Effects of the Pagami Creek Wildfire on Wood Inputs in Lake Isabella in Northern Minnesota

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COMPLETION REPORT SUBMITTED TO USDA FOREST SERVICE

Spring 2014

Introduction

Wood from trees along lake shorelines is important for the survival of many aquatic species. This wood provides an essential habitat for fish and small aquatic organisms and offers protection from predators (Marburg et al. 2006). It also serves as a medium on which algae and insect larvae can thrive. Terrestrial species that rely upon these aquatic organisms as part of their food web are secondarily affected, further necessitating the presence of wood in lakes (Gessner et al. 2004). A study conducted by Smokorowski et al. (2000) on three different lakes in Ontario, Canada showed that invertebrate and periphyton biomass was significantly greater on wood than open sediment. In addition, fish feed more efficiently and frequently in areas with large amounts of coarse wood, possibly due to increased food availability (Smokorowski et al. 2000).

There are several factors that affect the amount of wood present in lakes, including human development, forest harvest, and natural occurrences (Marburg et al. 2006). Regarding development, lakeshores are often cleared of trees to make way for homes and cabins. For this reason, in northern Wisconsin, USA, developed lakeshores have lower wood density overall than undeveloped lakeshores (Marburg et al. 2006). Wood density in lakes generally correlates with forest density (Schindler and Francis 2006), so harvest practices that decrease forest density may decrease the amount of wood present in lakes. Natural occurrences can also affect the amount of wood in lakes. For example, Darwin et al. (2004) determined that ice storms increased the amounts of downed logs and branches in forests due to breakage under the weight of the ice.

Another natural disturbance that may affect the amount of wood present in inland waters is wildfire. In streams, wildfire can affect the structural complexity of wood in the midterm and, in the long-term, fire may reduce the amount of wood as well (Vaz et al. 2011). In the Euro-

Mediterranean, less than a decade after wildfire, burned wood tended to be more homogeneous with fewer branches, providing less habitat and protection for aquatic species (Vaz et al. 2011). Furthermore, wood that has been burned in a fire is more likely to break down and therefore have less longevity than unburned wood (Vaz et al. 2011). Further study is needed to determine whether similar wood dynamics occur in lakes.

An opportunity to study wildfire-wood dynamics in a lake arose with the Pagami Creek Fire in northern Minnesota, USA. The Pagami Creek Fire originated due to a lightning strike 20.9 kilometers east of Ely, Minnesota (USDA Forest Service 2012). The fire was first detected on August 18th, 2011 but did not reach historical proportions until September of that year (USDA Forest Service 2012). A combination of low humidity, extremely dry conditions, and strong winds led to unprecedented propagation of the fire; by the time it ended in November 2011, it had affected 93,000 acres (USDA Forest Service 2012). The current study sought to determine the effects of the Pagami Creek Fire on wood levels and composition in Lake Isabella, which was located near the center of the fire.

Methods

Wood was sampled from five lakes in northern Minnesota, USA: Isabella, Wilson, Silver Island, Windy, and Whitefish (Figures 1-2). Lakes were within the Superior National Forest where anthropogenic development is generally limited to sparse roads and forest management. Lakes were chosen based on proximity to the Pagami Creek fire and similarities in size and shoreline. Moreover, because tree falling may depend on wind direction (Gennaretti et al. 2013), we attempted to select shorelines aligned and not aligned with the locally dominant wind direction. The area has a vegetation profile that is transitional between temperate (northern mixed) and boreal forest where average temperatures for summer and winter are 16.67 C and -

11.11 C, respectively (MN DNR 2013). Riparian vegetation was dominated by jack pine (*Pinus banksiana*) and paper birch (*Betula papyrifera*), most of which were 10-20 cm DBH.

Figure 1. Lake Isabella is shown, with sampled shorelines highlighted. The northwest shorelines were burned whereas the southeast shoreline was not.

Figure 2. Control lakes are shown, with sampled shorelines highlighted. No shorelines were burned.

Within each section of shoreline sampled, all wood pieces were assessed that met the following criteria. First, wood to be sampled had to have one end resting on the bank, and the other end submerged in the water (i.e., ramping pieces). Second, the submerged end had to have the entire diameter under water. Third, the wood had to include at least one meter of length above or in the water that was at least 10 cm diameter. Physical measurements were taken for each piece of wood: total length, diameters at the center and both ends, lateral distance from the shoreline to the center of the piece, elevation of the center above or below the water surface, horizontal angle relative to the water surface, orientation in degrees, percent of the wood surface that was burned (i.e., charred), percent covered with bark, whether the piece was bent or straight, if part of the piece was buried or rooted in the bank, if there was a rootwad present, and if the wood was firm. Complexity was measured for each piece of wood, where pieces with more branches and twigs had a higher complexity as described by Newbrey et al. (2005). Some measurements were later simplified in classes for the analysis: elevation (<-30, -30-30, >30), angle (<10, 10-20, >20), orientation (<20, 120-240, >240), bark/burned % (<33, 33-66, >66), buried (yes, no), and complexity (<20, ≥20). We geo-referenced the position of each piece of wood along the lake shoreline with a global positioning system (GPS); a digital image per piece was also recorded.

