Appendix I. Natural Range of Variation Analysis and Results

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Introduction

This document provides a summary and interpretation of the revised natural range of variation (NRV) analysis, which helps describe the ecological integrity of ecosystems. *Ecosystem integrity* is the quality or condition of an ecosystem when its dominant ecological characteristics occur within the NRV and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence (CFR 219.19). Prior to revising forest plans, the interdisciplinary team must determine the extent to which ecosystems relevant to the plan area have integrity (FSH 1909.12.1). Ecosystems have integrity when their composition, structure, function, and connectivity are operating normally over multiple spatial and temporal scales (FSH 1901.12.14). Determining ecosystem integrity includes:

1. Using the NRV or alternative approach to determine conditions that sustain the integrity of the selected key ecosystem characteristics.

2. Assessing and documenting the current condition and status of ecosystems using key ecosystem characteristics and projecting their future conditions and trends.

This document summarizes of the NRV condition, along with some discussion of future trend. The assessment as well as FEIS provide more detailed analysis on future conditions.

The NRV concept can be further summarized as follows (FSH 1909.12.05):

"NRV is the variation of ecological characteristics and processes over scales of time and space that are appropriate for a management application. The pre-European influenced reference period considered should be sufficiently long, often several centuries, to include the full range of variation produced by dominant natural disturbance regimes and should also include short-term variation and cycles in climate. The NRV is a tool for assessing the ecological integrity and does not necessarily constitute a management target or desired condition. The NRV can help identify key structural, functional, compositional, and connectivity characteristics for which plan components may be important for either maintenance or restoration of such ecological conditions."

Direction also includes (FSH 1909.12.14a 2015):

- The Interdisciplinary Team should use the NRV as the ecological reference model, unless the past information regarding the key ecosystem characteristic is lacking or the system is no longer capable of sustaining key ecosystem characteristics based upon likely future environmental conditions.
- The NRV can be compared to existing conditions and recent disturbance processes, allowing the Interdisciplinary Team to identify important compositional, structural, and functional ecosystem elements for developing plan components.
- The NRV does not represent a management target or desired condition.
- The NRV should be described as a range of conditions and dominant processes occurring over the period selected for analysis.

Ecosystem integrity and the NRV is used to develop proposed plan components (FSH 1909.12.23.11a):

"An understanding of the NRV provides context and insights to the design of plan components. Agency intent is to promote ecosystem integrity in the plan area. However, it may not be possible or appropriate to strive for returning key characteristics to past conditions throughout the plan area. Understanding the NRV is fundamental in strategic thinking and planning, even if restoration to historical conditions is not the management goal or possible on parts of the plan area. The NRV is useful for understanding each specific ecosystem, its existing ecological conditions, and its likely future character based on projections of climate. The goal of understanding NRV is to help design plan components to maintain or restore the integrity of the diversity of ecosystems and

habitat types throughout the plan area [to] provide an ecosystem (coarse filter) approach to maintaining the persistence of native species."

Where appropriate, plan components should be designed to maintain or restore the NRV of key ecosystem characteristics needed to promote ecosystem integrity in the plan area, although for specific areas within an ecosystem, the Responsible Official may determine that it is not appropriate, practical, possible, or desirable to contribute to restoring conditions to the NRV (FSH 1909.12.23.11a).

Changes from the original natural range of variation analysis

The original NRV analysis was conducted in 2017, as summarized in the report titled "*Helena - Lewis and Clark National Forest Natural Range of Variation Analysis for Forest Plan Revision Summary Report March 2017*". This work was redone in May of 2018 to incorporate several key modeling improvements, described below. These improvements increase the accuracy of the analysis, which is crucial to the development and validation of desired future conditions. As a result, the desired conditions related to vegetation presented in the 2020 Forest Plan changed between the DEIS and the FEIS.

- *Updated western spruce budworm logic*. This logic better reflects the cyclic nature of this insect and more closely predicts likely acreages affected. The probability of forests experiencing damage if hazard to the pest was present in adjacent areas was increased, and pathways were added to include all species that can be affected. Pathways were also added to allow infestation in small size classes (pole and seedling/sapling forests), where the most damage can occur when in proximity to larger trees. The overall result is more areas being affected by this insect.
- *Updated fire spread logic calibrations*. The updated logic better reflects the size and shape of fires on the landscape. With the previous logic, fires modeled as square shapes; with the improved logic, they grow organically. In addition, an error was corrected that occurred when fires bumped up against the boundary. In the previous model version, fires had to meet a randomly-drawn predetermined size within the landscape. This means they were often modeled burning upwind and down hills/into drainages, and spread out at the boundaries of landscapes. The fire would hit the modeling boundary and "bounce" back into the landscape, rather than progressing onto adjacent lands. In the corrected model version, the size of the fire includes an inferred amount of burning outside the landscape, which means less burning within the landscape. The modeling extent also included lands on adjacent NFs to allow disturbances to progress naturally. Finally, rather than assigning fire distribution individually to each geographic area (GA), the fire distribution was assigned to the Forest as a whole. These updates to fire logic collectively resulted in a reduction in the estimated historic levels of fire on the landscape, which are more realistic based on expert review. Although the estimated acres of fire are reduced in the updated NRV, it remains a primary driving disturbance.
- *Improved potential vegetation type (PVT) classification*. Following the initial NRV modeling, issues with the crosswalk of habitat type groups in SIMPPLLE to the R1 broad PVTs were discovered. The amount of the cold type was underrepresented, and the amount of cool moist was overrepresented. This arose because there is not a direct crosswalk between the habitat type groups in SIMPPLLE and the R1 PVTs. Several habitat type groups are nested within two different broad groups: "abla3" (F2) and "pico" (F1). Because the specific habitat types are not mapped, assumptions must be made as to which group each pixel belongs in based on factors such as elevation, aspect, and dominant species. The logic to assign R1 broad PVTs was updated to better reflect the split between cold and cool moist, resulting in better alignment with the known abundance of these types according to plot data. This resulted in changes in the conditions summarized by PVT.
- *Updated spatial input file*. After the original NRV, but before the DEIS, the input file (map) for SIMPPLLE was updated to better reflect the species presence measured on FIA plots. In addition, the modeling extent was updated to exclude vast areas of private land between the GAs so that the entire

HLC NF can be modeled as one simulation. Non-NFS lands within the HLC NF boundary, as well as in a buffer outside the boundary, are included in the modeling to ensure results take into account the condition of all lands and allow disturbances to progress across the landscape. The results of fires and vegetation treatments that occurred after the map imagery was collected were incorporated. This updated input file was used as the starting condition for the new NRV analysis, so that it is consistent with the starting condition for future modeling.

- *Excluded private land inholdings from the results.* In the original NRV analysis, the acres reported included private land inholdings within GA boundaries. Although the model is still run across all ownerships, the revised NRV analysis reports outputs for NFS lands only, which allows for a straight comparison to the existing condition and the future condition modeling. This change was minor in most landscapes, but in a few GAs (e.g., the Big Belts) this change was measurable due to high amounts of private land inholdings.
- *Pathway adjustments*: Several pathway adjustments were made for the DEIS and incorporated into the revised NRV. This included ensuring that lodgepole pine had a mechanism for re-seeding after fires if it was present prior to the fire (serotinous seed) or living stands are present nearby; and ensuring that whitebark pine has the opportunity to re-seed after a fire if there is a whitebark pine seed source on the landscape (to reflect potential seed caching by birds). The result of these changes is relatively minor, but may cause a slight reduction in spruce/fir abundance and increase in lodgepole pine or whitebark pine abundance after fire in some cases.
- *Updated existing condition data:* The existing condition data has been updated to incorporate the latest available information. Base forest inventory analysis (FIA) data was updated from the Hybrid 2007 dataset to the Hybrid 2011 dataset. The intensified grid FIA data was updated from the 2013 dataset to a 2016 dataset. These datasets reflect the latest available re-measurements of plots. Finally, for the FEIS, it was determined that R1 VMap provides the best available depiction of density class based on canopy cover, because it is measured directly from imagery, rather than from FIA, where it is estimated. The existing condition values for the revised NRV are therefore derived from R1 VMap instead of FIA for the density class attribute.

The project file contains detailed spreadsheets and charts that compare the original NRV results and existing condition estimates, with the revised NRV results and updated existing condition estimates. For brevity, this report only includes the revised NRV results.

Methodology

To quantify the NRV, modeling was done to simulate vegetation conditions prior to European settlement. The best available model is SIMulating Patterns and Processes at Landscape scaLEs (SIMPPLLE) Version 2.5. This model was developed in Region 1 to answer landscape management questions. SIMPPLLE uses existing data and grows it through time with parameters that reflect historic climate and disturbance.

Thirty simulation runs were done for 1,000 years to provide a range of possible outcomes. This reference period allowed the HLC NF to simulate the conditions associated with much of the time period known as the Medieval Climate Anomaly (about 950 to 1250), as well as the other end of the climate spectrum known as the Little Ice Age (early 1300s to about 1870s). The inclusion of the Medieval Climate Anomaly is valuable in that it might indicate conditions and processes that could occur in the modern climate regime.

Any single simulation can present a possible scenario of what could happen, but cannot be taken as a precise prediction. SIMPPLLE provides for interaction between disturbances and vegetative patterns (Chew et al. 2012). The starting SIMPPLLE spatial dataset was built to reflect the condition measured with FIA data as closely as possible, but minor differences are inherent due to the process of associating grid data to polygons. The existing condition classifications used are consistent with the R1 Classification System (Barber, Bush and Berglund 2011). SIMPPLLE labels are cross-walked to this system.

Climate is the primary parameter used to depict the historic condition. The Rocky Mountain Research Station advised that the best indicator of past climate for this application is the Palmer Drought Severity Index (PDSI). PDSI has been used as an indicator for historic climate in other vegetation reconstructions (McGarigal and Romme 2012). Data for the PDSI is for a set of gridded points covering the continental United States (https://www.ncdc.noaa.gov/). Data point 83 from the 2008 North American reconstruction was used to evaluate the climate for the HLC NF. PDSI is presented as an annual value that has to be generalized to a decadal average for simulations in SIMPPLLE. The data was smoothed using a Savitzky–Golay filter with a 51 year window and a third order polynomial, as shown in Figure 1. Each filtered data point from year 970 to 2000 was classified such that data in the lowest quartile is dry, the middle two quartiles are normal and the upper quartile is wet. Each decade was classified as dry, normal or wet based on the annual value with the majority of occurrences.

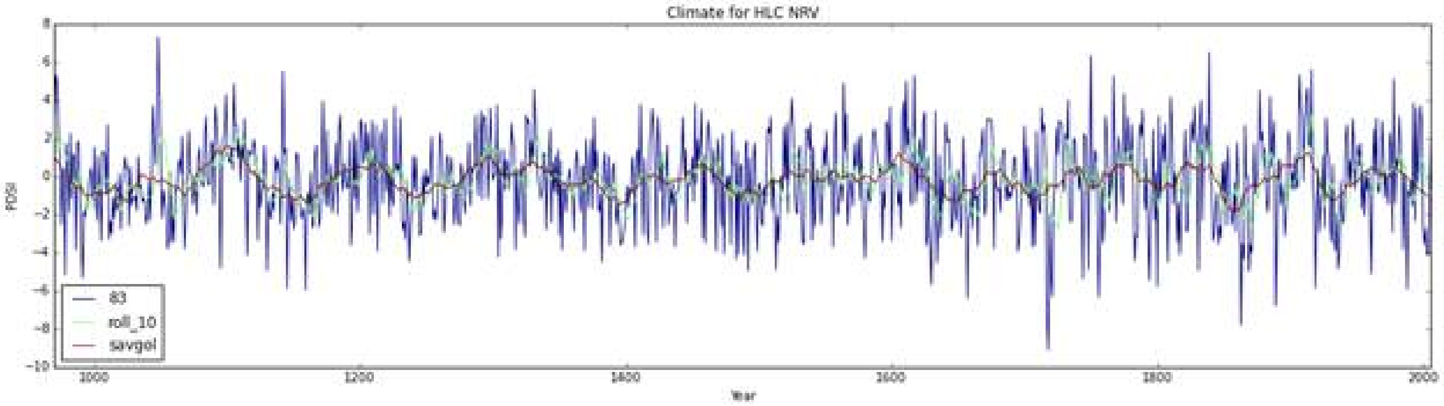


Figure 1. Smoothed Palmer drought severity index values to represent historic climate showing filtered data and rolling 10 year mean

Additional pathways and processes were calibrated to reflect the conditions on the HLC NF, including:

- *Successional Pathways*: Successional pathways are state and transitional models for each vegetation type that provide the foundation for the model. The existing data was reviewed, and pathways were added and/or modified based on expert judgement and successional theory.
- *Wildfire Processes*: Wildfire processes, including the probability of ignition, fire sizes, fire regimes (severities), weather ending events, and effects to successional pathways are key drivers in the model. Wildfire processes were calibrated using local fire history data, applicable fire history studies and publications, previous modeling efforts, and expert judgement.
- *Insect and Disease Processes*: The probability and effects of key insect and disease processes (bark beetles, defoliators, and root diseases) were also calibrated using the latest science regarding insect hazard and mortality trends, local data, and expert judgement.
- *Wildlife Habitat Definitions*: For the key wildlife habitats selected for modeling, the parameters used to define the habitat were developed based on the most recent inter-agency habitat modeling work available, other published literature, and expert judgement.

The NRV is compared to the existing condition throughout the analysis. Quantification of the existing condition is provided by queries directly from the most recent available FIA and FIA intensified plot data with 90%

confidence intervals. The NRV values shown in the charts reflect the averages across all time periods and SIMPPLLE model runs. Also see appendix H of the FEIS for more information regarding the data sources and SIMPPLLE model calibrations done for NRV modeling.

Potential vegetation types

Region 1 broad PVTs provide the foundation for stratification of the NRV. These broad groups are assemblages of habitat types (Milburn et al. 2015, Pfister et al. 1977, Mueggler and Stewart 1980). Generally, it is assumed that habitat type is fixed because it infers physical characteristics that influence site capability. To the extent that disturbances and climate alter growing conditions, it is possible that a habitat type could shift. However, it is not possible to predict or map this. The broad PVTs used for the HLC NF are shown in appendix D of the 2020 Forest Plan. Warm dry forest PVTs are generally the most abundant except in the Rocky Mountain Range GA, where cool moist types dominate. The Big Belts and Highwoods contain a particularly high proportion of warm dry types. Nonforested PVTs are extensive across the lands in between the island mountain ranges, and are important components within the GAs. Some PVTs that are rare or exist as small patches (such as alpine and riparian) are poorly captured with FIA data and PVT mapping.

Key ecosystem characteristics

Ecosystems are complex; it is only possible to quantify a subset of ecosystem characteristics. Table 1 lists the key ecosystem characteristics included in the revised NRV analysis. These characteristics include wildlife habitats of at-risk species or species of significant interest to the public that rely on vegetation characteristics that can be reasonably estimated using available modelling tools. These characteristics were analyzed at several scales as appropriate, including forest-wide, by GA, and/or by broad PVT.

Table 1. Key ecosystem characteristics of vegetation included in NRV analysis

Element	Characteristic
Composition	Cover type
	Tree species distribution
Structure	Forest size class
	Density class
	Vertical structure
	Large trees and large-tree structure
Pattern	Early successional forest openings
Wildlife Habitats	Canada lynx
	Flammulated owl
	Lewis’s woodpecker
	Elk

Analysis area

The HLC NF consists of 10 distinct geographic areas (GAs) spanning across a large portion of central Montana. The entire HLC NF was run as a single landbase, but results were summarized by GA when appropriate. Lands of all ownerships within the modeling extent were included. A map of the SIMPPLLE modeling extent is provided in appendix H.

Historic narrative

Vegetation on the HLC NF has changed through time. Along with physical site characteristics such as soils, the interactions of climate and disturbances determined the historic composition and structure of vegetation. Climate is a primary driver which exerts a strong influence on wildfire (Marlon et al. 2012, Littell et al. 2009) as well as insect and disease regimes. Vegetation varies with climate based on its direct influence on growing conditions as well as indirectly through its influence on disturbances. The last glacial period started roughly 40,000 years ago, reaching its peak 15,000 years ago; following this, a series of warming and cooling periods occurred (Losensky 2002). Following the Little Ice Age, some of the worst droughts and severe fires in the northwest occurred from the late 1800’s to the mid-1930’s (Barrett, Arno and Menakis 1997), a period which is correlated with a warm and dry climate phase.

In many areas of the HLC NF, limestone soils play a significant role in the location of plant communities (Losensky 1993b). Another unique feature of some landscapes are the woodland ecotones, which consisted of shrubby open-grown conifers which encroached into grasslands and periodically retreated with fire (ibid). Historic age class structures varied by cover type and GA; for example, in the Blackfoot most of the ponderosa pine forests were likely mature or old in 1900 due to the dry environment and prevalent underburning, while the Douglas-fir was dominated by mid-aged conditions and most lodgepole forests were less than 100 years old (ibid). In contrast, in the GAs with an island mountain range landform, a high proportion of young forest was present at that time as a result of frequent prairie fires (ibid). Early survey reports described in detail the forests and conditions that they observed in the GAs, including bull pine (ponderosa pine) at the lowest elevations, red fir (Douglas-fir), and lodgepole pine, along with less common species such as poplar (aspen and cottonwood), balsam fir (subalpine fir), spruce, and whitebark pine (Griffith 1904, Ayres 1900, U.S. Department of Agriculture 1926, Stickney 1907, Hatton 1904a, Hatton 1904b).

Wildfire is the most influential disturbance on the HLC NF, as lightning storms are common and provide a natural ignition source. Island mountain ranges, like many of the GAs on the HLC NF, support distinct fire regimes (Murray, Bunting and Morgan 1998). The protruding prominence of these ranges may attract a greater frequency of lighting-ignited fire; more fire can also result from the adjacency to steppe from which grass fires would spread (ibid). Island ranges may have a greater proportion burned in a given timespan than other landforms due to their limited extent; and have high landscape variability represented by a mosaic of distinguishable patches with distinct structures, compositions, and fuel loadings (ibid). Wind-speed during periods of drought may be more important than fuel or topographic parameters in facilitating large fire extent (ibid).

Coincident with a warm dry climate period, numerous reports indicate that large acreages on the HLC NF burned in the late 1800’s in many of the GAs (Stickney 1907, Hatton 1904a, U.S. Department of Agriculture 1926, Hatton 1904b, Janssen 1949, Barrett 2005a, Losensky 1993a, Murray et al. 1998, Ayres 1900); (Leiberg 1904). For example, both Hatton (1904b) Janssen (1949) noted evidence of extensive fires in the late 1800’s in the Big Belts which swept the range and gave rise to abundant pure, even-aged stands of Douglas-fir. Similarly, Aryes (1900) described evidence of extensive fire in the Rocky Mountain Range in 1889 which burned over 600 square miles with high severity during drought conditions, and gave rise to an increase in the abundance of lodgepole pine. During the period of settlement, human-caused fires associated with mining camps and settlements also increased in some areas, including the Elkhorns and Little Belts GAs (Griffith 1904, Leiberg 1904).

Early surveyors described the effects of the wildfires in the 1800’s as undesirable relative to the ecosystem values at that time, using terms such as “destructive”, “devastation”, and “destroyed” (Stickney 1907, Hatton 1904b, Ayres 1900). Some early settlers and surveyors recognized the importance of forest cover not only for timber value, but to protect water resources needed for downstream uses such as irrigation (Griffith 1904, Hatton 1904a). When the forest reserves were established in the early 1900’s fire suppression was considered to be necessary to protect resources. Fire suppression along with cooler, wetter climate conditions and grazing uses all contributed to an era of fire exclusion that was prominent from that time until roughly the 1980's. At that point, warmer and drier conditions again began to prevail, and along with a build-up of fuels in some areas contributed to an increase in the acreages burned despite fire suppression efforts. In addition to climate, this trend has been influenced by an increased recognition of the natural role of fires that resulted in policy shifts that allow some natural fires to burn.

Insect and diseases also historically played an important role in shaping vegetation. These processes are influenced by climate and interact with wildfire. An early boundary report in the Upper Blackfoot GA found that "a considerable quantity of the lodgepole pine had been severely damaged by bark beetles", which was "practically all mature", 120-160 years old at that time (U.S. Department of Agriculture 1926). Janssen (Janssen 1949) and Hatton (1904a) both noted that root disease in Douglas-fir in the Big Belts was widespread. In 1949, western spruce budworm was also in a "severe epidemic stage", in that GA which appeared to have started following red belt damage (Janssen 1949). Climate and weather play a major role in controlling insects, as does availability and quality of food and breeding habitat. Historically, insect populations would periodically build to high levels under favorable climatic and host conditions; cool climate conditions were not conducive to outbreaks.

A recent mountain pine beetle outbreak impacted the majority of pine forests across the HLC NF (Milburn 2015). Specifically, on the western part of the forest, roughly 2/3 of the lodgepole pine forests were impacted, with the most common change being a reduction in density. There has also been a reduction in ponderosa pine and lodgepole forest types, with a subsequent increase in subalpine fir and Douglas-fir; and the abundance of young forests increased as older trees were selectively killed. Other components of the forest were impacted, including an increase in small and medium snags, a decrease in old growth, and an increase in large woody debris. Similar vegetation changes undoubtedly occurred during historic outbreaks, although the severity and extent of the recent outbreak was influenced by anthropogenic factors such as fire exclusion that altered the condition and susceptibility of forests.

Human activities associated with settlement, such as urbanization, mining, logging, and grazing began in the mid to late 1800's in most GAs, the influences of which are not considered part of the NRV. In the Elkhorns GA, accessible timber was cut over extensively around the 1880's, and although regeneration was often "magnificent" it was also "menaced" by high amounts of woody debris left behind by fire and wasteful harvest practices (Griffith 1904, Stickney 1907). Other early surveys noted that in the Helena area "fire and the axe have made extensive invasions in the most accessible areas, and many of these show a present absence of forest conditions"; much of the accessible material was used for rail ties or cordwood (Hatton 1904b). Extensive mining indicated an ongoing demand for timber (Hatton 1904b, Griffith 1904).

Although Hatton (1904a) noted relatively little use of commercial timber within the Big Belts reserve due to a lack of roads, both he and Janssen (1949) noted that settlers established in the Big Belts in the 1870's, and tree cutting was extensive to support the demand for timber from the rapidly growing communities of Great Falls and Helena. This included cutting of the ponderosa pine forests in the foothills; followed by lightning fires that occurred in the late 1880's and early 1900's this resulted in a decline of ponderosa pine forests (ibid). These "ponderosa pine bench" areas were also cut over during the building of the Canyon Ferry, Holter, and Hauser dams in the late 1890's and early 1990's (ibid). Further, miners burned off whole drainages to expose ore leads; as a result many of these areas were deforested (ibid). Similarly, in the Little Belts 25% of the forest area on the landscape was "logged to exhaustion", and mining camps caused extensive fires since 1860 (Leiberg 1904).

In contrast, in the Upper Blackfoot GA reports indicate that due to inaccessibility there was not much demand for timber cutting during the early phases of settlement, and in 1926 the area was extensively forested with mature and over-mature forest (U.S. Department of Agriculture 1926). Similarly, early tree cutting was limited to "village use" in the Rocky Mountain Range, as "often the material can only be taken out with great difficulty" (Ayres 1900).

To a lesser extent than early harvest practices, modern vegetation management (since roughly 1940) has influenced composition and structure on a relatively small proportion of the HLC NF (8%).

NRV results and discussion

Introduction

This section summarizes the NRV results from SIMPPLLE that describe the envelope of vegetation conditions that were likely present in the plan area prior to European settlement. An understanding of the NRV provides insight into the dynamic nature of ecosystems, the components that have sustained the current complement of wildlife and plants, and the structural and functional properties of a resilient ecosystem. The NRV analysis includes inherent uncertainty and modeling limitations, and it is therefore necessary to use additional information to ensure that the desired conditions described in the plan meet future ecological and social needs.

Some NRV attributes are analyzed for individual GAs in addition to forestwide because each GA is unique. Attributes are also characterized by PVT to display conditions on the sites which have the capacity to support them. Due to limitations in available data and lack of statistical confidence, estimates are not broken down by PVT at the GA level. The extent to which existing conditions are similar or dissimilar to the NRV is discussed for each ecosystem characteristic. For most attributes, the 5th and 95th percentile ranges of the NRV outputs are reported, because this range eliminates rare outliers. However, the absolute minimum and maximum may be discussed where it provides additional context.

This report primarily focuses on disclosing the NRV condition and does not interpret future conditions and the effects of forest plan actions or alternatives. Further discussion of results of the NRV analysis as compared to the estimated effect of the 2020 Forest Plan and alternatives can be found in the FEIS.

Disturbances

Wildfires

Fire regimes exert a high level of influence on all key ecosystem characteristics. Historic wildfire regimes are analyzed in terms of the average acres burned per decade and fire severity. *Fire severity* describes immediate fire effects, as opposed to burn severity that depicts longer-term effects on vegetation and soils (Lentile et al. 2006). Fire severity is classified as low, mixed, or stand replacing based on effects to above-ground vegetation. To capture the differences in fire regimes and probability of fire in each GA, calibrations were done in the model by PVT, cover type, species fire resistance, and fire type under certain weather parameters. Historic fire occurrence and size data were used for calibrating fire probabilities.

Figure 2 displays the NRV for the average range acres burned by decade, by fire type, by broad PVT. The warm dry broad PVT tended to burn with mixed severity, while cool moist and cold sites tended to burn with stand replacing severity. Fires in nonforested PVTs are typically classified as stand replacing in the model, because they often kill the existing grasses, forbs, and shrubs. With all PVTs and fire types considered, the NRV estimates a 5th to 95th percentile range of 20,000 to 235,000 acres burned per decade across the HLC NF.

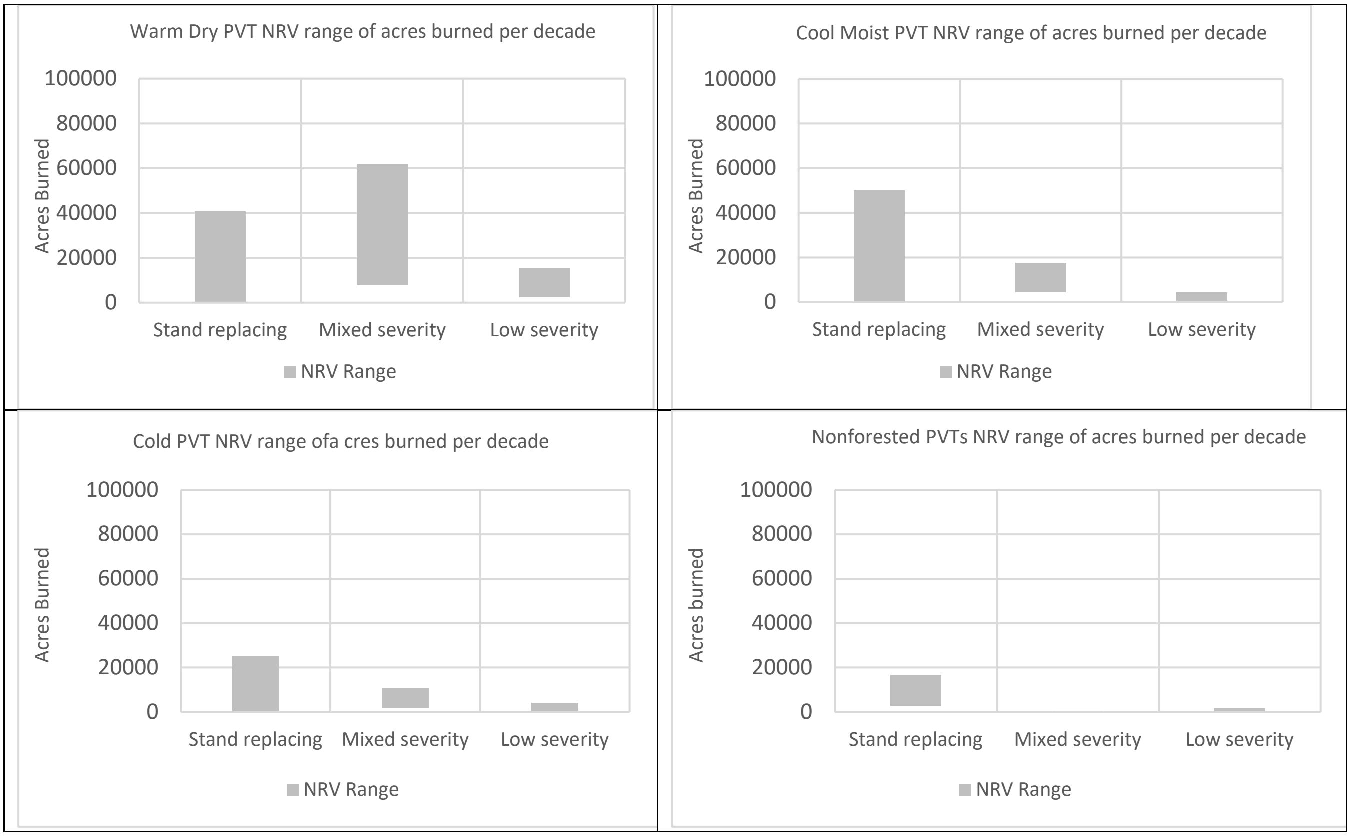


Figure 2. NRV .05-.95 range of acres burned per decade forestwide by PVT

The average acres burned per decade in the NRV (103,000 acres) is less than the average acres burned per decade since 1985 according to the Monitoring Burn Severity Trends (MTBS) database; this appears to contradict the well-researched trend that the role of fire has diminished from the NRV due to anthropogenic influences such as fire suppression. Therefore, further exploration of the data is warranted. It is critical to clarify that the overall NRV range (5-95 percentile of 20,000-235,000 acres/decade on NFS lands) is more appropriate to consider than the average acres/decade, because the historical "envelope" is more important than the single mean value.

First, the period of 1985-2015 is examined, because this represents when climate shifted to warm and dry, with associated increases in fire activity, and is often considered to represent a new/current fire regime. Decades are summarized as 1985-1994; 1995-2004; and 2005-2015. As shown in Table 2 and Figure 3, in most GAs the acres burned are below or at the low end of the NRV. In some GAs, the recent levels of burning have moved within the NRV range, but all except the Rocky Mountain Range remain within the NRV range. Although the forestwide totals are within the NRV range, it is important to note the spatial distribution of burning. Recent burning has been concentrated in some GAs but nearly absent from others, and represents different proportions of the forest total than what occurred in the NRV.

Table 2. Current burning (MTBS, 1985-2015) Compared to the NRV analysis (NFS lands only)

GA	Current Burning (30 years, 1985-2015, MTBS)			NRV (rounded to nearest 100)		
	Acres/decade	% of GA	% HLC NF acres burned	Acres/decade burned 5-95 percentile	% of GA	% HLC NF acres burned
Big Belts	15,743 (70-29,347)	5%	11%	2,700-51,400	6%	17%
Castles	2 (0-5)	0%	0%	150-11,000	4%	3%
Crazies	174 (0-511)	0%	0%	110-9,300	4%	2%
Divide	98 (0-193)	0%	0%	1900-35,500	6%	12%
Elkhorns	8,016 (0-23,745)	5%	6%	730-24,100	5%	7%
Highwoods	12 (0-35)	0%	0%	90-6,300	4%	2%
Little Belts	9,370 (3,584-14,909)	1%	7%	3,000-65,700	3%	20%
Rocky Mountain	80,018 (8,162-161,779)	10%	57%	2,200-55,600	2%	17%
Snowies	434 (0-1,249)	0%	0%	250-14,500	3%	4%
Upper Blackfoot	27,476 (6,850-43,847)	7%	19%	2700-47,200	5%	16%
Forestwide	**141,000 (79,262-190,221)**			**20,000-235,000**		

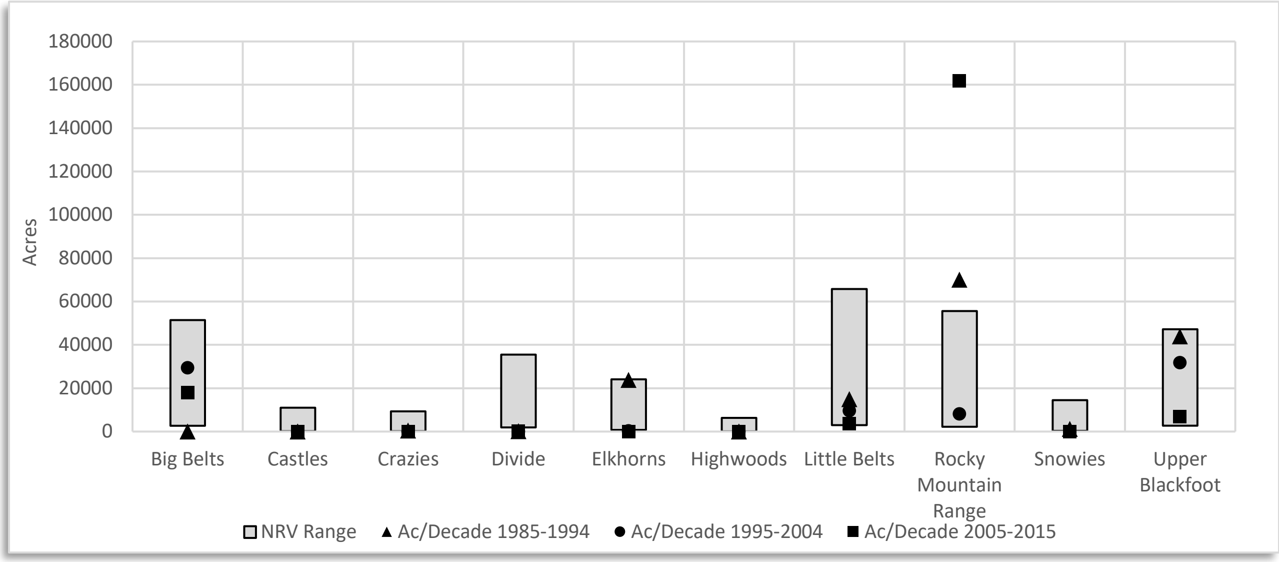


Figure 3. Acres burned/decade 1985-2015 (MTBS) compared to NRV 5-95 percentile ranges

A longer time scale of recent fire can be evaluated against the NRV, as shown in Table 3, to better understand the influences of the cool/moist climate period and fire exclusion era. The HLC NF fire history database was queried to show all fires since consistent records have been kept (1940-2016, 76 years). Decades are summarized as 1940-1949; 1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; and 2010-2016. Table 3 shows not only the 5-95 percentile range of the NRV, but also the absolute minimum and maximum acres burned in a decade. In most GAs, the average acres/decade burned since 1940 is at the lower end of the 5-95th percentile NRV range, with some below even the absolute minimum acres burned/decade (Castles, Divide, Highwoods). The maximum or upper bound of the range for actual acres burned is within the 95th percentile of the NRV for all GAs with the exception of the Rocky Mountain Range GA; however, the acres burned are within the absolute maximum of the NRV.

