

SPRUCE BEETLE EPIDEMIC-ASPEN DECLINE MANAGEMENT RESPONSE PROJECT (SBEADMR) SCIENCE TEAM MONITORING QUESTIONS, RESULTS, AND INTERPRETATION
GRAND MESA, UNCOMPAHGRE, AND GUNNISON NATIONAL FOREST

February 2024 UPDATE (*New information is highlighted below*)

1. Impacts of spruce bark beetle and subsequent salvage in Engelmann spruce and Engelmann spruce-aspen forests of the Gunnison National Forest on forest structure and tree regeneration

Lead: Battaglia

Years Measured: 2015 - 2020, 2023

Completed Monitoring			
Question	Indicators/Methods	Current Findings	Science Team Interpretation
a. Did unmanaged and previously managed stands respond differently to the spruce beetle epidemic?	1) Tree density 2) Stand Basal Area 3) Species Composition 4) Seedling regeneration density	<p>SPRUCE STANDS</p> <ul style="list-style-type: none"> • Spruce beetle induced tree mortality was similar among the previously managed and unmanaged stands • Average Live Trees per acre for unmanaged and previously managed stands about 383 to 472 • Average Live Basal Area for unmanaged and previously managed stands about 26 to 28 ft²/ac • Live trees are dominated by sizes less than 4 inch dbh • Previously managed stands have significantly more seedlings (<dbh) than the unmanaged stands. • 4 to 7% of live trees are cull • Species composition dominated by Engelmann spruce <p><i>2023 Remeasurement of a subset of plots (n= ##):</i></p> <ul style="list-style-type: none"> • 2023 resampling of intensive plots shows total live basal areas of 30 ft²/ac in both unmanaged stands and previously managed stands, with the majority of the live BA split between sapling and poles in unmanaged stands and saplings in the previously managed stands • 2023 resampling of intensive plots shows live trees per acre of 819 in unmanaged stands and 981 in previously managed stands (NS) • 2023 resampling of intensive plots shows that live trees per acre were dominated by the sapling size class (0-4.9 in DBH) 	<p>Initial assessment: In spruce dominated stands, both unmanaged and previously managed areas had similarly high rates of overstory mortality after the spruce beetle outbreak. This suggests that the shelterwood cuts in the 1990s didn't help the trees resist the beetle outbreak.</p> <p>However, these earlier treatments did aid in establishing spruce regeneration in the 1990s, allowing for these areas to be ahead in stand development and now are closer to reproductive age. The unmanaged stands also responded with an increase in seedling establishment during the beetle outbreak. Furthermore, both areas had a multi-cohort forest structure (i.e. multiple tree sizes), but dominated by sapling and seedling size classes. The beetles targeted spruce trees > 4 inch dbh. This suggests that diversity in tree sizes is important to enhance resilience to spruce bark beetle.</p> <p>In 2023, remeasurement of a subset of the initial assessment plots allowed us to look at trends over the past 5 to 8 years. Due to the spruce beetle killing the majority of pole and sawtimber sized spruce</p>

Completed Monitoring			
Question	Indicators/Methods	Current Findings	Science Team Interpretation
		<ul style="list-style-type: none"> • 2023 resampling of intensive plots shows live tree species composition dominated by spruce • 2023 standing dead; more dead pole and sawtimber than live trees in both unmanaged and previously managed stands <ul style="list-style-type: none"> ○ Unmanaged: <ul style="list-style-type: none"> ▪ 74% Spruce mortality poles ▪ 89% Spruce mortality sawtimber ○ Previously managed: <ul style="list-style-type: none"> ▪ 59% Spruce mortality poles ▪ 84% Spruce mortality sawtimber • 2023 resampling of intensive plots shows that unmanaged stands had more seedling regeneration than previously managed (Total: 4037 tpa vs 3211 tpa) but it was highly variable so not significantly different, however, <ul style="list-style-type: none"> ○ Seedling regeneration was a mix of aspen and spruce in the unmanaged stands, but was dominated by spruce in the previously managed stands <p>SPRUCE-ASPEN STANDS</p> <ul style="list-style-type: none"> • Spruce beetle induced tree mortality was similar among the previously managed and unmanaged stands • Average Live Basal Area for unmanaged and previously managed stands about 78 to 79 ft²/ac • Previously managed stands have twice as many live trees per acre than unmanaged stands (1104 vs 517) • Live spruce trees are dominated by sizes less than 4 inch dbh • Live aspen trees now dominate the overstory • No difference in the amount of seedling regeneration (<dbh); 3106 to 3627 per acre • Seedling regeneration is about 50:50 Aspen and Engelmann spruce • 1% of live trees are cull <p><i>2023 Remeasurement of a subset of plots:</i></p> <ul style="list-style-type: none"> • 2023 resampling of intensive plots shows average live basal areas for unmanaged and previously managed stands about 62 and 76 ft²/ac • 2023 resampling of intensive plots shows previously managed stands have 1367 live trees per acre and unmanaged stands have 955 trees per acre. 	<p>trees, in both unmanaged and previously harvested stands, live Basal Area is low. Much of the live Basal area is found within the pole and sapling sized classes and is increasing. When looking at the number of trees, most of the live trees are dominated by saplings and seedling size classes. We continue to observe suitable seedling establishment in both treatments; however, species composition of seedlings differs. Unmanaged stands are a mix of spruce and aspen, while the previously managed stands are dominated by spruce. As expected, most of the tree mortality was found in the pole and sawtimber size classes of the spruce, ranging from 59 to 89%, however the majority of standing dead is found in the sapling size class. [did most of the poles and sawtimber fall down already?]</p> <p>Overall, both the unmanaged and previously managed stands are dominated by trees <5 inch dbh of Engelmann spruce. Live tree density of these stands indicates suitable stocking. Both stands have high levels of pole- and sawtimber-sized mortality that will continue to contribute to coarse woody fuel loads.</p> <p>Spruce-Aspen Stands</p> <p>In spruce-aspen mixed stands similar trends were observed as in the spruce dominated stands. However, there is more living basal area in these forests due to the aspen not being impacted by the spruce bark beetle. These forests are now dominated by aspen in the overstory. Areas that were previously managed in the 1990s have twice as many live trees per acre with a mix of spruce and aspen. Both areas had a multi-cohort forest</p>

Completed Monitoring			
Question	Indicators/Methods	Current Findings	Science Team Interpretation
		<ul style="list-style-type: none"> • 2023 resampling of intensive plots shows that live trees were still dominated by the sapling size class (0-4.9 in DBH) • 2023 resampling of intensive plots shows aspen dominate the overstory in both unmanaged and previously managed stands • 2023 standing dead; more dead pole and sawtimber in unmanaged than live trees in unmanaged. Previously managed stands <ul style="list-style-type: none"> ○ Unmanaged: <ul style="list-style-type: none"> ▪ 77% Spruce mortality poles ▪ 100% Spruce mortality sawtimber ○ Previously managed: <ul style="list-style-type: none"> ▪ 57% Spruce mortality poles ▪ 70% Spruce mortality sawtimber ○ • 2023 resampling of intensive plots shows that unmanaged stands had more regeneration than previously managed (Total: 4872 tpa vs 3559 tpa), but it was highly variable so not significantly different, however, <ul style="list-style-type: none"> • Seedling regeneration was a mix of aspen and spruce 	<p>structure (i.e. multiple tree sizes). The beetles targeted spruce trees > 4 inch dbh. This suggests that diversity in tree sizes is important to enhance resilience to spruce bark beetle. Furthermore, the diversity in tree species increased this stand type's resilience. Stands continue to recruit new seedlings.</p> <p>In 2023, remeasurement of a subset of the initial assessment plots allowed us to look at trends over the past 5 to 8 years. Live Basal area was higher and distributed throughout the different size classes in this forest type due to the presence of the aspen. Aspen dominates the species composition. The spruce beetle killed 100% of the spruce sawtimber in the unmanaged stands and 70% in the previously managed stands. When looking at the number of trees, most of the live trees are dominated by saplings and seedling size classes. We continue to observe suitable seedling establishment in both treatments with a mix of spruce and aspen. The majority of standing dead is found in the pole and sapling size class for both Spruce and aspen.</p> <p>Overall, both the unmanaged and previously managed stands are dominated by trees <5 inch dbh of Engelmann spruce and Aspen. Live tree density of these stands indicates suitable stocking. Both stands have high levels of sapling- and pole-sized mortality that will continue to contribute to coarse woody fuel loads.</p>
b. To what extent did salvage impact forest structure?	1) Tree density 2) Stand Basal Area	<p>SPRUCE STANDS</p> <ul style="list-style-type: none"> • Salvage substantially reduced amount of dead BA and TPA • Live tree BA and TPA was reduced to 8-10 ft²/ac and 152 to 165 tpa • Seedling density in salvaged units similar to unmanaged and previously managed stands 	In spruce-dominated stands, salvage reduced dead tree density substantially, reducing the amount of future coarse wood inputs. Some live trees were lost to windthrow. While density is lower than in

