INTRODUCTION

Fires on the Kenai National Wildlife Refuge are considered to be desirable for reduction of forest fuels, for raising the carrying capacity of habitats for wildlife such as moose by encouraging new growth of hardwoods and willows, and to maintain higher diversity by creating a variety of successional stages on the landscape. Olson, *et al.* (2003) measured the change in the litter and surface layers of the forest floor due to the Mystery Creek burn, finding that 1.4 to 2.2 inches of the total depth of litter and duff was consumed, surface material biomass was reduced 54 to 63%, and duff biomass was reduced by 20 to 26%, but only three plots were studied and loadings of woody fuels were not reported. Magness and Morton (2003) reported increases in the relative abundance of willows compared with other shrubs after the Mystery Creek controlled burn, but presented no estimates of changes in absolute abundance of browse species. The objective of this study was to determine the effects of the 2002 Mystery Creek controlled burn and the 1994 Windy Point Burn on forest fuel loads, hardwood and willow abundance, and species richness.

The National Park Service Fire Management Handbook protocols (USDI National Park Service, 2001) were developed as a monitoring tool to assess vegetation and fuel loading over time as they relate to fire. Sampling of the plots was designed to measure the effects of fire over time on floral and fuel characteristics. The results were intended to be used as tools for assessing the effects of past fires and the appropriateness of potential management actions.

A total of 71 FMH plots have been installed on the Kenai National Wildlife Refuge from 1994 to 2001. Their distribution and history is portrayed in Table 1. Fifty-five of these plots were established pre-fire in areas of anticipated prescribed fire and 20 plots were put in after wildfires. Detailed vegetation data and an inventory of fuels were taken at each sampling of these plots. These data were entered into the National Park Service's FMH.EXE software.

Table 1. Distribution and time line of Kenai NWR FMH plots

Legend Pre-fire Fire Post-fire		Burn Area						
		Pothole Lake	**Mystery Creek**	**Moose Pens**	**Windy Point**	**Hidden Creek**	**Lilly Lake**	**East Road**
Total Plots		**4**	**42**	**9**	**4**	**4**	**4**	**2**
Year	**1991**	**Pothole Lake Fire**						
	1994	**4 plots est.**	**24 plots est.**	**6 plots est.**	**Windy Point Fire**			
	1995		**12 plots est.**	**3 plots est.**				
	1996		**6 plots est.**			**Hidden Creek Fire**		
	1997				**4 plots est.**	**4 plots est.**		
	1998						**4 plots est.**	
	1999				**All plots sampled**			
	2001							**2 plots est.**
	2002		**Mystery Creek Prescribed Burn (12 of the 1994 plots burned)**					
	2004		**11 of the 12 burned plots were sampled**		**All plots sampled**			

2. STUDY AREAS

Two study areas were examined for this area, both on the Kenai National Wildife Refuge, Kenai Peninsula, Alaska. The Mystery Creek study area included the land between the intersections of the two forks of Mystery Creek Road with the gas pipe line in burn units V and VI. The entire area had been burned by the stand-replacing1947 fire. Continuous stands of 50-year-old black spruce (*Picea mariana*) dominated, with a few older quaking aspen (*Populus tremuloides*) towering over the low spruce canopy (Fig. 1.). White spruce (*Picea glauca*) and paper birch (*Betula papyrifera*) were also present within the study area. This study area was burned in the 2002 Mystery Creek prescribed fire.

A

B

Figure 1. Photographs taken at the same location on Mystery Creek plot MC6 before (A) and after (B) fire.

The Windy Point study area was located within the 2,800 acre 1994 Windy Point fire on the southern shore of Tustumena Lake. This area had been black spruce forest and mixed white spruce and paper birch forest before the fire. Afterward, fire-killed deadfall and thick, continuous stands of birch seedlings characterized most of the burned area (Fig. 2.).

A B

Figure 2. Photographs taken at the same location on Windy Point plot WPB2 in 1997 (A) and 2004 (B). The staff is 2m tall.

3. METHODS

3.1 Sampling Design

Mystery Creek. The 42 Mystery Creek plots were installed and surveyed pre-fire over a three-year period from 1994 to 1996 within and near burn units where prescribed burns were planned. Plot locations were selected randomly with a constraint that none were to be adjacent to roads. All of the plots were installed in black spruce forest. Twelve of the plots established in 1994 were burned in the 2002 Mystery Creek prescribed burn. In 2004, one of these plots was not found, but the remaining 11 were resurveyed post-fire.

Windy Point. Four representative sites were chosen within the 1994 Windy Point Burn. Two of these plots were placed in mixed White Spruce and Paper Birch forest; two were placed in Black Spruce forest. These plots were sampled post-fire in 1997, 1999, and 2004.

3.2 Plot Layout

The 50m by 20m Plots were laid out and staked according to the FMH handbook methods (USDI National Park Service, 2001). The origin (center) of each plot was marked with a 6ft. metal fence post. A 50m tape was strung at a random azimuth with the origin at 25m. Two additional 50m tapes were laid 10m to each side of the centerline and parallel to it. This 50m by 20m rectangle was made square by triangulation, using more tapes to make 3-4-5 right triangles. From 10m, 20m, 30m, and 40m along the 0P to 50P line, 50ft. fuel transects were measured out at random azimuths. The origin (O), corners (Q1, Q2, Q3, Q4), and the midpoints of the sides (0P, 50P, P1, P2) were staked with ½" diameter, 2ft. long rebar stakes. The ends of the fuel transects (1A, 1B, 2A, 2B,

3A, 3B, 4A, 4B) were staked with ¼" diameter, 1ft. long steel rods. All stakes were labeled with aluminum tags as in fig. 3. below.