Table 3. Comparison of NRV range and acres burned 1940-2016 (NFS lands)

GA	Acres burned 1940-2016	Acres per decade 1940-2016	NRV 5-95 percentile acres burned per decade	NRV absolute min/max acres burned per decade
Big Belts	91,242	12,006 (0-65,657)	2,700-51,400	920-223,000
Castles	60	8 (0-43)	150-11,000	30-110,200
Crazies	1,952	257 (0-1,144)	110-9,300	30-62,000
Divide	589	77 (0-267)	1,900-35,500	400-164,000
Elkhorns	37,597	4,947 (0-37,311)	730-24,100	90-168,000
Highwoods	45	6 (0-35)	90-6,300	30-65,000
Little Belts	42,813	5,633 (498-12,353)	3,000-65,700	1,300-264,000
Rocky Mountain	362,603	47,711 (168-143,837)	2,200-55,600	680-220,000
Snowies	5,811	765 (0-2,780)	250-14,500	30-145,000
Upper Blackfoot	81,922	10,779 (0-36,886)	2,700-47,200	670-184,000
Forestwide	624,635	82,189 (2,155-257,194)	20,000-235,000	10,000-521,000

The Rocky Mountain Range GA is unique in its relationship to the NRV. This GA only accounted for 17% of the HLC acres burned in the NRV but accounts for 57% of the burning that has occurred since 1985; in other words, much of the recent fire on the HLC has been concentrated there. The total acres burned in recent decades exceeds the 95th percentile acres burned in a given decade in the NRV. However, the recent acres do not exceed the absolute maximum acres of burning/decade. Therefore, the recent levels of fire would have been uncommon but not unprecedented in the 1,000 years prior to European settlement. The Rocky Mountain Range contains large expanses of backcountry where natural fire has been allowed to occur. The burning that resulted in the average fire acres exceeding the NRV occurred during the last 30 years, following decades of very little fire. The large fire years in this GA occurred in notable dry fire seasons (1988, 2007, and 2015); refer to the figures in the following section. This landscape has made disproportionate strides in recent decades to make up for the earlier fire deficit.

The Upper Blackfoot also exceeded the average NRV acres burned per decade in recent years; however, the acres burned are well within NRV 5-95th percentile range per decade. The area burned from 1985-2015 in the Big Belts and Elkhorns is similar to NRV average and well within the 5-95th percentile range. Burning in the other landscapes has contributed little to the forestwide total, and have been at the low end or below the NRV range (Castles, Crazies, Divide, Highwoods, Little Belts, and Snowies).

Over time, as shown in Figure 4, the acres burned per decade forestwide were below the 5-95th NRV range except for 1980-1989; 2000-2009; and from 2010 to present day. This indicates that under recent climate and policy regimes, burning in recent decades has moved into the NRV range at the forestwide scale, and this trend is likely to continue given expected climate. The levels of recent burning are well within the absolute NRV maximum, indicating that such burning was uncommon but not unprecedented during the historic period. The following section includes graphs of the trend over this time period for each GA.

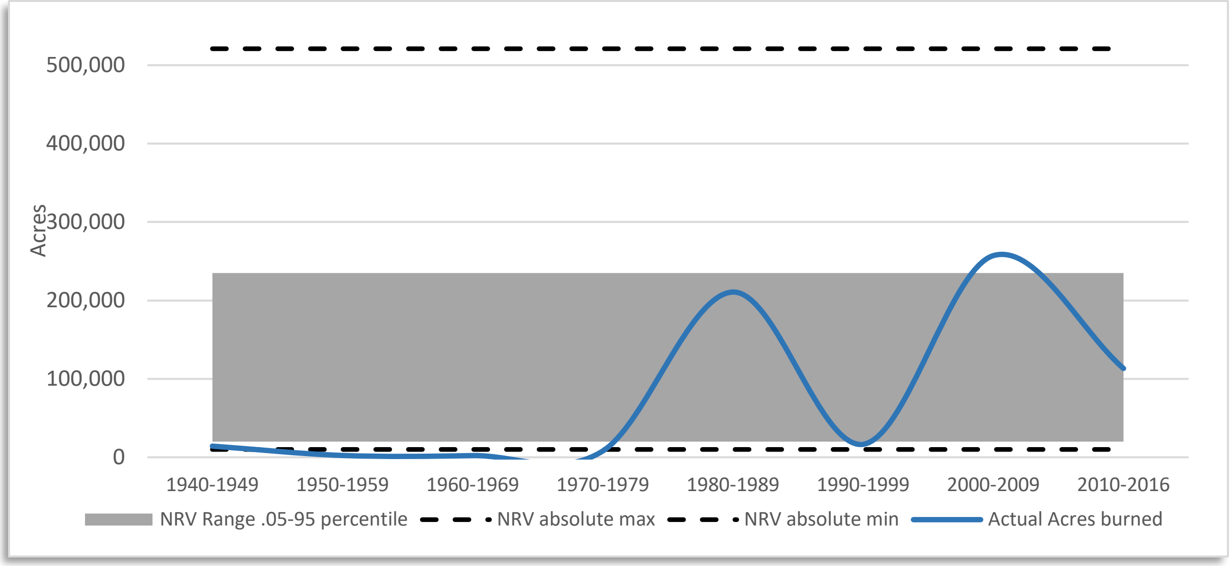


Figure 4. Forestwide acres burned/decade from 1940-2016 compared to NRV range

These data comparisons indicate that several GAs (Rocky Mountain Range, Upper Blackfoot, Elkhorns, and Big Belts) have moved within the NRV 5-95 percentile range for average fire acres burned/decade in the last 30 years. This does not mean that more burning should not or will not occur in those areas, but rather that continued burning may maintain the trend of being within the NRV. It also does not mean that the recent levels of burning have “made up” for the acres that would have burned since fire suppression began; all GAs except the Rocky Mountain Range are within the NRV ranges for area burned and likely remain “deficit” for acres that would have burned over the longer time period of fire exclusion. The NRV included cool/moist climate periods when less burning would occur, and the current condition reflects a warm/dry period (as well as other influences such as fuel buildup), and therefore it is reasonable to expect that future burning will be at the upper end of the NRV range; and it is not implausible that future burning could exceed the NRV.

These trends are consistent with the widely documented trend of a fire deficit in the West (Keane et al. 2002, Hessburg and Agee 2003, Westerling et al. 2006), as well as with studies that indicate wildfire acres burned are increasing after the long period of fire exclusion due to climate and other feedbacks such as fuel buildup and fire policies (Marlon et al. 2012, Westerling et al. 2006). The trends also agree with Hollingsworth (2004) which concluded that fire exclusion and cool moist climate conditions resulted in acreage burned well below historic levels prior to 1970; but that recent decades are approaching historic levels. Acres burned and the number of large fires have increased since 1980 in part due to 1) fuel buildup caused by fire exclusion (especially in low severity regimes); 2) the influence of a warm/dry climate on vegetation, fire behavior, and effectiveness of suppression; 3) recent fire policies that have allowed natural fires to burn; and 4) more complete record-keeping.

Still, in many areas, today’s fire intervals are longer than they were pre-settlement (Barrett et al. 1997, Barrett 2005b, Heyerdahl, Miller and Parsons 2006). Studies indicate that low or mixed severity, high frequency fire regimes that maintained low tree densities and favored fire-tolerant trees have shifted to stand-replacing regimes at less frequency; this influences succession and can reduce biodiversity when extensive areas are regenerated by fire that historically would have been mosaics (Barrett et al. 1997, Hessburg, Agee and Franklin 2005, Lehmkuhl et al. 2007). Changes may include higher tree density, more multi-storied stands and ladder fuels, and a greater homogeneity of structures across the landscape which results in a greater probability for disturbances to affect large areas (Hessburg et al. 2005).

Even in forest types where stand-replacing regimes are natural, such as lodgepole pine, at the landscape scale fire suppression may have induced mosaic homogeneity in forests that previously contained a heterogeneous mix of fire-initiated age classes (Barrett 1993). In these areas suppression (particularly of small fires) has decreased the acreage burned in normal fire seasons and reducing the natural variability in landscape patterns (ibid). As a result, the larger, contiguous blocks of uniform stands are subject to beetle outbreaks and catastrophic fires when fire weather is extreme (Hughes et al. 1990, Barrett 1993). Although fire intervals are generally long, patchy re-burns in regenerating lodgepole can occur at fairly short intervals; lodgepole has adapted to this by producing open cones at a very young age to fill in such gaps. Once these trees reach a mid-successional age, they then shift to producing serotinous cones in preparation for regenerating after the next stand replacing event.

In short, the lack of fire has disrupted successional processes, altered fire regimes, and altered landscape diversity in composition and structure. Given expected future climate conditions, fire will likely shape the landscape to a greater degree than management actions. The NRV modeling showed that stand replacing and mixed severity fires were at the higher end of their range in terms of the percent area burned during warm and dry climate periods. Multiple studies have predicted an increase in fire areas burned in the Rocky Mountains in part due to anthropogenic climate change (Abatzoglou, Rupp and Mote 2014, McKenzie et al. 2004, Yue et al. 2013, Riley and Loehman 2016, Clark, Loehman and Keane 2017). Therefore, while the NRV provides an important depiction of our past, the future of fire may exceed historic levels. The exact level is difficult to predict due to the uncertainty in many factors, such as fire suppression, policy, changes in anthropogenic emissions, as well as ecosystem conditions and other disturbances.

GA NRV ranges of acres burned compared to recent burning levels

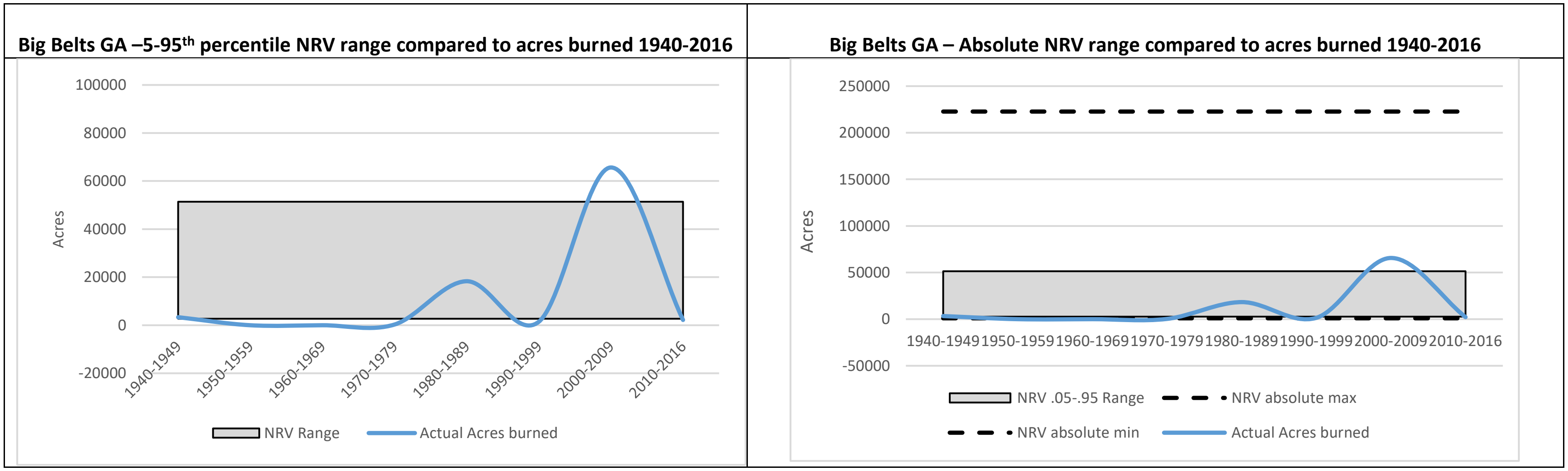


Figure 5. Big Belts NRV ranges of acres burned compared to recent burning levels

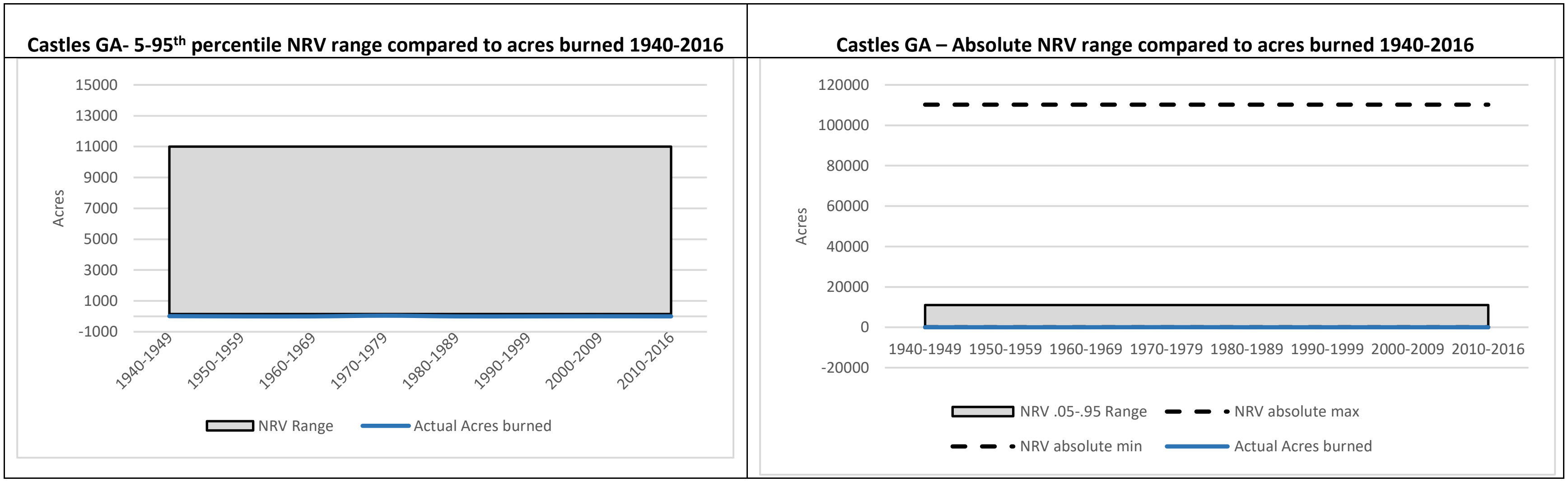
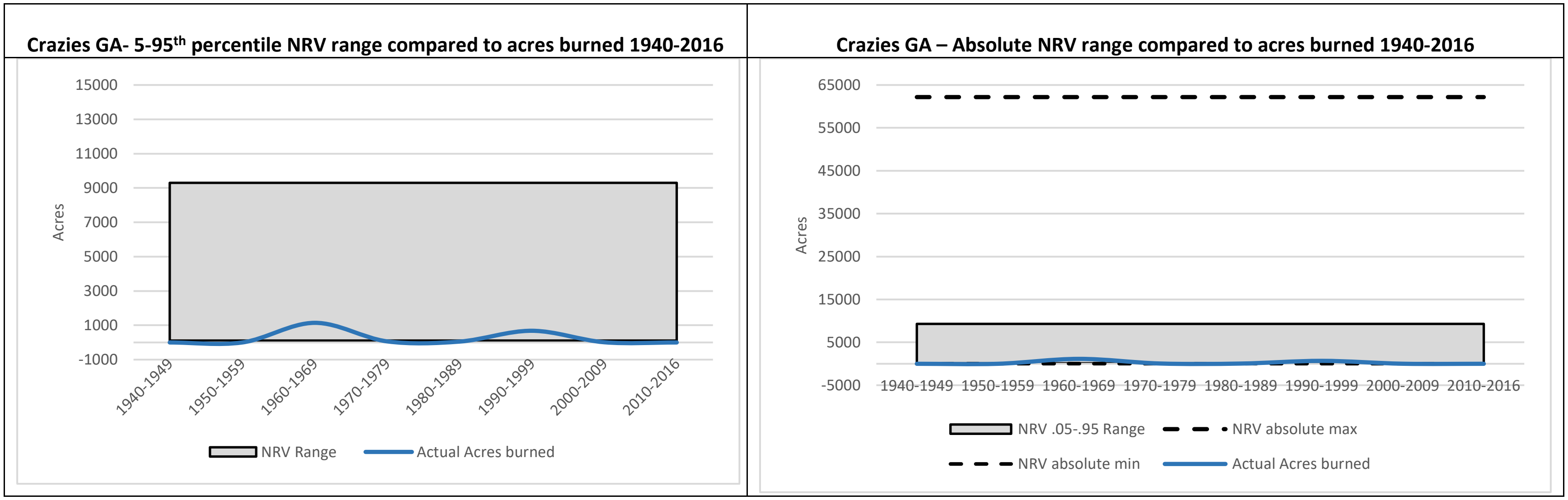


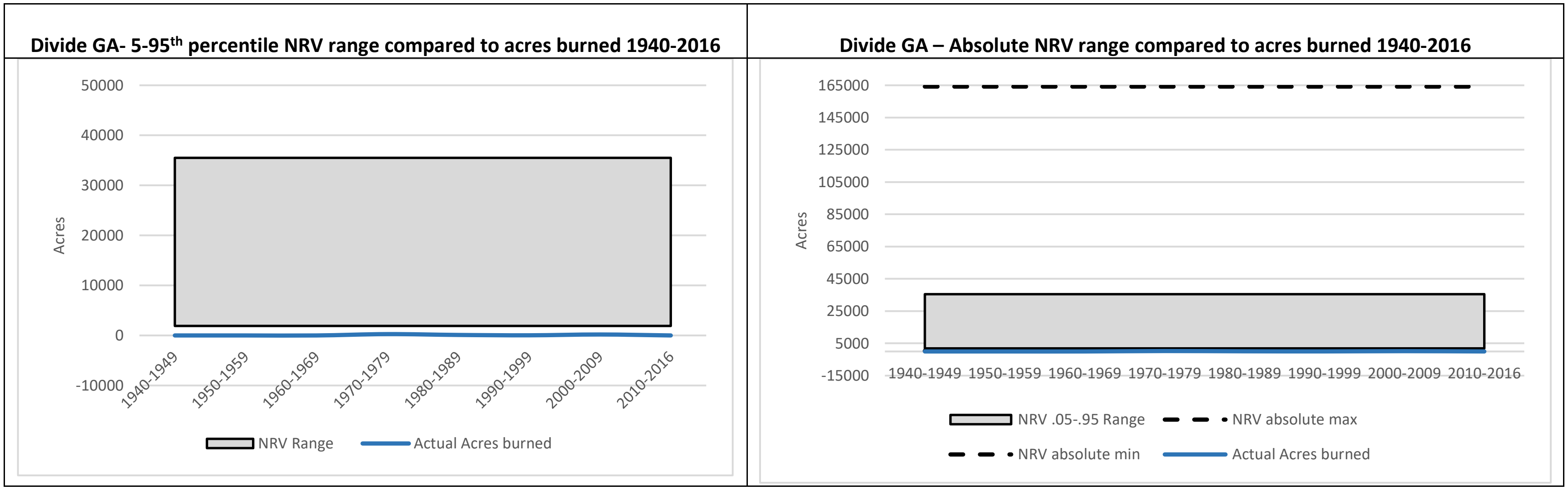
Figure 6. Castles NRV ranges of acres burned compared to recent burning levels



Crazies GA- 5-95th percentile NRV range compared to acres burned 1940-2016

Crazies GA – Absolute NRV range compared to acres burned 1940-2016

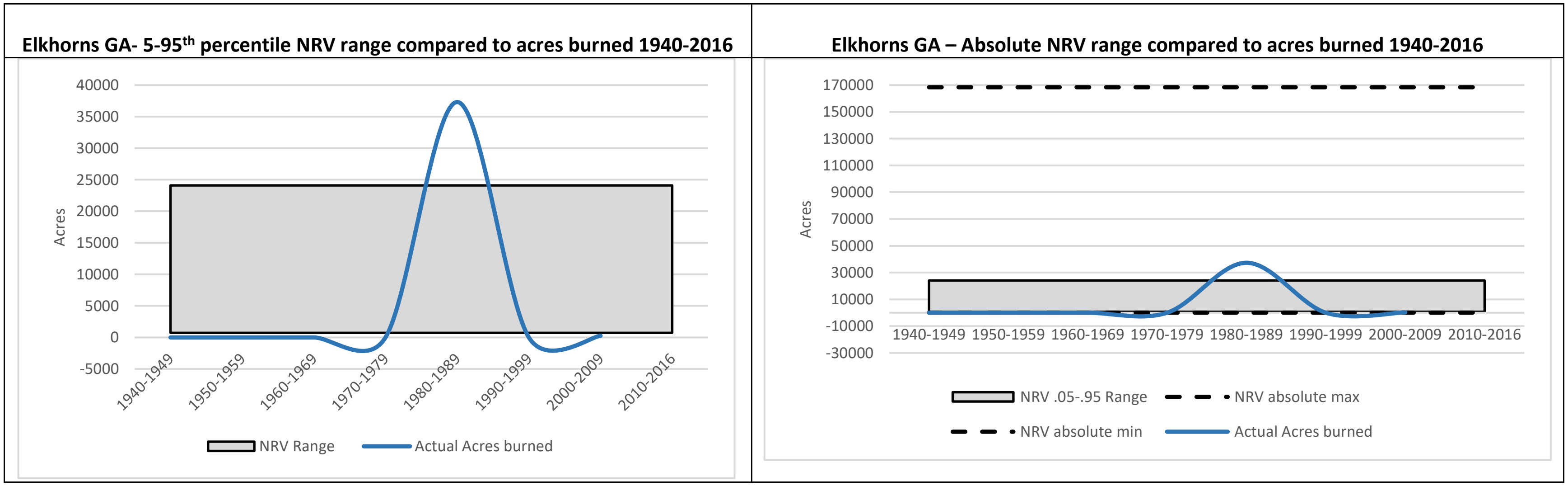
Figure 7. Crazies NRV ranges of acres burned compared to recent burning levels



Divide GA- 5-95th percentile NRV range compared to acres burned 1940-2016

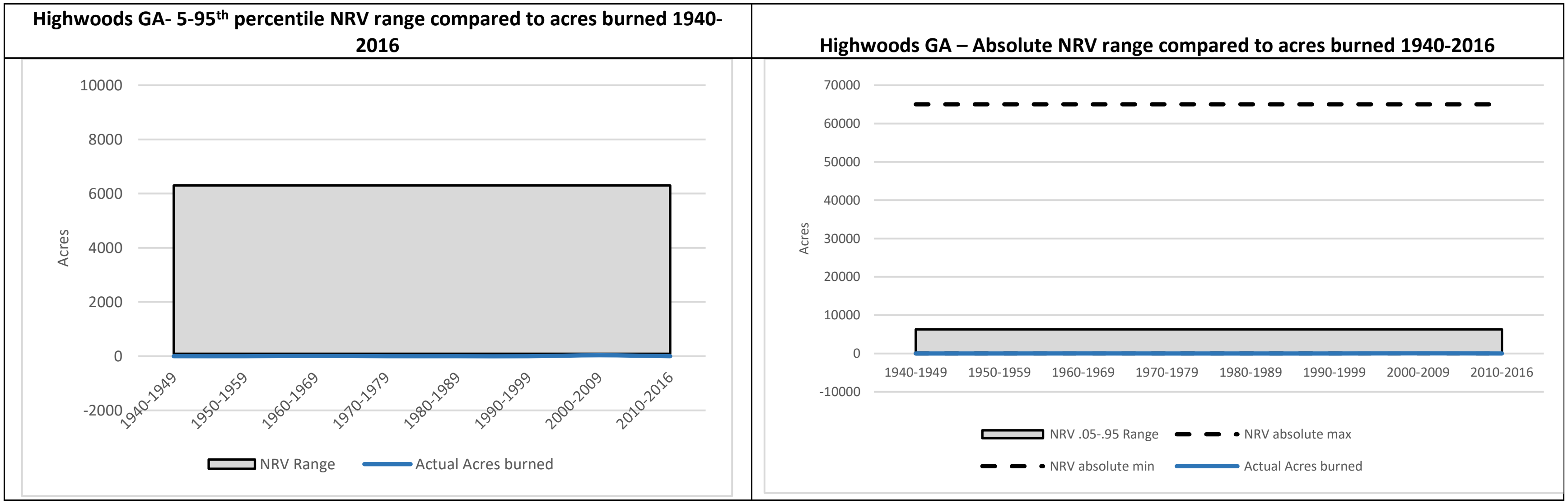
Divide GA – Absolute NRV range compared to acres burned 1940-2016

Figure 8. Divide NRV ranges of acres burned compared to recent burning levels


Elkhorns GA- 5-95th percentile NRV range compared to acres burned 1940-2016

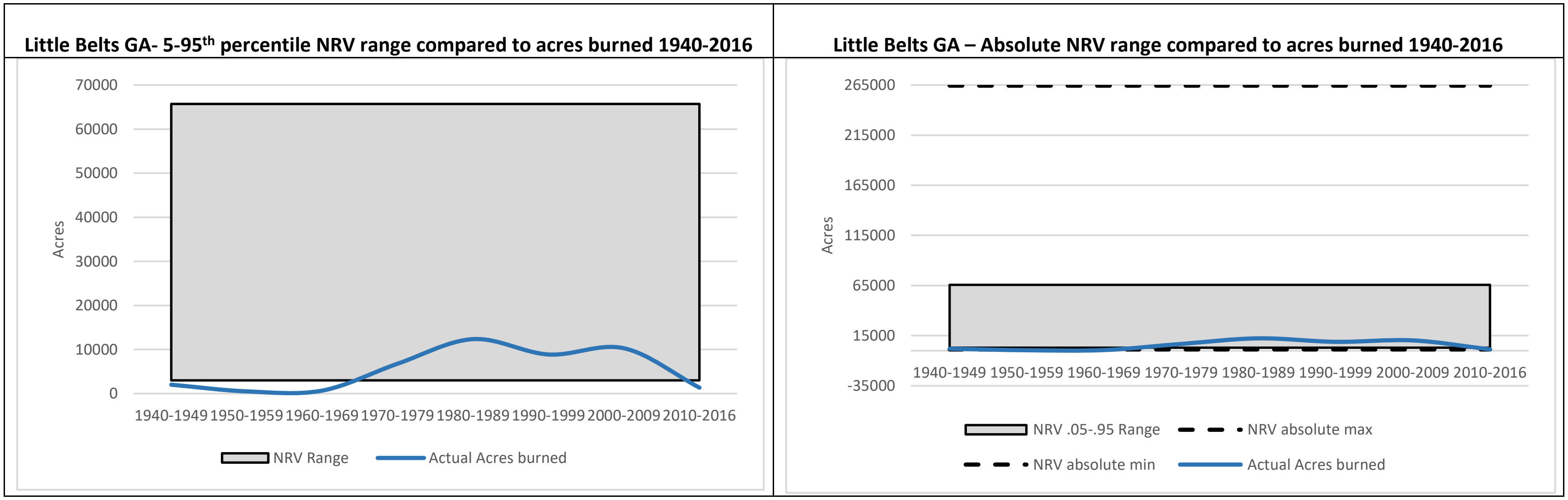
Elkhorns GA – Absolute NRV range compared to acres burned 1940-2016

Figure 9. Elkhorns NRV ranges of acres burned compared to recent burning levels


Highwoods GA- 5-95th percentile NRV range compared to acres burned 1940-2016

Highwoods GA – Absolute NRV range compared to acres burned 1940-2016

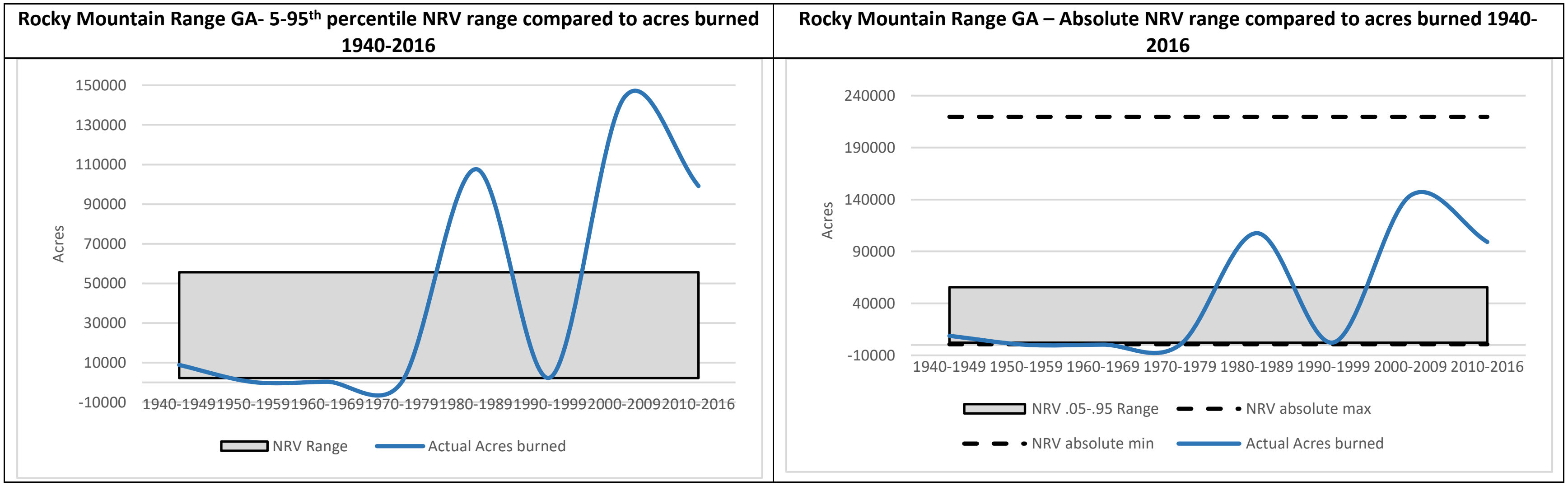
Figure 10. Highwoods NRV ranges of acres burned compared to recent burning levels



Little Belts GA- 5-95th percentile NRV range compared to acres burned 1940-2016

Little Belts GA – Absolute NRV range compared to acres burned 1940-2016

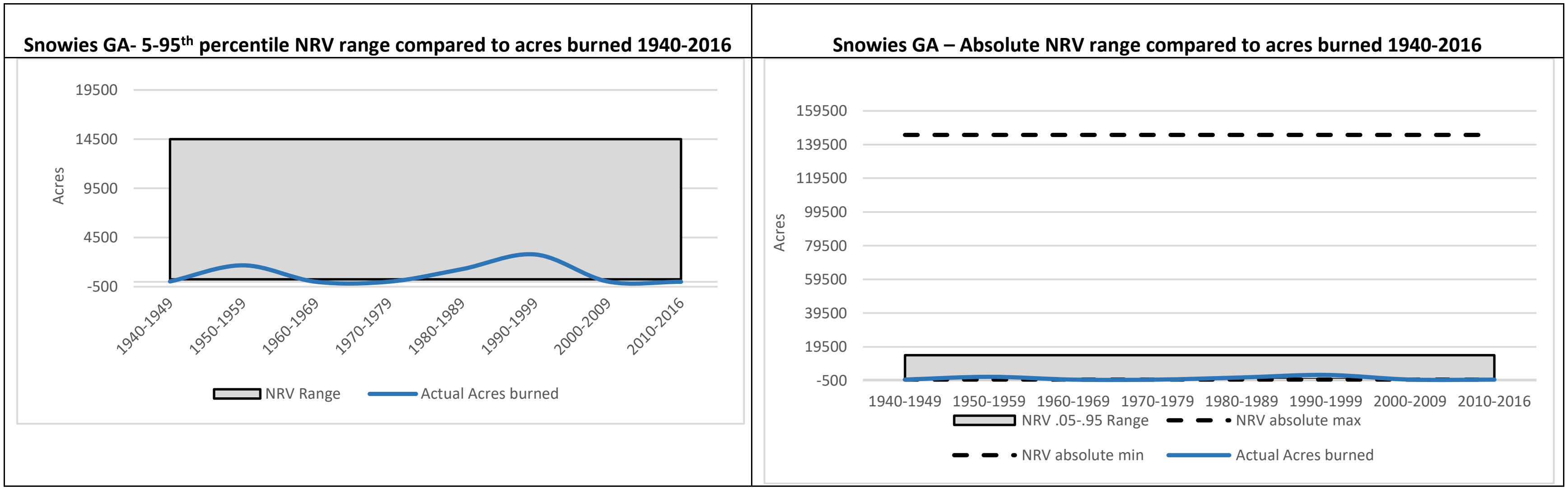
Figure 11. Little Belts NRV ranges of acres burned compared to recent burning levels



Rocky Mountain Range GA- 5-95th percentile NRV range compared to acres burned 1940-2016

Rocky Mountain Range GA – Absolute NRV range compared to acres burned 1940-2016

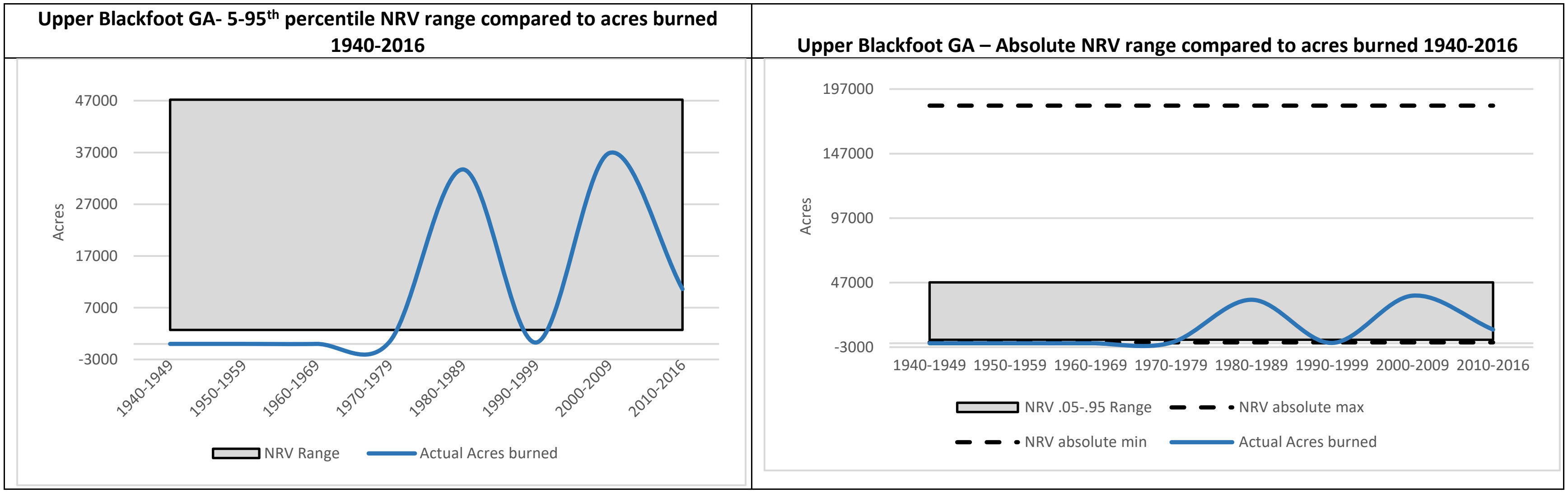
Figure 12. Rocky Mountain Range NRV ranges of acres burned compared to recent burning levels



Snowies GA- 5-95th percentile NRV range compared to acres burned 1940-2016

Snowies GA – Absolute NRV range compared to acres burned 1940-2016

Figure 13. Snowies NRV ranges of acres burned compared to recent burning levels



Upper Blackfoot GA- 5-95th percentile NRV range compared to acres burned 1940-2016

Upper Blackfoot GA – Absolute NRV range compared to acres burned 1940-2016

Figure 14. Upper Blackfoot NRV ranges of acres burned compared to recent burning levels

Insects and disease

Insect regimes are analyzed in terms of the average acres affected by decade for the major forest insect pests: mountain pine beetle, Douglas-fir beetle, and western spruce budworm. Root disease is the primary disease impacting the HLC NF, but not to a great degree due to the relatively dry climate east of the continental divide. Insect outbreaks are influenced by climate, disturbances, and the condition of vegetation. The current warm/dry climate cycle correlates with the increased extent of outbreaks that have occurred since the 1980's. The susceptibility of vegetation has supported recent outbreaks; for example in many landscapes there was a widespread homogeneity of mature lodgepole pine available to support mountain pine beetle. Human actions such as fire suppression, logging practices, and land development in conjunction with succession influence vegetation which in turn impacts insects and diseases.