Completed Monitoring			
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	3) Species Composition 4) Seedling regeneration density	<ul style="list-style-type: none"> • Seedlings (<dbh) averaged 1228 tpa in salvaged units • Seedling density in roadside salvage treatments only averaged 105 tpa • Species composition dominated by Engelmann spruce • Residual live BA in 2023 from salvaged sites is 11 ft²/ac and live TPA is 231 • Overstory species composition is dominated by spruce, and the saplings (0-4.9in DBH) are the dominant size class • 2023 resampling of intensive plots shows that seedling density was lowest in salvaged stands (2385 tpa) relative to previously managed (3211 tpa) and non-managed (4037 tpa), although variability suggests not significantly different <ul style="list-style-type: none"> ○ Species composition of the regeneration is a mix of Englemann spruce and aspen • 2023 resampling of intensive plots shows salvage stands are also dominated by sapling and seedling size class with a mix of Engelmann spruce and aspen • 2023 Salvage stands had little standing dead tpa in sawtimber size class, but some still in the pole and sapling size class: <ul style="list-style-type: none"> ○ Sawtimber: <1 TPA spruce, 0 TPA aspen ○ Pole: 32 TPA Spruce, 3 TPA Aspen ○ Sapling: 62 TPA Spruce, 0 TPA Aspen <p>SPRUCE-ASPEN STANDS</p> <ul style="list-style-type: none"> • Residual live BA in 2023 from salvaged sites is 41 ft²/ac and live TPA is 1123 • Overstory species composition is dominated by aspen, and the saplings (0-4.9in DBH) are the dominant size class • 2023 resampling of intensive plots shows that seedling density was highest in salvaged stands (6183 tpa) relative to previously managed (3559 tpa) and non-managed (4872 tpa) <ul style="list-style-type: none"> ○ Seedling density is dominated by aspens in the salvage areas • 2023 Salvage stands had little standing dead tpa in sawtimber size class, but some still in the pole and sapling size class: <ul style="list-style-type: none"> ○ Sawtimber: 5 TPA spruce, 3 TPA aspen ○ Pole: 43 TPA Spruce, 12 TPA Aspen ○ Sapling: 66 TPA Spruce, 38 TPA Aspen 	<p>the unmanaged and previously managed stands, salvage stands still have saplings and new regeneration densities that exceed stocking guidelines. Salvage logging activities did a good job protecting the advanced regeneration that will contribute to future stand structure. These activities should continue to protect any live trees in the stand to facilitate stand recovery.</p> <p>The 2023 remeasurements of salvage units indicate both the spruce-dominated and spruce/aspen mixed stands continue to recruit a mix of new aspen and Engelmann spruce seedlings. In fact, in the spruce/aspen stands, aspen recruitment is exceeding spruce recruitment. Standing dead trees are limited in the salvage units compared to the unmanaged and previously harvested stands.</p>

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c. Do unmanaged, previously managed, and salvaged stands have different survival and growth rates of the advanced regeneration after the spruce beetle epidemic and salvage?	1) Tree Survival 2) Surviving Tree Growth Rates (Remeasurement of tagged trees at forest inventory plots)	<p>SPRUCE STANDS</p> <ul style="list-style-type: none"> • Spruce overstory (> 5in dbh) survival ranged 64% to 91% • Lowest spruce overstory survival in salvaged stands, no difference in survival between previously managed and unmanaged stands (both 91%) • No difference in Aspen overstory survival across treatments (92% - 100%) • Spruce sapling (<5 in dbh) survival ranged 80% to 100%. • Lowest spruce sapling survival in salvaged stands, no difference between previously managed and unmanaged stands (~100%) • 100% aspen sapling survival across all treatments • No difference in spruce seedling (<dbh) survival across all treatments (88% - 94%) • Lowest spruce survival rates (pooled across treatments) in 0-4 inch size class (86%) • No difference in aspen seedling survival across treatments (93% - 100%) • 2023 Results: <ul style="list-style-type: none"> ○ Spruce overstory (>5 in dbh) survival ranged 66% to 80%, lowest in salvaged, highest in previously managed (80%). Survival unmanaged stands 79%. However, variability suggests no significant difference. <ul style="list-style-type: none"> ▪ Spruce overstory (>5 in dbh) height grew 0.54 to 0.77 feet per year (NS), and dbh increased 0.16 to 0.19 inches per year (NS) ○ Spruce sapling (<5in dbh) survival was 64% in salvaged stands and significantly lower, and 94%-98% in previously managed and non-managed stands, respectively. <ul style="list-style-type: none"> ▪ Spruce saplings (<5 in dbh) grew significantly slower, 0.33 feet per year in salvaged stands, versus 0.59 to 0.64 feet per year in other treatments. DBH increased 0.13 to 0.16 inches per year across all treatments, but wasn't significantly different among treatments. ○ Spruce seedling Survival ranged from 75% in non-managed and salvaged stands to 84% in previously managed , but not significantly different 	<p>In spruce dominated stands, spruce trees had high survival post-beetle. However, there was a decrease in survival (to 64%) for spruce in the salvage treatment, due to some windthrow and other agents. Spruce Seedling survival also remained high for the different treatments surveyed. Aspen survival across size classes remained high as well.</p> <p>Preliminary results from the spruce-aspen mixed stands indicate survival is high for both spruce and aspens. However, sample sizes are still low and we will be sampling summer 2023 to increase our ability for inference.</p> <p>Growth of surviving trees has not been assessed yet since we need several years of post-beetle/salvage response to fully understand the impacts.</p> <p>2023 remeasurements:</p> <p>Spruce dominated stands: The survival of spruce >5 inch dbh continues to be good with similar height and diameter growth among the different treatments. Spruce saplings (<5 inch dbh) did see a decrease in survival compared to the unmanaged and previously harvested stands. These saplings also grew slower in height, but diameter growth was similar. The spruce seedlings continue to survive and growth with similar values across the treatments. Inference for the aspen response was limited due to small sample size.</p>

