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Damage Agents and Condition of Mature Aspen Stands in Montana and Northern Idaho

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Introduction

Forest, range, and wildlife managers in the western United States have documented a 50–96% decline in total aspen (*Populus tremuloides* Michx.) forest acreage since European settlement (Bartos 2001). Data from the U. S. Department of Agriculture, Forest Service (USFS) Forest Inventory and Analysis (FIA) unit in Ogden, Utah suggest aspen acreages within Montana and Idaho are down 64% and 61% since settlement, respectively (Bartos 2001).

Aspen stand health has also shown declines since the 1970's. Two primary forces are most commonly cited as contributing to this decline; changes in fire regimes since European settlement and heavy ungulate browsing leading to inadequate regeneration (for example see Romme et al. 1995, Kay 1997, Bartos and Campbell 1998). More recently, severe and rapid dieback and mortality of aspen in Colorado, as well as Alberta, Saskatchewan, and Manitoba, Canada have been tied to drought (Hogg et al. 2008, Worrall et al. 2008). Forest diseases and insects are often notable as potential contributing or inciting factors (Frey et al. 2004) but play a largely undefined role in the decline of aspen.

Published data from long-term permanent monitoring plots established by the USFS FIA unit in Ogden confirmed the severity and extent of suspected decline symptoms and deterioration of aspen forests throughout its range in the Rocky Mountains from Canada to Mexico (Shaw 2004). The publication also recommended establishment of additional off-plot sites to further define extent and severity of decline in aspen clone health and examine the role of various damage agents.

Funding provided by USFS Evaluation Monitoring (project INT-F-06-01) allowed establishment of permanent monitoring plots in aspen stands in Nevada, Utah, southern Idaho and western Wyoming (USFS Region 4) in 2006 and 2007, and west and central Montana, and northern Idaho (USFS Region1) in 2008. Surveys were to supplement established FIA Forest Health Monitoring plot system efforts by providing additional data on forest damage/decline agents in aspen forests. Only results from Region 1 are reported here.

Methods

Plot locations were chosen from stands provided by land managers (USFS, Nature Conservancy, Indian Reservations, National Grasslands, and National Wildlife Refuges) that met the minimum criteria of having at least seven live aspen stems ≥5 in. diameter at breast height (dbh) within a 26.3 ft fixed radius plot (1/20th ac). Plots were randomly placed within stands but were required to meet the minimum criteria.

All plot centers were recorded using a global positioning system (GPS) and monumented with fence posts. Plot level data included slope, elevation, topographic position, primary and secondary tree species, relative clone stability, and successional status. Information on clone stability and successional status included specifics on trending stand direction (retreating, stable or expanding), conifer competition (none, minor or severe), successional status (non-successional or successional), and the expected future forest type. (Definitions for these data and others are found in Appendix A.)

All trees were tagged for future reference, beginning with the northern-most trees and moving clockwise. Data taken on aspen trees ≥5 in. dbh included: dbh, percent crown dieback (<33%, 33-66%, >66%), tree condition (live, new dead, older dead), crown class (dominant, codominant, etc.), and damage. Aspen dead long enough to have sloughed off most of their bark were not evaluated. Damage agents were identified by characteristic physical evidence; few agents were isolated or sent in for identification. Damage severity was rated as low, moderate, or high for the top three damage agents likely to affect future tree survival and growth. For all non-aspen tree species, only species, dbh, tree condition, and crown class were recorded.

Saplings (≥2 in. but <5 in. dbh) and regeneration (<2 in. dbh with no minimum height requirement) were sampled on three nested 6.8 ft radius (1/300th ac.) sub-plots located at the mid-point of radial lines at 120°, 240°, and 360° from plot center within each plot (Fig. 1). Data collected on saplings was the same as for trees, but stems were not tagged. Regeneration on each subplot was documented by recording the number of stems by species along with the three most commonly observed damage agents, percentage of stems affected by those three agents, and overall agent severity. Dead sprouts were included in the count with the highest severity rating. Non-aspen regeneration was recorded but damage was not determined.

All statistical analyses were performed using Microsoft Excel or SAS (version 9.3, SAS Institute Inc.). Tukey's honestly significant difference (HSD) was used for multiple comparisons of means due to our unequal sample sizes. Tukey's HSD is also considered conservative with a low Type I error rate (falsely rejecting the null hypothesis) and higher requirements for showing significant differences between treatments (=stronger variables for model building). The presence of various damage agents was related to dbh of aspen. To examine the effects of site variables on damage agent presence, data were converted to density by basal area. For every tree with a recorded pest agent, its entire basal area was considered affected.

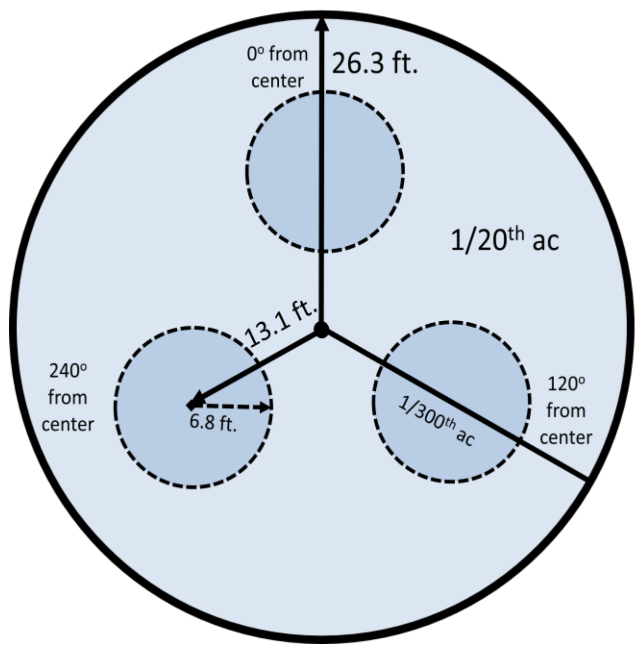

Figure 1: Configuration of plot and subplots used to determine condition of aspen stands in the Northern Rocky Mountains.

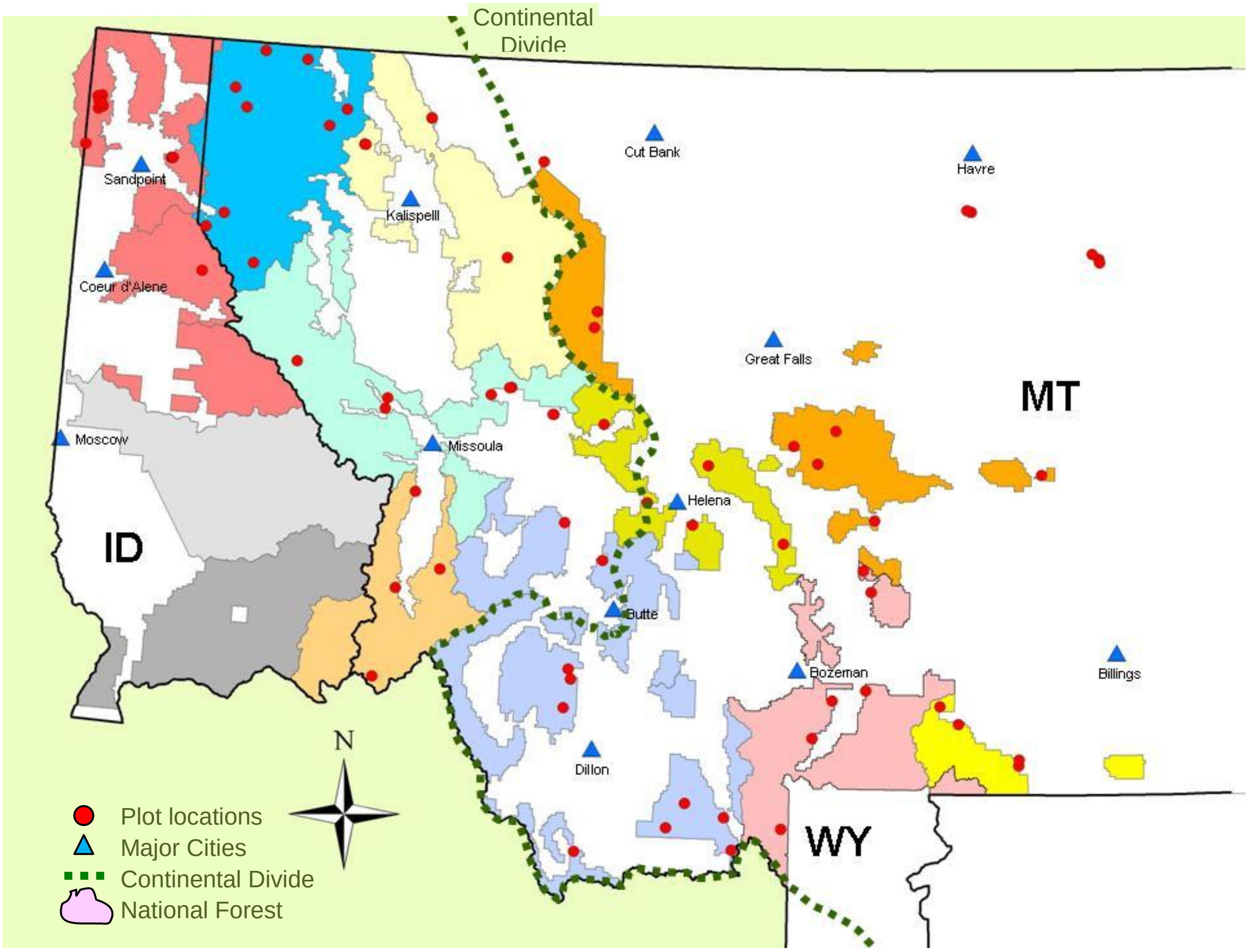

Figure 2: Location of permanent plots in aspen stands of northern Idaho and Montana monumented during the 2008 field season. Colored polygons represent different National Forests (or past Forests prior to combination with another).

Results and Discussion

During the summer of 2008, 76 permanent plots were established in aspen stands throughout portions of the Northern Region (Fig. 2); 65 in the western two-thirds of Montana and 11 in northern Idaho. Analyses were done on the 76-plot set, as well as comparing plots east and west of the Continental Divide (CD). Division by CD was chosen due to differences in temperature, precipitation, wind, and cloud cover, all of which effect vegetation. Climate of northern Idaho and Montana west of CD is described as 'modified north Pacific coast', where as Montana's climate east of CD is described as 'decidedly continental' (Western Regional Climate Center, 2010). A summary of plot locations by ownership, relationship to CD, state, and county are given in Tables 1 & 2.

<u>Plot data</u>

Plots ranged in elevation from 2265 to 8040 ft above sea level with those west of the CD significantly lower than those east (3761 ft average versus 5739 ft, respectively) ($P<0.05$, Tukey's HSD). Average slope for plots east and west of CD were similar (14^o and 15^o, respectively), although some steeper slopes were surveyed west-side (maximum of 81^o versus 37^o eastside). Surveyed aspen stands were located on all aspects, with 34% of stands on southern aspects, 26% on northern, 22% on eastern facing slopes, and 17% on western.

Due to bias in plot location toward easily accessible stands, topographic location results are unclear. In general, most plots were located on a slope rather than on a ridge top or a valley bottom, although more than half of plots west of

Table 1. Location of permanent plots established in aspen stands in Montana (MT) and northern Idaho (ID) in 2008. Most plots were placed on USDA Forest Service managed lands (FS).

Ownership	Forest/Area	Total	# west of Continental Divide	# east of Continental Divide
FS (MT)	Beaverhead-Deerlodge	10	2	8
	Bitterroot	4	4	
	Custer	4		4
	Flathead	5	5	
	Gallatin	6		6
	Helena	5	1	4
	Kootenai	9	9	
	Lewis & Clark	7		7
	Lolo	6	6	
FS (ID)	Idaho Panhandle	11	11	
Tribal	Blackfeet IR	1		1
	Fort Belknap	3		3
	Rocky Boys	3		3
Nature Conservancy	Blackfoot	2	2	
	TOTALS	76	40	36

CD were in valley bottoms. It is possible ridge tops have fewer aspen stands, but it is also likely that ridge tops are further from roads making them less accessible. Valley bottoms may also be underrepresented due to spring flooding that made them inaccessible.

For all but two plots west of CD the principal tree species was aspen. In the two remaining plots, conifer encroachment resulted in aspen being the second most dominant tree species. Secondary tree species were predominately Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Mayr), followed by Engelmann spruce (*Picea engelmannii* Parry) and pines (lodgepole [*Pinus contorta* Dougl. var. *latifolia* Engelm.] and ponderosa [*P. ponderosa* var. *scopulorum* Engel.]) east of CD, and Douglas-fir, followed by pines (lodgepole, ponderosa, and western white pine [*P. monticola* Dougl. ex D. Don]) and Engelmann spruce west (Table 3).

