Climate change-mediated expansion of Utah Juniper across the Bighorn Canyon National Recreation Area: Implications for bighorn sheep.

Robert E. Kissell, Jr., Ph.D., Department of Biology, Tennessee Technological University, Cookeville, TN 38505

Abstract: Bighorn sheep (*Ovis canadensis*), for which the Bighorn Canyon National Recreation Area is named, relies on curl-leaf mountain mahogany (CLMM; *Cercocarpus ledifolius*) as a staple dietary item. Curl-leaf mountain mahogany is often a climax community plant and has been thought to be so across much of the Bighorn Canyon National Recreation Area. As climate conditions have changed across the last 20-30 years Utah Juniper (*Juniperus osteosperma*) has been perceived to invade areas occupied by CLMM. Given the reliance by bighorn sheep on CLMM throughout the year, the decline of the forage species is expected to have a direct impact on the bighorn sheep population. This study addressed the current densities, recruitment density, and mortality rate of CLMM and Utah juniper in relation to precipitation (low, medium, high) and stand type (curl-leaf mountain mahogany, curl-leaf mountain mahogany-juniper, juniper). A second objective was to assess the allelopathic effect of juniper leaf litter on germination of CLMM seeds; limited germination prohibited completion of this objective. CLMM densities were the same within each stand type, and recruitment was highest in the south region. However, mortality of CLMM was also highest in the south region. Precipitation did not appear to affect density of CLMM. Juniper densities were least in the south in mixed stands and the same within juniper stands. Recruitment of juniper was similar in all stands across regions. Factors potentially affecting the mortality of CLMM in the south are allelopathic effects from juniper on CLMM germination, age of plants, overgrazing, and a changing climate.

INTRODUCTION

In response to concurrent growing ungulate populations along the Bighorn Canyon in the early 1990s, two studies, one addressing food habits of sympatric ungulates (Kissell 1996) and one addressing curl-leaf mountain mahogany (CLMM; *Cercocarpus ledifolius*) status (Peterson 1999), were conducted. Curl-leaf mountain mahogany was found to be a staple forage item for bighorn sheep (*Ovis canadensis*) throughout the year (Kissell 1996). Additionally, CLMM seedling density averaged 8333.1 seedlings/ha and was much higher than reported in other studies (Peterson 1999). Data collected in 2017 (Kissell, unpublished) indicated much lower seedling densities ranging from 12.2 to 963.3 seedlings/ha. One postulated factor that could negatively affect reproduction or seedling density included toxicity of leaf litter to seedlings (Jamison 1970, Davis and Brotherson 1991). Toxicity could be allelopathic related to Utah Juniper (*Juniperus osteosperma*; Jobidon 1986, Horman and Anderson 2003), which has been perceived to be increasing its range during the last 20 years.

Curl-leaf mountain mahogany and Utah juniper are both considered climax community species (Zlatnik 1999, Gucker 2006). In some locations, however, CLMM is a mid-seral species that is replaced by Utah juniper (Gucker 2006). Bighorn Canyon National Recreation Area has stands dominated by only Utah juniper, only curl-leaf mountain mahogany, and areas that are mixed stands of both. Prior to the mid-1990's, each of the stand types appeared to be static. In recent years, however, there has been a perceived increase in Utah juniper and a decline in curl-leaf mountain mahogany, especially on the southern end of the Bighorn Canyon where rainfall is least.

Given CLMM is a staple forage item for bighorn sheep year-round on the Bighorn Canyon, there is concern how the changing plant communities will affect bighorn sheep in the long-term. To understand some of the mechanisms responsible for the progression of the change to a new climax community the following objectives were addressed.

RESEARCH OBJECTIVES

1) Estimate the density, percent mortality, and recruitment (i.e., seedling) density of curl-leaf mountain mahogany and Utah juniper on the Bighorn Canyon National Recreation Area across a precipitation gradient.

2) Determine the effect of Utah juniper leaf litter chemistry and depth on the germination rate of curl-leaf mountain mahogany.