Using Google Earth®, each sampled lake shoreline was digitized at an eye altitude of 3,000 ft and the coordinates of wood recorded with GPS were overlaid. We determined the length of shorelines sampled and, at each piece of wood, we recorded the aspect of the shoreline. Then, the number of pieces of wood per meter of shoreline for each lake was calculated.

Differences in diameter and length between burned/unburned wood pieces in lakes were investigated by two randomization t-tests (with 10000 randomizations). To compare proportions of burned/unburned wood pieces according to each categorical variable, a frequency analysis was conducted comparing patterns in counts of burned and unburned pieces across the classes of each variable in contingency tables. We then explored the pattern of standardized residuals to reveal which cross classifications deviated the most and in what direction from the expected values, thus contributing the most to the lack of independence between burned status and the class of the variable. A one-sample t-test was used to test if wood per meter differed significantly between Lake Isabella's burned shoreline and the 12 unburned shorelines. In addition, a two-sample t-test was used for all data from unburned control lakes to determine whether wood per meter differed between the upwind shorelines (i.e., those nearer the northwest end of the lakes) and the downwind shorelines (i.e., those nearer the southeast). All analyses were made using the statistical software R (available online at http://www.r-project.org/).

Results

A total of 122 wood pieces were tallied, with counts distributed as shown in Table 1 by lake and burn status. The burned pieces averaged (mean ± SD) a length of 11.2 (±4.2) meters, a diameter of 16.0 (±4.8) cm, were 3.3 (±2.6) meters from shore, had a complexity of 74.1 (±57.4), and 58.7% had a rootwad, 15.2% were buried, 95.7% were firm, and 2.2% were bent (Table 2). The unburned pieces averaged a length of 7.0 (±3.3) meters, a diameter of 15.9 (±9.9) cm, were 2.4 (±1.4) meters from shore, had a complexity of 21.2 (±39.1), and 38.2% had a rootwad, 25% were buried, 89.5%were firm, and 7.9% were bent (Table 2).

Table 1. Total wood numbers for each of the five lakes with burned and unburned numbers shown.

Lake	Burn status		*Total*
	Burned	Unburned	
Isabella	46	11	*57*
Silver Island	0	19	*19*
Whitefish	0	8	*8*
Wilson	0	11	*11*
Windy	0	27	*27*
Total	*46*	*76*	*122*

Table 2. Percentage of pieces or averages (with standard deviations) of each of the variables for burned and unburned samples.

Variable	Burn status	
	Burned	Unburned
Angle	10.3 (±5.8)	10.8 (±8.5)
Aspect	160.5 (±60.1)	148.3 (±111.6)
Bark	71.3 (±38.9)	61.4 (±38.0)
Bent	2.2%	7.9%
Buried	15.2%	25%
Complexity	74.1 (±57.4)	21.2 (±39.1)
Diameter	16.0 (±4.8)	15.9 (±9.9)
Elevation	-30.3 (±67.8)	-11.4 (±42.3)
Firm	95.7%	89.5%
Lateral distance to shore	3.3 (±2.6)	2.4 (±1.4)
Length	11.2 (±4.2)	7.0 (±3.3)
Orientation	156.9 (±64.6)	139.3 (±95.4)
Rootwad	58.7%	38.2%

We found significant differences (Tukey contrasts for multiple comparisons of means; $P < 0.050$) between pairs of unburned lakes for Aspect, Bark, and Complexity indicating that there may be local effects on these variables. Because Whitefish Lake was involved in all the significant differences, we omitted its eight pieces of wood from the analysis of Aspect, Bark, and Complexity. The upwind, burned area at Lake Isabella had significantly more pieces of wood per meter of shoreline (10 per 100 meters) than all unburned shorelines sampled (3 per 100 meters, $t = -5.3$, $df = 11$, $p < 0.001$). Regarding unburned control lakes, wood per meter was not significantly different between upwind (2 per 100 meters) and downwind shorelines (4 per 100 meters, $t = -0.9$, $df = 10$, $p = 0.389$).

Characterizing lake wood pieces according to burn status

Lengths were significantly different between burn states ($t = -5.988$, $R = 10000$, $P < 0.001$), with burned pieces being longer (means: burned = 11.2 m; unburned = 7.0 m). Also, the contingency table test rejected the null hypothesis of no association between complexity and burn status ($\chi^2 = 35.1$, $P < 0.001$). The standardized residuals revealed that the percentage of burned wood pieces with complexity ≥ 20 was clearly higher than expected and the frequency of burned wood with complexity < 20 was lower than expected (Figure 3).

