Monitoring Plan for Vegetation Responses to Elk Management in Rocky Mountain National Park

By Linda C. Zeigenfuss, Therese Johnson, and Zachary Wiebe

Open-File Report 2011–1013

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Suzette Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia 2011

For product and ordering information:
World Wide Web: http://www.usgs.gov/pubprod
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth,
its natural and living resources, natural hazards, and the environment:
World Wide Web: http://www.usgs.gov
Telephone: 1-888-ASK-USGS

Suggested citation:
Zeigenfuss, L., Johnson, T., and Wiebe, Z., 2011, Monitoring plan for vegetation responses to elk management in Rocky Mountain National Park: U.S. Geological Survey Open-File Report 2011–1013, 94 p., http://pubs.usgs.gov/of/2011/1013/.

Contents

Figures

Appendix Figures

Tables

Appendix Tables

Monitoring Plan for Vegetation Responses to Elk Management in Rocky Mountain National Park

By Linda C. Zeigenfuss, Therese Johnson, and Zachary Wiebe

Abstract

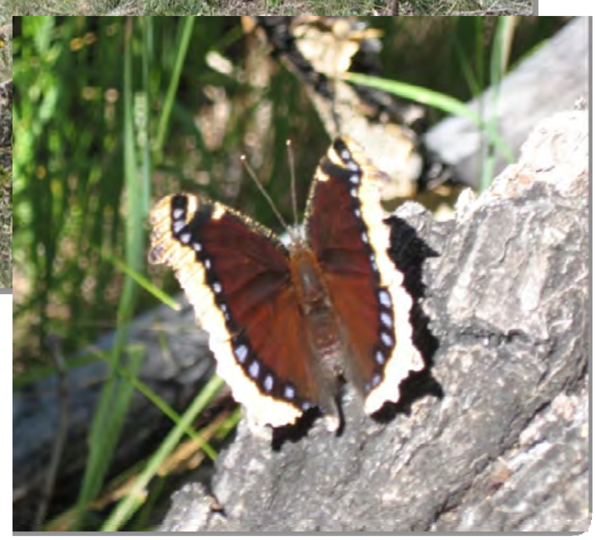
Rocky Mountain National Park (RMNP) in north-central Colorado supports numerous species of wildlife, including several large ungulate species among which Rocky Mountain elk (*Cervus elaphus*) are the most abundant. Elk are native to RMNP but were extirpated from the area by the late 1800s. They were reintroduced to the area in 1913–1914, and the elk population in the park grew to the point that park staff actively managed the herd from 1944 until 1968. In 1969, the active control of elk numbers was discontinued and replaced by natural regulation, and since then the herd has increased from approximately 500–600 animals to a high point ranging from 2,800 to 3,500 between 1997 and 2001. During this same period, there was an increase in the human population in the Estes Valley outside the park, which also provides elk range.

In recent years, there has been growing concern over the condition of vegetation in the park and conflicts between elk and humans, both inside and outside the park. In response to these concerns, RMNP developed an Elk and Vegetation Management Plan/Environmental Impact Statement (EVMP/EIS) to evaluate the effects of a range of alternatives for managing elk and vegetation in the park. The purpose of the EVMP/EIS is to guide management actions in the park over a 20–yr (year) time period to reduce the impacts of elk on vegetation and restore, to the extent possible, the natural range of variability in the elk population and affected plant and animal communities.

The EVMP outlines the desired future condition for three vegetation communities of concern where the majority of elk herbivory impacts are being observed: aspen, montane riparian willow, and upland herbaceous communities. Implementation of the EVMP aims to manage elk and vegetation on RMNP elk winter-range such that significant progress toward reaching these desired future conditions occurs over the 20-yr life of the plan. The management alternative that was selected relies on a variety of conservation tools including fencing, non-lethal redistribution of elk, use of various vegetation-restoration techniques, and lethal reduction of elk (culling).

The EVMP incorporates the principle of adaptive management to assess the effectiveness of management actions. Use of adaptive management in the EVMP means that RMNP managers will adjust management actions as needed to successfully achieve the EVMP's objectives. Determination of whether vegetation objectives are being achieved requires monitoring and evaluation of target vegetation communities. The objective of the work described in the current report was the design and implementation of a vegetation-monitoring program to help RMNP managers assess the effectiveness of their management actions and determine when and where to alter actions to achieve the EVMP's vegetation objectives. This monitoring plan details the process of selecting variables to be monitored, overall sampling design and structure, site selection, data collection methods, and statistical analyses to be used to conduct this monitoring

program in conjunction with the EVMP. We report the baseline conditions observed at the time of establishment of monitoring sites. We include detailed field protocols for site establishment and data collection, as well as timetables for sampling so that RMNP staff will be able to continue monitoring the sites established during this implementation stage, and continue to add new sites when necessary, as the execution of the EVMP proceeds over the next 20 yrs.



Introduction

Rocky Mountain National Park (RMNP) encompasses nearly 108,000 ha (hectares) of high-elevation forest, shrublands, meadows, and alpine tundra and rocklands in north-central Colorado. The park supports numerous species of wildlife, including several large ungulate species. The most abundant ungulate species in the park is Rocky Mountain elk (*Cervus elaphus*). Elk are native to RMNP but were extirpated from the area by the late 1800s. They were reintroduced to the area in 1913–1914, and the elk population in the park grew to the point that park staff actively managed the herd (through the removal of animals) from 1944 until 1968. The herd was maintained at a population of 350–800 elk during this time. In 1969, the active control of elk numbers was discontinued and replaced by natural regulation, and since then the herd has increased from approximately 500–600 animals to a high point between 1997 and 2001, with annual estimates ranging from 2,800 to 3,500 (U.S. Department of the Interior, 2007). During this same period, there was an increase in the human population in the Estes Valley outside the park, which also provides elk range.

The Rocky Mountain National Park/Estes Valley elk population migrates seasonally between high-elevation summer ranges and low-elevation winter-range where snow is less deep and forage more available in winter. The primary summer range includes subalpine and alpine areas within the park, as well as the Kawuneeche Valley on the west side of the park. Elk use summer range primarily during June, July, and August. In September, the majority of the elk herd typically begins to migrate to low-elevation winter-range in the Estes Valley on the east side of the park and adjacent areas outside the park, as well as areas further east. Elk typically return to the summer range beginning in May.

In recent years, there has been growing concern over the condition of vegetation in the park and conflicts between elk and humans, both inside and outside the park. This has led to multiple research studies focused on the effects of elk herbivory on the elk winter-range both within and outside RMNP (Stevens, 1980; Baker and others, 1997; Berry and others, 1997; Suzuki and others, 1999; Zeigenfuss and others, 1999; Singer and Zeigenfuss, 2002; Kaye and others, 2003; R. Monello, T. Johnson, and R.G. Wright, National Park Service, unpublished report, 2005). In response to these concerns, RMNP developed an Elk and Vegetation Management Plan/Environmental Impact Statement (EVMP/EIS) to evaluate the effects of a range of alternatives for managing elk and vegetation in the park. The purpose of the EVMP/EIS is to guide management actions in the park over a 20–yr (year) time period to reduce the impacts of elk on vegetation and restore, to the extent possible, the natural range of variability in the elk population and affected plant and animal communities (U.S. Department of the Interior, 2007). After extensive involvement of the public, as well as of other agencies and entities responsible for managing wildlife and habitat outside the park, the final EVMP/EIS was published in December 2007. A Record of Decision was issued on February 15, 2008.

The vegetation objectives of the EVMP/EIS are to restore and/or maintain the natural range of variation in vegetation conditions on the elk range, to the extent possible (U.S. Department of the Interior, 2007). This includes:

- preventing loss of aspen (*Populus tremuloides*) clones within high elk-use areas;
- restoration and maintenance of sustainable montane riparian willow (*Salix* spp.) as indicated by:
    - increasing montane riparian willow cover within suitable willow habitat on the primary winter-range;

  - maintaining or improving the condition of riparian and upland willow on the primary summer range;
- reducing the level of elk grazing on herbaceous vegetation.

The plan outlines the desired future condition for each of these identified vegetation types. The desired future condition of aspen on the primary winter-range and in the Kawunechee Valley is an increase in aspen regeneration such that at least 45 percent of stands develop a regeneration cohort within each decade. This will be reflected in a higher diversity of age classes so that the distribution of stem diameter at breast height (dbh) reflects many (approximately 75 percent) small-diameter stems, some (approximately 20 percent) medium-diameter stems, and few (approximately 5 percent) large-diameter stems. The desired long-term future condition of riparian montane willow is up to 70 percent willow cover within suitable willow habitat. The EVMP acknowledges that this level of recovery can't be accomplished within the 20-year timeframe of the plan, but calls for an annual progressive increase in willow cover on the elk range to at least 10 percent greater than baseline conditions over 20 years, indicating progress toward the desired future condition. The plan also calls for an increase in the amount of willow that reaches a height beyond the reach of elk browsing, with average height increasing to at least 20 percent greater than baseline conditions over the 20-yr life of the plan. The plan seeks to reduce the level of elk grazing on herbaceous vegetation and identifies maintenance in the diversity of grazing levels as the desired future condition for upland herbaceous vegetation, so that not all areas are heavily grazed.

The management alternative that was selected relies on a variety of conservation tools including fencing, non-lethal redistribution of elk, use of various vegetation-restoration techniques, and lethal reduction of elk (culling). This alternative was selected because it best meets the Park's general management objectives for protecting Park resources while being consistent with the Park's purpose, mission, and goals (U.S. Department of the Interior, 2008). The selected alternative calls for the gradual lethal reduction of elk to achieve a population size that is at the upper end of the population's natural range of variation (1,600–2,100 elk, with 600–800 wintering inside the park and 1,000–1,300 wintering outside the park). Up to 65 ha (160 acres) of aspen on the winter-range and in the Kawuneechee Valley, up to 105 ha (260 acres) of willow on the winter-range, and up to 73 ha (180 acres) of willow in the Kawuneechee Valley will be fenced to protect vegetation and promote habitat recovery. These areas were selected because they include areas most extensively impacted by elk herbivory and are subject to high concentrations of elk. Vegetation restoration will include the use of methods such as prescribed burning, mechanical treatments, and planting willow. Aversive conditioning (rubber bullets, cracker shot) and herding will also be used to help redistribute elk as needed.

The EVMP incorporates the principle of adaptive management to assess the effectiveness of management actions. Use of adaptive management in the EVMP means that RMNP managers will adjust management actions as needed to successfully achieve the EVMP's objectives. Determination of whether vegetation objectives are being achieved requires monitoring and evaluation of target vegetation-communities. The park needs established monitoring locations, adequate sample sizes, and tested and cost-effective methods to monitor the response of key vegetation communities to management actions. The objective of the work described in this report was to design and begin implementation of a vegetation-monitoring plan to help RMNP managers assess the effectiveness of their management actions and determine when and where to alter actions to achieve the EVMP's vegetation objectives.

Given the available funding, this monitoring plan focuses on the key vegetation types identified in the plan (upland herbaceous, montane willow, and aspen) on the low-elevation elk winter-range on the east side of the Park. An additional plan will need to be developed in order to monitor summer range (alpine and/or Kawunechee Valley). The methods described here would be appropriate for application to the Kawuneechee Valley and could be applied in similar fashion. During the first year of this project, we established several aspen sites in the Kawunechee Valley before the scope of this plan was limited, and data from those efforts are included here.