Figure 15 displays the NRV condition of average acres infested per decade compared to the most recent decade for which data is readily available: 2005-2015, using Aerial Detection Survey (ADS) data. Previous decades are not shown because electronic data prior to 2000 is not readily available. This shows that mountain pine beetle and western spruce budworm were well above the NRV for that period, while Douglas-fir beetle was at the lower end of its NRV. Root disease is not well captured by the available data sources, but it appears that the presence of root disease is likely within the NRV range. Insect events are expected to be cyclic in nature, and the wide NRV indicates periods with little to no activity as well as active periods.

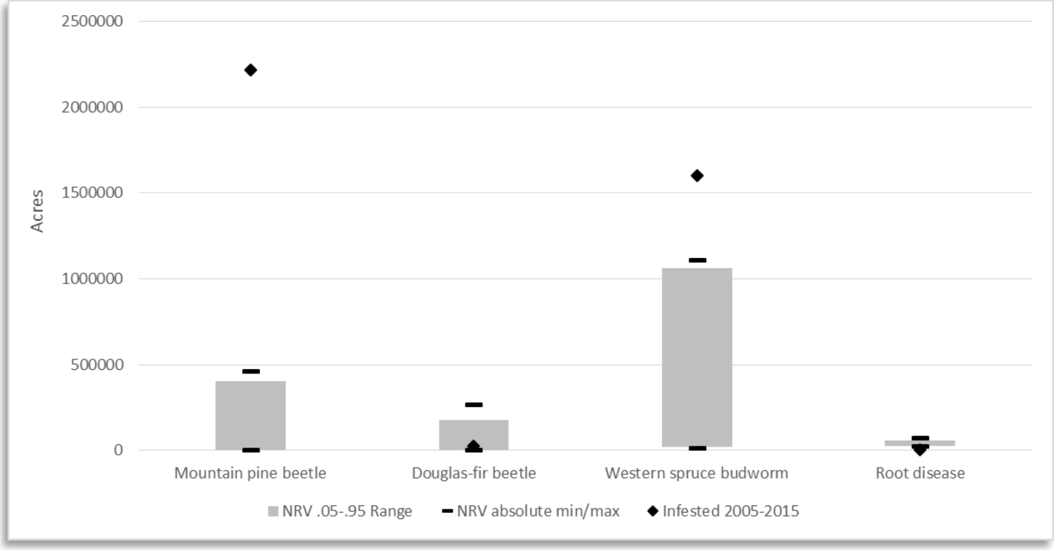


Figure 15. NRV acres impacted by insects and disease per decade compared to 2005-2015 forestwide

The large mountain pine beetle outbreak that occurred recently followed a period of little insect activity for many decades. Conversely, western spruce budworm events have been chronic episodes often correlated with warm and dry conditions. The span of recent available electronic data is limited to 2000-2015. As shown in the figures below, over this timespan mountain pine beetle activity exceeded the absolute maximum of the NRV range, indicating that this outbreak was unprecedented in the historical condition. Douglas-fir beetle has been at the low end of the NRV range since 2000. Western spruce budworm has shown a cyclic pattern within its NRV range.

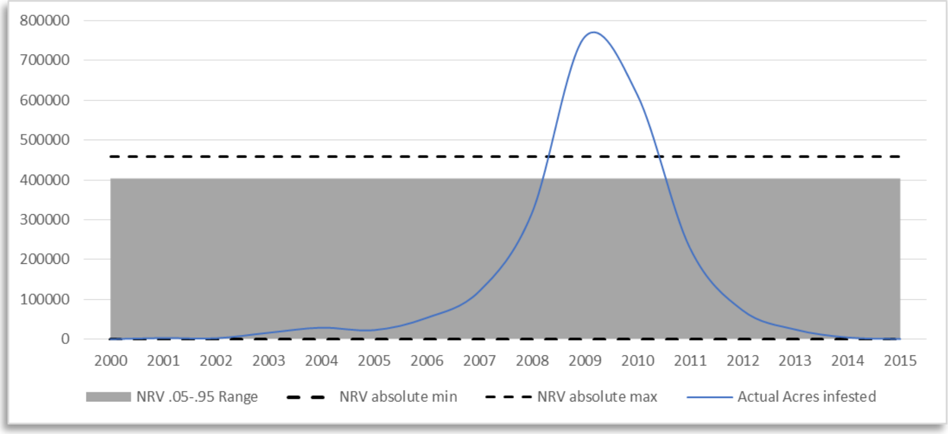


Figure 16. NRV acres infested/decade by mountain pine beetle compared to acres 2000-2015 forestwide

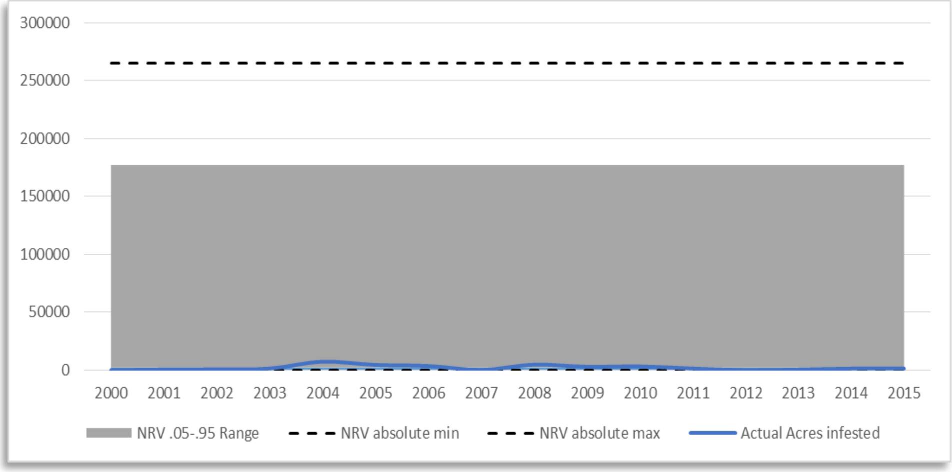


Figure 17. NRV acres infested/decade by Douglas-fir beetle compared to acres 2000-2015 forestwide

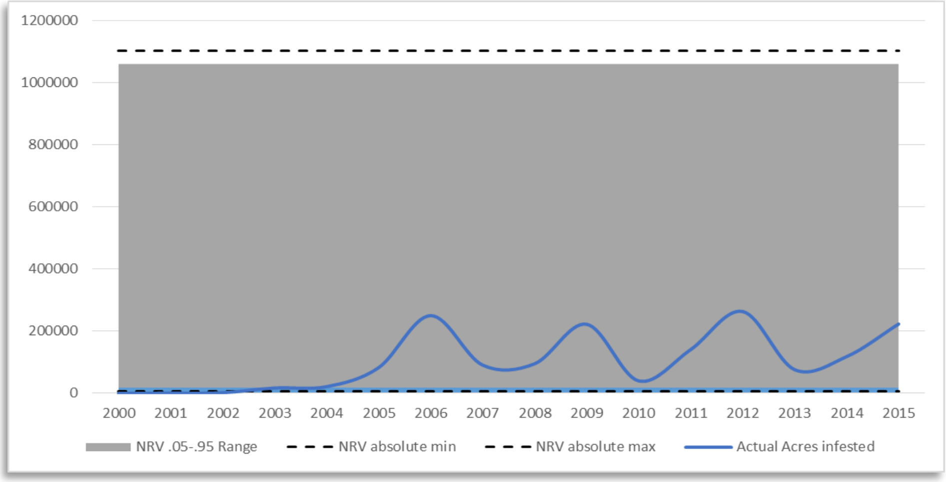


Figure 18. NRV acres infested/decade by spruce budworm compared to acres 2000-2015 forestwide

Severe bark beetle activity was at the high end of the NRV range during warm and dry periods. Many studies have found that increased warm and dry conditions in the future may promote or exacerbate native pest infestations; however, specifically in the case of mountain pine beetle, there are both positive and negative effects of a warming climate on population growth through phenological synchrony and generation timing (Halofsky et al. 2018a). It is likely that the future will bring insect activity at the upper end or above the NRV.

Composition

To represent vegetation composition on the HLC NF, two key ecosystem characteristics have been identified: 1) cover type (forested and non-forested types); and 2) the distribution of individual tree species on the landscape.

Cover Type

Cover types are groups of existing dominant vegetation (Milburn et al. 2015). Unlike PVT, cover type shifts through time on a site based on successional processes and disturbances. Without disturbance, forested cover types generally transition from early successional, shade intolerant species to late successional, shade tolerant species. Disturbances may intervene at any point in the successional trajectory to alter composition and structure. Appendix D of the 2020 Forest Plan describes the cover types found on the HLC NF. Nonforested cover types are not currently classified for Region 1; therefore, all nonforested cover types are grouped together for the model outputs. While the available FIA data includes estimates for sparsely vegetated areas, the SIMPPLLE model considers these to be non-vegetated, so they are excluded from the comparisons.

The way that cover types are classified in SIMPPLLE differs from the R1 Classification System. In the R1 Classification System, cover types are depicted by groupings of dominance types, which are based on the plurality of the most common species (Milburn et al. 2015, Barber et al. 2011). Conversely, SIMPPLLE tracks species based on a label that lists the common species, but does not indicate relative abundance. For example, a label of “DF-LP” does not indicate whether Douglas-fir or lodgepole pine is dominant. To build a crosswalk for cover type, logic was developed based on the relationships between SIMPPLLE species labels and the dominance types in VMap. For example, if “DF-LP” SIMPPLLE pixels were most commonly correlated with a Douglas-fir dominance type in VMap, then this label was cross-walked to a Douglas-fir cover type.

A critical limitation of this method occurs for species that were more prevalent in the NRV than the existing condition. For example, a label of “WB-AF” most commonly correlates to a spruce/fir type in today’s VMap. However, historically the abundance could have been heavier to whitebark pine, and perhaps would have been a whitebark pine cover type. There is no way in SIMPPLLE to know which species in the mix was more dominant. For this reason, results must be placed into context with the knowledge that the NRV may depict many whitebark pine cover types as spruce fir; and similarly aspen may be masked in many other cover types.

Cover type forestwide and by broad potential vegetation type

As shown in Figure 19, the NRV analysis at the forestwide scale indicates that the ponderosa pine and spruce/fir cover types are below the NRV range of abundance on the landscape, while the mixed mesic conifer type (Douglas-fir) and lodgepole pine types are higher. Ponderosa pine may be less abundant due to fire exclusion and type conversion to Douglas-fir, a well-established trend in the West over the last century. Conversely, the spruce fir type may be less abundant due to recent large-scale fires that have not yet recovered, or regenerated to a more fire-adapted early seral species such as lodgepole pine. In other areas, fire exclusion may have promoted spruce/fir, but warming and drying conditions along with increased fire activity are ameliorating this trend when summarized at the forestwide scale.

While aspen and whitebark pine appear to be similar or even slightly above their NRV, most likely these types are actually at or below the NRV given the limitations in the modeling, and literature sources that indicate these types are less abundant than they were historically ((Tomback 2007, Shepperd, Bartos and Mata 2001). The analysis also indicates that nonforested types are more abundant than they were historically; however, this is most likely reflecting areas that have recently burned and have not yet reforested, as opposed to natural meadows and parks. Many studies applicable to the HLC NF indicate that tree encroachment has reduced the extent and health of true nonforested cover types as compared to the historic condition (Means 2011, Heyerdahl et al. 2006).

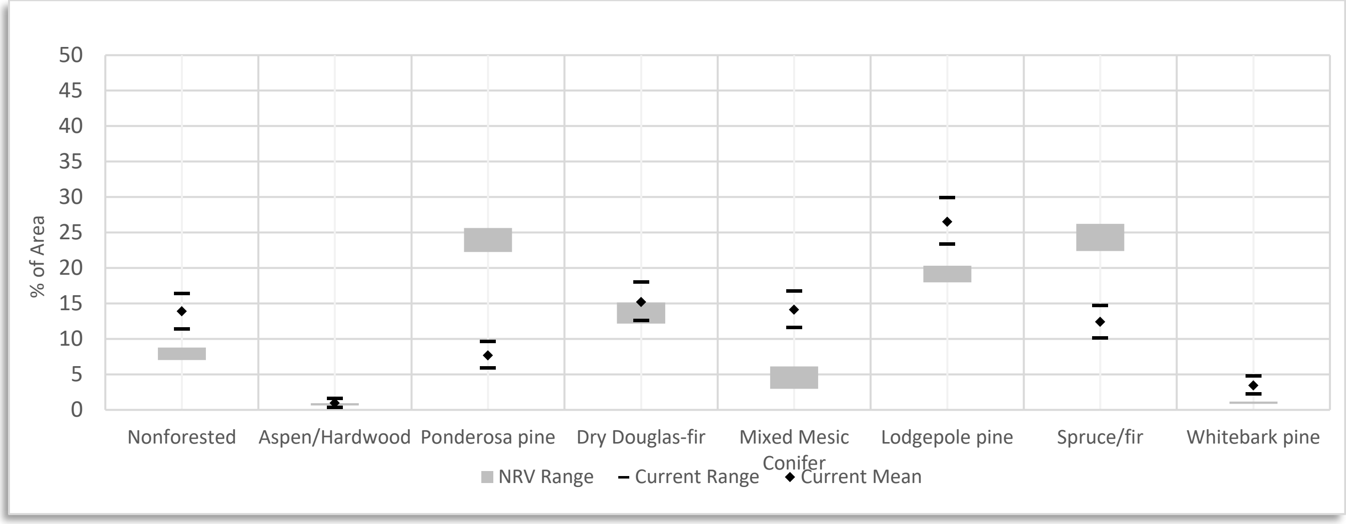


Figure 19. NRV range of cover types compared to existing condition, HLC NF forestwide

The most substantial shifts from the NRV to the existing condition of cover types occurred in the warm dry PVT (Figure 20), where the reduction in the ponderosa pine cover type occurred in favor of mixed mesic conifer (Douglas-fir dominated) and lodgepole pine. Other cover types such as spruce/fir and aspen occurred to a small extent where moisture was less limiting. Warm dry PVTs also support savanna areas on the hottest, driest sites where tree cover is 5-10% canopy cover. These areas are nonforested (dominated by grasses and shrubs), but would have supported widely scattered conifers. Savannas blended into transitional ecotones of true grass and shrublands which may be more prevalent in the future given expected climate and disturbance regimes. While the analysis estimated that the current abundance of nonforested types is higher than the NRV, this is in part due to recent fires, and varies by GA.

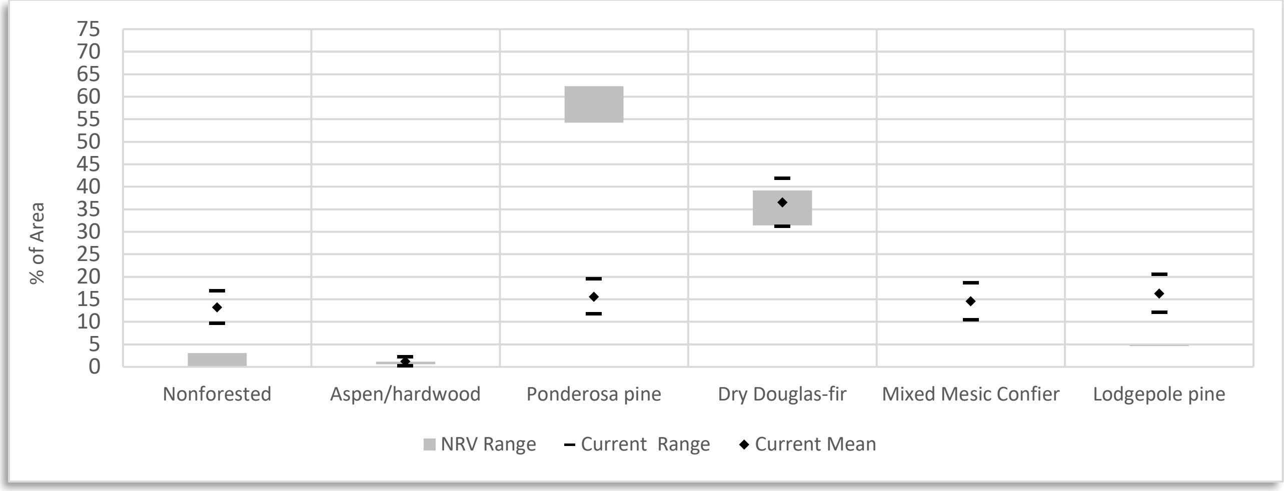
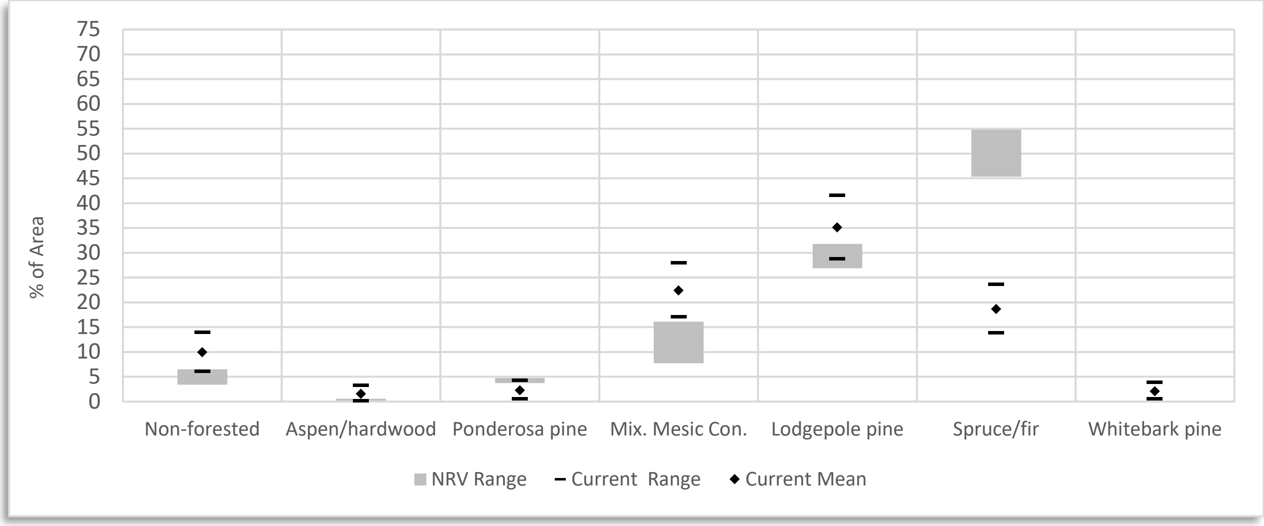


Figure 20. Warm dry potential vegetation type NRV range of cover type compared to existing condition

As shown in Figure 21, in the cool moist PVT the spruce/fir cover type may be less abundant than it was historically, for the reasons described at the forestwide scale. The mixed mesic conifer (Douglas-fir) type and to a lesser extent lodgepole pine may be overrepresented.



Western larch cover type excluded because the NRV and existing estimate are negligible at the forestwide scale.

Figure 21. Cool moist potential vegetation type NRV range of cover type compared to existing condition

In the cold PVT (Figure 22), modeling suggests that the spruce/fir cover type is below the NRV, but likely that includes some whitebark pine cover types. If more accurate labeling were possible, results would likely show a lower NRV range for spruce fir and higher range for whitebark pine. The spruce/fir type may dominate in more productive areas such as moist aspects, swales, moist basins, and riparian areas.

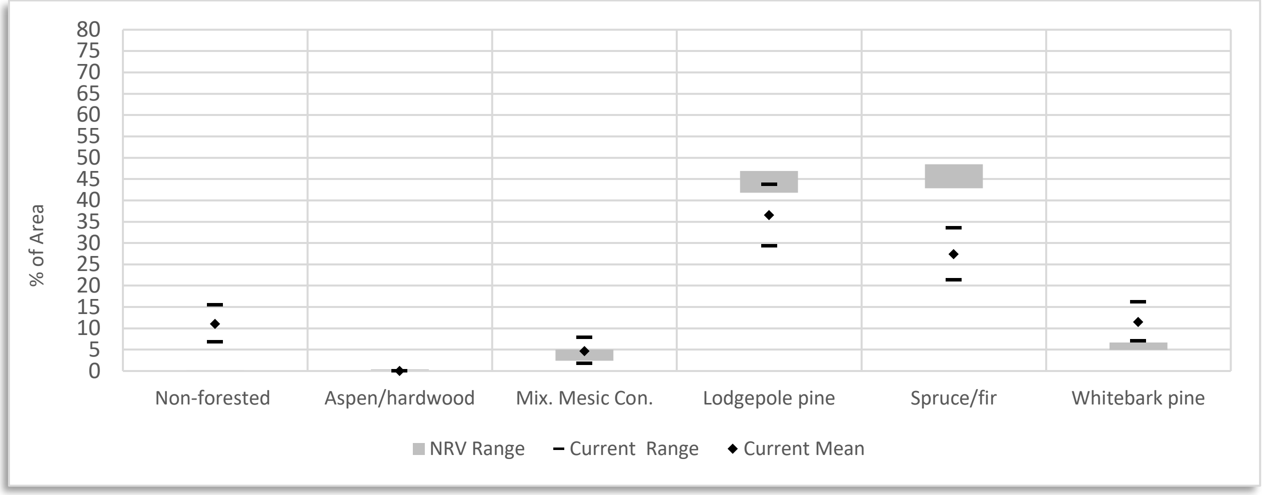


Figure 22. Cold potential vegetation type NRV range of cover type compared to existing condition

At the broad scale, exclusion of fire has resulted in a higher proportion of shade tolerant species at the expense of shade-intolerants. This is most evident in types where high frequency, low severity fires would have been common, such as the warm dry PVT. Low elevation, dry forests have experienced perhaps the greatest magnitude of change in composition, structure and function because of fire suppression, forest management, and climate change (Hessburg and Agee 2003, Hessburg et al. 2005, Westerling et al. 2006). Still, even cover types adapted to long fire return intervals and stand-replacing severities such as lodgepole pine have changed in some areas because these forests also burned in low-to mixed-severity events historically which created variable age structures and patterns (Kashian et al. 2005, Hardy, Keane and Stewart 2000).

In the modeling, the aspen/hardwood, dry Douglas-fir, mixed mesic conifer, whitebark pine, and nonforested cover types tended to be at the higher end of their NRV abundance during warm/dry periods. These cover types are promoted by fire and/or are tolerant of dry conditions. The ponderosa pine cover type tended to peak just before warm/dry periods, and decline during the warm dry period. Although this type (which consists of ponderosa pine and/or limber pine) is one of the most adapted to tolerating drought, this decline may be due to fire and the expansion of nonforested types at the lower margins of where trees grow. Future warm and dry climate conditions will likely be conducive to increasing the abundance of ponderosa pine and nonforested cover types. In general, more fire on the landscape will also be conducive to promoting aspen and whitebark pine, but these species may also be limited by moisture. The potential to increase whitebark pine is particularly uncertain due to contributing stressors such as the exotic disease white pine blister rust.

Spruce/fir generally declines or is at the lower end of its range during warm and dry climate periods, as it is less adapted to drought and fire; therefore, in the face of future warm and dry climates, it is uncertain if it is feasible that this type will fully return to the historic condition. Rather, placing an importance on this habitat where it can thrive, and especially where it meets other ecosystem needs such as providing lynx habitat, will be an important management consideration. Lodgepole pine does not show a tight relationship to climate trend, but is expected to continue to thrive under future fire regimes provided that sites retain enough seed and moisture.

Cover type by geographic area

The existing and NRV proportions of cover types vary across the GAs, driven by fixed factors such as the array of PVTs, topographical isolation, and dynamic processes such as disturbances and human uses.

Nonforested cover types

Nonforested cover types include grass, shrub, and riparian grasses/shrubs, and open savannas; but may also include recently disturbed forest types that have not yet reforested. The forestwide averages indicated that generally the abundance of nonforested cover types is above the NRV. However, this may be due to the inclusion of recovering forested sites in the estimate of the existing condition. Further, the NRV ranges span across cool/moist, normal, and warm/dry climate periods that occurred in the past. Because these types showed a correlation of increasing during warm and dry periods, if only such periods were considered in the average it is likely that the existing condition would be at the low end or below the NRV.

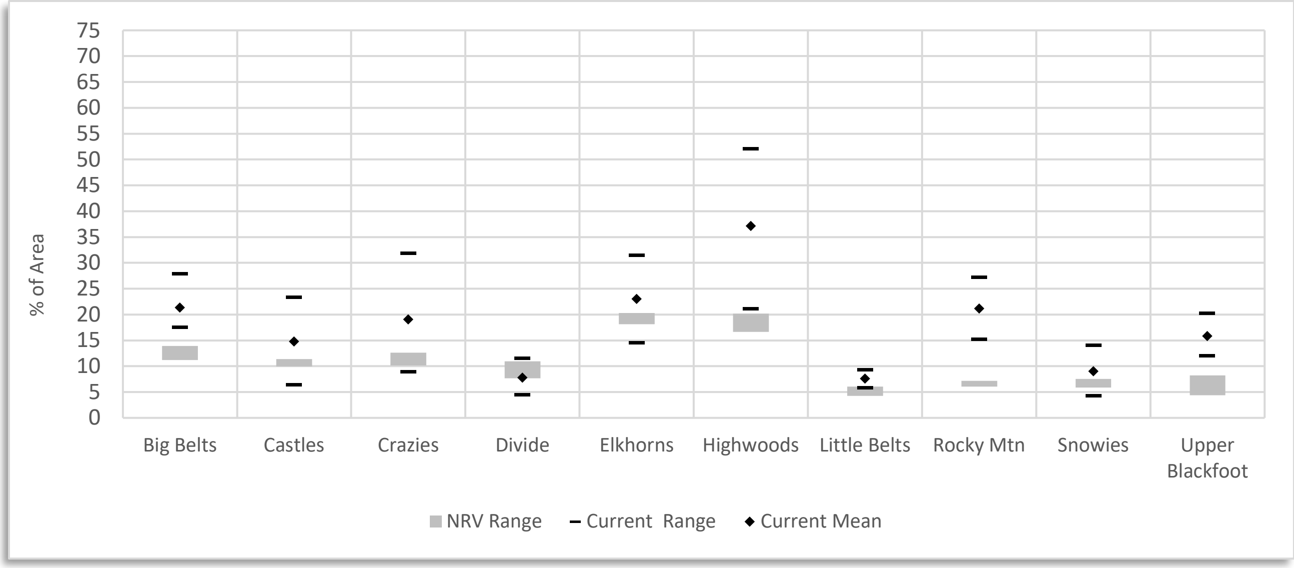


Figure 23. NRV range of nonforested cover types compared to existing condition, by GA

Nonforested PVTs have experienced shifts in specific species composition and structure but are poorly represented in available data sources. Multiple literature sources indicate that nonforested vegetation cover types have declined relative to the historical condition. As described in the Assessment, in the HLC NF plan area there have been declines in acres of fescue, bunchgrass, sagebrush, and native forb cover types, largely attributable to agricultural development but also encroachment of woodland types such as juniper and exotic weed species. One of the key changes that has occurred in the west includes a reduction in native grasslands and shrublands, and an expansion of dry forests and woodlands; grazing and associated reduction in fire frequency (due to the loss of fine fuels) are the primary causes of woodland expansion although climate change and increased atmospheric carbon dioxide are also suggested as contributing factors (Hessburg and Agee 2003). Fire exclusion and drought has allowed conifers and/or sagebrush to invade grasslands, and altered the mosaic of conifer savannah and sagebrush steppe (Barrett et al. 1997, Heyerdahl et al. 2006).

In addition to the abundance of nonforested vegetation cover types, the condition and health of these types has been altered. There is no means to model the potential shift in composition or structure of these types. However, activities such as livestock grazing have likely altered vegetation, especially riparian areas. Also, the introduction of invasive plants has substantially altered some plant communities. Finally, the expansion of conifers into grass and shrublands has occurred as a result of factors such as climate, grazing and fire exclusion. For the most part, if trees are present a site it would be classified as a warm dry forested PVT. Areas in this type that are considered nonforested (less than 10% tree cover) may include open savannas as well as grass/shrub communities perpetuated by fire. Increased conifer expansion in some of these areas is often considered to be undesirable, although the NRV indicates that trees did encroach into nonforested PVTs during cool and moist climate periods.

Aspen/hardwood cover type

The existing condition of the aspen cover type is similar to the modeled NRV in all GAs; however, other literature sources indicate that aspen was likely more prevalent historically (Shepperd et al. 2001, Bartos 2001). Aspen is prevalent in the Highwoods to the greatest extent, as compared to the other GAs; but in all cases, it represents a small proportion of the landscape. It is expected that aspen/hardwood will be promoted with future warm, dry climate conditions, to occur at the high end of the NRV or possibly above. These types showed a correlation of increasing during warm and dry periods. Further, because the aspen cover type may be underrepresented in the NRV species classification, it is likely the NRV range could be slightly higher than shown in Figure 24.

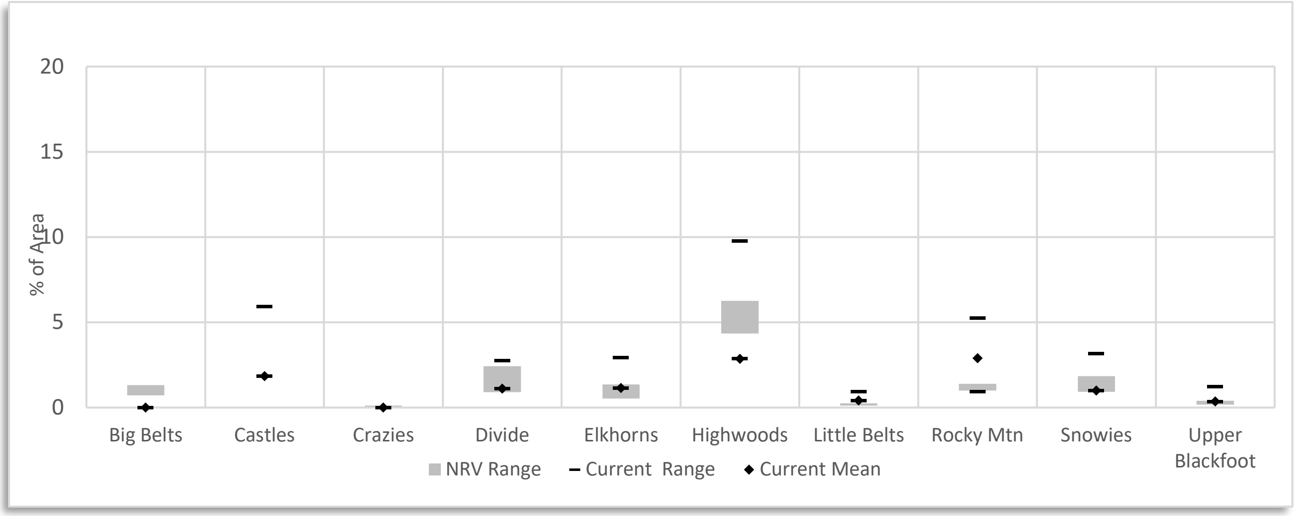


Figure 24. NRV range of the aspen/hardwood cover type compared to existing condition, by GA

Ponderosa pine cover type

The ponderosa cover type is below the NRV for abundance across all GAs except for the Snowies. This type may be promoted with future drought on many sites where it will out-compete Douglas-fir, but conversely may retract on the driest sites where fire and moisture limitations promote nonforested cover types. Therefore, the future may bring an overall increase in many GAs but likely not to fully achieve the NRV ranges. The highest potential to increase or maintain the ponderosa pine cover type can be found in the Big Belts, Little Belts, and Snowies. Some GAs such as the Castles, Crazies, Highwoods and Rocky Mountain Range have a very low to no existing ponderosa pine (and therefore, little seed source), and the species could only be promoted through management interventions such as planting. The Divide, Elkhorns, and Upper Blackfoot GAs have little of this cover type proportionately across the GA, but do have fairly extensive areas with at a ponderosa pine component present on portions of their area and therefore have important opportunities to increase the ponderosa pine cover type.