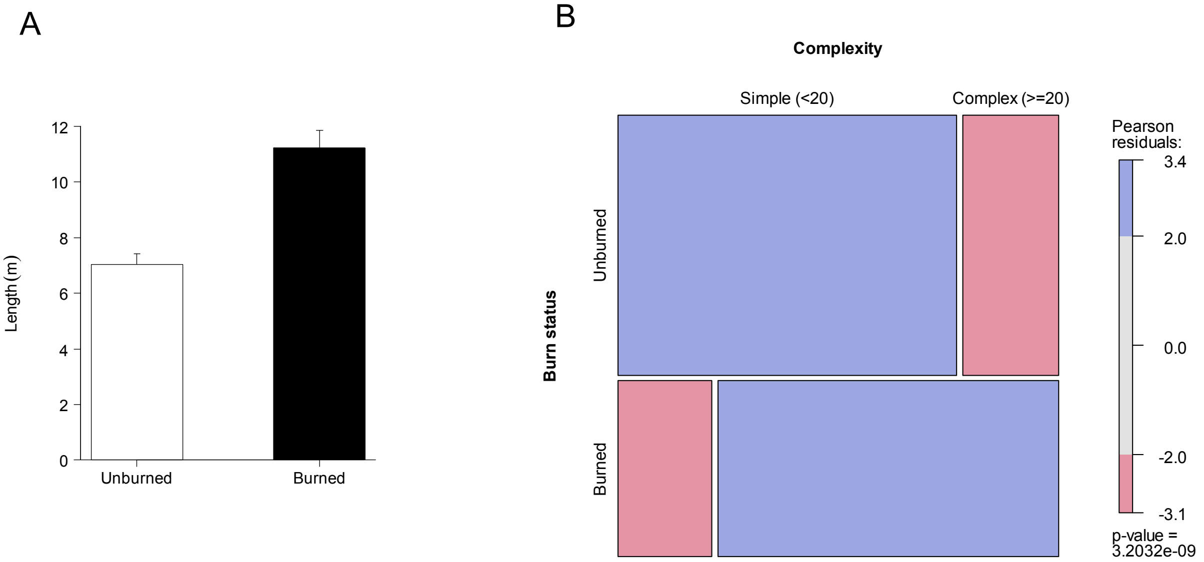

Figure 3. Relationships between burn status and lake wood characteristics. (A) Bar plot of mean lengths (error bar equal 95% confidence interval) of unburned and burned wood pieces in the lake shorelines. (B) Mosaic plots associating burn status of the wood pieces in the lake shorelines with its branch complexity. Rectangles are proportional to observed frequencies and color reflects the magnitude and significance of residuals from contingency table tests.

Regarding the positioning of wood pieces, burned wood was located at significantly greater distances from shore (means: burned = 3.3 m; unburned = 2.4 m; $t = -2.2, R = 10000, P < 0.001$), and orientation ($\chi^2 = 13.3$, P = 0.001) and aspect ($\chi^2 = 25.8$, P < 0.001) were also not independent of burned status. With respect to orientation and aspect, burned wood tended to be more frequently between 120 and 240 degrees in both cases than expected.