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		<ul style="list-style-type: none"> ▪ Spruce seedling height growth was ranged from 2.3 inches per year in non-managed stands to 2.6 inches per year in previously managed and salvaged stands (NS) ○ Aspen seedling survival was 56% in previously managed stands (low sample size), 75% in non-managed stands, and 85% in previously managed stands <ul style="list-style-type: none"> ▪ Aspen seedling height growth was about 2 inches per year in non-managed and salvaged sites, and 4 inches per year in previously managed sites, though sample size was low <p>SPRUCE-ASPEN STANDS</p> <ul style="list-style-type: none"> • 100% Spruce overstory (> 5 in dbh) survival across all treatments • 97% - 100% Aspen overstory survival across treatments • 100% Spruce sapling (< 5 in dbh) across all treatments • 99% to 100% Aspen sapling survival across all treatments • 98% - 100% Spruce seedling (<dbh) survival in previously managed and salvaged stands, 91% survival in non-managed stands • Lowest Spruce seedling survival rates in 0-4 inch and 4-8 inch size classes, pooled across treatments (95%) • 97% to 100% Aspen seedling survival in previously managed and salvaged stands, 83% survival in non-managed stands • Lowest Aspen seedling survival rates in 0-4 inch and 4-8 inch size classes, pooled across treatments (~88%). • 2023 Results: <ul style="list-style-type: none"> ○ Spruce overstory (>5 in dbh) survival was 67% in non-managed stands, and 96% in previously managed and salvaged stands. <ul style="list-style-type: none"> ▪ Spruce overstory (>5 in dbh) height grew slower, 0.3 feet per year in salvaged sites, compared to 0.53 feet per year in previously managed sites, and 0.63 feet per year in non-managed sites. ▪ Spruce overstory (>5in dbh) dbh increased much slower (0.04 inches per year) in non-managed stands, compared to 0.13 inches per year in salvaged stands, and 0.22 inches per year in previously managed stands. 	<p>Spruce/aspen mixed stands:</p> <p>The survival of both overstory spruce and aspen continues to be good across all treatments. Spruce overstory survival and dbh growth was lower in the unmanaged stands, but the height growth was fastest. Spruce saplings continue to have similar survival and dbh growth, but height growth was slowest in the salvaged units. Spruce seedlings still surviving well with similar height growth among the treatments.</p> <p>The aspen overstory has good a similar survival across treatments with similar height growth, but dbh growth slower in the salvaged stands. Aspen saplings continue to have good survival with similar dbh growth among treatments, but higher height growth in the salvaged treatments. Aspen seedlings are also doing well, with substantial height and dbh growth in the salvaged areas.</p>

Completed Monitoring			
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		<ul style="list-style-type: none"> ○ Spruce sapling (<5 in dbh) survival was 100% in non-managed stands, and 96% to 97% in previously managed and salvaged stands (NS). <ul style="list-style-type: none"> ▪ Spruce saplings (<5 in dbh) height grew slower , 0.3 feet per year in salvaged sites, 0.43 feet per year in previously managed sites, and 0.60 feet per year in non-managed sites. ▪ Spruce saplings (>5in dbh) dbh increased 0.10 inches per year in previously-managed stands, and 0.15 to 0.16 inches per year in non-managed and salvaged stands (NS) ○ Spruce seedling Survival ranged from ~80% in non-managed and salvaged stands to 90% in previously managed stands <ul style="list-style-type: none"> ▪ Spruce seedling height growth was 1.3 inches per year in salvaged stands, 1.5 inches per year in previously managed stands, and 1.9 inches per year in non-managed stands ○ Aspen overstory (>5 in dbh) survival was 83% in salvaged stands and 91-93% in non-managed and previously managed stands (NS). <ul style="list-style-type: none"> ▪ Aspen overstory (>5 in dbh) height grew 0.88 feet per year in previously managed sites, 0.96 feet per year in non-managed sites, and 1.21 feet per year in salvaged sites (NS). ▪ Aspen overstory (>5in dbh) dbh increased 0.09 inches per year in salvaged stands, 0.14 inches per year in previously managed stands, and 0.18 inches per year in non-managed stands. ○ Aspen sapling (<5 in dbh) survival was 80% in non-managed stands, 88% in previously managed stands, and 94% in salvaged stands (NS) <ul style="list-style-type: none"> ▪ Aspen saplings (<5 in dbh) height grew 0.36 feet per year in salvaged sites, 0.39 feet per year in previously managed sites, and 0.56 feet per year in non-managed sites ▪ Aspen saplings (<5in dbh) dbh increased 0.07 to 0.09 inches per year across all treatments (NS) 	

Completed Monitoring			
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		<ul style="list-style-type: none"> ○ Aspen seedling survival was ~73% in non-managed and salvaged stands and 80% in previously-managed stands (NS) <ul style="list-style-type: none"> ▪ Aspen seedling height growth was 1.9 inches per year in previously harvested stands, 2.5 inches per year in non-managed stands, and significantly higher with 5.3 inches per year in salvaged stands 	
d. Do unmanaged, previously managed, and salvaged stands have different seed production rates after the spruce beetle epidemic and salvage?	Seed production (seed traps)	<p>SPRUCE STANDS</p> <ul style="list-style-type: none"> • 28 seed traps were collected 2017 – 2018 • Previously managed sites averaged 7 seeds per plot, unmanaged 2 seeds per plot, and salvage <1 seed per plot in 2018. <ul style="list-style-type: none"> • 428 potential seed producing trees in plots (overstory and sapling, live or hit by beetles), only one greater than 11.8 in (30cm) dbh in 2018. • Seed was collected from 10 plots (49 traps) 2018-2019 • Previously managed sites averaged 61 seeds per plot, unmanaged 28 seeds per plot, and salvage 33 seeds per plot in 2019 • No statistically significant differences between treatments in 2019 • Seed was collected from 10 plots (49 traps) 2019-2020 • Previously managed sites averaged 7 seeds per plot (60,984 seeds/acre), unmanaged 6.3 seeds per plot (55,177 seeds/acre), and salvage 7.3 seeds per plot (63,888 seeds/acre) • No statistically significant differences between treatments in 2020 <p>SPRUCE-ASPEN STANDS</p> <ul style="list-style-type: none"> • Seed was collected from 10 plots (50 traps) 2018-2019 • Previously managed sites averaged 49 seeds per plot, unmanaged 33 seeds per plot, and salvage 40 seeds per plot • No statistically significant differences between treatments in 2019 • Seed was collected from 13 plots (64 traps) 2019-2020 	From 2017 - 2019, seed production has varied. This annual variability is to be expected as Engelmann spruce seed production is known to vary in space and time. While one year (2018 seed production year) is higher than the other two years, it is important to recognize that the treatments (unmanaged, previously harvested, and salvaged) had similar seeds per plot found. This suggests that Engelmann spruce seeds are still present and dispersing on the landscape.

Completed Monitoring			
Question	Indicators/Methods	Current Findings	Science Team Interpretation
		<ul style="list-style-type: none"> Previously managed sites averaged 15.4 seeds per plot (134,165 seeds/acre), unmanaged 20.7 seeds per plot (180,048 seeds/acre), and salvage 5.6 seeds per plot (48,787 seeds/acre). <p>No statistically significant differences between treatments in 2020</p>	
e. Do unmanaged, previously managed, and salvaged stands impact snowshoe hare use after the spruce beetle epidemic and salvage?	1) Snowshoe hare presence (pellet counts)	<p>SPRUCE STANDS</p> <ul style="list-style-type: none"> In 2018 Mean hare density highest in unmanaged sites (0.19 hare/ha) and previously managed sites (0.17 hare/ha) Mean hare density lowest in salvage (0.02 hare/ha) No statistical difference between treatments. <ul style="list-style-type: none"> Same trends in 2019 – highest in unmanaged (0.18 hare/ha), followed by previously managed (0.15 hare/ha), and salvaged (0.04 hare/ha) No statistical differences between treatments <ul style="list-style-type: none"> In 2020, mean hare density highest in unmanaged (0.19 hare/ha), followed by previously managed (0.13 hare/ha) and salvage (0.007 hare/ha) Salvaged sites significantly different than unmanaged ($p = 0.005$) and previously managed ($p = 0.012$) sites <ul style="list-style-type: none"> In 2023, mean hare density was highest in previously managed stands (0.28 hare/ha), followed by unmanaged (0.10 hare/ha), and salvage (0.005 hare/ha) <p>SPRUCE-ASPEN STANDS</p> <ul style="list-style-type: none"> Mean hare density in 2019 highest in unmanaged stands (0.51 hare/ha), followed by previously managed (0.10 hare/ha), and salvage (0 hare/ha) Unmanaged statistically different from salvaged ($p < 0.01$) and previously harvested ($p < 0.01$) In 2020, mean hare density highest in salvaged stands (0.27 hare/ha), followed by unmanaged stands (0.16 hare/ha), and previously managed stands (0.12 hare/ha). This differs from previous trends No statistical difference between sites In 2023, mean hare density was highest in unmanaged stands and previously managed stands (0.52 and 0.51 hare/ha, respectively), followed by salvaged stands (0.34 hare/ha). 	<p>Over the past three years, monitoring of hare pellets in the Engelmann spruce dominated stands has demonstrated that snowshoe hares continue to utilize areas that were impacted by the spruce beetle. However, this past year, field data suggested that salvage areas had lower hare density. Hare pellet counts in the salvage areas were always lower in the previous years, but not significant.</p> <p>In contrast to the Engelmann spruce dominated stands, areas that had a mix of Engelmann spruce and Aspen showed that initially hares favored the unmanaged and previously managed stands. However, in 2020, salvaged stands had higher hare pellet counts (i.e. higher hare use), although the variability did not detect significant differences among treatments.</p> <p>Based on these variable results, exploration of options to mitigate impacts to dense horizontal cover during salvage is should be considered. It is critical to continue to steer salvage away from high-quality Canada lynx habitat. A significant outstanding question at this time is the longevity of salvage impacts on hare density and why is varies from year to year.</p> <p>Insights after several years of observation (2023) Hare density varies year to year across the unmanaged, previously managed, and salvage areas. In general, spruce/aspen mixed stands experience</p>