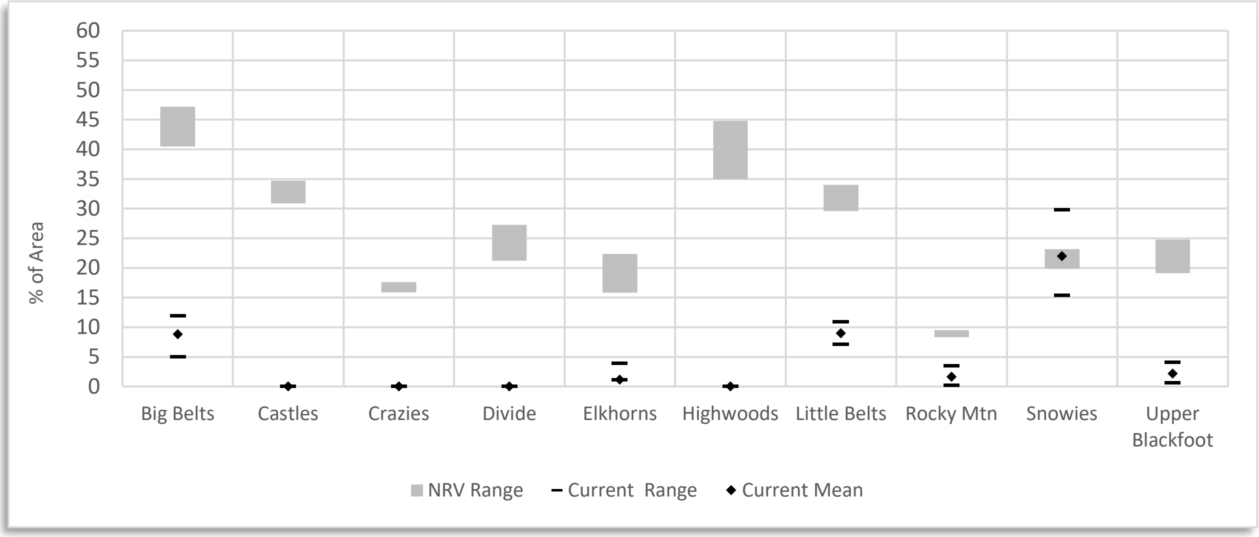


Figure 25. NRV range of the ponderosa pine cover type compared to existing condition, by GA

Dry Douglas-fir and mixed mesic conifer cover types

The dry Douglas-fir and mixed mesic conifer types are dominated by Douglas-fir. The forestwide averages indicate that the mixed mesic conifer type is above the NRV range for abundance, and the dry Douglas-fir type is similar to NRV. By GA, the results for dry Douglas-fir showed a variety of trends (Figure 26). Douglas-fir can function as the most shade intolerant species that dominates on dry sites in areas where ponderosa pine distribution is limited. However, it can also function as a shade tolerant that dominates over ponderosa pine in the absence of disturbance and can encroach into savanna and nonforested plant communities.

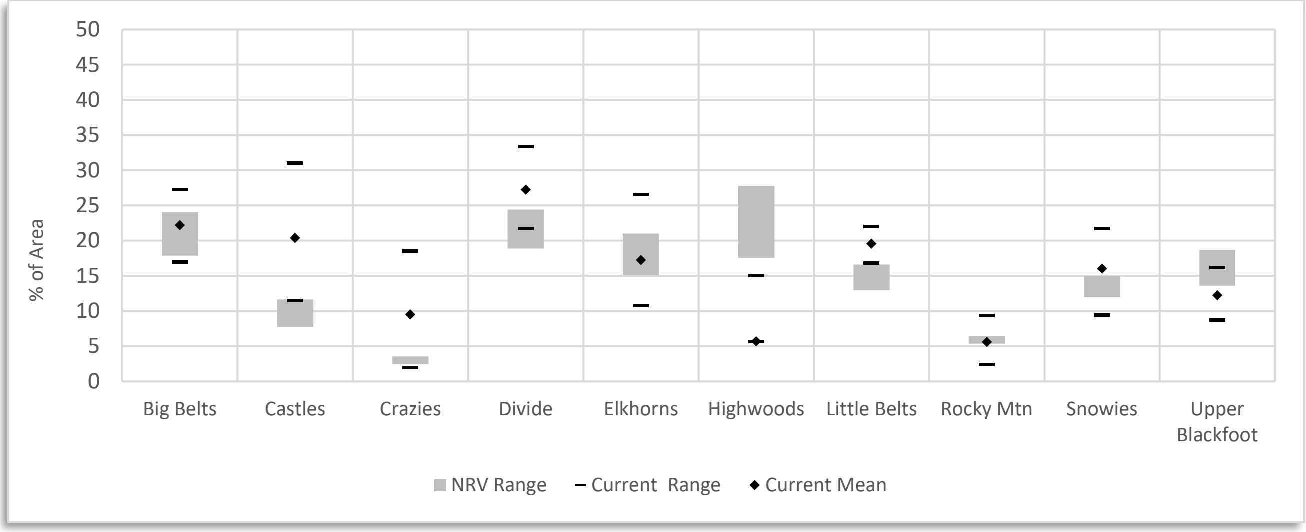


Figure 26. NRV range of the dry Douglas-fir cover type compared to existing condition, by GA

The mixed mesic conifer type was generally above the NRV for all GAs except the Rocky Mountain Range. It is expected that these types will be promoted with future drought on more moist sites where Douglas-fir functions as a shade intolerant species and tolerates drought better than lodgepole pine, spruce, or subalpine fir, but conversely may retract on the driest sites where ponderosa pine can better withstand drought.

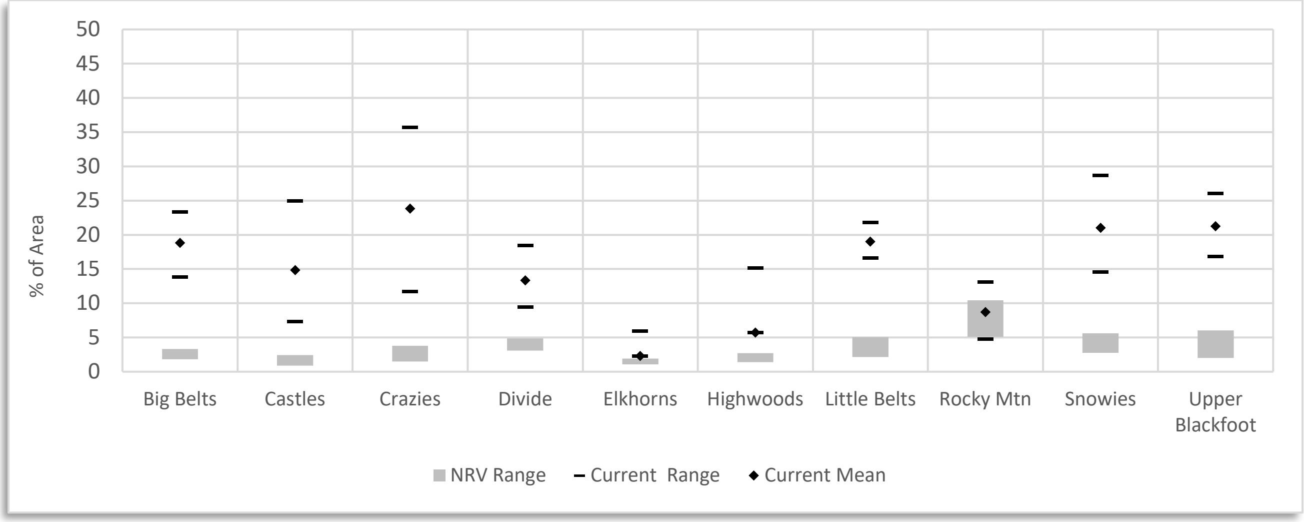


Figure 27. NRV range of the mixed mesic conifer cover type compared to existing condition, by GA

Western larch mixed conifer cover type

The western larch mixed conifer cover type would only potentially occur on the Upper Blackfoot GA, where it is at the farthest east end of its natural distribution range. Because so few individuals are present, they are not well represented with broad scale grid data or remotely sensed mapping, and places where it is a dominant component are very minor. The existing condition shows only a trace (0.1%) of this cover type occurring in the Upper Blackfoot, and the NRV does not extend beyond that amount, although more widespread individual or minor components of this species are known to occur. Given its low water-use efficiency, this species may be expected to be limited to low energy aspects in future warm, dry conditions. However, it would be an important aspect of biodiversity on cooler sites, including areas where cold temperatures might have limited it in the past.

Lodgepole pine cover type

The forestwide averages indicate that this type is generally slightly above or similar to the NRV depending on the broad PVT. Figure 28 shows that this trend varies by GA. In particular, in the Crazies and Snowies GA the lodgepole pine cover type is below the NRV, whereas the Divide, Highwoods, and Little Belts appear to be above. All other GAs are similar to the NRV. Although not particularly drought tolerant, it is expected that future climates may promote this species on moist, high elevation sites where fire disturbance promotes it over shade tolerant species such as spruce and fir, but conversely retract from drier sites where Douglas-fir is more drought tolerant. Therefore, the future may bring slight shifts or maintenance within the NRV ranges depending on the other species present.

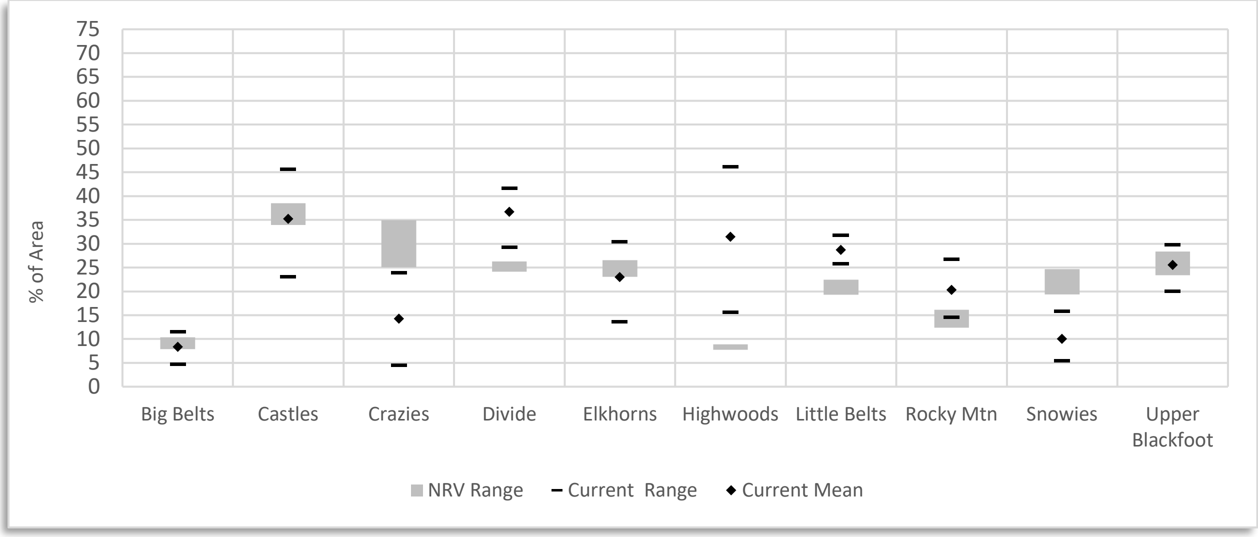


Figure 28. NRV range of the lodgepole pine cover type compared to existing condition, by GA

Spruce/fir cover type

The forestwide averages indicate that spruce/fir is below the NRV, whereas the whitebark type is similar to or above the NRV. By GA, spruce/fir is below the NRV in several large GAs (Rocky Mountain Range, Little Belts, and Upper Blackfoot), but similar to the NRV in all other GAs. This supports the conclusion discussed in the forestwide section, in that recent large fires have played a large role in reducing spruce/fir, as such disturbances have been occurring particularly in the Rocky Mountain Range and Upper Blackfoot. Therefore, retaining healthy spruce/fir in those GAs may be more important than in the other GAs.

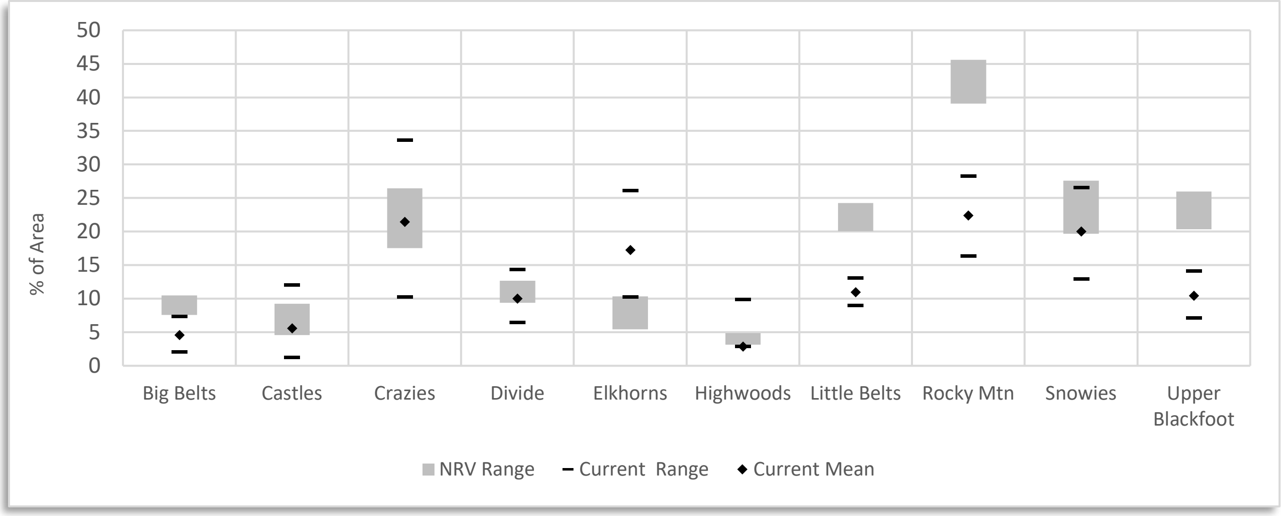


Figure 29. NRV range of the spruce/fir cover type compared to existing condition, by GA

Whitebark pine cover type

The whitebark pine trend is similar for all GAs. As discussed in the forestwide section, it is most likely that the whitebark pine cover type is below NRV. The results for individual tree species in the next section provides more context for subalpine fir, Engelmann spruce, and whitebark pine. It is expected that future climates and disturbances may promote the whitebark pine cover type on the coldest, driest sites where it is more hardy than other species, but its success will also depend on the exotic disease white pine blister rust and restoration efforts.

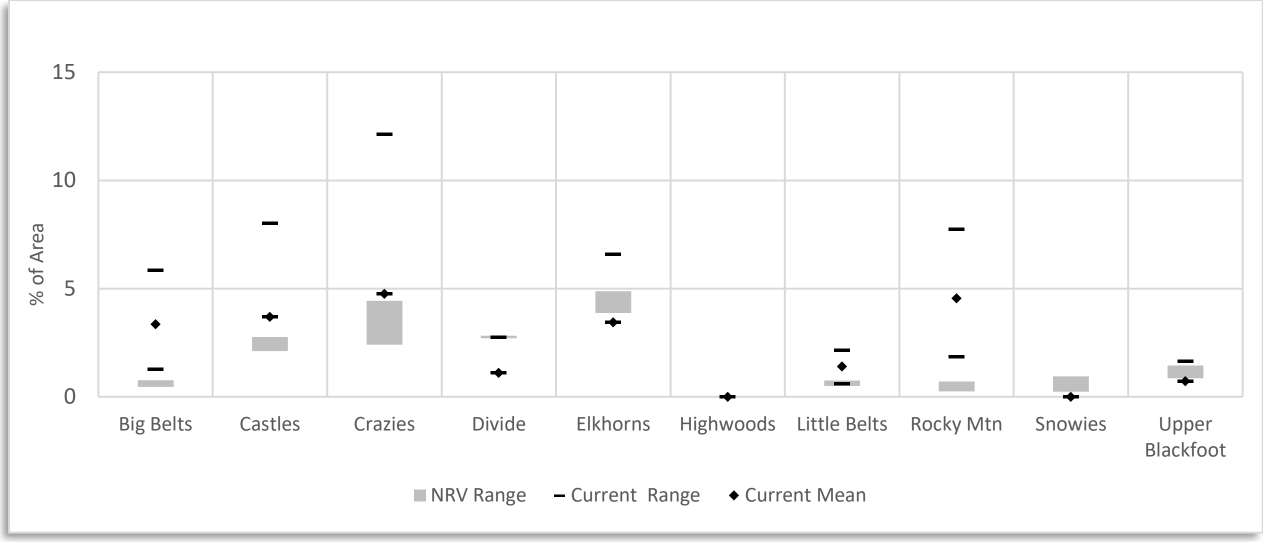


Figure 30. NRV range of the whitebark pine cover type compared to existing condition, by GA

Tree species distribution

In addition to cover type, which is a grouping based on the most dominant species, it is useful to understand the extent and distribution of individual tree species. The distribution of each species is estimated by the percentage of the area that contains at least one live tree per acre. This provide a more detailed assessment of species diversity. Individual tree species can occur in multiple PVTs and cover types. Some species are of particular management interest. For example, whitebark pine is a candidate species for listing under the Endangered Species

Act. Other species are commonly a focus of interest due to their condition, threats, wildlife habitat values, and/or public interest, including aspen, ponderosa pine, limber pine, western larch, and Rocky Mountain juniper.

The modeling cautions described for the cover types do not apply to this attribute. The presence of a species is noted in SIMPPLLE based on whether it is a component of the species label; no cross-walking was needed to relate to the presence of a species noted in the existing condition data. However, it is possible that the species presence in SIMPPLLE does not capture minor or rare species on a site, since the labels only capture the most common 1 to 4 species present. This attribute only reflects whether a species is present or not and does not indicate its condition or abundance; a pixel with 1 tree present of a given species would be counted the same as a pixel with 1,000 trees present of the species. Therefore, important distinctions in structure and condition between the NRV and existing condition cannot be inferred with this attribute alone. Because multiple species are often present on a site, the proportions of all species together add up to more than 100% of the landscape area.

Tree species distribution forestwide and by broad potential vegetation type

Figure 31 shows the NRV range of tree species distribution forestwide, compared to the existing condition. At this scale, the extent of most species are within or near the NRV. However, the extent of ponderosa pine is below the NRV, while the extent of lodgepole pine, Douglas-fir, and Engelmann spruce is above.

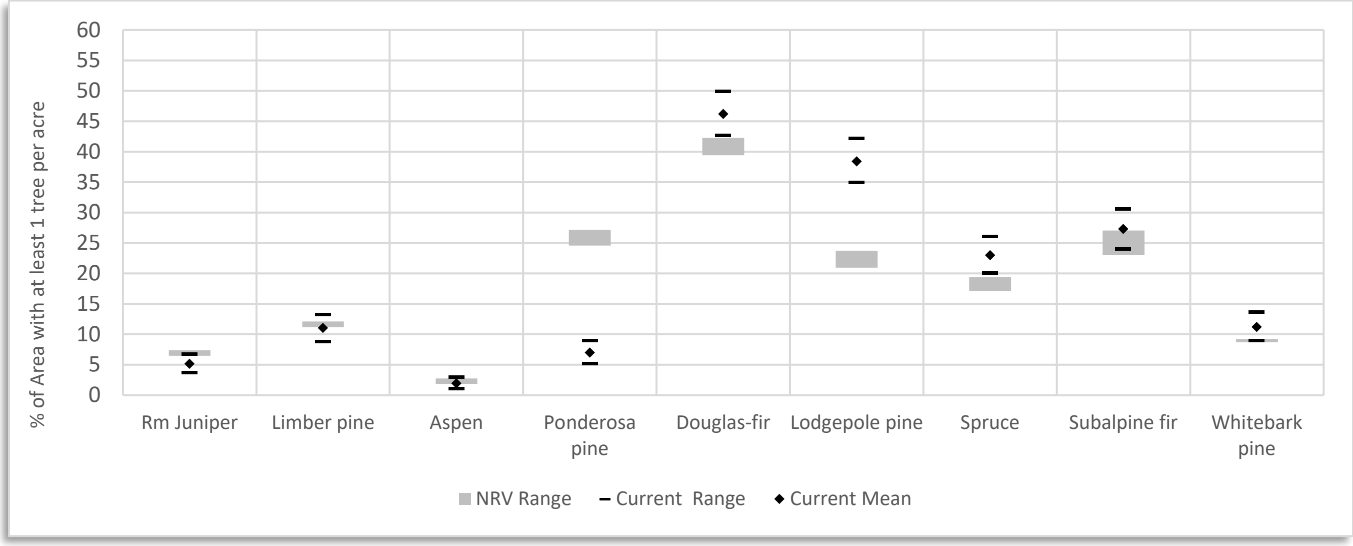


Figure 31. NRV range of the tree species distribution compared to existing condition, forestwide

In the warm dry PVT (Figure 32), the existing distribution of ponderosa pine is below the NRV, and lodgepole pine and Engelmann spruce are above the NRV. The extent of the other species are similar to the NRV. While the extent of Douglas-fir as an individual tree species is similar to the NRV, the previous section showed that the mixed mesic conifer cover type, which is dominated by Douglas-fir, is above the NRV. This may indicate that Douglas-fir as a component is naturally widespread, but should be the dominant species (cover type) on fewer areas than it is currently in this PVT.

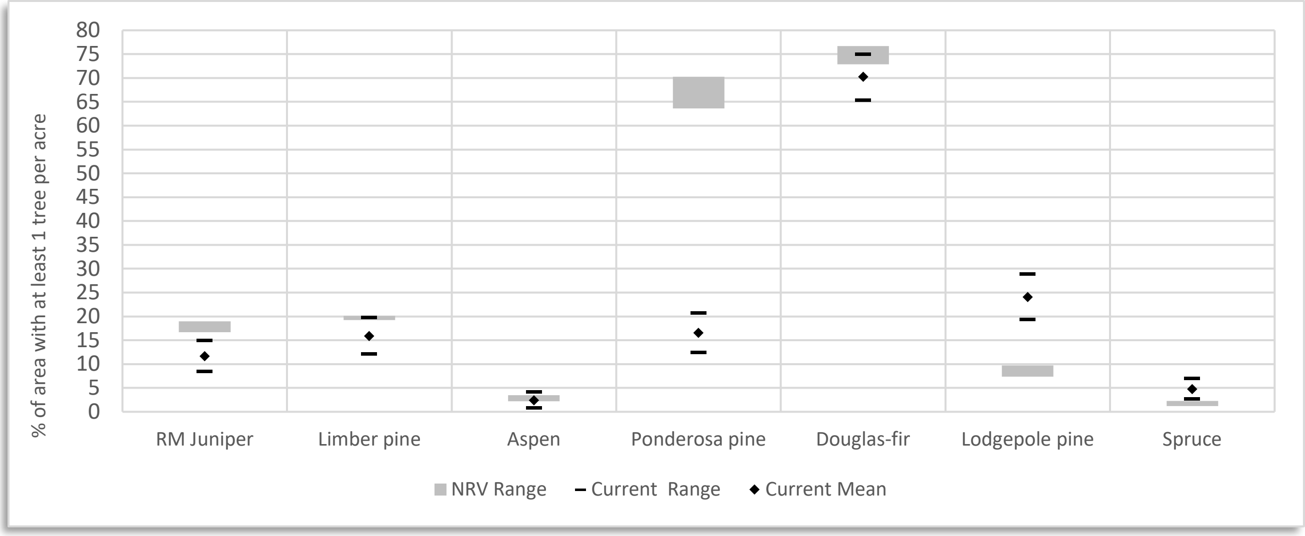


Figure 32. Warm dry PVT tree species distribution NRV compared to existing condition

In the cool moist PVT (Figure 33), distribution of Douglas-fir and lodgepole pine are currently above the NRV, while the other species are similar to the NRV. Engelmann spruce and whitebark pine also appear to be slightly above the NRV but the confidence interval of the estimates nearly overlaps the NRV range.

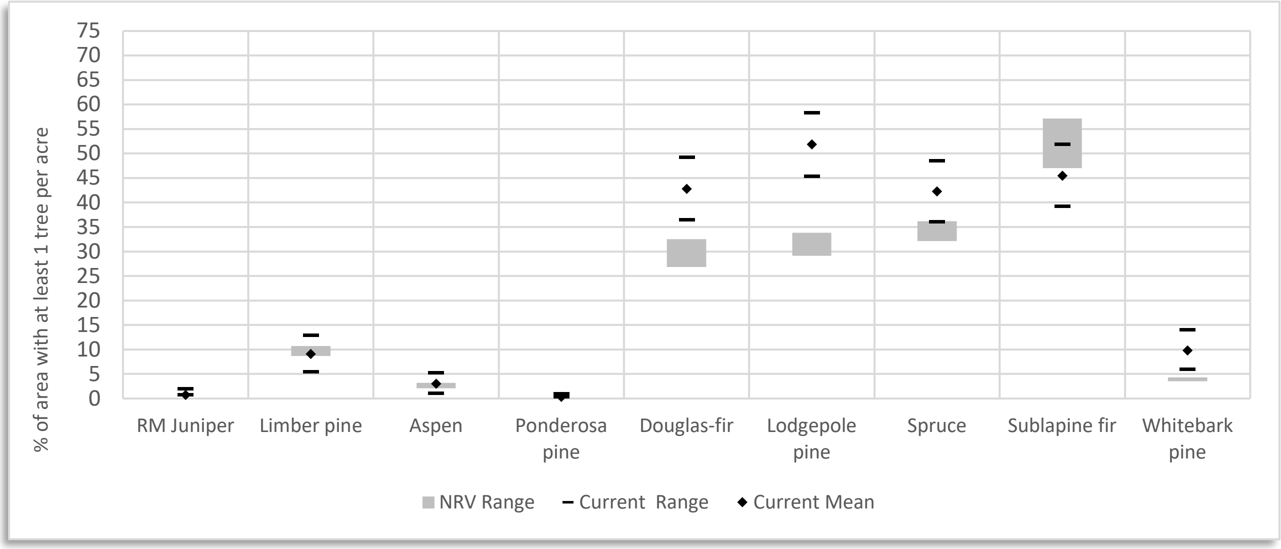


Figure 33. Cool moist PVT tree species distribution NRV compared to existing condition

In the cold PVT (Figure 34), most species are similar in extent to the NRV condition, except that whitebark pine is slightly below and subalpine fir slightly high, although in both cases the confidence interval of the existing condition estimate nearly overlaps with the NRV range.

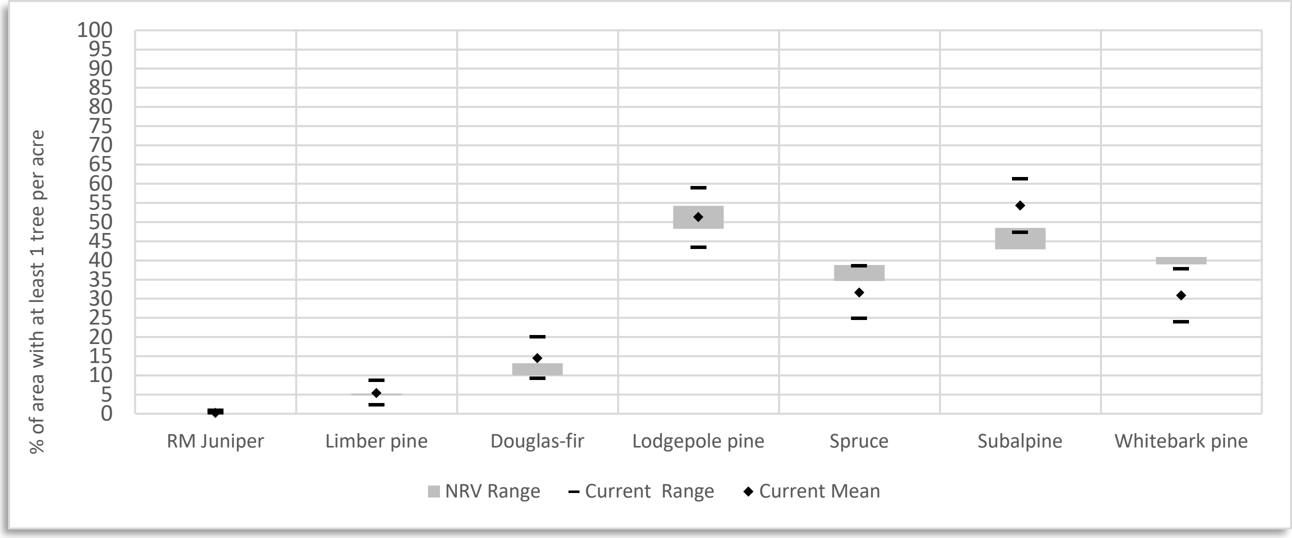


Figure 34. Cold PVT tree species distribution NRV compared to existing condition

The trend of these species according to climate condition in the past may help provide context for the future, which is expected to be warm and dry. In general, Douglas-fir declined during warm/dry periods. This differs from the trend for the dry Douglas-fir cover type, reflecting the relationship that while Douglas-fir may still dominate areas, it declines as a minor species where it may be outcompeted by species such as ponderosa pine. Rocky Mountain juniper and ponderosa pine also decline in warm dry periods; even though they are drought-hardy species, decreases may be due to increased fire that favors nonforested types. In warm dry PVTs, it is likely that ponderosa pine may thrive and outcompete Douglas-fir where moisture remains adequate and fires do not remove the seed source; but some sites may convert to a non-forested or savanna condition. Limber pine and aspen also tend to increase with warm/dry conditions in the past, likely due to increased fire.

At higher elevations, lodgepole pine generally increases during warm/dry periods, while both subalpine fir and Engelmann spruce decrease and become more confined to riparian areas and moist PVTs. Therefore, it is possible that lodgepole may remain above or at the high end of the NRV range in the future. Whitebark pine presence decreases during warm/dry periods, although the whitebark cover type (where it is dominant) increases – this may be because whitebark individuals spread into the cool moist PVTs during cool/moist climate periods, but retract during times of drought and become limited to the cold PVT.

Tree species distribution by geographic area

The existing and NRV distribution of species varies across the GAs, driven by similar factors as described for cover types. The species are addressed in order of where they occur along an elevational gradient.

Rocky Mountain juniper (*Juniperus scopulorum*)

Rocky Mountain juniper tends to become abundant in the later stages of succession in nonforested PVTs or the hottest, driest sites in the warm dry PVT. It is also widespread as a minor component in other forest areas. When dominant, it is considered part of the ponderosa pine cover type, which is below NRV for all scales of interest. As shown in Figure 35, juniper is present on a fairly small proportion of the landscape, and is most notably above NRV in the Big Belts GA. The modeling indicates that it is below the NRV in other GAs (Divide, Highwoods, Little Belts, and Upper Blackfoot), and similar to NRV in the remaining areas. Although it is an important component of the ecosystem, juniper expansion can lead to the decline of grass and shrublands and altered fire regimes. The NRV range includes cool/moist, normal, and warm/dry periods. Given that the species tends to decline during warm/dry periods, in favor of nonforested species promoted by fire, in the future it is likely most appropriate to expect it to occur at the low end of the NRV.

Although the modeling would suggest that the extent of Rocky Mountain juniper is similar to, and slightly less than, the NRV condition in many areas, other studies suggest that this species is likely more extensive than it was historically, invading grass and shrublands in the absence of natural fire regimes (Kitchen 2010). For this species, it is particularly important to reiterate what this attribute does, and does not, indicate. The tree species presence attribute does not indicate the structure or condition of the species on the landscape. The extent of juniper shown in the NRV modeling could include areas where there is only one tree present, whereas in those same areas there may be many more stems present in the existing condition. Therefore, while the overall species extent and distribution may be within the NRV, the density or condition of the species on those sites may not be.

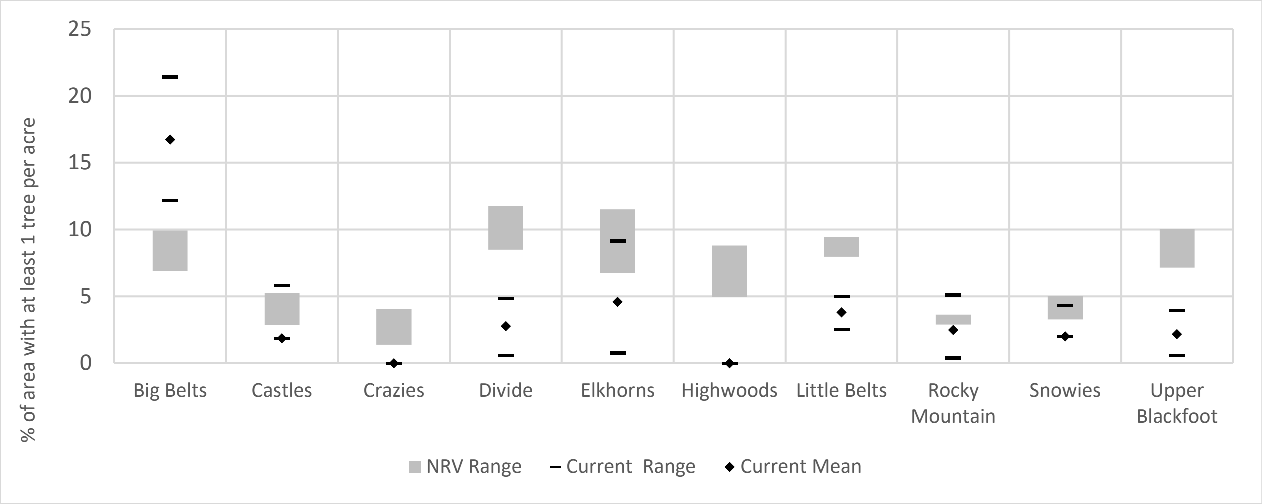


Figure 35. Rocky mountain juniper NRV distribution compared to existing condition, by GA

Limber pine (*Pinus flexilis*)

Limber pine is closely associated to limestone substrates and can occur across a wide range of elevations on the HLC NF. While at the forestwide scale the current abundance is generally within the NRV, it is slightly below the NRV for the warm dry PVT. By GA (Figure 36), it is generally at the low end or below NRV in most areas except for the Snowies and Little Belts, where it is above. The extent of this species is similar to the NRV range for the Rocky Mountain Range and Upper Blackfoot GAs. When this species is dominant, it is considered part of the ponderosa pine cover type, which is below NRV for all scales of interest. Because of the influence of multiple threats, including white pine blister rust and mountain pine beetle, as well as winter damage, drought, and competition from other conifers, the trend of limber pine appears to be a decline. The natural fire regime and the alteration thereof is an important influence on the abundance and health of limber pine. While it tended to increase during warm/dry modeling periods, some sources indicate that limber pine expanded in some areas due to fire exclusion, and may be less viable on the driest sites in drought conditions (Halofsky et al. 2018b).