Methods

A previous monitoring plan outlined several important ecological concerns in RMNP and included chapters that presented basic information for monitoring aspen throughout the park and for monitoring montane, upland, and willow communities on the park winter-range (Stohlgren, 2001). We based the design of our elk-vegetation management monitoring plan upon elements of this earlier plan. Stohlgren (2001) used data collected in prior studies of the target communities to develop suggested sample sizes, plot sizes, and timetables for measurement (for further detail, see "Design of Monitoring Methods). We took these plans a step further and fit them into a sample design that included the ability to analyze different elk management treatments (for example, fencing) and elk ranges (for example, "core" or "non-core" winter-range; see below) in the park. The EVMP defined the primary elk winter-range, as well as the area within the primary winter-range where elk concentrate during winter (Moraine Park/Beaver Meadows, Horseshoe Park). We refer to this area as the "core" elk winter-range. In this project, we refined the boundaries of the core winter-range based on further analysis of elk-distribution data (fig. 1). This core winter-range is determined to a great extent by available vegetation types and elevation. The area of the primary winter-range outside the core winter-range is referred to as "non-core" winter-range (fig. 1). The baseline data collected by this project define the difference in current conditions between core and non-core ranges. It is expected that most fencing will occur in core areas since this is where vegetation restoration needs are greatest. The management alternative that is being implemented relies to a large degree on improvement of aspen and willow conditions inside fences, while ensuring at a minimum that conditions do not decline outside fences.

We used the Rocky Mountain National Park Vegetation Map (Salas and others, 2005) as our source for the locations of aspen and upland communities (fig. 2). Willow communities were identified based on the park vegetation map (Salas and others, 2005), willow habitat mapping in Moraine and Horseshoe parks done in 1999 (Peinetti and others, 2002), willow habitat mapping in Beaver Meadows conducted as part of this project, and maps of areas with the potential to support willow in Moraine and Horseshoe parks that were developed by hydrologists and wetland researchers (E. Gage and D. Cooper, Colorado State University, written communication, 2006). For willow and upland types, the extent and abundance of these vegetation communities is greater in the core than the "non-core" winter-range (fig. 2). In the case of upland vegetation, it was difficult to find an adequate number of suitable non-core sample sites. Available willow habitat in the non-core winter-range was limited to three main areas where the majority of sampling sites had to be clustered. There was nearly 2.5 times the amount of aspen cover in the non-core winter-range compared to the core winter-range.

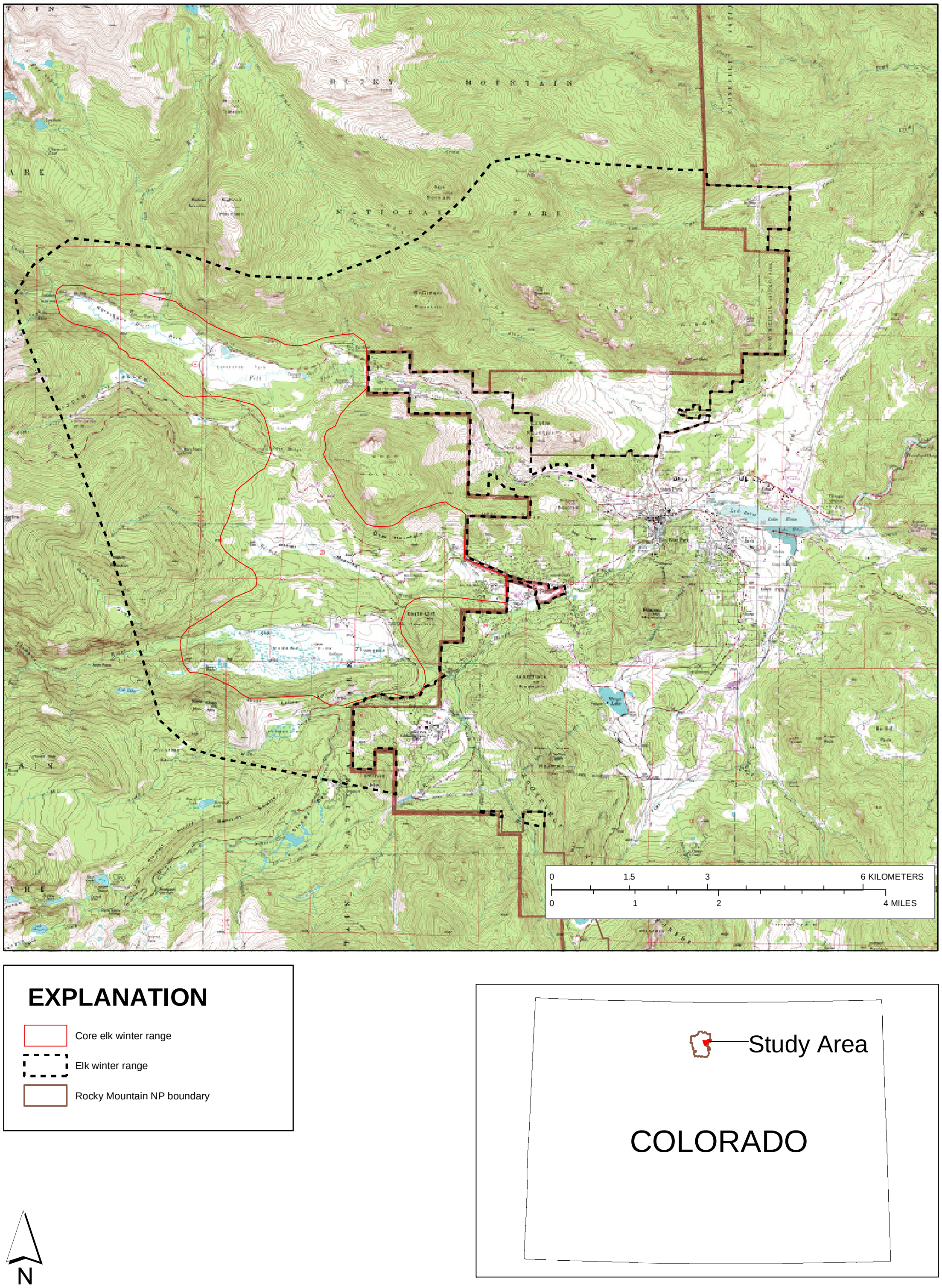


Figure 1. Map of the primary elk winter-range and core elk winter-range in Rocky Mountain National Park, Colo.

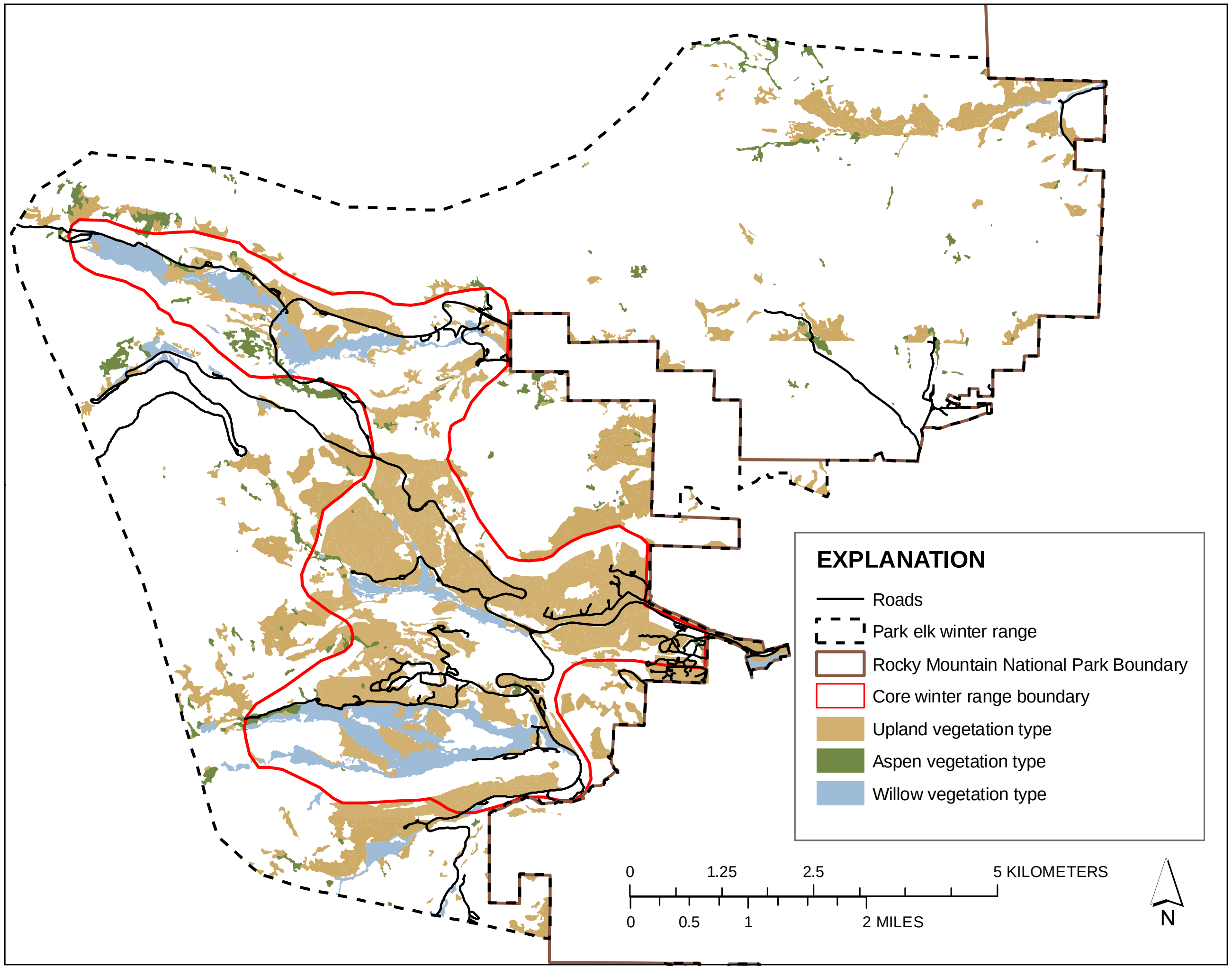


Figure 2. Map of aspen, willow, and upland vegetation communities from which monitoring sites were selected on elk winter-range in Rocky Mountain National Park, Colo. The extent of vegetation types was derived from park vegetation maps (Salas and others, 2005) and hydrologic information (E. Gage, Colorado State University, written communication, 2006). The validity of vegetation types was determined by field visits.

Selection of Monitoring Variables and Determination of Thresholds

The selection of the variables to be measured by this monitoring program was determined to a great extent in the Elk and Vegetation Management Plan (U.S. Department of the Interior, 2007) based on the desired future condition identified for each vegetation type (aspen, willow, and upland herbaceous) in the plan. The EVMP identifies specific indicators to be monitored as part of plan implementation and provides thresholds to be used in evaluating management actions and how well objectives are being met (U.S. Department of the Interior, 2007, p. 56–58). The indicators and thresholds presented in the EVMP were determined based on the best available information at the time the plan was written. We clarified and refined the indicators and thresholds in this monitoring plan (table 1) based on new information, as well as the evaluation of baseline conditions presented in this monitoring plan (see "Baseline Condition" section) in combination with research results from earlier studies used in developing the EVMP. The selected indicators are the measurable variables that will be monitored. These include variables that directly represent desired future conditions (aspen regeneration, willow cover and height), as well as variables linked to achieving those results (consumption of willow and upland herbaceous vegetation, referred to as offtake). Vegetation response toward desired conditions will be measured every five years to allow adequate response time, while consumption will be measured annually to provide the ability to distinguish offtake trend from interannual variation in this dynamic variable.