Completed Monitoring			
Question	Indicators/Methods	Current Findings	Science Team Interpretation
			more use than spruce dominated stands. In spruce/aspen stands, salvage unit had similar use as unmanaged and previously managed stands. In contrast, salvage negatively impacted hare use in spruce dominated stands.
f. Do unmanaged, previously managed, and salvaged stands have different air and soil temperature after the spruce beetle epidemic and salvage?	1) Microclimate (air and soil temperature) (temperature dataloggers)	<p>SPRUCE STANDS</p> <ul style="list-style-type: none"> • Summer air temperatures are higher in salvaged areas <p>Earlier snowmelt in salvaged areas but with a much larger range of melt dates</p> <p>SPRUCE-ASPEN STANDS</p>	<p>There are too few sample points at this time to have confidence that a recommendation is needed. However, if the relationship between salvage and higher temperatures is further established, exploring options to use patch attributes (e.g. shape, orientation) to mitigate impacts on temperature would be recommended.</p> <p>2023 update: We are currently working to analyze this extremely large dataset</p>
g. Do unmanaged, previously managed, and salvaged stands have different surface fuel loads after the spruce beetle epidemic and salvage?	Surface Fuel Loads (Brown's transects/ Litter-duff depth measurements)	<p>SPRUCE</p> <ul style="list-style-type: none"> • Average coarse wood fuel loads between 10 to 15 tons/acre; currently not different among treatments • Unmanaged and previously managed: Standing dead trees average 145 to 150 ft²/ac and 341 to 393 trees per acre (future inputs into Coarse Wood loads) • Salvage: Amount of standing dead is low (i.e. future inputs minimal) <p>SPRUCE-ASPEN</p> <ul style="list-style-type: none"> • Unmanaged and Previously managed stands: Average coarse wood fuel loads between 10 to 15 tons/acre • Unmanaged and Previously managed stands: Standing dead trees average 72 to 77 ft²/ac and 288 to 354 trees per acre (future inputs into Coarse Wood loads) 	<p>Current coarse wood fuel loads aren't different and are within normal ranges among the treatments. However, as dead trees begin to fall the areas that were not salvaged will have significant amounts of heavy fuel loads.</p>

2. Developing and implementing resiliency treatments in Engelmann spruce and Engelmann spruce-aspen forests of the Grand Mesa and Gunnison National Forest

Lead: Battaglia

Years Measured: 2020 - 2022

Ongoing Monitoring			
Question	Indicators/Methods	Current Findings	Science Team Interpretation
a. How do different group sizes implemented in group selection influence successful regeneration establishment and growth?	<ol style="list-style-type: none"> 1) Tree density 2) Stand Basal Area 3) Species Composition 4) Seedling regeneration density 5) microclimate 	<ul style="list-style-type: none"> • In Summer 2020, we measured the pretreatment forest inventory for the Rainbow treatment area (West of Gunnison). • Once the area is harvested we can report changes in the forest structure and tree regeneration 	No results to base interpretation on at this time.
b. How do modified shelterwood cuts and group selection cuts influence successful regeneration establishment and growth in spruce-dominated forests?	<ol style="list-style-type: none"> 1) Tree density 2) Stand Basal Area 3) Species Composition 4) Seedling regeneration density 5) microclimate 	<ul style="list-style-type: none"> • 25 out of 30 planned pre-treatment plots were established in Bald TS in 2021. The remaining five plots will be established in 2022. • Results will be available after the timber sale is implemented. 	No results to base interpretation on at this time.

7. Impacts of sudden aspen decline and subsequent harvest in aspen forests on forest structure and tree regeneration

Lead: Battaglia

Years Measured: 2022

<i>Completed Monitoring</i>			
Question	Indicators/Methods	Current Findings	Science Team Interpretation
a. Did harvest impact aspen regeneration density in SAD affected stands?	Regeneration Density	<p><u>Shepherd et al. 2015 finding for 2010 – 2012:</u></p> <ul style="list-style-type: none"> • Regeneration density was higher in cut stands relative to uncut stands in low and moderate mortality levels in 2010, 2011, and 2012 <ul style="list-style-type: none"> ○ Low mortality: cut regeneration densities were <10 times greater than uncut densities for 2010, 2011, and 2012 ○ Moderate mortality: cut regeneration densities were <6 times greater than uncut densities for 2010, 2011, and 2012 • Regeneration density in high mortality stands was higher in cut stands relative to uncut stands only in 2010. There was no statistical difference between cut and uncut in high mortality for 2011, or 2012 • Regeneration density in cut treatments was highest in low mortality stands and lowest in high mortality stands for each year • Regeneration showed a trend of decline with time since treatment from 2010 – 2012 <p><u>2022 Findings</u></p> <ul style="list-style-type: none"> • Regeneration density was higher in cut stands relative to uncut stands in low mortality stands <ul style="list-style-type: none"> ○ 9500 stems/acre vs 2500 stems/acre • Regeneration density was higher (but NOT statistically) in cut stands relative to uncut stands in moderate mortality stands <ul style="list-style-type: none"> ○ 5300 stems/acre vs 3200 stems/acre • Regeneration density was not statistically higher in cut stands relative to uncut stands in high mortality stands <ul style="list-style-type: none"> ○ 2500 stems/acre vs 1800 stems/acre ○ Regeneration density in high mortality cut stands was statistically not different from any uncut stands across all mortality levels 	<p>Overall, aspen sprouting regeneration density decreased as the stands developed over the past 12 years. This was expected since density dependent mortality happens as sprouts compete with each other.</p> <p>After 12 years, aspen regeneration density was still significantly higher in the areas that had low SAD mortality and was clearfelled. In contrast, while the initial sprouting density was higher initially in the clearfelled moderate severity SAD areas, by 12 years post-treatment that significance went away even though the average density was a few thousand stems greater. In the areas that had high SAD mortality, both the initial and post-12 years measurements demonstrate that there was no significant difference in sprouting density with or without clearfelling.</p> <p>Overall, based on the sprouting density metric alone, early identification of aspen stands that are starting to show symptoms of SAD and clearfelling them would provide opportunities to get substantial initial sprouting AND maintain high levels of sapling density (9500 stems/acre) at least 12 years post treatment. Those stands that had moderate SAD mortality (20-60% SAD mortality) did initially produce substantial higher initial sprouting after clearfelling than the uncut stands, but that difference narrowed through time. In these stands, clearfelling could be used to initiate a high amount of sprouting to offset browsing pressure and reduce future woody fuel loads. In areas that had high SAD mortality (>60% mortality), clearfelling didn't appreciatively increase the sprouting initially or 12 years post.</p>