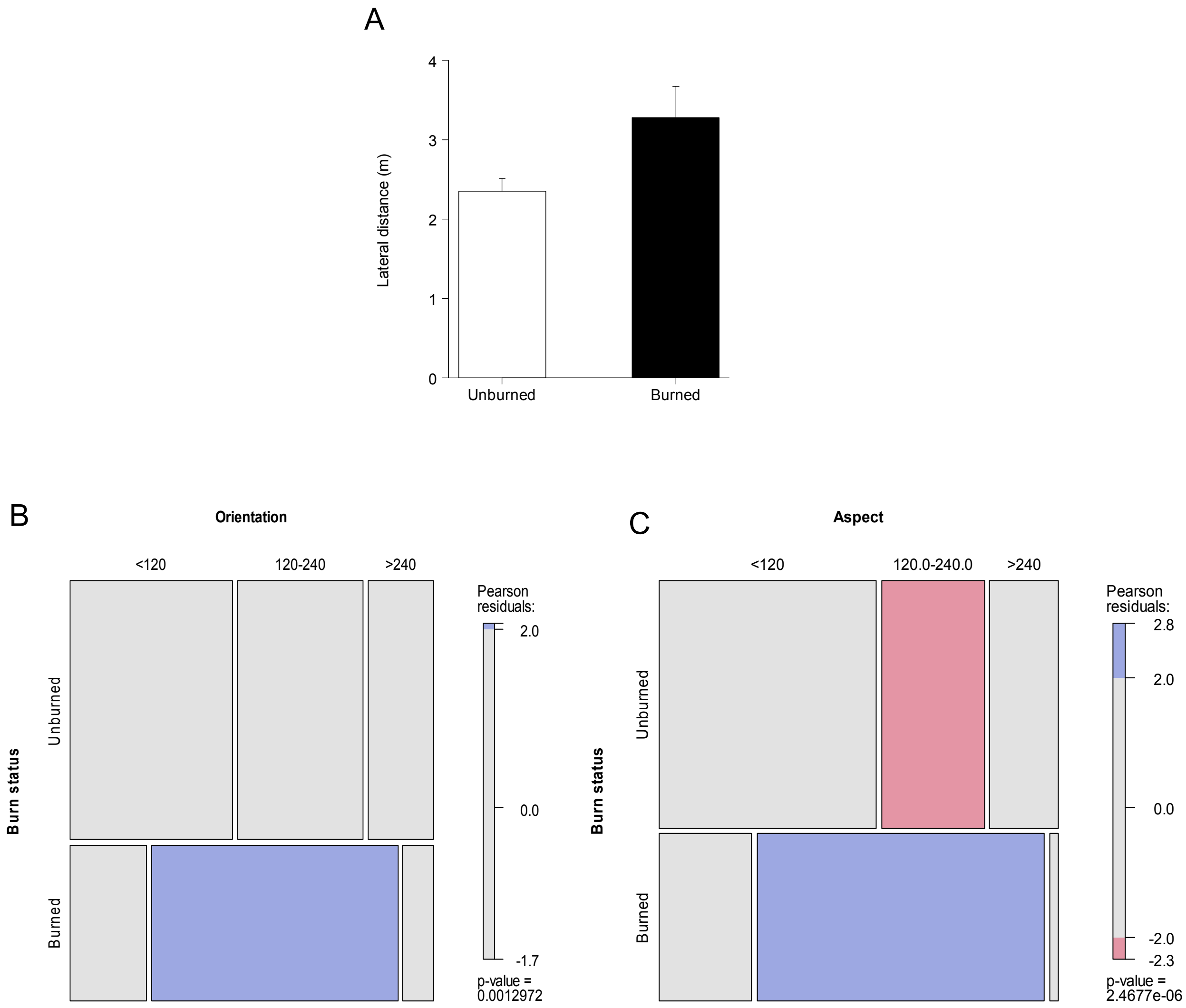

Figure 4. Relationships between burn status and positioning of lake wood. (A) Bar plot of mean lateral distances to the shoreline (error bar equal 95% confidence interval) of unburned and burned wood pieces in the lake shorelines. (B, C) Mosaic plots associating burn status of the wood pieces in the lake shorelines with its orientation (B), or with the aspect of the shoreline (C), both in degrees. Rectangles are proportional to observed frequencies and color reflects the magnitude and significance of residuals from contingency table tests.

Discussion

Wood is essential in aquatic ecosystems as it is habitat for fish, small aquatic organisms, insect larvae and algae (Marburg et al. 2006). Natural occurrences are one of the many factors that contribute to wood inputs in lakes, and include wildfires that can affect wood recruitment for decades (Gennaretti et al. 2013). Wildfires are a common occurrence in nature, and the effect of wildfire on wood in lakes is not well studied. The purpose of this study was to determine the effects of the Pagami Creek Fire of 2011 on wood levels and composition in a northern Minnesota lake, Lake Isabella.

The data are consistent with a pulse of whole, burned trees in the shoreline area impacted by the wildfire. Burned pieces tended to be oriented and along aspects of 120 to 240 degrees, and in fact all were found along the burned shoreline at Lake Isabella. Although pre-fire conditions are not known, the lack of upwind/downwind differences at the unburned control lakes was informative. Specifically, the lack of differences indicates there is not a consistent upwind/downwind pattern in shoreline wood stocks in unburned lakes in the study area. The burned wood pieces that were sampled were both significantly longer and significantly more complex than the unburned wood sampled. The longer and more complex wood pieces sampled suggest that the wildfire caused whole trees to fall into the water, with much of the trunks and branches intact. Furthermore, the burned pieces were more likely to have rootwads present. Rootwads on the burned wood suggests that the pieces were whole trees that tipped into the water with the rootwad intact, whereas the unburned pieces were often branches or pieces that were broken down over time. This influx of whole of trees is important because wood with greater branching complexity tends to be more stationary and provides more habitat (Vaz et al. 2011). Furthermore, rootwad presence has been found to help stabilize wood in aquatic ecosystems (Merten et al. 2010). Greater stability may extend the longevity of habitat provided for aquatic organisms.

In the short term, the pulse of wood in burned lakes may be a boon to aquatic organisms. Wood can host a greater invertebrate biomass than open sediment by providing both substrate and a source of food for these organisms (Smokorwski et al. 2006). Additionally, a species-habitat complexity relationship was found with wood where more structurally complex habitat increased the species richness (O'Conner 1991). The Pagami Creek wildfire apparently caused the input of significantly more complex wood than what was previously available for the organisms of the lake, and may be beneficial by providing habitat and protection. This study also included wood with an anchor on the shore in the form of a rootwad. Anchored pieces may provide habitat for terrestrial organisms as well, and can still create habitat over deep water for various aquatic organisms (Guyette and Cole 1999).