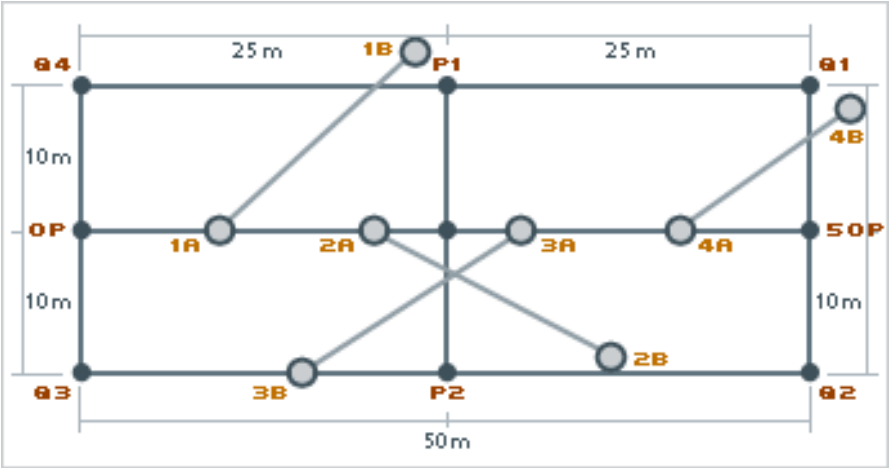

Figure 3. FMH Plot Layout

GPS location, descriptive directions, known fire history, and plot centerline azimuth were recorded. In the Mystery Creek area, tagged 6ft. metal fence posts were installed as reference stakes along access roads. The bearing and distance from the reference stake to the plot were recorded.

3.3 Fire Descriptions

Mystery Creek. This prescribed fire was started by USFWS personnel on June 22, 2002. Flaming fronts and smoldering fire burned much of unit V on June 22 and unit VI between July 1st and July 3rd. On the days while most of the burning was taking place, humidity ranged from 39 to 53%, average temperatures ranged from 64 to 71° F, and average wind speed ranged from 1 to 5 mph (Olson, *et al.*, 2003). When the area was surveyed in 2004, the area was charactereized by blackened, partially burned duff, little brush, and blackened, standing black spruce poles.

Windy Point. An escaped campfire started the Windy Point fire on August 30, 1994. The fire burned mostly slowly in the duff, eventually consuming 2,800 acres of black spruce forest and mixed white spruce and hardwood forest by the time the fire was considered to be out around September 30 (USDI, 1994). This late-season fire had a long residence time, usually completely consuming the litter and duff layers in much of the burn area. (Should ask Ed for a report on the 1995 fire plots as a reference.) When the plots were established, the area was characterized by standing snags and downed slash over mineral soil with high densities of new birch seedlings.

3.4 Sampling

Fuels. Fuels were inventoried along four 50ft. transects using the methods of Brown (1974) and Brown et al. (1982) as described in the handbook. From the A stake of each transect (e.g. 1A, 2A), a 50ft long, 1cm wide tape was stretched to the corresponding B stake (e.g. 1B, 2B) so that 0ft. was at A and 50ft was at B. Table 2. lists the standard transect lengths for which each size class of woody fuel was tallied on most Mystery Creek plots, but sometimes different transect lengths were used. The transect length for 0-1/4" woody fuels was reduced to 6ft. on the Windy Point Burn plots. Along each transect, every particle of downed woody material intercepted along the right side of the tape (the right side proceeding from 0ft. to 50ft.) from the ground up to 6ft. above the ground was tallied for each size class. A particle or branch was tallied on the basis of whether its imaginary longitudinal, possibly curved centerline crosses the tape. Intercepts of parts of standing trees were ignored. Cones, bark, and leaves were not counted. When multiple branches or twigs of a limb were intercepted, each intercept was tallied. Particles buried more than halfway into the duff at the point of intersection were ignored. Diameters of logs over 3" and whether or not they were sound or rotten were recorded.

Table 2. Standard Transect Lengths for Woody Fuel Size Classes at Mystery Creek

Fuel Diameter	Transect Length
0 – ¼" (1hr.)	12ft. (0ft. to 12ft.)
¼" – 1" (10hr.)	12ft. (0ft. to 12ft.)
1" – 3" (100hr.)	12ft. (0ft. to 12ft.)
3" + (100hr.)	50ft. (0ft. to 50ft.)

Litter and duff depth measurements were taken using a trowel and ruler graduated in 1/10in. increments at 1ft., 5ft., 10ft., 15ft., 20ft., 25ft., 30ft., 35ft., 40ft., and 45ft. along each 50ft. transect. Litter was defined as all non-woody plant material on the forest floor excluding living vascular plants. Living and dead mosses and lichens were included in this layer. The duff layer was defined as organic matter at various stages of decomposition between the litter layer and mineral soil.

Vegetation Sampling. Seedling trees, defined by a DBH < 2.5cm, within a usually 10m by 5m rectangle (described by the points O, P1, 30m on the Q4-Q1 tape, and 30m on the 0P-50P tape) were tallied by species. When seedling trees were dense (≥ 50 individuals per $50m^2$), the sampling area was reduced to a rectangle 2.5m by 5m (described by the points O, 5m on the P1-P2 tape, and 27.5m on the 0P-50P tape). Because of extremely high seedling densities, $1m^2$ and $2m^2$ plots were used on some of the Windy Point Burn plots.

