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Landscape-Scale Dynamics of Aspen in Rocky Mountain National Park, Colorado

Margot W. Kaye[1], **Kuni Suzuki**[2], **Dan Binkley**[1], **and Thomas J. Stohlgren**[3]

Abstract—*Past studies of quaking aspen in Rocky Mountain National Park suggested that the aspen population is declining due to intensive browsing by elk (Cervus elaphus). These studies were conducted in the elk winter range, an area of intensive elk impact. The elk summer range experiences less intense grazing pressure. We tested the hypothesis that impacts of elk would be greater in the elk winter range than the summer range with landscape-scale data from the Park. The detrimental effects of elk on aspen are highly localized and, at larger spatial scales, elk browsing does not seem to be influencing the aspen population.*

Quaking aspen forests can be considered both a rare and important habitat type in the central Rocky Mountains. In the region of Rocky Mountain National Park, Colorado, aspen forest covers less than 10% of the forested landscape. However, considerable floral and faunal diversity is associated with the forest type (DeByle 1985; Turchi et al. 1995). Aspen has been called a "hotspot" of diversity (Stohlgren et al. 1999), and it is valued for its aesthetic beauty. Within the Park, many studies have concluded that aspen forests are in decline due to excessive browsing by elk (*Cervus elaphus*) (Baker 1997; Olmsted 1979; Packard 1942). These studies have focused on portions of the elk winter range within the Park, which itself is only a fraction of the landscape (figure 1).

The elk winter range represents the area in the Park that is most likely to be highly impacted by elk (DeByle 1985). Large numbers of animals (approximately 2,000 individuals in 1999) rely on these low-elevation areas for winter forage. The browsing of stems and shoots of aspen trees by elk both removes new growth and creates wounds for pathogen introduction (Hinds 1985; Krebill 1972). The summer range, in contrast, is a much larger, high-elevation area where elk densities are lower and forage availability is much higher due to the summer growing season and the loss of snowpack. Due to differential use of the winter and summer ranges within the Park, one would expect the impacts of elk to be much greater in the winter range than the summer range.

The spatially dependent foraging patterns of elk indicate that the effects of elk browsing should be site dependent, and therefore studies of the effects of elk on aspen will likely be influenced by their spatial scales. Previous studies of aspen that focused on the elk winter range in the Park considered small spatial scales. To gain a broader understanding of the status of aspen in the Park, landscape-scale studies are necessary to measure the status of aspen throughout the Park, where elk forage intensity ranges from low to high.

This paper summarizes the results of two landscape-scale studies of aspen conducted within Rocky Mountain National Park. A goal of both studies was to determine the effects of elk on aspen. The first study measured regeneration in aspen stands in the elk summer and winter ranges in the Park and the surrounding Roosevelt National Forest (Suzuki et al. 1999). We only used the data collected from the Park by Suzuki et al. (1999). The second study surveyed