In the longer term, as the burned wood is gradually broken down there may be little or no new wood recruited from riparian trees for some time (Guyette and Cole 1999). Due to the intensity of the fire, no unburned mature trees were observed along the burned shoreline, and no unburned pieces were present in that sampled area. After this type of clearing of riparian vegetation, small bushes are often the first to reappear followed by trees due to the length of time required for trees to regrow. Following a mass clearing of riparian trees after a logging event, Guyette and Cole (1999) found that it took as many as 100 years for new wood to be recruited. A wildfire is comparable to a logging event due to the large scale clearing of riparian vegetation from these catastrophic events. Marburg et al. (2009) suggests that within two decades half the logs may be lost from the littoral zone if inputs were to cease. In particular, Gennaretti et al. (2013) found sizeable reductions in recruitment rates of large pieces of wood following wildfires in Quebec, a difference which persisted for 100 years. With few new inputs for an extended period, the wood present in the aquatic ecosystems could disappear, with deleterious effects on aquatic organisms.

Aside from changes in the quantity of wood, the quality may also be different with burned pieces. Burned wood has low protein and lipid content and high ash content compared to unburned wood (Mihuc and Minshall 1995). These chemical differences may limit the organisms that can thrive on burned substrate (Mihuc and Minshall 1995). Burned pieces may thus be less beneficial as a substrate for organisms such as macroinvertebrates, although Vaz et al. (2014) found no macroinvertebrate differences at the community level. Burned pieces may also break into smaller pieces more readily as they become weak or brittle.

Finally, climate changes have had an effect on wildfire activity worldwide, and models predict further increases in the future (Flannigan et al. 2009). This increase is shown on both fire occurrence and intensity (Flannigan et al. 2009), and is concerning due to the effects of wildfire on lake ecosystems. Wildfire inputs are consistent with whole, burned trees causing lakes worldwide to have changes in input rates. Decreased input following a wildfire may affect aquatic organisms living in these systems for multiple decades.

Acknowledgements

The authors would like to thank the USDA Forest Service and Wartburg College for funding and materials used to assist with sampling. We would like to thank Therin Bradshaw and Jeremy Corbett for their assistance in data collection, and Jason Butcher for his help in selecting locations and support for the project.

Literature Cited

Darwin AT, Ladd D, Galdins R, Contreras TA, Fahrig L. 2004. Response of Forest Understory Vegetation to a Major Ice Storm. Journal of the Torrey Botanical Society. 131(1):45-52.

Flannigan MD, Krawchuck MA, de Groot WJ, Wotton BM, Gowman L. 2009. Implications of changing climate for global wildland fire. International Journal of Wildland Fire. 18:483-507.

Gennaretti F, Arseneault D, Begin Yves. 2013. Millennial stocks and fluxes of large woody debris in lakes of the North American taiga. Journal of Ecology.

Gessner MO, Inchausti P, Persson L, Raffaeili DG, Giller PS. 2004. Biodiversity Effects on Ecosystem Functioning: Insights from Aquatic Systems. Oikos. 104(3): 419-422.

Marburg AE, Turner MG, Kratz TK. 2006. Natural and anthropogenic variation in coarse wood among and within lakes. Journal of Ecology. 94(3): 558-568.

Marburg AE, Bassak SB, Kratz TK, Turner MG. (2009). The demography of coarse wood in north temperate lakes. Freshwater Biology. 54:1110-1119.

Merten E, Finlay J, Johnson L, Newman R, Stefan H, Vondracek B. 2010. Factors influencing wood mobilization in streams. Water Resources Rearch. 46: 1-13.

Mihuc TB, Minshal WG. 1995. Trophic generalists vs. trophic specialists: implications for food web dynamics in post-fire streams. The Ecological Society of America. 76(8):2361-2372.

Minnesota Department of Natural Resources. 2013. Climate. www.dnr.state.mn.us/faq/mnfacts/climate.hmtl

Newbrey MG, Bozek MA, Jennings MJ, Cook JE. (2005). Branching complexity and morphological characteristics of coarse woody structure as lacustrine fish habitat. Canadian Journal of Fisheries and Aquatic Sciences. 62:2110-2123.

O'Conner NA. (1991). The effects of habitat complexity on the macroinvertebrates colonizing wood substrates in a lowland stream. Oecologia. 84(4):504-512.

Schindler DE, Francis TB. 2006. Degradation of Littoral Habitats by Residential Development: Woody Debris in Lakes of the Pacific Northwest and Midwest, United States. Ambio. 35(6):274-280.

Smokorowski KE, Pratt TC, Cole WG, McEachern LJ, Mallory EC. 2000. Effects on periphyton and macroinvertebrates from removal of submerged wood in three Ontario Lakes. Canadian Journal of Fisheries and Aquatic Sciences. 63(9):2038-2049.

USDA Forest Service. 2012. Pagami Creek Wildfire. Duluth (MN): Superior National Forest.

Vaz PG, Warren DR, Pinto P, Merten EC, Robinson CT, Rego FC. 2011. Tree type and forest management effects on the structure of stream wood following wildfires. Forest Ecology and Management. 262(3):561-570.

Vaz PG, Dias S, Pinto P, Merten EC, Robinson CT, Warren DR, Rego FC. 2014. Effects of burn status and conditioning on colonization of wood by stream macroinvertebrates. Freshwater Science. 33(3). DOI: 10.1086/676657.

