FOREST HEALTH EVALUATION R2-14-02
Aspen Conditions on National Forests in the Northern Rocky Mountain Region
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Introduction

Quaking aspen (*Populus tremuloides*) is an important and widely distributed species in the Western United States. Aspen forests support a variety of values such as diversity, wildlife, watersheds, and aesthetics. In the national forests of the northern Rocky Mountain Region this species comprises approximately 1% of the Bighorn cover, 3% of the Black Hills and 1% of the Shoshone (Witt 2008, DeBlander 2002 and Menlove 2008). It is a relatively rare component in these forests and there is concern regarding the health of this ecologically important species.

Long-term monitoring plots (Shaw 2004) and aerial detection surveys (Worrall et al. 2008) suggest extensive sudden decline and deterioration of aspen forests in the Rocky Mountains. Changes to the fire regimes since European settlement and heavy browsing (Bartos and Campbell 1998, Kay 1997, Romme et al. 1995, Sheppard et al. 2006), drought (Hogg et al. 2008, Worrall et al. 2008), and climate change (Rehfeldt et al. 2009, Worrall et al. 2013) have been suggested as factors contributing to decline and mortality. Several forest diseases and insects are also implicated in the recent aspen mortality (Dudley 2011, Guyon and Hoffman 2011, Fairweather et al. 2008, Marchetti et al. 2011, Steed and Kearns 2010). Aerial surveys in Wyoming provide general information regarding the extent and location aspen mortality, but not the condition of regeneration, or specific damage agents associated with mortality.

To determine management recommendations, the distribution and severity of mortality, and causal agents involved must be identified. In this study, damage agents and site variables were measured to examine what is contributing to aspen mortality.

Methods

Sample design. Plots were established systematically in the Bighorn National Forest in 2009 and remeasured in 2012. Plots were established in 2008 and remeasured in 2012 in both the Black Hills and Shoshone National Forests. Stands were 2 acres or larger, composed of 50% or more aspen, and had a minimum spacing of approximately 1 mile.

Forty-five, 60 and 50 stands were sampled in the Bighorn, Black Hills and Shoshone National Forests, respectively. Three circular plots were established in each stand for both trees (1/50 acre) and for tree regeneration (1/500 acre). The spacing between plots was approximately 2 chains (40 meters). Regeneration plots were established due east and 16.7 feet from tree plot centers. Plots were installed 35 feet or more from stand edges, roads, or major trails.

General plot and root disease measurements. At each plot center coordinates, elevation, slope position, slope, and aspect were recorded. A dominant or codominant tree at each plot was cored to determine approximate stand age and recent 10-year radial growth. Heights of cored trees were measured to estimate site index.

Root disease pathogens were assessed as present/absent for all plots and frequencies were quantified for stands. Trees were examined within 1.5 chains of plot centers. *Armillaria* spp. were confirmed by examining three recent dead trees per plot (9 per stand) for the presence of mycelial fans and/or rhizomorphs. If the pathogen was found, root disease was confirmed by examining two live aspen trees per plot (6 per stand) for the presence of mycelial fans. Trees with root disease symptoms were preferentially selected. White mottled rot (*Ganoderma applanatum*) was confirmed by examining 10 recent dead trees (30 per stand) for the presence of conks. If recent dead trees were not present, trees with root disease symptoms were examined next and then healthy trees.

Tree measurements. Tree species and diameter at breast height (DBH) were recorded in all plots. All trees over 3 inches DBH were tallied. In 2012, DBH was not measured with the exception of newly established trees. Trees were classified by condition (live or recent dead). Recent dead trees had all their bark and at least some fine branches and were estimated to have died within 3 years. Live aspen trees were tagged and crown condition (percentage live crown) was visually estimated. Mean crown condition was calculated using live aspen trees per plot. Tree mortality rates per plot were calculated based on the number of recent dead trees in 2008 or 2009, and on the number that died between 2008/2009 and 2012.

Damage agents were recorded for each live and recent dead aspen tree, and were summarized as percentage of stems per plot. For most damage agents, any amount of damage was recorded. Foliage diseases and defoliating insects were only recorded if they damaged ≥ 25% of the crown. Animal and other physical damages were only recorded if they damaged ≥ 25% of the crown or stem.

Regeneration measurements. Regeneration was classified by species, host condition (living or dead), and size class (seedling or sapling). Seedlings were 1 foot to 4.5 feet high and saplings were greater than 4.5 feet and less than 3 inches DBH. Regeneration variables calculated included numbers and percentages of regeneration per acre. Damage agents were tallied by host condition and size class for live and dead aspen regeneration.

Climate variables. Eleven climate variables were derived using the Spline Model of Climate (Rehfeldt 2006) based on mean stand coordinates. Variables included: 30-year mean annual indices from 1971 to 2000 for annual and growing season precipitation; annual, maximum, and minimum temperature; annual moisture index (AMI) and summer moisture index (SMI); and 30-year mean annual indices from 1961 to 1990 for daily mean relative humidity, total growing degree-days, number of days with minimum temperature ≤ 32 fahrenheit, and number of days with maximum temperature ≥ 90 fahrenheit. SMI is slightly modified from Rehfeldt (2006), being defined as the inclusive months between last spring frost day and first fall frost day.

Statistical analyses. Stand means were calculated from the three plots per stand. Percentage aspen mortality was categorized as healthy (0 - 8% mortality) and unhealthy (>8% mortality). Mean crown condition was categorized as healthy (100-75% live crown) or unhealthy (< 75% live crown). Crown condition categories were determined using live aspen crown means. For regeneration, the numbers of seedling and sapling stems per acre was categorized as high (≥ 1,000 stems per acre) or low (0 - < 1,000 stems per acre). Data was analyzed by t-Test for two sample tests, using SAS release 9.4; for all tests $\alpha = 0.05$.

Results-Bighorn National Forest

Mean live tree crown condition was 84%in 2009 and 88% in 2012. Mean tree mortality was 4% and 6% per year in 2009 and 2012 respectively (Table 1). The mean aspen regeneration was 3219 stems per acre in 2009 and 3433 stems per acre in 2012.