DESIGN

Objective 1: A natural study, two-factor analysis of variance design was used to assess the effect of precipitation and stand type on density, percent mortality and recruitment density of CLMM and Utah juniper. Treatments were precipitation (low (< 25.4 cm), medium (> 25.4 and < 38.1 cm) and high (> 38.1 cm)) and cover type (CLMM-juniper stands, CLMM stands, and juniper stands). The response variables were density, percent mortality and number of seedling plants of each species. Replicates were 0.1 ha plots in each of the treatments.

Objective 2: An experimental two-factor analysis of variance design was used to assess the effect of chemical inhibition by leaf litter and depth of leaf litter on the germination rate of curl-leaf mountain mahogany. Treatments were amount of chemical inhibitor (0%, 1%, and 10%) and leaf litter depth (0 cm, 2.5 cm, and 5, cm). The response variable was emergence rate. Replicates were containers of 10 seeds per container.

METHODS

Objective 1: A total of 20 plots, 0.1 ha (31.6 m X 31.6 m) in size, were randomly selected in each cover type (CLMM-juniper and juniper) in each of three precipitation regions of the Bighorn Canyon National Recreation Area; a natural gradient of increasing precipitation exists from south to north (USDOI 1981). A geographic information system was used to randomly select locations of plots. Plots were at least 100 m apart; all plots were oriented north-south. Global positioning system units were used to navigate to plots. Plots were delineated using measuring tapes and a compass.

The number of live CLMM and Utah juniper plants were enumerated in each plot to calculate density. The number of plants of each species having at least 50% dead standing branches were enumerated to calculate percent mortality. The number of seedlings (< 10 cm; Peterson 1999) was enumerated to estimate seedling density.

Data were examined to insure assumptions of normality and equal variance were met. Assumptions of parametric testing were not met so multiple non-parametric analysis of variance tests were performed. Given multiple tests were performed on the same data set, a sequential Bonferroni adjustment was made. Analyses examining interactions was not possible given the non-parametric approach.

Objective 2: CLMM seeds were collected throughout the summer as they matured. No more than 50 seeds were collected from any one plant. A minimum of 1,500 seeds was collected. Seeds were stored in paper bags until returning to Tennessee Tech University. Seeds were placed in a freezer that maintained temperatures below -1 °C for 120 days to simulate overwintering and stratification that normally occurs in the field and to maximize germination (Gucker 2006).

Methods of Horman and Anderson (2003) were followed to make the leachate to assess chemical inhibition of germination of curl-leaf mountain mahogany. Utah juniper leaf litter was collected from the Bighorn Canyon National Recreation Area to make 1% and 10% leachates. Litter was sifted through a #20 hardware mesh to separate soil from litter. One gram of litter was soaked in 100 ml of distilled water for 24 hours at 20 °C (Jobidon 1986). The leachate was poured through a #60 mesh filter. A 10% leachate was made using 10 g of litter per 100 ml of water and isolated using a #60 mesh filter.

Containers using 1 part sand and 1 part standard potting soil was used. Collected litter was placed on top of containers with litter treatments (2.5 cm and 5.0 cm). Ten seeds were placed into each of the containers. Seeds were placed 2.5 cm below the top of litter and on the top of the soil for the control. Soil was watered until saturated with one of the treatment solutions. Containers were placed in a plant growth chamber set for a 12 hour diurnal 10°C-15°C regime. Plants were watered with their assigned saturation levels once per week. Percent emergence was recorded daily for the first 3 weeks and every 3 days for the remaining weeks until all seeds have germinated or were considered dead.

Data were examined to insure assumptions of normality and equal variance were met. A two factor analysis of variance was used to assess differences in treatments. Range tests were used to determine which levels of each treatment differ. Analysis of variance tests were conducted for each factor independently to assess differences among levels if interactions occurred.

RESULTS

Objective 1: Data were collected from 18 May to 24 July 2017. A total of 164 plots was sampled (Table 1). Few sampling plots were accessible from within the canyon and a limited amount of area was available for sampling CLMM stands in the central region (Figure 1) which resulted in a low sample size.