Two 1m by 50m shrub density transects were usually placed along the outside of the plot along the outside of the Q4-Q1 tape and the Q3-Q2 tape. The number of shrubs within the transects was tallied by species. Only shrubs with more than half of their bases within the transect were counted. Lingonberry (*Vaccinium vitis-idaeus*) was ignored because individuals were difficult to define.

The densities of herbs and ground cover were estimated using a 50m point-intercept transect and ten $1m^2$ quadrats. The 50m transect stretched from 0m at the Q4 stake to 50m at the Q1 stake. Beginning at 30cm (not 0cm) and at 30cm intervals thereafter, a 6mm by 25mm by 1m meter stick was held plumb (vertical), touching the ground next to the tape (the side to the outside of the plot, the left side proceeding from Q4 to Q1). At each point, every species on the ground within a circular area roughly 4cm in diameter was recorded as well as every plant species that touched the meter stick above

the ground. Each species that touched the meter stick was scored exactly once, even if multiple individuals or multiple parts of one individual touched the meter stick more than once. Dead plant parts (e.g., dead grass blades) were not counted. Foliage or branches intercepted from trees over 2m tall were not counted.

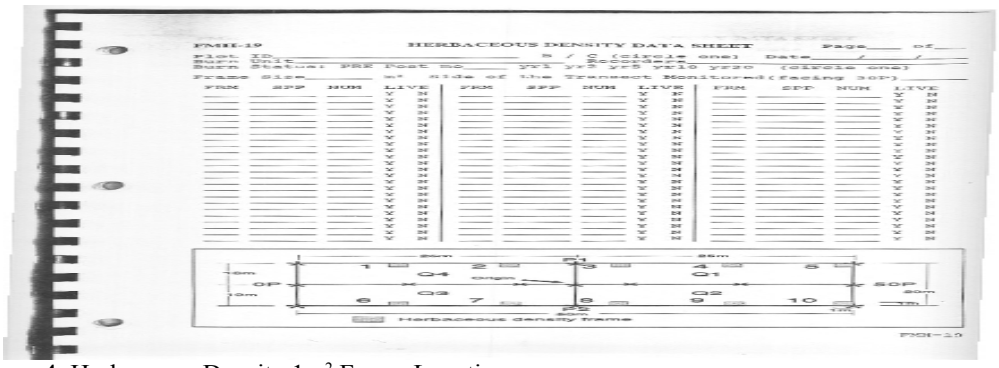

Figure 4. Herbaceous Density 1m^2 Frame Locations

Herbaceous density was also estimated by cover estimates within ten 1m^2 quadrats at 9-10m, 19-20m, 29m-30m, 39m-40m, and 49-50m along the inside of the Q4-Q1 and Q3-Q2 tapes (fig. 4.). At each 1m^2 area, a 1m^2 frame made of PVC tubing was set on the ground and ocular estimates were made of the percent cover of every species and substrate within the square.

3.5 Analysis Methods

Fuels. Fuel loads were calculated for each plot and sampling date using the methods of Brown (1974) and USDI National Park Service (2001). These are the same formulas used by the FMH.EXE program. For each fuel transect, *slopecorr*, the slope correction factor, was calculated using the following formula.

$$slopecorr_t = \sqrt{1 + [(slope_t)(0.01)]^2}$$

where t = index for transects, and *slope* = % slope of the transect. For woody fuels except 1,000hr. fuels, *obscorr*, fuel particle observations corrected for slope, was calculated for each plot using the following formula.

$$obscorr = \sum_{t=1}^{n} [(obs_t)(slopecorr_t)]$$

where n = number of transects, t = index for transects, *obs* = fuel particle count for the transect, and *slopecorr* = slope correction factor. For woody fuels except 1,000hr. fuels, *ta*, tons per acre, was computed for each plot using the following formula.

$$ta = \frac{11.64(obscorr)(w_d)(w_s)(w_a)}{tranlength}$$

where 11.64 is a constant, *obscorr* = fuel particle observations corrected for slope, w_d = weighted average squared diameter, w_s = weighted average specific gravity, w_a = weighted average angle to horizontanl, and *tranlength* = sum of the lengths of all transects (ft.). For 1,000hr. fuels, *obscorr*, fuel particle observations corrected for slope, was calculated for each plot using the following formula.

$$obscorr = \sum_{t=1}^{n}\left[\left(\sum_{i=1}^{obs} diameter_i^{\,2}\right)\left(slopecorr_t\right)\right]$$

where n = number of transects, t = index for transects, *obs* = number of observations, i = index of observations, *diameter* = particle diameter (in.), and *slopcorr* = slope correction factor. Tons per acre, *ta*, of 1,000hr. fuels for each plot was computed with the following equation.

$$ta = \frac{11.64(obscorr)(w_s)(w_a)}{tranlength}$$

where 11.64 is a constant, *obscorr* = fuel particle observations corrected for slope, w_s = weighted average specific gravity, w_a = weighted average angle to horizontanl, and *tranlength* = sum of the lengths of all transects (ft.). Tons per acre of litter and duff, *ta*, was calculated for each plot using the following formula.

$$ta = 1.815(B)(d)$$

where 1.815 is a constant, B = bulk density (lb./ft.^{3}), and d = average duff/litter depth (in.) over all transects on a plot.

