



Biological Evaluation RCSC-20-06

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**Aspen Health on National Forests in the Northern Rocky Mountain Region
(2008/2009 to 2019)**

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Introduction

Quaking aspen (*Populus tremuloides*) is a widely distributed species in the western United States, but in the northern Rocky Mountain Region it is a rare component of forests. In national forests (NF) of the northern Rocky Mountain Region this species comprises only 1% of the Bighorn, 3% of the Black Hills, and 1% of the Shoshone cover types (DeBlander 2002, Menlove 2008, Witt 2008). Since aspen forests provide diversity, support wildlife, are an important component of watersheds, and have aesthetic value, there are concerns regarding the health of this relatively rare forest cover type.

Aspen surveys of the northern Rocky Mountain Region were initiated due to concerns of extensive and sudden decline and deterioration of aspen forests in other parts of the Rocky Mountains (Shaw 2004, Worrall et al. 2008). These concerns were reiterated by NF, news media, and the public. Climate change (Rehfeldt et al. 2009, Worrall et al. 2013), drought (Hogg et al. 2008, Worrall et al. 2008), and changes in the fire regimes since European settlement combined with increased browsing (Bartos and Campbell 1998, Kay 1997, Romme et al. 1995, Sheppard et al. 2006) have been suggested as factors contributing to decline and mortality of aspen, a short-lived species. However, earlier surveys of the northern Rocky Mountain Region found mortality rates to be normal (Blodgett et al. 2017). Those surveys also found damage agents previously reported in the region.

Damage agents are diseases, insects, animals (including human damage), or other biotic/abiotic factor that can cause damage or death to a host tree. Several diseases and insects are associated with aspen mortality (Dudley 2011, Fairweather et al. 2008, Frey et al. 2004, Guyon and Hoffman 2011, Hogg et al. 2008, Hogg and Michaelian 2014, Marchetti et al. 2011, Rehfeldt et al. 2009, Steed and Kearns 2010, Worrall et al. 2010, 2013). In previous surveys the main damage agents associated with aspen mortality were identified in the northern Rocky Mountain Region (Blodgett et al. 2017). Those included sooty-bark canker (*Encoelia pruinosa*), Cytospora canker (*Valsa sordida/Cytospora chrysosperma*) and aspen trunk rot (*Phellinus tremulae*). Although 33 damage agents were found in trees with up to eight in an individual tree, only the three were consistently associated with aspen mortality.

Tree health, regeneration stocking, and the main damage agents associated with aspen mortality in the area were reassessed. The objectives of this study were to describe changes in aspen mortality and damage agents over time.



Methods

Sample design. Aspen stands were resampled from June 24 to August 27, 2019 (Figure 1). Stands were originally surveyed in the Black Hills and Shoshone NFs in 2008 and in the Bighorn NF in 2009. Stands were also surveyed in 2015 and 2012. In the Bighorn NF 29 of the original 45 stands were sampled (64%). In the Black Hills NF 36 of the original 60 plots were sampled (60%). In the Shoshone NF 32 of the original 50 plots were sampled (64%). Permanent plots were originally established, but they were removed in 2019, and the number of stands sampled were reduced to reduce travel time and sample days.

The study design consisted of four circular plots per aspen stand (previously three circular plots were sampled). Stands were greater than 2 acres, composed of 50% or more aspen, and had a minimum spacing of approximately 1 mile. For both trees (≥ 3 inches DBH) and tree regeneration (< 3 inches DBH), 1/20-acre plots were established. The spacing between plots within stands was approximately 2 chains. Plots were installed 35 feet or more from stand edges, roads, or major trails.

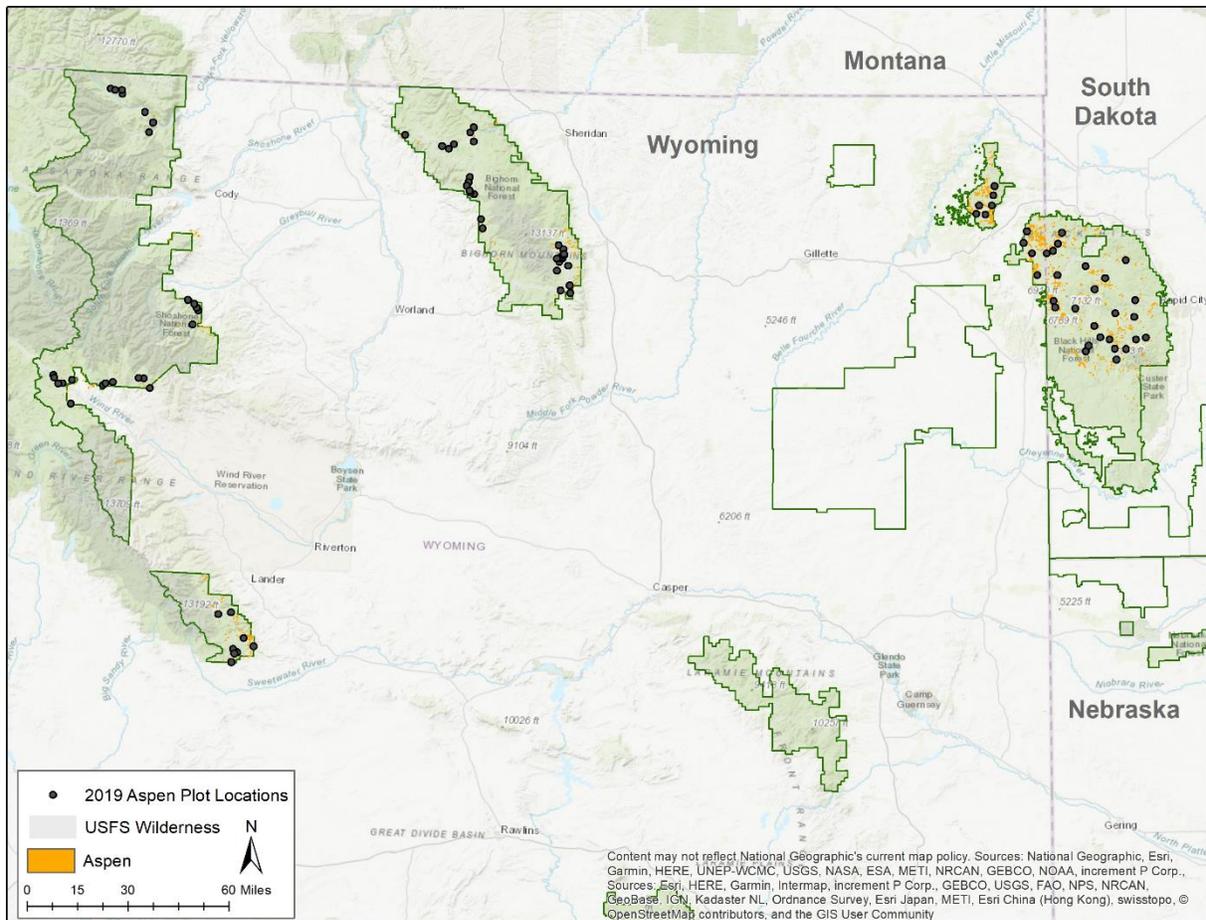


Figure 1. Location of stands sampled in 2019 and aspen cover type.