East of CD most stands were considered stable (58% of plots), although 33% appeared to be expanding and 8% showed signs of retreating or diminishing. By comparison, west of CD 50% of plots were recorded as retreating, 39% stable, and only 11% expanding. Similarly, 78% of plots without conifers present were found east of CD while 70% with severe conifer competition

Table 2. Location of permanent plots established in aspen stands in Montana and northern Idaho in 2008 by county.

ST	County	Total
MT	Beaverhead	4
	Blaine	3
	Broadwater	1
	Carbon	2
	Cascade	1
	Fergus	2
	Flathead	5
	Gallatin	1
	Glacier	1
	Hill	3
	Jefferson	1
	Lewis & Clark	4
	Lincoln	6
	Madison	4
	Meagher	3
	Mineral	1
	Missoula	3
	Park	4
	Powell	6
	Ravalli	4
	Sanders	3
	Stillwater	2
	Teton	1
ID	Bonner	10
	Shoshone	1

were west. Overall, however, most stands were found to have some level of conifer in-growth.

Stands not expected to succeed to another forest type in the near future (28%) were equally divided between expanding or remaining stable for the near future, with either no (43%) or only minor (57%) conifer competition. As expected, stands deemed successional (72%) - usually to one or more conifer species - had either minor (62%) or severe (38%) conifer competition, and were equally divided between being called stable or retreating.

Most plots were expected to move toward dominantly conifer forest types, barring a significant disturbance event in the near future. Only plots east of the CD were recorded as not succeeding to some tree species other than aspen. Of plots east of CD expected to succeed to some other forest type, Douglas-fir was the dominant type, with pines (lodgepole and ponderosa) and spruce and/or true fir types also indicated. West side plots were largely expected to succeed to spruce and/or true fir types or Douglas-fir, with western white pine as a possible type in Idaho (15%) (Table 3).

Our descriptions of plot status are somewhat different from those used in other aspen studies. Often-used definitions from Bartos (2001) describe western aspen as existing in one of three primary conditions: 1) stable, 2) successional to conifer, and 3) decadent and falling apart. Using these definitions, most of our stands would be 'successional' (any conifer competition), with only 4 eastern and 1 western plots as 'stable' (expanding without conifer competition), and none as 'decadent' (retreating without conifer competition). However, several of our stands with conifer competition had old, sparse aspen stems and lacked regeneration, so may fit the 'decadent' definition.

Table 3. Tree species currently second-most common on plot, and species expected to dominate in future.

Tree Species	Current Secondary Tree Species* E	Current Secondary Tree Species* W	Expected Future Dominant Tree Species** E	Expected Future Dominant Tree Species** W
Aspen	(17% with aspen as only species)	5%	23%	8%
Douglas-fir	39%	43%	29%	32%
Spruce-True Fir	17%	30%	16%	35%
Pines***	25%	13%	26%	14%
Other****	3%	10%	6%	11%

*Aspen was primary on all but 2 plots W of CD

**5 of 36 plots E of CD and 3 of 40 plots W of CD are missing data

***Lodgepole, ponderosa, and, W of CD, western white pine

****Mostly hardwood species (shrubby tree and cottonwood) as current secondary species; mostly other conifers in predicted future vegetation

Aspen Tree and Sapling Data

A total of 1,423 aspen ranging in dbh from 2 to 24.2 in. were examined. Basal area-weighted average dbh for all aspen trees and saplings was 8.7 in. No significant difference in this weighted average dbh was found between east (8.1 in.) and west (9.2 in.) of the CD (Table 4).

Shepperd and others (2001) note that a histogram of size (and presumably age) should show the inverse 'J' distribution if a stand is self-regenerating. The data from our 76 plots indicate the general condition of aspen stands in Region 1 is healthy (Fig. 3). Regeneration, defined as sprouts of any height but less than 2 inches in dbh, averaged 2,984 stems per acre and is represented by the <2.0 in. dbh diameter category. All other diameter classes are from sapling (2-4.9 in. dbh) and tree (5+ in. dbh) data.

The majority of aspen in the tree size class occupied the dominant and co-dominant crown positions (81%), 12% were intermediate, 1% were suppressed, and 5% had spike (dead or broken) tops. As expected, the aspen saplings occupied the lower crown canopy with 55% in the intermediate crown class, while 30% were in the co-dominant crown class, 11% were considered suppressed, and 4% had spike tops. Plots east of the CD had a significantly greater proportion of aspen with spike tops (10.2%) than those west of the CD (2.3%) ($P<0.05$). This likely reflects both the presence of sooty-bark canker and the greater incidence of wood borer damage east of the CD (discussed below).

Of the live aspen trees, the majority (82%) had minor crown dieback (1-33%), 16% had moderate crown dieback (34-66%), and 2% had severe dieback (> 66% of their crowns dead). The aspen saplings had a similar proportion exhibiting moderate crown dieback at 15%, with 83% having minor dieback, and 1% having severe crown dieback. Plots east of the CD had a higher proportion of trees with moderate crown dieback than did plots west of the CD (22% and 13%, respectively) ($P<0.05$). If crown mortality reflects past defoliation events, dieback could be attributed to foliar insects, diseases, or weather (ie. late spring freezes). Of special note, plots at higher elevations and in more southern locations had greater proportions of trees with severe crown dieback (Pearson's correlation coefficient (r) = 0.31, P=0.006 and r = 0.35, P=0.002, respectively). It is possible that plots at higher elevations, many of which were the southern-most plots (leading up to Yellowstone National Park), are subject to more frequent or intense freeze events.

At the time of this survey, 93% of aspen trees (≥ 5 in. dbh) were alive, 5% were classified as newer dead, and 2% were older dead. For aspen saplings, 85% were alive, 10% were recent dead, and 4% were older dead. The proportion of dead aspen did not differ significantly between plots east and west of the CD (11.1 and 9.6%, respectively) (P>0.05) (Table 4), nor was mortality level related to elevation, slope position, clone stability, successional status, or degree of conifer competition. The highest percent of recent mortality (bark still tight on tree) was 29% found on one plot on the Lolo National Forest.

Shepperd (2008) describes sudden aspen decline (SAD) as rapid (1-2 years) mortality of mature trees with a lack of new sprouting after overstory mortality. SAD is not normal stand succession, but may be related to climate/drought. In some areas with SAD symptoms, a third or more of mature stems died within a couple of years. With ‘recent’, on-plot mortality at a 29% maximum (7% average), our plots do not fit the definition of SAD. In studies of SAD in Colorado and Arizona, higher mortalities were associated with lower elevations. Evaluation of the limited mortality observed in this survey failed to detect any association between recent mortality and elevation.

Aspen density averaged 626 trees per acre (tpa) across all plots and ranged from 140 to 2140 tpa (Table 4). For aspen ≥5 in. dbh, density was slightly higher in plots east of the CD (342 tpa) than west (285 tpa), though that difference was not statistically significant. Densities of aspen saplings (2-4.9 in. dbh), averaged 314 tpa, with averages of 281 tpa east of the CD and 345 tpa west of the CD. Plot elevation was positively correlated with aspen density (r = 0.24, P=0.037). Aspen density did not vary by slope position, clone stability, successional status, or degree of conifer competition.

DeByle (1985) notes that dense, even-aged stands of aspen that have at least 400 stems per acre when they reach 13 ft tall are usually healthy enough to withstand considerable tree losses. Bartos and Cambell (1998) describe stands having fewer than 500 regeneration stems per acre (5-15 feet tall) as being at risk. Stands under complete regeneration (e.g. clear-cut or stand replacing fire) are likely to have more stems than stands regenerating under a mature overstory. Thus, it is unclear if the 400-500-stem threshold is also appropriate for uneven-aged stands. Comparison is also difficult as our size classes were based on diameter rather than height. However, if we consider the number of saplings (2-4.9 in. dbh) a reasonable surrogate, 55 (72%) plots would not meet the 400 stem threshold: (11 of these registered no regeneration). If the regeneration <2 in. dbh but greater than 5 ft tall were included, the stems-per-acre count would be great enough to meet the threshold on many plots.

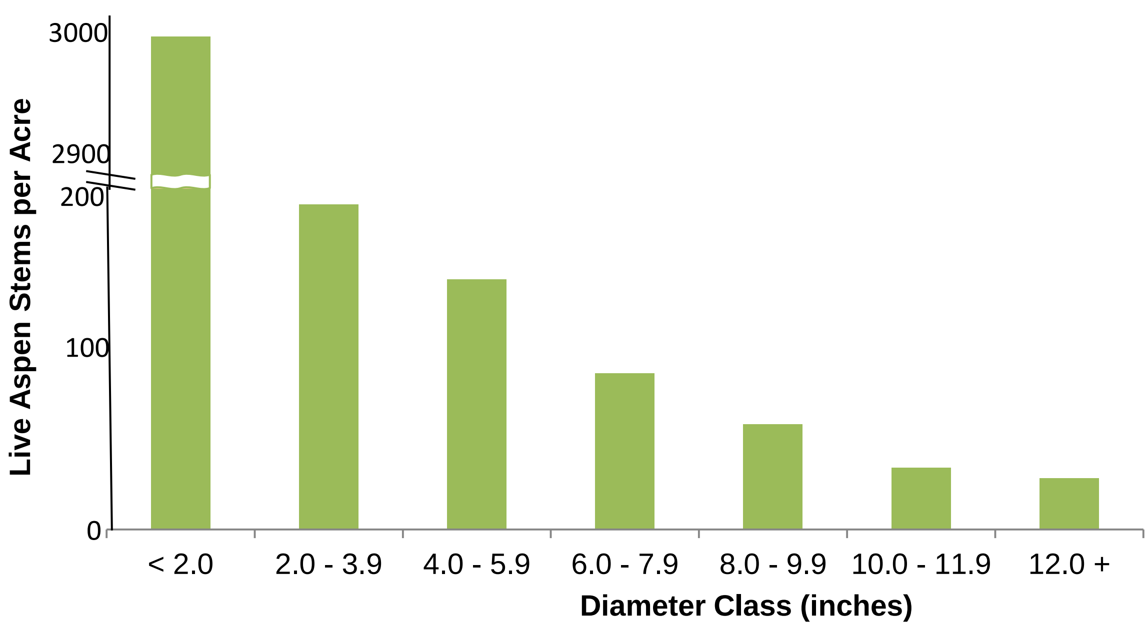

Figure. 3 . Mean stem density per acre of live aspen by 2-in. diameter classes in 76 permanent plots.

Table 4. Montana and northern Idaho aspen survey summary statistics.

	All Plots					Plots East of Continental Divide					Plots West of Continental Divide				
				Range					Range					Range	
Variable	N	Mean	Std Dev	Min.	Max.	N	Mean	Std Dev	Min.	Max.	N	Mean	Std Dev	Min.	Max.
Elevation (ft)	76	4698	1405	2265	8040	36	5739	1041	3571	8040	40	3761	962	2265	6334
Total aspen trees per acre (tpa)	76	626	470	140	2140	36	622	408	160	1520	40	630	524	140	2140
Aspen ≥ 5" dbh tpa	76	312	130	40	700	36	342	145	140	700	40	285	110	40	620
Aspen 2" - 4.9" dbh tpa	76	314	458	0	1800	36	281	393	0	1300	40	345	513	0	1800
Dead aspen tpa	76	69	104	0	600	36	61	68	0	260	40	76	129	0	600
Dead aspen ≥ 5" dbh tpa	76	23	28	0	120	36	31	28	0	100	40	16	27	0	120
Dead aspen 2-4.9" dbh tpa	76	46	104	0	600	36	31	67	0	200	40	60	128	0	600
Percent of all aspen dead	76	10.3	10.4	0.0	40.5	36	11.1	8.9	0.0	27.8	40	9.6	11.7	0.0	40.5
Basal area weighted mean aspen dbh (in)	76	8.7	3.0	3.3	16.3	36	8.1	2.4	4.1	13.9	40	9.2	3.4	3.3	16.3
Aspen sprouts per acre	76	2984	5040	0	31600	36	3511	3751	0	19100	40	2510	5978	0	31600
Percent of plots with aspen sprouts		85.5					97.2					75.0			

Table 5. Damages recorded on aspen trees and saplings in Montana and northern Idaho survey plots.