The thresholds for aspen regeneration, willow cover, and willow height are the baseline conditions across the winter-range. Over the 20-yr life of the management plan, there should be a progressive increase in aspen regeneration, willow cover, and willow height to the desired future conditions (U.S. Department of the Interior, 2007), but increases will not necessarily be linear over time. Increases are expected to occur within fenced areas and may or may not occur in unfenced core areas or non-core winter-range. However, a net increase across the entire winter-range is expected to occur. Data gained from separate evaluations of conditions in fenced core, unfenced core, and non-core winter-range in comparison to individual baseline conditions (see "Baseline Condition" section) in each of those types will be important to understand changes, either increasing or decreasing, in each type. This understanding will also ensure that management actions can be altered as needed to achieve objectives across the winter-range. Thresholds for consumption of willow and upland herbaceous vegetation are the baseline offtake levels that, at a minimum, should not increase across the winter-range. Differences in offtake trends between non-core and unfenced core areas may indicate shifts in range use; however, no net increase in the weighted average across all grazed areas should be observed. Baseline data indicate there is diversity of grazing levels across the landscape, which will be maintained by limiting areas subject to very high grazing levels.

The EVMP did not set management objectives for upland shrubs; however, a large proportion of the upland vegetation type is made up of shrublands. Herbaceous offtake in any of these areas is likely dependent upon the amount of shrub cover on the site. Changes in shrub cover may influence offtake rates rather than changes in elk use. Therefore, we included periodic measures of shrub cover along with our upland herbaceous measures. These measures will also be useful in helping park managers monitor changes in upland shrubs. However, any significant changes in upland shrub cover, heights, and species composition must be analyzed with caution because these shrublands are also used to a great extent by mule deer. Since reductions in elk populations or changes in their distribution could impact mule deer populations (positively or negatively), any observed declines in upland shrub cover could be attributed either to herbivory

Table 1. Vegetation types and their desired future conditions, indicator variables, and thresholds to be used in implementing the Rocky Mountain National Park elk-vegetation monitoring plan. [dbh, diameter at breast height; m, meter; cm, centimeter; yr, year]

Vegetation category	Desired future condition[1]	Indicator	Thresholds
Aspen	At least 45% of aspen across the winter range regenerating. Distribution of stem dbh reflects many (~75%) small-diameter stems, some (~20%) medium-diameter stems, and few (~5%) large-diameter stems.	Stem density by height and diameter class.	Progressive increase in aspen regeneration above the baseline level of 13% (presence of stems < 2 cm dbh reaching 1.5–2.5 m tall). Progressive shift in the distribution of stem sizes toward the desired future condition.
Riparian Montane Willow	At least 31% willow cover within suitable willow habitat across the winter range. Average willow height of at least 1.1 m.	Willow consumption	No net increase in annual willow offtake across the winter range above the baseline level of 35%.
		Cover	Progressive increase in willow cover across the winter range above the baseline level of 21%.
		Structure	Progressive increase in willow height across the winter range above the baseline level of 0.9 m.
Upland Herbaceous	Reduction of the level of elk grazing on herbaceous vegetation and maintenance of a diversity of grazing levels across the landscape.	Herbaceous consumption	No net increase in winter upland herbaceous offtake across the winter range above baseline levels of 47%, with ≤ 25% of sites with offtake > 70% and ≤ 10% of sites with offtake > 85%.

[1]Desired future conditions for willow are specific to the 20-yr time frame of plan implementation.

by elk or mule deer. These complicating factors were the reason the EVMP avoided setting management objectives for the upland shrub vegetation type.

Design of Sampling Structure and Site Selection

The management alternative that is being implemented relies on the improvement of aspen and willow conditions inside fences, while ensuring at a minimum that conditions do not decline outside fences. In order to monitor the effects of the full range of management actions being implemented, we selected a sampling design which stratifies vegetation communities into elk winter-range zones of fenced core winter-range, unfenced core winter-range, and non-core winter-range. This allows separate monitoring of vegetation responses to management actions for each type of range. Managers can determine whether management actions in one zone might have positive or negative impacts on another elk winter-range zone. For example, if removal of available elk forage due to the fencing of large areas of willow habitat leads to declines in willow cover and height and increases in browse pressure on non-core or unfenced core willow habitat, the sample sizes and stratification should be adequate to indicate and assess such changes. This will allow park managers to adapt their management strategies to address the impacts of management to any specific stratum. While there is the possibility that vegetation types may change over the time period of this plan (for example, an aspen stand might grow on an upland site), for the purposes of this monitoring plan, all original vegetation type designations will be maintained throughout the 20-yr monitoring period associated with the EVMP.

At the outset of this study, very little pilot data were available for assessing appropriate sample sizes for aspen plots. Although several studies of aspen in the park have been conducted over the past several decades, (Olmsted, 1997; Baker and others, 1997; Kaye and others, 2003; Suzuki and others, 1999) either the measurement variables or sample selection (non-random methods) were not comparable or the raw data were not available. Stohlgren (2001) recommended a sample size of 10–15 plots per strata, but consultation with D. Binkley (Colorado State University, written comm., 2010) as to the objectives of the EVMP and the elk-vegetation monitoring plan described here, led to agreement that 20 sites per strata should be adequate to assess the level of change indicated in the EVMP (table 2).

The sample size for willow monitoring was based upon data from willow studies conducted in 1994–1998 on the core winter-range of elk in Rocky Mountain National Park (Singer and Zeigenfuss, 2002; Zeigenfuss and others, 2002) and from estimates derived with the assistance of biologists from the National Park Service Inventory and Monitoring (I&M) Program's Rocky Mountain Network (W. Schweiger, National Park Service, written comm., 2006). Estimates of necessary sample size from the I&M program were based not on data but rather on information from a monitoring perspective that assumes at the simplest level the use of design-based inference to generate measures of status that use proportions to express results (for example, in year y, x percent +/- a confidence interval of the park winter-range has willow above some established threshold of significance for a single sample interval). These initial analyses estimated a need for a minimum of 35 sites per vegetation type in each elk winter-range zone (table 2). We verified that this was an adequate number of sample sites based upon the data available from the studies of Zeigenfuss and others (2002) and Singer and Zeigenfuss (2002). Park managers requested that any analysis of sample size include options whereby 95 percent statistical power could be achieved, as well as a lower power (in this case 90 percent) to detect differences similar to those observed between fenced and unfenced areas in the earlier study. We used a two-sample power test which compared the means at the end of the 1994–1998 study

Table 2. Sample design of elk-vegetation management monitoring program at Rocky Mountain National Park, Colo.

Vegetation type	Variables sampled	Elk winter-range zone	# sites needed	# sites established (2006–2009)
Upland	Winter herbaceous offtake	Core winter-range	25	25
	Shrub cover Shrub species	Non-core winter-range	25	23
Aspen	Size class density and distribution	Unfenced core winter-range	20	22
		Fenced core winter-range	20	23
		Non-core winter-range	20	20
		Kawuneechee Valley	20	8
Willow	Shrub cover	Unfenced core winter-range	35	35
	Shrub species	Fenced core winter-range	20	22
	Willow height	Non-core winter-range	35	34
	Annual offtake (only unfenced areas)	Kawuneechee Valley	35	0

between fenced and unfenced treatments for two variables, willow canopy area (we used this as an equivalent to willow cover) and willow average height. We performed these comparisons between the measured variables in the first and fourth years of the study in the fenced treatments as well. To estimate potential sample sizes for the variable of offtake rates, we used a one-sample power test since this could only be measured at unfenced sites. We investigated necessary sample sizes to get within plus or minus 7 percent of the observed mean (assumed to be the true mean) for 3 yr of offtake samples.

The results of these tests gave a range of sample sizes depending upon the variable being tested and the type of comparisons being made (table 3). We found that a sample size of 35 sites would give a power of 95 percent in 75 percent of cases and a power of 90 percent in 87.5 percent of cases for height and canopy area data. For offtake data, which can greatly vary each year, a sample size of at least 41 sites was necessary to get within 7 percent of the true mean with a power of 95 percent in the year which had the highest variability. However, when we averaged offtake over all years, we found a sample size of 33 was sufficient to determine offtake over all sites. Based on these results, we determined that a sample size of 35 would be more than adequate to measure the effectiveness of fences in reducing the effects of elk herbivory and increasing willow growth, as well as to measure variations in offtake levels equal to those observed during the earlier study. However, we had limited resources for establishing monitoring sites, and the park also has limited resources to monitor sites. We determined, in agreement with park resource managers that, since the fenced willow areas were going to be limited to approximately half the area of core winter-range willow habitat and since several monitoring sites were going to be located in each fenced area because of the large sizes of the fenced enclosures, we would limit the sample size in fenced core winter-range willow to 20 sites.

We determined the sample size for upland monitoring (table 2) based upon analyses in the RMNP long-term monitoring plan (Stohlgren, 2001). This earlier analysis used data from two studies of offtake in upland habitats (Stevens, 1980; Singer and Zeigenfuss, 2002) to determine that a sample size of 25 was adequate to predict mean values of herbaceous offtake within 20 percent of the true mean 90 percent of the time.

We used a stratified, random sampling design to select potential monitoring sites. Using ArcGIS 9.2, we selected the vegetation communities of interest and clipped them using the winter-range boundary. We then further separated those vegetation polygons that fell within the

Table 3. Estimates of needed sample sizes to achieve powers of 0.9 and 0.95 to detect changes similar to those observed in studies of willow growth in Rocky Mountain National Park 1994–1998 (Singer and Zeigenfuss, 2002; Zeigenfuss and others, 2002).

Treatments compared	Variable measured	Sample size needed to achieve power of 0.9	Sample size needed to achieve power of 0.95
Fence vs. unfenced	Canopy area	15	18
	Average height	9	11
	Maximum height	14	17
Fenced yr 1 vs. yr 4	Canopy area	18	21
	Average height	29	36
Year 1	Offtake (w/in +/-7%)	27	33
Year 2	Offtake (w/in +/-7%)	24	29
Year 3	Offtake (w/in +/-7%)	33	41
Average years 1–3	Offtake (w/in +/-7%)	27	33

core winter-range from the entire winter-range to create maps of core and non-core winter-range vegetation communities.

Finally, we used maps of potential fence locations to clip fenced vegetation polygons from the core winter-range map. The final results were three maps each for aspen and willow types (non-core winter-range, fenced core winter-range, and unfenced core winter-range) and two maps for upland vegetation types (core and non-core winter-range). We then used either the random-point generators included in ArcGIS 9.2 or Hawth's Tools (H. Beyer, *www.spatialecology.com*) to generate random points in each vegetation type and elk winter-range zone. A minimum distance of 250 m (meters) between upland sites was imposed to allow movement of grazing cages over a large enough area to prevent site overlap while preventing resampling within the same site within a short time frame. Since willow and aspen monitoring plots were fixed in size, no minimum distance between plots was used, but plot boundaries could not overlap each other. Not all sites that appeared appropriate on the map were found to be suitable upon site visit, in which case the site was replaced with another randomly selected site.