			Clearfelling would be appropriate if attempting to reduce surface fuel loads.
b. Did harvest impact aspen regeneration height in SAD affected stands?	Stem Height	<p>Sheppherd et al. 2015 finding for 2010 – 2012:</p> <ul style="list-style-type: none"> • Stem height was higher in cut vs uncut stands in low and moderate mortality levels in 2012 • Cutting had no effect on stem height in high mortality stands in 2012 • Stem height in both cut and uncut treatments in high mortality stands were higher than uncut stands in low and moderate mortality levels in 2012. <p>2022 Findings</p> <ul style="list-style-type: none"> • Stem heights were higher in cut vs uncut stands in low and moderate mortality levels in 2022 • Stem heights in cut stands in high mortality were not statistically different from uncut stands across all mortality levels 	<p>The trend of taller stems in the clearfelled low and moderate SAD impacted stands versus the uncut areas continued 12 years post-harvest. On average, these stems were about 5 to 6 meters tall (16 to 20 feet tall) compared to 2 to 3 meters (5 to 10 ft) tall in the uncut areas that experienced SAD low to moderate mortality.</p> <p>The high mortality SAD areas didn't have differences in aspen sprout heights initially or after 12 years. After 12 years, the sprouts were on average 4 meters tall (13 feet).</p> <p>Overall, clearfelling in the low and moderate SAD impacted stands allowed faster growth of the sprouts than that observed in the uncut stands. This faster growth initially and 12 years post-harvest and the increase in sprout density ensures sufficient recruitment into the overstory and reduces the impact of browsing.</p> <p>A similar trend of fast height growth was observed in the high mortality SAD stands whether they were cut or not. It seems that removing the overstory via harvesting or through high levels of SAD mortality provides more resources (I.e. more light) for sprout growth.</p>

3. Landscape-scale impacts of spruce bark beetle and climate on forest change

Lead: Sibold

Years Measured: 2015 - 2023

Ongoing Monitoring			
Question	Indicators/Methods	Current Findings	Science Team Interpretation
a. How are topographic influences on weather shaping patterns of forest change in Engelmann spruce-dominated forests of the Gunnison Basin?	Topographic influences on weather/climate, and forest change. (Temperature dataloggers installed at FIA plots with a spruce component)	<ul style="list-style-type: none"> • We installed sensors at 40 FIA plots No results at this time. <p>Note: This is a coarse-scale study at the landscape-scale. We are also pursuing similar questions at a finer scale within a subsection of valleys in the Gunnison Drainage that will increase the value and interpretations of this study.</p> <p>FIA sensors were not collected in 2020 (Covid) but 106 sensors from the Elk/West Elk study area were collected and downloaded. Data are being cleaned winter 2020-21.</p>	No results to base recommendation at this time.
b. How are spruce-dominated forests changing in response to the spruce beetle outbreak?	LiDAR and field data documenting pre-outbreak forest conditions in the Elk Mountains. Re-measuring four large (40x40m) plots (first est. 2015) and installing 70 new (20x20 m) plots throughout the study area to calibrate remotely sensed data. Temperature loggers will be installed in plots.	<p>Large plots were re-located and re-sampled in 2018. The most notable change is the continued mortality of subalpine fir on the landscape. Subalpine fir mortality began in the GMUG, Colorado and the Rocky Mountains in the early 2000s and continues today. Subalpine fir is the least drought adapted tree species on the GMUG landscape and mortality is related to frequent high-severity drought conditions that stress trees directly and facilitates other stressors such as western balsam bark beetle.</p> <p>In summer 2019 we installed 68 intensive plots within the Elk/West Elk study area. Within plots we measured seedlings, saplings, trees, dense horizontal cover (DHC). In the four directions where we measured DHC(N,E,S,W), we also measured cover density in 1x1m square 2m high volumes and counted hare pellets within the transect. We also installed temperature sensors at 1.8m and ground level, mapped site coordinates with a very high-resolution GPS (<20cm), and installed seed traps.</p> <p>53 of 68 plots from 2019 were revisited in 2020 to change temperature sensors and count hare pellets.</p> <p>Based on data from 2019 and 2020:</p> <p>1) As expected, hare pellet densities in spruce-fir dominated forests that have not been impacted by spruce beetle, tend to increase with increasing DHC. However,</p>	<p>These results are just from a very small sample size, with the larger sample size being analyzed in 2020. Nonetheless, the considerable decline in subalpine fir reinforces what is evident on the broader landscape. Although subalpine fir is of relatively low value in the context of timber, it does provide highly valuable habitat for species including Canada lynx.</p> <p>The increase in pellet counts at 20% suggests that lower levels of DHC could provide valuable hare habitat in spruce-fir forests that have not been impacted by spruce beetle.</p> <p>The heterogeneous nature of DHC at relatively fine scales (<100-200m) stresses the challenges of quantifying DHC within treatment areas.</p> <p>Fine-scale heterogeneity in DHC and hare pellet counts means that it is challenging to identify large areas that are key for Canada lynx conservation.</p>

Ongoing Monitoring			
Question	Indicators/Methods	Current Findings	Science Team Interpretation
		<p>pellet counts do not increase linearly but instead increase rapidly at 20% DHC and stays high. The 20% threshold is lower than expected.</p> <p>2) DHC is extremely heterogeneous on the landscape, with close plots (200m) with similar slope, aspect, elevation and fire history often having large differences in DHC measurements. This is hypothesized to reflect fine scale variability in soils, soil water availability and canopy closure.</p> <p>3) DHC and hare pellet densities are heterogeneous at fine scales (100-200m).</p> <p>January 2022 update: I compiled all DHC plots from within the Lidar footprint for this question. After QA/QC work, I am using approximately 200 plots in the model. I am using the Forest-Based Classification and Regression model in the Spatial Analyst toolbox of ArcGIS Pro to analyze and predict DHC for this footprint. The Lidar data is consistently a top predictor of DHC along with topographic features, broad-scale climate conditions, soils and productivity (Landsat derived NPP). I am currently working to improve the model and might have to change to a “boosted” model. Specific concerns with the current model are its limited ability to differentiate DHC in middle ranges of DHC values (35-65% DHC). Nonetheless, I do have a landscape-scale predictive model of DHC for this footprint. The current model is broadly in agreement with the Canada lynx usage model created by Dr. David Theobald for this area.</p> <p>The first draft of the topoclimate model will have a similar footprint to the Lidar footprint and should be available to incorporated into this model in February, 2022. This should improve the model, currently the only climate data in the model are long-term precipitation data and no temperature data are included. While the predictive model will be useful for management within this footprint it also demonstrates the potential value of Lidar for predicting habitat conditions/DHC for the broader GMUG landscape.</p>	<p>Modeling results should be used for decision making at broader spatial scales (landscape) and in conjunction with other lines of evidence of spatial patterns of Canada lynx habitat quality. Specifically, these landscape-scale layers of dense horizontal cover would be best used to identify 1) larger areas (hundreds to thousands of acres) of high-quality habitat, and 2) the relationship of Canada lynx habitat with likely spruce-fir refugia sites and modeled habitat corridors. Ideally, prior to any large-scale management decisions, modeled habitat values should be verified in the field by a USFS biologist.</p>
c. Is the spruce beetle outbreak changing the extent or location of high-quality lynx habitat in the Gunnison Basin?	1) Recent work on lynx habitat usage in response to spruce beetle-altered forest conditions in the Rio Grande NF	In December, 2019 USFS GTAC shared a draft version of the change detection work which will be a critical resource for this work. The draft was very complete and was in agreement with patterns of changes that are evident on the landscape. A final version of the work is expected in February which will include data transfer.	Spruce and connectivity modeling provides spatial information on where spruce habitat, critical for Canada lynx, and corridors will persist into the future under different warming scenarios. This information could be used to identify locations on the landscape where spruce would be anticipated to persist into the future or where management