Aspen mortality was relatively low in most stands. Only 24% of the stands had more than 8% mortality, with a high of 13% and 18% in 2009 and 2012, respectively (Figure 1). Mortality increased by 2% on average from 2009 to 2012. There was a correlation between mortality in 2009 and mortality in 2012, indicating stands with elevated mortality the first year continued to have elevated mortality. Average crown condition was healthy in both years. Only two stands had average crown condition under 75% in 2009, and three stands in 2012 (Figure 2). All other site, tree, climate and damage agents were not correlated with tree mortality.

Sooty bark canker was a frequently identified damage agent, often with large expanding cankers, and was determined to be a major contributor to tree mortality. The difference in sooty bark infections between live trees and recently killed trees was significant in both 2009 and 2012. In 2009, 5% of live trees had sooty bark, while 48% of recently dead had infections ($P < 0.001$). In 2012, 6% of live trees had sooty bark infections and 61% of recently dead had infections ($P < 0.001$).

Stand mortality rates increased with increased white mottled rot (*Ganoderma applanatum*) ($P = 0.043$) which was found in 22% of the stands. Armillaria root rot was found in 73% of the stands, but was not correlated with stand mortality rates. Unlike other damage agents, root diseases were assessed per plot as opposed to individual trees.

The most commonly found agent was Cytospora canker. While Cytospora canker was common, it often caused minor damage (< 1 inch diameter), frequently stopped expanding, and cankers healed without causing significant impact to trees. However, Cytospora does seem to be playing a role in tree mortality, as there were significant differences in Cytospora infections between live and dead trees. In 2009, 34% of live trees had Cytospora while 50% of dead trees had infection ($P = 0.008$). In 2012, 39% of live trees had Cytospora and 70% of recently dead had infections ($P < 0.001$).

Table 1. Bighorn National Forest aspen summary statistics

Variable	**Mean**	**SD**	**Minimum**	**Maximum**
Elevation (feet)	7901	534	6805	9368
Age (years)	80	19.4	26	124
DBH (inches)	7.8	1.9	4.5	12.0
10 Year Growth (mm)	10.3	2.6	5.1	16.1
Mortality 2009 (%)	4	3.4	0	13
Mortality 2012 (%)	6	4.1	0	18
Crown Condition 2009 (%)	84	7.3	50	95
Crown Condition 2012 (%)	88	6.8	66	97
Total Regeneration (stems/acre)	3774	3344	0	15000
Total Live Aspen Regeneration 2009	3219	3328	0	9167
Total Live Aspen Regeneration 2012	3433	3272	0	10833
Damages Recorded on Aspen (% affected)				
Cytospora Canker 2009	33	19.3	4	86
Cytospora Canker 2012	41	21.8	4	82
Sooty Bark Canker 2009	11	9.6	0	37
Sooty Bark Canker 2012	10	10.2	0	34
Phellinus Trunk Rot 2009	5	10.2	0	51
Phellinus Trunk Rot 2012	7	11.6	0	50
Poplar Borer 2009	1	1.8	0	8
Poplar Borer 2012	7	8.5	0	33
Animal Damage 2009	23	19.1	0	81
Animal Damage 2012	20	18.9	0	70

Aspen trunk rot (*Phellinus tremulae*), poplar borer, and animal damage (largely rubbing on the stem from elk or moose) were the only other damages found on more than 5% of stems, and none appeared to contribute to mortality. There were 28 other damage agents affecting less than 5% of the trees (see appendix), but they had little impact on tree health.