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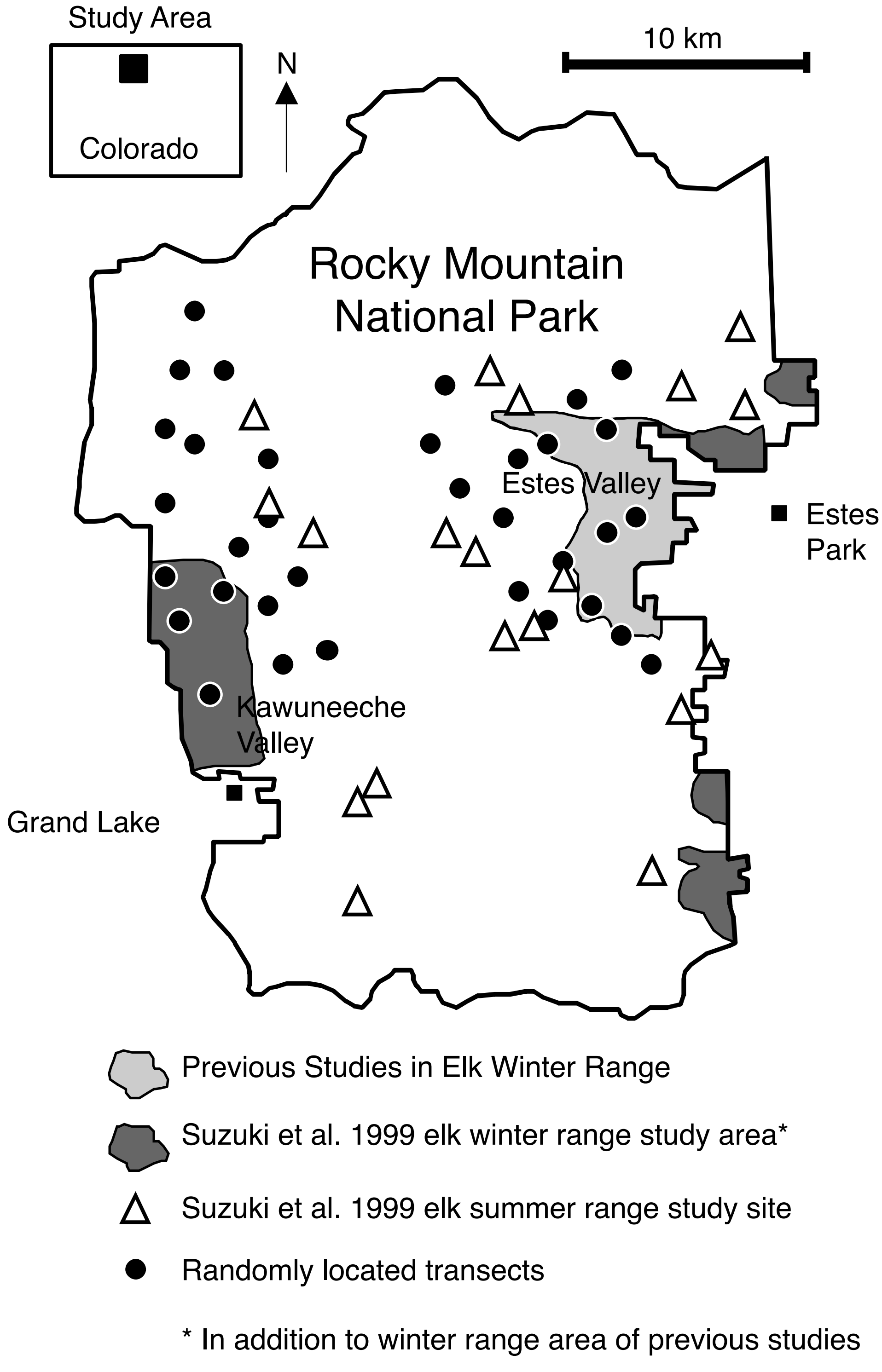

Figure 1—Location of study sites within Rocky Mountain National Park. Light gray areas represent the study areas in Estes Valley for Packard (1942), Olmsted (1979), and Baker et al. (1997). Suzuki et al. (1999) collected data from the Estes Valley area, as well as from other sites in the elk winter range (dark gray) and elk summer range (open triangles). Randomly located belt transects were surveyed throughout the park to describe the aspen population (black circles).

aspen in randomly selected areas throughout the Park and described aspen patch characteristics and degree of elk browsing. Based on the results of previous studies (Baker 1997; Olmsted 1979; Packard 1942), we hypothesize that the effects of elk browsing will be higher in aspen stands within the elk winter range than in stands in the summer range. The effects of elk browsing on aspen were measured by the amount of aspen regeneration, degree of browsed bark, and other forest metrics that represent stand condition (e.g., aspen basal area, density, and cover).

As mentioned above, aspen covers a small portion of the landscape but it is an important habitat type. An accurate description of the amount of aspen on the landscape requires high-resolution data. Many of the estimates of aspen cover in the region of the Park have been based on remotely sensed data such as LANDSAT imagery and aerial photographs and have found a cover of approximately 2%. We used the data from the ground survey to calculate the percent cover of aspen throughout the Park and to compare the resolution of remotely sensed data to field data.