Design of Monitoring Methods

The sample methods we used in this plan were based upon many sources. Plot sizes for aspen plots were based upon recommendations found in Stohlgren's (2001) Rocky Mountain National Park long-term monitoring plan where a plot size of 5m × 5m was determined to be suitable for assessing size and age class structure of pure and mixed aspen stands (Stohlgren, 2001). A 5- to 10-yr sampling interval was recommended as adequate to detect major changes in these variables. The draft sampling protocols we developed for aspen monitoring were reviewed by D. Binkley and W. Romme of Colorado State University, who have conducted extensive aspen research including research in RMNP. Their review comments were incorporated into the final protocol. The original protocol called for aging aspen trees using increment cores taken from stems in each site in order to determine age of small-diameter aspen trees; however, based on concern expressed that excessive coring might introduce additional sources for disease entry and thus imperil aspen stands that are already in decline, we eliminated coring and instead used size classes as an indicator of age and regeneration status. We designed sampling protocols for aspen that measure size classes of both aspen trees and saplings, number of alive and dead stems, and general degree of bark damage and signs of ungulate use at each monitoring site (Appendix 1).

Plot sizes for willow sites were based upon subplot sizes outlined in the draft protocols for wetland monitoring to be used by the National Park Service Rocky Mountain Vital Signs Monitoring Network (D. Cooper, Colorado State University, written comm.). We determined that a 4m × 4m plot size would be adequate to measure willow cover and height. Willow cover and average heights are determined by measuring all willows on the plot (Appendix 2). Since the primary methods to estimate shrub cover, height, and browsing are time intensive, we also incorporated an additional, faster, but less accurate method to measure shrub cover, species composition, and height using a line-intercept method (Canfield, 1941). This method measures only the parts of individual plant canopies that intercept a 5.7-m transect line and determines percent cover as the percent of the line intercepted by shrubs instead of basing measurements on plot and plant canopy areas. Our intention was to introduce some flexibility and options into the monitoring plan such that in years when funds might not be sufficient to conduct the full suite of sampling, monitoring could still be conducted albeit with some sacrifice in either (1) power to detect trends in measured variables, (2) accuracy of measures, or (3) both accuracy and power. Willow-monitoring methods were reviewed by D. Cooper and E. Gage of Colorado State University and D. Johnston of the Colorado Division of Wildlife. All reviewers had experience with willow measurements and are familiar with willow conditions in RMNP.

The methods described above will enable the park to determine changes in willow cover within areas that are currently considered willow habitat (fig. 2). However, they may not be as accurate in detecting landscape-scale changes in willow habitat, particularly if large-scale changes in hydrology take place, as has happened in the western end of Moraine Park over the last several decades. Therefore, it would be prudent for the park to use aerial imagery (either aerial photography or high-resolution satellite imagery) to determine changes in landscape-scale willow cover over the next 20 yr, revisiting the imagery ideally at 5-yr intervals, minimally at 10-yr intervals, to determine the extent of cover loss or expansion at this broader scale.

Collecting data on the baseline condition using this method was beyond the scope of the current project. Acquiring satellite imagery is significantly less expensive than using conventional aerial photography and the processing costs are considerably lower as well (table 4). However, as new sources of remotely-sensed imagery become available, it may be that much of the cost of this method may be absorbed or shared with other projects.

Two methods of measuring ungulate browsing on willow were incorporated into the willow-monitoring protocols. The “stem-scaled diameter difference method” (also called the DD2 method in Bilyeu and others, 2007) calculates offtake as the difference between diameter at

Table 4. Cost estimates to identify willow cover on the primary winter-range using remotely-sensed imagery. Estimates assume acquisition of imagery for 210-km^2 area encompassing primary winter-range. [km^2, square kilometers]

Task	Type of remote imagery	
	Satellite imagery	Aerial photography
Acquisition of imagery	$13,500	$95,000
Processing	$16,500	$53,000
Comparative analysis to previous data	$20,000	$20,000
Total	$50,000	$168,000

bud scar and at browse point scaled by the number of shoots browsed on the entire stem (equation 1).

$$DD2 = \left(\frac{b}{b+u}\right) \times \left(\frac{D_p - D_t}{D_b - D_t}\right) \quad (1)$$

In this equation,
b, the number of browsed shoots on the stem;
u, the number of unbrowsed shoots;
D_p; shoot diameter at the point of browsing;
D_t; the average diameter of unbrowsed shoot tips; and
D_b; the diameter at the base of the shoot.

This method of estimating browse levels was used in previous studies in RMNP, (Singer and Zeigenfuss, 2002) and the thresholds identified in the EVMP were based upon these methods. We included this method in our monitoring design to provide a less time-consuming alternative if needed.

In recent years, Bilyeu and others (2007) developed a novel method for scaling browse estimates to account for elk preference for larger, more productive shoots. The "production-weighted diameter difference method" (DD3) recommended by Bilyeu and others (2007) accounts for the fact that browsers often browse more productive shoots and it estimates the percentage of biomass removed based upon shoot size of browsed and unbrowsed shoots (equation 2).

$$DD3 = \left(\frac{b \times B}{b \times B + u \times U}\right) \times \left(\frac{D_p - D_t}{D_b - D_t}\right) \quad (2)$$

In this equation,
B, average pre-browse mass of browsed shoots; and
U, the average mass of unbrowsed shoots.

This method requires slightly more field time, but provides greater accuracy in results.

Bilyeu and others (2007) also recommended the use of a method called the biomass comparison method in areas experiencing intense herbivory. This method accounts for the complete consumption of shoots by browsers. However, this method is very labor intensive—it requires site visits in both spring and fall, marking and then remeasuring the same stems each sample period, and a wider group of shoot samples for building regressions to estimate biomass removed and the development of several regression equations for each species. We conducted pilot studies that indicated that elk were browsing beyond the current year's growth and we therefore tried to employ the biomass comparison method to measure offtake as part of this monitoring program. Unfortunately, our results from this method were very poor and inconsistent, likely attributable to observer error in the initial sampling. However, we believe that even with more detailed protocols and training describing the procedure, the costs outweigh the benefits of using this method due to the large amounts of time related to measuring shoots in the fall, locating marked stems again each spring, and calculating regressions.

As part of the EVMP, park managers will be taking measures to ensure elk migration to summer ranges, so summer offtake is anticipated to be minimal. The DD2 and DD3 methods described above estimate total annual willow offtake but are being used as analogous to winter offtake only, because summer offtake should be minimal under this management plan. However, weather conditions may cause summer offtake to be substantial in some years (for example, late snows might keep elk on the winter range into the calving season and then for a post-parturition period extending into the summer, or drought may cause elk to abandon summer range earlier because of low forage availability). Alternatively, portions of the elk herd may alter their behavior over time which could lead to decreased migration to the summer range, despite management actions intended to encourage seasonal migration. If this occurs, park managers may feel the need to begin to evaluate summer offtake. This could be done using the methods described above, but would require at least one sampling during the later part of each summer (in addition to the spring measures described above) in order to determine the amount of offtake which occurs during the summer season.

While there are a variety of methods for estimating herbaceous offtake, we chose the method that has been used in the majority of prior studies and that has also been used as the basis for determining the threshold levels of offtake in the EVMP (Appendix 3). This method involves the use of movable grazing cages to protect plants from grazers during the grazing season (in this case, winter) and then clipping plots protected by the grazing cage and paired plots outside the cage to determine percentage of offtake (Bonham, 1989). The cages are moved to a new site at the beginning of each sampling period to protect a new plot from grazing. No individual plot is protected for more than a single sampling season because long-term grazing exclusion could potentially lead to litter accumulation, species composition changes, and productivity changes inside the ungrazed plots. Such changes from long-term grazing exclusion could result in incorrect estimates of annual offtake. Because the grazing cages will be moved over the site over many years, a plot with set boundaries was not used. Instead, each site was marked in one location and the measured area includes roughly all area of the upland vegetation within 125 m of that site marker. Cages are moved within this site for each offtake sampling. Winter offtake is determined by comparing biomass at the end of winter inside the cage to that remaining in the uncaged, grazed plot using Equation 3.

$$O_w = 100 \times \left[\frac{(B_i - B_o)}{B_i} \right] \qquad (3)$$

Here,

O_w, the percent of standing crop remaining at the end of the growing season that is used overwinter;

B_i, the amount of biomass in caged plot at the end of winter; and

B_o, the amount of biomass in paired uncaged plot at the end of winter.

Upland shrub cover and height will be measured by species using the line-intercept method (described above) for willow on a 30 m transect through the site (Appendix 3).

Temporal Sampling Design

The temporal sampling design for this monitoring protocol varies across metrics and community type. The nature of the offtake indicators requires annual monitoring, particularly as offtake measures are subject to a high degree of interannual variability based upon factors such as weather and ungulate population size. However, the sampling of all sites each year would be labor intensive and costly. Therefore, we selected a split-panel, serially alternating design with consecutive year revisits (Urquhart and Kincaid, 1999) to allow us to account for this interannual variability in the monitoring of offtake in both upland herbaceous and willow communities. We divided our 20-yr monitoring period (2009–2028) into five panels, such that each site would be visited for offtake measures twice within each 5-yr period. We then divided the total number of sites in each vegetation type and elk winter-range zone by 5 to determine how many sites would be assigned to any given panel (table 5). The repeat sampling at a site in this design allows estimation of annual changes from a direct comparison at a sample point, while allowing more precise estimates of long-term trends when points are remeasured after five yr. We also attempted to balance the temporal aspects of this design with the spatial distribution of sites. Therefore, within each vegetation type and elk winter-range zone, we visually grouped the randomly placed sites into spatial “neighborhoods” of five sites (one for each panel), then sites within the “neighborhood” were randomly assigned to one of the five panels (fig. 3). The “neighborhood” is defined as a group of sites that are spatially close together and linked by topography as much as possible. For example, one neighborhood in figure 3 falls within the Horseshoe Park/North Deer Mountain area, while another includes Upper Beaver Meadows. In this way, the sampling will be balanced to take into account spatial phenomena that may affect only one particular area in a given year. The social nature of an ungulate that moves and feeds in herds (like elk) can result in large spatial heterogeneity in offtake on the landscape (with some locations being more heavily grazed due to number of animals concentrated in a group) in addition to typically occurring heterogeneity in offtake resulting from the distribution of desirable forage species.

Measures of willow cover and structure, upland shrub cover, and aspen stem density tend to change more slowly over the span of many years, so we selected a design where all sites were revisited on a 5-yr basis. From labor, cost, and planning perspectives, this should allow the park to plan for larger field crews every fifth year to sample all sites and to use the existing labor base to conduct annual sampling.

Table 5. Example of split–panel, serially alternating design used for sampling offtake in this monitoring program. This example shows a vegetation type and strata (for example, upland core) with a total of 25 monitoring sites, but in any given sampling year, only 10 sites will be visited.