	All Plots					Plots East of Continental Divide					Plots West of Continental Divide				
				Range					Range					Range	
Variable	N	Mean	Std Dev	Min.	Max.	N	Mean	Std Dev	Min.	Max.	N	Mean	Std Dev	Min.	Max.
Percent aspen with no dieback	76	0.3	1.9	0.0	14.3	36	0.4	2.4	0.0	14.3	40	0.3	1.4	0.0	8.3
Percent aspen with light dieback	76	79.2	19.7	20.0	100.0	36	73.7	20.5	22.2	100.0	40	84.2	17.7	20.0	100.0
Percent aspen with moderate dieback	76	17.6	17.7	0.0	77.8	36	22.3	18.4	0.0	77.8	40	13.4	16.2	0.0	70.0
Percent aspen with severe dieback	76	2.6	4.9	0.0	25.0	36	3.3	6.1	0.0	25.0	40	2.0	3.4	0.0	13.3
Aspen ≥ 5" dbh with wood borer damage (%)	76	46.1	31.6	0.0	100.0	36	63.1	27.5	9.1	100.0	40	30.8	27.1	0.0	91.7
Aspen 2-4.9" dbh with wood borer damage (%)	42	33.6	35.7	0.0	100.0	22	38.6	37.3	0.0	100.0	20	28.0	33.9	0.0	100.0
Aspen ≥ 5" dbh with defoliating insects (%)	76	27.1	30.0	0.0	100.0	36	28.5	27.5	0.0	92.9	40	25.9	32.3	0.0	100.0
Aspen 2-4.9" dbh with defoliating insects (%)	42	36.9	37.2	0.0	100.0	22	46.6	39.4	0.0	100.0	20	26.3	32.4	0.0	100.0
Aspen ≥ 5" dbh with foliage dieases (%)	76	8.2	20.3	0.0	100.0	36	5.9	12.7	0.0	50.0	40	10.3	25.3	0.0	100.0
Aspen 2-4.9" dbh with foliage dieases (%)	42	13.5	28.4	0.0	100.0	22	10.4	26.5	0.0	100.0	20	16.9	30.6	0.0	100.0
Aspen ≥ 5" dbh with bark wounds (%)	76	30.3	24.3	0.0	100.0	36	23.7	22.1	0.0	77.8	40	36.3	25.0	0.0	100.0
Aspen 2-4.9" dbh with bark wounds (%)	42	36.5	37.9	0.0	100.0	22	19.1	29.8	0.0	100.0	20	55.6	37.1	0.0	100.0
Aspen ≥ 5" dbh with minor foliar insects (%)	76	3.5	14.3	0.0	92.9	36	0.4	2.0	0.0	11.8	40	6.2	19.3	0.0	92.9
Aspen 2-4.9" dbh with minor foliar insects (%)	42	11.0	26.4	0.0	100.0	22	12.2	30.4	0.0	100.0	20	9.8	21.8	0.0	90.9
Aspen ≥ 5" dbh with sooty bark canker (%)	76	13.5	17.7	0.0	81.3	36	17.6	20.4	0.0	81.3	40	9.7	14.0	0.0	64.7
Aspen 2-4.9" dbh with sooty bark canker (%)	42	11.9	25.2	0.0	100.0	22	12.4	30.6	0.0	100.0	20	11.4	18.4	0.0	60.0
Aspen ≥ 5" dbh with Cytospora canker (%)	76	6.7	10.4	0.0	52.9	36	7.3	8.7	0.0	41.2	40	6.1	11.8	0.0	52.9
Aspen 2-4.9" dbh with Cytospora canker (%)	42	14.3	21.2	0.0	100.0	22	16.3	25.4	0.0	100.0	20	12.2	15.6	0.0	40.0
Aspen ≥ 5" dbh with Phellinus stem decay (%)	76	10.8	18.7	0.0	80.0	36	10.2	17.5	0.0	77.8	40	11.4	20.0	0.0	80.0
Aspen 2-4.9" dbh with Phellinus stem decay (%)	42	4.9	17.6	0.0	100.0	22	2.3	10.7	0.0	50.0	20	7.9	22.9	0.0	100.0

Many stands in the West are becoming old and decadent. These over-mature stems become targets for insects and diseases and provide diminishing support to the clone (Shepperd et al. 2001). More than 55 damaging agents were recorded on aspen ≥2 in. dbh (Appendix B). The principal insect and disease agents and their relationships to plot characteristics are described below. Additional information for National Forests is provided in Appendix C.

Principal Insects

The most commonly recorded damages were wood boring beetles (Table 5; Fig. 4) including poplar borer (PB) (*Saperda calcarata* Say, Cerambycidae) (Fig. 5 F-J) recorded on 21.7% of stems, bronze poplar borer (BPB) (*Agrilus granulatus* Say, Buprestidae) (Fig. 5 A-D_1) on 14.1%, poplar dicera (PD) (*Dicera tenebrica* (Kirby), Buprestidae) (Fig. 5 D_2-E) on 2.2%, and unidentified/generic wood borers on 10.3%. The poplar dicera and two other, less common buprestids, *Poecilonota cyanipes* Say (eastern poplar borer) and *P. montana* Chamb. were not identified until late in the year. These buprestids emit frass from their entrance holes (as do PB) but may also have meandering galleries under the bark (like BPB), likely resulting in misidentifications among these wood borers early in the survey.

All together, wood borers were recorded on 43.6% of aspen surveyed, 46.4% of stems ≥5 in. dbh and 30.1% of stems 2-4.9 in. dbh. Wood borer damage was significantly greater east of the CD (mean basal area affected 79.8 ft^2/ac) compared to west of the CD (47.6 ft^2/ac). Greater wood borer damage was recorded in plots at higher elevations and more northern locations (P=0.0025 and P=0.0072, respectively). Wood borers were recorded on 60% of dead aspen stems. Presence of wood borer damage was not related to stem diameter (Wald χ^2=2.1, P=0.143), though this may be an artifact of combining individual wood borers into a single damage category.

The importance of wood borers, especially the buprestids, may go unnoticed as their entry wounds are often difficult to see. Their entry holes can serve as introduction points for diseases such as Cytospora canker (Jacobi and Shepperd 1991), which may further mask wood borer activity. Unfortunately, we were not able to differentiate the various wood borer species in the data. However, the literature describes a few differences among the species (see Jones et al. 1985 and Solomon 1995). All tend to focus attacks on trunks or large branches, often preferring over-mature or injured trees. The PB prefers trees growing in open or sparsely stocked stands with unshaded or partially shaded trunks, conditions often characteristic of decadent stands. Likely due to its habit of tunneling deep into wood, most stems selected by PB are 3 in. in diameter or greater, although stems as small as 1.5 in. dbh may be attacked.

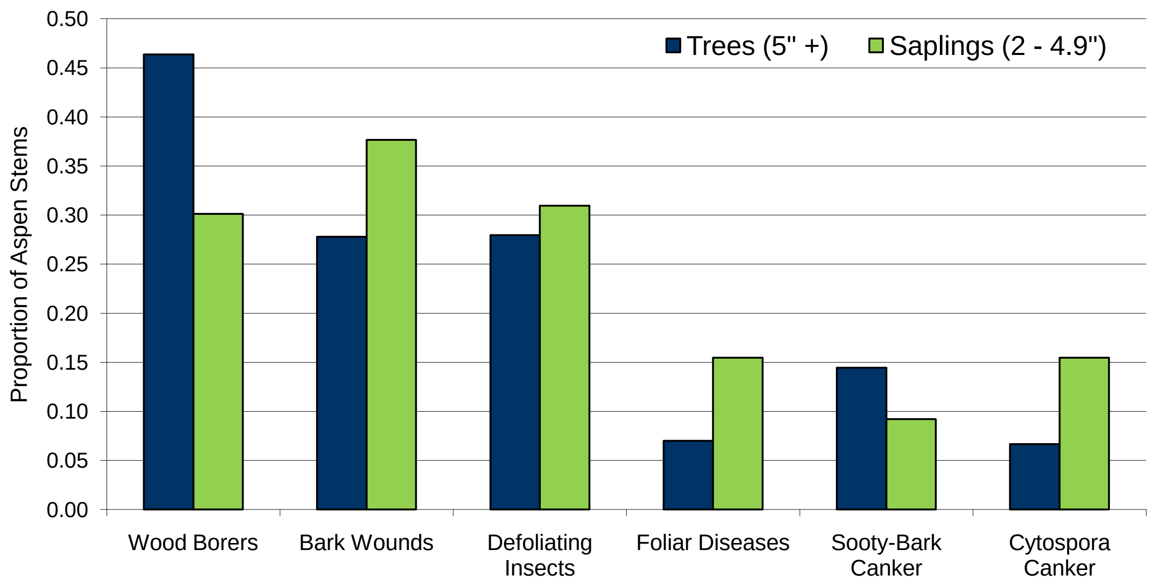

Figure 4. Most commonly recorded damaging agents on aspen trees and saplings in Montana and northern Idaho.

In addition to old and injured trees, BPB also likes young trees released from suppression by other trees. Principally a phloem feeder, BPB can be considered the most aggressive of our wood borers. The PD appears to be the least aggressive, preferring open wounds, and sick, dying, or recently dead trees. As with PB, it prefers open grown trees with trunks exposed to sunlight as might be found in decadent stands.

Defoliating insects included large aspen tortrix (*Choristoneura conflictana* [Walker]) (Fig. 6 A_2) (17.9%), aspen leaf tier (*Sciaphila duplex* [Walsingham]) (1.1%), aspen two leaf tier (*Enargia decolor* [Walker]) (Fig. 6 A_1) (6.7%), leafrollers (*Pseudexentera oregonana* [Walsingham]) (Fig. 6B) (3.6%), and forest tent caterpillar (*Malacosoma disstria* Hübner) (only on one sapling: 0.07%). Combined, these defoliators were recorded on 28.5% of aspen. Defoliation, however, can be expected to fluctuate spatially and temporally. Significantly greater mean levels of defoliator damage (Fig. 6 C) were recorded in plots with no conifer competition (mean affected basal area 57.4 ft^2/ac) compared to plots with minor conifer competition (26.6 ft^2/ac), but were not related to any other site variables.

Figure 5. Wood borers found during our survey included the bronze poplar borer (A-D_1), poplar Dicera (D_2-E), and poplar borer (F-J)

Minor foliar insects and mites included a wide range of insects that generally cause leaf deformation rather than removing large chunks of leaf tissue; leafhoppers, leaf miners, mites, and various aphid species were in this group (Fig. 6 D-K). (See Appendix B for full list.) These minor foliar insects were present on 2.6% and 10.5% of aspen trees and saplings, respectively. Both categories of defoliating insects were more commonly associated with smaller diameter aspen, likely because larger stems tended to have more serious agents. Since only three agents were recorded per tree, these defoliating and foliage-deforming insects often were not recorded. However, many of these minor insects were present at low levels on most plots (personal observations).

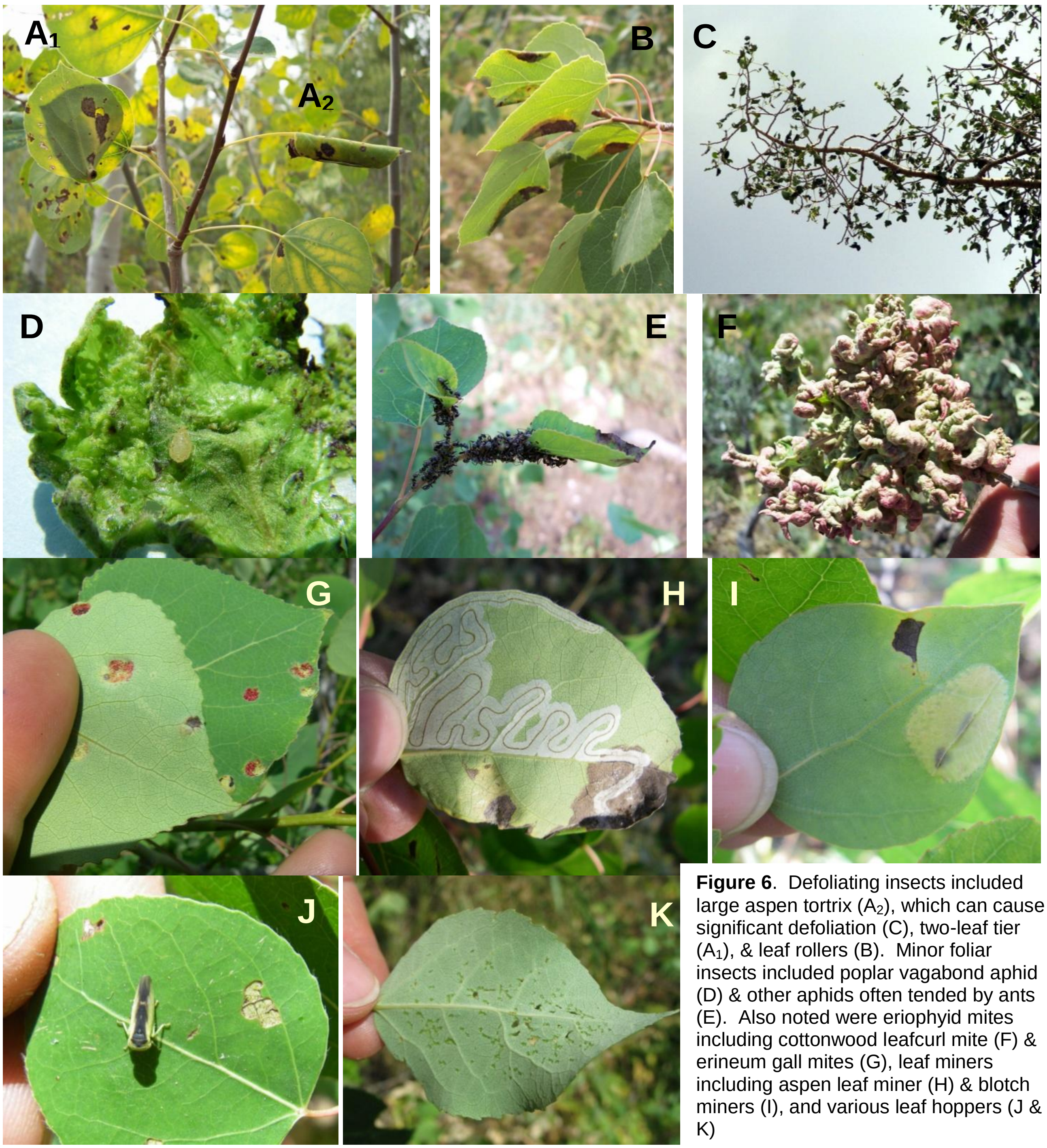

Figure 6. Defoliating insects included large aspen tortrix (A_2), which can cause significant defoliation (C), two-leaf tier (A_1), & leaf rollers (B). Minor foliar insects included poplar vagabond aphid (D) & other aphids often tended by ants (E). Also noted were eriophyid mites including cottonwood leafcurl mite (F) & erineum gall mites (G), leaf miners including aspen leaf miner (H) & blotch miners (I), and various leaf hoppers (J & K)