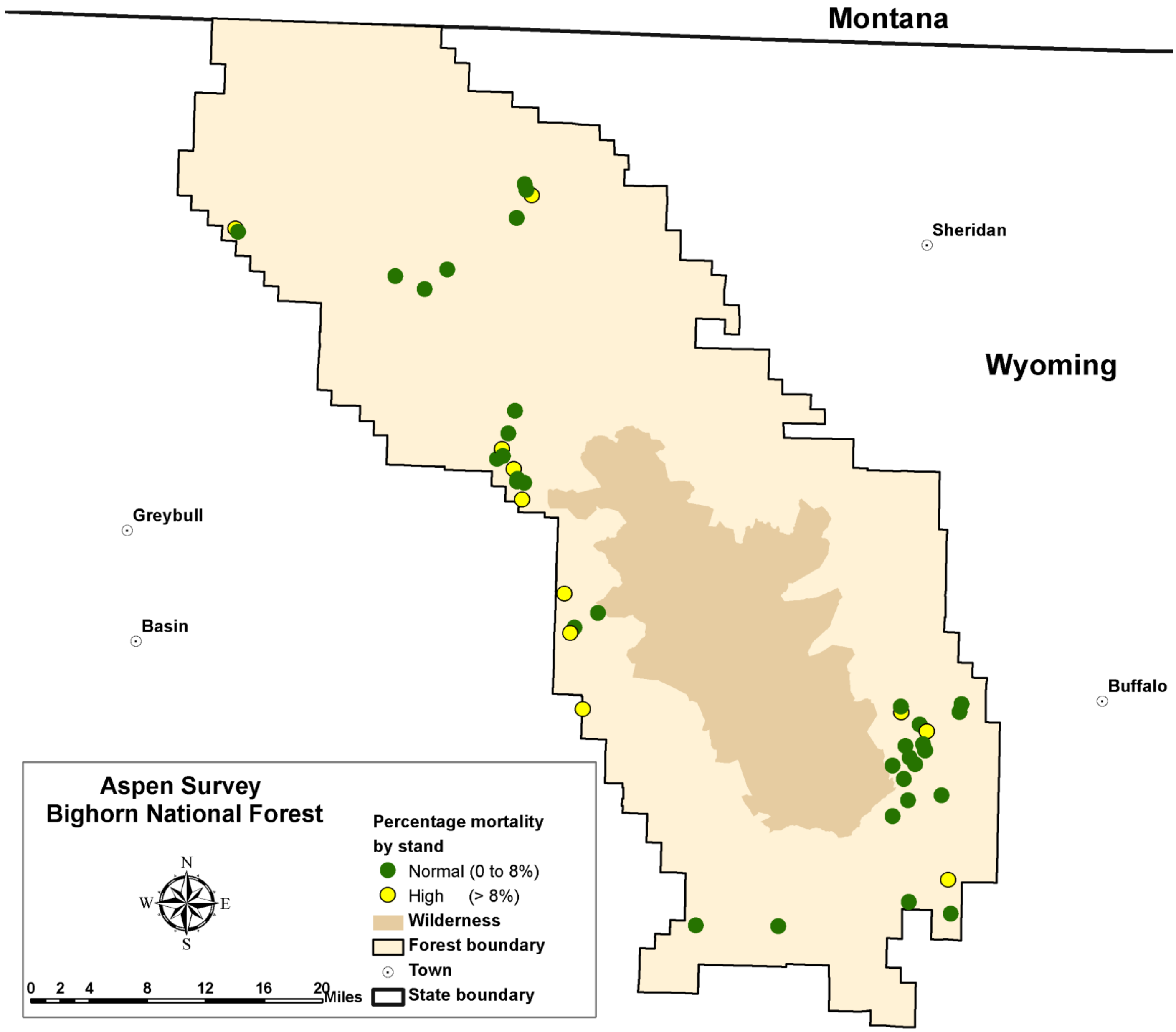

Figure 1. Aspen mortality associated with stands in 2012.

Figure 2. Healthy aspen stand (left), and an unhealthy aspen stand (right) in the Bighorn National Forest.

Regeneration was greater than 1000 stems per acre in most stands (Figure 3). In 2009, 15 of 45 stands had less than the desired amount of regeneration. In 2012, only 10 stands fell below 1000 stems per acre. Many of the stands that had little or no aspen regeneration had the densest overstory, so little regeneration would be expected. The most common damage found on aspen seedlings and saplings was animal browsing, which was on 17% and 26% of aspen stems in 2009 and 2012, respectively. The only other damage of note on seedlings and saplings was various cankers, which affected 4% and 13% of stems in 2009 and 2012, respectively. There were 25 other damage agents (see appendix) affecting less than 5% of the regeneration, but they had little impact on regeneration health.

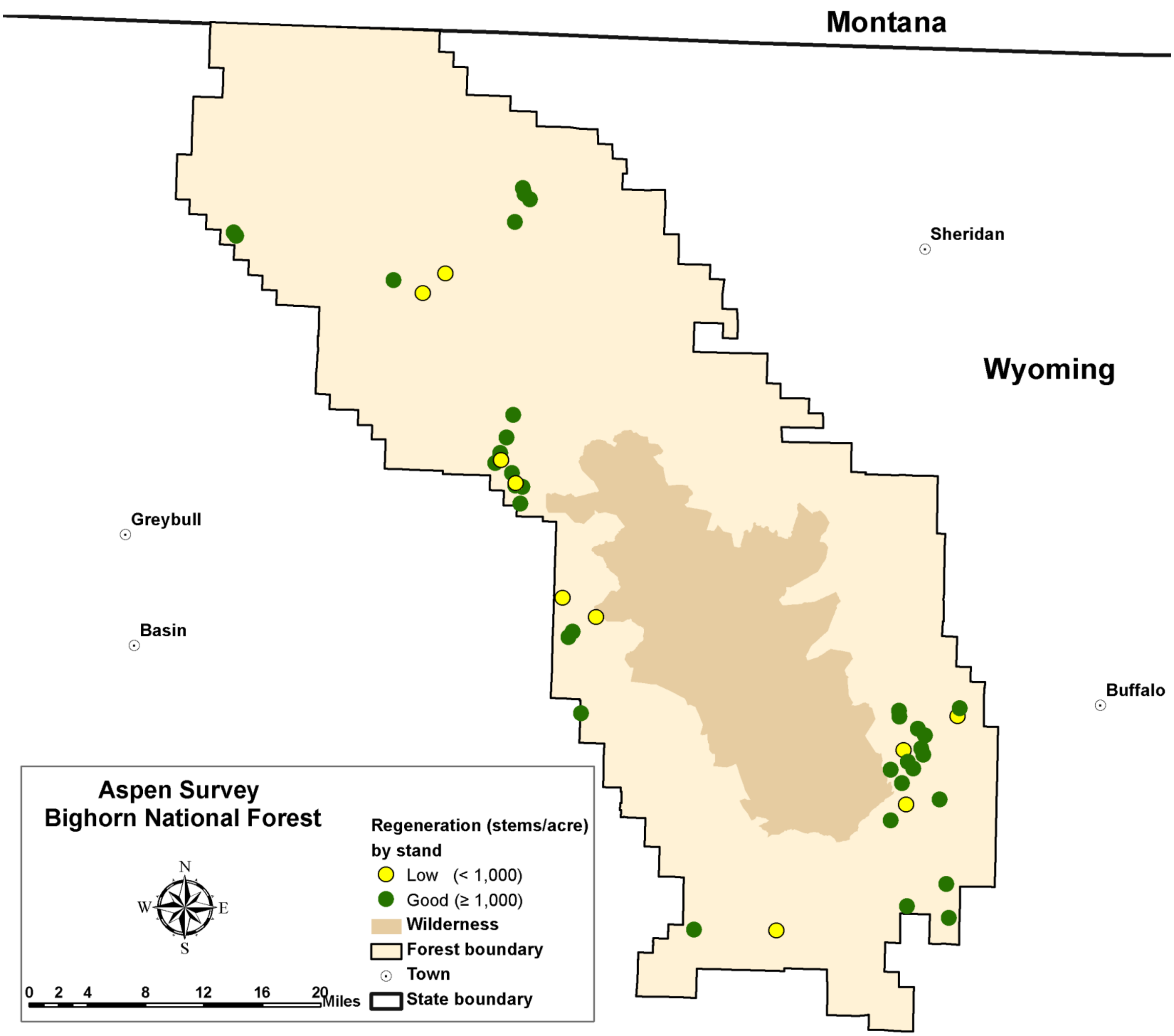

Figure 3. Amount of aspen regeneration associated with stands in 2012.

Results-Black Hills National Forest

Mean live tree crown condition was 88% in 2008 and 90% in 2012. Mean tree mortality was 2% and 6% per year in 2008 and 2012 respectively (Table 2). The mean aspen regeneration was 2911 stems per acre in 2008 and 1906 stems per acres in 2012.