Fuel constants were extracted from the FMH.EXE software and from Brown (1974). Table 3. lists the fuel constants used.

Table 3. Fuel Constants

		Fuel Type						
		1hr.	10hr.	100hr.	1000hr. sound	1000hr. rotten	litter	duff
Fuel Constants	w_d	0.006	0.24	2.19	-	-	-	-
	w_s	0.67	0.65	0.49	0.4	0.3	-	-
	w_a	1.13	1.13	1.13	1	1	-	-
	B	-	-	-	-	-	1.1	7.2

Browse Species. Since the seedling tree plot size varied among some of the FMH plots and sometimes between different years on the same FMH plot, the tallies of seedlings of all tree species on the seedling plots were converted to densities. Seedling height class data were sometimes not collected before 2004 and trees were occasionally ignored on the 50m transects, so tree cover estimates and height classes were not analyzed. Cover estimates of willows from the 1m^2 quadrat and 50m transect methods were averaged for each plot. Tallies of willows on the shrub transects were converted to densities.

Species Richness. The species richness of vascular plants was measured on each plot by counting the total number of vascular plant species observed on each plot by the seedling tree, belt transect for brush density, $1m^2$ herbaceous density quadrats, and 50m transect methods and the total number of species encountered by all of these methods. Trees encountered on the $1m^2$ herbaceous density quadrats and on the 50m transect were excluded because they had been sampled or entered into the database inconsistently for these methods. (Later versions of the FMH.EXE program disallowed entry of tree species into the $1m^2$ quadrat data.) Because the level of plant identifications became more specific over time, some groups, especially the lichens and bryophytes, were not considered in this analysis. In cases where identification became much more specific (e.g. grasses, which were simply identified as grasses before 2004 and identified to the species level in 2004), only the broader categories were considered so that the later estimates of richness were not artificially inflated relative to the earlier estimates. The list of taxa considered in the analysis is included as Appendix B.

4. RESULTS

4.1 Fuels

Mystery Creek. Within the Mystery Creek controlled burn, the fire consumed some of most categories of fuels, leaving charred duff and mostly standing burned, often limbless black spruce poles. The litter layer, predominantly living mosses and lichens before the fire, was mostly burned off and was replaced by a thin layer of fallen spruce needles. The fire usually burned the upper part of the duff, leaving a charred, shallower duff layer. Most categories of fuels and the total amount of fuels on the Mystery Creek plots decreased (fig. 5.), but sound woody stems greater than three inches in diameter and fine fuels increased. Pre-fire total fuel loading ranged from 34 to 72 tons/acre. The average total fuel loading on the Mystery Creek plots decreased by 28% from 48.1 to 35.1 tons/acre. Post-fire total fuel loads ranged from 19 to 61 tons/acre. Duff was the largest component, accounting for 79% of fuels before the fire and 90% of fuels after the fire. Decaying logs were the most drastically reduced, decreasing by 86% from 4.20 tons/acre, 8.8% of total fuels to 0.584 tons/acre, 1.7% of total fuels. Sound logs increased by 81%. Fine fuels increased by 270%, but even after the fire they comprised a small portion (0.3%) of total fuels. The mean depth of the organic layer dropped by 33% from 4.24 inches to 2.84 inches and its biomass was reduced by 21% from 40.7 to 32.2 tons/acre (fig. 7.).

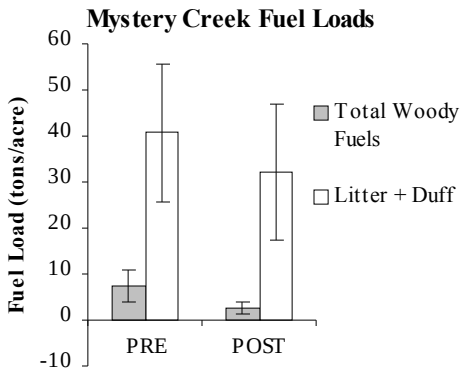

Figure 5. Pre- and post-burn dead and downed fuel loads (tons/acre) at Mystery Creek.

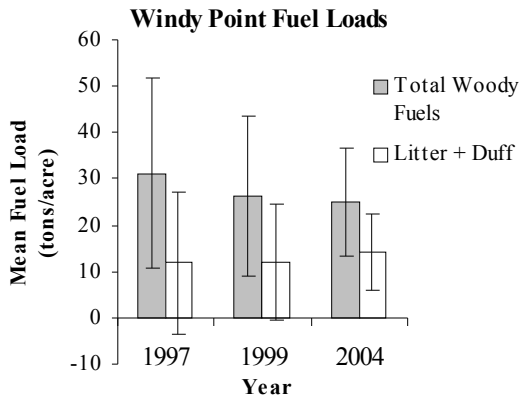

Figure 6. Windy Point Fuel Loads (tons/acre) from 1999 to 2004.

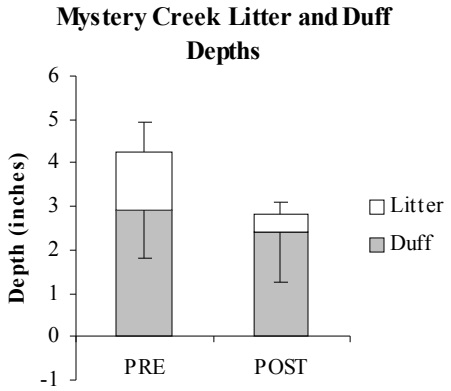

Figure 7. Pre- and post-burn average litter and duff depths (inches) at Mystery Creek.