Methods

Rocky Mountain National Park is located in the Front Range of north-central Colorado and straddles the Continental Divide. The Park covers an area of approximately 107,536 ha and elevations ranging from 2,300 m to 4,300 m. Aspen covers less than 10% of the forested area of the park and is found at all forested elevations.

Suzuki et al. (1999) gives a detailed description of the methods used to determine the extent and timing of regeneration throughout the Park. We divided the Park landscape into three zones relative to the intensity and season of elk use: (1) highest use—elk winter range in Estes Valley, between 2,400 and 2,800 m elevation (using data from Baker et al. 1997 and additional data from this project); (2) moderate use—elk winter range inside the Park, but outside Estes Valley; and (3) lowest use—elk summer range inside the Park, above 2,800 m elevation (figure 1). In each zone, all aspen stands were mapped and then a sub-sample of stands was chosen at random for measurement. We focused only on aspen stands that did not have major conifer encroachment and that had dominant individual trees that were >50 years old.

In the elk winter range of Estes Valley, Baker et al. (1997) identified 72 stands of aspen (stand defined as >10 trees), and they selected 17 stands for measurement. We mapped an additional four stands and sampled two. In the elk winter range outside Estes Valley, we mapped 34 stands and sampled 16. In the elk summer range, we mapped 387 stands and sampled 23 stands.

We followed the measurement procedures used by Baker et al. (1997) to allow comparisons between the studies. In each sampled stand, 10 x 10 m plots were subjectively located to represent a typical portion of the stand. In each plot, we tallied (by 20-mm diameter classes) the number of live aspen trees >2.5 m tall (above the reach of elk browsing, a value used by Baker et al. [1997]) and >20 mm diameter at 1.4 m d.b.h. (diameter at breast height). Ten or more increment cores were taken in each plot to determine stem ages, covering the entire range of diameter classes. Tree ages were determined to within five years of accuracy. We used the relationship between diameter and age within each plot to estimate the age of the uncored trees.

In the second study, an unbiased description of the aspen population, we conducted a ground survey. Thirty-six points were randomly located throughout the forested area of the central portion of Rocky Mountain National Park. From each point we surveyed two perpendicular belt transects, each 1,000 m long and 50 m wide. We recorded the position and size of each patch encountered within the belt transects and collected descriptive data within sample plots.

Within each aspen patch encountered in the belt transects, we subjectively located 5 m x 5 m plots to represent a typical portion of the patch. Within each plot, the following information was recorded for stems >1.5 m in height: number of stems, d.b.h. (taken at 1.4 m), height, and a visual estimate of percent bark browsed. We counted the number of stems <1.5 m in height, what we will refer to as "aspen regeneration." We calculated averaged percent of bark browsed for all stems within the plots, patch basal area (m^2/ha), and density (stems/ha). We separated data from patches based on their locations within elk summer or winter ranges, and we compared means using analysis of variance with a significant p-value of less than 0.05.

Results

We used data from 58 aspen stands and 36 randomly located transects throughout Rocky Mountain National Park to determine the impacts of elk on aspen (figure 1). Aspen regeneration was low in Estes Valley, with 20% of the aspen stands developing a regeneration cohort in the past 25 years (figure 2). Regeneration was higher in other areas of elk winter range in the Park (45% of stands) and in the elk summer range (high elevation) of the Park (70% of stands) (figure 2).

We ground-surveyed a total of 238 hectares throughout the Park. In that area, we encountered 112 aspen patches that covered 6.4% of the landscape—more than three times as much cover as the 2% estimated from remotely sensed data. Of the 112 aspen patches, 49 were within the elk winter range of the Park and 63 within the summer range. Mean percent bark browsed in the elk winter range (mean = 67%, SE = 4.9) was higher (p = 0.005) than mean percent bark browsed in stands within the summer range (mean = 49%, SE = 4.1) (figure 3a). Mean regeneration for elk winter range and mean regeneration for elk summer range were not significantly different (winter range mean = 21,906 stems/ha, SE = 4,175; summer range mean = 19,095 stems/ha, SE = 4,411) (figure 3b), but it is interesting to note that the mean number of regenerating stems per hectare in the elk winter range was higher. Mean basal area and density for aspen patches in the elk winter and summer ranges were not significantly different (winter range mean basal area = 23.75 m^2/ha, SE = 4.25; summer range mean basal area = 26.16 m^2/ha, SE = 3.62; and winter range