Table 2. Black Hills National Forest aspen summary statistics

Variable	Mean	SD	Minimum	Maximum
Elevation (feet)	5677	596.2	4518	6682
Age (years)	58	20	18	104
DBH (inches)	6.9	2.0	3.3	11.9
10 Year Growth (mm)	12.5	5.0	6.2	27.0
Mortality 2008 (%)	2	3.1	0	12
Mortality 2012 (%)	6	5.1	0	23
Crown Condition 2008 (%)	88	8.9	40	99
Crown Condition 2012 (%)	90	13.5	8.3	100
Total Regeneration (stems/acre)	4364	4606	0	24333
Total Live Aspen Regeneration 2008	2911	4950	0	36667
Total Live Aspen Regeneration 2012	1906	2203	0	13000
Damages Recorded on Aspen (% affected)				
Cytospora Canker 2008	36	23.6	0	100
Cytospora Canker 2012	50	26.9	0	100
Sooty Bark Canker 2008	33	24.8	0	95
Sooty Bark Canker 2012	39	27.0	0	91.7
Black Canker 2008	11	14.5	0	61
Black Canker 2012	9	12.1	0	55.6
Phellinus Trunk Rot 2008	20	23.7	0	100
Phellinus Trunk Rot 2012	28	26.7	0	97
Bronze Poplar Borer 2008	14	18.2	0	100
Bronze Poplar Borer 2012	18	19.6	0	79
Poplar Borer 2008	4	8.4	0	50
Poplar Borer 2012	17	18.1	0	59

Only 23% of the stands in the Black Hills had more than 8% mortality, with a high of 12% and 23% in 2008 and 2012, respectively (Figure 4). Average mortality increased by 4% from 2008 to 2012. There was a strong correlation between mortality in 2008 and mortality in 2012, indicating stands with high mortality in 2008 had high mortality in 2012. Only one stand had average crown condition under 75% in 2008, and three stands in 2012 (Figure 5). No other site or tree characteristics were well correlated with tree mortality.

Sooty bark canker was a common damage agent, often with large expanding cankers, and was considered to be the most significant factor causing tree mortality. The difference in sooty bark infections between live trees and recently killed trees was significant in both 2008 and 2012. In 2008, 30% of live trees had sooty bark, while 71% of recently dead had infections ($P < 0.001$). In 2012, 33% of live trees had sooty bark infections and 86% of recently dead had infections ($P < 0.001$).

White mottled rot (*Ganoderma applanatum*) increased with stand mortality rates ($P = 0.038$) and was found in 28% of the stands. Armillaria root rot was found in 97% of the stands, but was not correlated with stand mortality rates.

The most frequently found damage agent was Cytospora canker. While this canker was common, it was often minor (< 1 inch diameter), frequently stopped expanding, and cankers healed without causing impact to trees. There was some correlation between Cytospora and tree mortality, and there were significant differences in Cytospora infections between live and dead trees. In 2008, 34% of live trees had Cytospora while 50% of dead trees had infection ($P = 0.013$). In 2012, 46% of live trees had Cytospora and 70% of recently dead had infections ($P < 0.001$).

Bronze poplar borer was less common. However, it did appear to contribute to increased mortality. The difference in bronze poplar borer between live trees and recently killed trees was significant in 2012. In 2012, 14% of live trees had bronze poplar borer, while 40% of recently dead were attacked ($P < 0.001$).

Aspen trunk rot (*Phellinus tremulae*), poplar borer, and black canker were the only other damages found on more than 5% of stems, and none appeared to contribute to mortality. There were 26 other damage agents affecting less than 5% of the trees (see appendix), but they had little impact on tree health.