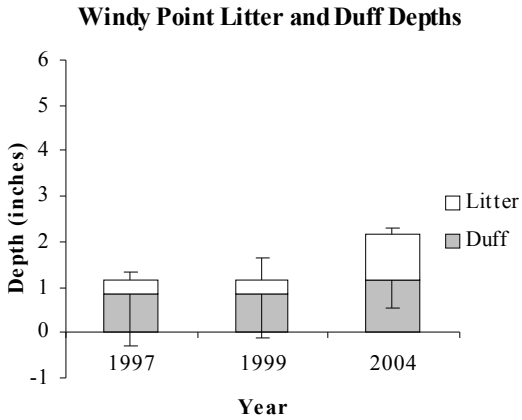

Figure 8. Average litter and duff depths (inches) at Windy Point.

Windy Point. On the Windy Point plots, nearly all of the woody fuels had fallen during or soon after the fire so that little new woody material was added over the study period and little change was observed. The thin, often absent soil organic layer was colonized by mosses after the fire. On two of the plots, the organic layer received substantial amounts of leaf litter from growing paper birch seedlings.

All classes of woody fuels decreased over the study period (fig. 6.). The total mass of woody fuels decreased by 20% from 31.2 to 25.1 tons/acre between 1997 and 2004. Total fuel loads ranged from 3.8 to 20.0 tons/acre in 1997, from 2.8 to 16.2 tons/acre in 1999, and from 4.2 to 12.1 tons/acre in 2004. The mean depth of the organic layer grew by 67% from 1.16 to 1.94 in. and its biomass increased by 16% from 11.9 to 14.1 tons/acre between 1997 and 2004 (fig. 8.).

4.2 Browse Species

Mystery Creek. Most measures of browse species on the Mystery Creek plots were greater after the fire than beforehand. The density of birch seedlings increased from 0.11 to 0.23 individuals/m^2 and aspen seedling density increased from 0.0073 to 0.064 individuals/m^2 (fig. 9.). No cottonwoods were encountered. The density of willows

decreased from 0.047 to 0.019 individuals/m^2, but cover estimates of willows conflicted (fig. 11.). The 50m transect showed an increase from 0.055 to 0.099 % cover while the 1m quadrats showed a decrease from 0.50 to 0.064 % cover.

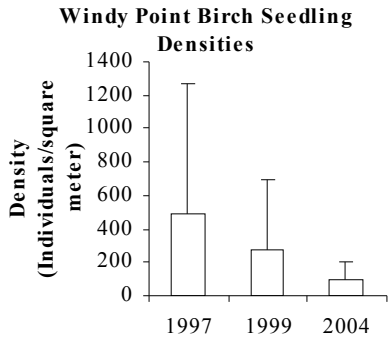

Figure 9. Average seedling density of paper birch (individuals/m^2) at Windy Point from 1997 to 2004.

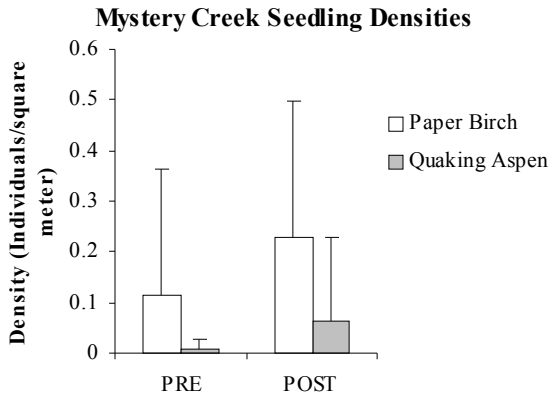

Figure 10. Pre- and post-fire seedling densities (individuals/m^2) at Mystery Creek.

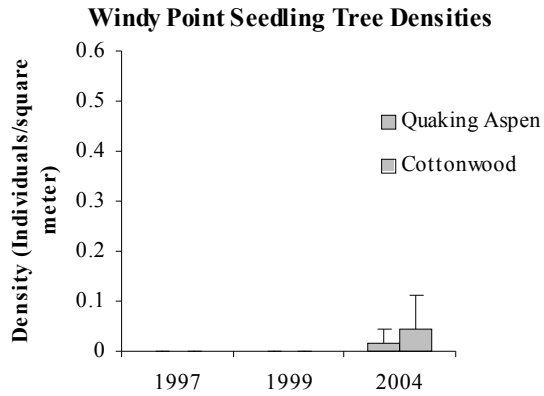

Figure 11. Seedling densities (individuals/m^2) at Windy Point from 1997 to 2004.

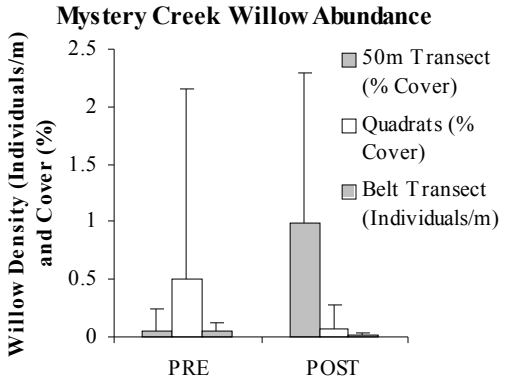

Figure 12. Pre- and post-fire willow abundance (individuals/m^2 and % cover) at Mystery Creek.