Panel #	Metric	# sites (n=25)	Sampling year											
			1	2	3	4	5	6 7 8			9	10	11	12
All sites	Site info Shrub cover Shrub height Photos	25	X				X					X		
1	Offtake	5	X	X				X	X				X	X
2	Offtake	5		X	X				X	X				
3	Offtake	5			X	X				X	X			
4	Offtake	5				X	X				X	X		
5	Offtake	5					X	X				X	X	

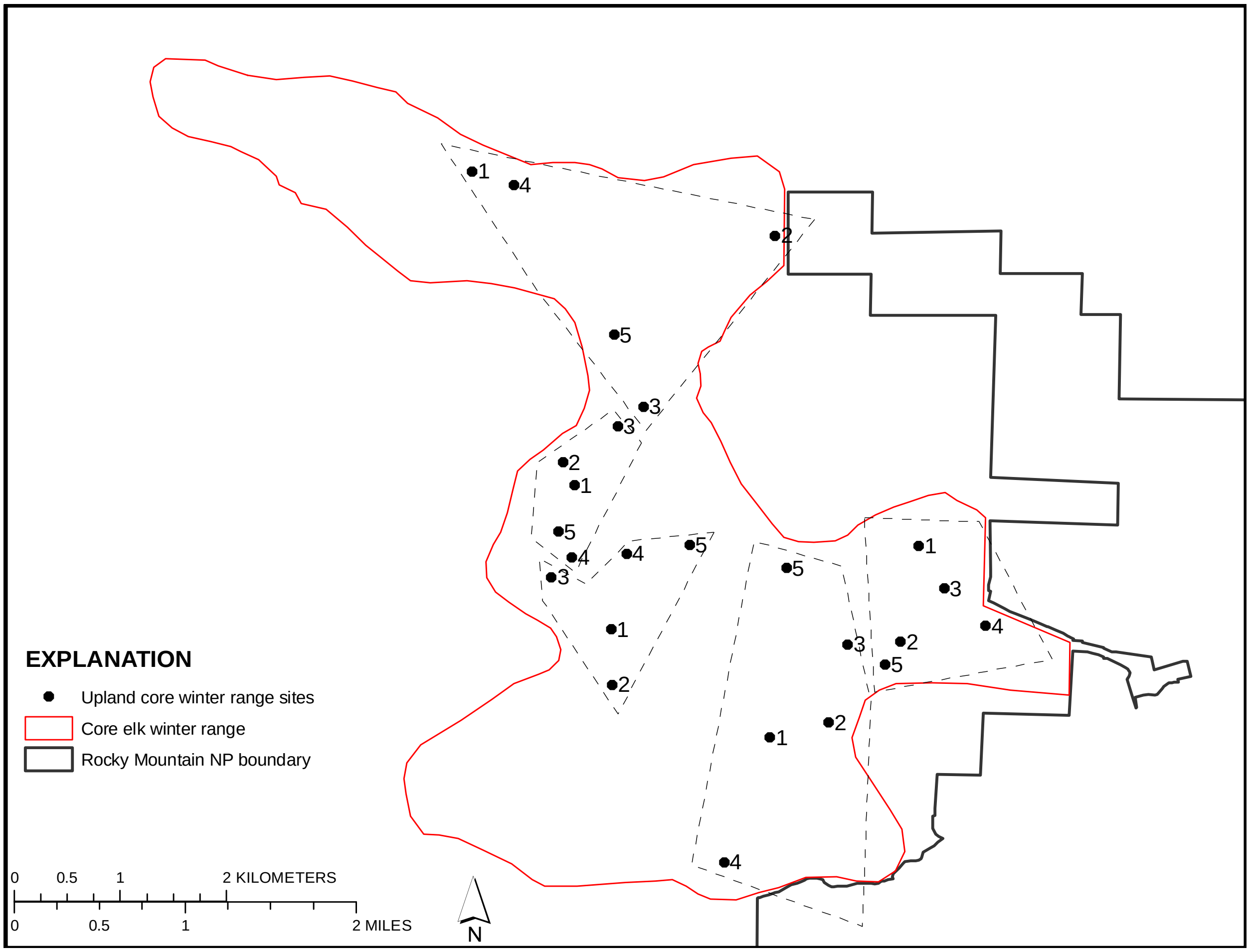


Figure 3. An example of how random points were grouped into spatial "neighborhoods" for random assignment to temporal sampling panels. Each "neighborhood" has one point in each of the five panels. A panel consists of all the points measured within a year.

Establishment of Monitoring Sites and Collection of Baseline Data

Establishment of 210 monitoring sites began in 2006 (some aspen and upland sites) and extended through 2009 (willow and aspen sites, table 2). Baseline data were collected from all sites at their establishment. Of the 210 total sites, 73 sites were aspen sites including 20 sites in the non-core winter-range, 22 unfenced sites in the core winter-range, 23 fenced sites in the core winter-range, and 8 sites in the Kawuneechee Valley (fig. 4). The majority of these sites were established during 2006–2008; however, some designated fenced sites were not established until late summer 2009 when park managers had determined which sites might potentially be fenced over the life of the management plan. Nine aspen fences were constructed in late summer and fall 2009. All baseline data at fenced sites were collected prior to, or within a month of, completion of aspen fences. Some of the sites had baseline data collected in fall 2009 (after the first year of elk-culling actions had taken place) but prior to or coincident with the establishment of aspen fences.

During the establishment of aspen sites, we measured general site characteristics, aspen suckering and regeneration (live and dead), aspen tree size and density (live and dead), degree of bark scarring, and we also photographed each site. Suckering in aspen sites was defined as small-diameter (less than 2 cm (centimeters) dbh) stems less than 1.5 m in height. Regeneration (those stems likely to grow into the tree canopy) was defined as small-diameter (less than 2 cm dbh) stems 1.5 m to 2.5 m in height. Stems greater than 2.5 m are generally beyond the height of elk browsing and were considered to have successfully recruited into the canopy. Bark scarring was categorized by the amount of the trunk surface less than 2.5 m in height that was scarred by ungulate browsing on the majority of trees in a site.

A total of 91 willow sites were established in 2008 and 2009 (fig. 5). There was a dearth of suitable sites in the non-core for the willow vegetation type and this resulted in the establishment of one less willow non-core site than planned. Shrub cover and height, shrub species composition, winter offtake, and plot photos were collected during baseline-data collection in willow sites. Most willow sites were established in 2008 (77 sites) and had baseline cover and height data collected at time of establishment. Forty-seven of these sites had baseline offtake data collected at the end of winter 2008–2009, which was the first year of elk culling, and also after the establishment of 28 ha (70 acres) of fenced willow habitat in three locations on the core winter-range during fall 2008. The remaining 30 sites either fell within fenced areas and had little or no offtake during this winter, had no willow within the plot to measure offtake in the baseline year, or in a few cases, were not collected due to difficulties locating sites or meeting time and labor constraints (these sites were scheduled for measurement in 2009–2010). The minimal level of culling in winter 2008–2009 likely had little effect on elk-distribution patterns; however, it is possible that establishment of the elk fences may have increased willow offtake in non-fenced core winter-range.

Sites selected for the “fenced” strata were based on initial projections of locations to be fenced in plan implementation. In 2009, after further identification of potential fence locations, an additional 14 monitoring sites were established (including two additional sites to provide for changes in projected fence locations). Some fence locations have not been confirmed, and it is uncertain when fencing will be completed, as it depends on funding availability and other factors. Therefore, the actual status of these sites will need to be accounted for during data analysis. At the time fences are established, park managers should resurvey baseline condition prior to fencing if more than 3 yr have passed since the establishment of these sites. These sites are included, however, in the count of sites needed to properly sample the fenced treatment.

One non-core site was eliminated after it was established, due to a water table that was so high that the markers were underwater the majority of the year. Since the non-core willow sites are clustered in the four small areas on the non-core winter-range (Hidden Valley, Cow Creek, Glacier Creek, and Hallowell Park) and these areas are quite saturated with sites, we decided not to replace this site.

A total of 48 upland sites were established, the majority of them in 2006 and 2007 (fig. 6). There was also a dearth of suitable sites in the non-core for the upland vegetation type which resulted in the establishment of two less upland non-core sites than planned. One upland site was eliminated after it was established because of subsequent assessment of potential danger from rock slides. Many upland sites were inspected and rejected as unsuitable (reasons include improper vegetation type, proximity too near sites already selected for monitoring, and location within developed areas) in the non-core winter-range and we eventually selected only 22 non-core upland sites. Baseline data collected at the time of establishment included: site characteristics; shrub cover, height, and species composition; herbaceous offtake; and site photos.

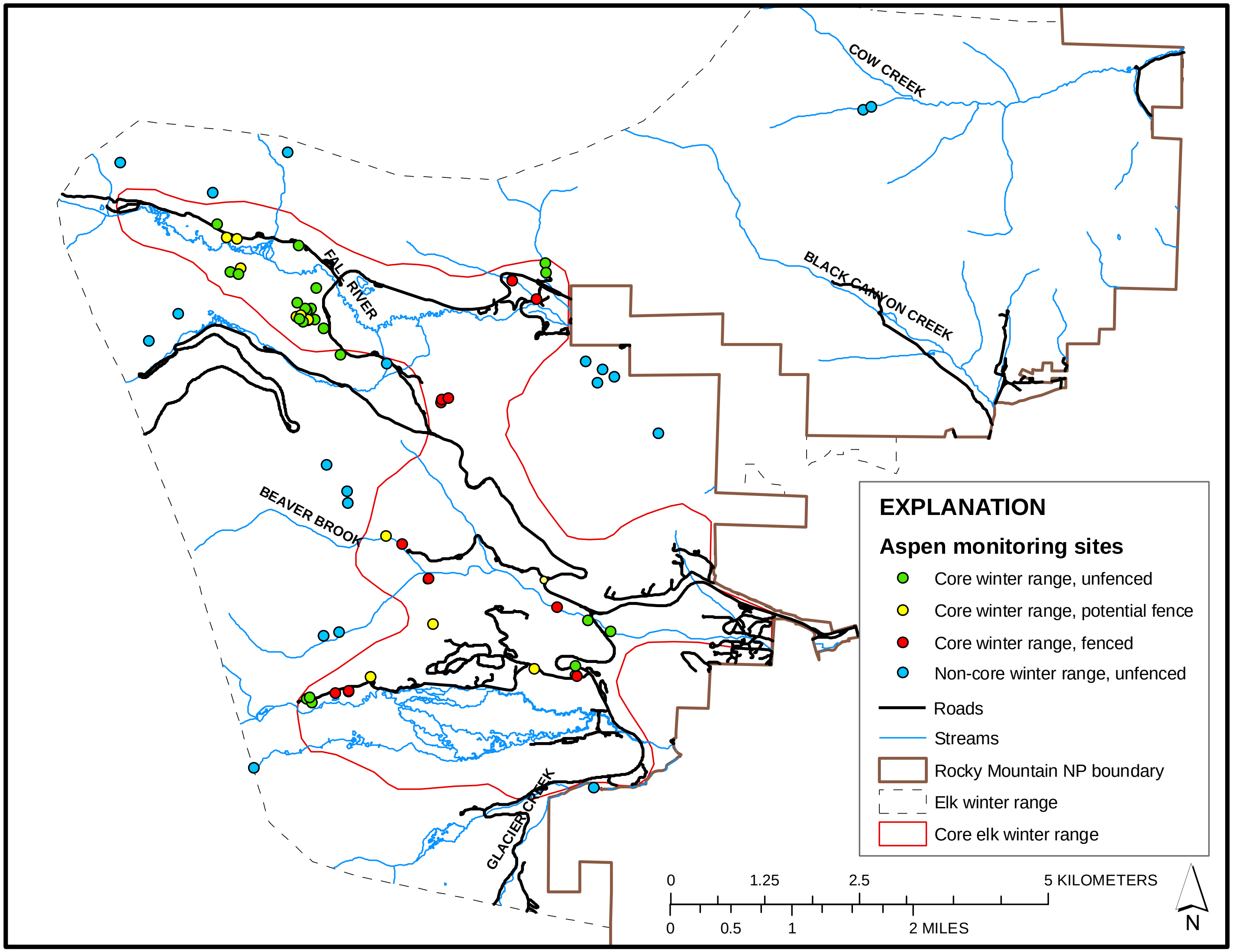


Figure 4. Locations of aspen-monitoring sites on elk winter-range in Rocky Mountain National Park, Colo. Sites (yellow on map) were established as part of the "fenced" strata in locations identified to potentially be fenced based on the best available information as of fall 2009.