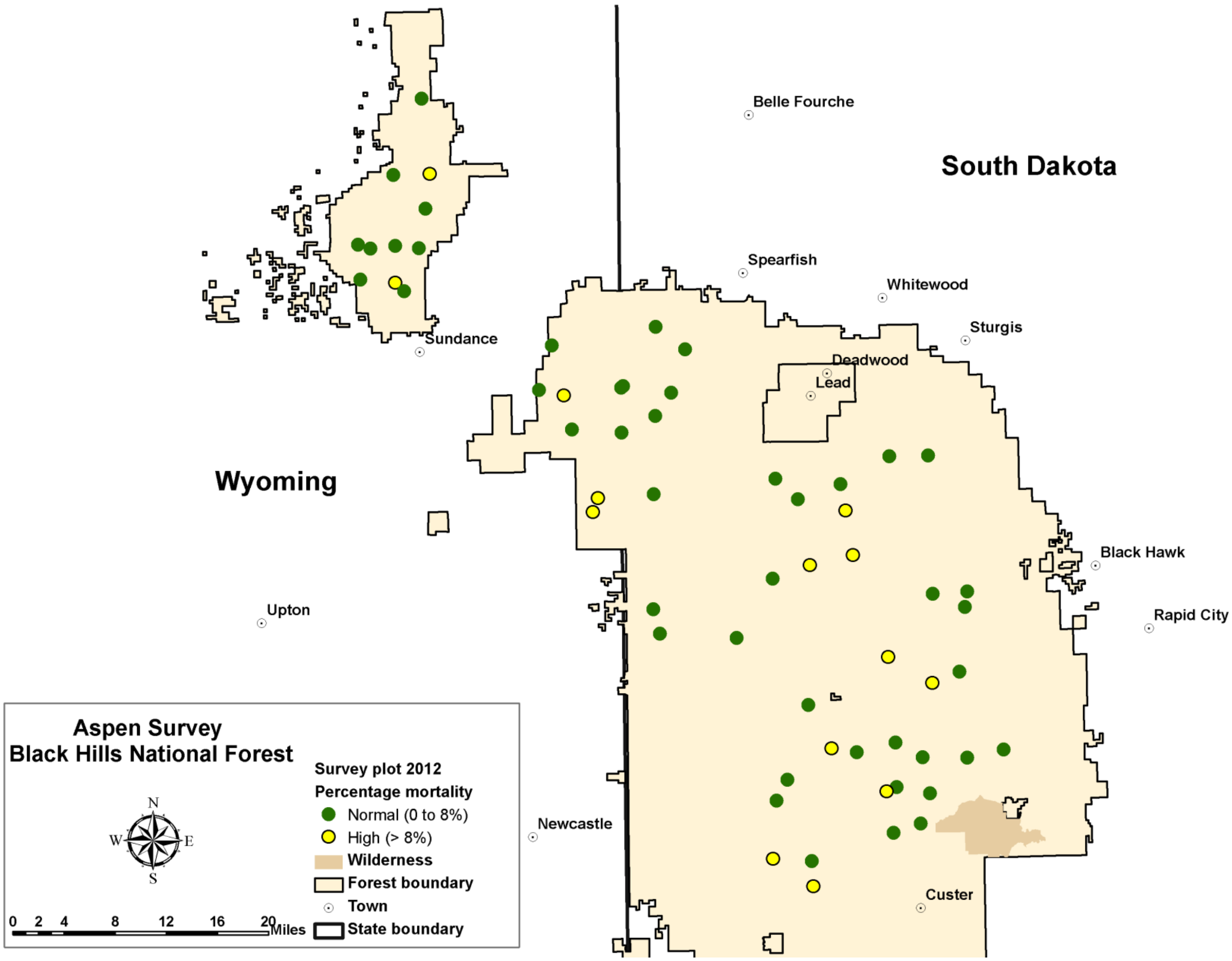

Figure 4. Aspen mortality associated with stands in 2012.

Figure 5. Healthy aspen stand (left), and an unhealthy aspen stand (right) in the Black Hills National Forest.

All regeneration, regardless of species, was greater than 1000 stems per acre in 90% of the stands, but in many stands other hardwood species were more common than aspen. In 2008, 35% of the stands had less than 1000 stems per acre of aspen regeneration. In 2012, 40% of the stands fell below 1000 aspen stems per acre (Figure 6). The competing woody vegetation probably explains most of the low aspen regeneration. Many stands with little or no regeneration had the densest overstories, so a large number of aspen seedlings would not be expected. The most common damage found on aspen seedlings and saplings was animal browsing, which was on 22% and 32% of aspen stems in 2008 and 2012, respectively. The only other damage of note on seedlings and saplings was various cankers, which affected 8% and 24% of stems in 2008 and 2012, respectively. There were 25 other damage agents (see appendix) affecting less than 5% of the regeneration, but they had little impact on regeneration health.

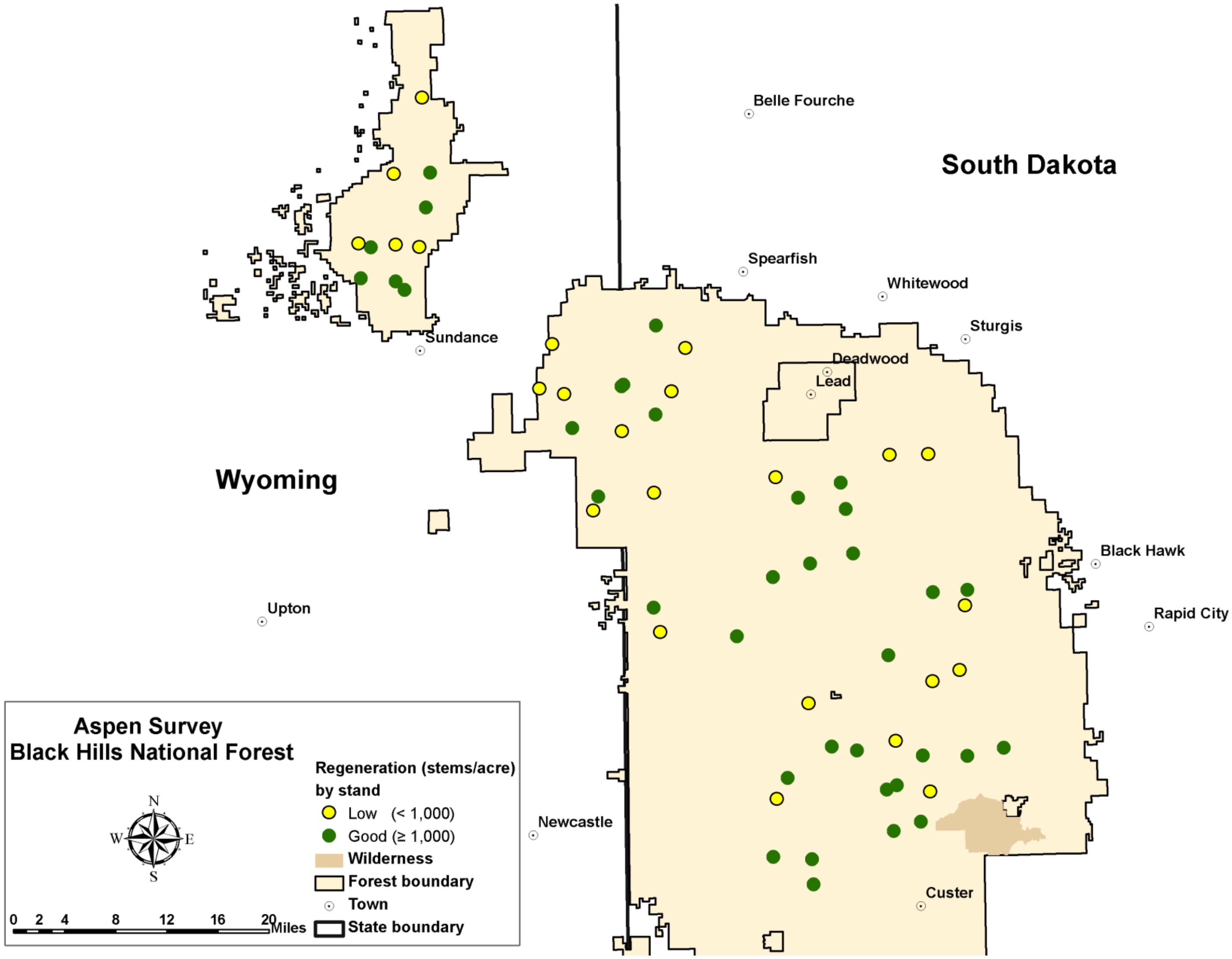

Figure 6. Amount of aspen regeneration associated with stands in 2012.