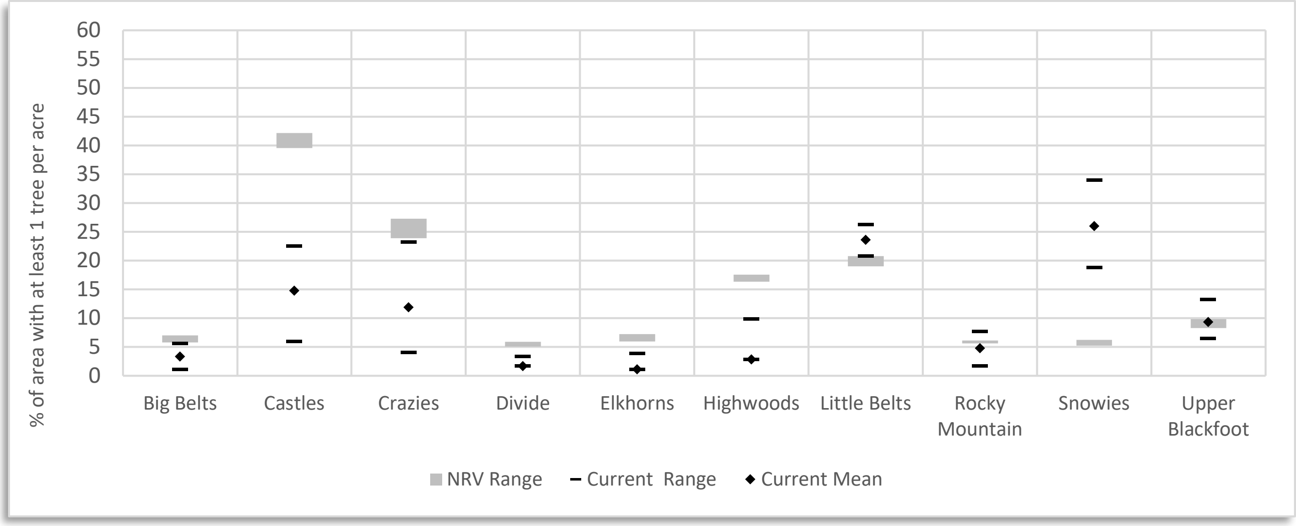


Figure 36. Limber pine NRV distribution compared to existing condition, by GA

Aspen (*Populus tremuloides*)

The modeling showed that at the forestwide scale, and in the warm dry and cool moist PVTs, aspen distribution is generally within its NRV. When this species is dominant, it is part of the aspen/hardwood cover type, which is also generally within the NRV at the forestwide scale. This trend holds true for most GAs (Figure 37), except that this species is below the NRV in the Big Belts and the Snowies. The modeling does not show substantial differences between the existing condition and NRV, in part due to the limitations in the available mapping and data for this species, which is often present in stringers along riparian zones or small upland patches. However, multiple literature sources indicate that aspen is less common than it was historically because of encroachment and overtopping by conifers, overgrazing by cattle and large native herbivores, and the absence of fire (Shepperd et al. 2001, Kaye, Binkley and Stohlgren 2005). Because aspen tended to increase during warm dry climate periods, it would be expected to be at the high end of its NRV in the future, in which case increases in this species would be desirable in most GAs, and may be promoted by fire.

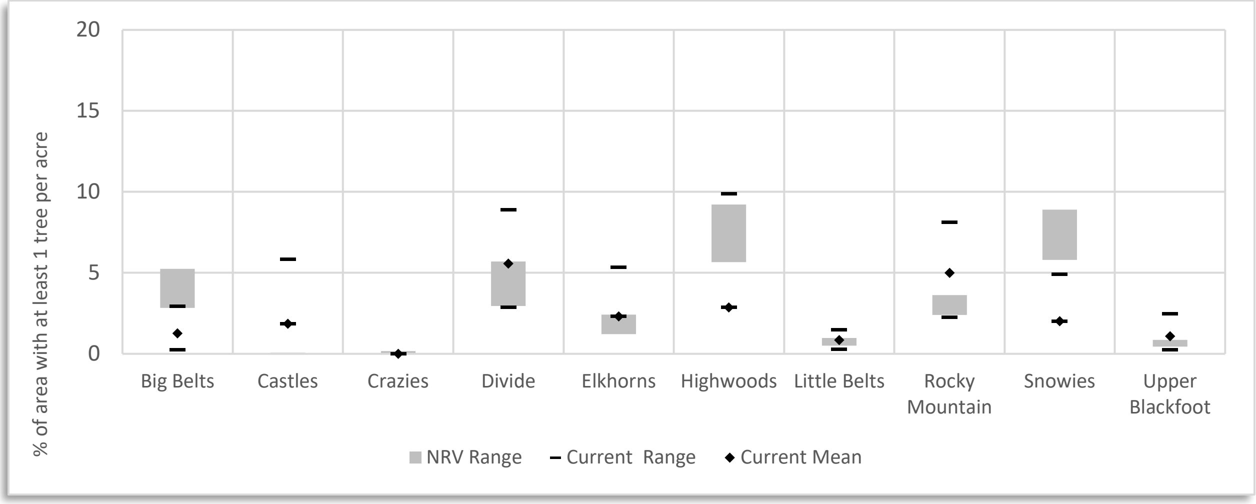


Figure 37. Aspen NRV distribution compared to existing condition, by GA

Cottonwood (*Populus trichocarpa*)

On the HLC NF, cottonwood is confined to riparian areas with fluctuating water tables and is more common on the low lying private lands outside of the Forest boundary. While present in limited areas, it is poorly represented in data sources and modeling, with both only showing trace amounts. This species has likely been reduced from historic conditions, but may suffer further in drought conditions (Halofsky et al. 2018b).

Ponderosa pine (*Pinus ponderosa*)

The modeling showed that ponderosa pine is well below the NRV range forestwide, specifically in the warm dry PVT. This trend holds true in all GAs (Figure 38), except for the Snowies, where ponderosa pine is prevalent on the Little Snowies mountain range. Ponderosa pine is the most heat and drought resistant conifer on the HLC NF and may be expected to increase in areas where it competes with Douglas-fir. Conversely, its establishment may be restricted on the driest habitat types, and it may not regenerate after stand replacing fires that remove the seed source. The distribution and structure of ponderosa pine has been affected by fire exclusion and mountain pine beetle. Fire exclusion has contributed to denser forests with greater competition for resources, higher stress and greater risk of insect attack and stand-replacing fire (Pollet and Omi 2002, Sala et al. 2005). Fire exclusion has allowed succession to promote Douglas-fir over ponderosa pine in some areas. In some GAs, such as the Highwoods, Crazies, and Rocky Mountain Range, this species is currently rare or not present.

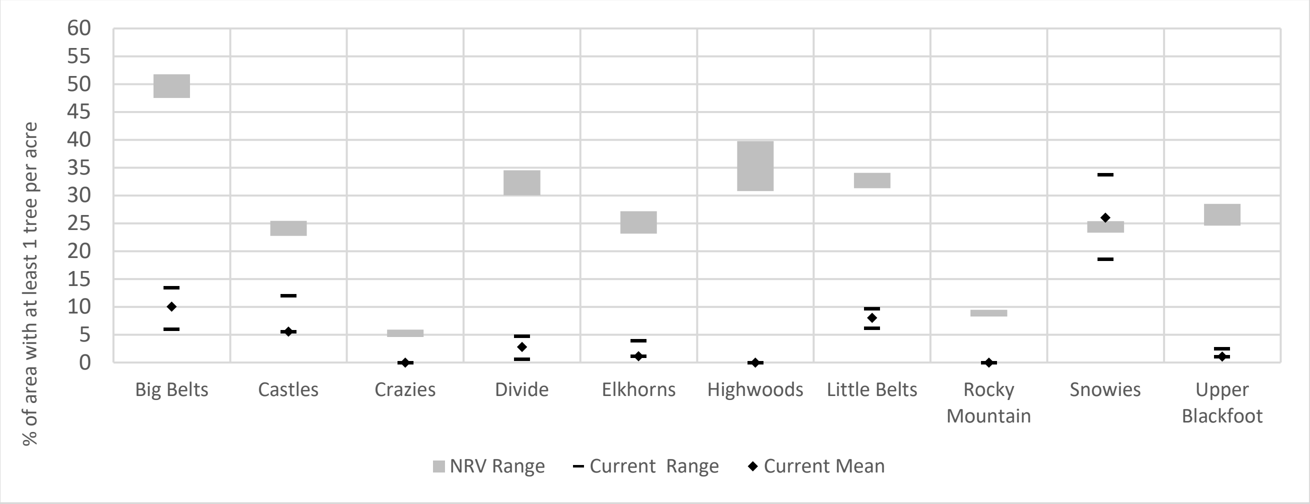


Figure 38. Ponderosa pine NRV distribution compared to existing condition, by GA

Douglas-fir (*Pseudotsuga menziesii*)

At the forestwide scale, Douglas-fir distribution is above the NRV, especially in the cool moist PVT. When it is dominant, Douglas-fir is part of either the dry Douglas-fir or mixed mesic conifer cover type, depending on the moisture regime; the latter is generally above the NRV condition especially in the warm dry PVT. Figure 39 shows that the Castles, Crazies, Little Belts, and Snowies GAs have existing distributions of Douglas-fir well above the NRV. However, other GAs are within the NRV, and the Highwoods and Big Belts are below the NRV. Douglas-fir was at the lowest end of its NRV range during warm and dry climate periods; therefore, in the future a presence at the low end of the NRV may be appropriate. Douglas-fir may have become more common than it was historically because fire exclusion has allowed the species to persist in places where frequent fire would promote more shade intolerant species, primarily ponderosa pine. However, on more mesic sites Douglas-fir functions as the most shade intolerant species and is relatively drought tolerant. Therefore, it may be desirable to promote this species over less drought-tolerant lodgepole pine in some areas. Douglas-fir is one of the primary tree species components on the HLC NF and is expected to remain a dominant component.

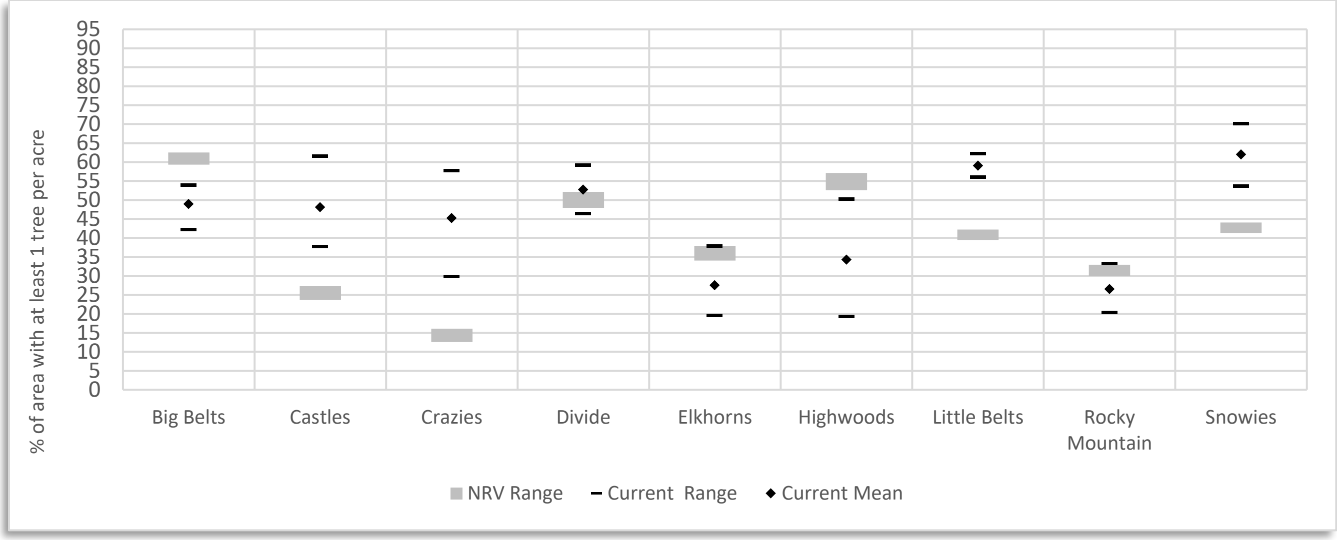


Figure 39. Douglas-fir NRV distribution compared to existing condition, by GA

Western larch (*Larix occidentalis*)

Western larch is, and historically was, only found in the Upper Blackfoot GA (at the far eastern edge of its natural range), primarily in the cool moist PVT. It is likely less abundant than it was historically primarily due to fire exclusion. As with cover type, the data available for larch is not compelling, with the NRV showing only up to 0.1% presence and the existing condition ranging from 1.1-2.1%. Western larch is particularly vulnerable to potential future warming, limiting it to higher elevations and moist sites.

Lodgepole pine (*Pinus contorta*)

Lodgepole pine is a major component of most landscapes, dominating cool moist sites but maintaining a presence in all PVTs. At the forestwide scale and in all PVTs except cold, the distribution of this species is above NRV. When it is dominant, it constitutes the lodgepole pine cover type, which is generally above the NRV forestwide and in the warm dry PVT. As shown in Figure 40, in some GAs lodgepole pine is more extensive than it was historically (Divide, Highwoods, Little Belts, Rocky Mountain Range, and Upper Blackfoot); but similar to the NRV in the other GAs. This species tended to be at the higher end of its NRV during warm/dry periods, and future climates and increased fire would be expected to promote it especially on cool sites. The species may retract to some extent on drier sites where Douglas-fir may be more drought tolerant; but overall is expected to remain a major component on the landscape.

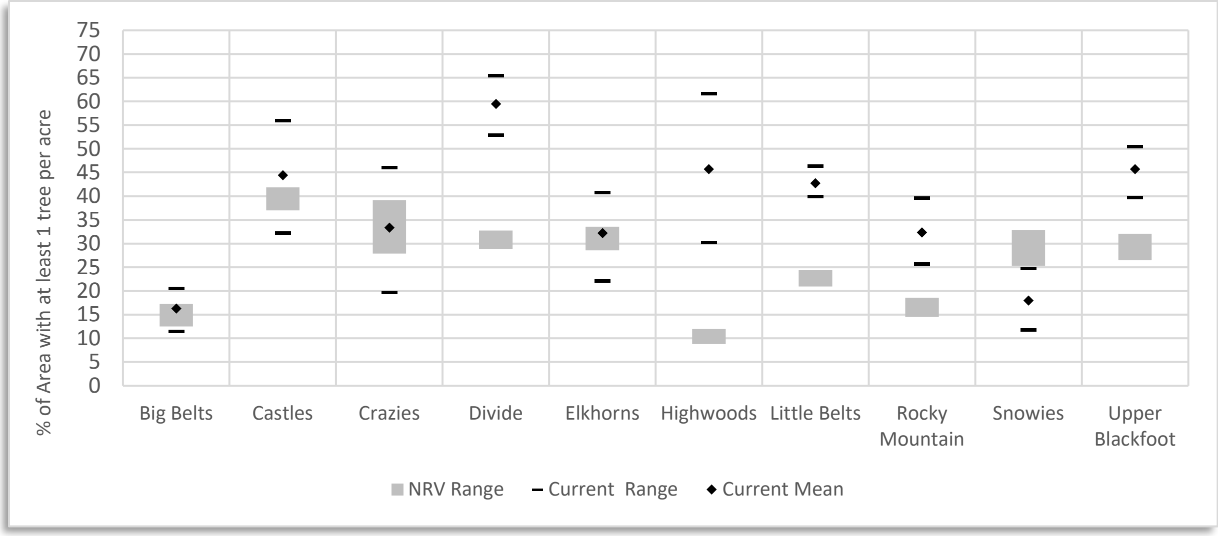


Figure 40. Lodgepole pine NRV distribution compared to existing condition, by GA

Engelmann spruce (*Picea engelmannii*)

Engelmann spruce is often confined to riparian areas and moist sites. Its extent is currently similar to or slightly above the NRV at the forestwide scale, and on all PVTs. When dominant, this species is part of the spruce/fir cover type, which is generally below the NRV, especially on the large GAs (Rocky Mountain Range, Little Belts, and Upper Blackfoot). Trends of Engelmann spruce as an individual species vary by GA (Figure 41). In the Elkhorns, Little Belts, and Snowies, the existing condition is above NRV, but in the other GAs it is similar to the NRV. Subalpine fir, the other component of the spruce/fir cover type, is much more common than Engelmann spruce, and therefore the trends for the cover type are more closely driven by that species. Engelmann spruce was generally at the low end of its NRV during warm and dry climate periods. It is more abundant than it was historically in some areas due to fire exclusion that has allowed advanced succession to occur where it would compete with lodgepole pine and whitebark pine. Engelmann spruce provides an important component of riparian and refugia areas that are protected from disturbance and persist to an old age but may be more restricted to the most moist sites at the lower end of its NRV with expected future climate and disturbances.

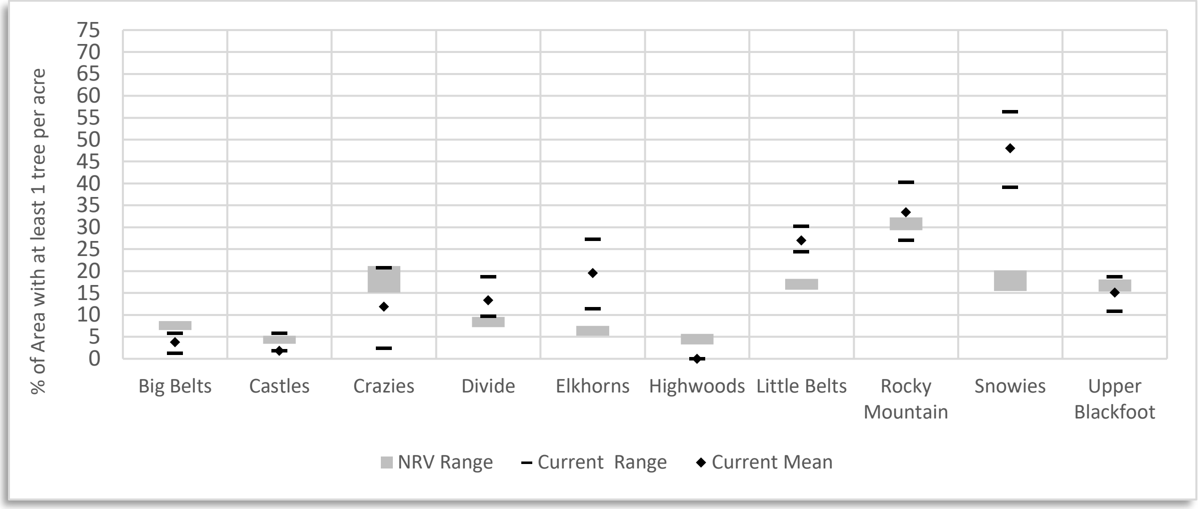


Figure 41. Engelmann spruce NRV distribution compared to existing condition, by GA

Subalpine fir (*Abies lasiocarpa*)

Subalpine fir is a common component on high elevation moist sites across the HLC NF; when dominant, it is part of the spruce/fir cover type. The NRV modeling at the forestwide scale showed that its current distribution is similar to the NRV, but that the spruce/fir cover type is less common than the NRV. This may be due to recent large fires in the Rocky Mountain Range GA where this type was most abundant; in other areas, this species and type may be more abundant than it was historically due to fire exclusion that has allowed advanced succession to occur primarily in lodgepole pine and whitebark pine cover types. As shown in Figure 42, the current distribution is above the NRV in the Crazies, Divide, Elkhorns, and Upper Blackfoot. It is similar to the NRV in the other GAs. Like spruce, this species was at the lowest end of its NRV during warm and dry climate periods and is not well-suited to drought, so in the future it may be expected to persist at the lower end of its NRV, and to occur on the moistest and/or highest elevation sites.

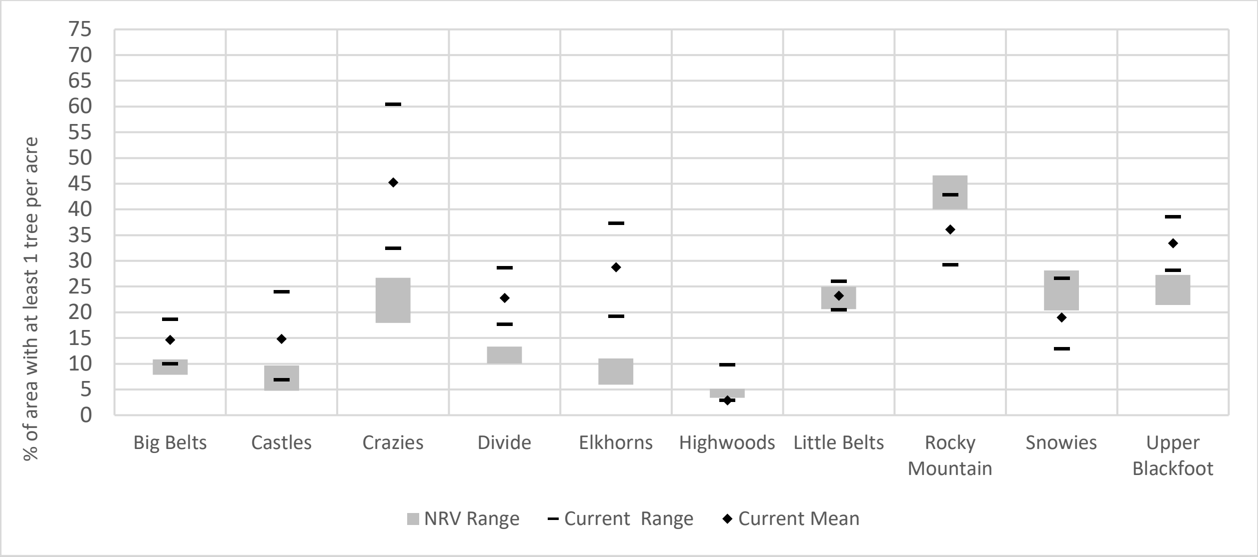


Figure 42. Subalpine fir NRV distribution compared to existing condition, by GA

Whitebark pine (*Pinus albicaulis*)

Whitebark pine is a keystone species that primarily occurs on the cold PVT, and to a lesser extent on cool moist. It is present on most GAs except the Highwoods. At the forestwide scale, the distribution of this species is just below the NRV on the cold PVT, where it is most suited to grow. When dominant, it comprises the whitebark pine cover type, which is similar to or slightly above the NRV depending on the GA. However, the cover type is not well-classified due to the limitations in species abundance as described in the cover type section. Figure 43 shows that the distribution of whitebark pine is generally similar to the NRV, although slightly above in the Castles and slightly below in the Little Belts and Snowies.

Many literature sources have found that whitebark pine is less abundant than it was historically due to a number of factors including fire exclusion, mountain pine beetle outbreaks, climate shifts, and the exotic disease white pine blister rust. The convergence of these threats has led to its status as a candidate species under the Endangered Species Act. Most of the whitebark pine on the HLC NF has been impacted by these factors, as evidenced by “ghost forests”; still, in these areas generally some seedlings or saplings persist, and therefore species presence is still noted in the existing condition. Whitebark pine tended to be at the higher end of its NRV during the warm/dry modeled climate periods, and although the effects of future climates are particularly uncertain for this species it is cold and drought-tolerant.

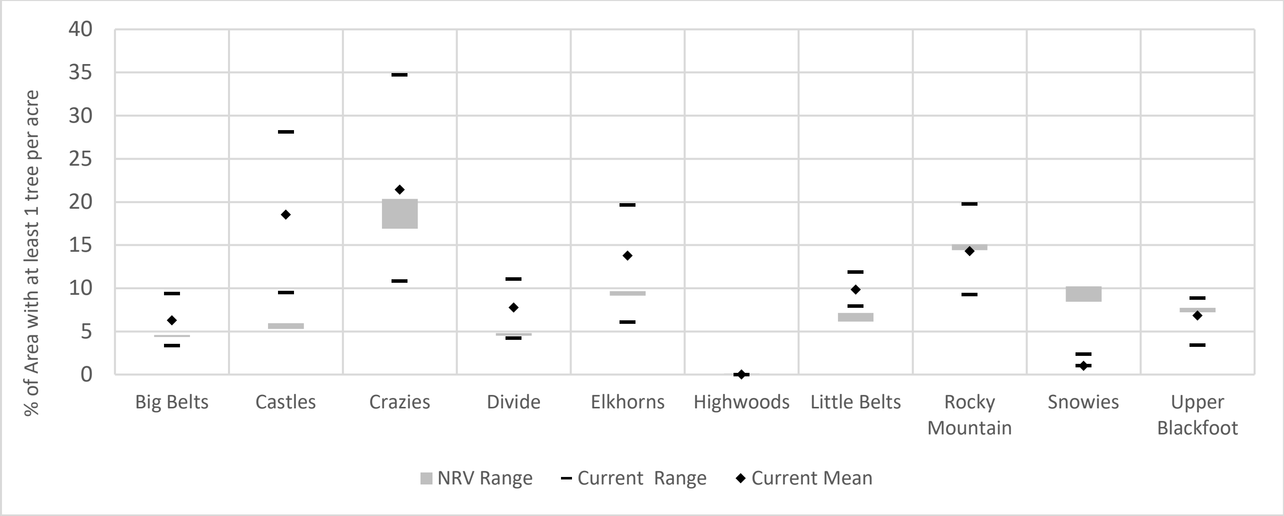


Figure 43. Whitebark pine NRV distribution compared to existing condition, by GA

Structure

The NRV analysis examines four vegetation components of ecosystem structure, all of which are related to forested vegetation types: forest size class, forest density class, forest vertical structure class, and the patch size of early successional forest openings.

Forest size class

Forest size classes are categories of tree size, based on the average basal area weighted diameter of live trees. Appendix D of the 2020 Forest Plan shows the definitions for size class. Size classes change as forests grow, and depend upon individual species traits, site productivity, climate, and disturbances. Some species, such as lodgepole pine, typically do not grow larger than the small or medium class based on their physiology and short-lived nature. Other species such as Douglas-fir or ponderosa pine are long-lived and capable of growing to large sizes especially in open conditions. Size class is not directly relatable to tree age, but can give a general idea of the array of forest successional stages across the landscape.

The way SIMPPLLE and the R1 Classification System classify size class is not the same. The R1 Classification System is based on basal area-weighted diameter (average size), so many areas in a given size class may have trees that are smaller and/or larger than the size class range. In SIMPPLLE, size class is not a product of average diameter, but rather a ruleset reflecting the expected tree sizes present based on age; these assumptions placed emphasis on the largest trees. Therefore, in SIMPPLLE a stand could be classified into a large tree size class, and a similar area might be classified as a medium by the R1 Classifier. This relationship is not generally problematic for the smaller size classes but shows divergent results when comparing the large and very large size classes.

To enable a direct comparison between the existing condition and the NRV, the SIMPPLLE results for the large and very large size classes were adjusted. To do this, the relationship of large tree presence and forest size classes was analyzed in the FIA data, and that relationship used to create a consistent NRV adjustment. This resulted in decreasing the amount of large and very large outputs from SIMPPLLE in proportion to increasing other classes. This methodology is documented further in appendix H of the FEIS.

Forest size class forestwide and by broad potential vegetation type

Figure 44 shows the NRV analysis for size class across the HLC NF. At this scale, the small tree size class is well above the NRV range, and the medium class is at the upper end or slightly higher than the NRV. Conversely, the large and very large size classes are below the NRV. In some areas fire suppression may have caused decreases in the proportion of seedling/sapling forests that would have been created by stand-replacing disturbances. Similarly, the lack of low-intensity disturbances in long-lived cover types may have caused a decrease in the large and very large size classes by perpetuating high densities where individual tree growth is inhibited. The recent mountain pine beetle outbreak may also have contributed to an increase in the small tree size class.

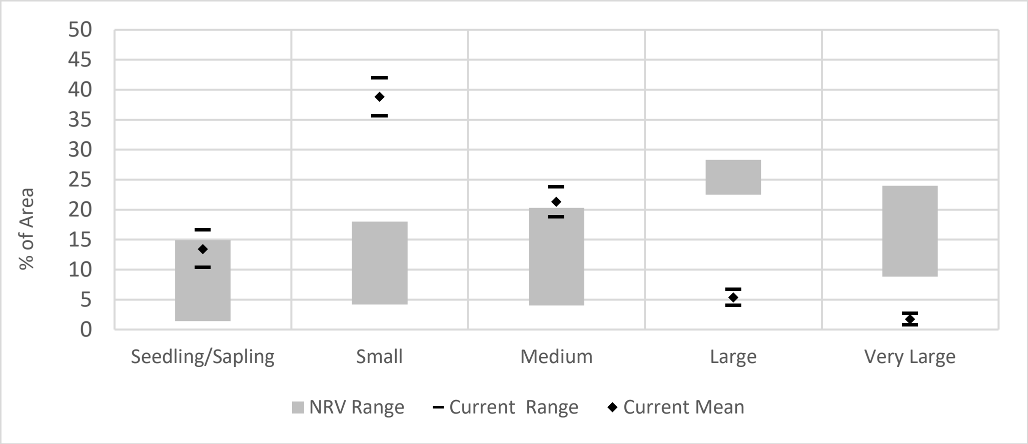


Figure 44. NRV range of size class compared to existing condition, forestwide

In the warm dry PVT (Figure 45), the existing proportions of small and medium size classes are well above the NRV, while the large tree and very large classes are below. Large and very large tree sizes classes would likely have been relatively open or clumpy patch mosaics, with the large tree component being long-lived species capable of surviving moderate or low severity fire when mature (such as ponderosa pine and Douglas-fir). In sheltered riparian areas, groves of large Engelmann spruce could develop. Compared to cool moist and cold PVTs, the warm dry PVT is the most substantially different from the NRV condition, congruent with our understanding of the effects of suppressing fires in these high frequency, low severity fire regimes.

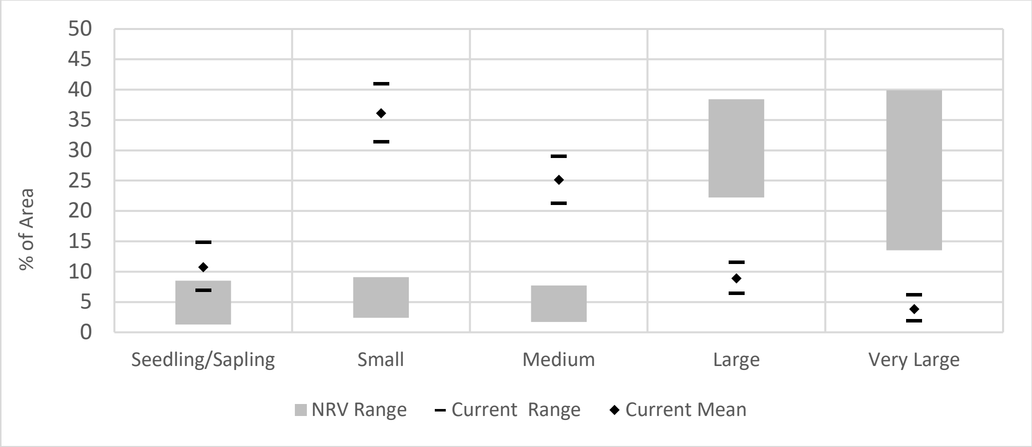


Figure 45. Warm dry PVT NRV range of size class compared to existing condition

For the cool moist PVT (Figure 46) the abundance of the small tree class is above the NRV, while the existing proportion of large and very large size classes are below the NRV. However, the medium class is within the NRV, albeit at the upper end. In large part, this is due to this type being dominated most commonly by lodgepole pine, which naturally does not reach large sizes. In areas with large size classes, a fire tolerant large diameter overstory tree layer would typically exists (Douglas-fir) atop a more dense mid and understory tree layer. Large, old Engelmann spruce could occur in sheltered, moist riparian settings.

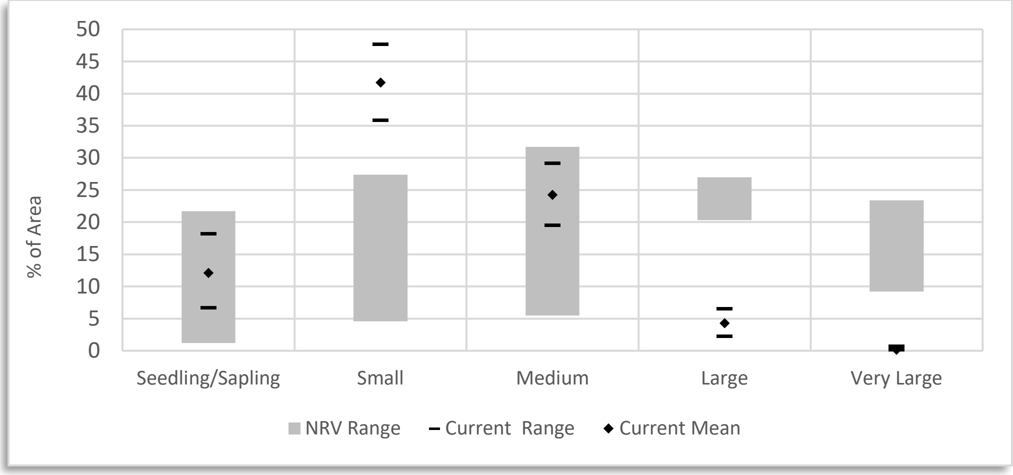


Figure 46. Cool moist PVT NRV range of size class compared to existing condition

For the cold PVT, the existing proportion of the small tree size class is at the upper end or slightly above the NRV, and the large and very large tree size classes are below. The abundance of the very large tree class is naturally low because the harsh conditions and species present on these sites make the achievement of a very large size difficult. Whitebark pine was historically the large tree component, tolerant of the moderate or low severity fires that typically occurred. Large subalpine fir and Engelmann spruce could develop in moist areas.