Ongoing Monitoring			
Question	Indicators/Methods	Current Findings	Science Team Interpretation
	<p>2) Landscape-scale change-detection work by the USFS to create a new layer of high-quality lynx habitat.</p>	<p>In 2020 I focused on modeling future patterns of spruce forest distributions under different climate scenarios (A1 = continued warming; B1/B2 not as rapid of warming) for different climate projections for the years 2060 and 2090. The range of future climate projections (different scenarios and models) should provide relatively robust end points for best- and worst-case scenarios for spruce, which is being used as a proxy for Canada lynx habitat. These results show that there is a very large range of potential future spruce cover scenarios – from a rapid decline to almost no spruce cover by 2060 and basically no cover in 2090 in the A1 climate scenario to relatively modest declines in the B1/B2 scenario. These models also show where on the landscape efforts to maintain spruce forests for habitat for Canada lynx and other subalpine species will most likely be successful.</p> <p>I also modeled landscape connectivity for Canada lynx for the A1, and B1/B2 models for 2060 and 2090. These models continue to identify the eastern portion of the Gunnison basin as a critical area for connectivity for Canada lynx between the San Juan Mountains and northern Ranges in Colorado.</p> <p>January 2022 update: Similar to the Lidar work above, I have compiled all recent (since 2017) DHC plots collected by my lab and USFS staff and USFS contractors that collected data for the change detection work. After QA/QC, I am working with about 440 plots and using the Forest-Based Classification and Regression model in the Spatial Analyst toolbox of ArcGIS Pro to analyze and predict DHC for the Gunnison Drainage. Because this area includes large areas of high-severity spruce beetle outbreak I am able to identify the landscape implications of the outbreak for DHC. Specifically, I am representing outbreak severity in the model as the change in Net Primary Productivity (NPP) from a baseline calculated for the early 2000s compared to 2017, when most of the DHC plots were sampled in the beetle-killed areas. Beetle outbreak severity, as represented as change in NPP, is consistently a top variable in the model. I am having similar success and challenges as within the Lidar footprint/study area, specifically that it is challenging to differentiate between middle ranges of DHC values.</p> <p>While I have a predictive landscape-scale model of DHC for the Gunnison basin at this time, I am working to improve the model. I am also currently overlaying the current model with Dr. Theobald’s layer of Canada lynx usage layer and the earlier</p>	<p>should focus on maintaining spruce on the landscape (corridors). This information can be used to identify appropriate treatments, exclusion of treatment or post-treatment management including reforestation.</p> <p>Similar to 3b, the landscape-scale model of Canada lynx habitat quality can be used in conjunction with modeled projections of the persistence of larger (hundreds to thousands of acres) patches of spruce forest in the context of projected warming. Ensemble spruce projections were completed earlier in this project. Management activities that are detrimental to Canada lynx habitat could be excluded from areas of current and projected high-quality habitat. In the context of connectivity, corridor areas that are modeled as high-quality habitat today but unlikely to persist into the future likely represent locations where a climate change resistance strategy (e.g. maintaining spruce in locations where it is no longer regenerating naturally) will have the largest benefit. Moreover, these locations likely represent places with underlying conditions (soils, topography) where resistance will have the largest chance of success.</p>

Ongoing Monitoring			
Question	Indicators/Methods	Current Findings	Science Team Interpretation
		work on future spruce cover under different climate scenarios. This will allow us to start to identify locations on the landscape that have high-quality habitat that is being used and expected to persist into the future under different climate scenarios. This will be helpful to identify potential management options in these areas.	

Completed Monitoring			
Question	Indicators/Methods	Current Findings	Science Team Interpretation
d. How is the spruce beetle outbreak influencing Engelmann spruce and aspen regeneration?	1) Spruce forest landscape change in response to the spruce beetle outbreak. (Forest inventory plots)	<ul style="list-style-type: none"> • Pre- and post-outbreak spruce establishment is not related to elevation. • 45% of post-outbreak seedling establishment can be explained by 1) site moisture (lower total solar exposure at landscape scale, and increased moisture retaining features (litter, moss at fine scales), and 2) increased regeneration in response to increased canopy mortality. <p>We also found a significant pulse of regeneration in 2015 that is associated with the record-setting cool, wet spring and summer of that year.</p>	<ul style="list-style-type: none"> • Elevation is a poor guide to predicting the future of spruce on the GUMG landscape in the context of the combined impacts of spruce beetle and climate change. • Identifying the influence of salvage on spruce is more difficult than just taking into account elevational influences on temperature. • Identifying species to replant following salvage should take into account other topographic variables instead of elevation. Specifically, replanting spruce on lower-elevation sites with moderately steep north-facing aspects is likely to be successful and help maintain spruce on the landscape in an era in which it is projected to see significant declines in extent.
e. How does salvage influence site-level weather conditions?	Temperature sensors were installed at the soil, surface and at ~1.8m height above ground level.	<p>Surface temperature sensors indicate a statistically significant difference in snow melt dates between harvested and non-harvested control sites. Snowmelt is later in harvested sites</p> <p>Surface temperature sensors indicate a statistically significant difference in average summer temperatures with harvested sites being cooler during the growing season as compared to non-harvest control sites.</p> <p>Air temperature sensors indicate a statistically significant difference in average summer air temperatures, with harvest sites being cooler than non-harvest control sites.</p>	<ul style="list-style-type: none"> • Overall, salvage sites have later snowmelt and cooler temperatures (surface and 2m). The overall influence is a shorter growing season. Moreover, the combination of later snowmelt and cooler conditions would be expected to decrease soil moisture stress on seedlings. These conditions would be expected to mitigate recent and projected warmer temperatures and decreased precipitation, and facilitate spruce establishment. However, spruce establishment is a complicated process with more influences than summer season weather conditions.

4. Impacts of spruce bark beetle and subsequent salvage in Engelmann spruce and Engelmann spruce-aspen forests of the Gunnison National Forest on understory plant composition and surface fuels 1 to 2 years post treatment.

Lead: Coop and Mattson

Years Measured: 2017

Completed Monitoring			
Question	Indicators/Methods	Current Findings	Science Team Interpretation
a. How is the spruce beetle outbreak and salvage influencing understory plant composition and surface fuels?	1) Understory plant cover 2) species composition 3) Fine fuels	<ul style="list-style-type: none"> • Total vegetation cover decreased in salvage • Species diversity decreased in salvage units • Species richness did not differ • Salvage increased fine surface fuel loads • Salvage decreased litter and duff loads • Salvage increased %wood cover <p>Salvage decreased %bare ground, %litter, and % moss cover</p>	<p>Short-term outcomes of salvage treatments demonstrated an increased in the amount of fine fuels and decreased total vegetation cover. The decrease in vegetative cover was a result of lower shrub cover. Exotic species cover was low and similar among salvaged and non-salvaged areas. Increases in fine fuels were evident in the salvage units, but values still are within normal ranges.</p> <p>We expect over the long-term, vegetation will recover due to increased light availability and other resources. However, we do not know how understory plant cover and composition will shift. Longer-term monitoring of these sites will help understand this change.</p>