Plot and tree measurements. Coordinates and elevation were recorded at each plot center. Tree species and diameter at breast height (DBH) were recorded for all live trees ≥ 3 inches DBH and for recent dead aspen. Recent dead aspen had all their bark and at least some fine branches intact and were estimated to have died within 3 years.

For 2019 and the first sample year, mortality was estimated using recent dead aspen trees; estimated mortality = number of recent dead trees divided by three. Since all trees we tagged in 2008/2009 (including new trees in 2012), the 2012 and 2015 mortality values are based on the real number of trees that died since last sampled; mortality = dead trees/year.

Damage agents were recorded for each live and recent dead aspen tree and were summarized as percentage of stems per plot. In 2019, the survey focused mostly on the three main damage agents associated with aspen mortality in the northern Rocky Mountain Region (Blodgett et al. 2017); previously all significant tree damages were recorded.

Regeneration measurements. Regeneration was classified by species and only live regeneration was recorded in 2019. Regeneration variables included number of stems per acre and percentages by species. Only damage agents affecting regeneration at the stand level were noted; previously all significant damages were recorded as a percentage of live and dead regeneration.

Results

Bighorn National Forest. Mean tree mortality was 4% in 2009, 6% in 2012, 3% in 2015, and 5% in 2019 (**Table 1, Figure 2**). Aspen mortality was relatively low in most stands. Only five stands had greater than 8% mortality (**Figure 3**).

Three damage agents can explain most of the observed tree mortality (**Figure 2**). The most common damage agent in trees was *Cytospora* canker (**Table 1**). The number of *Cytospora* cankers increased in live aspen but decreased slightly in dead aspen trees since 2015. Sooty bark canker was the second most common damage agent in trees. The number of sooty bark cankers decreased in both live and dead aspen trees since 2015. Aspen trunk rot was the third most common damage agent. This disease increased in both live and dead aspen trees since 2015. The most common boring insects, poplar borer (*Saperda calcarata*) and bronze poplar borer (*Agrilus liragus*), were uncommon in 2019 (0.2% of the trees combined). Other minor damage agents included other canker diseases (0.5%) and *Ganoderma* root disease (0.1%).

Mean aspen regeneration was 1,536 stems per acre in 2019. Several stands had $<1,000$ stems per acre in 2019 (**Figure 3**), but only five stands had both poor regeneration and $>8\%$ mortality. Many of the stands that had $<1,000$ stems per acre of regeneration had the densest overstory, so little regeneration would be expected. A few stands had competing conifer regeneration, but aspen made up 95% of total regeneration. In 2019, shepherd's crook (*Venturia tremulae* var. *grandidentatae*) damaged or killed most of the regeneration in 20% of stands. Marssonina leaf blight (*Marssonina* sp.) was damaging regeneration in 10% of stands.

Table 1. Bighorn National Forest summary statistics

Variable	2009	2012	2015	2019
DBH-live aspen (inches)	7.8	7.8	8.6	8.6
Mortality (% per year)	4	6	3	5
Common damages recorded in aspen trees (% affected)				
Cytospora canker-live aspen	34	39	17	21
Cytospora canker-dead aspen	50	70	20	19
Sooty bark canker-live aspen	5	6	20	9
Sooty bark canker-dead aspen	48	61	97	80
Aspen trunk rot-live aspen	6	6	2	5
Aspen trunk rot-dead aspen	6	19	1	6

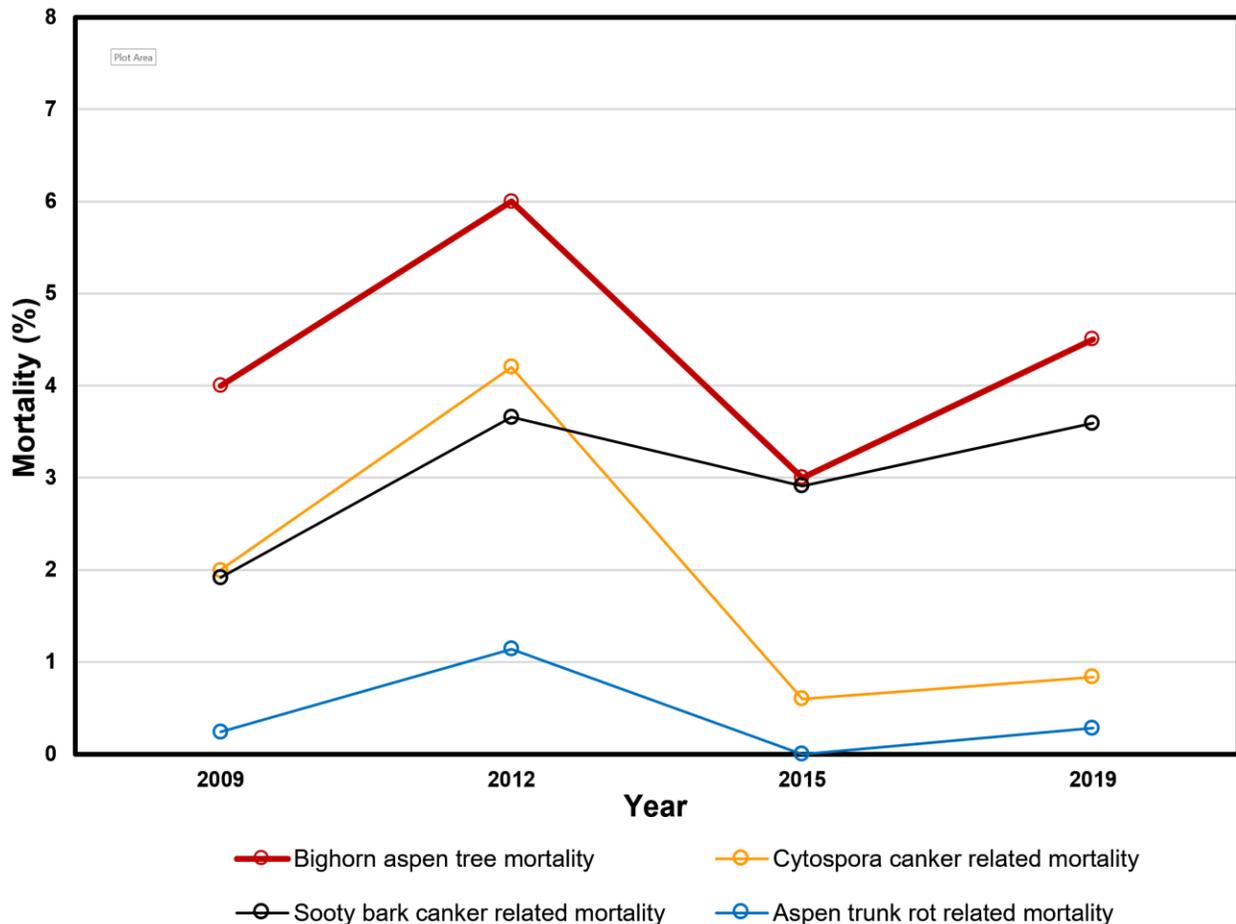


Figure 2. Mean aspen tree mortality in the Bighorn National Forest from 2009 to 2019; with relative amount of mortality caused by the three main damage agents. Multiple damage agents can contribute to mortality, thus individual damage agent totals can exceed total mortality.