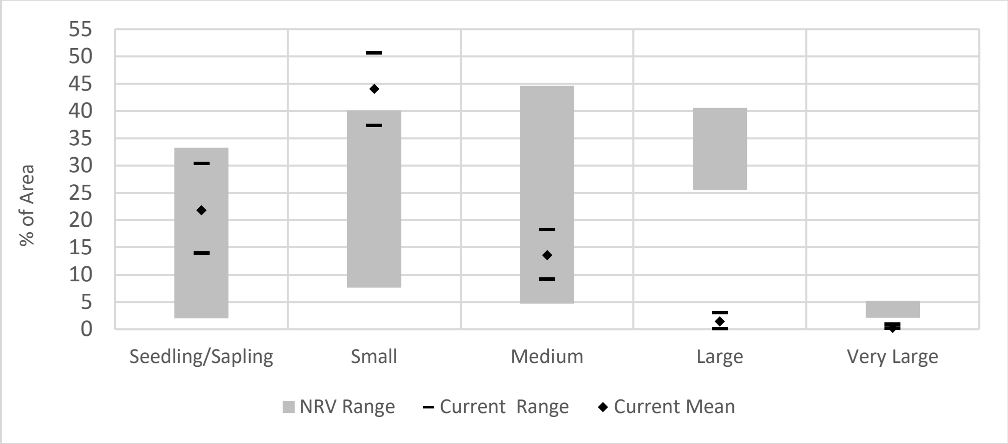
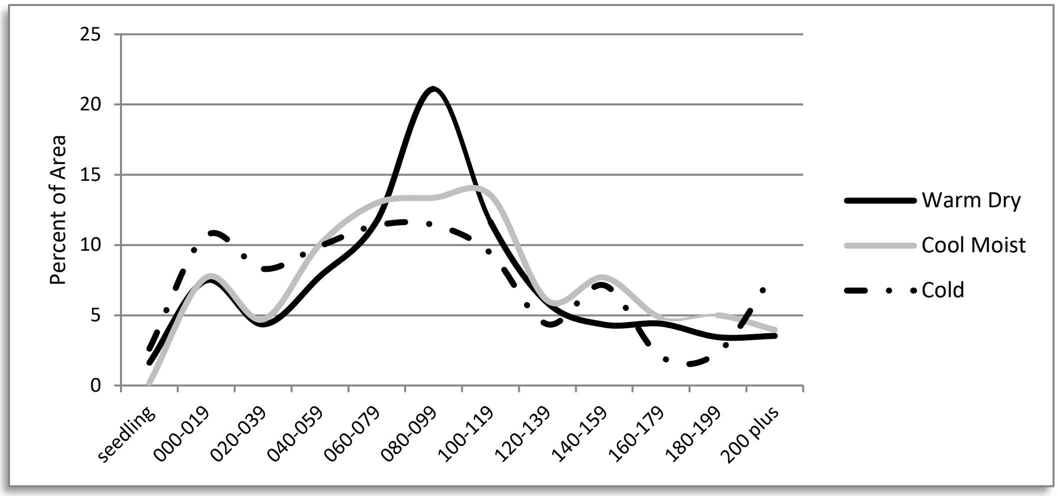


Figure 47. Cold potential vegetation type NRV range of size class compared to existing condition

Size class is not equivalent to age class, and there is no NRV assessment of age class. However, the existing condition of age class distribution by PVT, as shown in Figure 48, supports the trends seen in size class. Particularly in the warm dry PVT, there is a high preponderance of middle-aged forests that may roughly correlate to the small and medium size classes. Across the HLC NF, most forests are between 20 and 199 years old. Old forests over 200 years old are relatively rare, as are large and very large tree size classes. Based on the NRV of size class, the NRV distribution of age classes was likely more evenly distributed. Given that large size classes were more abundant historically, it is reasonable to include that older age classes were also more abundant.



Source: R1 Summary Database (FIA data, Hybrid 2007 dataset, queried 2015).

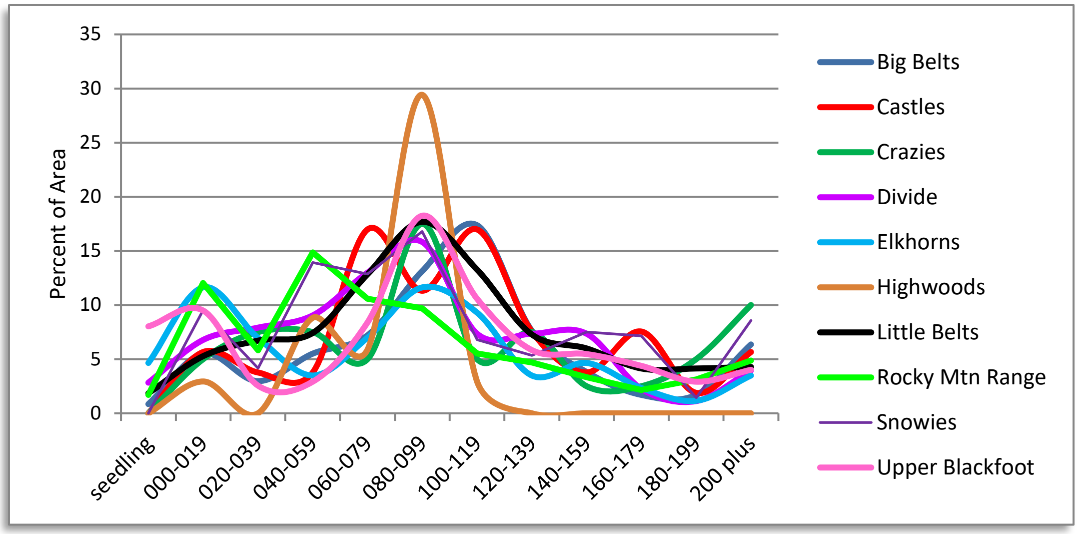
Figure 48. Existing condition age class distribution by broad PVT

The seedling/sapling size class tends to increase and then start falling during warm/dry periods, perhaps in response to increased fire and then growth into small trees. The small tree class consistently increases toward the higher end of its NRV during warm/dry periods, whereas the medium tree class is at the lowest end of its range during these periods. The large and very large tree classes also tend to begin declining during warm/dry periods, perhaps also due to increased fire activity, although they would remain important components on the landscape.

Forest size class by geographic area

The following sections explore the NRV trends for each size class by GA. In general, the GAs show trends similar to forestwide averages.

Age class data was also summarized for each GA, as shown in Figure 49. The Highwoods GA has an especially pronounced bell-shaped curve with the 80-99 year old age class far more abundant than any other classes; this is a function of the disturbance regime in this range. As a small island mountain range, it can be subject to fires that sweep up from the prairie and affect the entire GA. This occurred in the late 1800’s, and there has been little disturbance since; therefore, the age class distribution of the Highwoods GA is not diverse. The other GAs follow this trend to a lesser extent because they have had more regular disturbance. For example, the Rocky Mountain Range has a notably different and more regular age class distribution, not only because it is part of a larger connected landscape but also because it has had a more active fire history in the last century.



Source: R1 Summary Database (FIA data, Hybrid 2007 dataset, queried 2015).

Figure 49. Existing condition age class distribution by GA

Seedling/sapling size class

As shown in Figure 50, all GAs contain existing proportions of the seedling/sapling size class within or at the higher end of the NRV range, largely because of recent fires and the mountain pine beetle outbreak. The most notable exception is the Highwoods, which contains essentially no seedling/sapling forests due to a lack of recent disturbance. The wide range of variation of the seedling/sapling class is linked to stand-replacing disturbance regimes, and is most abundant in the cool moist PVT. Forests spend a relatively short amount of time in this successional stage of development, generally growing into the small tree stage within 30 or 40 years, except on poor or harsh growing sites.

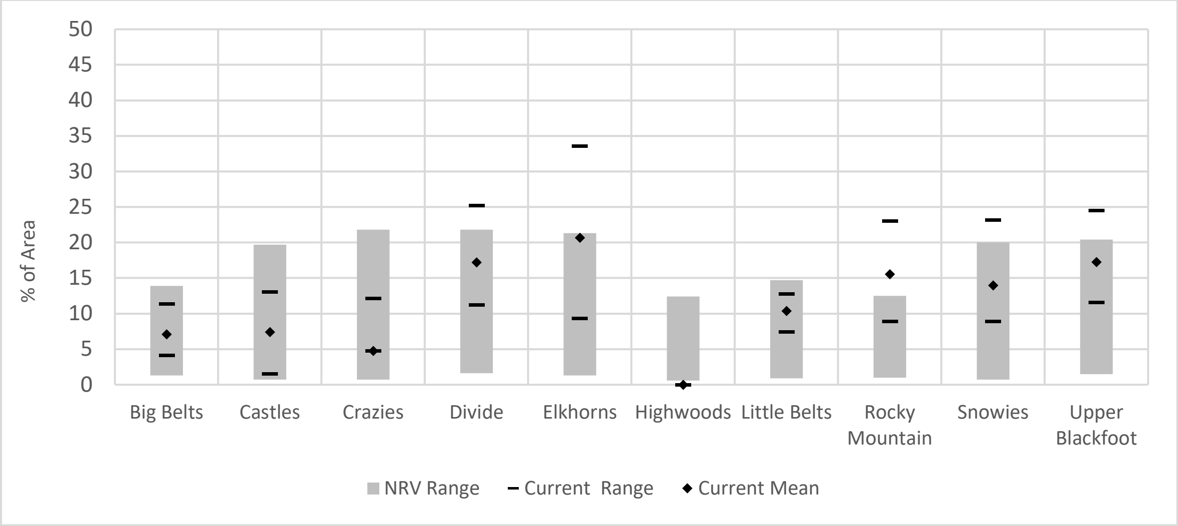


Figure 50. Seedling/sapling size class NRV range compared to existing condition, by GA

Small and medium tree size classes

All GAs have a higher proportion of small tree size class than the NRV, although the confidence intervals for the Elkhorns, Highwoods, and Upper Blackfoot are within or near the upper bound of the NRV. The disparity between existing and NRV conditions is most dramatic for the Big Belts, Castles, Divide, Little Belts, and

Snowies. Some of these were areas hardest hit by the mountain pine beetle. Conversely, for most GAs, the existing proportions of the medium tree size class are within the NRV. The exceptions are the Big Belts, Highwoods, and Little Belts, where results indicate that the medium tree size class is more abundant than the NRV. The small and medium size classes are often associated with densely stocked stands originating from past wildfires or prior harvesting. Forests may be diverse within these classes and may also contain seedling/sapling trees in the understory canopy and/or large trees in the overstory. Forests may remain in the small and medium size classes for many decades. Some forests (i.e. lodgepole pine) may remain in these classes their entire lifespan.

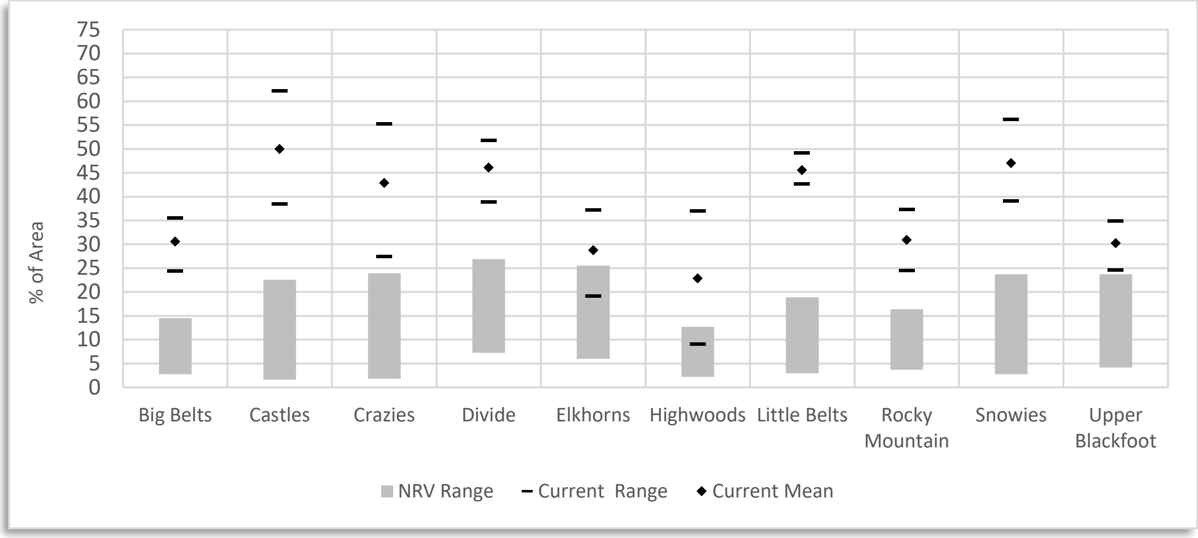


Figure 51. Small tree size class NRV range compared to existing condition, by GA

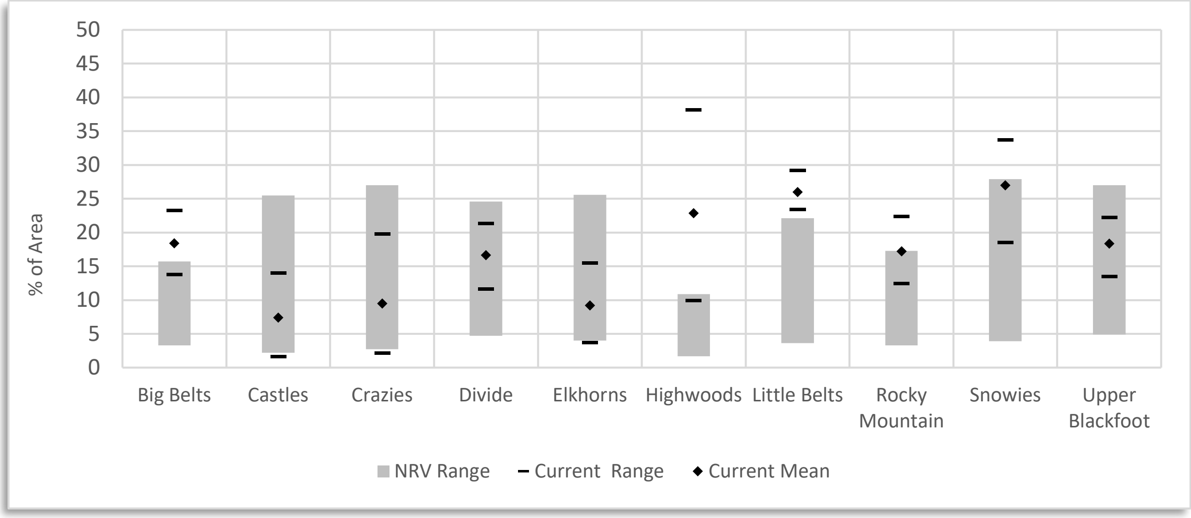


Figure 52. Medium tree size class NRV range compared to existing condition, by GA

Large and very large tree size classes

The large tree size class is currently underrepresented in all GAs as compared to the NRV (Figure 53). In most GAs, the very large tree size class is also more abundant in the NRV than the existing condition (Figure 54). Several GAs, however, are either within or very near the NRV for the very large size class (Castles and Crazies). A proportion of the large and very large size classes may be late successional or old growth forest. In some places, the species and growing sites inhibit tree growth to a large size. The correlation to climate period may indicate that large and very large trees would be at the lower end of their NRV range during warm/dry periods such as those expected in the future; however, this level would still exceed the existing condition.

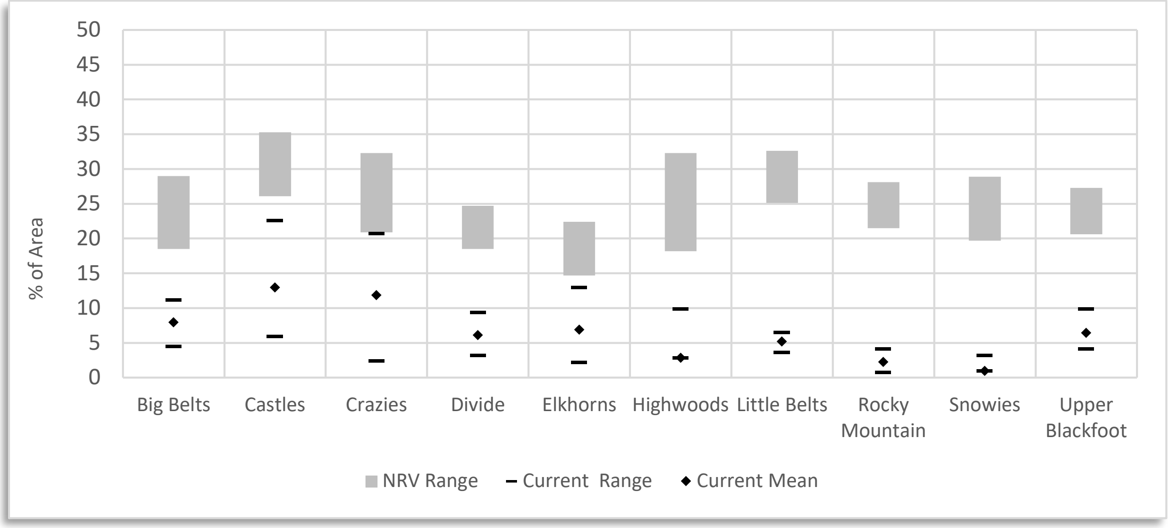


Figure 53. Large tree size class NRV range compared to existing condition, by GA

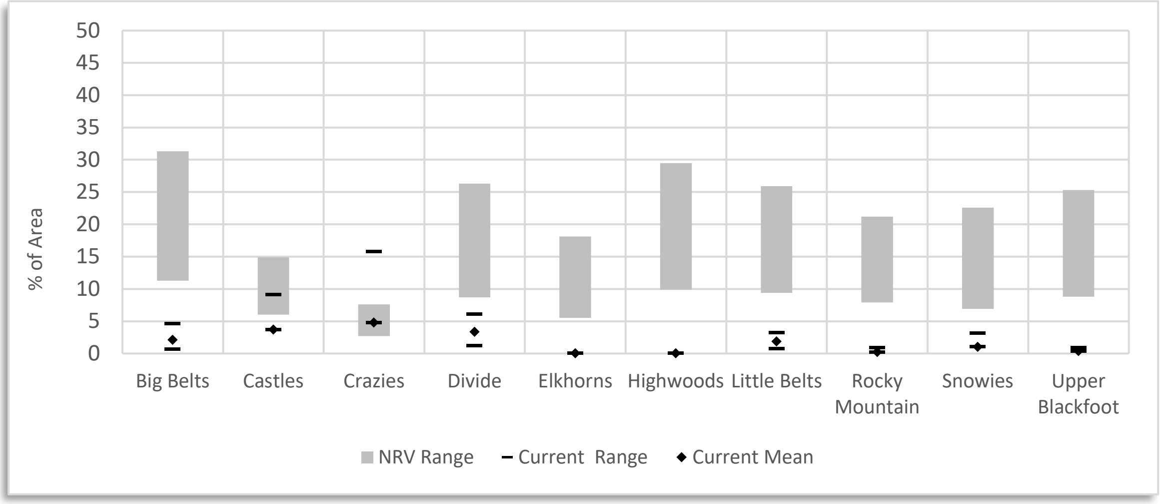


Figure 54. Very large tree size class NRV range compared to existing condition, by GA

Forest Density Class

Forest density class is depicted by using classes of canopy cover, which is a measure of the vertical coverage of tree crowns in a stand as a percentage of the land area; refer to appendix D of the 2020 Forest Plan for definitions of the density classes used. Density is influenced by the carrying capacity of the site as well as disturbances and varies by species. For example, lodgepole pine tends to grow more densely than ponderosa pine. Density class can also shift as forests grow, tending toward higher densities at later successional stages of stand development, for example when shade tolerant understories develop under mature canopies. Density classes can be used to describe habitat qualities and resiliency to disturbances. The existing condition for density class is depicted by the latest R1 VMap, rather than FIA. Canopy cover is more directly measured by remotely sensed imagery, whereas it is estimated based on species and size calculations when FIA data is summarized. In short, the R1 VMap is more accurate for this attribute. As a result of using this information rather than FIA, there are no confidence intervals associated with the existing condition data.

Density Class forestwide and by broad potential vegetation type

Figure 55 displays the NRV analysis for density class across the HLC NF, showing that medium/high forest densities are below the NRV, and the abundance of high density is just above the NRV. This is consistent with the trends of fire exclusion which promotes higher forest density, and the increased abundance of shade tolerant species in some areas which tend to grow at higher densities than their shade intolerant competitors.

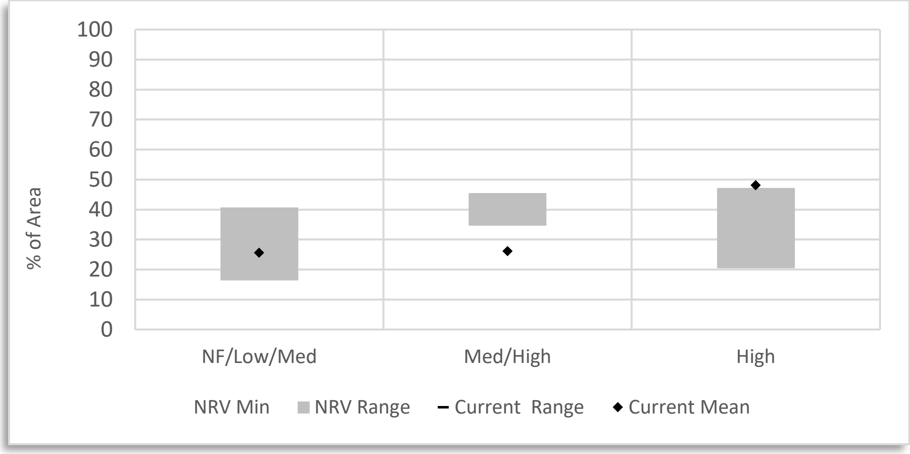


Figure 55. NRV range of density classes compared to existing condition, forestwide

As shown in Figure 56, the distribution of density classes is generally within the NRV for the warm dry PVT. An increase in higher forest densities due to fire exclusion is well-documented in the dry forests found on this PVT; however, recent fire and insect activity that has lowered densities or even created nonforested conditions may have tempered this trend when examined across this type on the HLC NF. The abundance of high density forests is in the upper end of the NRV range while the medium/high forests are at the low end of the range; this should likely shift in the future as lower density forests are more common in warm/dry climate periods such as that expected in the future.

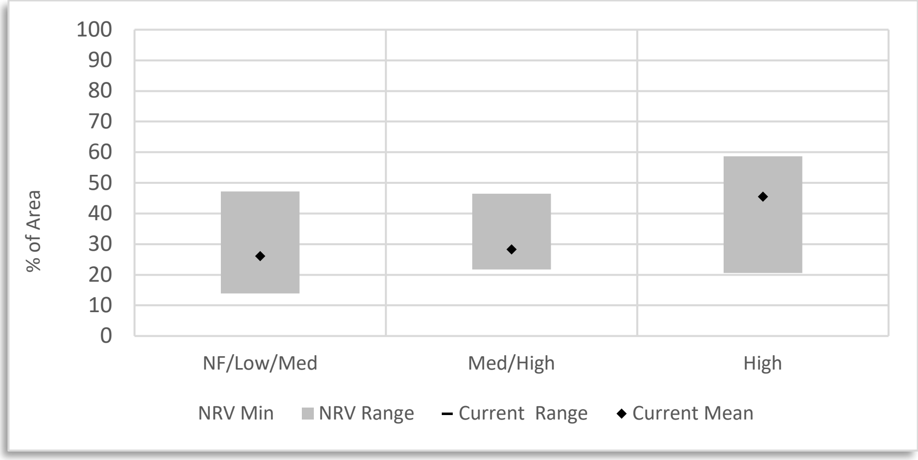


Figure 56. Warm dry PVT NRV range of density classes compared to existing condition

On the cool moist (Figure 57) and cold PVTs (Figure 58), the medium/high density class is lower than the NRV and conversely the high density class is higher than the NRV. This may be indicative of more dense understories of shade tolerant trees developing under lodgepole pine and/or whitebark pine canopies in the absence of fire disturbance, and/or with the release of these components due to mountain pine beetle infestation.

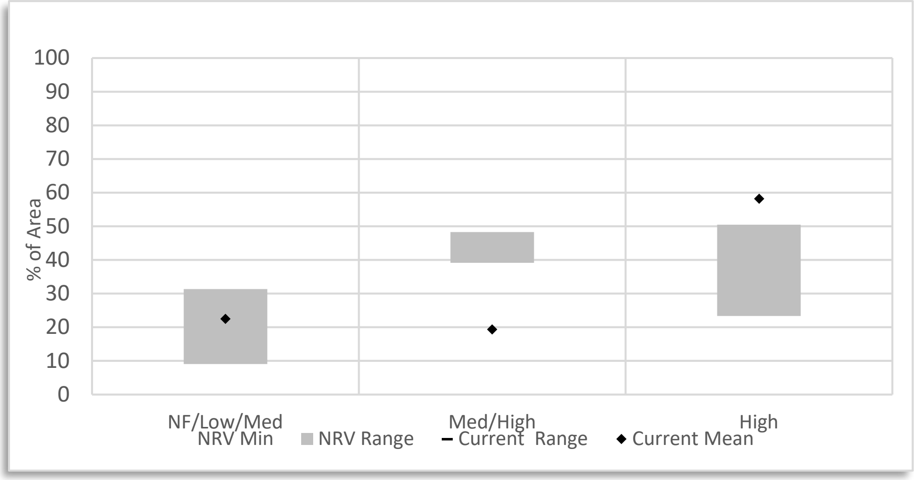


Figure 57. Cool moist PVT NRV range of density classes compared to existing condition

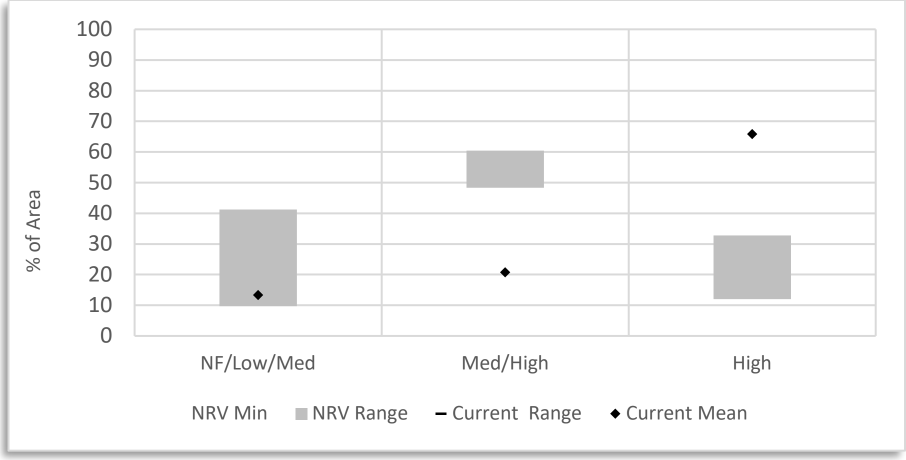


Figure 58. Cold PVT NRV range of density classes compared to existing condition, forestwide

Low and medium density forests were at the higher end of their NRV ranges during warm/dry periods, whereas medium and high-density forests were at the lowest end of their ranges. Similar trends may be expected given expected future climate and disturbances. More open densities tend to be more resilient to both fire as well as insects and diseases. Conversely, higher densities are also important conditions to provide certain wildlife habitat conditions. The differences in density class are fundamentally a function of the PVTs, cover types, size classes found on the landscape, as some forest types and successional stages naturally grow more densely than others.

Density class by geographic area

Nonforested/low/medium density

Nonforested areas are typically defined as those with <10% canopy cover and includes grass/shrub areas (0-5% cover of trees) as well as very open forest savannas maintained by frequent disturbance (5-10% canopy cover). This category may also include forested areas that have not yet regenerated after a disturbance. However, in the SIMPPLLE model the 0-10% canopy cover conditions are combined low density forests (<25% canopy cover), if a forest species type is listed. Further, the medium class was combined with the low class in the 2020 Forest Plan, because the distinction is not crucial for plan components or wildlife species. Therefore, the nonforested, low, and medium forest density classes were combined for this analysis (canopy cover 0-39.9%).

At the forestwide scale and broad PVT, the abundance of nonforested/low/medium density forests is within the NRV range. Figure 59 shows that the existing condition of the nonforested/low/medium density areas are also within the NRV for all GAs except the Elkhorns, where they are underrepresented. The finding in the Elkhorns is supported by a study in that GA which found that there has been a three-fold increase in the amount of closed-canopy forest at the expense of grass, shrub, and open tree stands compared to historical conditions (Barrett 2005a). In other GAs, the abundance of these low-density forests (or nonforested areas) is at the low end of the NRV range, particularly the Divide, Highwoods, Little Belts, and Snowies. Given that lower density forests are more common during warm/dry climate periods, in the future a shift towards the mid or upper range of the NRV for these GAs may be expected or warranted.

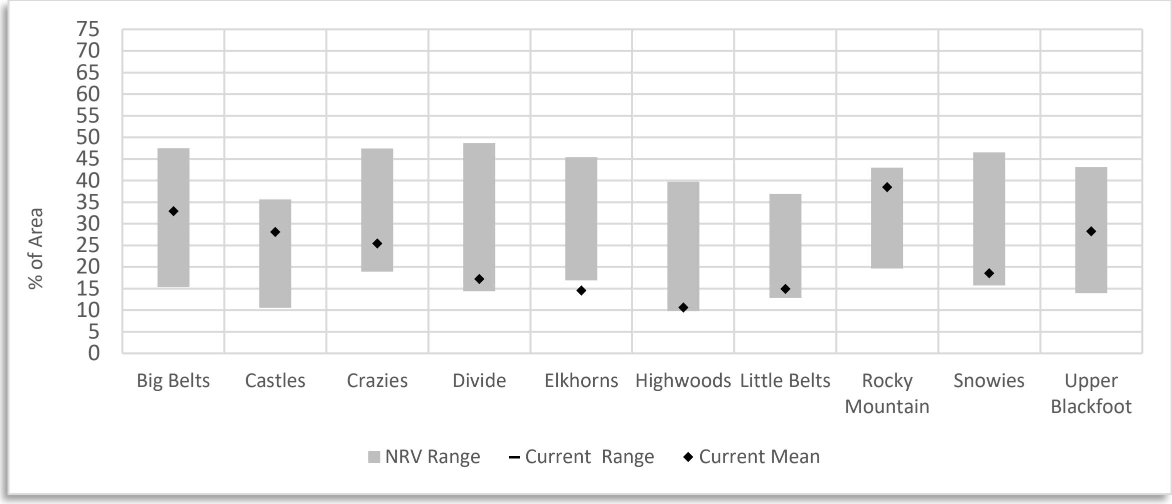


Figure 59. Nonforested/low/medium density class NRV compared to existing condition, by GA

Medium/high density

Medium/high density forests were below the NRV at the forestwide scale, and for the cool moist and cold PVTs. By GA, as shown in Figure 60, this density class is underrepresented in some GAs (Big Belts, Crazies, Highwoods, Little Belts, Rocky Mountain Range, and Snowies); slightly overrepresented in the Castles; and within the NRV for the Divide, Elkhorns, and Upper Blackfoot, although at the low end of the range. The medium/high density class may be underrepresented in some areas due to disturbances that have created nonforested or low-density forests; or conversely, in some areas, a lack of disturbance that has promoted high density forests. The latter case is the most common condition, because high density forests are overrepresented at the forestwide scale and in the cool moist and cold PVTs.

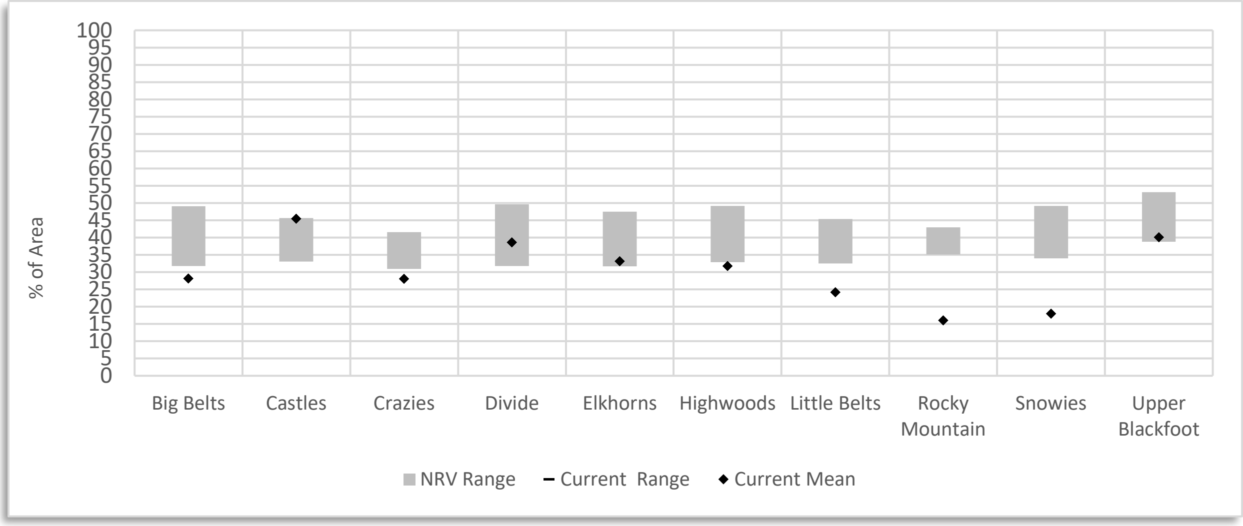


Figure 60. Medium/High density class NRV compared to existing condition, by GA

High density

Medium/high density forests were below the NRV at the forestwide scale, and for the cool moist and cold PVTs, and this generally correlates with high density forests being above the NRV. As shown in Figure 61, high density forests are above the NRV in most GAs except the Big Belts, Castles, Divide, and Upper Blackfoot. The high density forests were overrepresented in the cool moist and cold PVTs, which likely reflect lodgepole pine and spruce/fir forests.