ID	Location	D1 cm	D2 cm	D3 cm	Length m	Elevation cm	Angle	Orientation	Lateral m	Burn	Bark	Bent	Burried	Complexity	Firm	Rootwad
1	Isabella	11.7	16.3	17.4	2.9	-170	45	182	3.7	0	0	n	n	25	y	n
2	Isabella	16.1	21.6	24.9	5.6	-30	10	198	1.7	0	100	n	r	3	y	y
3	Isabella	23.5	26	26.8	7.1	-30	5	284	0.9	0	100	n	n	1	y	n
4	Isabella	17	19.8	19	2.4	-11	15	156	0.3	0	0	n	n	1	n	n
5	Isabella	3.4	9.5	18.2	17.1	-19	10	56	-0.7	0	50	n	r	121	y	y
6	Isabella	18.5	16.8	1	12.4	-17	10	26	-1.2	0	100	y	n	28	y	n
7	Isabella	6.3	13.1	19.1	14.1	-55	10	230	1.2	0	90	n	n	183	y	n
8	Isabella	29	22.3	26	4.8	-55	25	264	1.2	0	100	n	n	1	y	y
9	Wilson	18.4	21.3	25.8	2.8	-13	10	158	0.8	0	90	n	n	36	n	n
10	Wilson	4.2	11.6	15.7	8.4	2	5	98	4.2	0	90	n	r	5	y	y
11	Wilson	7.8	13.2	14.9	3.5	-2	10	40	1.7	0	100	n	n	1	n	y
12	Wilson	14.4	11.1	7.6	6.9	13	10	20	2.1	0	60	n	n	1	y	y
13	Wilson	13.2	8.9	9.8	5.1	-25	5	60	2.4	0	20	n	n	1	n	y
14	Wilson	14.4	9.8	5.9	9.7	-23	10	198	2.9	0	20	n	n	5	y	n
15	Wilson	18.4	9.6	8.3	10.3	40	10	111	2.4	0	90	n	n	15	y	n
16	Wilson	13.3	9.9	7.6	5.1	30	15	40	1.4	0	40	y	r	1	y	y
17	Wilson	16.1	16.6	14.3	5.2	29	15	36	2.6	0	80	n	n	1	y	y
18	Wilson	15	13.1	10.5	8.4	25	10	40	3.8	0	80	n	n	1	y	n
19	Wilson	8.4	12.2	12.4	6.8	19	20	70	2.5	0	100	n	n	1	n	n
20	Isabella	6.8	19.3	27.5	15.5	-24	10	180	3.7	90	90	n	n	93	y	y
21	Isabella	37.1	32	19.3	11	-127	15	228	0.9	100	0	n	n	70	y	n
22	Isabella	1	17.1	31.5	17.2	3	5	220	8.6	60	60	n	n	105	y	n
23	Isabella	1	18.6	24.7	11.5	-18	5	156	3	40	40	n	n	76	y	y
24	Isabella	22.2	17.7	1	12.2	-25	5	168	2.4	80	80	n	n	94	y	n
25	Isabella	23.8	15.1	1	17	-47	10	174	2.4	100	100	n	n	204	y	y
26	Isabella	1	17.1	22.1	7.6	-38	10	176	2.7	40	40	n	n	83	y	y
27	Isabella	22.3	15.9	1	11.4	47	10	200	4.9	100	100	n	n	42	y	y
28	Isabella	29.8	21.2	1	11.4	37	10	214	5.7	60	100	n	n	74	y	y
29	Isabella	17.7	12.7	1	13.2	-5	5	174	4.8	100	100	n	n	109	y	n
30	Isabella	17.6	11.4	1	9.6	3	25	180	1.2	80	100	n	r	29	y	y
31	Isabella	25.1	14.7	1	14.2	9	5	250	3.3	80	90	n	n	77	y	y
32	Isabella	1	15.3	40.7	15	2	5	200	7.3	90	90	n	n	220	y	y
33	Isabella	1	11.2	16.5	5.6	6	5	250	3.2	30	100	n	n	84	y	n
34	Isabella	29	13.9	1	7.6	-9	5	166	3.6	30	100	n	r	121	y	y
35	Isabella	16.2	15.3	18.5	8	-3	5	224	4	40	0	n	n	19	y	n
36	Isabella	13	13	10.9	9.8	20	10	196	4.9	20	0	n	n	3	y	n
37	Isabella	36	19.1	1	20.4	-15	10	120	14.1	20	0	n	n	77	y	y
38	Isabella	18.3	15.4	12.4	6.1	-15	15	120	3.4	100	0	n	n	1	y	n
39	Isabella	27.9	13.7	1	12	-32	10	134	5.2	10	10	n	n	44	y	y
40	Isabella	1	13.8	20.4	15.6	26	15	110	4.9	90	100	n	n	11	y	n