Principal Diseases

Two canker diseases were among the most common damaging agents infecting aspen in this study: sooty-bark canker (*Encoelia pruinosa* [Ellis & Everth.] Torkelson & Eckblad) and Cytospora canker (*Valsa soridida* Nitschke). Sooty-bark canker (Fig. 7 A-C) is considered the most deadly canker pathogen of aspen in the West (Hinds 1985). It is aggressive and can girdle and kill mature aspen in just a few years (Juzwik et al. 1978). Sooty-bark was recorded on 13.5% of aspen; 14.4% of stems ≥5 in. dbh and 9.2% of stems 2–4.9 in. dbh (Table 5). It was present on 75% of dead aspen stems, and there was a positive, though weak, correlation between presence of sooty-bark canker and presence of wood borers ($r = 0.28$, $P = 0.016$). Sooty-bark canker was also related to the proportion of trees with severe crown dieback ($P>F=0.0001$, $R^2=0.182$) and to the proportion of aspen with spike tops ($P>F=0.003$, $R^2=0.110$). Sooty-bark canker was more commonly recorded on larger diameter aspen (Wald $\chi^2=15.5$, $P<0.0001$). This supports findings from studies in Colorado that found prevalence of sooty-bark cankers increased with aspen diameter as well as age (Juzwik et al. 1978).

Cytospora canker (Fig. 7 D-F) was recorded on 8.2% of aspen; 6.7% of trees and 15.5% of saplings. This level of infection may be underestimates as many bark wounds may have been related to old canker activity, particularly Cytospora. Cytospora canker was more commonly recorded on smaller diameter aspen (Wald $\chi^2=28.1$, $P<0.0001$) (Table 5). Past studies also found Cytospora common on small trees or branches of larger trees (Guyon et al. 1996). It typically kills only those trees under significant stress from environmental conditions (Guyon et al. 1996) or other damaging agents, and is not thought to occur on healthy, vigorous, or undamaged trees.

Black canker, (Fig. 7 G-H) caused by *Ceratocystis fimbriata* Ellis & Halst., is considered the most common aspen canker in the West following Cytospora (Hinds 1985). Through our surveys of aspen stands in Montana and northern Idaho, black canker was recorded on only 3.1% of aspen. Nevertheless, in plots where it was present it often caused considerable damage to the infected tree.

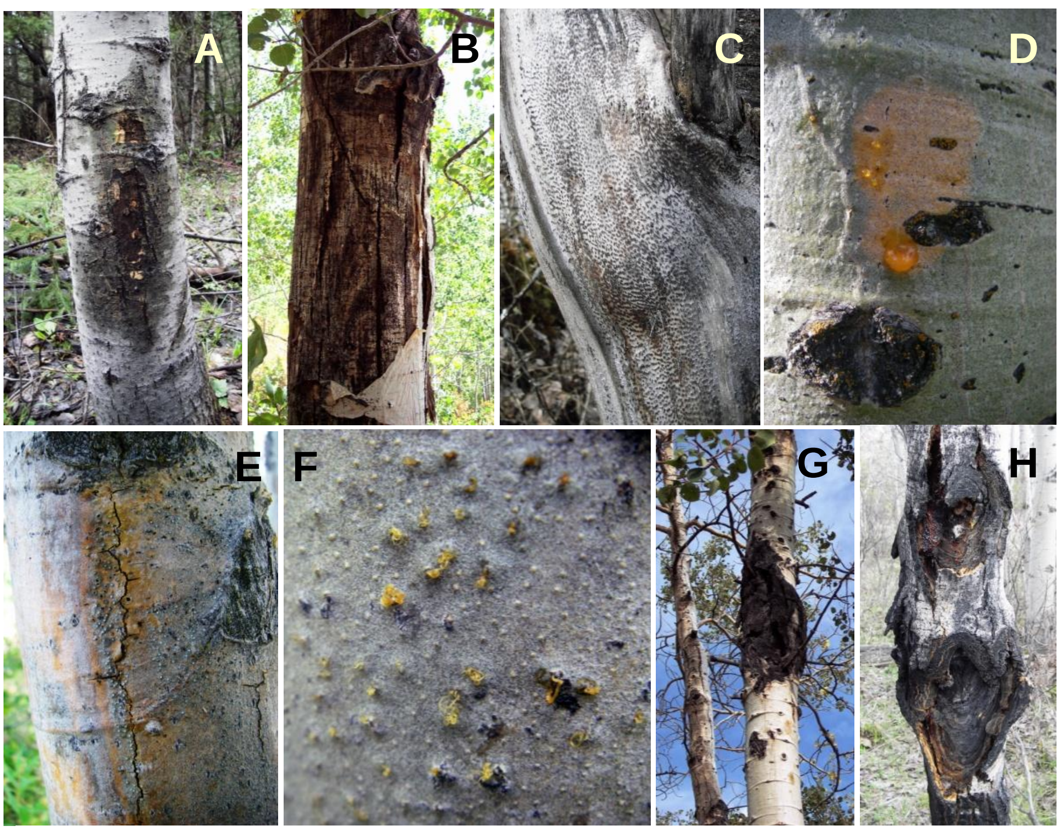

Figure 7. Principle cankers were sooty-bark (A-C), Cytospora (D-F), and black canker (G-H).

Ink spot (*Ciborinia whetzelii* [Seaver] Seaver) (Fig. 8 A-B) and Marssonina leaf blight (*Marssonina sp.*) (Fig. 8 C) foliar diseases were found infecting 8.4% of aspen and were more common on saplings (15.5%) than trees (7.0%). Foliar diseases affected significantly more aspen basal area in stands with no conifer competition (30.8 ft^2/ac) than stands with minor conifer competition (7.3 ft^2/ac). Damage by foliar diseases is usually limited to premature defoliation, which can result in growth reduction in severely infected trees. Small trees can be killed after years of repeated defoliation (Hinds 1985). In general, the fungi that cause foliar diseases are favored by abundant rainfall in the spring and summer, and smaller trees and the lower crowns of bigger trees are most heavily infected. In this study, foliar diseases were more common on smaller diameter aspen (Wald χ^2=10.5, P=0.001).

Stem decay fungi were recorded on 10% of surveyed aspen (Appendix B). Aspen trunk rot caused by *Phellinus tremulae* (Bondartsev) Bondartsev & Borisov (Fig. 8 D-F) is the most common decay of aspen in North America and was the most frequently recorded decay organism. *Phellinus tremulae* was recorded on 8.7% of aspen stems, 9.9% of aspen trees and 2.9% of aspen saplings. It was most frequently recorded on larger diameter aspen (Wald χ^2=56.4.5, P<0.0001), which is typical for stem decay fungi that are known to cause increasing volume losses with increasing stem age. The frequency of infection by stem decay fungi in this survey is likely underestimated because it was determined solely by observation of external signs, such as conks, and no dissection of stems occurred. Unfortunately, there are often no external indicators of decay making it difficult to predict its internal presence.

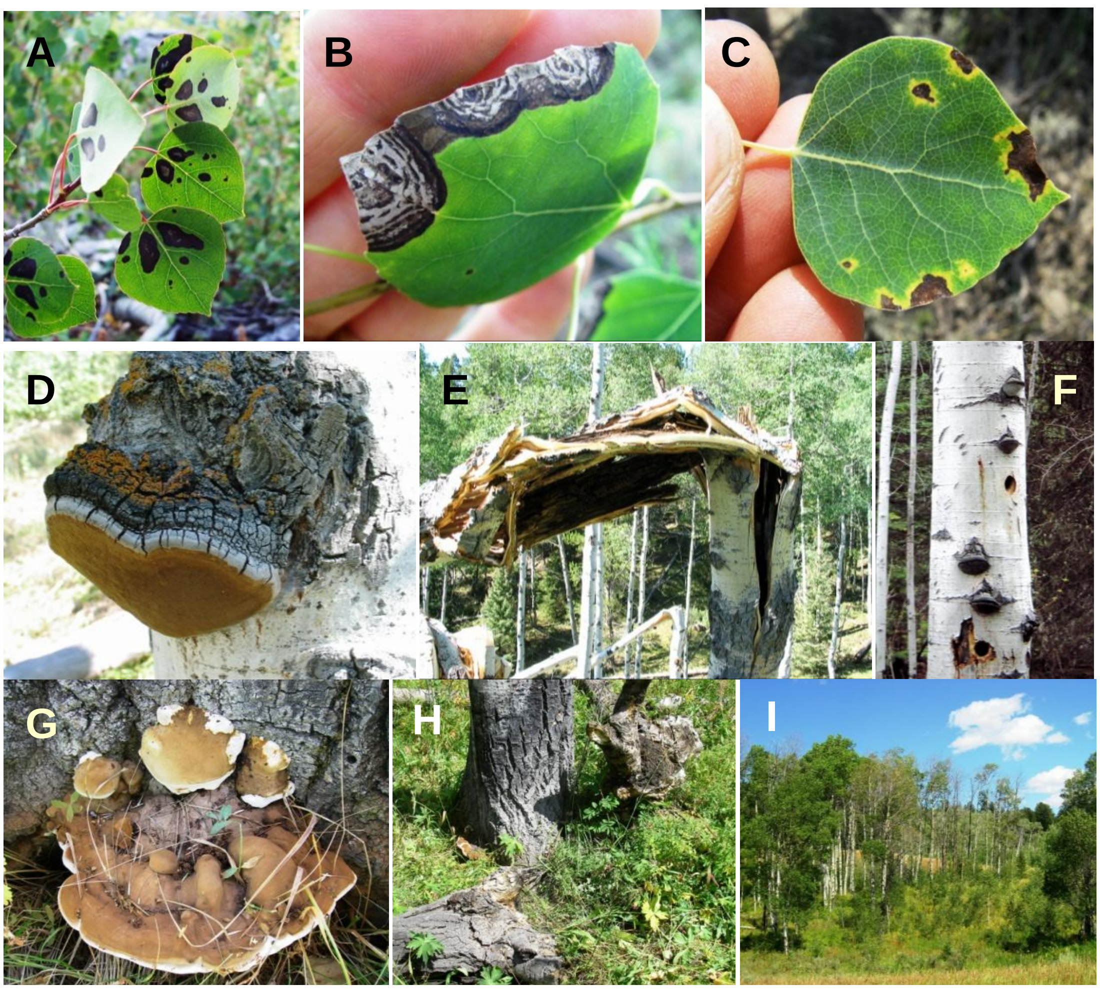

Figure 8. Principle foliar diseases included ink spot (A-B) and Marssonina leaf blight (C). Aspen trunk rot was the main agent causing stem decay (D-F). Although not common, the stands where we found white-mottled root/butt rot were severely affected (G-I).

Root diseases can be a serious health issue in aspen clones. *Ganoderma applanatum* (Pers.) Pat. (Fig. 8 G-I), also known as artist's conk, causes a white-mottled root and butt rot and is a common cause of windthrow in aspen stands. Only one aspen infected by Ganoderma was recorded in the plots established in this study, although several aspen clones with mortality and windthrow attributable to Ganoderma were observed in the vicinity of Earthquake Lake on the Gallatin NF (Fig. 8 I).

Armillaria solidipes Peck (a currently recognized older name for *A. ostoyae*) causes a yellow-white stringy root and butt decay that results in chlorosis, premature defoliation, and reduced shoot growth, as well as mortality and windthrow. Armillaria was rarely observed through the course of this survey and was reported on two aspen saplings. Plot selection criteria (min. seven live aspen stems ≥5 in. dbh) for this study would have likely precluded the establishment of permanent plots in root disease centers.