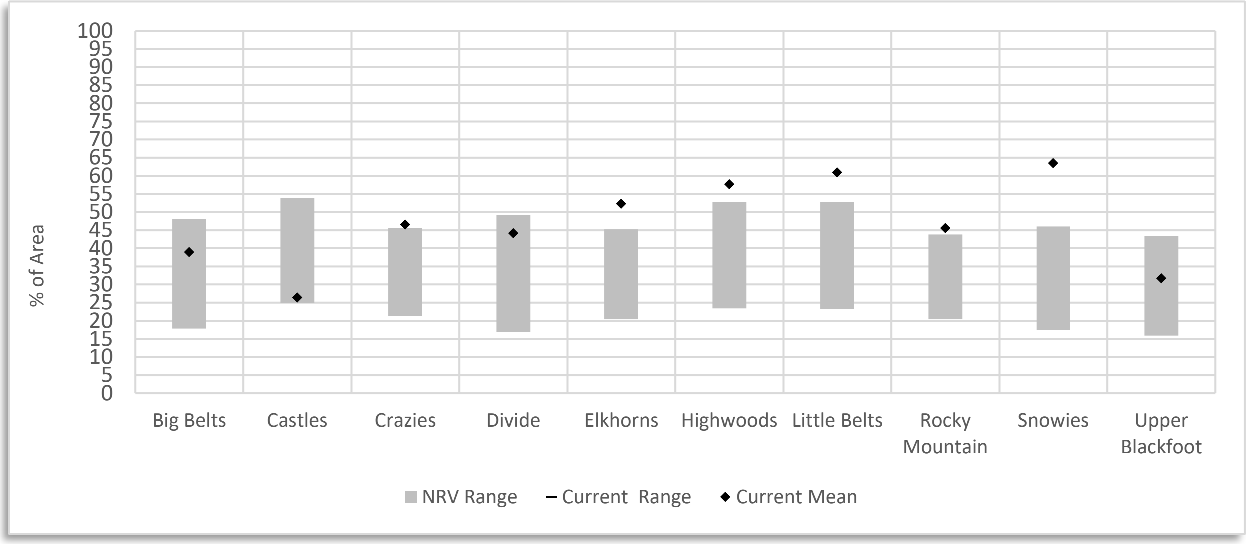


Figure 61. High density class NRV compared to existing condition, by GA

Forest vertical structure class

Vertical structure class is a depiction of the number of canopy layers present. This characteristic is driven by succession, individual species traits, and disturbances. Some cover types, such as spruce/fir, naturally develop a continuous canopy structure made up of multiple layers of shade tolerant species. Other types, such as ponderosa pine, would tend to have the number of canopy layers reduced periodically by frequent natural fires, although these events also promote a multi-storied character with open densities. Conversely, natural fire in some Douglas-fir stands would create small canopy openings where understory layers could establish; in the absence of fires stands remain in a closed single-storied condition. Some types, such as lodgepole pine, tend to grow in a single-storied condition which is perpetuated by periodic stand replacing disturbances. In the absence of disturbance these forests can slowly develop shade tolerant canopy layers. Three vertical structure classes are modeled: single storied (SS); 2-storied; and 3+ or multi-storied (MS). The NRV trends are closely tied to PVT. Figure 62 shows that on the warm dry PVT, the abundance of single storied forests are substantially higher than the NRV, and multi-storied forests less abundant. The single-storied forests may include ponderosa pine or Douglas-fir where low severity disturbance has not opened the canopy to allow understory trees to establish.

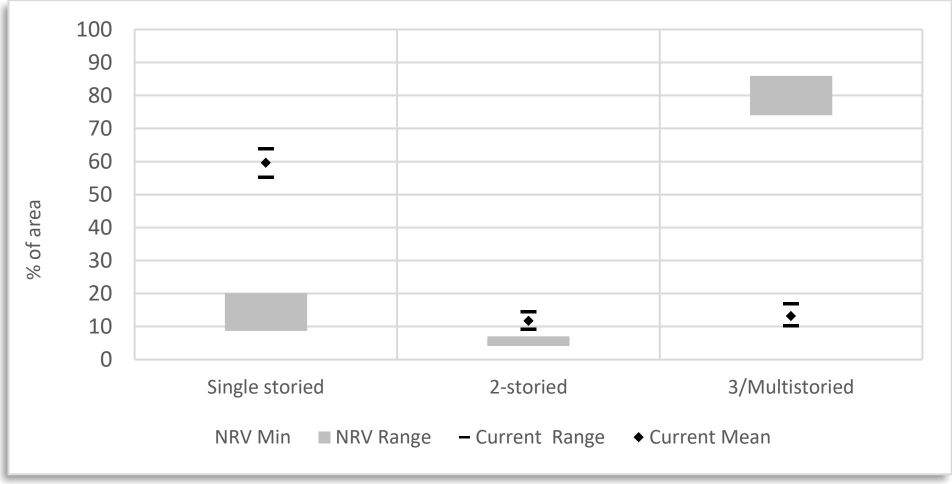


Figure 62. Warm dry PVT NRV of vertical structure class compared to existing condition

On the cool moist PVT (Figure 63), the abundance of single storied forests is slightly above NRV and multistoried forests below, but to a lesser degree than in the warm dry PVT. This may reflect the under-abundance of spruce/fir forests in some areas, which would tend to grow in a multistoried condition. A single storied condition would also naturally be abundant, reflecting the traits of the most common species present on this PVT, lodgepole pine.

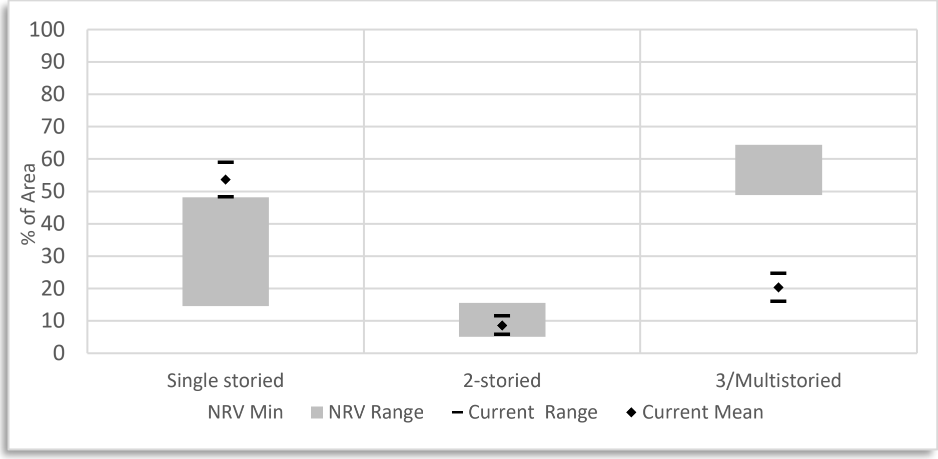


Figure 63. Cool moist PVT NRV of vertical structure class compared to existing condition forestwide

In the cold PVT (Figure 64), single storied forests are within the wide NRV and multistoried forests are below. In the past, fire may have promoted more open and uneven-aged whitebark pine forests. The single storied forests are most likely dominated by lodgepole pine or whitebark pine, given that spruce and fir would more likely grow in a multistoried condition.

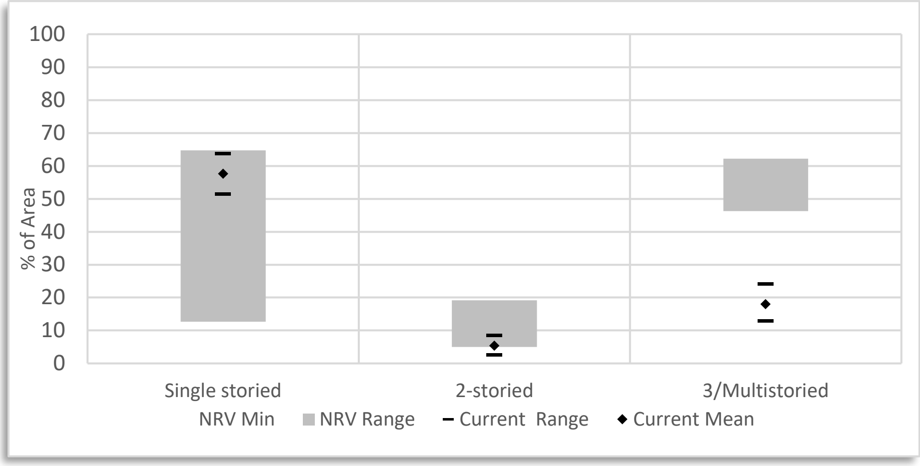


Figure 64. Cold PVT NRV of vertical structure class compared to existing condition

Single-storied forests appear to increase and be at the high end of their NRV ranges during warm/dry periods. Therefore, it is reasonable to expect that even if the single storied forest abundance approaches the NRV, it will remain slightly above or within the upper end of the range. Two storied conditions are overall less abundant and tend to be at the low and but slightly increasing during warm dry periods. Multi-storied conditions decrease and are at the low end of their NRV range during warm/dry periods. A focus on increased resiliency through decreased density may be important given future expected climate and disturbances. For most tree species, the combination of less canopy layering and/or lower tree densities would generally be more resilient to disturbances, although dense multi-layered conditions are also important for certain wildlife habitats.

Landscape pattern: early successional forest openings

The connectivity of ecosystems influences characteristics such as watershed function, wildlife habitat, and the flow of genetic material. The patch and pattern of vegetation has been influenced by many factors including climate, disturbance regimes, and human management. As described in the Assessment, some studies indicate that there has been a general trend of decreasing patch size and increased landscape fragmentation compared to the historic condition in the Upper Missouri River Basin, which includes the HLC NF plan area. There are many ways to assess landscape patch and pattern, depending on the condition or species of interest. For this analysis, early successional forest openings were assessed as one aspect of landscape pattern.

Early successional forests are those in the early stages of stand development, dominated by seedlings and saplings. The dominance of grass, forbs, shrubs and short trees creates a patch with strong contrast (e.g., “edge”) that is distinctly different from adjacent forest patches. Not only does this allow for accurate detection and measurement of the patch and resulting landscape patterns (past, present and future), but the seedling/sapling forest patch type is also meaningful for evaluation of wildlife habitat, forest cover, and connectivity. The larger trees and denser forest cover present in the adjacent forest patches provide the connectivity of habitat important to many wildlife species. Early successional stages also represent the crucial initiation point of forest development and thus greatly influence potential future conditions and patterns.

Both the NRV and existing condition were estimated using SIMPPLLE. The estimates include the seedling/sapling size class and grass/shrub/forb communities on forested PVTs, which are in transition from a recent disturbance but are expected to reforest. Table 4 shows the results for the arithmetic mean size of early successional forest patches.

Table 4. NRV patch size of early successional forests compared to the existing condition

Patches > 5 acres	Forestwide	Warm dry PVT	Cool moist PVT	Cold PVT
NRV mean patch size	78 (45-119)	45 (30-70)	64 (44-84)	59 (39-84)
Existing mean patch size	163	91	133	76

The modeling results indicate that the average seedling/sapling patch size in the existing condition is generally larger than the patches in the NRV. This may be due to recent large fires and the mountain pine beetle outbreak which created large patches and influenced the overall patch size at the broad scale. In particular, the NRV modeling tending to distribute stand-replacing fire on many small patches rather than a few large patches, although the total acres burned was similar or more than the existing fire regimes in most periods and landscapes (as discussed in the wildfire section above). Although the current average patch size is higher than the NRV when averaged at the broad scale, fragmentation and small patch size could still be an issue in some landscapes or at smaller scales.

Early successional patches in the NRV of the warm dry PVT are smaller than in the other PVTs, due to a more frequent low severity disturbance regime which may cause a complex mosaic of within-stand structures including small patches and canopy openings. Patches in the cool moist PVT tend to be larger due to a preponderance of lodgepole pine and infrequent, high severity disturbances. Patch sizes in the cold PVT reflect a mixed fire regime.

The largest patch sizes are correlated with warm/dry climate periods. More fire might mean more, larger openings, resulting in patch sizes that trend towards the upper end of the NRV range with expected future climate and disturbances. Forestwide, fire will continue to be the primary activity that creates early successional forest openings, particularly the large sized openings.

Wildlife habitats

The vegetation key ecosystem characteristics have a direct bearing on wildlife habitat. The concept of a coarse filter approach is that maintaining the appropriate ecosystem diversity for composition, structure, function, and connectivity will provide for the habitat needs of most native terrestrial wildlife species. Therefore, the NRV abundance of terrestrial wildlife habitat conditions is inherently part of the array of vegetation characteristics.

Certain species have specific habitat requirements that may not be met solely by providing for ecosystem integrity at a broad or coarse filter level. These species' habitats may require additional consideration at the fine filter level in order to understand needs and the role that NFS lands may play in meeting them. The potential NRV for habitats of some species are of particular interest because they are 'At-Risk', as defined by the 2015 planning directives, or because of specific public or management interest. Not all at-risk or management interest species require a fine-filter approach, however, or have habitat needs that lend themselves to vegetation modeling. We identified species of either conservation or other management interest for which habitat requirements are highly correlated with specific, quantifiable vegetation attributes. Habitat models were developed to identify the conditions that would meet their habitat requirements. These definitions are based on the best scientific information available and are consistent, to the extent applicable, with recent modeling work done for east-side forests in Region 1. The species selected for the revised NRV analysis include:

- Canada lynx

- Flammulated owl
- Lewis's woodpecker
- Elk

This list is slightly different than the original NRV analysis; namely, elk are included and goshawk are not. Elk habitat was added based on the development of appropriate modeling criteria that were not available at the time of the original NRV analysis. Elk were identified as a management indicator species in the 1986 Forest Plans, and analysis of certain aspects of elk habitat serves as a proxy for other big game species. Elk also remain a focus of significant public interest. Northern goshawks were listed in the 1986 plans as a management indicator species for old growth forest. Research has demonstrated that goshawks are not dependent on old growth and are therefore a poor indicator of that type of forest (Samson 2006b, U.S. Department of Interior 1998, Bush and Lundberg 2008a, Brewer et al. 2009), and information has become increasingly available indicating that goshawks and their habitat may be more widespread and available than previously thought. Samson (2006b) concluded that goshawk nesting habitat is abundant and well-distributed throughout the Region, and goshawks are not a species of conservation concern for the HLC NF.

The type of data and basis for estimates of existing habitat are discussed below for each species. The comparisons displayed and discussed below are intended to be a very broad look at existing conditions compared to the estimated inherent capacity of the HLC NF to provide and sustain these habitats.

Canada lynx

Canada lynx are listed as Threatened under the federal Endangered Species Act. The historic distribution of lynx in Montana is not well documented but it appears that they historically occupied only portions of the HLC NF, with some island ranges occupied only intermittently and others not at all (USFWS 2014). Lynx are highly dependent on snowshoe hare, which in turn are dependent on boreal (primarily spruce-fir) forest (Interagency Lynx Biology Team 2013). Certain structural stages appear to be key to maintaining populations of snowshoe hare. Specifically, hares require forests that provide either dense young conifers, or mature conifer stands with multiple canopy layers. Both types provide horizontal cover that serves as some protection against predation (ibid). Both also have conifers protruding above or hanging down to snow level, providing both protection and forage for snowshoe hares. These structural features are difficult to model using available vegetation data, however, and must be inferred from a combination of tree size class, canopy cover and, where available, disturbance history. Attempts to model lynx/snowshoe hare habitat are further complicated by the fact that certain habitat types develop structure differently depending on landscape features such as slope, aspect, and elevation.

The series of figures below shows the estimated NRV range compared to the existing condition of the four structural stages generally used to describe lynx habitat: *early stand initiation*, *stand initiation*, *mature multistory*, and *other*. These structural conditions are identified only on lands determined to be potential lynx habitat. Detailed information regarding how the structural stages are defined in the model, as well as how potential lynx habitat is identified, is provided in appendix H of the FEIS. The ranges shown reflect the percentages of potential lynx habitat that would be in these various structural stages. For this comparison, the existing condition estimates are taken from the starting point of the SIMPPLLE model. Other data sources and methodologies may be available for other analysis purposes; the values in this report should be used for general comparisons to the NRV.

There is a wide amplitude in the NRV ranges, reflecting the dynamic nature of the structural stage as well as possibly the level of uncertainty regarding the NRV estimates. The structural stage with the narrowest estimated NRV range is the mature multi-storied habitat; at the Forest level and in all GAs, the existing condition is at the low end or below the NRV. The stand initiation conditions are generally at the low end of the NRV range in most landscapes. Early stand initiation habitat is within or above the NRV in all GAs; the Rocky Mountain Range and Upper Blackfoot GAs are above the NRV for this habitat condition due to recent fires. The "other" lynx habitat category is not depicted; it is the most abundant and makes up the remainder of the potential lynx habitat that does not meet one of the structural stage criteria shown in the charts.

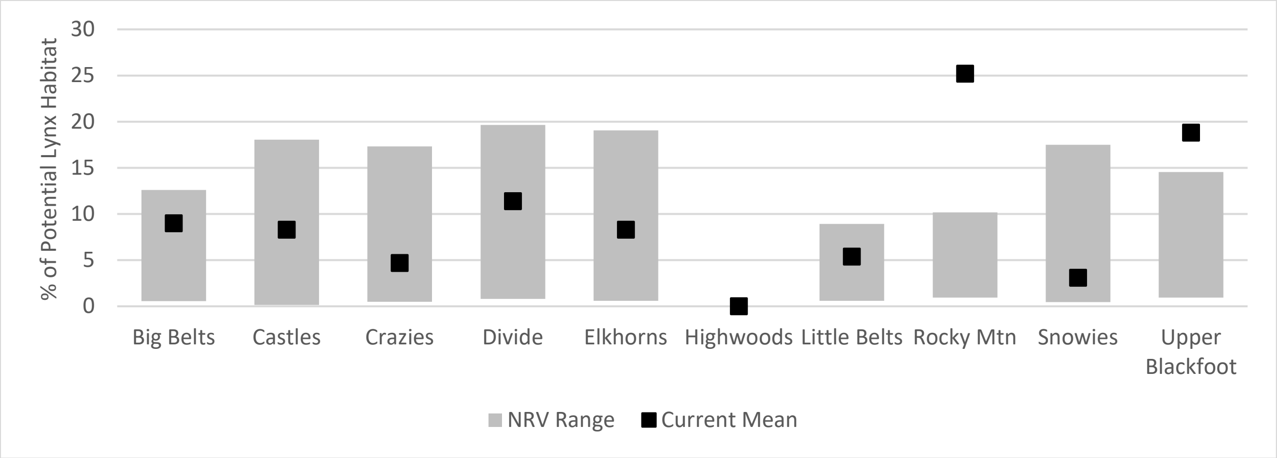


Figure 65. Lynx early stand initiation habitat forestwide and by GA, compared to existing condition

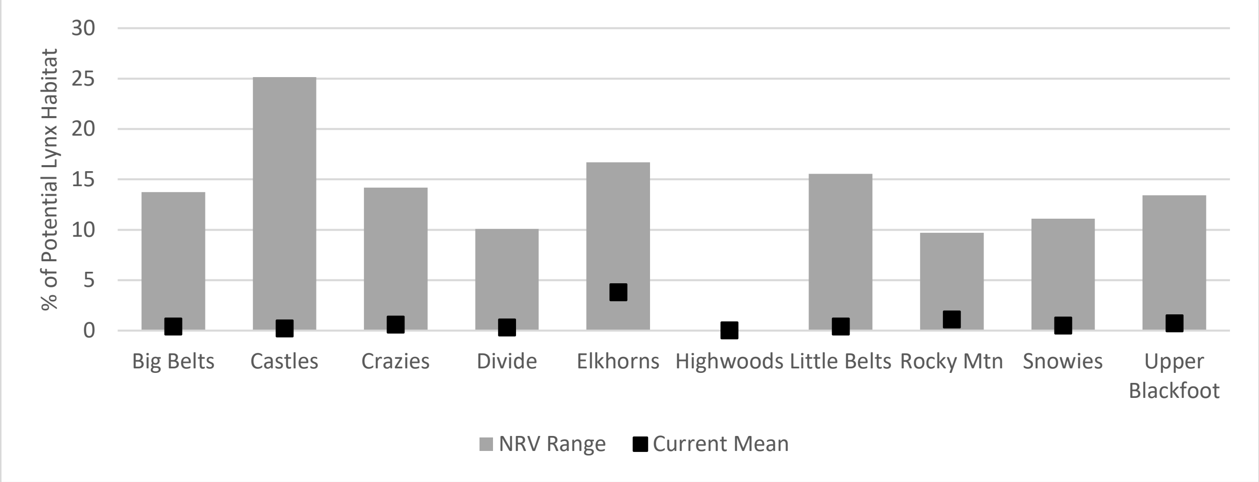


Figure 66. Lynx stand initiation habitat forestwide and by GA, compared to existing condition

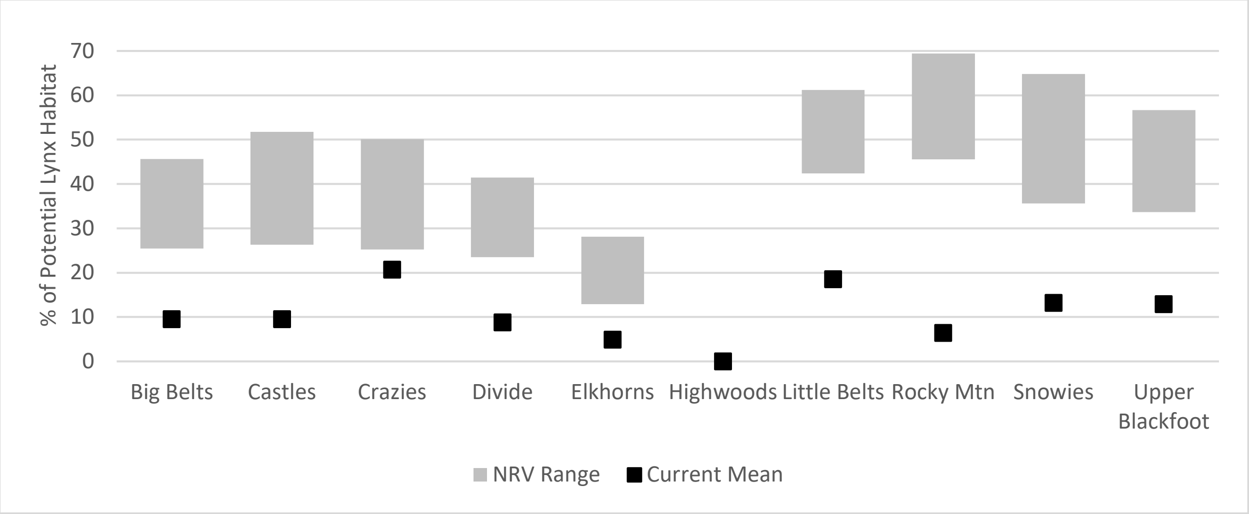


Figure 67. Lynx mature multistory habitat forestwide and by GA, compared to existing condition

Flammulated owl

Flammulated owls are a species of conservation concern for the HLC NF and are known to occur in only four of the ten GAs. They are dependent on large diameter, open ponderosa pine forests, although some literature indicates possible use of large, open Douglas fir types where ponderosa pine is absent (USDA 2011). Although modeling of the ponderosa pine cover type provides some information about potential flammulated owl habitat, the specific combination of cover type (ponderosa pine), tree size, and canopy cover queried from the model better approximates the estimated NRV for this species and for others that may require or use similar habitat. Estimates of existing flammulated owl habitat were made for the Assessment of the HLC NF (U.S. Department of Agriculture 2015) using data and queries described by Samson (Samson 2006a) and Bush and Lundberg (Bush and Lundberg 2008b). Those estimates are not directly comparable with estimates from SIMPPLLE. The estimates in this report should be used for comparisons to the NRV. The range for the estimated NRV and existing habitat is shown in Figure 68.

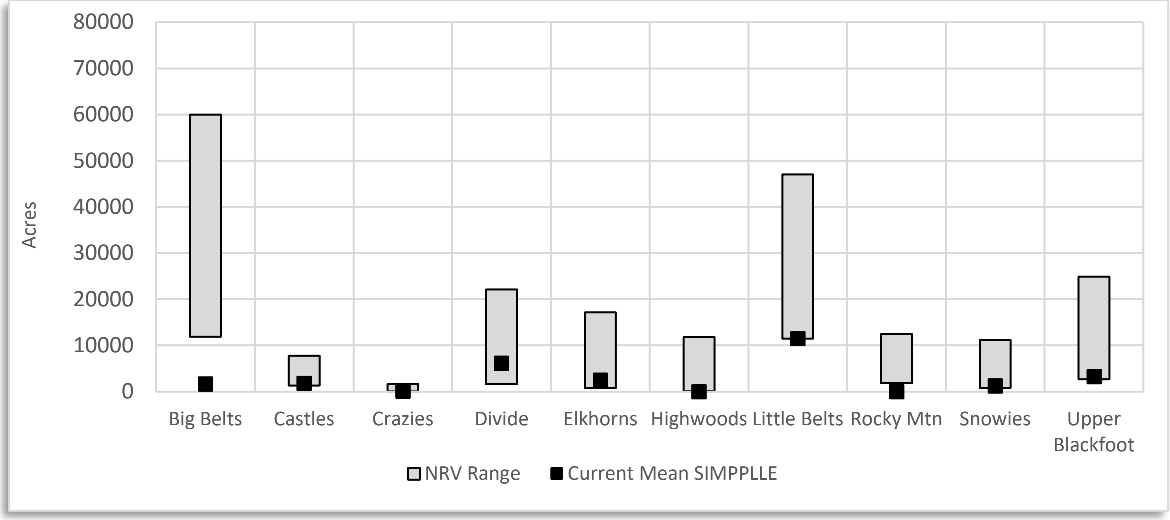


Figure 68. Flammulated owl nesting habitat NRV range of acres compared to existing condition, by GA

In all GAs the current estimates of flammulated owl nesting habitat are below or at the low end of the NRV. This parallels the coarse filter look at the ponderosa pine, which estimates that both abundance and distribution of ponderosa pine is below the NRV range for most GAs (see Figure 25, Figure 31, and Figure 38). Additionally, the existing large tree component of the warm-dry broad PVT, which includes ponderosa pine, appears to be below the estimated NRV (Figure 45), and the existing abundance of large snags in the warm dry broad PVT also appears to be lower than the NRV (Figure 80). Both the coarse filter and fine filter look at flammulated owl nesting habitat indicates that it may be less prevalent in most GAs than the NRV range. The NRV range in some GAs is broad, indicating the dynamic nature of the type as well as the level of uncertainty.

Although we modelled flammulated owl habitat for all GAs, this species has not been documented on the Lewis and Clark portion of the HLC NF (Rocky Mountain Range, Highwoods, Little Belts, Castles, Crazies, and Snowies GAs). All but the Rocky Mountain Range GA of the Lewis and Clark portion of the HLC NF are outside the known distribution of flammulated owls in Montana (Montana Natural Heritage Program and Montana Fish Wildlife and Parks 2019). The Rocky Mountain Range GA lacks ponderosa pine except for a few widely scattered individual trees and small stands, which may explain the absence of flammulated owls. The parameters used to model the NRV for this species included only vegetation types with large ponderosa pine.

Lewis’s woodpecker

Lewis’s woodpeckers are a species of conservation concern for the HLC NF, and are known to occur in only three of the ten GAs (Divide, Elkhorns, Big Belts), with historic records also in the Divide, Little Belts, Castles, and Highwoods GAs. Habitat for Lewis’s woodpeckers is similar to that described for flammulated owls, with the addition of large old cottonwoods in riparian areas and possibly a reliance on forests maintained by fire (Montana Natural Heritage Program and Montana Fish Wildlife and Parks 2019). The existing condition is estimated from the SIMPPLLE input file. The comparison of the estimated NRV and the existing abundance for this habitat is displayed in Figure 69.

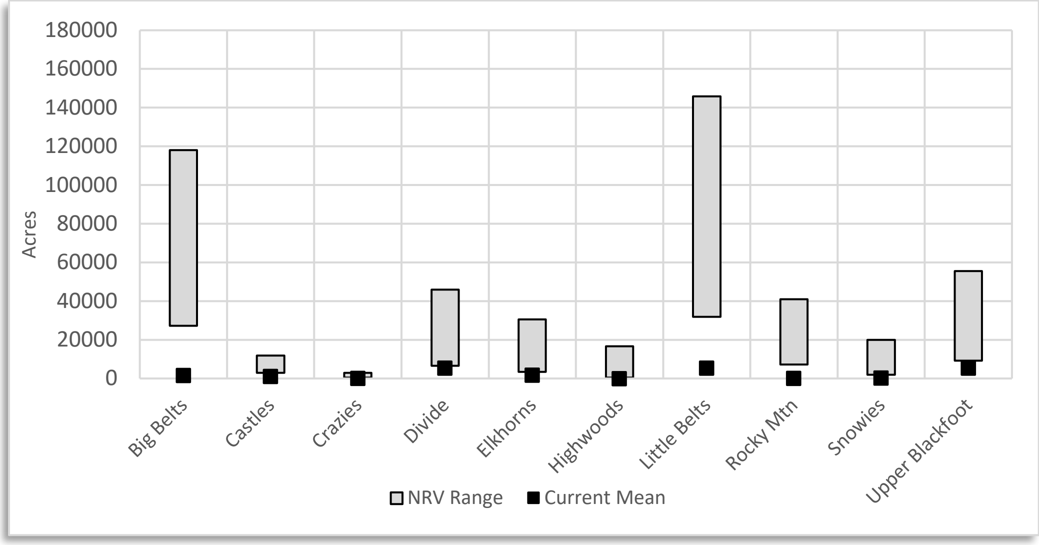


Figure 69. Lewis’s woodpecker nesting habitat NRV range of acres, by GA

As with flammulated owl, it appears that the greatest potential for Lewis’s woodpecker habitat is in the Big Belts, Little Belts, and Upper Blackfoot GAs and possibly the Rocky Mountain Range, Divide, and Elkhorns. Like flammulated owls, Lewis’s woodpeckers may be dependent on ponderosa pine, which does not occur on the Rocky Mountain Range GA except as isolated individual trees and small stands. Nevertheless, the known distribution of Lewis’s woodpeckers in Montana includes all GAs on the HLC NF (Montana Natural Heritage

Program and Montana Fish Wildlife and Parks 2019). Recent observations of Lewis's woodpeckers in the Divide GA may reflect presence of additional habitat in surrounding areas, including west of the Continental Divide.

Elk hiding cover

Management of elk habitat and elk distribution on NFS and adjoining lands have been issues of public interest for decades, and have often focused on the concept of elk security as a means to influence elk distribution and vulnerability to harvest. Elk security is defined as "the protection inherent in any situation that allows elk to remain in a defined area despite an increase in stress or disturbance associated with the hunting season or human activities" (Lyon and Christensen 1992). Management of elk security has often focused on management of human access through road and trail restrictions in combination with consideration or management of hiding cover. Hiding cover is defined as "vegetation capable of hiding ninety percent of a standing adult elk from the view of a human from a distance equal to or less than 200 feet" (ibid). There has been some question about the degree to which hiding cover on NFS lands may or may not influence overall elk distribution, particularly during hunting season. The NRV range presented here provides some insight into the inherent potential for various GAs to provide hiding cover, which may help to provide some context for management planning.

Estimates of hiding cover are usually made using estimates of canopy cover and may be coupled with estimates of other vegetation characteristics, such as Potential Natural Vegetation. The existing condition is estimated using the SIMPPLLE input file. Elk security, which considers distance from open motorized access routes and may include consideration of hiding cover, is usually analyzed and managed at the scale of an elk analysis unit. For this report we are only attempting to understand the natural range of a vegetation characteristic (hiding cover) on the landscape relative to its current condition, so we display hiding cover simply as total acres within a GA. This serves to address the question at a broad scale for forest-level planning, and avoids implications that a specific scale or percent is desired. Hiding cover is evaluated and displayed here by season, reflecting the different areas used seasonally by elk, and the different vegetation conditions that may provide cover in those areas and during those seasons. The estimated NRV for this habitat is displayed in the following figures, which include comparison with the estimated existing acres of available hiding cover.

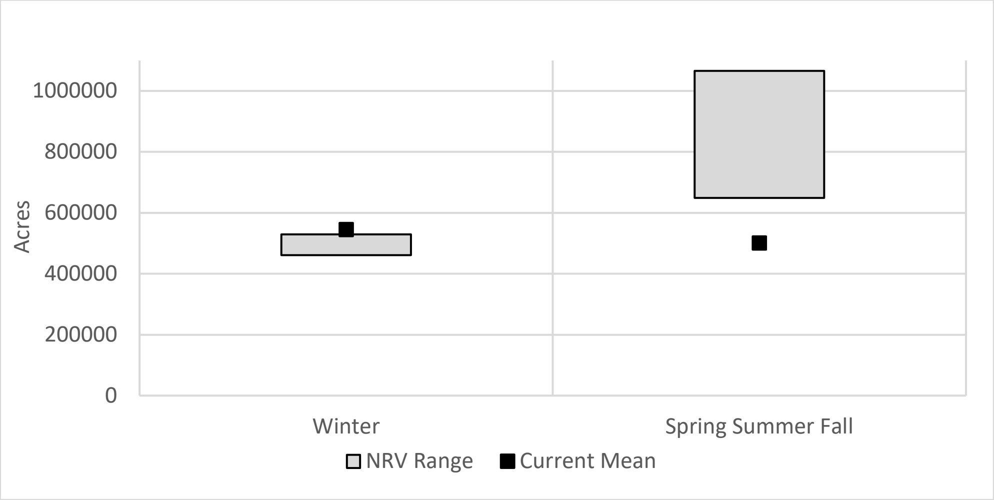


Figure 70. Rocky mountain elk habitat NRV compared to existing condition forestwide

Forestwide, the current amount of winter hiding cover is just above the NRV range, whereas the spring/summer/fall hiding cover is below.