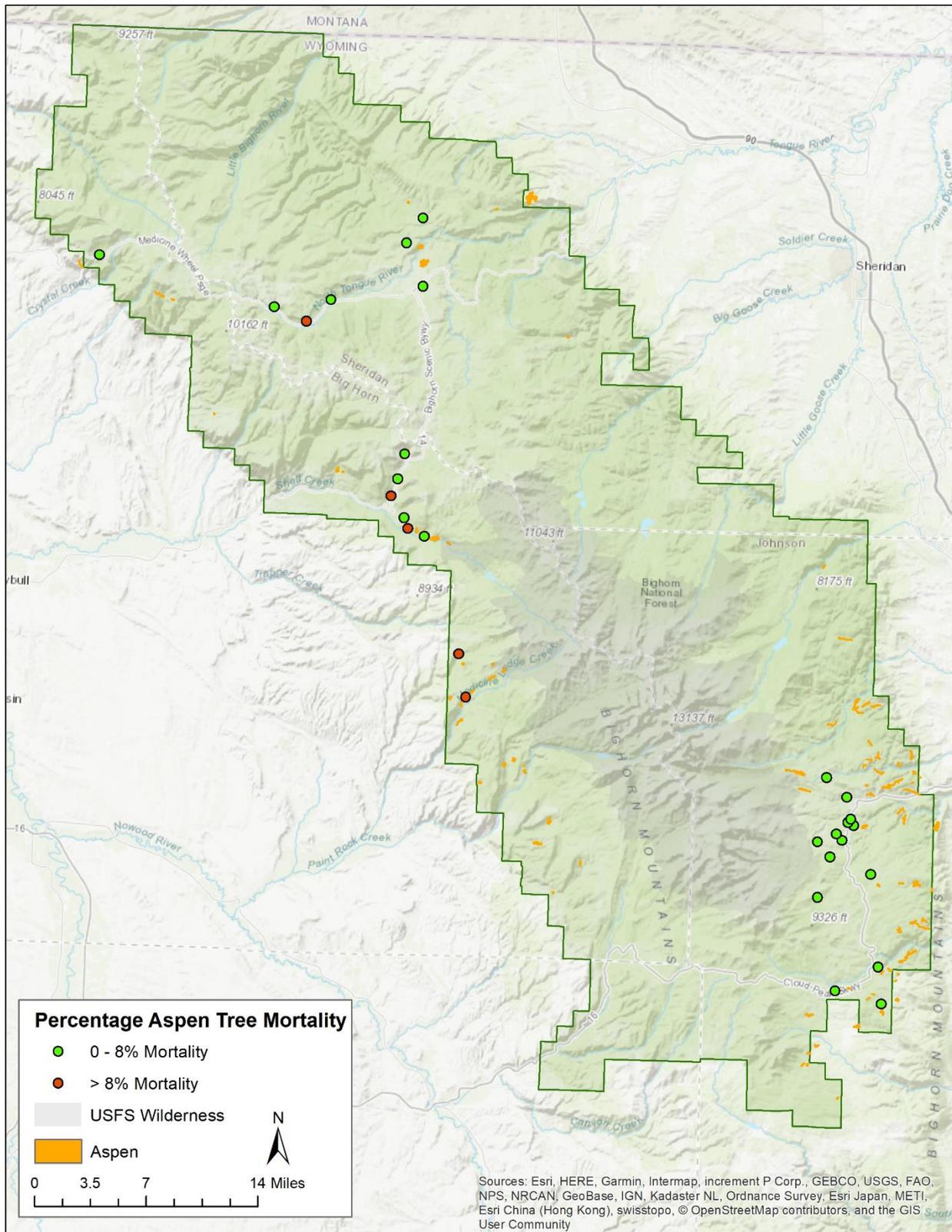


Figure 3. Aspen tree mortality in the Bighorn National Forest in 2019.

Black Hills National Forest. Mean tree mortality was 2% in 2008, 6% in 2012, 7% in 2015, and 5% in 2019 (**Table 2, Figure 5**). Aspen mortality was relatively low in most stands, though eight stands had greater than 8% mortality (**Figure 6**).

Three damage agents can explain most observed tree mortality (**Figure 5**). The most common damage agent in trees was aspen trunk rot (**Table 2**). Since 2015, this disease increased in live aspen but decreased in dead aspen trees. Sooty bark canker was the second most common damage agent in trees. The number of sooty bark cankers decreased in live aspen but increased in dead aspen trees since 2015. Cytospora canker was the third most common damage agent. The number of Cytospora cankers decreased in both live and dead aspen trees since 2015. Cytospora cankers did increase with tree mortality. The most common boring insects, poplar borer and bronze poplar borer, were uncommon in 2019 (0.5% of the trees combined). Other minor damage agents included Ganoderma root disease (2%) and other canker diseases (0.5%).

Mean aspen regeneration was 296 stems per acre in 2019. Most stands had <1,000 stems per acre in 2019 (**Figure 7**), but only eight stands had both poor regeneration and >8% mortality. Similar to the Bighorn NF, stands that had <1,000 stems per acre of regeneration had the densest overstory, so little regeneration would be expected. Several stands had competing hardwood and/or conifer regeneration, and aspen made up only 66% of the regeneration on average. Competing woody vegetation probably explains much of the low aspen regeneration. Although we did not look at competing grasses and forbs, this non-woody vegetation might explain some of the low aspen regeneration and may have hidden some of smaller aspen regeneration. Overall, the number of seedlings and saplings has declined on the Black Hills and in 2015 averaged below 1,000 stems per acre. This decreasing trend continued into 2019. Marssonina leaf blight was damaging regeneration in a few stands.

Table 2. Black Hills National Forest summary statistics

Variable	2008	2012	2015	2019
DBH-live aspen (inches)	7.0	6.9	7.4	7.5
Mortality (% per year)	2	6	7	5
Common damages recorded in aspen trees (% affected)				
Cytospora canker-live aspen	34	47	28	11
Cytospora canker-dead aspen	50	71	48	12
Sooty bark canker-live aspen	30	33	14	12
Sooty bark canker-dead aspen	71	86	45	78
Aspen trunk rot-live aspen	21	28	23	31
Aspen trunk rot-dead aspen	16	43	34	24