ID	Location	D1 cm	D2 cm	D3 cm	Length m	Elevation cm	Angle	Orientation	Lateral m	Burn	Bark	Bent	Burried	Complexity	Firm	Rootwad
41	Isabella	18.1	12.4	1	8	10	10	160	4	80	100	n	n	26	y	n
42	Isabella	17.6	12.6	1	7.4	13	10	160	3.7	80	100	n	n	31	y	n
43	Isabella	23.6	17.6	1	13.8	42	15	140	6.9	10	10	n	n	98	y	y
44	Isabella	26.9	21.8	1	10.5	-15	10	52	2.7	40	30	n	n	61	y	n
45	Isabella	30.8	18.3	1	12.4	-26	5	9.4	4.1	90	100	n	n	59	y	y
46	Isabella	40.2	30.5	1	12.1	-21	5	90	3.6	100	90	n	n	132	y	n
47	Isabella	23.1	14.2	1	17.4	95	5	120	0.9	60	90	y	n	88	y	y
48	Isabella	19.2	20.8	19.7	3.8	-37	30	330	-1.2	70	40	n	n	1	y	n
49	Isabella	19.3	15.4	1	8.5	-28	10	150	2.9	40	100	n	r	85	y	y
50	Isabella	17.4	14.3	1	14.6	-23	5	94	0	20	90	n	n	193	y	n
51	Isabella	27.8	12	1	12.2	-7	5	110	4.9	80	100	n	n	103	y	n
52	Isabella	21	23.4	18.4	7.6	32	10	84	4.2	50	30	n	n	1	n	n
53	Isabella	27.7	19.8	1	10.2	-45	20	120	2.9	90	100	n	r	114	y	y
54	Isabella	14	13.3	13	3.5	-31	15	128	1.1	60	100	n	n	1	n	n
55	Isabella	23.3	14.5	12.2	7.4	-40	10	156	0.8	100	0	n	n	1	y	n
56	Isabella	22.9	19.5	17.3	2.7	-53	20	140	0.4	60	90	n	r	1	y	y
57	Isabella	26.1	19.5	1	11.8	-85	5	160	1.4	90	100	n	n	67	y	y
58	Isabella	44	30.2	1	14.2	-110	15	160	2.2	100	100	n	n	96	y	y
59	Isabella	29	21.4	1	12.4	-57	10	126	2.8	40	20	n	n	23	y	y
60	Isabella	26	23.4	1	10.5	-120	5	80	2.6	80	100	y	r	80.6	y	r
61	Isabella	16.3	11.3	1	12.2	-90	10	350	1.2	90	100	n	n	105	y	y
62	Isabella	26.9	18.2	1	11.2	-160	15	60	4	40	100	n	n	132	y	y
63	Isabella	23.8	20.7	22.9	9.2	-6	5	90	2.3	100	100	n	n	29	y	y
64	Isabella	17.7	33.2	33.7	9.6	-150	20	90	1.9	100	100	n	r	6	y	y
65	Isabella	23.9	16.1	1	9.2	-59	5	126	1.4	80	100	n	n	125	y	y
66	Isabella	39.9	33.4	1	23.4	-340	10	172	-2.2	90	90	n	y	194	y	y
67	Isabella	14.1	15.3	10.7	3.2	-10	10	50	1.6	0	70	y	n	3	n	n
68	Isabella	7.1	9.2	11	2.6	-20	10	258	1.4	0	0	n	n	1	y	n
69	Isabella	17.6	12.7	1	8.4	-46	20	240	4.2	0	100	n	r	136	y	y
70	Silver Island	5.9	11.4	14.1	5.8	-22	10	240	1	0	40	n	n	7	y	n
71	Silver Island	12.4	18.2	29.8	6.7	-40	15	210	1.7	0	60	n	n	3	y	n
72	Silver Island	16.7	18.4	20.4	7.8	-36	10	168	3.9	0	100	n	n	10	y	n
73	Silver Island	16.2	13.1	12.2	6.6	-24	5	200	2.3	0	60	n	n	1	y	n
74	Silver Island	20.3	19.1	12.4	7.4	-19	10	156	3.4	0	100	n	r	22	y	y
75	Silver Island	22.1	19	9	11.5	-10	5	180	5.8	0	100	n	n	3	y	n
76	Silver Island	10.4	12.7	17.6	5.4	-34	10	22.6	2.7	0	60	n	r	5	y	y
77	Silver Island	23.2	12.7	2	8.1	15	5	40	3.2	0	0	n	n	30	y	n
78	Silver Island	19.9	19.9	20.9	5.4	-3	10	60	2.7	0	40	n	r	1	y	y
79	Silver Island	16.4	17.8	21.9	5.5	-26	15	80	1.3	0	100	n	n	1	y	n
80	Silver Island	20.4	18.7	13.8	9.5	22	5	80	4.8	0	0	n	n	3	y	n