Other Biotic and Abiotic Agents

Bark wounds were recorded on 27.8% of aspen trees and 37.7% of aspen saplings (Fig. 4) (see Table 5). This category includes mechanical damage and wounds caused by wind, sapsucker feeding, and other animal damage such as clawing, debarking, and rubbing (Fig. 9 A-F). Significantly greater aspen basal area with bark wounds was recorded west of the CD (52.2 ft^2/ac) than east of the CD (28.9 ft^2/ac) ($P<0.05$). Aspen bark, because it is thin and alive, is very susceptible to wounding. While bark wounding itself will rarely kill mature aspen, the wounds can serve as entry points for pathogens, especially canker-causing fungi (Hinds 1985).

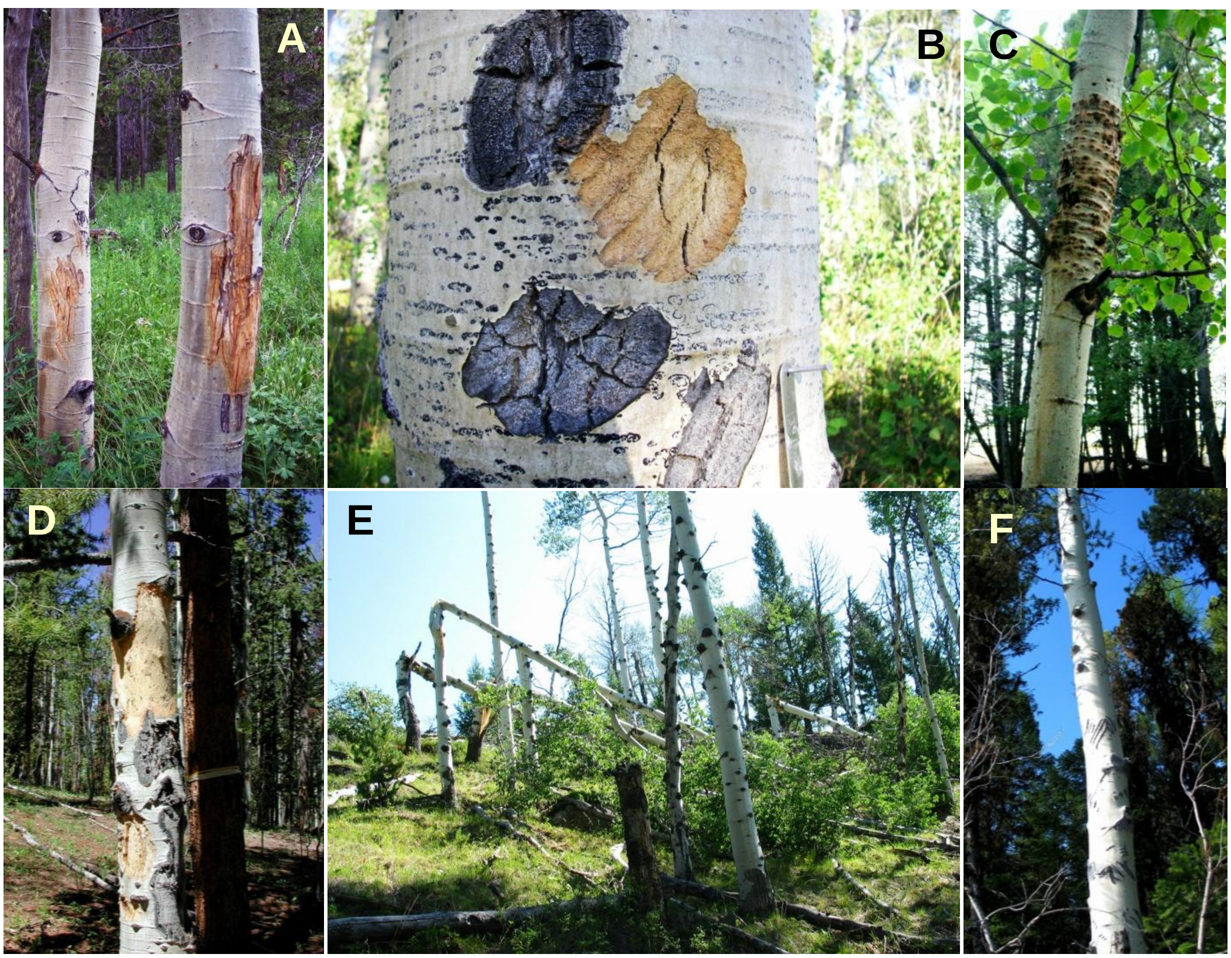

Figure 9. Many agents can cause bark and cambium damage from ungulate rubbing and chewing (A-B), sapsucker pecking (C), bear feeding and clawing (D,F), and wind (E).

Regeneration

Aspen regeneration was present on 86% of plots. Aspen sprout densities ranged from 0 to 31,600 sprouts per acre (spa); 46% of plots had 1,500 or more spa. Plots east of the CD had an average of 3,511 spa while plots west of the CD had an average of 2,510 spa, but those densities were not significantly different. Although dead sprouts cannot be separated from live in our data, the percentage of dead was low (personal observation). Seedlings of tree species other than aspen were also present on 53% of plots with densities ranging from 0 to 5300 seedlings per acre. What constitutes a stand of healthy regeneration in terms of spa is unclear. However, with several plots having no measured regeneration and others with numbers well above 2,500, it is clear we have a range of conditions. Although the count of live and dead sprouts cannot be separated in this study, agent severity often reflects the level of mortality attributed to that agent; agents attributed with causing sprout mortality were given the highest severity ranking.

Principal Insects

Defoliating insects were found damaging aspen sprouts on 32% of plots, and 10% of all sprouts had damage from these leaf eaters (Fig. 10). Most defoliators on regeneration were the same as those seen in the canopy of saplings and trees (Fig. 6 A-C). As with the larger stems, we did not see outbreak activity in the regeneration by any of the defoliating insects during our survey.

Minor foliar insects were recorded on 9% of sprouts (Fig. 6 D-K). As noted with the trees and saplings, impact of these insects is relatively low. Their unusual activity can sometimes draw attention, and if present in large numbers on a small sprout they can have an impact on sprout health (Jones et al. 1985).

Principal Diseases

Aspen shoot blight (*Venturia macularis* (Fr:Fr) E. Muller & Arx) was recorded on 33% of plots and 16% of aspen sprouts (Fig. 10 and 11 A-C). Shoot blight differs from other foliar diseases in that it is not restricted to the leaf. It also causes dieback of new terminal shoots and can kill aspen suckers (Hinds 1985). Significantly greater proportions of aspen sprouts were damaged by shoot blight in plots east of the CD (19%) compared to plots west of the CD (3.5%) ($P<0.05$). Of the 25 plots where shoot blight was infecting aspen sprouts, 3 had associated damage rated at the highest severity indicating that shoot blight was causing sprout mortality.

Foliar diseases, including ink spot and Marssonina leaf blight (Fig. 8 A-C), were present on 51% of plots and affected 28% of aspen sprouts (Fig. 10). The severity of damage to regeneration by foliar diseases was rated as low or moderate on all plots.

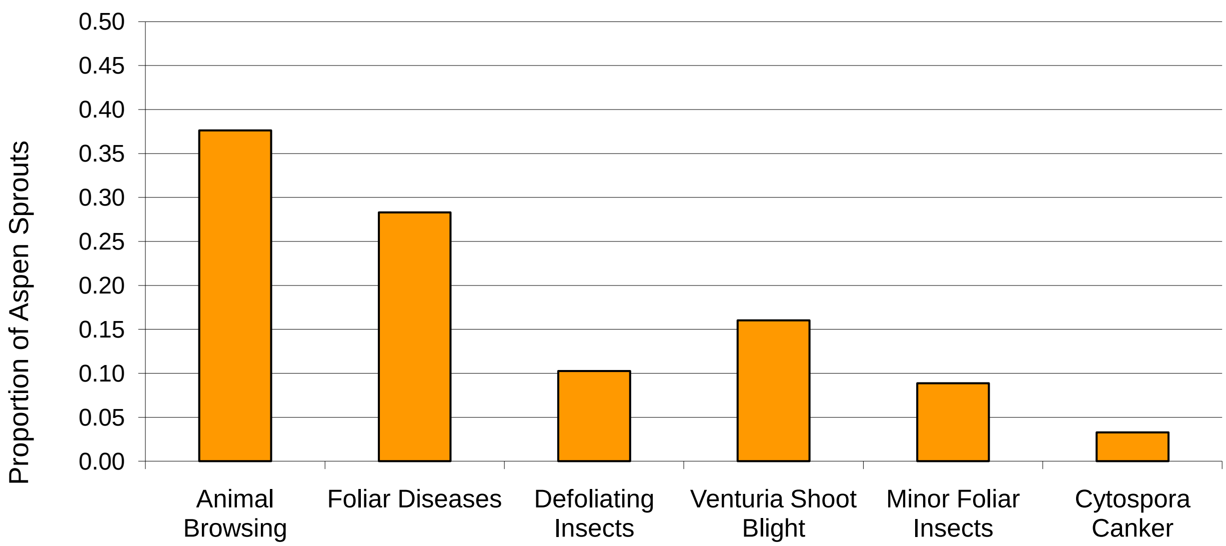

Figure 10. Most commonly recorded damaging agents on aspen sprouts in Montana and northern Idaho.

Cytospora canker (Fig. 7 D-F) was present on 3% of aspen sprouts. Although Cytospora canker was not frequently recorded, it was given the highest severity rating in 10 of the 16 plots on which it was present. Although generally considered a secondary agent, this indication of significant damage attributable to Cytospora canker likely denotes aspen sprouts growing under stress with abundant opportunities for injuries to their bark. Every instance of Cytospora canker rated at the highest severity level in our plots was accompanied by damage by other agents including Venturia shoot blight, animal browsing, and animal rubbing.

Other Biotic and Abiotic Agents

Browse damage (Fig. 11 D-F) was the most commonly recorded damage to aspen sprouts (Fig. 10). It was present on 64% of plots (75% of plots with aspen sprouts) and affected 38% of aspen sprouts. Significantly greater proportions of aspen sprouts had browse damage in plots east of the CD (40.1%) compared to plots west of the CD (20.1%). Of the 65 plots with aspen sprouts, 27 had one or more subplots on which browsing had the highest severity ranking.

Although no attempt was made to identify the animals responsible for browse damage, evidence of livestock, elk, and deer activity were noted. Browse damage is known to reduce the health, vigor, growth, and density of aspen regeneration (DeByle 1985; Shepperd and Fairweather 1993; Wooley et al. 2008). In some areas, heavy ungulate pressure has been blamed for stand regeneration failure (Forest Service 1999). Not only does grazing remove the new shoots necessary to feed the clone, but browsing damage from trampling, nipping, or otherwise wounding the trees provides an avenue for introduction of Cytospora canker (Jacobi and Shepperd 1991).

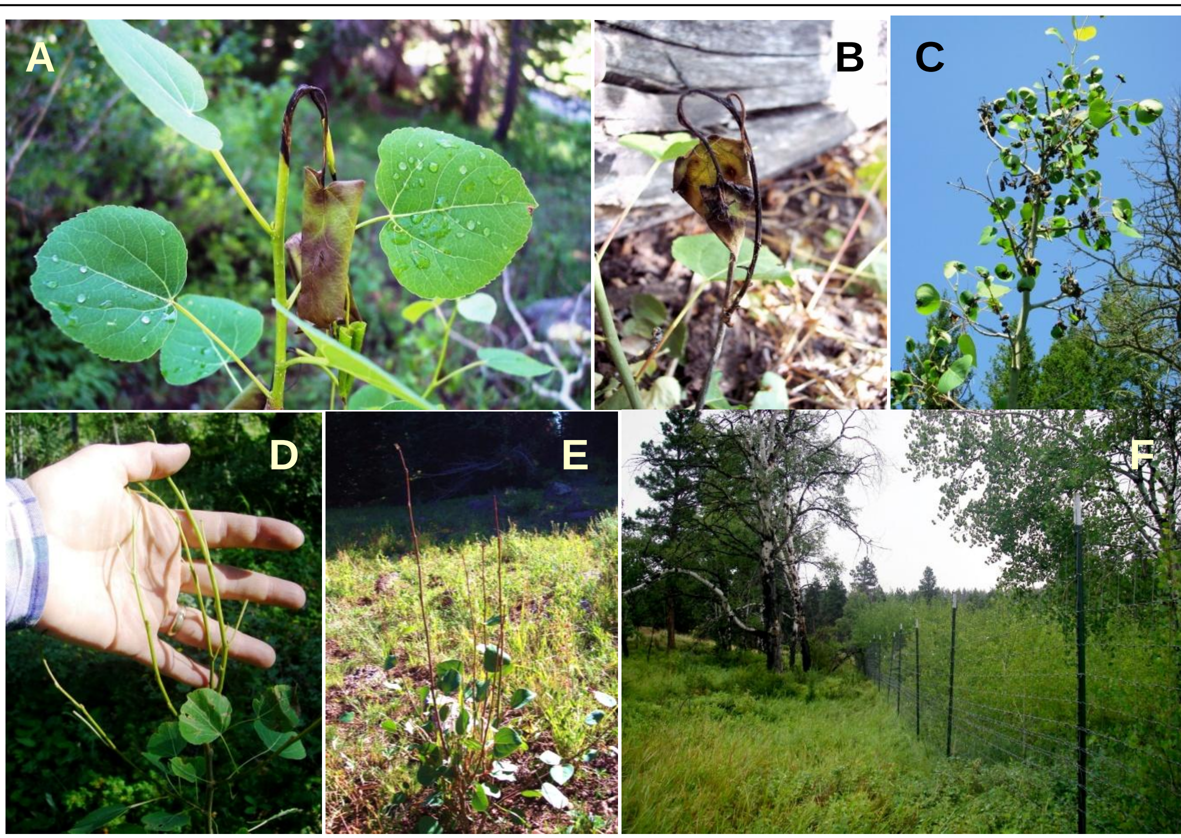

Figure 11. Both Venturia shoot blight (A-C) and grazing (D-E) can cause significant damage to regeneration.