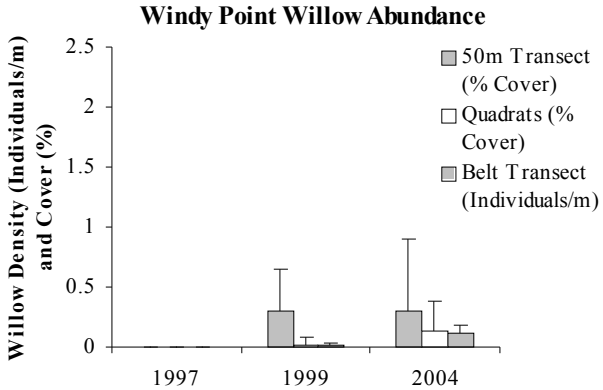

Figure 13. Willow abundance (individuals/m^2 and % cover) at Windy Point from 1997 to 2004.

Windy Point. Recruitment of birch seedlings at Windy Point was high (494 indivuals/m^2) in 1997, dwindling sharply to densities of 90 individuals/m^2 by 2004, but

birch seedlings still dominated the plots (fig. 9.). The density of birch seedlings varied widely among the plots. In 1997, one plot had a density of birches of 1630 individuals/m^2, while two other plots had birch densities close to 1 individual/m^2. A handful of cottonwoods (0.045 individuals/m^2) and quaking aspens (0.015 individuals/m^2) appeared between 1999 and 2004 (fig. 11.). A few willows took hold on the plot between 1997 and 1999, climbing by 2004 to 0.12 individuals/m^2 and about 0.2% of cover, still a small component of available browse (fig. 13.).

4.3 Species Richness

Mystery Creek. The average number of species encountered at each plot in the Mystery Creek study area increased from 9.73 before the fire to 11.55 afterward (fig. 14.). The 50m line-intercept, herbaceous density quadrats, and seedling tree methods all showed increases in richness. A decrease was observed only on the belt transect for brush density, where the mean number of shrub species encountered decreased from 3.45 to 3.09.

Windy Point. Vascular plant species richness on the Windy Point plots increased for all methods between 1997 and 2004, but most of the increase happened between 1999 and 2004 (fig. 15.). The average number of species observed per plot increased from 8.00 in 1997 to 8.50 in 1999 and 10.00 in 2004.

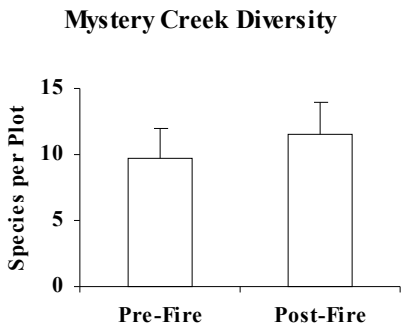

Figure 14. Mystery Creek pre- and post-burn diversity (species per plot)

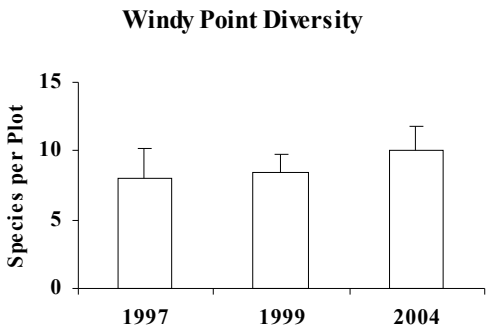

Figure 15. Windy Point Diversity (species per plot) from 1997 to 2004.

5. DISCUSSION

5.1 Fuels

Mystery Creek. Consumption by fire caused the reduction of most fuel categories. Black spruce deadfall accounted for the increases in sound, large-diameter fuels and fine fuels. Olson, et al. (2003) reported slightly, but consistently, deeper duff depths than what is reported here. This was more likely a result of sampling error than methodological differences because both methods should have produced accurate duff depths. Their reporting of litter and duff biomass was also higher than what is reported here, but most of the difference is attributable to their deeper depths reported.

Windy Point. On the Windy Point plots, most of the deadfall occurred shortly after the fire, so there was not an increase in the amounts of woody fuels. Their gradual decrease may have been due to decomposition. Growth of mosses and possibly increasing production of fallen leaves caused the increasing litter and duff depths.

The strong differences in the composition of fuels between the Mystery Creek and Windy Point burn areas were caused by differences in the forest types before the fire and differences in fire behavior. Large amounts of deadfall from the white spruce and paper birch forests in the Windy Point area accounted for their much greater loads of woody fuels than the Mystery Creek forest of small black spruce trees. Although no litter and duff measurements from before fire exist from the Windy Point plots, it was clear that the fire burned almost all of the litter and duff in contrast to the Mystery Creek area, where most of the duff remained after the fire and duff continued to comprise most of the total fuel load.

5.2 Browse Species

Mystery Creek. The fire did not greatly change the amount of available browse. The increases in hardwood seedling tree densities were due to new recruitment after the fire, but the actual amount of browse available may not have increased since the new seedlings were mostly very small individuals. The amount of willow browse available may have increased slightly, but the fire did not lead to a dramatic increase and they remained relatively scarce. The single willow individual in fig. 1. may typify the willows on the Mystery Creek plots, recovering to almost the same size by 2004 as it had been in 1994.