5. Assessment of socioeconomic impacts of SBEADMR

Lead: Cheng, Dunn

Years Measured: 2020, 2022

Ongoing Monitoring			
Question	Measurement Method	Current Findings	Science Team Interpretation
<p>a. To what extent do USFS administrative costs change over the SBEADMR project timeframe? What issues affect costs?</p>	<p><input type="checkbox"/> Administrative cost data was gathered for the East zone for FY 17-18 which focused on salvage treatments. These costs were annualized to provide preliminary cost estimates and updated for 2020 wage adjustments.</p> <p><input type="checkbox"/> Stumpage, Brush Disposal, Surface Rock replacement, and Road Maintenance Deposits collected.</p> <p><input type="checkbox"/> Narrative from USFS timber staff about factors affecting costs</p>	<ul style="list-style-type: none"> • Preliminary Cost per acre treated (2020): Planning – treatment design, layout, road design: \$327; Treatment Contract Administration - \$89; Science Team \$24; Adaptive Management Group \$3; Non-road contracts (wildlife surveys, stand exams, etc.) \$35; Road contracts (construction, re-construction, maintenance) \$381. Grand Total = \$859. • Preliminary Cost per volume (CCF) of timber produced (2020): Planning – treatment design, layout, road design: \$19; Treatment Contract Administration - \$5; Science Team \$2; Adaptive Management Group \$1; Non-road contracts (wildlife surveys, stand exams, etc.) \$2; Road contracts (construction, re-construction, maint.) \$22. Grand Total = \$51. • Stumpage and Deposits Collected from 20 treatments: Stumpage - \$1,091,659; Brush Disposal - \$226,117; Surface Rock Replacement - \$185,801; Road Maint. Deposits – 14,098 Note: Brush disposal, surface rock replacement and road maintenance deposits pay for required work in general treatment areas (e.g. replacing rock on haul routes, burning of slash piles and rehabilitating burn scars, etc.). • Personnel costs by percentage for East Zone FY 17-18: 22% planning, 57% presale (layout, cruise, rx development, etc.), 21% treatment implementation. <ul style="list-style-type: none"> • Largest factor affecting sale administration cost is personnel time. • Treatment Implementation (2022): Contract Administration cost per acre treated-\$43.45 Contract Administration cost per CCF sold-\$2.40 • Personnel costs for contract administration by percentage for North Zone FY 21: <ul style="list-style-type: none"> • Contracting officer 12%, Sale Accounting 2%, Sale Administrator 86% • Sale administrator is largest personnel cost for contract administration. 	<p>It is not clear at this point how administrative costs have changed over the course of the project. Personnel costs have been identified as the largest issue affecting cost with pre-sale activities being the largest component of cost.</p> <p>Administrative costs were less for North Zone estimates than in previous years when cost estimates were gathered for the East Zone. East Zone estimates were for salvage harvest and North Zone is a resiliency treatment. The estimates for North Zone were based on data availability that was limited to one completed project, so difficult to draw conclusions with small sample size.</p>

Ongoing Monitoring			
Question	Measurement Method	Current Findings	Science Team Interpretation
b. To what extent does timber output and revenue change over the SBEADMR project timeframe?	Compile data from districts on: <ul style="list-style-type: none"> <input type="checkbox"/> Commercial timber: acres, timber volume <input type="checkbox"/> Commercial revenue per volume <input type="checkbox"/> Non-commercial: acres by treatment type and objective <input type="checkbox"/> No bid sales <input type="checkbox"/> Contracts issued by type and size: timber sale; stewardship contract; Indefinite Delivery-Indefinite Quantity (IDIQ) 	<ul style="list-style-type: none"> • Acres treated/timber volume (CCF) produced: 2017 3,985/59,818; 2018 4,587/72,131; 2019 4,014/83,167; 2020 (Q1 & Q2) 3,629/56,549 Timber revenues: 2017: \$551,008; 2018: \$1,388,810; 2019: \$321,862; 2020: \$400,641 • Commercial Revenue per volume (\$/CCF): 2017 \$9.16; 2018 \$11.14, 2019: \$4; 2020: \$7 • There have not been any non-commercial treatments implemented to date. • A single no-bid took place in 2020, Kannah Timber Sale, due to winter logging restrictions. Upon collaborating with the Grand Mesa Nordic Club, winter logging will be allowed through mid-December. Industry is now supportive and sale will be advertised in upcoming weeks • Timber sales are transitioning from salvage harvest to more green (resiliency) operations in the SBEADMR project area. • Over \$1.5 million has been collected over project lifespan with Montrose Forest Products as the primary purchaser (88%), CSFS (12%), and others (<1%) (as of 2020 update) 	
c. In what ways does the SBEADMR project contribute wood volume to the wood products industry?	Compile data from districts on: <ul style="list-style-type: none"> <input type="checkbox"/> Wood utilization by producer size (e.g., small vs large mills); <input type="checkbox"/> Change in number of producers 	<ul style="list-style-type: none"> • 60% of timber volume produced utilized by Montrose Forest Products (MFP). 26% by Colorado State Forest Service. 7% by the National Wild Turkey Federation. The remaining 7% went to various small purchasers. • MFP produced 2" by 4" and 2" by 6" studs in 8', 9', and 10' lengths from Spruce, Lodgepole pine, Sub-Alpine fir and White fir harvested from SBEADMR timber sales. • The number of producers has not deviated much over time. Only 6 documented producers from 2017-2020 dominated by MFP. • Wood Products from Sales: FY 2017 59,818 CCF (97% went to producing studs) FY 2018 72,131 CCF (100% to producing studs) 	There are few small-scale producers utilizing timber from SBEADMR project. Majority of timber utilization is through sawlogs processed by MFP. With available complete data (FY 2017,2018) majority of timber is processed to studs. New purchaser in 2022 K and K Lumber.
d. What are direct non-government employment impacts on wood producers from SBEADMR project implementation?	Compile data from wood producers on: <ul style="list-style-type: none"> <input type="checkbox"/> Annual assessment of producers' employment resulting from SBEADMR. 	Montrose Forest Products reports that no additional manpower has been added to sawmilling staff nor have they added loggers or log truckers as a direct result of SBEADMR timber but without SBEADMR timber sales it would be difficult to continue operating the sawmill at current capacity. SBEADMR timber sales are reported as very important to maintain their current level of mill production. <ul style="list-style-type: none"> • Estimates for employees of logging and trucking companies working on SBEADMR projects 2017-2020. 	SBEADMR has not had a significant impact on local producers' employment, but is noted as important for local mill supply chain. Data shows large number of employees in the trucking and logging sectors supported by SBEADMR projects. Loggers interviewed also made

Ongoing Monitoring			
Question	Measurement Method	Current Findings	Science Team Interpretation
		Logging Companies: 2017: #Logging Companies-5, Combined Employees-40; 2018: #Logging Companies 5, Combined Employees 35; 2019: #Logging Companies-1, Combined Employees-12; 2020: #Logging Companies-3, Combined Employees-16. Trucking Companies (2017-2020): #Trucking Companies-3, Combined Employees-12.	large equipment purchases (3 machines) for SBEADMR projects.