CLMM stands and CLMM-juniper stands exhibited between 34% and 56% of plants with ≥ 50% dead tissue on the plants (Table 2), with the southern region exhibiting the most decadence. Percent seedling CLMM ranged from 0% in the junipers in the central region to 8.6% in the mixed stands in the southern region. Percent seedling junipers ranged from 0% in the CLMM stands in the north to 14.6% in mixed stands in the south. A higher percentage of seedling CLMM was observed in the southern region than the other two regions regardless of stand type.

Density of CLMM declined in stands with more juniper in each region (Table 3). Juniper density increased in stands with more juniper, as expected, in the north and south regions, but the density of juniper was the same in each stand type within the central region (Table 4). Seedling CLMM density relationships relative to stand type were the same for the central and south regions with little recruitment in juniper stands, as expected (Table 5). Seedling juniper density was the same across the central and south regions, with no recruitment in the north in CLMM stands (Table 6). Percent CLMM mortality was greatest in the south in CLMM and CLMM-juniper stands, the same across stand types in the central region, and greatest in the CLMM-juniper stands in the north (Table 7). Percent juniper mortality did not differ among stand types in the north and central regions, but was higher in the CLMM stands in the south (Table 8). Within each region, the ratio of CLMM to Juniper declined within stands with less CLMM, as expected. Very little juniper was in CLMM stands in the north (Table 9).

Stand types had similar CLMM densities across regions (Table 10). Juniper density varied across regions in the CLMM and CLMM-juniper stands, but was the same across regions in juniper stands (Table 11). Seedling CLMM density was greatest in the south in CLMM and CLMM-juniper stands and was almost 0 in juniper stands (Table 12). Seedling juniper density was the same across regions within each stand type (Table 13). Percent mortality of CLMM was higher in the south in CLMM and CLMM-juniper stands and the same across regions in the juniper stands (Table 14). Percent mortality of juniper was consistent across regions in CLMM-juniper stands and varied across regions in the CLMM and juniper stands (Table 15). No differences across regions in ratios of CLMM to juniper existed in the CLMM-juniper or juniper stands, but few juniper were in the CLMM in the north which resulted in a skewed ratio (Table 16).

Objective 2: Percent germination of seeds was zero in year 1 and 3% in year 2. Seed germination was also examined at two different temperatures in year 2. One temperature was at that which CLMM is reported to germinate best (Gucker 2006; i.e., 10-15 degrees Celsius) and the other temperature was much higher (25 degrees Celsius). No seeds germinated at the lower temperature and only 3%

germinated at the higher temperature. No seeds germinated in the replicates of the experimental units used. Insufficient data were collected to perform analyses.

DISCUSSION

Densities of CLMM on the Bighorn Canyon National Recreation Area were in the range reported in other studies (Schultz et al. 1990, Peterson 1999), but much lower than in other studies in Montana (Duncan 1975). Densities of CLMM and juniper were expected to increase across respective stand types. For example, juniper should decrease when moving from juniper stands to CLMM-juniper stands to CLMM stands. This reflected sampling of areas that were correctly classified. The reason for no difference in the central region for juniper may be low sample size. The CLMM-juniper stands in the central region were very limited in availability.

Precipitation was expected to be the driving force behind differences across regions. However, CLMM was not affected by precipitation across the precipitation gradient. CLMM is thought to have evolved as a drought tolerant species (Gucker 2006), and the pattern of density across the precipitation gradient is inductively supportive of this. Juniper density, by comparison, varied depending upon stand type. Within pure juniper stands there was no regional (i.e., precipitation) effect. The variation observed is in need of further study.

Precipitation is known to have a significant effect on seedling survival of CLMM when seedlings are under trees, but little effect when seedlings are in the open (Ibanez et al. 1999). Most seedling plants are in the open in the south and central regions, but likely under a canopy of trees in the north. With greater precipitation comes greater plant production and, therefore, greater canopy cover. The south region exhibited the highest density of seedling CLMM plants in CLMM and CLMM-juniper stands and was thought to have the most open area among the regions. However, we did not collect canopy cover information to substantiate this relationship. Complicating this relationship is that leaf litter depth inhibits germination of seeds (Stringham et al. 2015). The density of seedling CLMM plants in CLMM and CLMM-juniper stands was ≥ 5-fold greater in the south compared to the other two regions. Factors causing this are unknown and in need of further study.