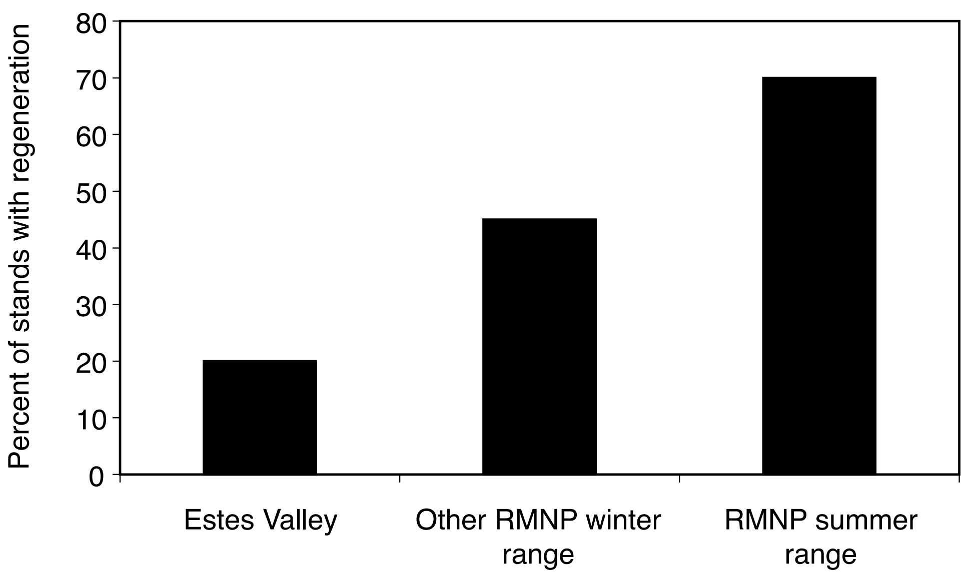

Figure 2—Percent of stands with regeneration in the past 25 years from Suzuki et al. (1999). Nineteen stands were sampled in Estes Valley, the region of highest elk foraging. Sixteen stands in other regions of the elk winter range in the Park than Estes Valley were sampled. The area of lowest elk browsing was the elk summer range in the Park, where 23 stands were sampled.