Conclusion

Our results suggest that rapid stand decline noted in other regions (SAD) is not prevalent in Montana and northern Idaho. We observed only low levels of mortality within plots, and it appeared to have occurred over many years rather than suddenly. Plot selection may have biased our surveys against dying stands, which likely would not have met the minimum threshold of 7 large stems within plot. However, in our travels we saw few stands with heavy, recent die-off. A couple stands south of Ennis, MT on the eastern edge of the Gravelly Range appeared to have most overstory stems with graying crowns, but no surveys were conducted due to lack of access. In the same general vicinity, NE of Earthquake Lake, other highly degraded stands were found to have significant infection by Ganoderma root disease. To better determine the health of our study stands, root condition surveys would probably need to be conducted (see Shepperd et al. 2001).

Although not sudden, Montana and northern Idaho appear to be experiencing aspen decline. In the absence of fire, advancing succession with increased conifer encroachment and aspen's increased susceptibility to diseases and insects has resulted in declining aspen stands. In addition, heavy ungulate grazing detected where regeneration was present, has resulted in stands that appear unable to regenerate themselves. If climate change results in less precipitation and higher temperatures, we could find recurring drought to be an important factor in future mortality (Rehfeldt et al. 2009; Hogg et al. 2008). Some authors suggest that extreme drought events provide a stimulus for mortality, adding the 'sudden' factor into previously slow declines (Rehfeldt et al. 2009).

Without fire, aspen stands in the West are often invaded by conifer species, which will predominate after 80-120 years (Hinds 1985; Mueggler 1994). Mixed aspen stands may have up to 50% of the stocking in coniferous species, without apparent detrimental effect to the below-ground root system. Above this level, impacts to aspen stem growth can be significant (Shepperd et al. 2001). In fact, conifer competition has been noted as a principle cause of decline in western aspen stands (Bartos 2001). West of CD, our aspen stands tended to be small, isolated patches surrounded by heavily encroaching conifers. Stands to the east had less conifer competition and tended to be larger in area. Nevertheless, Wirth and others (1996), evaluating aspen east of CD in southwest MT (Gravelly Range), found an approximately 47% decline in aspen area from 1947-1992, largely attributable to conifer invasion.

Sprouting can occur in stands with significant conifer competition. However, many of these areas also have high ungulate pressure and slower sprout growth rates, resulting in significant sprout loss and energy cost to the already stressed clone (DeByle 1985, Shepperd et al. 2001). These same ungulates can also cause bark damage from antler rubbing and bark chewing leading to damage and death of trees otherwise too large to be browsed. These stressors help lead to the ultimate demise of aspen within conifer stands.

Future work related to this study may include remeasurement of these permanent plots to determine change in aspen condition over time. A field guide to identify the many biological agents that affect aspen is also under construction and should be available in the near future. In addition, we are also collaborating with other studies to look at climate impacts on observed aspen mortality and decline throughout the western United States.

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Photograph Acknowledgements

DESCRIPTION	PHOTOGRAPHER	LOCATION
Title header	H. Kearns	Gallatin NF
Figure 5 A	T. Zegler	Region 4
Figure 5 B	T. Zegler	Region 4
Figure 5 C	T. Zegler	Region 4
Figure 5 D	B. Steed	Gallatin NF (2)
Figure 5 E	B. Steed	Lewis & Clark NF (7)
Figure 5 F	T. Zegler	Custer NF (4)
Figure 5 G	T. Zegler	Region 4
Figure 5 H	T. Zegler	Region 4
Figure 5 I	B. Steed	Gallatin NF (6)
Figure 5 J	T. Zegler	Helena NF (1)
Figure 6 A	T. Zegler	Region 4
Figure 6 B	T. Zegler	Region 4
Figure 6 C	M. Loewen	
Figure 6 D	B. Steed	Missoula area
Figure 6 E	T. Zegler	Region 4
Figure 6 F	T. Zegler	Region 4
Figure 6 G	B. Steed	Lewis & Clark NF (0)
Figure 6 H	B. Steed	Region 4 (sID)
Figure 6 I	B. Steed	Beaverhead-Deerlodge NF (9)
Figure 6 J	B. Steed	Beaverhead-Deerlodge NF (9)
Figure 6 K	B. Steed	Beaverhead-Deerlodge NF (9)
Figure 7 A	B. Steed	Lolo NF (5)
Figure 7 B	T. Zegler	Region 4
Figure 7 C	B. Steed	Blackfoot Nature Conservancy (1)
Figure 7 D	B. Steed	Lewis & Clark NF (6)
Figure 7 E	B. Steed	Beaverhead-Deerlodge NF (10)
Figure 7 F	T. Zegler	Lewis & Clark NF (4)
Figure 7 G	T. Zegler	Region 4
Figure 7 H	B. Steed	Blackfoot Nature Conservancy (2)
Figure 8 A	T. Zegler	Region 4
Figure 8 B	B. Steed	Charles M. Russell NWR
Figure 8 C	B. Steed	Charles M. Russell NWR
Figure 8 D	B. Steed	Beaverhead-Deerlodge NF (Ennis RD)
Figure 8 E	B. Steed	Beaverhead-Deerlodge NF (Ennis RD)
Figure 8 F	B. Steed	Lolo NF (5)
Figure 8 G	B. Steed	Gallatin NF (6)
Figure 8 H	B. Steed	Gallatin NF (6)
Figure 8 I	B. Steed	Gallatin NF (6)
Figure 9 A	T. Zegler	Region 4
Figure 9 B	B. Steed	Beaverhead-Deerlodge NF (9)
Figure 9 C	B. Steed	Beaverhead-Deerlodge NF (Fleecer)
Figure 9 D	B. Steed	Region 4 (NE Utah; Mtn Home)
Figure 9 E	B. Steed	Beaverhead-Deerlodge NF (Ennis RD)
Figure 9 F	B. Steed	Lolo NF (4)
Figure 11 A	T. Zegler	Region 4
Figure 11 B	T. Zegler	Region 4
Figure 11 C	B. Steed	Lewis & Clark NF (0)
Figure 11 D	B. Steed	Lewis & Clark NF (6)
Figure 11 E	T. Zegler	Region 4
Figure 11 F	B. Steed	Helena NF (3)

Appendix A: Definitions of data collected

HEADER DATA	
Plot #	4-letter land manager code (e.g. BHDL = Beaverhead-Deerlodge National Forest) + 2-number identifier
Date	mm/dd/yyyy
Crew	initials of all crew members
State	2 letter state code (MT=Montana, ID=Idaho)
County	county
Ownership	land manager (FS=Forest Service, IR=Indian Reservation, NC=Nature Conservancy)
NF/RD/FO	name of National Forest, Ranger District, Field Office, etc.
T/R/Sec (optional)	Township / Range / Section
maps (optional)	name of best map for locating site
GPS parking	NAD83, UTM coordinate of good parking spot
GPS other pts (optional)	NAD83, UTM coordinate of other important points, especially for locating or accessing plot
GPS plot center	NAD83, UTM coordinate of plot center (stake)
GPS center elevation	plot center elevation in feet above sea level per GPS coordinate
Primary tree sp	4-letter genus-species code of dominant tree species (over and understory combined)
Secondary tree sp	4-letter genus-species code of secondary tree species (over and understory combined)
Slope	slope in degrees as average of values looking upslope and down slope from center
Aspect	aspect in degrees
Slope position	RIDGE TOP or SLOPE or VALLEY BOTTOM
Stand direction	RETREATING (minimal aspen regeneration), STABLE (significant aspen regeneration within stand), EXPANDING (aspen regeneration outside as well as inside of stand)
Conifer competition	NONE (no conifers in dominant or co-dominant and little to no conifer regeneration), MINOR (conifers in stand but usually <25% in co-dominant or dominant), SEVERE (if conifer competition affecting stand condition; usually >25% of dominant or co-dominant))
Successional status	NON-SUCCESSIONAL (expected to remain as an aspen-dominated stands for many years to come), SUCCESSIONAL (barring disturbance stand likely to continue succession toward being conifer-dominated; conifer competition would likely have to be 'yes')
Expected future forest type	4-letter genus-species codes of the principle tree species likely to dominate site barring disturbances (often includes any non-aspen species listed in primary or secondary tree species
Photographs taken	all plots have 5 photos minimum (toward center showing stake, from stake looking N, E, S, and W); also agent photos or others of interest
TREE and SAPLING DATA:	
Tree species	4-letter genus-species code (e.g. POTR5 for *Populus tremuloides* or PSME for *Pseudotsuga menziesii*)
ID	tag number for TREES (tags placed at DBH and facing toward center starting with trees at N and working clockwise) : subplot number (angle from center: 0, 120, 240) + 2-number count (e.g. 01, 02) for SAPLINGS
DBH	diameter at breast height (DBH) (4.5 feet) recorded in inches
Dieback	determined as the percentage of crown that should be alive that is not categorized into one of four classes: 0=no dieback (rare); 1=<33% of crown lost (most common), 2=33-66% of crown lost, 3=>66% of crown lost (not common)
Tree Condition	0=live tree, 1=recently dead (bark still attached), 2=older dead (bark detaching or detached)
Crown Class	dominant, co-dominant, intermediate, suppressed, open grown, or spike topped (broken or dead top)
Damage 1	identification number of damage agent that is having or has had the greatest impact on future survival
Severity 1	rating of 1 to 3 with 1=light damage of cambium over <33% of circumference, 2=moderate damage of cambium over 33=66% of circumference, 3=heavy damage, often resulting in death, of <66% of circumference of cambium
Damage 2	identification number of damage agent that is having or has had the second greatest impact on future survival
Severity 2	(as with Severity 1)
Damage 3	identification number of damage agent that is having or has had the third greatest impact on future survival
Severity 3	(as with Severity 1)
REGENERATION DATA:	
Tree species	4-letter genus-species code (e.g. POTR5 for *Populus tremuloides* or PSME for *Pseudotsuga menziesii*)
Degree	subplot angle from center (0, 120, or 240)
SeedCount	number of seedlings, live and dead, <2-inches diameter with no minimum height requirement
Damage 1	identification number of damage agent that has greatest impact on the greatest number of stems
Dam1%	percentage of seedlings with this damage agent present
Severity 1	average severity rating for seedlings with this first damage agent [=(#stems with severity1 x 1) + (# stems with severity2 x 2) + (# stems with severity3 x 3) / # stems with agent present]
Damage 2	identification number of damage agent with second greatest impact on greatest number of stems
Dam2%	(as with Damage1%)
Severity 2	(as with Severity 1)
Damage 3	identification number of damage agent with third greatest impact on greatest number of stems
Dam3%	(as with Damage1%)
Severity 3	(as with Severity 1)

Appendix B. A list of damage agents found east (eMT) and west (wMT/nID) of the Continental Divide