Windy Point. Competition among birch seedlings growing at extremely high densities and possibly foraging by herbivores lead to a sharp decline in the numbers of birch individuals between 1997 and 2004. Their biomass and amount of browse available have increased dramatically as these seedlings have grown (fig. 2.), but since height class data were not collected before 2004, this could not be demonstrated numerically. Quaking aspen and cottonwoods were slower to colonize the burn and appeared in much lower densities than birch, possibly due to fewer nearby seed sources.

5.3 Species Richness

Mystery Creek. Before the fire, most of the Mystery Creek plots were almost uniformly blanketed by a bryophyte and lichen carpet with a think dwarf shrub layer of mostly lingonberry. Some of the plots were not burned completely so that, by the time the plots were resurveyed two years after the fire, they were comprised of unburned patches and areas with various degrees of burn severity, producing a mosaic of assemblages ranging from a species composition identical to its pre-burn state to a set of post-fire colonists such as fireweed and rock harlequin. Even when plots were completely burned, for most vascular plant species at least some individuals survived. Retention of survivors and the appearance of new colonists lead to the increased vascular plant diversity.

Windy Point. The gradual increase in vascular plant species richness between 1997 and 1999 and the faster increase between 1999 and 2004 were caused by new colonists appearing on the plots. Quaking aspens, cottonwoods, and most of the willows appeared only after 1999, accounting for most of the stronger increase in diversity between 1999 and 2004.

5.4 Methodological Problems

Because the sample sizes were small (n=11 for Mystery Creek and n=4 for Windy Point), the standard deviations of all the estimates were high. This was true even though the measurements made on each plot were presumably very accurate because of the

extensive sampling on each plot. The selection of representative instead of random plot locations, differences in the way data was recorded, and variation in plot sizes also presumably contributed to higher error and made the results less applicable to the larger areas.

Because no data were taken before the Windy Point fire, no quantitative inferences could be made about the effects of the fire; conclusions could only be made about succession afterward. Likewise, the effects of fire at Mystery Creek were not completely separable from other changes over time because no control plots were sampled after the fire.

Inconsistencies in the amount and quality of data collected lead to some methods being excluded from analysis. Cover estimates of birch seedlings at Windy Point could not be compared because they were sometimes ignored on the 50m transects. The level of plant identifications became more specific by 2004, which necessitated the omission of the later, more specific identifications from analysis so that they could be compared with the earlier data. These omissions rendered the richness numbers to be invalid as measures of absolute species richness and of value only for relative comparisons among the study areas and sampling years.

Some of the differences between litter and duff biomass presented here and in Olson *et al.*, (2003) were due to the use of different organic matter densities in the calculation of biomass from depths. We used densities for black spruce and white spruce litter and duff from the FMH.EXE software, which probably were not as representative for the study areas as Olson, *et al.*'s constants. They determined the densities of different types of duff and litter by sampling material from the study area and measuring mass and volume.

6. Recommendations

Plot sizes and transect lengths should be consistent so that the FMH.EXE software can be used for analysis, so that unnecessary variation is removed, and so that bias is diminished. Plant identifications to the species level should be made whenever possible. If a plant cannot be identified in the field, it should be collected and preserved for later determination. Duff and litter should be sampled from the plots under study so that their densities can be determined empirically instead of from sources that may not apply well to the area under investigation.

Ideally, several times as many plots in a study area should be sampled so that the standard error can be reduced and a statistical analysis can be performed. Plots should be selected randomly to reduce bias and so that valid inferences can be made about the broader areas.

Since these plots have been sampled over the last ten years, producing a substantial amount of data, sampling on them should continue at the intervals prescribed by the Fire Monitoring Handbook so that long-term effects of fire are measured. If a study with similar goals of monitoring fuel loading and vegetation within areas of prescribed or natural fires were to be designed independent of the FMH protocols, the number of plots should be multiplied, the amount of sampling on each plot should be reduced to make this feasible, and the plots should be distributed broadly in a randomized way within the area of interest. The plots should be sampled at predetermined intervals whether or not wildfires have not occurred so that pre-burn data will exist in areas where fire is not predictable and so that controls will automatically be sampled.

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Appendix A. Means and Standard Errors of Estimates by Study Area and Date