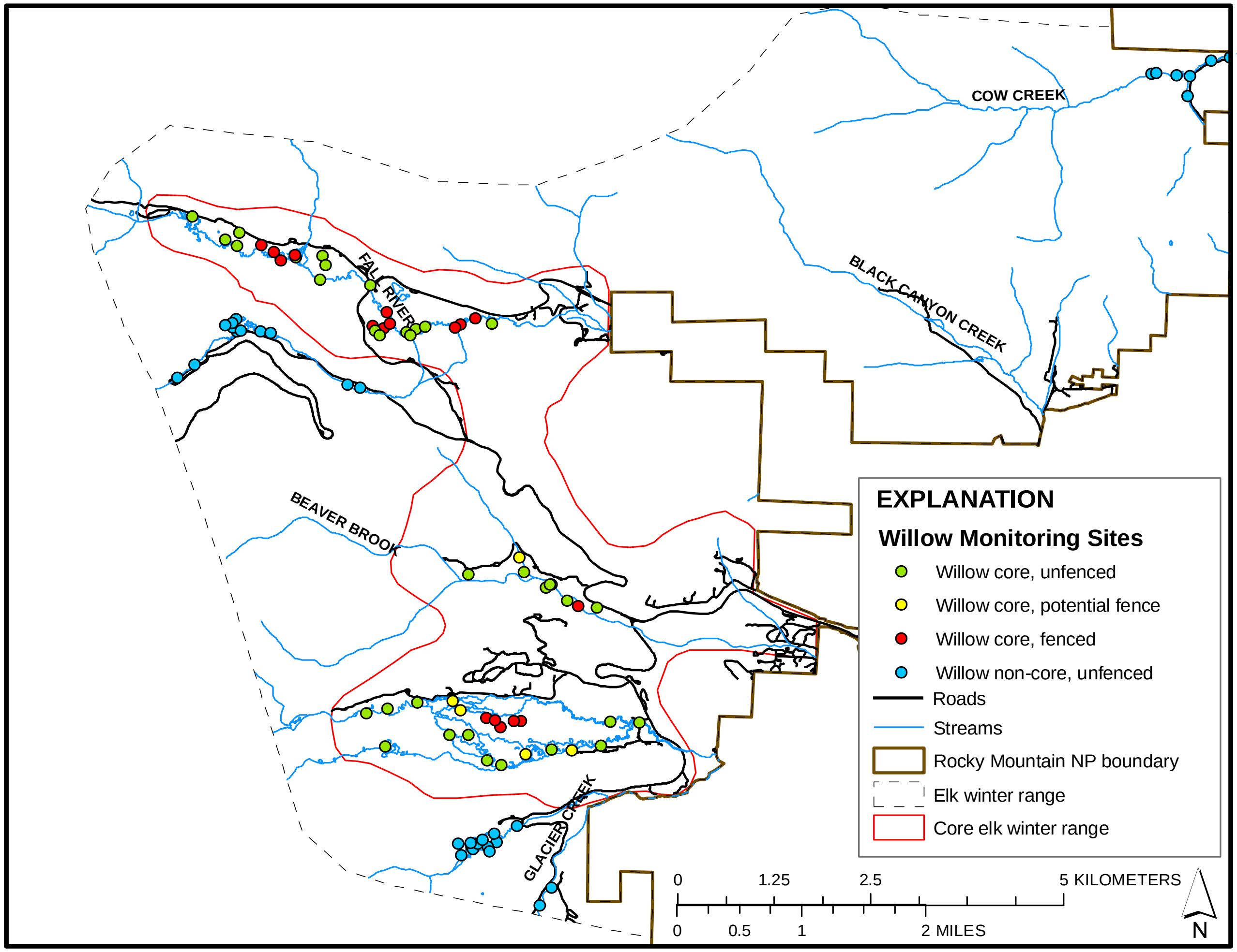


Figure 5. Locations of willow-monitoring sites on elk winter-range in Rocky Mountain National Park, Colo. Sites (yellow on map) were established as part of the "fenced" strata in locations identified to potentially be fenced based on the best available information as of fall 2009.

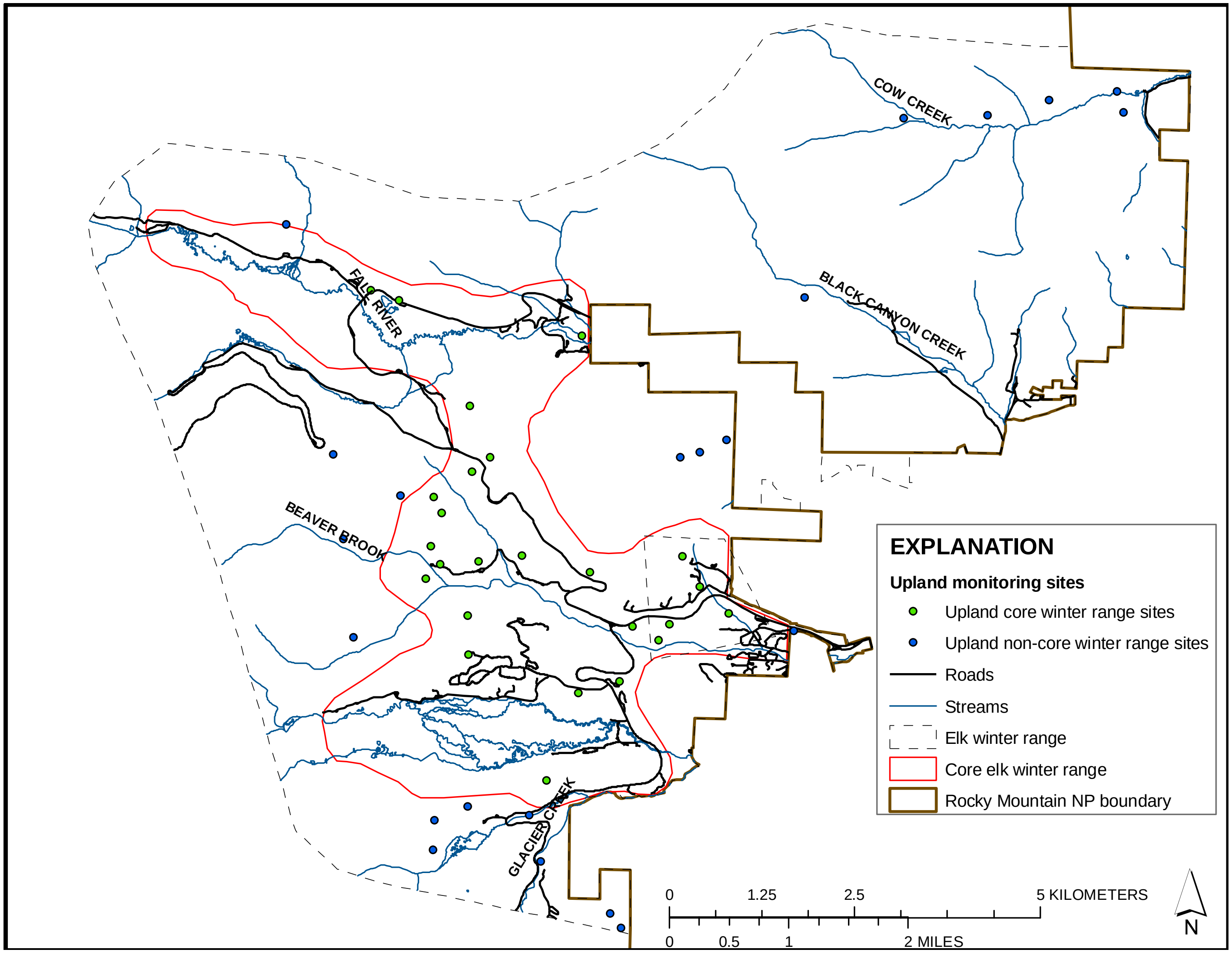


Figure 6. Locations of upland vegetation monitoring sites on elk winter-range in Rocky Mountain National Park, Colo.

Data were summarized before analysis. Aspen data were tallied by plot for each category (suckers/regeneration; small-, medium-, large-diameter stems) and then analyzed by core and non-core winter-range sites. Fenced sites were analyzed as part of the core winter-range because fence effects should not have been evident at the time of baseline-data collection, but we did look at these sites separately to see if they reflected baseline conditions similar to unfenced core sites. The percent of winter-range zones that showed aspen regeneration were determined by calculating the percent of measured plots in each winter-range zone that showed regeneration (stems less than 2 cm dbh, 1.5–2.5 m tall). Estimates of regeneration for non-core and core winter-range were weighted by the proportion of total aspen winter-range in each zone (non-core = 72.8 percent, core = 27.2 percent) and then averaged to determine regeneration rates for the entire winter-range.

Willow shrub cover was calculated, using the line-intercept method, by totaling the entire length (in meters) of the transect line that was intercepted by willow for the site and then dividing by 5.7 m (the length of the transect line) and multiplying by 100 to get a percent cover value. Willow shrub cover was derived, using the macroplot method, by calculating the canopy area of each individual willow that intersected the macroplot (canopy diameter measures were converted to area measures using the elliptical area formula), then multiplying by the proportion of the willow plant that fell within the macroplot. Individual canopy areas were then totaled for the plot and divided by the macroplot area (16 m^2) and multiplied by 100 to derive percent willow cover estimate for the site. Average willow heights were determined for each site, using the macroplot method, by averaging all height measures of willows that fell within the plot and, using the line intercept method, by averaging height measures of all willows that intercepted the transect line. Willow offtake was calculated using equations 1 and 2 for each measured stem and was then averaged to determine offtake values for each site. Core and non-core site offtake, cover, and height values were then averaged to get offtake values for each elk winter-range zone. Fenced sites were analyzed as part of the core winter-range because fence effects should not have been evident at the time of baseline data collection, but we did look at these sites separately to see if they reflected similar baseline conditions as unfenced core sites. Estimates of offtake, cover, and height for non-core and core winter-range were weighted by the proportion of total willow winter-range area in each zone (non-core = 12.8 percent, core = 87.2 percent) and then averaged to determine offtake for the entire winter-range.

Upland herbaceous offtake was derived by calculating offtake for each individual cage pair using equation 3. Then all three offtake measures collected at each site were averaged to derive the offtake for the site. Negative offtake values (greater standing crop outside the cage than inside) were only removed if the value was greater than -100 percent, to avoid inflating offtake data or creating a skewed data set by rounding these values to zero. Site-level upland herbaceous offtake, shrub cover, and height data were then averaged to get values for each elk winter-range zone. Estimates of offtake, cover, and height for non-core and core winter-range were weighted by the proportion of total upland winter-range in each zone (non-core = 42.2 percent, core = 57.8 percent) and then averaged to determine offtake for the entire winter-range.