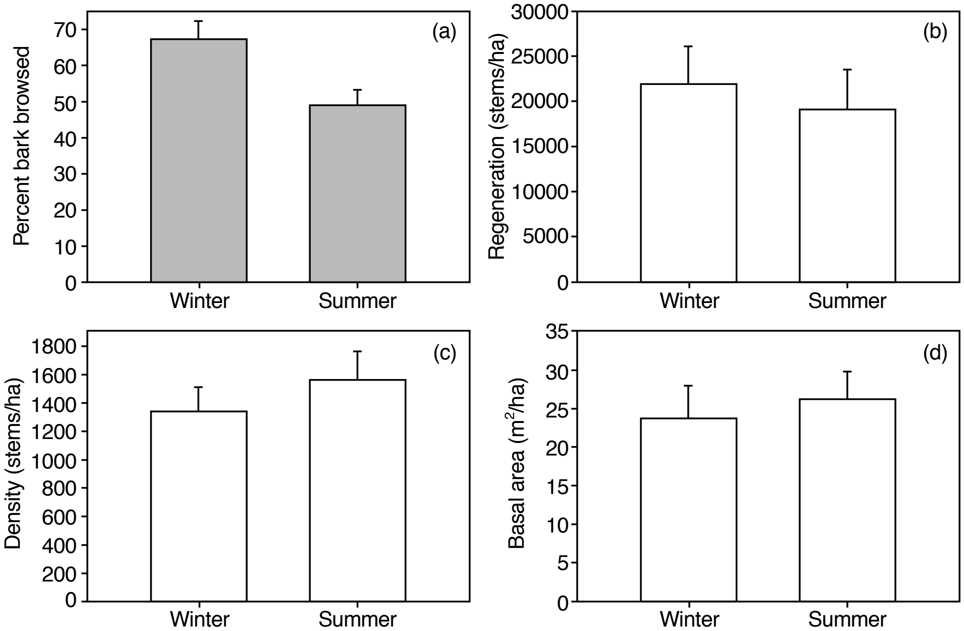

Figure 3—Comparison of aspen characteristics in the summer and winter range, based on data from the randomly located ground survey. Based on ANOVA analysis, only percent bark browsed (a) was significantly different. Regeneration (b), density (c), and basal area (d) were not significantly different between the elk summer and winter ranges.

mean density = 1,339 stems/ha, SE = 169; summer range mean density = 1,558 stems/ha, SE = 199) (figure 3c and 3d). Percent aspen cover in the elk winter range was 6.8% and 5.7% in the elk summer range.

Aspen patch size ranged from over 1 hectare in size to less than 1 m^2, with 44% of the patches being less than 200 m^2 (figure 4). Patches larger than 1 hectare were too large to measure accurately on the ground. Over a quarter of the aspen patches had 100% aspen in the canopy, while approximately 40% of the aspen patches had greater than 50% conifers in the canopy (i.e., more conifer in the canopy than aspen) (figure 5).

Discussion

For five decades, researchers have predicted the demise of aspen in Rocky Mountain National Park (Berry et al. 1997; Olmsted 1979; Packard 1942; White et al. 1998). Packard (1942), based on his study of aspen in the elk winter range, predicted that within a few years of his study all the aspen would have died and would not be replaced by new stems. This dire forecast has not come true, as we documented with the percent cover of aspen found in the elk winter range and throughout the Park. Subsequent studies of aspen in the Park also attributed aspen decline to elk browsing (Baker et al. 1997; Olmsted 1979). Our results showed that in local areas of high elk browse, aspen regeneration is depressed. However, when we looked at a broader scale and at areas where elk browsing was less intense, we found that aspen has been regenerating in at least 50% of the stands in the past 25 years. The Park began its policy of natural regulation for the elk population in 1968 and since then the elk population has increased to approximately 2,000 individuals. During the past 25 years, elk impacts should have been at their highest. The highly localized impacts of elk on aspen regeneration in the past 25 years allows for small-scale preservation efforts such as elk exclosures to protect particular aspen clones or patches.

Patterns of aspen regeneration showed high variability within zones and locations. Although aspen regeneration in most of Estes Valley was low (as