ID	Location	D1 cm	D2 cm	D3 cm	Length m	Elevation cm	Angle	Orientation	Lateral m	Burn	Bark	Bent	Burried	Complexity	Firm	Rootwad
81	Silver Island	17.1	16.3	16.6	8.2	-140	20	110	0.9	0	60	n	r	7	y	y
82	Silver Island	15.3	13.3	16.8	8.2	6	5	60	2.2	0	0	n	n	1	y	n
83	Silver Island	27.4	23.4	23.7	2.9	-130	60	160	0.2	0	100	n	n	1	y	n
84	Silver Island	14.4	10.1	1	11.2	6	10	74	5.6	0	100	n	n	111	y	n
85	Silver Island	10.9	7.8	1	8.2	19	5	60	4.1	0	20	n	n	51	y	n
86	Silver Island	17	16.6	154	3.1	4	5	150	1.5	0	0	n	n	1	y	n
87	Silver Island	17.7	10.7	1	9.3	-18	10	130	0.8	0	90	n	n	93	y	n
88	Silver Island	17.6	18.7	23.2	6.5	-45	20	106	1	0	90	n	r	7	y	y
89	Windy	209	17.4	1	10.4	-29	10	92	2.8	0	100	n	n	78	y	n
90	Windy	19.6	16.5	14.9	4.5	-24	25	50	2	0	0	n	n	12	y	n
91	Windy	28.3	24.8	27.1	4.1	42	10	140	2	0	0	n	n	1	y	n
92	Windy	14.4	14.2	15.8	4.2	33	15	30	2.1	0	60	n	n	1	y	n
93	Windy	5.6	11.1	12.2	7.4	-43	10	20	2.5	0	10	n	n	37	y	n
94	Windy	12.3	12.4	11.9	5.5	-46	10	270	2.2	0	90	n	n	79	y	n
95	Windy	9.8	12.4	19.1	4.1	-63	5	260	2	0	60	y	r	1	y	y
96	Windy	11.9	13.8	14.7	5.6	-22	10	134	3.5	0	100	n	n	1	y	n
97	Windy	18.5	14.6	15.6	3.8	52	10	160	1.9	0	80	n	n	1	y	y
98	Windy	18.3	17.2	15.1	12.5	110	10	150	6.3	0	100	n	r	1	y	y
99	Windy	17.4	12.9	8.2	7.2	-46	5	58	2.3	0	100	n	n	23	y	n
100	Windy	14.7	13.9	15.6	3.2	-23	15	306	1.6	0	100	n	n	1	y	n
101	Windy	11.6	10.2	4.3	5.6	16	5	180	2.4	0	50	n	n	7	y	n
102	Windy	18.6	13.8	7.2	12	-4	5	180	2.6	0	70	n	n	3	y	n
103	Windy	20.9	16.2	13.6	5.9	27	5	20	2.7	0	10	n	n	1	y	n
104	Windy	22.3	19.4	15.8	11.4	120	5	10	5.7	0	90	n	r	1	y	y
105	Windy	14.1	12.4	9.4	7.4	12	5	350	3.7	0	20	n	r	1	y	y
106	Windy	17.6	11.9	11.1	7.4	12	5	350	3.7	0	60	n	r	1	y	y
107	Windy	6.9	15.4	16.2	6.5	16	10	30	3.2	0	100	n	r	1	n	y
108	Windy	13.2	11.4	10.1	5.6	12	10	340	2.8	0	100	n	n	1	y	y
109	Windy	19.4	15.8	12.7	7.6	9	10	74	2.9	0	100	n	n	5	y	n
110	Windy	12.3	10	8.3	9.8	-3	5	22.6	4	0	30	n	n	1	y	n
111	Windy	15.6	13.1	8.5	7.6	-19	5	250	2.3	0	100	n	n	1	y	n
112	Windy	15.1	13.2	7.4	4.7	-11	5	40	2.3	0	80	n	n	5	y	n
113	Windy	12.3	11.9	13.1	3.2	-16	15	20	1.4	0	70	n	r	1	n	y
114	Windy	11	11.7	13.1	4.4	-11	10	70	2.2	0	100	n	n	1	y	n
115	Windy	16.1	15.7	13.6	4.9	21	10	210	2.4	0	10	n	r	1	y	y
116	Windy	24.2	18.8	13.9	8.6	-17	5	336	2.1	0	100	n	n	7	y	y
117	Whitefish	15.2	8.8	1	6	5	5	134	2.2	0	0	n	n	69	y	n
118	Whitefish	19.6	16.3	1	15.4	-23	5	130	2.6	0	40	n	n	153	y	y
119	Whitefish	19.2	13.9	5.6	17.8	-42	5	140	2.2	0	40	n	n	54	y	y
120	Whitefish	25.9	22.2	17.8	3.2	9	5	150	1.1	0	0	n	n	17	y	n

ID	Location	D1 cm	D2 cm	D3 cm	Length m	Elevation cm	Angle	Orientation	Lateral m	Burn	Bark	Bent	Buried	Complexity	Firm	Rootwad
121	Whitefish	18.4	13	1	8.7	-36	15	180	1.5	0	70	n	r	84	y	y
122	Whitefish	20.9	14.9	6.6	3.5	12	5	260	1.2	0	0	y	r	27	y	y
123	Whitefish	24.8	16.3	7.4	5.2	-27	10	300	0.6	0	20	n	n	1	y	n
124	Whitefish	14.7	11.3	10.4	4.8	-6	5	248	2.4	0	20	y	n	1	y	n