Tests for differences between core and non-core winter-range were determined using non-parametric and general linear models as appropriate. All statistical analyses were performed using SAS v. 9.1 statistical analysis software (SAS Institute, 2003).

Baseline Condition

Aspen

We found that only two aspen-monitoring sites in the core winter-range and one site in the non-core winter-range had no suckering (stems less than 1.5 m tall, approximate dbh 0–2 cm) within the monitoring plots. However, only approximately 7 percent of the core winter-range had any stems that would indicate successful regeneration (stems 1.5–2.5 m tall and less than 2 cm dbh), and none of the stems observed on the core winter-range exceeded 2.0 m in height. The non-core winter-range had slightly better regeneration with 15 percent of the winter range having stems less than 2 cm dbh and 1.5–2.5 m tall. Average aspen regeneration on the entire winter-range (weighted for the area of aspen stands in core and non-core winter-range) was approximately 12.8 percent plus or minus 3.6 percent. Based on the patterns observed in the data, we created a matrix to display the number of sites showing poor, moderate, and high suckering and regeneration (table 6, fig. 7). While several sites on the winter range showed moderate or high suckering, very few of these also showed moderate or high regeneration. No differences were found in height or stem counts between core winter-range areas that were planned to be fenced and those not fenced.

In the Kawuneechee Valley, half of the established monitoring sites had poor suckering and half had moderate suckering. There was no evidence of successful stand regeneration occurring in the eight Kawuneechee Valley stands at the time of monitoring-site establishment in 2007.

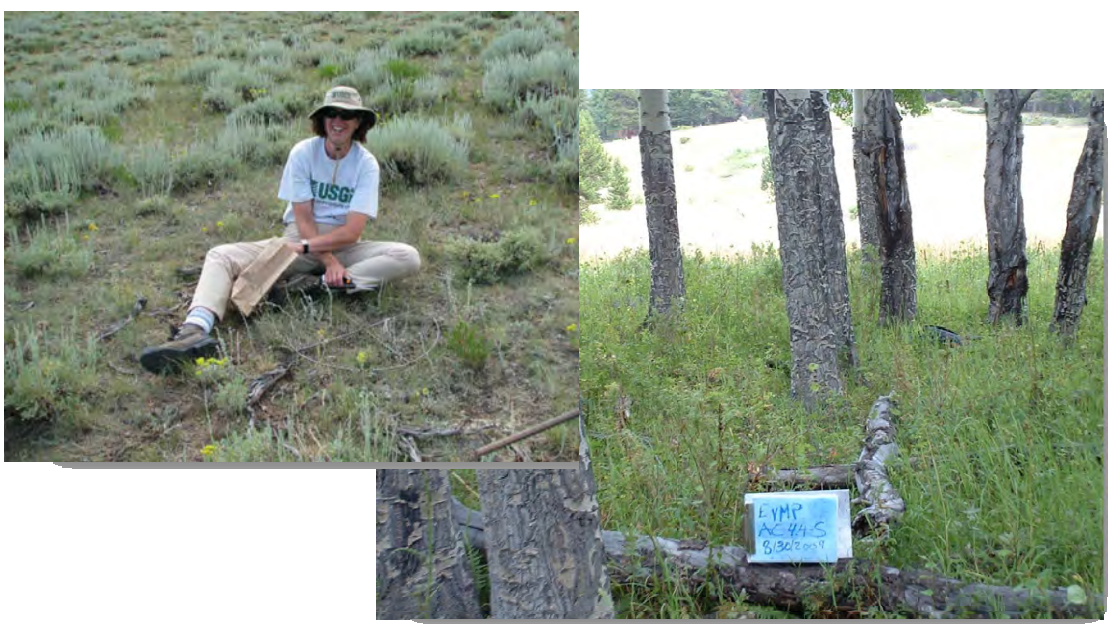
Table 6. Matrix of suckering and regeneration observed on aspen-monitoring sites on the elk winter-range of Rocky Mountain National Park, Colo. Designation of poor, moderate, and high levels is based on patterns observed in the data. Data gathered 2006–2009. Some sites had baseline data collected in fall 2009, after the first year of elk-culling actions.

		Regeneration (stems 1.5 to 2.5 m in height)		
	Suckering (total stems < 1.5 m in height)	**Poor (0 stems/acre)**	**Moderate (< 324 stems/acre)**	**High (≥ 324 stems/acre)**
Core winter-range sites	Poor (0–1,700 stems/acre)	15	1	0
	Moderate (1,700–4,500)	13	1	0
	High (> 4,500 stems/acre)	14	1	0
Non-core winter-range sites	Poor (0–1,700 stems/acre)	13	0	0
	Moderate (1,700–4,500)	3	0	0
	High (> 4,500 stems/acre)	1	2	1
Kawuneechee Valley	Poor (0–1,700 stems/acre)	4	0	0
	Moderate (1,700–4,500)	4	0	0
	High (> 4,500 stems/acre)	0	0	0

Figure 7. Examples of differing levels of aspen suckering (all stems < 2.5 m in height) and regeneration (stems 1.5–2.5 m height) on elk winter-range of Rocky Mountain National Park, Colo.

Distribution of stem size tends toward having the majority of stems in the larger size classes (greater than 15 cm dbh). However, the distribution is fairly even in these larger size classes (fig. 8) and is consistent with the findings of Binkley (2008) which indicated a lack of recruitment of young trees over the past 2–3 decades in low-elevation stands on the east side of the park but also indicated a trend of continuous recruitment of trees in the century preceding this time period. The density of small-diameter trees tended to be slightly greater in the non-core winter-range than in the core winter-range, but much lower in the Kawuneechee Valley (fig. 8). We defined small-diameter size class as less than 10 cm dbh, medium diameter size class as 10–20 cm dbh, and large-diameter size class as greater than 20 cm dbh based on patterns observed in the data and consultation with an aspen expert who has experience working in the park (D. Binkley, Colorado State University, written comm.). The structure observed in all monitoring sites is far from the desired future condition of 75 percent small-diameter, 20 percent medium-diameter, and 5 percent large-diameter stems (fig. 9).

Bark scarring is used here as an additional index to the level of browsing that has occurred historically in these monitoring sites. Its usefulness will be limited in determining decreases in browsing over the short term, but reductions in the number of scarred stems may begin to occur over the long term if browsing declines and aspen regeneration occurs. Bark scarring was heavy in the core winter-range, with 88 percent of the core winter-range having 75–100 percent bark scarring of the trunk surface and the remaining winter-range showing scarring on 50–75 percent of the trunk surface (fig. 10). Bark scarring was not as heavy in the non-core winter-range with 50 percent of the winter-range aspen being scarred on 75–100 percent of the trunk surface, 40 percent scarred on 50–75 percent of the trunk surface, and 10 percent of having less than 50 percent of the trunk surface scarred (fig. 10). In the Kawuneechee Valley, bark scarring was much more variable, with only 12 percent having heavy (75–100 percent of the trunk surface scarred) scarring, 50 percent having moderate (50–75 percent) scarring, and 38 percent having low levels (less than 50 percent) of bark scarring. This may be due to the fact that fewer elk winter in the Kawuneechee Valley, when bark browsing may be more likely to occur due to limited forage availability. Signs of ungulates (scat, tracks, browse, and animal observations) were prevalent at all sites.



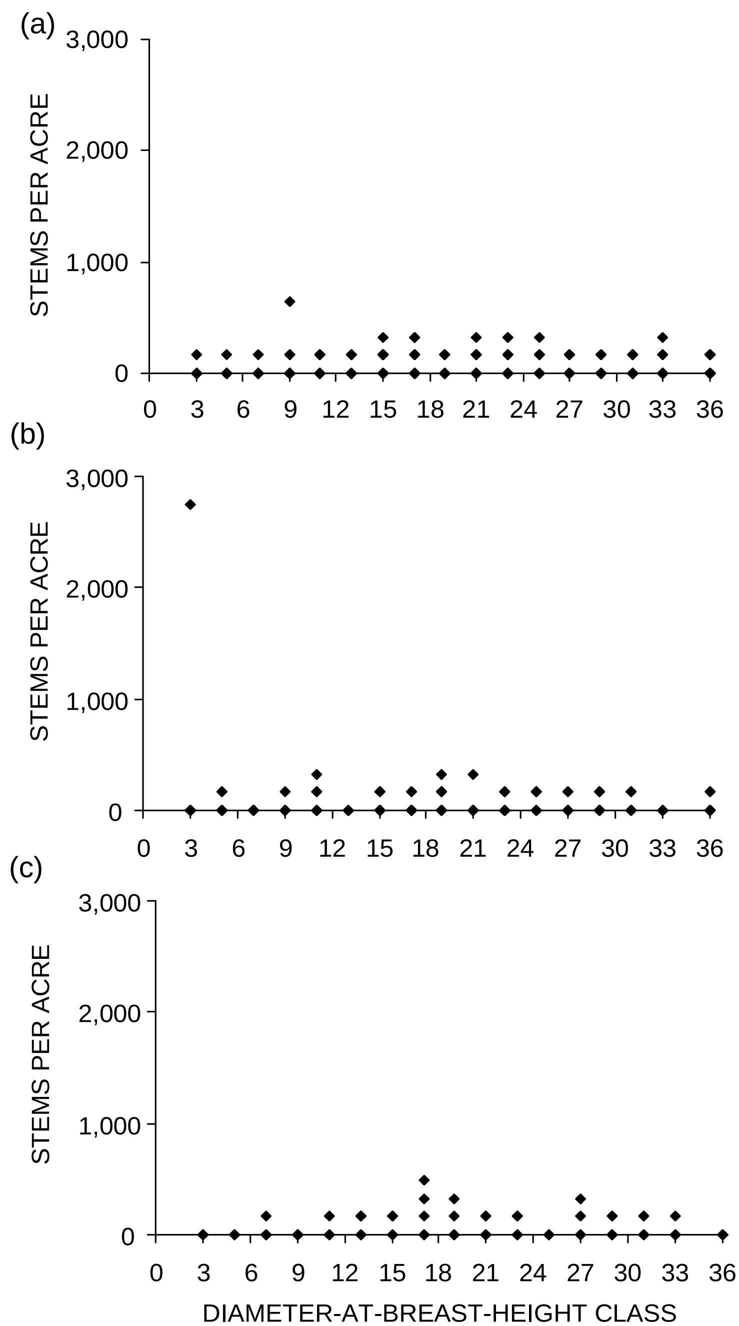


Figure 8. Distribution of stems (> 2 cm dbh) per acre in various aspen dbh classes on (a) core winter-range, (b) non-core winter-range, and (c) Kawuneechee Valley monitoring sites in Rocky Mountain National Park, Colo. Each dbh class covers a range of 2 cm and numbers on x-axis denote midpoint. [dbh, diameter at breast height; cm, centimeter]