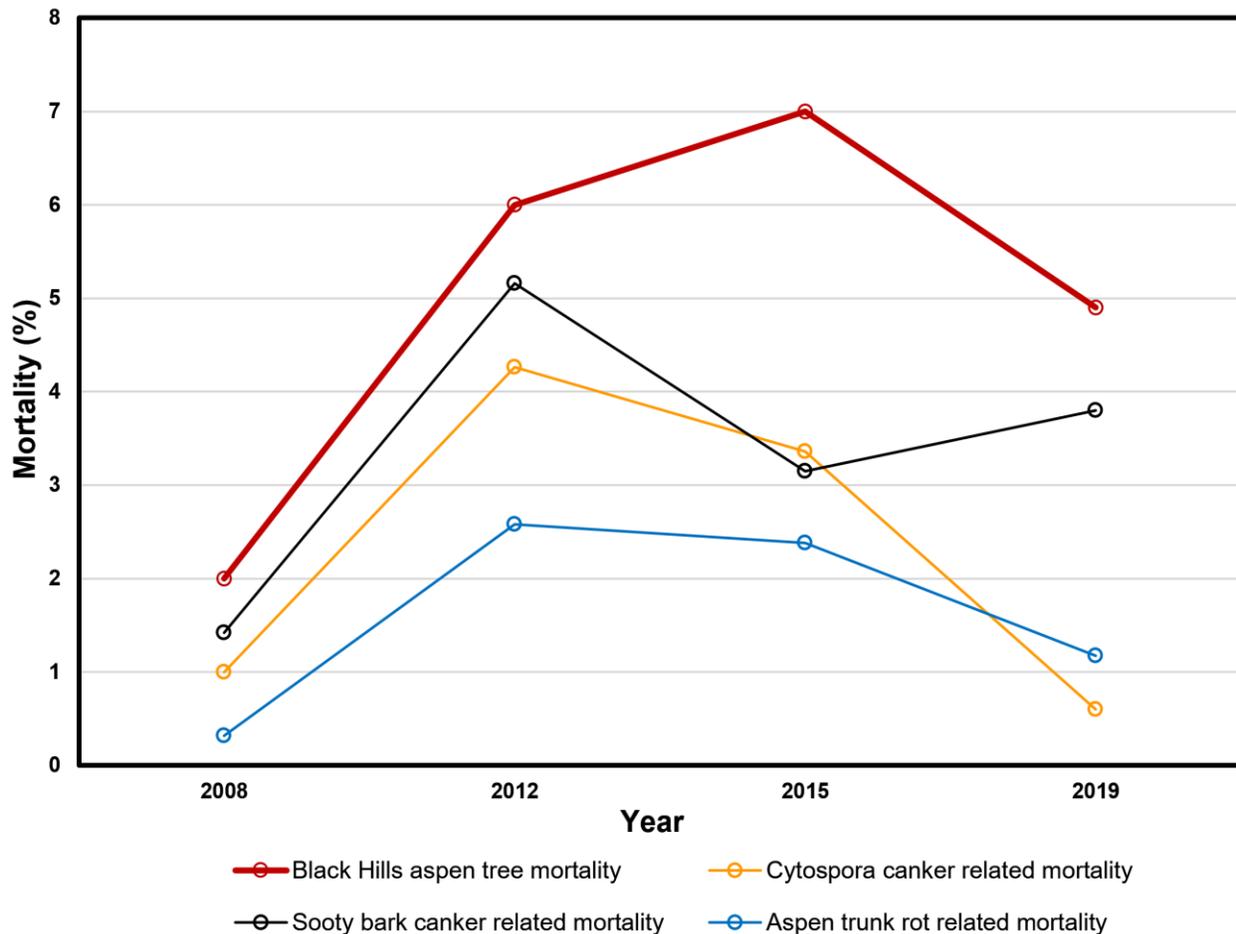


Figure 5. Mean aspen tree mortality in the Black Hills National Forest from 2008 to 2019; with relative amount of mortality caused by the three main damage agents. Multiple damage agents can contribute to mortality, thus individual damage agent totals can exceed total mortality.

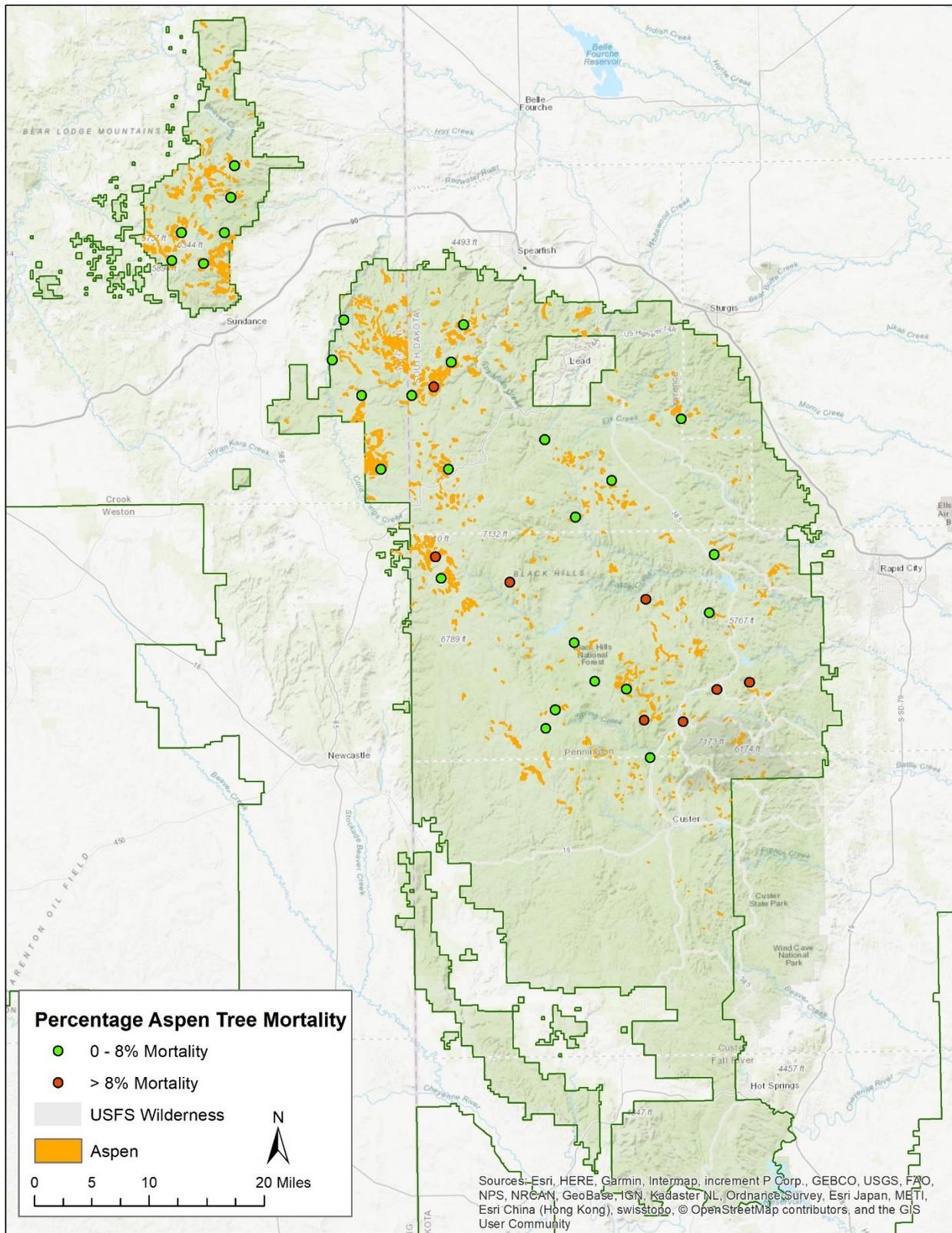


Figure 6. Aspen tree mortality in the Black Hills National Forest in 2019.