TYPE	SCIENTIFIC NAME	DAMAGE GROUP	eMT	wMT / nID
DISEASES				
Foliar & Shoot				
GENERIC-Foliar Fungus		FOLIAR DISEASE		SR
Ink Spot	*Ciborinia whetzelii*	FOLIAR DISEASE	TSR	TSR
Shoot Blight	*Venturia macularis*	VENTURIA	SR	TSR
Melampsora Rust	*Melampsora medusae*	FOLIAR DISEASE		T
Marsonnina Leaf Spot	*Marssonina sp.*	FOLIAR DISEASE	TSR	TSR
Cankers				
GENERIC-Canker			TS	TS
Sooty-Bark Canker	*Encoelia pruinosa*	SOOTY BARK	TSR	TS$_D$R
Black Canker	*Ceratocystis fimbriata*		T	T
Nectria Canker	*Nectria galligena*		TS$_D$	
Snake Canker	*Cryptosphaeria populina*			T
Cytospora Canker	*Valsa sordida (Cytospora chrysosperma)*	CYTOSPORA	TSR	TSR
Aspen Rough Bark Disease	*Diplodia tumefaciens, Rhytidiella baranyayi, Curcubitaria staphula, etc.*		T	T
Root and Butt				
GENERIC-R&B Rot			T$_D$	
White Mottled Rot	*Ganoderma applanatum*		T	E
Armillaria Root Disease	*Armillaria solidipes*			S
Stem Decay				
GENERIC-Stem Decay			T	T
White Trunk Rot	*Phellinus tremulae*		TS	TS
Scaly Pholiota	*Pholiota squarrosa*		T$_D$	
Oyster Mushroom	*Pleurotus ostreatus*		T$_D$	T$_D$
Peniophora	*Peniophora polygonia*			T
Coal Fungus	*Daldinia concentrica*		T	
Inky Cap	*Coprinus atramentarius*		T	T
Red belt	*Fomitopsis pinicola*			T
Bacterial Wetwood	(many)		T	T
Silver Leaf Disease	*Chondrostereum purpureum*			R

T=ON TREES >5"	
S=ON SAPLINGS 2-5"	
R=ON REGENERATION SPROUTS <2"	
E=SEEN IN REGION BUT NOT CAPTURED IN PLOT DATA	
$_D$=SEEN ONLY ON DEAD TREES	
Recorded as high as primary agent	TSR
Recorded as high as secondary agent	TSR
Recorded only as high as tertiary agent	TSR
*Species confirmed professionally	

TYPE	SCIENTIFIC NAME	DAMAGE GROUP	eMT	wMT / nID
INSECTS				
Borers				
GENERIC-Stem Borer	(C=cerambycidae; B=buprestidae)	WOOD BORER	TS	TS
Poplar Borer	*Saperda calcarata* (C)	WOOD BORER	TS	TS
Bronze Poplar Borer	*Agrilus granulatus** (B)	WOOD BORER	TSR	TS
Poplar Dicera &	*Dicera tenebrica**	WOOD BORER	TS	S
Eastern Poplar Borer	*Poecilonote cyanipes**			
	*P. montanus**			
GENERIC-Branch borer			T	T
Twig Gall Fly	*Hexomyza schineri*		R	R
Poplar Gall Saperda	*Saperda inornata & S. populnea* (C)		T	S
Poplar Branch Borer	*Oberea schaumii* (C)		T	
Poplar Butt Borer	*Xylotrechus obliteratus* (C)		T	
Bark Beetle	*Procryphalus mucronatus**		T$_D$S	
Ambrosia Beetle	*Typodendron retusum**		TS	TS$_D$
A Bark-Mining Fly	(unidentified)		E	E
Foliar				
GENERIC-Foliar Insect			TR	TR
Large Aspen Tortrix	*Choristoneura conflictana*	DEFOLIATING INSECT	TSR	TSR
Aspen Leaf Tier	*Sciaphila duplex*	DEFOLIATING INSECT	TSR	TSR
Aspen Two-Leaf Tier	*Enargia decolor*	DEFOLIATING INSECT	TSR	TSR
Leafrollers	*Pseudexentera oregonana*	DEFOLIATING INSECT	TSR	TSR
Forest Tent Caterpillar	*Malacosoma disstria*	DEFOLIATING INSECT	E	S
Salt and Pepper Moth	*Biston cognataria*		E	
Leafhoppers	(various)	MINOR FOLIAR INSECT	TSR	TSR
Aspen Leaf Miner	*Phyllocnistis populiella*	MINOR FOLIAR INSECT	R	TSR
Aspen Blotchminer	*Phyllonorycter tremuloidiella*	MINOR FOLIAR INSECT	E	
Poplar Aphid	(2 or more species possible)	MINOR FOLIAR INSECT	R	R
Eriophyid Gall Mite	Acari: Eriophyidae	MINOR FOLIAR INSECT	SR	TSR
Cottonwood Leaf-Curl Mite	*Aculus lobulifera*	MINOR FOLIAR INSECT	R	
Poplar Petiole Gall	*Pemphigus populitransversus*		TR	R
Spittle Bugs	Cercopidae (*Clastoptera* sp?)		E	
BIOTIC/ABIOTIC				
Fire			T	T
Frost	(note 'crack' or 'foliar')		T	TS
Sunscald			R	
Broken Top			TS$_D$	TSR
Mechanical		BARK WOUNDS	TSR	TSR
Beaver			E	E
Wildlife Home/Hole			T	T
Sapsucker		BARK WOUNDS	T	TS
Animal-Rubbing		BARK WOUNDS	TSR	TSR
Animal-Debarking		BARK WOUNDS		T
Animal-Trampling		BARK WOUNDS	R	R
Animal-Browsing		ANIMAL BROWSING	R	R
Animal-Clawing		BARK WOUNDS	T	TS
Other Animal		BARK WOUNDS	T	

Appendix C. Plot means by National Forest

	Beaverhead-Deerlodge NF Plots					Bitterroot NF Plots				
				Range					Range	
Variable	N	Mean	Std Dev	Min.	Max.	N	Mean	Std Dev	Min.	Max.
Elevation (ft)	10	6843	637	5835	8040	4	4786	933	3621	5906
Total Aspen tpa	10	962	638	180	1820	4	430	310	140	780
Aspen ? 5" dbh tpa	10	352	140	180	660	4	230	74	140	300
Aspen 2" - 4.9" dbh tpa	10	610	657	0	1500	4	200	245	0	500
Dead aspen tpa	10	110	182	0	600	4	85	114	0	240
Dead Aspen ? 5" dbh tpa	10	20	25	0	60	4	10	20	0	40
Dead Aspen 2-4.9" dbh tpa	10	90	191	0	600	4	75	96	0	200
Percent of all aspen dead	10	10.4	10.5	0.0	33.0	4	11.9	14.9	0.0	30.8
Basal area weighted mean aspen dbh (in)	10	7.7	2.6	4.4	11.8	4	10.9	3.9	7.0	16.3
Aspen sprouts per acre	10	3840	4236	100	11500	4	1750	2299	200	5100
Percent of plots with aspen sprouts		100					100			
Percent aspen with no dieback	10	0.0	0.0	0.0	0.0	4	0.0	0.0	0.0	0.0
Percent aspen with light dieback	10	76.3	14.8	50.0	96.6	4	83.3	14.7	66.7	100.0
Percent aspen with moderate dieback	10	18.4	11.0	3.4	40.0	4	11.9	9.0	0.0	20.0
Percent aspen with severe dieback	10	5.3	6.0	0.0	16.7	4	4.8	6.3	0.0	13.3
Aspen ? 5" dbh with wood borer damage (%)	10	52.6	23.0	18.2	92.3	4	14.0	20.2	0.0	42.9
Aspen 2-4.9" dbh with wood borer damage (%)	6	25.5	21.4	0.0	54.5	2	10.0	14.1	0.0	20.0
Aspen ? 5" dbh with defoliating insects (%)	10	19.8	20.8	0.0	64.7	4	35.0	43.6	0.0	90.0
Aspen 2-4.9" dbh with defoliating insects (%)	6	46.7	37.0	9.1	100.0	2	33.3	47.1	0.0	66.7
Aspen ? 5" dbh with foliage dieases (%)	10	1.0	2.1	0.0	5.6	4	20.4	34.4	0.0	71.4
Aspen 2-4.9" dbh with foliage dieases (%)	6	0.0	0.0	0.0	0.0	2	0.0	0.0	0.0	0.0
Aspen ? 5" dbh with bark wounds (%)	10	40.6	26.1	5.9	77.8	4	23.7	22.4	10.0	57.1
Aspen 2-4.9" dbh with bark wounds (%)	6	20.5	28.7	0.0	76.9	2	50.0	70.7	0.0	100.0
Aspen ? 5" dbh with minor foliar insects (%)	10	0.5	1.5	0.0	4.8	4	19.6	34.7	0.0	71.4
Aspen 2-4.9" dbh with minor foliar insects (%)	6	5.9	6.8	0.0	14.3	2	20.0	28.3	0.0	40.0
Aspen ? 5" dbh with sooty bark canker (%)	10	16.4	23.8	0.0	78.3	4	20.6	24.2	0.0	46.7
Aspen 2-4.9" dbh with sooty bark canker (%)	6	23.8	41.1	0.0	100.0	2	26.7	9.4	20.0	33.3
Aspen ? 5" dbh with *Cytospora* canker (%)	10	5.6	4.5	0.0	11.8	4	0.0	0.0	0.0	0.0
Aspen 2-4.9" dbh with *Cytospora* canker (%)	6	13.9	14.3	0.0	35.7	2	20.0	28.3	0.0	40.0
Aspen ? 5" dbh with *Phellinus* stem decay (%)	10	7.5	14.8	0.0	44.4	4	1.8	3.6	0.0	7.1
Aspen 2-4.9" dbh with *Phellinus* stem decay (%)	6	0.0	0.0	0.0	0.0	2	10.0	14.1	0.0	20.0

Appendix C. Plot means by National Forest, cont.

	Custer NF Plots					Flathead NF Plots				
				Range					Range	
Variable	N	Mean	Std Dev	Min.	Max.	N	Mean	Std Dev	Min.	Max.
Elevation (ft)	4	6066	272	5756	6367	5	3890	281	3586	4149
Total Aspen tpa	4	830	491	240	1380	5	628	846	200	2140
Aspen ≥ 5" dbh tpa	4	355	198	140	560	5	268	58	200	340
Aspen 2" - 4.9" dbh tpa	4	475	492	0	900	5	360	805	0	1800
Dead aspen tpa	4	80	123	0	260	5	8	11	0	20
Dead Aspen ≥ 5" dbh tpa	4	30	35	0	60	5	8	11	0	20
Dead Aspen 2-4.9" dbh tpa	4	50	100	0	200	5	0	0	0	0
Percent of all aspen dead	4	11.0	12.9	0.0	25.0	5	3.2	4.4	0.0	9.1
Basal area weighted mean aspen dbh (in)	4	6.7	2.3	4.1	9.6	5	12.0	4.4	4.5	15.0
Aspen sprouts per acre	4	2825	2155	200	5400	5	2060	1739	500	4100
Percent of plots with aspen sprouts		100					100			
Percent aspen with no dieback	4	0.0	0.0	0.0	0.0	5	0.0	0.0	0.0	0.0
Percent aspen with light dieback	4	84.1	10.3	68.8	89.7	5	70.0	31.8	20.0	100.0
Percent aspen with moderate dieback	4	15.9	10.3	10.3	31.3	5	26.6	28.5	0.0	70.0
Percent aspen with severe dieback	4	0.0	0.0	0.0	0.0	5	3.4	4.8	0.0	10.0
Aspen ≥ 5" dbh with wood borer damage (%)	4	67.7	12.7	53.6	83.3	5	16.6	5.4	7.1	20.0
Aspen 2-4.9" dbh with wood borer damage (%)	3	55.6	50.9	0.0	100.0	1	0.0	.	0.0	0.0
Aspen ≥ 5" dbh with defoliating insects (%)	4	45.7	25.2	12.5	71.4	5	1.4	3.2	0.0	7.1
Aspen 2-4.9" dbh with defoliating insects (%)	3	81.5	32.1	44.4	100.0	1	0.0	.	0.0	0.0
Aspen ≥ 5" dbh with foliage dieases (%)	4	9.7	11.2	0.0	20.8	5	0.0	0.0	0.0	0.0
Aspen 2-4.9" dbh with foliage dieases (%)	3	25.9	35.7	0.0	66.7	1	0.0	.	0.0	0.0
Aspen ≥ 5" dbh with bark wounds (%)	4	12.5	3.7	8.3	16.7	5	31.7	29.8	0.0	80.0
Aspen 2-4.9" dbh with bark wounds (%)	3	7.4	6.4	0.0	11.1	1	55.6	.	55.6	55.6
Aspen ≥ 5" dbh with minor foliar insects (%)	4	0.0	0.0	0.0	0.0	5	5.0	7.7	0.0	17.6
Aspen 2-4.9" dbh with minor foliar insects (%)	3	3.7	6.4	0.0	11.1	1	16.7	.	16.7	16.7
Aspen ≥ 5" dbh with sooty bark canker (%)	4	11.3	11.6	0.0	25.0	5	7.7	8.1	0.0	18.2
Aspen 2-4.9" dbh with sooty bark canker (%)	3	7.4	12.8	0.0	22.2	1	0.0	.	0.0	0.0
Aspen ≥ 5" dbh with *Cytospora* canker (%)	4	6.5	6.2	0.0	14.3	5	5.2	4.9	0.0	10.0
Aspen 2-4.9" dbh with *Cytospora* canker (%)	3	11.1	11.1	0.0	22.2	1	5.6	.	5.6	5.6
Aspen ≥ 5" dbh with *Phellinus* stem decay (%)	4	3.0	3.9	0.0	8.3	5	14.4	20.8	0.0	45.5
Aspen 2-4.9" dbh with *Phellinus* stem decay (%)	3	0.0	0.0	0.0	0.0	1	0.0	.	0.0	0.0

Appendix C. Plot means by National Forest, cont.