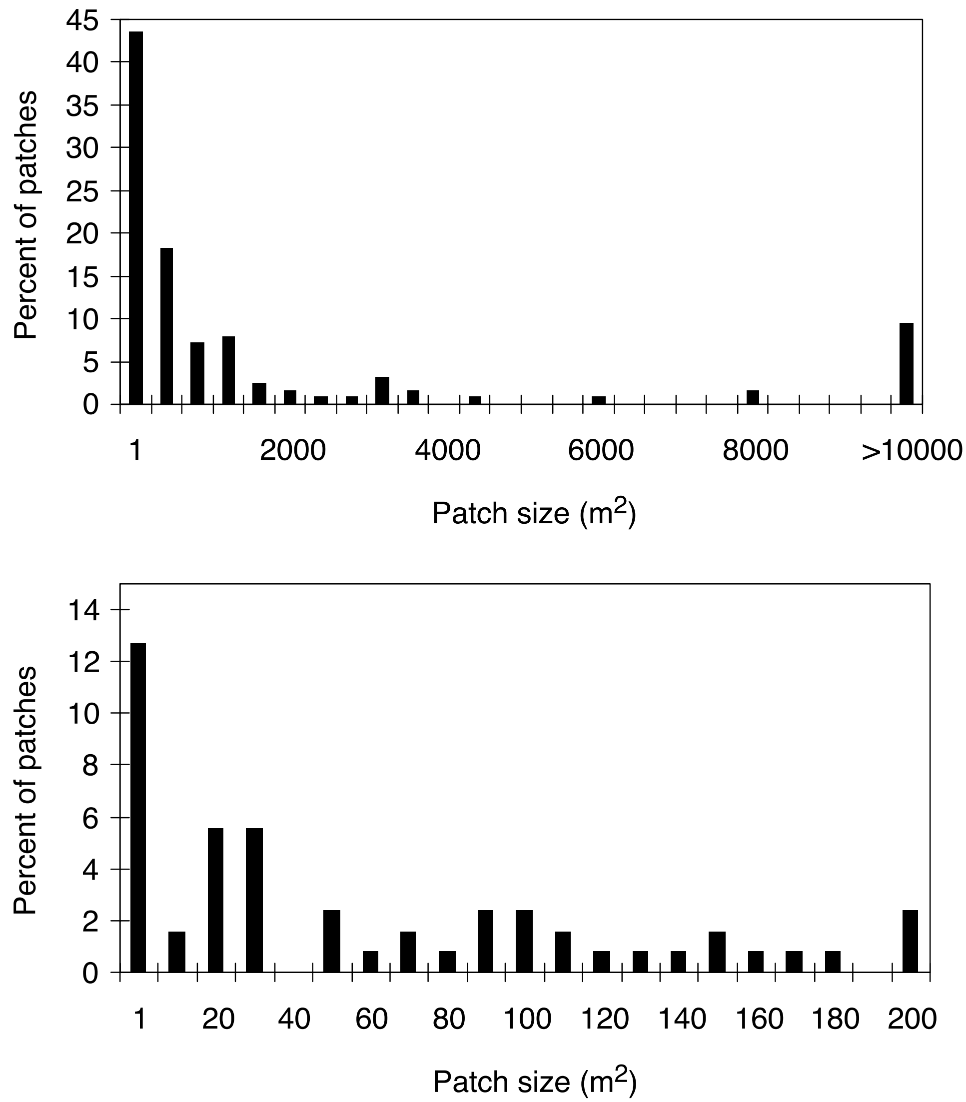

Figure 4—Distribution of patch size 1-10,000 m^2 (a, top graph) and 1-200 m^2 (b, bottom graph). Approximately 13% of all patches were smaller than 10 m^2 (b), which was the smallest patch detected by aerial photographs. Ten percent of all patches were >10,000 m^2 (a). Ground measurements of large patches were inaccurate, so remotely sensed data may be more suited to describe such patches.

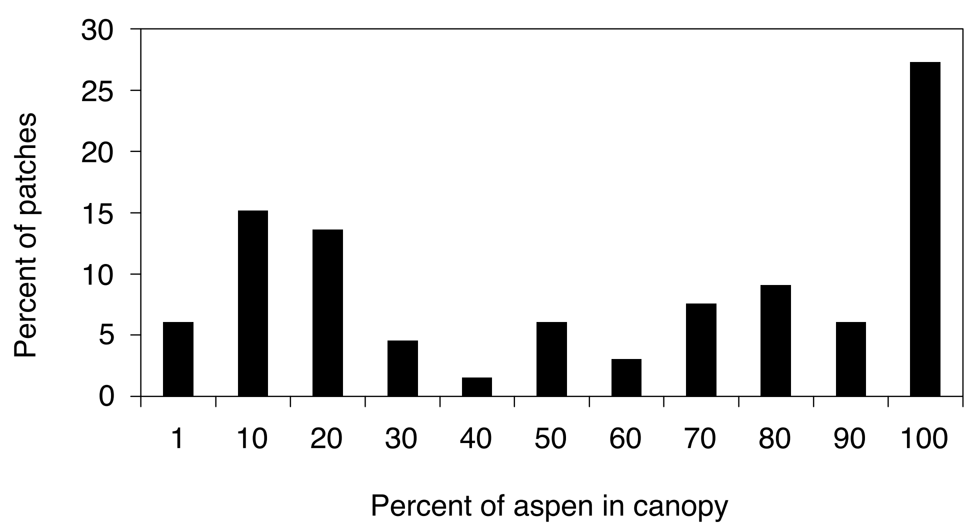

Figure 5—Percent of aspen in the canopy of aspen patches encountered in the belt transects. Twenty-eight percent of the patches had 100% aspen within the canopy, but 40% of the patches had less than 50% aspen in the canopy. The remaining species in the canopy are conifers.