While seedling juniper densities differed within stand types, precipitation did not have an effect across regions. Seedling juniper densities, reflective of recruitment, indicated a common pattern across the study area. Utah juniper is a drought resistant species that has been in the Bighorn Basin and surrounding area for more than 3,000 years (Jackson 2006). Utah juniper has increased its range since European settlement and this is thought to be due, in part, to overgrazing, fire suppression, and climate change (Walker et al 1996, Zlatnik 1999). Given the south region is overgrazed and considered "unhealthy" (Ricketts 2004), it may likely be contributing to the increase in occurrence.

Mortality of CLMM is greatest in the south region and differ from rates of mortality in the central and north regions. Factors potentially affecting the mortality of CLMM in the south are age of plants, overgrazing, and a changing climate. CLMM stands have been observed to persist for approximately 250-300 years before a sharp reduction in stand density (Schultz et al. 1991). The age of stands is currently unknown. The south region is within the Pryor Mountain Wild Horse Range and grazing may play a role in the observed rates. Changes to the plant community and how the ungulates on site have adapted is in need of examination. In the mixed stands, juniper mortality was not affected. This is the stand type that is likely to demonstrate the interactions between species, if they exist.

Ratios of CLMM to juniper may be used as a baseline metric to measure how communities change over time. CLMM was used in the numerator in this ratio so values above 1 indicate more CLMM plants than juniper plants and vice versa. As stand types proportionally had less CLMM lower ratios were expected and this was observed within each region. Use of this metric is recommended to track changes in the plant communities.

Literature Cited

Bunting, S. C. 1990. Prescribed fire effects in sagebrush-grasslands and pinyon-juniper woodlands. In: Alexander, M. E., and G. F. Bisgrove, editors. The art and science of fire management: Proceedings of the 1st Interior West Fire Council annual meeting and workshop; 1988 October 24-27; Kananaskis Village, AB. Information Rep. NOR-X-309. Edmonton, AB: Forestry Canada, Northwest Region, Northern Forestry Centre: 176-181.

Duncan, E. A., 1975. The ecology of curl-leaf mountain mahogany (*Cercocarpus ledifolius* Nutt.) in southwestern Montana with special reference to use by mule deer. M.S. Thesis, Montana State University, Bozeman, MT. 87 pp.

Gucker, C. L. 2006. Cercocarpus ledifolius. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/.

Horman, C. S., and V. J. Anderson 2003. Understory response to Utah juniper litter. Journal of Range Management 56:68-71.

Ibáñez, I., E. W. Schupp, and J. L. Boettinger. 1999. Successional history of a curleaf mountain mahogany stand: a hypothesis. In: McArthur, E. D., W. K. Ostler, and C. L. Wambolt, editors. Proceedings: shrubland ecotones; 1998 August 12–14; Ephraim, UT. Proceedings. RMRS-P-11. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 102-107.

Jackson, S. T. 2006. Vegetation, environment, and time: The origination and termination of ecosystems. Journal of Vegetation Science 17:549-557.

Jameson, D. A. 1970. Degradation and accumulation of inhibitory substances from Juniperus osteosperma (Torr) Little. Plant and Soil 33:213-224.

Jobidon, R. 1986. Allelopathic potential of coniferous species to oldfield in eastern Quebec. Forest Science. 32:113-118.

Kissell, Jr., R. E. 1996. Population dynamics, food habits, seasonal habitat use, and spatial relationships of bighorn sheep, mule deer and feral horses in the Pryor Mountains, Montana/Wyoming. Ph.D. Dissertation, Montana State University, Bozeman, MT. 153 pp.

Peterson, J. 1999. Ungulate/vegetation dynamics in the Pryor Mountain Wild Horse Range. Ph.D. Dissertation, Colorado State University, Fort Collins, CO. 155 pp.

Ricketts, M. J., 2004. Pryor Mountain Wild Horse Range survey and assessment. Natural Resources Conservation Service, Department of Agriculture, Bozeman, MT.