	Gallatin NF Plots					Helena NF Plots				
				Range					Range	
Variable	N	Mean	Std Dev	Min.	Max.	N	Mean	Std Dev	Min.	Max.
Elevation (ft)	6	6182	454	5614	6818	5	5301	623	4339	5975
Total Aspen tpa	6	527	457	160	1140	5	788	593	240	1480
Aspen ≥ 5" dbh tpa	6	227	68	160	340	5	268	79	160	380
Aspen 2" - 4.9" dbh tpa	6	300	395	0	800	5	520	581	0	1200
Dead aspen tpa	6	70	90	0	220	5	52	44	20	100
Dead Aspen ≥ 5" dbh tpa	6	20	18	0	40	5	12	11	0	20
Dead Aspen 2-4.9" dbh tpa	6	50	84	0	200	5	40	55	0	100
Percent of all aspen dead	6	11.5	10.3	0.0	25.0	5	9.8	10.4	1.4	27.8
Basal area weighted mean aspen dbh (in)	6	9.2	3.4	5.1	13.9	5	7.5	3.0	4.2	11.3
Aspen sprouts per acre	6	3050	1511	1200	4600	5	5840	7730	0	19100
Percent of plots with aspen sprouts		100					80			
Percent aspen with no dieback	6	2.4	5.8	0.0	14.3	5	0.0	0.0	0.0	0.0
Percent aspen with light dieback	6	60.0	24.2	33.3	88.9	5	78.4	32.6	22.2	100.0
Percent aspen with moderate dieback	6	29.0	21.7	5.6	55.6	5	21.6	32.6	0.0	77.8
Percent aspen with severe dieback	6	7.9	10.6	0.0	25.0	5	0.0	0.0	0.0	0.0
Aspen ≥ 5" dbh with wood borer damage (%)	6	78.5	23.9	41.7	100.0	5	56.1	37.1	0.0	100.0
Aspen 2-4.9" dbh with wood borer damage (%)	3	70.8	19.1	50.0	87.5	4	21.0	21.9	0.0	50.0
Aspen ≥ 5" dbh with defoliating insects (%)	6	11.3	14.2	0.0	33.3	5	34.0	34.0	0.0	78.6
Aspen 2-4.9" dbh with defoliating insects (%)	3	20.8	19.1	0.0	37.5	4	14.8	23.9	0.0	50.0
Aspen ≥ 5" dbh with foliage dieases (%)	6	11.6	19.0	0.0	44.4	5	13.3	21.7	0.0	50.0
Aspen 2-4.9" dbh with foliage dieases (%)	3	0.0	0.0	0.0	0.0	4	44.3	42.4	0.0	100.0
Aspen ≥ 5" dbh with bark wounds (%)	6	27.4	20.9	11.1	66.7	5	29.7	18.4	8.3	57.1
Aspen 2-4.9" dbh with bark wounds (%)	3	12.5	12.5	0.0	25.0	4	36.7	43.2	0.0	83.3
Aspen ≥ 5" dbh with minor foliar insects (%)	6	2.0	4.8	0.0	11.8	5	18.6	41.5	0.0	92.9
Aspen 2-4.9" dbh with minor foliar insects (%)	3	0.0	0.0	0.0	0.0	4	47.7	55.2	0.0	100.0
Aspen ≥ 5" dbh with sooty bark canker (%)	6	18.2	22.9	0.0	62.5	5	10.7	16.3	0.0	36.8
Aspen 2-4.9" dbh with sooty bark canker (%)	3	0.0	0.0	0.0	0.0	4	14.8	23.9	0.0	50.0
Aspen ≥ 5" dbh with *Cytospora* canker (%)	6	10.3	16.0	0.0	41.2	5	3.6	5.5	0.0	12.5
Aspen 2-4.9" dbh with *Cytospora* canker (%)	3	16.7	14.4	0.0	25.0	4	0.0	0.0	0.0	0.0
Aspen ≥ 5" dbh with *Phellinus* stem decay (%)	6	17.6	30.7	0.0	77.8	5	0.0	0.0	0.0	0.0
Aspen 2-4.9" dbh with *Phellinus* stem decay (%)	3	0.0	0.0	0.0	0.0	4	0.0	0.0	0.0	0.0

Appendix C. Plot means by National Forest, cont.

	Idaho Panhandle NFs Plots					Kootenai NF Plots				
				Range					Range	
Variable	N	Mean	Std Dev	Min.	Max.	N	Mean	Std Dev	Min.	Max.
Elevation (ft)	11	3045	462	2431	3619	9	3153	530	2265	3985
Total Aspen tpa	11	447	415	140	1540	9	444	277	260	1120
Aspen ≥ 5" dbh tpa	11	229	107	40	420	9	322	127	220	620
Aspen 2" - 4.9" dbh tpa	11	218	451	0	1500	9	122	295	0	900
Dead aspen tpa	11	22	37	0	120	9	22	38	0	120
Dead Aspen ≥ 5" dbh tpa	11	13	18	0	60	9	22	38	0	120
Dead Aspen 2-4.9" dbh tpa	11	9	30	0	100	9	0	0	0	0
Percent of all aspen dead	11	0.1	0.1	0.0	0.2	9	5.1	6.3	0.0	19.4
Basal area weighted mean aspen dbh (in)	11	8.5	3.0	3.3	13.5	9	9.3	3.0	5.0	14.0
Aspen sprouts per acre	11	900	1266	0	4200	9	6156	12022	0	31600
Percent of plots with aspen sprouts		63.6					55.6			
Percent aspen with no dieback	11	0.8	2.5	0.0	8.3	9	0.0	0.0	0.0	0.0
Percent aspen with light dieback	11	90.6	16.5	45.5	100.0	9	82.5	16.4	50.0	100.0
Percent aspen with moderate dieback	11	7.6	16.6	0.0	54.5	9	15.3	13.7	0.0	41.7
Percent aspen with severe dieback	11	1.1	2.4	0.0	6.7	9	1.6	3.2	0.0	8.3
Aspen ≥ 5" dbh with wood borer damage (%)	11	50.0	34.1	0.0	91.7	9	27.9	19.1	0.0	51.6
Aspen 2-4.9" dbh with wood borer damage (%)	5	52.7	46.9	0.0	100.0	3	3.7	6.4	0.0	11.1
Aspen ≥ 5" dbh with defoliating insects (%)	11	38.0	31.3	0.0	100.0	9	4.9	11.8	0.0	35.5
Aspen 2-4.9" dbh with defoliating insects (%)	5	37.3	41.3	0.0	100.0	3	33.3	57.7	0.0	100.0
Aspen ≥ 5" dbh with foliage dieases (%)	11	9.1	30.2	0.0	100.0	9	1.1	3.2	0.0	9.5
Aspen 2-4.9" dbh with foliage dieases (%)	5	17.3	38.8	0.0	86.7	3	0.0	0.0	0.0	0.0
Aspen ≥ 5" dbh with bark wounds (%)	11	52.9	31.0	7.1	100.0	9	28.1	14.4	9.7	50.0
Aspen 2-4.9" dbh with bark wounds (%)	5	82.0	24.9	50.0	100.0	3	77.8	38.5	33.3	100.0
Aspen ≥ 5" dbh with minor foliar insects (%)	11	4.3	12.9	0.0	42.9	9	0.0	0.0	0.0	0.0
Aspen 2-4.9" dbh with minor foliar insects (%)	5	0.0	0.0	0.0	0.0	3	0.0	0.0	0.0	0.0
Aspen ≥ 5" dbh with sooty bark canker (%)	11	6.7	8.2	0.0	25.0	9	13.7	20.2	0.0	64.7
Aspen 2-4.9" dbh with sooty bark canker (%)	5	0.0	0.0	0.0	0.0	3	0.0	0.0	0.0	0.0
Aspen ≥ 5" dbh with *Cytospora* canker (%)	11	1.7	4.0	0.0	12.5	9	14.9	20.4	0.0	52.9
Aspen 2-4.9" dbh with *Cytospora* canker (%)	5	0.0	0.0	0.0	0.0	3	3.7	6.4	0.0	11.1
Aspen ≥ 5" dbh with *Phellinus* stem decay (%)	11	7.9	17.7	0.0	44.4	9	11.2	20.1	0.0	61.9
Aspen 2-4.9" dbh with *Phellinus* stem decay (%)	5	0.0	0.0	0.0	0.0	3	0.0	0.0	0.0	0.0

Appendix C. Plot means by National Forest, cont.

	Lewis & Clark NF Plots					Lolo NF Plots				
				Range					Range	
Variable	N	Mean	Std Dev	Min.	Max.	N	Mean	Std Dev	Min.	Max.
Elevation (ft)	7	5363	377	4658	5838	6	3959	547	3030	4437
Total Aspen tpa	7	406	175	180	740	6	753	382	200	1140
Aspen ≥ 5" dbh tpa	7	334	96	180	460	6	353	129	200	500
Aspen 2" - 4.9" dbh tpa	7	71	111	0	300	6	400	395	0	900
Dead aspen tpa	7	69	65	20	200	6	147	157	0	420
Dead Aspen ≥ 5" dbh tpa	7	40	35	0	100	6	30	41	0	100
Dead Aspen 2-4.9" dbh tpa	7	29	76	0	200	6	117	160	0	400
Percent of all aspen dead	7	15.6	9.1	4.3	27.0	6	17.2	15.2	0.0	38.2
Basal area weighted mean aspen dbh (in)	7	7.7	1.3	6.3	9.5	6	8.9	2.2	5.6	12.2
Aspen sprouts per acre	7	2957	1757	100	5700	6	2483	2134	0	5400
Percent of plots with aspen sprouts		100					83.3			
Percent aspen with no dieback	7	0.0	0.0	0.0	0.0	6	0.6	1.4	0.0	3.3
Percent aspen with light dieback	7	71.1	21.2	33.3	93.3	6	83.2	10.4	64.7	95.0
Percent aspen with moderate dieback	7	25.5	21.1	0.0	58.3	6	14.8	11.3	5.0	35.3
Percent aspen with severe dieback	7	2.5	4.3	0.0	9.1	6	1.5	2.4	0.0	5.6
Aspen ≥ 5" dbh with wood borer damage (%)	7	71.4	30.9	9.1	100.0	6	19.0	26.7	0.0	68.0
Aspen 2-4.9" dbh with wood borer damage (%)	3	44.4	50.9	0.0	100.0	4	18.4	21.8	0.0	50.0
Aspen ≥ 5" dbh with defoliating insects (%)	7	30.4	31.7	0.0	72.2	6	18.0	19.1	0.0	50.0
Aspen 2-4.9" dbh with defoliating insects (%)	3	11.1	19.2	0.0	33.3	4	7.8	9.7	0.0	20.0
Aspen ≥ 5" dbh with foliage dieases (%)	7	3.7	9.9	0.0	26.1	6	31.0	38.5	0.0	88.0
Aspen 2-4.9" dbh with foliage dieases (%)	3	0.0	0.0	0.0	0.0	4	46.9	41.3	0.0	100.0
Aspen ≥ 5" dbh with bark wounds (%)	7	14.6	11.0	0.0	31.8	6	45.2	14.4	24.0	68.0
Aspen 2-4.9" dbh with bark wounds (%)	3	33.3	57.7	0.0	100.0	4	50.9	29.2	11.1	80.0
Aspen ≥ 5" dbh with minor foliar insects (%)	7	0.0	0.0	0.0	0.0	6	0.0	0.0	0.0	0.0
Aspen 2-4.9" dbh with minor foliar insects (%)	3	0.0	0.0	0.0	0.0	4	0.0	0.0	0.0	0.0
Aspen ≥ 5" dbh with sooty bark canker (%)	7	23.3	26.9	4.3	81.3	6	8.6	11.2	0.0	28.0
Aspen 2-4.9" dbh with sooty bark canker (%)	3	33.3	57.7	0.0	100.0	4	9.4	18.8	0.0	37.5
Aspen ≥ 5" dbh with *Cytospora* canker (%)	7	12.8	8.8	4.5	26.1	6	10.1	10.2	0.0	26.7
Aspen 2-4.9" dbh with *Cytospora* canker (%)	3	55.6	50.9	0.0	100.0	4	19.9	15.4	0.0	37.5
Aspen ≥ 5" dbh with *Phellinus* stem decay (%)	7	10.5	16.6	0.0	44.4	6	26.2	32.2	0.0	80.0
Aspen 2-4.9" dbh with *Phellinus* stem decay (%)	3	0.0	0.0	0.0	0.0	4	28.1	48.3	0.0	100.0