6. Assessment of progress and performance of the SBEADMR collaborative monitoring and adaptive management process

Lead: Cheng, Beeton, AMG

Years Measured: 2021, 2022

Ongoing Monitoring			
Question/Topic	Measurement Method	Current Findings	Science Team Interpretation
a. Is the collaborative adaptive management process functioning as it was originally intended/expected by participants?	Questionnaire and/or focus group asking similar questions annually to track progress.	<ul style="list-style-type: none"> 66% of respondents agreed or strongly agreed that the right people were engaged in the process (representative cross-section). A majority of respondents reported that the SBEADMR process increased their understanding or knowledge of ecological processes in spruce-fir and aspen systems (82%), the effects of treatments on ecological systems (70%), and the USFS decision-space in planning and implementation (74%). 61% agreed or strongly agreed that the SBEADMR processes increased their understanding of socio-economic conditions and processes related to forest management, while only half reported that the process increased their knowledge of the impacts of treatments on socio-economic conditions. A majority of respondents felt that: a) the collaborative process created a space for open communication and dialogue to achieve the stated goals of the record of decision (69%); b) participants agree about the key problems that impact their landscape (63%; and c) the process has helped participants identify shared priorities and strategies for treatment implementation (65%). Less agreed that participants agree about the strategies to solve problems and achieve goals (44%) and the “why” of the SBEADMR project (51%). A majority of respondents agreed or strongly agreed that the GMUG staff were responsive to collaborative and public input (74%), new scientific information (82%), changing conditions on the ground (77%), and whether they use lessons learned from monitoring and adaptive management to improve their management actions (77%). A majority of respondents agreed or strongly agreed that the GMUG staff were responsive to collaborative and public input (74%), new scientific information (82%), changing conditions 	<p>The SBEADMR process is generally meeting its goals of diverse participation, collaborative learning, developing shared understanding and agreement, transparency, responsiveness, trust- and relationship-building, and a participatory collaborative process. Yet, participants identified some areas that need improvement. For example:</p> <ul style="list-style-type: none"> Participants suggested a number of individuals/organizations to invite or consult with on projects Learning and understanding of socio-economic forest management context Shared understanding and agreement around the priorities for achieving goals, and the “why” of the SBEADMR project. This may be due to turnover, shifts to resiliency treatments, among others. More opportunities to understand and inform annual implementation cycle – particularly treatment design and annual adjustments or adaptations that are made. <p><i>Recommendations:</i></p> <ul style="list-style-type: none"> <i>Increased involvement and/or consultation with the following groups:</i> Colorado Parks and Wildlife, Tribes, the West Region Wildfire Council, water resources and water districts, WUI community groups, fisheries and aquatic resources groups, and other NGOs (e.g., the Great Old Broads, sierra club, western Colorado alliance). CO DNR; CO Fire Commission; CO Forest Health Council <i>Enhance opportunities for public outreach and engagement:</i> Continue to invest and/or enhance new and continue traditional modes of communicating SBEADMR updates (e.g., newspapers, radio, website, press releases, additional community engagement with district rangers/staff); hire a communication specialist. <i>Opportunities for learning and shared understanding:</i> Conduct pre- and post-treatment field trips in same location when applicable; Provide field-trip de-briefs with GMUG staff, AMG, and interested participants; Facilitate greater learning around the fuels management component of SBEADMR; Identify a common definition and understanding of resilience among the group, especially as move into

		<p>on the ground (77%), and that they use lessons learned from monitoring and adaptive management to improve their management actions (77%).</p> <ul style="list-style-type: none"> • 44% and 63% of respondents agreed or strongly agreed that GMUG staff and other stakeholders collaborated as much as they would like in treatment design and monitoring and adaptive management, respectively. • At the AMG meeting in October 2022, we facilitated a discussion on recommendations to improve the collaborative process. We highlighted the many steps that had already been taken or were being considered to improve the process, and we assessed which, if any, additional recommendations from the collaborative adaptive management process evaluation should be prioritized in the short-term. Suggestions for improvement included: <ul style="list-style-type: none"> • Increase communication and outreach to groups and develop methods to track communication channels. In this vein, developing a list of definitions and acronyms may support external communication; • Increase the number and type of designated seats to increase opportunities for collaboration, including but not limited to recreation interests, and community wildfire mitigation collaboratives, for example; • Coordinate collaborative discussions and dialog on what is meant by resiliency in the context of SBEADMR and the GMUG; • Increase transparency about how science informs lynx management and mitigation; • Allow AMG to attend annual FLT meeting where AMG recommendations for adaptation are considered; and • Create an inventory of community wildfire collaboratives and forest health initiatives in the GMUG. 	<p>green tree “resiliency” treatments; Develop onboarding processes for new and existing personnel</p> <ul style="list-style-type: none"> • <i>Transparency and responsiveness</i>: Make explicit connections between what design features are being used to mitigate the impacts to snowshoe hare, how science has informed that decision, and the outcomes of treatment in areas lynx and snowshoe hare may be impacted; Consider how to integrate new scientific information brought to the group that may be of concern to local participants but may be outside the scope of SBEADMR; Continue investing in note-taking during field trips. • <i>Collaboration throughout the process</i>: Consider opportunities to provide more detail on planned treatments during out-year planning (year 2) so that participants can more meaningfully contribute to and inform treatment design and implementation; Increase opportunities for dialogue among AMG and FLT regarding what recommendations were considered, what adaptations were made, and why or why not; Enhance communication internally with GMUG staff so that all resource specialists are aware of new projects prior to public meetings. • <i>Outputs to work towards in next two years</i>: <ul style="list-style-type: none"> o Evaluate the successes and challenges of the process and recommendations for improvement and publish in reports, blogs, publications. o Be ready to go after increased stand and federal funding to support wildfire mitigation. • The AMG reviewed, refined, and prioritized several recommendations to improve the collaborative process at the October 2022 AMG meeting. We suggest the AMG periodically review and revise these recommendations as they address them or as new recommendations arise. It will be important to develop methods and metrics (and roles, expectations) to track progress towards addressing the recommendations.
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<p>b. To what extent has stakeholder participation changed over the project timeframe?</p>	<p>Track participation in the AMG and/or SBEADMR public engagement activities over time – an indicator of the “collaborative-ness” of the process.</p>	<ul style="list-style-type: none"> Majority of participants in AMG were active participants, meaning that they were present at 6 or more meetings (n-12), compared to 4 partial participants and 1 non-participant. The diversity of seats present at each meeting rose following the signing of the ROD (above 90%) at one point, though participation has declined and remained relatively low since the Jan 2020 AMG meeting, potentially a result of the COVID-19 pandemic. Vacancy in regular and alternate seats remains a challenge. Some seats were present at every meeting (e.g., an environmental/conservation seat, west zone), while others were intermittently present An additional seat became vacant in April 2022. 	<p>A Core group of ‘doers’ has remained invested and committed to the collaborative adaptive management process. Some vacancies in key positions and intermittent participation in the AMG were observed. The logistical challenges of a large project spread out across a large geography, unpaid volunteers supporting efforts, and time required to fully engage in all annual activities was prohibiting. Further, there are currently several forest restoration initiatives in the region that compete for participants’ time and energy (CFLRP, RMRI, Taylor AMG).</p> <p>One suggestion from the AMG was to Increase the number and type of designated seats to increase opportunities for collaboration, including but not limited to recreation interests, and community wildfire mitigation collaboratives, for example.</p>
<p>c. What adaptations have been made based on the results of administrative studies?</p>	<p>Document what and how scientific research and/or monitoring results and findings are brought into implementation and adaptation decision-making, to demonstrate a clear link between monitoring/research and adaptive management decisions.</p>	<ul style="list-style-type: none"> We conducted a document review of the AMG Adaptive Implementation Annual Reports, FLT Management Reviews, community reports, and interviews to identify what adaptations have occurred post-NEPA decision. Our database includes a cumulative list of adaptations, and we have classified adaptations into five categories: administrative, planning, implementation, science and monitoring, and collaborative process adaptations. It will be updated annually after the AMG and FLT completes and publishes the Adaptive Implementation Annual Report. The document will be a living document housed on CFRI’s institutional BOX account and annually uploaded to the CFRI-hosted SBEADMR website. <ul style="list-style-type: none"> The database and complete list of adaptations can be found here: https://cfri.box.com/s/w1zyrl5gjl07qinxjti3xsfalbkp21 	<ul style="list-style-type: none"> SBEADMR has made many adaptations related to planning, science and monitoring, and implementation activities specifically, and the collaborative process more generally, since the Record of Decision was signed. These reflect adaptations based on public and AMG feedback, recommendations from GMUG staff, new scientific research, and/or monitoring results. The number of adaptations attests to the commitment of the group to the adaptive management cycle and feedback loop. While some adaptations have been made based on monitoring results, we expect the number of these to increase in the coming years and after SBEADMR has completed due to the mismatch in scale between the timing of SBEADMR and the time required to see results on the ground.