Shultz, B. W., R. J. Tausch, and P. T. Tueller. 1991. Size, age, and density relationships in curlleaf mahogany (Cercocarpus ledifolius) populations in western & central Nevada: competitive implications. The Great Basin Naturalist. 51: 183-191.

Shultz, B. W., P. T. Tueller, and R. J. Tausch. 1990. Ecology of curlleaf mahogany in western and central Nevada: Community and population structure. Journal of Range Management 43:13-20.

Stringham, T.K., P. Novak-Echenique, P. Blackburn, C. Coombs, D. Snyder, and A. Wartgow. 2015. Final Report for USDA Ecological Site Description State-and-Transition Models, Major Land Resource Area 28A and 28B Nevada. University of Nevada Reno, Nevada Agricultural Experiment Station Research Report 2015-01. p. 1524.

United States Department of Interior (USDOI). 1981. Final general management plan environmental impact statement wilderness recommendation. Denver Service Center, Denver, CO, 319 pp.

Walker, S. C., D. K. Mann, and E. D. McArthur. 1996. Plant community changes over 54 years within the Great Basin Experimental Range, Manti-La Sal National Forest. In: Barrow, Jerry R.; McArthur, E. Durant; Sosebee, Ronald E.; Tausch, Robin J., editors. Proceedings: shrubland ecosystem dynamics in a changing environment; 1995 May 23-25; Las Cruces, NM. Gen. Tech. Rep. INT-GTR-338. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 66-68.

Zlatnik, E. 1999. Juniperus osteosperma. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available: https://www.fs.fed.us /database/feis/plants/tree/junost/all.html.

Table 1. Number of plots sampled in each stand type and each region of the Bighorn Canyon National Recreation Area during summer 2017 to estimate the density of live and dead plants and number of seedling plants.

Region	Juniper-Curl-leaf Mountain Mahogany	Juniper	Curl-leaf Mountain Mahogany	Total
North	19	20	20	59
Central	20	20	6	46
South	19	20	20	59
Total	58	60	46	164

Table 2. Average number of juniper and curl-leaf mountain mahogany plants alive and dead, based on ≥ 50% dead tissue, per hectare in three different stand types across three regions of precipitation on the Bighorn Canyon National Recreation Area in summer 2017.

		Juniper			Curl-leaf mountain mahogany		
Stand Type	Region	Alive	Dead	Juvenile	Alive	Dead	Juvenile
Juniper-Curl-leaf mountain mahogany	North	387.7	117.0	7.6	641.5	219.9	12.3
	Central	365.6	107.2	5.0	986.7	337.8	10.6
	South	196.5	67.8	14.6	633.3	353.2	59.6
Juniper	North	589.4	140.6	13.9	143.3	28.3	0.6
	Central	428.3	45.0	5.0	45.0	8.3	0.0
	South	454.4	135.0	2.2	34.4	7.2	0.6
Curl-leaf mountain mahogany	North	30.0	3.3	0.0	1133.3	269.4	1.1
	Central	222.2	37.0	3.7	1744.4	296.3	5.6
	South	95.6	57.8	2.8	1470.0	622.8	86.7

Table 3. Differences in curl-leaf mountain mahogany density (number/ha) among stand types within each region on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a region indicate no difference.

Stand Type	North		Central		South	
CLMM	1,133.3	A	1,744.4	A	1,470.0	A
CLMM-Juniper	641.5	B	986.7	B	633.3	B
Juniper	143.3	C	45.0	C	34.4	C

Table 4. Differences in Utah juniper density (number/ha) among stand types within each region on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a region indicate no difference.

Stand Type	North		Central		South	
CLMM	30.0	A	222.2	A	95.6	A
CLMM-Juniper	387.7	B	365.6	A	196.5	B
Juniper	589.4	C	428.3	A	454.4	C

Table 5. Differences in seedling curl-leaf mountain mahogany density (number/ha) among stand types within each region on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a region indicate no difference.