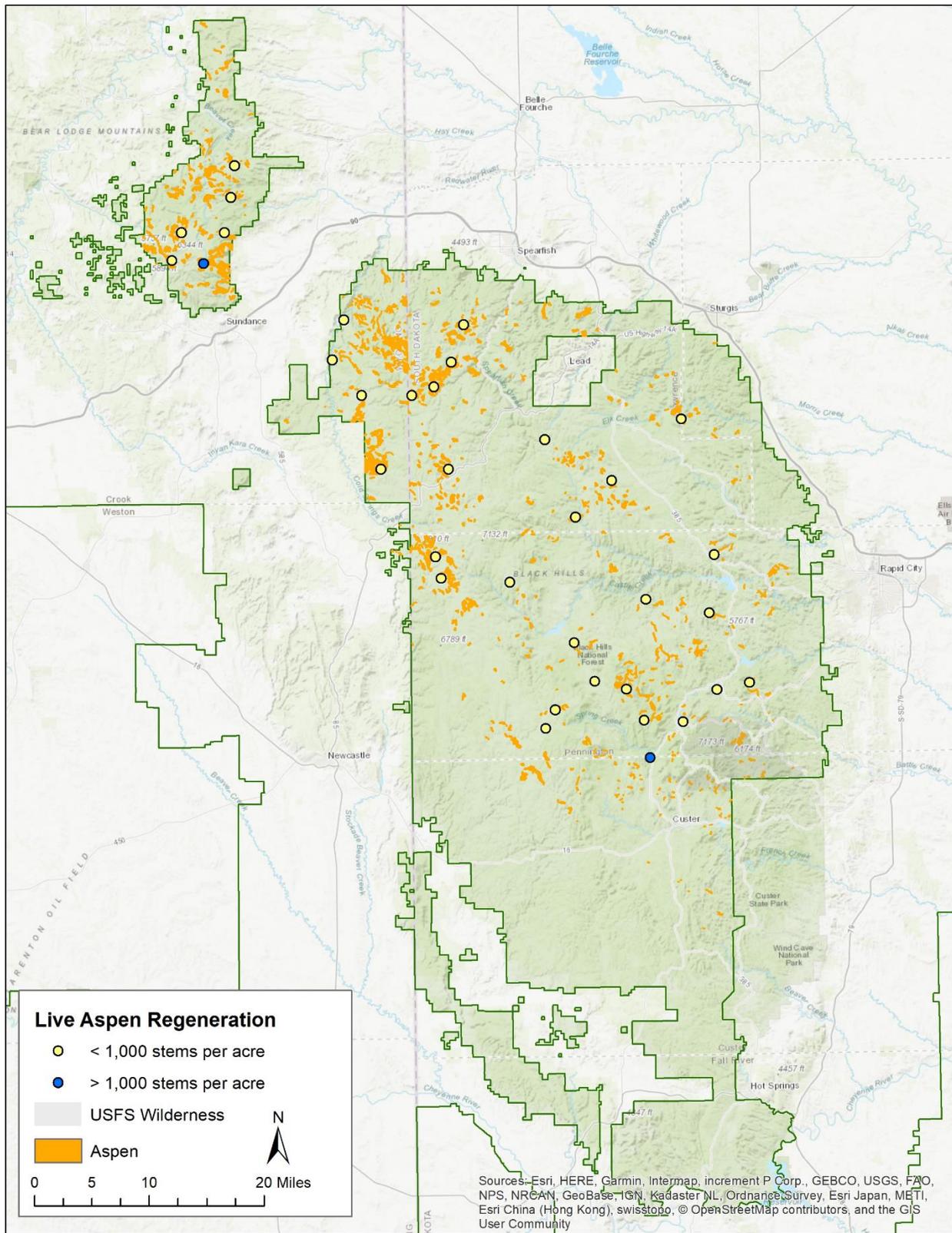


Figure 7. Aspen regeneration numbers in the Black Hills National Forest in 2019.

Shoshone National Forest. Mean aspen tree mortality was 4% in 2008, 6% in 2012, 5% in 2015, and 6% in 2019 (**Table 3, Figure 8**). Mortality was relatively low in most stands, though eight stands had greater than 8% mortality (**Figure 9**). Much of the tree mortality in one stand was due to fire. Extensive fire damage caused aspen mortality in 2012, 2015, and 2019.

Three damage agents can explain most of the observed tree mortality (**Figure 8**). The most frequently observed damage in trees was *Cytospora* canker (**Table 3**). Since 2015, the number of *Cytospora* cankers decreased slightly in live and decreased in dead aspen trees. Sooty bark canker was the second most common damage agent in trees. Since 2015, the number of sooty bark cankers decreased slightly in live aspen but increased in dead aspen trees. Aspen trunk rot was the third most common damage agent. Since 2015, this disease decreased in both live and dead aspen trees. The most common boring insects, poplar borer and bronze poplar borer, were uncommon in 2019 (0.6% of the trees combined). Other minor damage agents included *Ganoderma* root disease (1%) and other canker diseases (<0.1%).

Mean aspen regeneration was 1,450 stems per acre in 2019. Several stands had <1,000 stems per acre in 2019 (**Figure 10**), but only one stand had both poor regeneration and >8% mortality. Many of the stands that had <1,000 stems per acre of regeneration had the densest overstory, while others had competing conifer regeneration, therefore little regeneration would be expected. *Marssonina* leaf blight was damaging regeneration in 3% of the stands.

Table 3. Shoshone National Forest summary statistics

Variable	2008	2012	2015	2019
DBH-live aspen (inches)	7.0	7.1	7.5	7.1
Mortality (% per year)	4	6	5	6
Common damages recorded in aspen trees (% affected)				
Cytospora canker-live aspen	38	46	29	26
Cytospora canker-dead aspen	71	82	50	34
Sooty bark canker-live aspen	12	18	9	8
Sooty bark canker-dead aspen	43	61	39	79
Aspen trunk rot-live aspen	6	11	10	3
Aspen trunk rot-dead aspen	13	13	11	3