Results-Shoshone National Forest

In 2008 and 2012, mean crown condition was 85% (Table 3). Mean tree mortality was 4% and 6% per year in 2008 and 2012 respectively. The mean aspen regeneration was 4070 stems per acre in 2008; and 4180 in 2012.

Table 3. Shoshone National Forest aspen summary statistics

Variable	Mean	SD	Minimum	Maximum
Elevation (feet)	8097	643.2	6521	9333
Age (years)	78	24.8	14	122
DBH (inches)	7	2.1	3	11
10 Year Growth (mm)	8	2.8	2	18
Mortality 2008 (%)	4	4.0	0	13
Mortality 2012 (%)	6	5.3	0	24
Crown Condition 2008 (%)	85	12.1	27	99
Crown Condition 2012 (%)	85	12.4	45	99
Total Regeneration (stems/acre) 2012	4510	2973	0	13833
Total Live Aspen Regeneration 2008	4070	3572	500	16333
Total Live Aspen Regeneration 2012	4180	2872	0	13667
Damages Recorded on Aspen (% affected)				
Cytospora Canker 2008	42	22.6	0	97
Cytospora Canker 2012	51	25.6	0	97
Sooty Bark Canker 2008	16	14.6	0	62
Sooty Bark Canker 2012	22	21.0	0	78
Black Canker 2008	6	10.6	0	53
Black Canker 2012	7	10.1	0	44
Phellinus Trunk Rot 2008	7	12.2	0	51
Phellinus Trunk Rot 2012	9	13.8	0	67
Bronze Poplar Borer 2008	9	9.1	0	44
Bronze Poplar Borer 2012	17	16.6	0	83
Poplar Borer 2008	5	9.2	0	42
Poplar Borer 2012	17	17.6	0	94
Cryptosphaeria Canker 2008	5	7.7	0	25
Cryptosphaeria Canker 2012	7	10.1	0	44
Animal Damage 2008	5	11.9	0	71
Animal Damage 2012	5	12.9	0	81

Only 22% of the stands had more than 8% mortality, with a high of 13% and 23% in 2008 and 2012, respectively (Figure 7). Mortality increased by 2% on average from 2008 to 2012. Three stands had high or total fire caused mortality. There was a strong correlation between mortality in 2008 and mortality in 2012. Crown condition was generally high in both years. Only four stands had average crown condition under 75% in 2008, and nine stands in 2012 (Figure 8). No other site or tree relationships were correlated with tree mortality.

Sooty bark canker was found frequently causing tree mortality. The difference in sooty bark infections between live trees and recently dead trees was significant in both 2008 and 2012. In 2008, 12% of live trees had sooty bark, while 43% of recently dead had infections ($P < 0.001$). In 2012, 18% of live trees had sooty bark infections and 61% of recently dead had infections ($P < 0.001$).

Cytospora canker was the most common disease observed, but damage was typically minor. There was some correlation between Cytospora and tree mortality, and there were significant differences in Cytospora infections between live and dead trees. In 2008, 38% of live trees had Cytospora while 70% of dead trees had infection ($P < 0.001$). In 2012, 46% of live trees had Cytospora and 82% of recently dead had infections ($P < 0.001$).

Bronze poplar borer was also causing tree mortality. The difference in bronze poplar borer infestations between live trees and dead trees was significant in both 2008 and 2012. In 2008, 6% of live trees had bronze poplar borer, while 28% of recently dead were infested ($P < 0.001$). In 2012, 11% of live trees had bronze poplar borer and 48% of recently dead had infested ($P < 0.001$).

Cryptosphaeria canker was uncommon, but did appear to contribute to increased mortality. The difference in Cryptosphaeria infections between live trees and recently killed trees was significant in 2012. In 2012, 4% of live trees had Cryptosphaeria infections and 18% of recently dead had infections ($P = 0.002$).

Aspen trunk rot (*Phellinus tremulae*), poplar borer, black canker, and animal debarking were the only other damages found on more than 5% of stems, and all appeared to be secondary agents with no relation to tree mortality. There were 24 other damage agents affecting less than 5% of the trees (see appendix), but they had little impact on tree health. White mottled rot (*Ganoderma applanatum*) was found in 10% of the stands and Armillaria root rot was found in 31% of the stands. These root diseases had no relation with stand mortality rates.