Stand Type	North		Central		South	
CLMM	1.1	A	5.6	A	86.7	A
CLMM-Juniper	12.3	B	10.6	A	59.6	A
Juniper	0.6	A	0.0	B	0.6	B

Table 6. Differences in seedling Utah juniper density (number/ha) among stand types within each region on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a region indicate no difference.

Stand Type	North		Central		South	
CLMM	0.0	A	3.7	A	2.8	A
CLMM-Juniper	7.6	B	5.0	A	14.6	A
Juniper	13.9	B	5.0	A	2.2	A

Table 7. Differences in curl-leaf mountain mahogany percent mortality among stand types within each region on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a region indicate no difference.

Stand Type	North		Central		South	
CLMM	16	AB	14.0	A	30.3	A
CLMM-Juniper	23.2	A	23.0	A	34.7	A
Juniper	9.5	B	12.2	A	5.9	B

Table 8. Differences in Utah juniper percent mortality among stand types within each region on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a region indicate no difference.

Stand Type	North		Central		South	
CLMM	21.3	A	11.5	A	41.8	A
CLMM-Juniper	20.2	A	19.2	A	23.1	B
Juniper	21.4	A	8.7	A	20.6	B

Table 9. Differences in curl-leaf mountain mahogany to Utah juniper ratio among stand types within each region on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a region indicate no difference.

Stand Type	North		Central		South	
CLMM	5522244.0	A	8.5	A	31.5	A
CLMM-Juniper	2.1	B	3.1	B	4.6	B
Juniper	0.6	C	0.3	C	0.1	C

Table 10. Differences in curl-leaf mountain mahogany density (number/ha) among regions within each stand type on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a stand type indicate no difference.

Region	CLMM		CLMM-Juniper		Juniper	
North	1133.3	A	641.5	A	143.3	A
Central	1744.4	A	986.7	A	45.0	A
South	1470.0	A	633.3	A	34.4	A

Table 11. Differences in Utah juniper density (number/ha) among regions within each stand type on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a stand type indicate no difference.

Region	CLMM		CLMM-Juniper		Juniper	
North	30.0	A	387.7	A	589.4	A
Central	222.2	B	365.6	A	428.3	A
South	95.6	C	196.5	B	454.4	A

Table 12. Differences in seedling curl-leaf mountain mahogany density (number/ha) among regions within each stand type on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a stand type indicate no difference.

Region	CLMM		CLMM-Juniper		Juniper	
North	1.1	A	12.3	A	0.6	A
Central	5.6	A	10.6	A	0.0	A
South	86.7	B	59.6	B	0.6	A

Table 13. Differences in seedling Utah juniper density (number/ha) among regions within each stand type on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a stand type indicate no difference.

Region	CLMM		CLMM-Juniper		Juniper	
North	0.0	A	7.6	A	13.9	A
Central	3.7	A	5.0	A	5.0	A
South	2.8	A	14.6	A	2.2	A

Table 14. Differences in curl-leaf mountain mahogany percent mortality among regions within each stand type on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a stand type indicate no difference.

Region	CLMM		CLMM-Juniper		Juniper	
North	16.0	A	23.2	A	9.5	A
Central	14.0	A	23.0	A	12.2	A
South	30.3	B	34.7	B	5.9	A

Table 15. Differences in Utah juniper percent mortality among regions within each stand type on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a stand type indicate no difference.

Region	CLMM		CLMM-Juniper		Juniper	
North	21.3	AB	20.2	A	21.4	A
Central	11.5	A	19.2	A	8.8	B
South	41.8	B	23.1	A	20.6	A

Table 16. Differences in curl-leaf mountain mahogany to Utah juniper ratio among regions within each stand type on the Bighorn Canyon National Recreation Area in summer 2017. Like letters within a stand type indicate no difference.