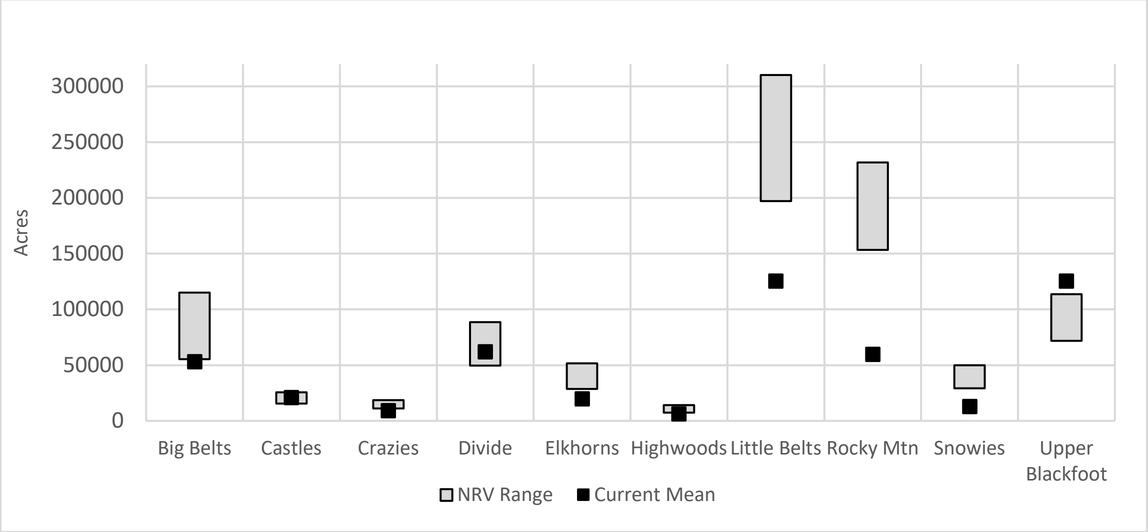


Figure 71. Rocky mountain elk spring/summer/fall hiding cover NRV, by GA, compared to existing condition

For many GAs, the estimated existing spring/summer/fall hiding cover is within the modeled NRV range. This habitat is below the NRV range in the Elkhorns, Little Belts, Rocky Mountain Range, and Snowies GAs; and above the NRV range in the Upper Blackfoot.

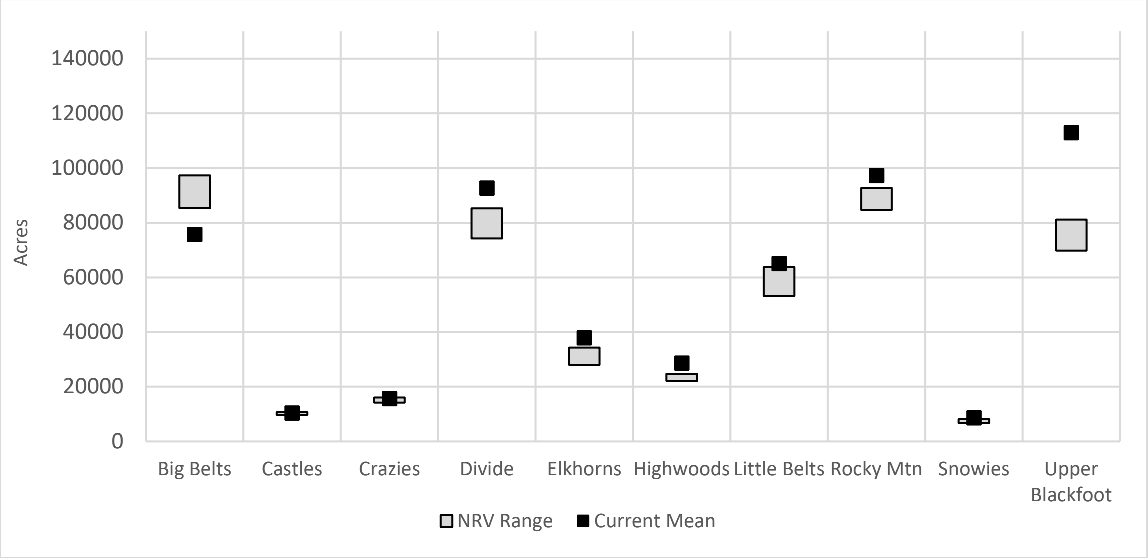


Figure 72. Rocky mountain elk winter hiding cover NRV, by GA, compared to existing condition

Winter hiding cover is estimated only for areas mapped as elk winter range. On some GAs, relatively little winter range occurs on NFS lands compared to the surrounding landscape. Currently, the Big Belts is the only GA that appears to provide less winter hiding cover than the estimated NRV range. All other GAs have an abundance of winter hiding cover within or above the NRV.

Additional key characteristics

Large and very large live trees

Large trees are those greater than or equal to 15” diameter, and very large trees are those greater than or equal to 20” diameter. These trees are important to wildlife species while alive, as snags upon death, and as large downed woody material when they fall. They are also important in creating and sustaining forests resilient to disturbances, in particular if they are fire-tolerant species. They have the potential to survive fires, providing seed to reforest burned areas, and provide live components in landscapes dominated by burned trees. This attribute reflects the average quantity of large and very large live trees on the landscape, distributed in groups or scattered individuals. This attribute is complementary but different than forest size class, which reflects the average diameter. Large and very large live trees are often found in areas classified as large or very large size class, but they also occur as minor components in areas with a smaller average size class where they are too few in numbers to offset the abundance of smaller trees. This attribute was not ultimately included in the 2020 Forest Plan as a desired condition, because the desired condition for large-tree structure (below) sufficiently provides for large and very large trees.

SIMPPLLE does not model large and very large trees per acre. The information source used to assess NRV is an analysis that estimated large and very large trees inside and outside wilderness and roadless areas for NFs east of the Continental Divide in Region 1 (Bollenbacher et al. 2008), with queries of period FIA data updated in 2017. The amount of large and very large trees in wilderness and roadless areas could be indicative of historical levels because these areas have been less impacted by anthropogenic influences (Bollenbacher et al. 2008). The data in wilderness/roadless areas that is used to depict the NRV was summarized prior to the recent mountain pine beetle outbreak. This is compared to existing condition estimates derived from the most recent FIA data (2011), for each snag analysis group. Snag analysis groups are consistent with R1 broad PVTs, except that lodgepole pine dominated forests are broken out because this species is unique relative to its tree size and snag characteristics.

As shown in Figure 73 and Figure 74, the confidence intervals around the existing condition estimates are within or partially overlap the NRV. This indicates that the abundance of large and very large trees is generally within the NRV at the forestwide scale. The data is not available at the GA-area scale; based on the trends for size class, which showed that large and very large size classes are less common than they were historically, it is likely that the abundance of large and very large trees is underrepresented in some areas. However, compared to the large and very large size classes, these trees are present on a larger area of the landscape as minor components.

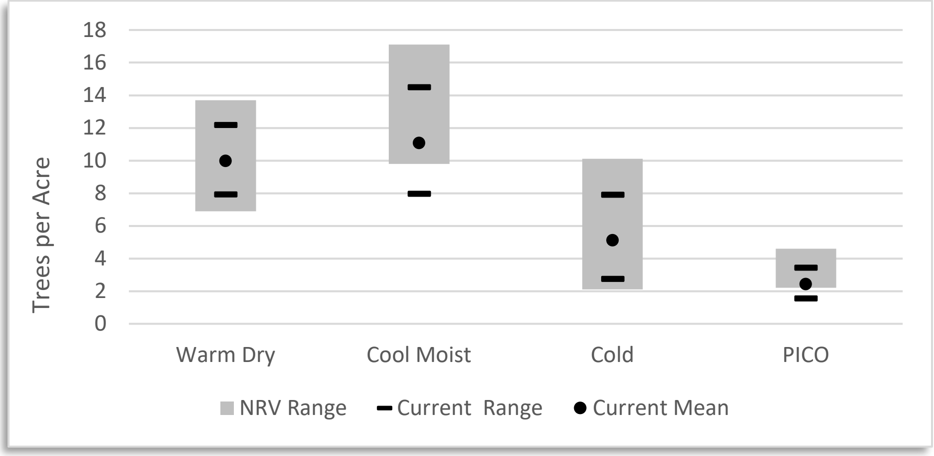


Figure 73. Large trees per acre, NRV compared to existing condition

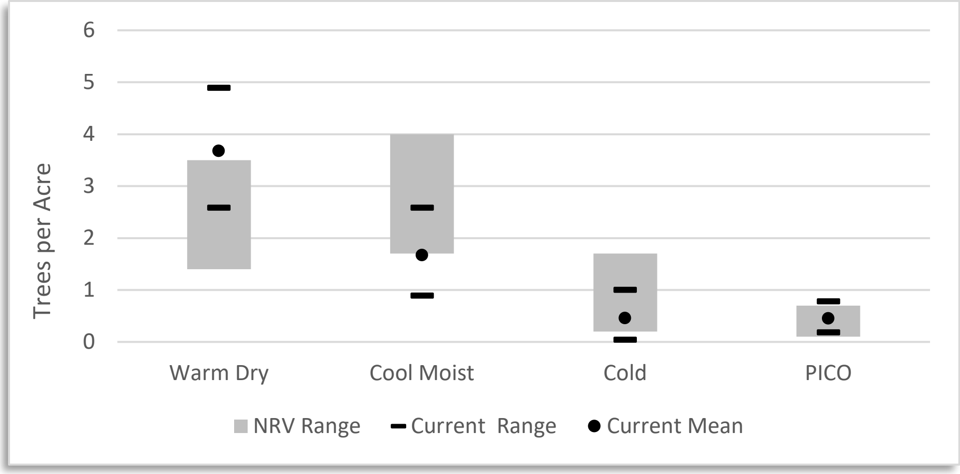


Figure 74. Very large trees per acre, NRV compared to existing condition

The existing condition for large and very large trees per acre is consistent with the NRV (wilderness and roadless areas. This may indicate that the overall quantity of large and very large trees is not substantially different than the amount that would occur naturally. Still, it is likely that in some landscapes large and very large trees are less prevalent than they were historically, given that large and very large size classes are below the NRV, and the understanding that early harvesting practices removed many large trees. These trees also likely declined due to fires and insect and disease activity. In addition, the trend that forest densities are higher than the NRV would indicate that large tree development has been inhibited. Stand density is an important factor that influences the development of large trees; lower densities in young forests may help develop large trees in the future.

Large-tree structure

Several key characteristics have thus far addressed tree size, including size class and the quantity of large and very large trees. Here, a third element is explored called “large-tree structure”. Large-tree structure categories are defined by the presence of certain minimum quantities of large or very-large trees and provides complementary information by displaying the proportion of the landscape that contains enough of these trees to be meaningful for ecosystem functions such as seed dispersal and wildlife habitat. As with individual large and very large trees, large-tree structure may occur in any forest size class. Areas with large-tree structure are defined in appendix D of the 2020 Forest Plan. These definitions are based on quantities of trees that would be meaningful to wildlife habitat and represent a substantial influence on forest structure and process (such as providing seed).

The way existing data is classified into large-tree structure roughly correlates to the way SIMPPLLE classifies the large/very large size class. Unlike the size class analysis, the SIMPPLLE estimates for the large and very large size class are not adjusted, because the presence of large and very large trees influenced the classification in a similar fashion. The existing condition is estimated using the latest FIA data.

Figure 75 and Figure 76 display the NRV proportion of the landscape with large-tree structure compared to the existing condition, forestwide and by broad PVT. For all PVTs, the existing condition of large category is below the NRV. Except in the cold PVT, the existing distribution of very large category is also below the NRV, but not to a great extent as these trees tend to be rare naturally on the HLC NF. The mechanisms that have caused the large-tree structure to be less than the NRV are the same as described for the large and very large size class.

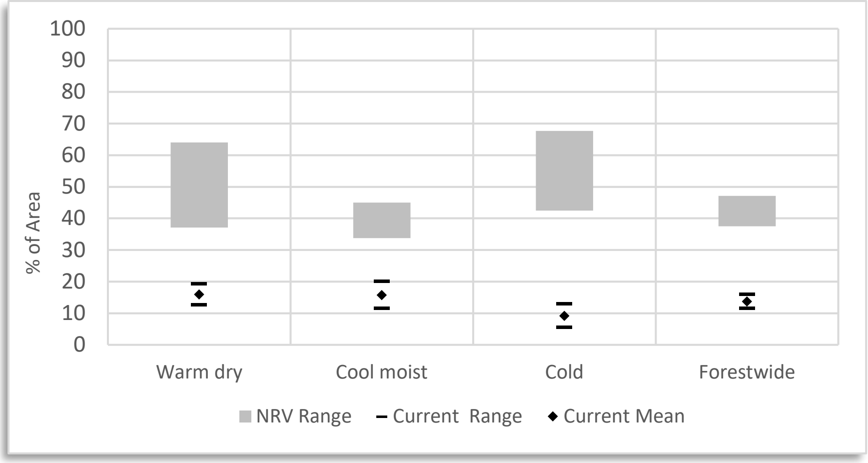


Figure 75. NRV of large-tree structure, large category, compared to existing condition, forestwide and by PVT

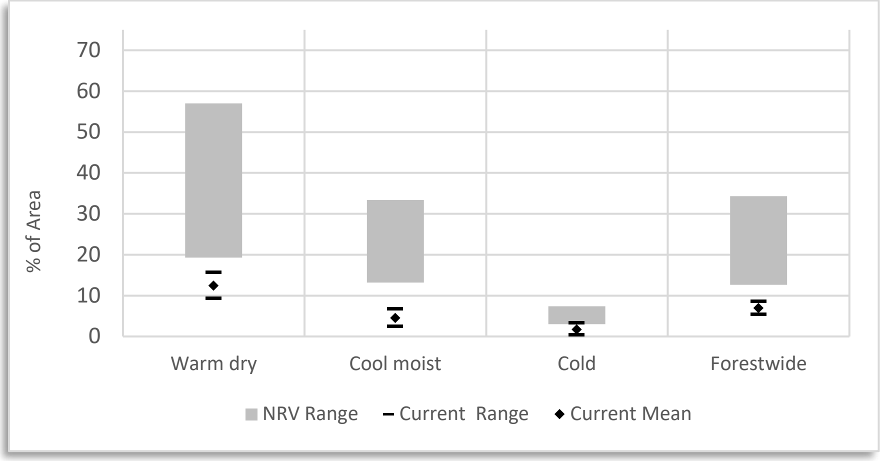


Figure 76. NRV of large-tree structure, very large, compared to existing condition, forestwide and by PVT

Figure 77 and Figure 78 display the comparison of NRV to existing condition for these components by GA. The trends are generally consistent with the forestwide averages, although the range around the existing condition estimate approaches the lower bound of the NRV in the Crazies, Elkhorns, and Highwoods. For the very large category, the Castles, Crazies, and Elkhorns have existing levels similar to the NRV, and all other GAs are below.

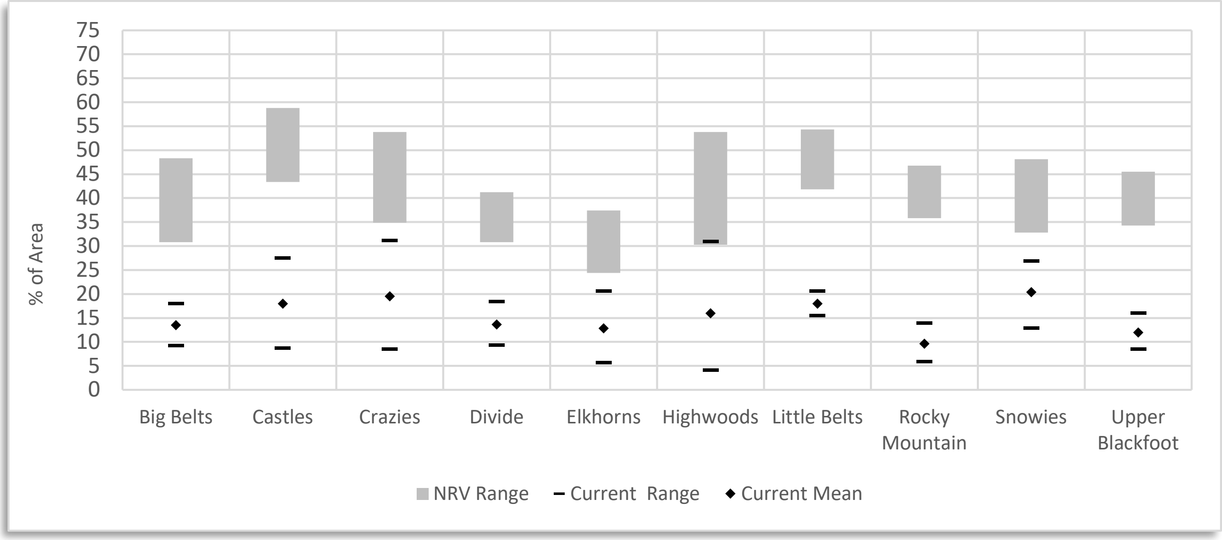


Figure 77. NRV distribution of large-tree structure, large category, compared to existing condition, by GA

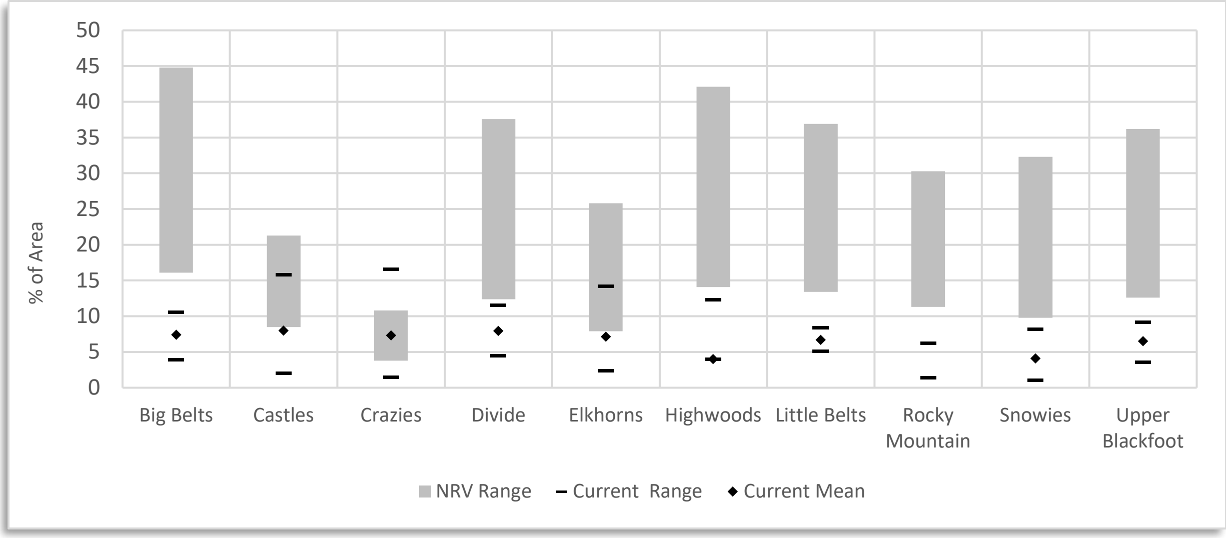


Figure 78. NRV distribution of large-tree structure, very large category, compared to existing condition, by GA

The development of large trees is influenced by growing conditions, disturbances, and species traits. On the HLC NF, the common tree species most likely to reach large and very large size classes are ponderosa pine and Douglas-fir, and to a lesser extent Engelmann spruce, whitebark pine, subalpine fir, and western larch. Large trees may develop where frequent disturbance maintains low density, and/or on productive sites which provide ample moisture and nutrients for individual tree growth. Large tree development also occurs in refugia areas protected from disturbance. The comparison of the NRV of SIMPPLLE size classes to the existing condition indicates that, similar to size class, large-tree structure is less abundant across the landscape than it was historically.

Snags

Snags, or standing dead trees, are important elements of forest structure, diversity, and wildlife habitat. Fire is the dominant natural disturbance process that creates snags. Natural mortality occurs also due to competition, insects, diseases, and other natural events. The availability of large snags depends on the growth of large live trees. Large snags are of particular interest due to their longevity and suitability for wildlife habitat. SIMPPLLE does not provide a quantified NRV for snags. NRV ranges are derived from recent literature (Bollenbacher et al. 2008) for medium (10"+ diameter), large (15" +), and very large (20"+) snags using data within wilderness/roadless areas prior to the mountain pine beetle outbreak. Snag characteristics in these areas may be indicative of a natural condition because disturbances have been allowed to occur and human management is limited (ibid). Updated snag queries were conducted by the Regional Office to augment the Bollenbacher et al 2008 report in March of 2017; these updated figures are used.

Snags are summarized by snag analysis groups, which are synonymous with the broad PVTs, except that lodgepole pine dominated areas ("PICO") are analyzed separately. Different snag conditions are expected in these types based on the natural disturbance regime. For example, the availability of snags in the warm dry PVT would be influenced by a low severity, high frequency disturbance regime which supplies a fairly constant flow of snags. By contrast, the cool moist PVT would contain more variability in snag quantity and distribution due to a high severity, low frequency regime. Lodgepole is summarized separately because the processes that create and maintain snags are unique for this species. Lodgepole snags tend to be small in diameter and are created by large stand replacing events. Thus, they tend to occur as "pulses" on the landscape. Further, these snags are not windfirm and tend to fall relatively quickly.

As Figure 79 shows, the trees per acre of medium snags tend to be within the NRV, although at the upper end of the range in the warm dry PVT. This is a common tree size and large snag pulses can occur after events such as large wildfires that kill smaller trees of all species.

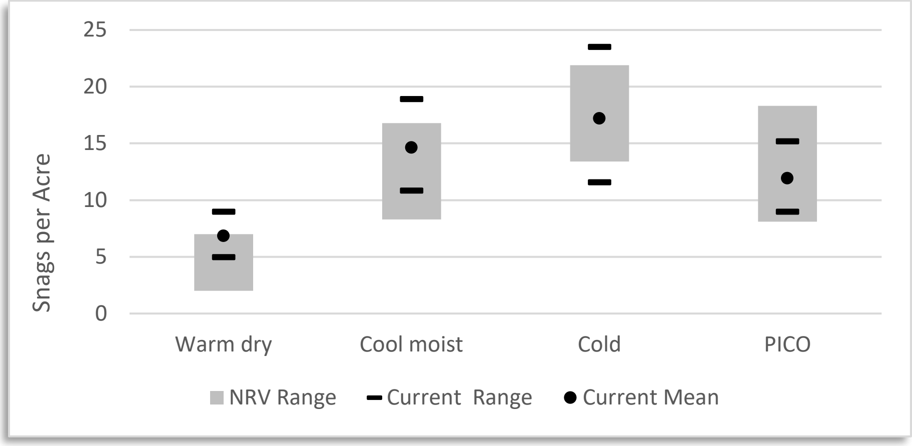


Figure 79. NRV of medium snags per acre compared to the existing condition by snag analysis group

Large snags (Figure 80) are much less common than medium snags; however existing conditions are generally within or slightly higher than the NRV condition, due to recent insect outbreaks and wildfires.

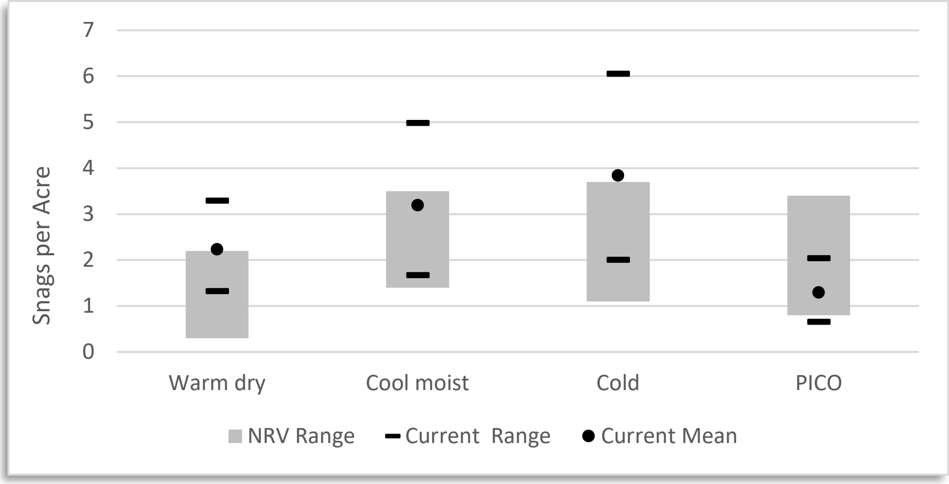


Figure 80. NRV of large snags per acre compared to the existing condition by snag analysis group

Very large snags are rare, as are very large live trees, on the HLC NF. The existing snags per acre of this size are generally consistent with the NRV ranges in the cold and PICO snag analysis groups, but slightly higher than the NRV in warm dry and cool moist due to recent disturbances.

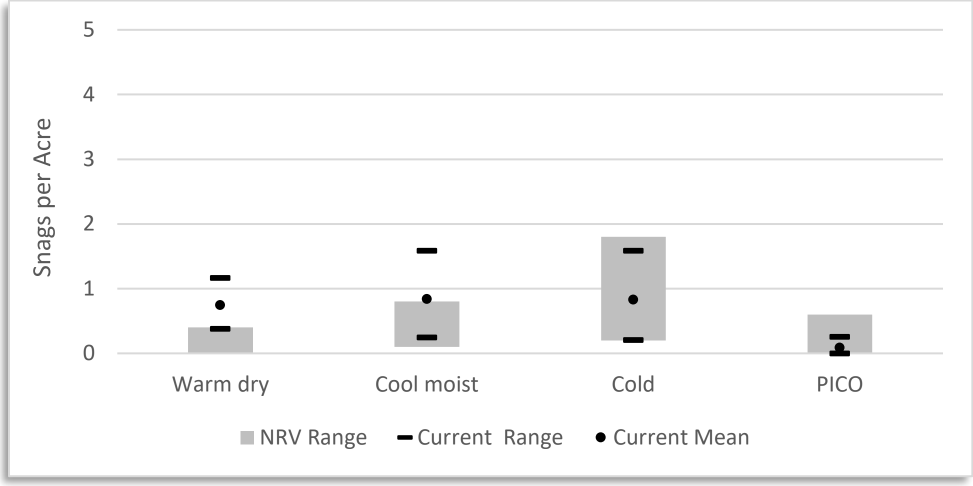


Figure 81. NRV of very large snags per acre compared to the existing condition by snag analysis group

Snags are irregularly distributed. Large and very large snags may be naturally rare on the HLC NF (Bollenbacher et al. 2008), as influenced by the processes that allow large and very large trees to grow. The interactions of processes that influence the snag resource are complex. For example, fire suppression may have caused a reduction in the amount of snags that would otherwise have been created with fire. Conversely, snags could be more abundant currently in places where fire or insect-caused mortality may be more severe than would be expected historically due to increased forest homogeneity or fuel build-up. In the future, we may expect larger pulses of snags with more fires and insect outbreaks. Because large and very large live trees and components may be below the NRV, this indicates that development of large snags may also be below the NRV in the future.

Downed woody debris

Downed woody debris on the forest floor provides for feeding, hiding, denning, and shelter habitat to numerous wildlife species, and is important for long term nutrient cycling and other ecosystem functions. Downed wood is recruited as snags and branches fall and diminish over time through decomposition or by being consumed by wildfire. Therefore, the trend of downed wood is intertwined with all of the disturbances and drivers that affect vegetation. Both quantity and distribution of this material is important. Downed woody debris cannot be modeled with SIMPPLLE. Different amounts, sizes, and distributions are meaningful for different resources (wildlife, fuels, and soils). For wildlife habitat, downed wood of the largest sizes (>10" diameter especially) is the most valuable, and the most meaningful measure is percent cover of downed wood. However, this measure is not available in available data sources. For both fuels and soils considerations, a common measure is tons/acre of woody material greater than 3" diameter; this is quantifiable with FIA data. 3" is also the minimum size for coarse woody debris used in the best available scientific information (Brown, Reinhardt and Kramer 2003).

The quantities and distribution of downed woody debris in wilderness and roadless areas are used to describe the NRV. Table 5 was developed to compare NRV and existing condition in terms of large woody debris distribution (>3" diameter) using FIA plot data; the methodology for these queries is described in appendix H of the FEIS. There is no appreciable difference in the distributions in wilderness/roadless areas versus the landscape as a whole. The information shows that 30 to 50% of the landscape has no woody debris present, and that distribution is greatest on cool moist broad PVT. Most of the woody debris present is <10 tons/acre, with small portions of the landscape containing higher amounts.

Table 5. Distribution of large woody debris (1000-fuels or >3" dbh)

Scale		CWD Distribution (Presence)				
		>=0 tons/ac	>=5 tons/ac	>=10 tons/ac	>=20 tons/ac	>=40 tons/ac
Forest-wide	Wild/IRA	56%	26%	14%	6%	2%
	Existing	55%	25%	15%	6%	2%
Warm dry	Wild/IRA	59%	19%	4%	0%	0%
	Existing	57%	17%	6%	1%	0%
Cool moist	Wild/IRA	64%	42%	26%	10%	3%
	Existing	65%	43%	28%	11%	3%
Cold	Wild/IRA	52%	23%	17%	11%	5%
	Existing	51%	24%	16%	9%	3%

Table 6 shows a potential NRV for quantity of large woody debris (in wilderness and roadless) compared to the existing condition of woody debris >3" diameter. The existing condition is similar to the NRV forestwide and in the warm dry PVT, but slightly less in cool moist and cold.

Table 6. NRV and existing tons/acre of large woody debris >3" diameter by broad PVT

Scale	Tons/ac >3" diameter	
	In wilderness/IRA	Existing condition
Forestwide	5.64 (4.8-6.6)	5.24 (4.57-5.98)
Warm dry	3.4	3.38 (2.66-4.19)
Cool moist	10.6	7.22 (5.81-8.76)
Cold	10.3	7.04 (5.33-8.91)

The best available scientific information regarding the NRV condition for coarse woody debris on the HLC NF was reviewed (Brown et al. 2003, Graham et al. 1994). Brown et al (2003) take into account many considerations of woody debris, including wildlife habitat, soil nutrient cycling, fire hazard and behavior, soil heating, and historic levels of coarse wood. The ecosystem conditions described are relevant to the HLC NF, although they are most specific to conditions found west of the continental divide. The natural range of downed wood, particularly in the warm dry types on the HLC NF, is likely lower than that specified by Brown et al (2003) because the data for this type includes areas which are open savannas, where grass and shrubs dominate and trees are widespread.

The broad PVTs would be expected to have different levels of downed wood based on disturbance ecology. The warm dry PVT would be expected to have the least quantity overall, as well as the least percentage of area with downed wood, indicating that relatively high proportions of this type area may have very low levels of downed wood at any given time consistent with the natural disturbance regimes expected in drier cover types such as ponderosa pine and Douglas-fir. Conversely, the cool moist and cold PVTs would have higher levels of downed wood that is distributed across a higher proportion of the area, especially in spruce/fir and lodgepole pine.

Fire suppression, particularly on dry sites, has likely allowed for a buildup of downed wood in some areas that would otherwise have been maintained at lower levels. Even so, the current average tons per acre of large woody debris is lower on these sites (such as ponderosa pine and dry Douglas-fir) than on moist sites where woody debris would naturally be higher (such as spruce/fir). Recent large scale mortality events such as the beetle outbreak are expected to create high downed woody debris levels across large areas in the short term, particularly in the lodgepole pine cover type. Homogeneity in forest conditions perpetuates pulse in downed wood. Hotter/drier conditions and more fires might mean less downed wood, or possibly wider swings in amounts/distributions.

Old growth

Old growth is a late-stage successional forest condition that is valuable for wildlife habitat and biodiversity. Old growth is defined for Region 1 based on minimum criteria such as tree age, size, stand density, and other components such as snags and downed wood (Green et al. 1992). There is no means to quantify the NRV for old growth, because the characteristics can be determined only through site specific inventory. Further, there is no know best available scientific information to quantify the NRV condition of old growth abundance, distribution, or patch size specific to the landscapes on the HLC NF. However, based on the minimum tree size requirement, old growth is most likely to be found where large-tree structure is distributed. However, only a proportion of areas with large/very large tree components are actually old growth. The FIA data (Table 7) show that nearly half (44%) of the plots with large-tree structure are old growth today.

Table 7. Proportion of plots that are old growth forestwide, base FIA

Large/Very Large Tree Subclass	% old growth
Large Tree Concentrations	20% (14-26)
Large or Very Large Tree Concentrations	24% (17-31)
Large or Very Large Tree Concentrations Not Present	5% (4-7)

Large-tree structure can be compared to large and very large size classes in SIMPPLLE. Therefore, in rough terms, 44% of the areas in the unadjusted large and very large size classes in the NRV may have been old growth (Table 8). The large size class is lower than the NRV and increases are desired; therefore, it is likely that there is also less old growth on the landscape than in the NRV, especially in the warm dry PVT. Although the analysis serves only as a rough proxy of a rigorous NRV analysis, it supports the notion that old growth is likely less abundant on the HLC NF, at the broad scale, than it was historically, with the possible exception of the cool moist broad PVT. This trend may vary by GA and at smaller scales depending on the unique disturbance history and vegetation types of a given area.

Table 8. Existing old growth (Hybrid 2011) and potential NRV abundance

Scale	Existing Condition[1]	Potential NRV[2]
Forestwide	11% (9-13)	20-25%
Warm dry	8% (6-11)	33-52%
Cool moist	14% (10-19)	11-19%
Cold	15% (11-20)	28-40%

1 Existing condition is based on FIA plots, Hybrid 2011 dataset

2 NRV is based on 44% of the large/very large size classes modeled in SIMPPLLE

Literature sources indicate that in fire prone landscapes the historic amount of old growth was probably not very high. For example, in the island mountain range GAs, old growth was not very abundant historically due to frequent prairie fires (Losensky 1993b). Fire exclusion may have altered old growth in all areas. Increasing tree densities and canopy layers may have increased tree stress and vulnerability to mortality from insects, pathogens, and high intensity crown fires. Landscapes with a heterogeneity in age class, species composition, and structure can provide for a more stable proportion of old growth over time than those with a homogeneous character. Old growth will be subject to increased disturbances and may represent important refugia areas for biological legacies, seed sources, habitat, and carbon storage.

Summary

The NRV results displayed in this report provide the context for understanding ecosystem integrity on the HLC NF and will be used as a backdrop throughout the forest plan revision process. One key function of this analysis will be to inform the development of desired future conditions for vegetation key characteristics. Along with NRV, additional considerations will inform the desired conditions, including but not limited to: ecosystem resilience and adaptation given the uncertainties of future climate and disturbances which may differ from the climate conditions of the past; sustaining important wildlife habitat conditions; consideration of social and economic factors; and consideration of other human uses on the landscape. Therefore, while the desired conditions may not always be equivalent to the NRV, they are governed by a prevailing concept to maintain ecosystem resilience as informed by this evaluation of NRV.

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