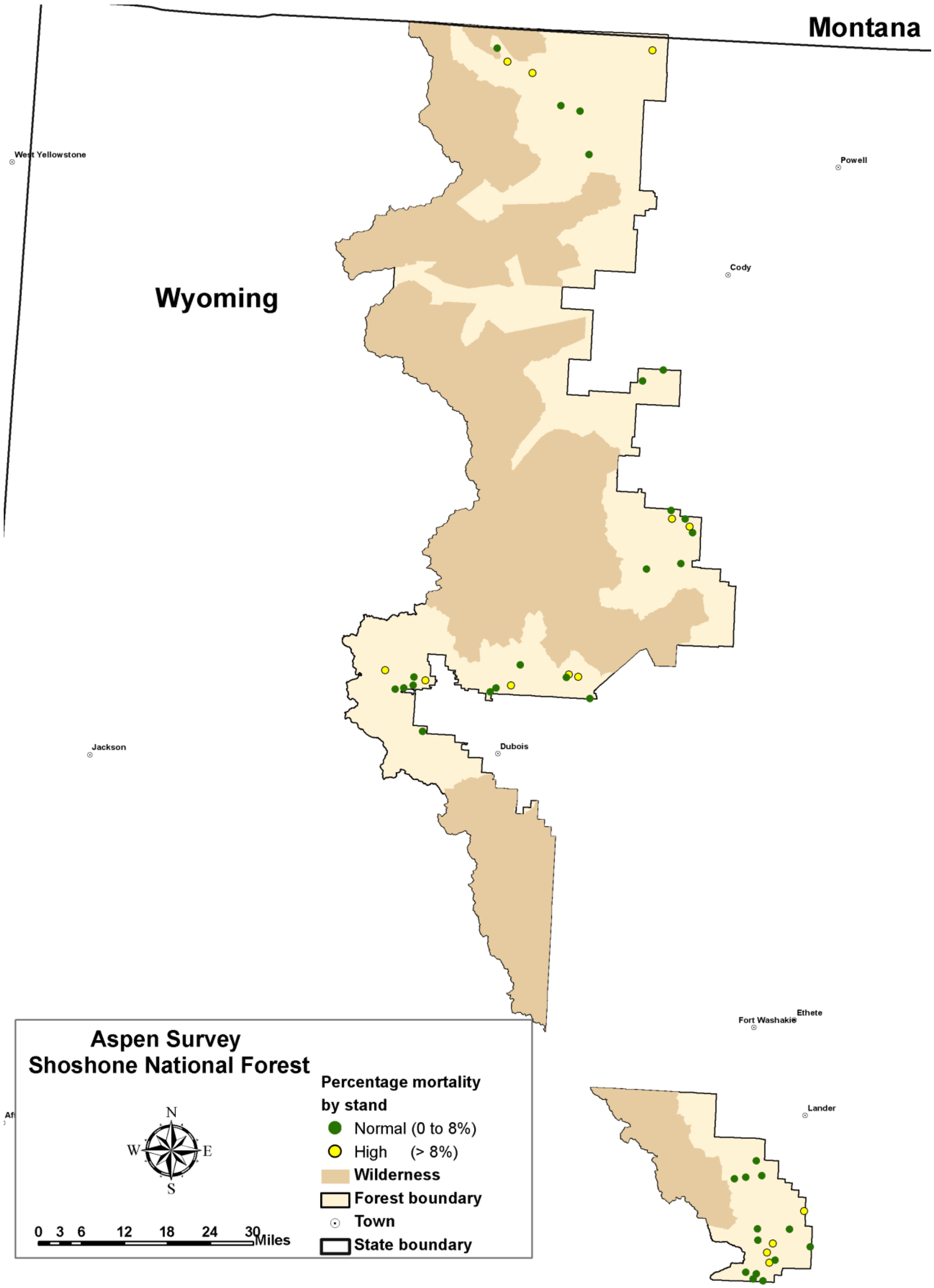

Figure 7. Aspen mortality associated with stands in 2012

Figure 8. Healthy aspen stand (left), and an unhealthy aspen stand (right) in the Shoshone National Forest.

In 2008, 8% of the stands had less than 1000 stems per acre of aspen regeneration. In 2012, 6% of the stands (3 stands) fell below 1000 aspen stems per acre (Figure 9). One stand had a recent fire and one stand had the densest overstory, so little regeneration would be expected in 2 of the 3 stands. The most common damage found on aspen seedlings and saplings was animal browsing, which was on 17% and 10% of aspen stems in 2008 and 2012, respectively. Also common on seedlings and saplings was various cankers, which affected 10% and 15% of stems in 2008 and 2012, respectively. There were 25 other minor damage agents (see appendix) affecting less than 5% of the regeneration.

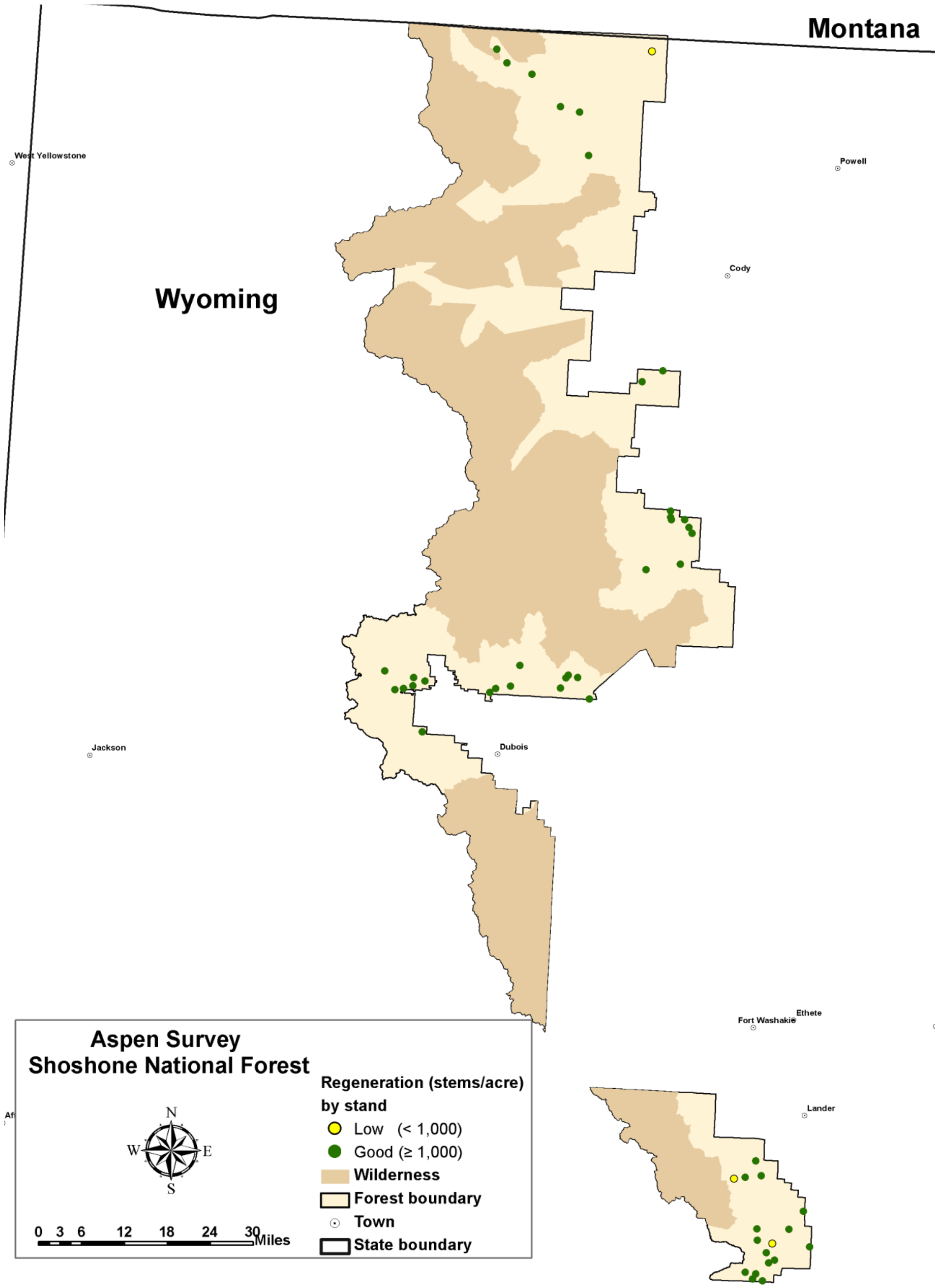

Figure 9. Amount of aspen regeneration associated with stands in 2012.