		Mystery creek				Windy point					
		Pre-fire		Post-fire		1997		1999		2004	
		mean	se	mean	se	mean	se	mean	se	mean	se
Fuel Load (tons/acre)	1hr.	0.128	0.089	0.474	0.394	0.362	0.179	0.282	0.244	0.252	0.207
	10hr.	0.741	0.616	0.271	0.145	2.01	0.64	1.57	0.27	1.05	0.40
	100hr.	1.82	1.96	0.722	0.462	7.13	2.57	5.29	1.61	4.19	2.07
	1000hr. Sound	0.460	0.571	0.832	1.10	20.8	19.9	19.3	17.7	18.9	12.4
	1000hr. Rotten	4.20	2.30	0.584	0.484	0.861	1.40	0.00	0.00	0.679	1.02
	1000hr. Total	4.66	2.34	1.42	1.18	21.7	20.8	19.3	17.7	19.6	13.0
	All Woody Fuels	7.36	3.45	2.88	1.37	31.2	20.5	26.4	17.3	25.1	11.6
	Litter	2.65	1.33	0.888	0.525	0.570	0.388	0.595	0.922	2.03	0.21
	Duff	38.1	14.4	31.3	14.9	11.4	15.2	11.3	12.6	12.1	8.23
	Litter + Duff	40.7	15.1	32.2	15.0	11.9	15.4	11.9	12.5	14.1	8.2
	Total Fuels	48.1	13.2	35.1	14.2	43.1	33.7	38.3	27.4	39.2	14.8
Depth of Organic Layer (in.)	Litter	1.33	0.67	0.445	0.263	0.286	0.194	0.298	0.462	1.02	0.11
	Duff	2.92	1.10	2.39	1.14	0.869	1.161	0.862	0.962	0.924	0.629
	Litter + Duff	4.24	1.56	2.84	1.21	1.16	1.29	1.16	1.03	1.94	0.61
Seedling Densities (#/m^2)	Paper Birch	0.11	0.25	0.23	0.27	494	773	278	421	90	110
	Cottonwood	0	0	0.064	0.167	0	0	0	0	0.045	0.066
	Quaking Aspen	0.0073	0.0185	0.23	0.27	0	0	0	0	0.015	0.030
Willow Abundance	50m Transect (% Cover)	0.055	0.18	0.99	1.30	0	0	0.30	0.35	0.30	0.60
	1m^2 Quadrats (% Cover)	0.50	1.66	0.064	0.211	0	0	0.025	0.050	0.13	0.25
	Belt Transect (#/m^2)	0.047	0.071	0.019	0.023	0	0	0.013	0.019	0.12	0.064
Diversity (Species per Plot)	Seedling Trees	1.64	0.67	1.91	1.04	2	0	2	0	2.75	0.96
	50m Transect	6.09	1.92	7.45	2.58	4.25	1.89	4.25	1.5	5.25	1.71
	1m^2 Quadrats	5.64	1.80	7.73	2.00	4.25	1.26	4.75	0.96	5.25	1.26
	Belt Transect	3.45	1.13	3.09	1.51	1.00	0.82	0.75	0.96	2.00	0.82
	All Methods	9.73	2.24	11.55	2.46	8.00	2.16	8.50	1.29	10.0	1.8

Appendix B. Species Considered in Analysis of Diversity

Scientific Name	Common Name	Species Code
Achillea borealis	Yarrow	ACBO1
Actaea rubra	Baneberry	ACRU1
Arctostaphylos uva-ursi	Bearberry	ARUV1
Betula nana	Dwarf Birch	BENA1
Betula papyrifera	Paper Birch	BEPA1
Corydalis sempervirens	Rock Harlequin	COSE1
Echinopanax horridum	Devil's Club	ECHO1
Empetrum nigrum	Crowberry	EMNI1
Epilobium angustifolia	Fireweed	EPAN1
Epilobium latifolia	River Beauty	EPLA1
Equisetum arvens	Field Horsetail	EQAR1
Equisetum pratense	Meadow Horsetail	EQPR1
Equisetum scirpoides	Dwarf Scouringrush	EQSC1
Equisetum sylvaticum	Woodland Horsetail	EQSY1
Equisetum spp	Horsetail species	EQUI1
Galium boreale	Northern Bedstraw	GABO1
Galium triflorum	Sweet-Scented Bedstraw	GATR1
Geranium erianthum	Wild Geranium	GEER1
Geocaulon lividum	False toadflax	GELI1
Poaceae	Total Grasses	GRAS1
Gymnocarpium dryopteris	Oak Fern	GYDR1
Ledum palustre	Labrador tea	LEPA1
Linnaea borealis	Twin flowser	LIBO1
Listera cordata	Heartleaf twayblade	LICO1
Lupinus nootkensis	Nootka lupine	LUNO1
Lycopodium annotinum	Stiff clubmoss	LYAN1
Lycopodium clavatum	Running clubmoss	LYCL1
Lycopodium complanatum	Creeping jenny	LYCO2
Moehringia lateriflora	Bluntleaf sandwort	MOLA1
Oxycoccus microcarpus	Small cranberry	OXMI1
Picea Glauca	White spruce	PIGL1
Picea Mariana	Black spruce	PIMA1
Picea spp.	Spruce species	PISP1
Polemonium acutiflorum	Tall Jacob's ladder	POAC1
Populus balsamifera	Cottonwood	POBA1
Populus tremuloides	Quaking aspen	POTR1
Pyrola asarifolia	Liverleaf wintergreen	PYAS1
Pyrola grandiflora	Large-flowered wintergreen	PYGR1
Pyrola secunda	Sidebells wintergreen	PYSE1

Scientific Name	Common Name	Species Code
Ribes spp.	Currant species	RIBE1
Ribes glandulosum	Skunk currant	RIGL1
Ribes hudsonianum	Northern black currant	RIHU1
Rosa acicularis	Prickly Rose	ROAC1
Rubus spp.	Bramble species	RUBU1
Rubus chamaemorus	Cloudberry	RUCH1
Rubus pedatus	Trailing Raspberry	RUPE1
Sambucus racemosa	Elderberry	SARA1
Salix spp	Total willows	SASP1
Sorbus sitchensis	Sitka Mountain Ash	SOSI1
Spiraea beauverdiana	Alaska Spirea	SPBE1
Streptopus amplexifolius	Claspleaf twistedstalk	STAM1
Trientalis europaea	Starflower	TREU1
Vaccinium spp.	*Vaccinium* species (usually *V. uligonusum*)	VACC1
Vaccinium uliginosum	Bog blueberry	VAUL1
Vaccinium vitis-idaea	Lingonberry	VAVI1
Viburnum edule	Squashberry	VIED1