Region	CLMM		CLMM-Juniper		Juniper	
North	5522244.0	A	2.1	A	0.6	A
Central	8.5	B	3.1	A	0.3	A
South	31.5	B	4.6	A	0.1	A

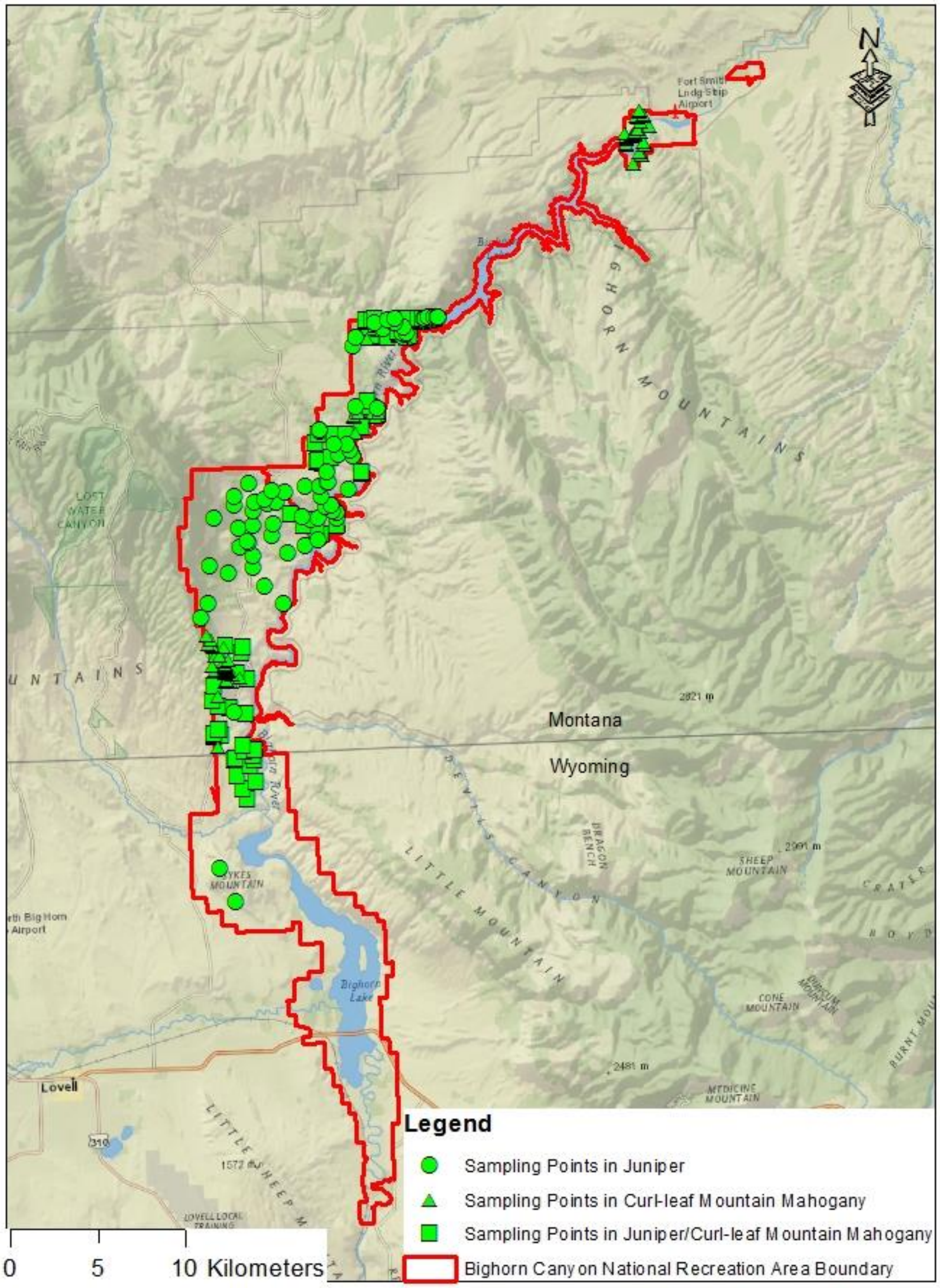

Figure 1. Locations of curl-leaf mountain mahogany, Utah juniper, and mixed curl-leaf mountain mahogany-Utah juniper stands sampled in summer 2017, on the Bighorn Canyon National Recreation Area for density, recruitment, and mortality of curl-leaf mountain mahogany and Utah juniper plants.