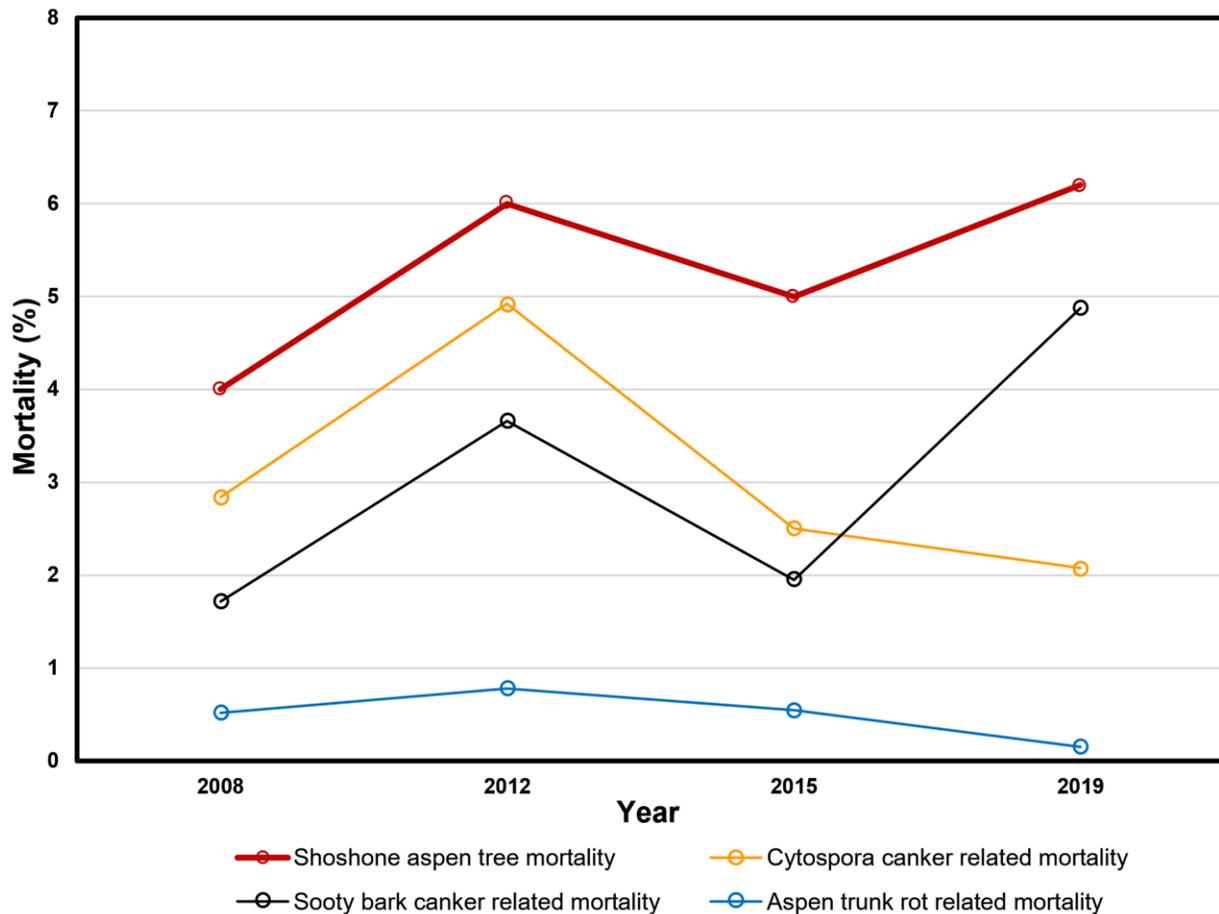


Figure 8. Mean aspen tree mortality in the Shoshone National Forest from 2008 to 2019; with relative amount of mortality caused by the three main damage agents. Multiple damage agents can contribute to mortality, thus individual damage agent totals can exceed total mortality.

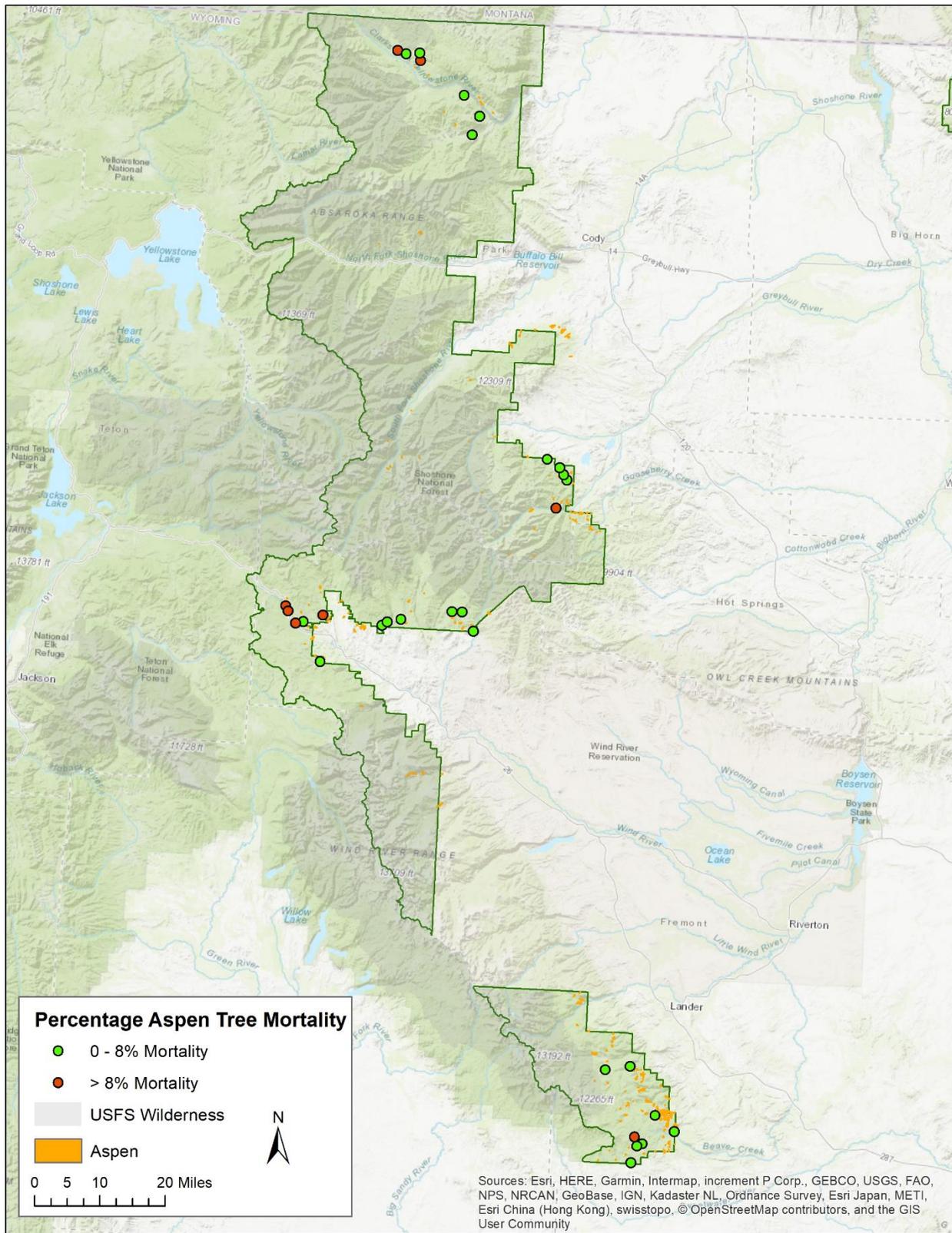


Figure 9. Aspen tree mortality in the Shoshone National Forest in 2019.