Discussion

Aspen stands are relatively healthy across the Northern Rocky Mountain Region (Figure 10). In all forests, average crown condition was high, with little dieback or decline. Average stand mortality was generally low, indicating no significant tree mortality events are occurring. Crown condition was not related to future mortality, and so even stands that appear healthy can and do incur tree death. Tree mortality does appear to be associated with individual stands, so stands that are seeing above average mortality are expected to continue to have higher mortality rates.

Various factors including drought, tree diseases, and insects have been associated with aspen mortality (Frey et al. 2004, Hogg et al. 2008, Marchetti et al. 2011, Rehfeldt et al. 2009, Worrall et al. 2010, 2013). Since tree mortality does seem to be occurring on a stand level, there are likely local site conditions or agents that are contributing to the mortality. There was no noticeable relationship between tree mortality and factors such as elevation, slope, aspect or weather events such as moisture or temperature in these forests. Although there was no good connection, stands on drier sites or those experiencing drought are generally more susceptible to damage agents and higher tree mortality.

One of the most important tree mortality agents not tied to drier sites was Ganoderma. There was a significant trend in both the Bighorn and Black Hills, but not the Shoshone, between high stand mortality and Ganoderma root disease. This disease appears to be one of the most important agents leading to tree death. This is similar to previous findings that Ganoderma is at least locally important in death of mature trees, particularly on moist sites (Ross 1976, Hinds 1985). In most cases, it was found killing mature trees and not regeneration. These stands will continue to exist, just as a different age class.

Sooty bark canker was the other major mortality causing agent across all forests as has been suggested in previous studies (Hinds 1985). It appeared to be killing trees without causing a decline in crown condition, as there were numerous trees with full, healthy crowns that had large cankers. These trees were found to be dead in the following remeasurement (Figure 11). Sooty bark is found throughout all forests, so reducing wounds for canker entry may be the only option for reducing its impact. In all forests, there were also relatively high numbers of cankers found on aspen seedlings and saplings (Figure 12). Many of these were associated with browsing damage as the presumed entry point for the canker. On small trees, we did not identify which specific fungus was causing cankers, however it is fair to assume many could be sooty bark which will result in tree death of these smaller stems.

Bronze poplar borer and Cytospora are likely the most important of the other damage agents killing mature trees. Bronze poplar borer was rarely found in the Bighorns, but was frequent in both the Shoshone and Black Hills. In these latter two cases there is a significant relationship between the borer and tree mortality. Cytospora is harder to define as it was extremely frequently observed, however, the majority of cankers were very small, already healed over or likely to be healed over. Many were associated with some other wound. It is unlikely that the majority of Cytospora cankers were going to cause any significant tree mortality. Again, many seedlings and saplings did have cankers, of which a large proportion could be Cytospora. In smaller stems, this canker could be a factor in causing tree death. The three principal canker and borer agents causing mortality in our study area are often associated with aspen mortality throughout the region (Dudley 2011, Guyon and Hoffman 2011, Fairweather et al. 2008, Marchetti et al. 2011, Steed and Kearns 2010).

The other damage agents encountered were far less important than those already discussed. Some were found in a relatively high percentage of trees, such as Phellinus or poplar borer, but seemed relatively unimportant in causing tree mortality. Others such as Cryptosphaeria, appeared to have a role in tree mortality but were found relatively infrequently on the landscape. Consequently, damage agent aggressiveness, frequency, and tendency with mortality should all be considered when determining probable impact to aspen.

We found no strong correlation between tree age and mortality. Since the most important mortality agents are relatively common and present throughout the forests, older trees have more chances to be exposed to these other agents. This will increase the likelihood of infection or attack over time, and in turn tree mortality.

Overall, aspen regeneration was common and relatively dense across all forests. There were occasional stands with below average regeneration, however there was not a good relationship with the small number of seedlings and any particular damage agent. Browsing is often cited as a factor preventing successful aspen regeneration (Bartos and Campbell 1998, Kay 1997, Romme et al. 1995). Jacobi and Shepperd (1991) found canker diseases to be a factor associated with low regeneration in clearcuts. Both these factors were commonly noted in seedlings in these forests. The most important factors in reducing aspen regeneration seemed to be more related to individual sites. Factors such as dense overstory, competing regeneration from other species and in a few cases fire, appeared to have a much greater impact on reducing aspen seedlings than other damage agents. That being said, cankers could play a part in reducing the number of aspen that regenerate on a site.

Management recommendations.

- Regenerate older aspen stands by clearcutting or other methods. Removal of aspen trees with extensive cankers and competing tree species should be considered.
- Treating stands with above average mortality should remove all mature trees to reduce the impacts of Ganoderma, particularly on moist sites.
- Exclosure fencing would reduce animal damage that provides an entry point for cankers to infect trees.

Figure 10. Typical healthy aspen stand.

Figure 11. Cytospora cankers in a live aspen tree (left), and sooty bark canker in a live (center) and dead (right) aspen tree.

Figure 12. Animal browsing with cankers in aspen seedlings (left and center), and canker in an aspen sapling (right).

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APPENDIX

Damage agents found on less than 5% of the trees, from most to least common included: black canker, bronze poplar borer, Cryptosphaeria canker, broken tops, dead tops, other mechanical damage, wood borers, animal damage, decay fungi, Diplodia canker, dead major branches, Hypoxylon canker, defoliating insects, foliage diseases, large aspen tortrix, Nectria canker, unidentified diseases, bark beetle, fire, and lightning.

Damage agents found on less than 5% of the regeneration, from most to least common included: foliage diseases, animal debarking, shepherd's crook, unidentified diseases, dead top, animal damage, non-animal mechanical damage, forest tent caterpillar, unidentified insect, bronze poplar borer, leafroller, bark beetle, white mottled rot, and ambrosia beetle.