reported by Baker et al. [1997]), we found two regenerating stands of aspen in Estes Valley. On the west side of the Park, stands sampled in the elk winter range (Kawuneeche Valley) showed no cohort establishment since 1926. Aspen regeneration was strong in many areas of the elk winter range, except for Estes Valley and Kawuneeche Valley. Elk density is extremely high in Estes Valley, where >90% of elk in the Park spend the winter (Larkins 1997). The winter elk population is much lower in Kawuneeche Valley, but summer use is very heavy (Larkins 1997).

The unbiased ground survey allowed us to compare the condition of aspen in the elk winter and summer ranges. The only significant difference we found between aspen in the two ranges was the percent of bark browsed. Wounds created by elk browsing on aspen bark and cambium allow for the introduction of pathogens into the stem. Consequently, bark browsing may affect the long-term condition of aspen patches by increasing aspen mortality due to disease. However, current measurements of aspen stands in the winter range show that neither stand density nor basal area have been affected by elk browsing. Interestingly, bark browse is the most visible characteristic we measured in aspen patches. The higher amount of bark browsed in the elk winter range could lead to unfounded alarm over the status of aspen in this area.

Other aspen patch characteristics such as regeneration, density, and basal area were not statistically different between the two ranges. Our values of regeneration from the ground survey may over-represent the amount of successful regeneration that occurs in the Park. Stems that are under 2 m in height are susceptible to elk browsing and self thinning (Brown and DeByle 1987), so many of the short stems may not successfully grow into the canopy. However, the high densities of stems shorter than 2 m indicate that aspen has the potential to recruit new stems into the canopy. White et al. (1998) suggested that declining aspen stands would have low density (<500 stems/ha). We found that aspen in the elk winter range, where we expected aspen decline due to intense elk browsing, had average densities of 1,339 stems/ha. This average density in the elk winter range falls within the range of known values for aspen in the Rocky Mountains (Kemperman and Barnes 1976), as do our values of basal area (Brown and DeByle 1987; Chen et al. 1998; Peet 1988).

Data from the ground survey showed that there is more aspen in the central portion of the Park than previously expected. Aspen covers 6.8% of the landscape, which is approximately three times more aspen than detected by remotely sensed data. Over a third of the aspen patches encountered in the ground survey had more conifer stems in the canopy than aspen. These patches may be difficult to detect with remotely sensed data. The smallest patch identified with aerial photographs (1:15,800) was 10 m^2. Over 10% of the patches that we encountered were smaller than 10 m^2. These patches may not contribute much to the total percent cover of aspen in the Park and they are not likely "hotspots" of diversity, but they represent the source of aspen available on the landscape. Aspen is a clonal species that quickly colonizes canopy openings (Parker and Parker 1983). In the case of a forest disturbance such as fire, windstorms, or insect outbreaks, these small aspen patches may quickly invade the disturbed area and create larger aspen stands.

Conclusions

Based on the presence of aspen regeneration in the elk winter range and lack of significant differences in aspen characteristics between the elk winter and summer ranges, we did not find enough evidence to support our hypothesis that that the effects of elk browsing were greater in the elk winter range than the summer range. Therefore, we reject our hypothesis. Suzuki et al.'s (1999) study showed that elk browsing has affected aspen regeneration in local areas such as Estes Valley. At larger spatial scales, there is no evidence that elk browsing has prevented aspen regeneration in the elk winter and summer ranges in Rocky Mountain National Park during the past 25 years. The unbiased ground survey provided evidence that elk browsing in the winter range has not brought about a change in stand characteristics when compared to the summer range where elk use is less intense.

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