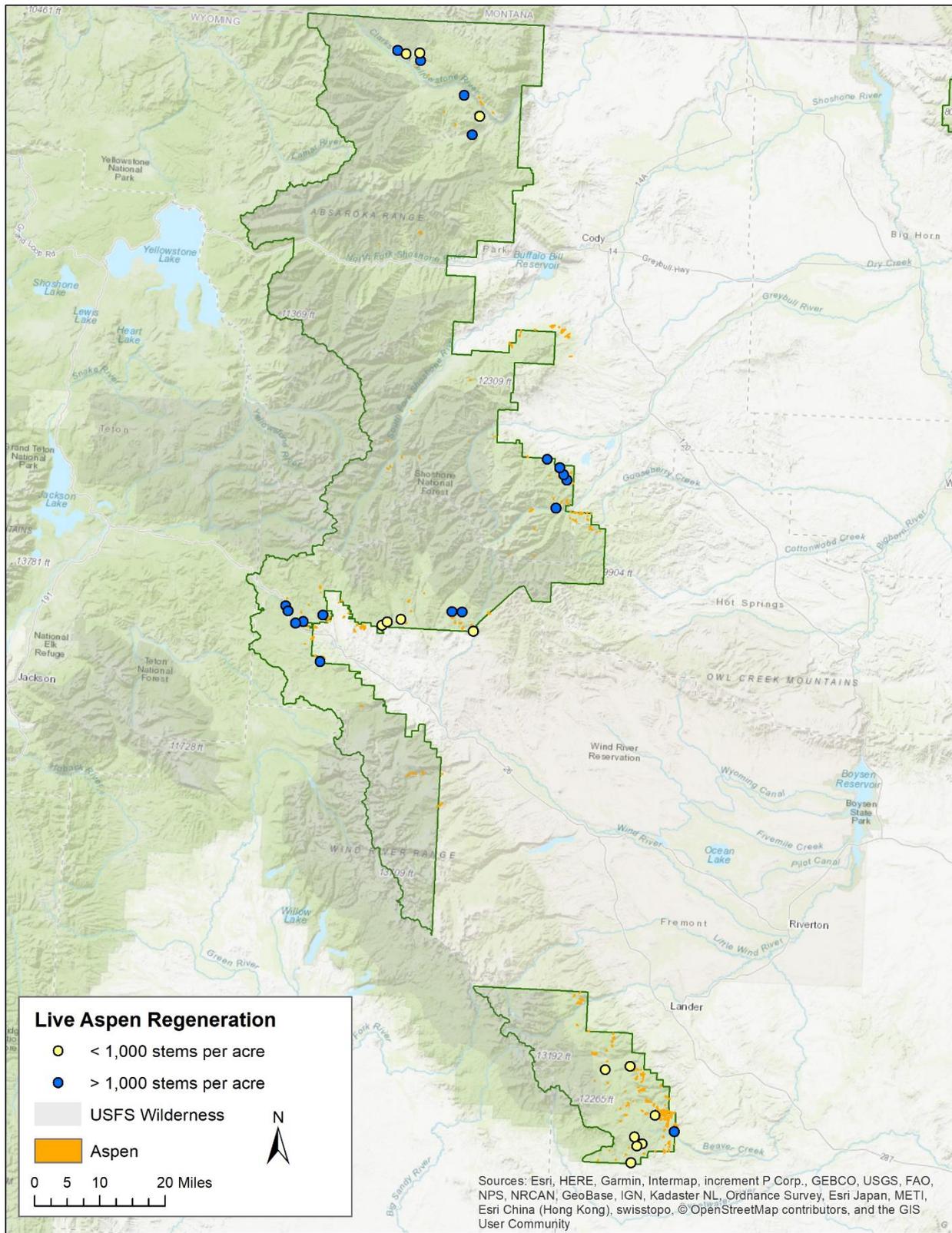


Figure 10. Aspen regeneration numbers in the Shoshone National Forest in 2019.

Discussion

Most aspen stands in these three forests are healthy. Aspen tree mortality has remained consistent and low in all three forests since 2008/2009 (**Figure 11**). This suggests no significant tree mortality events are occurring. Yet, slightly elevated tree mortality has occurred in a few stands. Stands that are seeing above average mortality are expected to continue to have elevated mortality. The number of seedlings and saplings has decreased in all three forests starting in: 2012 in the Black Hills, 2015 in the Bighorn, and 2019 in the Shoshone National Forests (**Figure 11**).

Various 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). We found 33 damage agents in aspen trees with up to eight in an individual tree (Blodgett et al. 2017), but only three were common and correlated with tree mortality. Other damage agents can cause tree mortality, but their correlations with aspen mortality were not significant and they were infrequent. A damage agent's aggressiveness, correlation with mortality, and incidence should be considered when defining important agents that can impact trees at the landscape level.

Damage agents causing mortality in our study have been associated with aspen mortality in other areas (Dudley 2011, Fairweather et al. 2008, Guyon and Hoffman 2011, Marchetti et al. 2011, Steed and Kearns 2010). Consistent with our earlier surveys (Blodgett et al. 2017), sooty bark and *Cytospora* cankers and aspen trunk rot were the three most common and damaging agents in the northern Rocky Mountain Region. Sooty-bark canker is the most aggressive damage agent and was previously suggested as a major mortality agent of aspen (Hinds 1985). This damage agent was frequently observed in live trees and was very common in recent dead trees (**Figure 12**). Sooty bark canker also increased with tree mortality, often with large-expanding cankers, and was considered the most significant contributor to tree mortality. Although *Cytospora* canker was more common and is causing mortality, it is a less aggressive pathogen (**Figure 12**). *Cytospora* cankers did increase with tree mortality suggesting it is an important mortality agent. While this canker was common, it often formed small diameter cankers, frequently stopped expanding, and cankers often healed without causing significant tree impacts. The incidence of aspen trunk rot remained consistent during this 10+ year survey. This disease increased with tree mortality suggesting it is an important mortality agent. Aspen trunk rot kills trees through stem breakage resulting from internal decay and is more common in mature trees (**Figure 13**).

Factors such as a dense overstory, competing regeneration from other species, and in a few cases fire, have reduced aspen regeneration in many stands. Having fewer than 1,000 stems per acre is normal in older/dense aspen stands. Additionally, browsing is often cited as a factor limiting 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. In 2019, we did not look at browsing or canker damage to regeneration. However, in our three earlier surveys browsing and canker damage were the main damage agents in aspen regeneration in all three forests (Blodgett et al. 2017). Cankers were frequently associated with browse damage, suggesting browsing is an important infection-court for the damaging canker fungi. Shepherd’s crook reduced regeneration in some Bighorn NF stands and *Marssonina* leaf blight caused some aspen regeneration damage in all three forests (Figure 14).

Aspen is a short-lived species, especially in the northern Rocky Mountain Region. This species typically lives for less than 80 to 100 years; if not killed earlier by various damage agents. Mortality levels up to 8% are common in aspen stands. A model was constructed using the mean regeneration plus trees, mortality, and in-growth values observed in these forests over 10+ years (Figure 15). The model generates a typical reverse J-shaped curve with the modeled stand stabilizing at 85 mature trees per acre. Since the model predicts several of the original aspen regeneration are still alive after 80 (55 aspen) and 100 (20 aspen) years, the mean mortality rate (4.9%) recently observed in these forests are likely low for an aspen cover type. An 8% mortality rate still gives 4 of the original aspen alive in 80 years and 1 alive in 100 years.

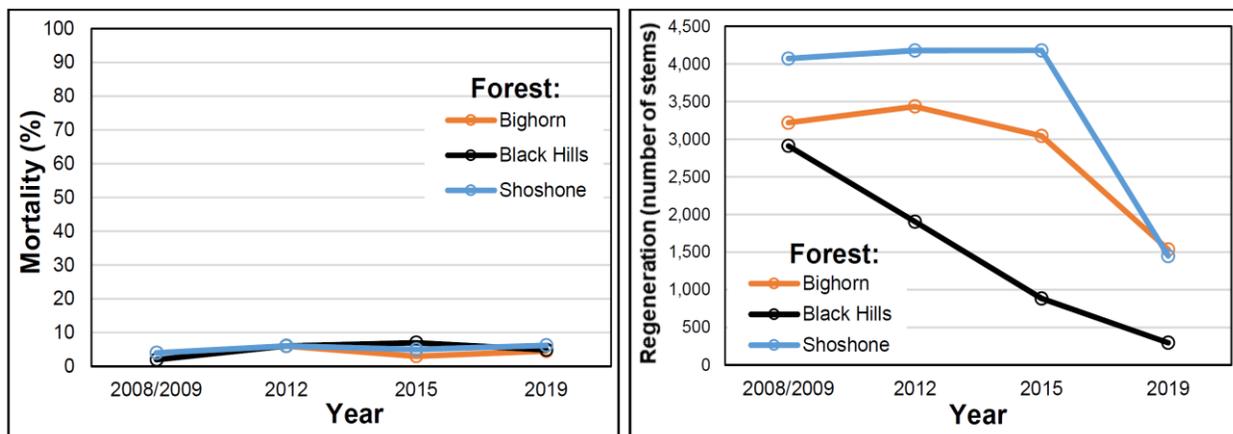


Figure 11. Aspen tree mortality from 2008/2009 to 2019 (left). Regeneration (stems per acre) from 2008/2009 to 2019 (right).



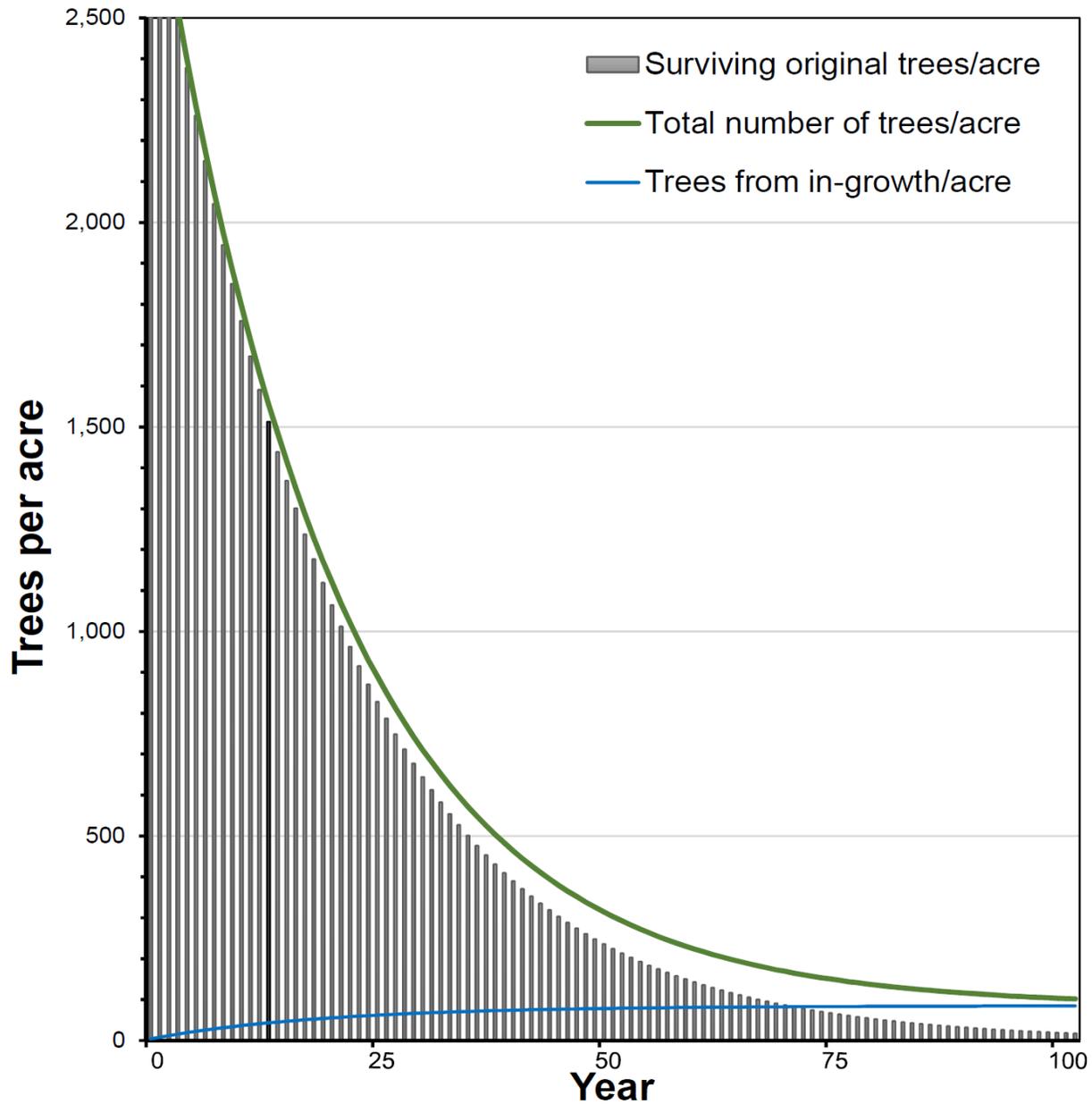
Figure 12. Sooty-bark canker in a live (left) and dead (middle) aspen, and *Cytospora* canker in a live aspen (right).



Figure 13 Aspen trunk rot conk (left), an aspen snapped by aspen trunk rot (middle), and a *Ganoderma* root disease conk.



Figure 14. Shepherd's crook symptoms in aspen seedlings (left and middle), and *Marssonina* leaf blight symptoms in an aspen leaf (right).



Years	Surviving original trees per acre	Trees from in-growth per acre	Total number of trees per acre
80 years	55	83	138
100 years	20	84	104
200 years	0	85	85

= stable at ≈ 155 years

Figure 15. Modeled total number of live trees per acre at 80, 100, and 200 years; given the mean tree mortality (4.9 trees per year), mean regeneration (2,593 stems), mean number of trees (314 stems), and mean tree in-growth (0.15 stems per year). Input values are the mean values of the three forests over the 10+ years of this study.

Management Recommendations

- Regenerate older aspen stands by clearcutting, prescribed fire, or wildfire to stimulate regeneration and help maintain aspen on sites.
- Sooty-bark canker and aspen trunk rot (not *Cytospora* canker) tends to attack older trees, so managing aspen in rotations of less than 100 years would reduce losses from those diseases.
- Avoiding wounds should reduce the likelihood of infections from sooty bark and *Cytospora* canker diseases resulting in reduced canker-caused mortality in trees and regeneration.
- Partial cutting in aspen stands is strongly discouraged since wounding often results in canker infections. Partial cutting also might result in subsequent wounding as a result of increased boring insects.
- Exclosure fencing would reduce animal browsing and stem damage that provides an entry point for canker-fungi to infect both trees and regeneration. This would also reduce mortality caused by these diseases.
- Clonal variation in susceptibility to decay has been demonstrated for aspen trunk rot. Favoring clones with low levels of decay would select for resistance.
- Aspen trunk rot conks are good indicators for detecting and estimating decay. Decay typically extends 8-12 ft in each direction from conks, and cull increases with number of conks.

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