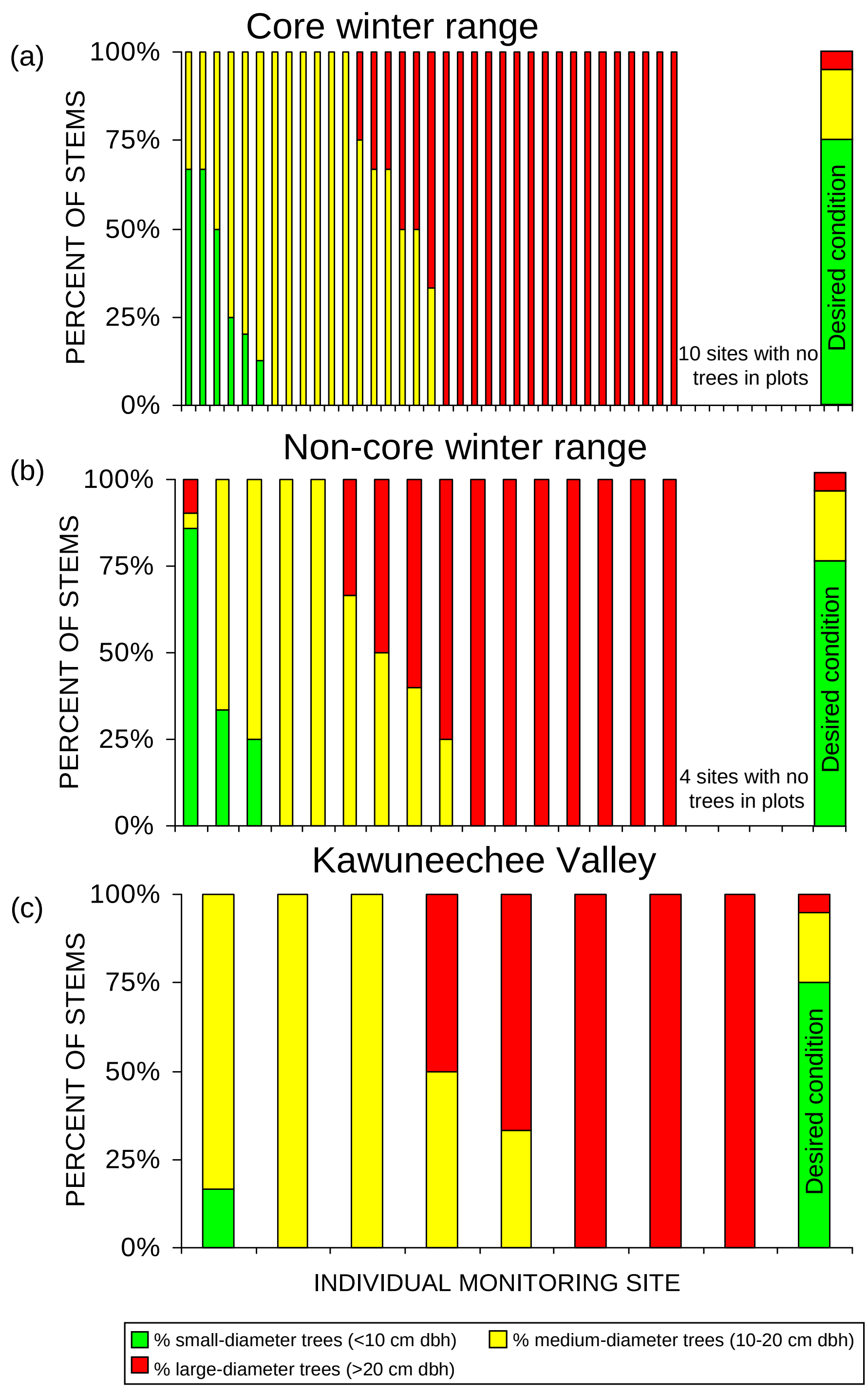


Figure 9. Distribution of stems among dbh classes from small (2–10 cm dbh), medium (10–20 cm dbh), and large stems (greater than 20 cm dbh) in (a) core winter-range, (b) non-core winter-range, and (c) Kawuneechee Valley aspen monitoring sites in Rocky Mountain National Park, Colo. Each bar represents one site, and the right-end bar represents the desired condition for aspen stands in the park.

Figure 10. Degree of bark scarring less than 2.5 m high on aspen trees on the elk winter-range of Rocky Mountain National Park was categorized as light (less than 50 percent of the trunk scarred by browsing, left photo), moderate (50–75 percent scarred, center photo), or heavy (greater than 75 percent scarred, right photo).

Willow

Baseline browse measurements were collected from 47 sites in spring 2009. Of the 58 core willow sites, willows at 23 sites were measured in 2009, an additional 5 sites had no willow within the sample microplots to be measured, willows at 16 sites were behind existing fences and therefore elk had little or no opportunity for browsing on these willows during that winter (some browsing may have occurred as the fences were being constructed in fall 2008), and the remaining 14 sites were installed in summer 2009 and therefore the willows at these sites could not be measured until spring 2010. Of the 33 non-core sites, only 25 were able to be sampled in 2009, 3 more had no willow within the sample plot, 2 were underwater and we were unable to relocate the corner markers, and an additional 3 were not able to be sampled. The data were analyzed using both DD2 and DD3 methods (Singer and others, 2002; Bilyeu and others, 2007). Our data indicate that elk on the RMNP winter-range do preferentially browse more productive shoots ($P < 0.0001$, unbrowsed shoot basal diameter = 2.03 plus or minus 0.03 mm [mean plus or minus standard error], browsed shoot basal diameter = 2.86 plus or minus 0.05 mm). Since the DD3 method scales the offtake by the average size of browsed shoots, and elk in our monitoring area prefer larger shoots, this indicates that DD3 will provide a more accurate method for determining offtake compared to the DD2 method. Annual offtake was slightly higher using the DD3 method (table 7) compared to the DD2 method. Offtake was greater in the core winter-range than the non-core winter-range ($P < 0.0004$).

Percent cover of willow was estimated using both line intercept and macroplot area data. The two measures yielded similar results in the core winter-range willow, but willow percent cover estimates were approximately 7.5 percent higher using the macroplot area compared to the

Table 7. Baseline willow consumption measurements on the elk winter-range of Rocky Mountain National Park, Colo., 2008–2009. Note: Data were collected following winter 2008–2009. Baseline offtake data was collected at the end of winter 2008-2009, which was the first year of elk culling, and also after the establishment of 28 ha (70 acres) of fenced willow habitat.

	Production-weighted diameter-difference method (DD3)			Stem-scaled diameter-difference method (DD2)		
	Annual offtake (%)	Range (%)	n	Annual offtake (%)	Range (%)	n
Core winter-range	36.9 ± 3.0	14.6–62.5	23	34.4 ± 2.9	14.0–58.3	23
Non-core winter-range	21.9 ± 3.6	0–57.0	24	18.0 ± 3.2	0–49.7	24
Entire winter-range (weighted by area)	34.9 ± 2.3		47	32.3 ± 2.2		47

line-intercept data in the non-core winter-range willow sites, though this difference was not significant when averaged over all the winter range (P > 0.31, table 8). Willow cover ranged from 0 percent to over 100 percent (due to overlapping canopies). Overall, willow cover was nearly twice as great on the non-core winter-range compared to core winter-range (P < 0.03). However, on the winter range as a whole, the weighted-average willow cover is far from the long-term desired future condition of 70 percent cover. Only 7 of the 91 monitoring sites had willow cover greater than or equal to 70 percent, and most of these sites (5 of 7 sites) were located in the non-core winter-range.

Willow height was also measured using both line-intercept and macroplot measures. In all cases, the macroplot measures yielded average height measurements that were approximately 10–20 percent shorter than the line-intercept method, but the differences in average heights were not significant (P > 0.2) between methods overall. Therefore, the line-intercept method may overestimate average willow heights. Data analysis using just line-intercept height data should be carefully interpreted. Willows were nearly a meter taller on average in the non-core winter-range than in the core winter-range using both measurement methods. No differences were found in height or cover between core winter-range areas that were planned to be fenced and those not fenced.

Table 8. Willow cover and height measurements on the elk winter-range of Rocky Mountain National Park, Colo., 2008–2009. Some baseline height and cover measures were collected in summer 2009 after the initiation of Elk and Vegetation Management Plan elk management actions (fencing and culling). [cm, centimeters]

	Line-intercept measures (mean ± standard error)		Macroplot measures (mean ± standard error)		# of sites
	Willow cover (%)	Height (cm)	Willow cover (%)	Height (cm)	
Core winter-range	18.5 ± 2.7	94.5 ± 10.5	19.3 ± 3.3	79.5 ± 7.0	57
Non-core winter-range	29.2 ± 4.8	184.4 ± 20.8	36.6 ± 5.4	165.7 ± 19.0	34
Entire winter-range (weighted by area)	19.3 ± 2.2	102.4 ± 9.2	20.7 ± 2.7	86.6 ± 6.8	91

Upland

Winter offtake levels on upland herbaceous plants averaged 52.1 percent plus or minus 5.9 percent on core winter-range and 40.3 percent plus or minus 1.0 percent on non-core winter-range (fig. 11). The average offtake for the entire winter-range, weighted for the area of upland vegetation in core and non-core winter-range, was 47.1 percent. The EVMP/EIS calls for moving elk off the winter range during the summer, so, in 2007, we also collected baseline information on summer herbaceous offtake at the monitoring sites. These data indicate little difference overall in summer offtake between the core and non-core upland winter-range. Average standing crop removed in August 2007 was 17.1 percent plus or minus 3.9 percent (n = 25) in the core winter-range and 15.0 percent plus or minus 3.2 percent (n = 14) in non-core winter-range, indicating that some amount of offtake is occurring during the summer season but that it is much lower than the offtake during the winter season.

Upland shrub cover averaged 11.5 percent plus or minus 2.0 percent on core winter-range and 18.9 percent plus or minus 3.4 percent on non-core winter-range. Based on the observed vegetation types, our monitoring sites were similarly distributed between upland vegetation categories on the core and non-core winter-range (table 9). Mean upland shrub cover was 14.8 percent plus or minus 1.9 percent across the primary winter-range (average weighted for proportion of upland area in core and non-core winter-range). Graminoid-dominated sites (upland herbaceous montane, Ponderosa Pine (*Pinus ponderosa*) graminoid, and Ponderosa Pine rocklands) made up approximately 27 percent of all the monitoring sites, while the remaining 73 percent consisted of shrubby sites (Ponderosa Pine shrublands, big sagebrush shrublands, bitterbrush shrublands, and undifferentiated shrublands).

Herbaceous offtake in upland areas was negatively related to total shrub cover (P = 0.007) with the highest offtake levels found in the herbaceous upland montane (mean over all years = 67.5 percent plus or minus 9.5 percent), and lowest in areas with high shrub cover: sagebrush, bitterbrush, and undifferentiated shrublands (table 9). This may have been due to a variety of reasons, including higher availability of digestible forage in areas with low shrub cover and possibly the influence of shrubs on snow cover throughout the winter. However, when averaged over all years, the two upland vegetation categories with the highest offtake levels (greater than 55 percent) were upland herbaceous montane and Ponderosa Pine rockland.

Retrospective Sample Size Tests

We used the baseline data to further test our sample sizes to determine if they were indeed large enough to detect a small degree of change at a high level of power. We tested the ability to detect a 5 percent and 10 percent change from our measured baseline condition with power of 0.9 and 0.95 (table 10). Our results indicated that our samples sizes are indeed adequate to measure 5 percent changes in upland herbaceous offtake, willow offtake, and willow cover with a high power. However, the current sample size was only able to adequately measure a 10 percent change in willow height at such a high power. However, these tests will provide managers the ability to adjust samples sizes to meet their needs, if necessary.

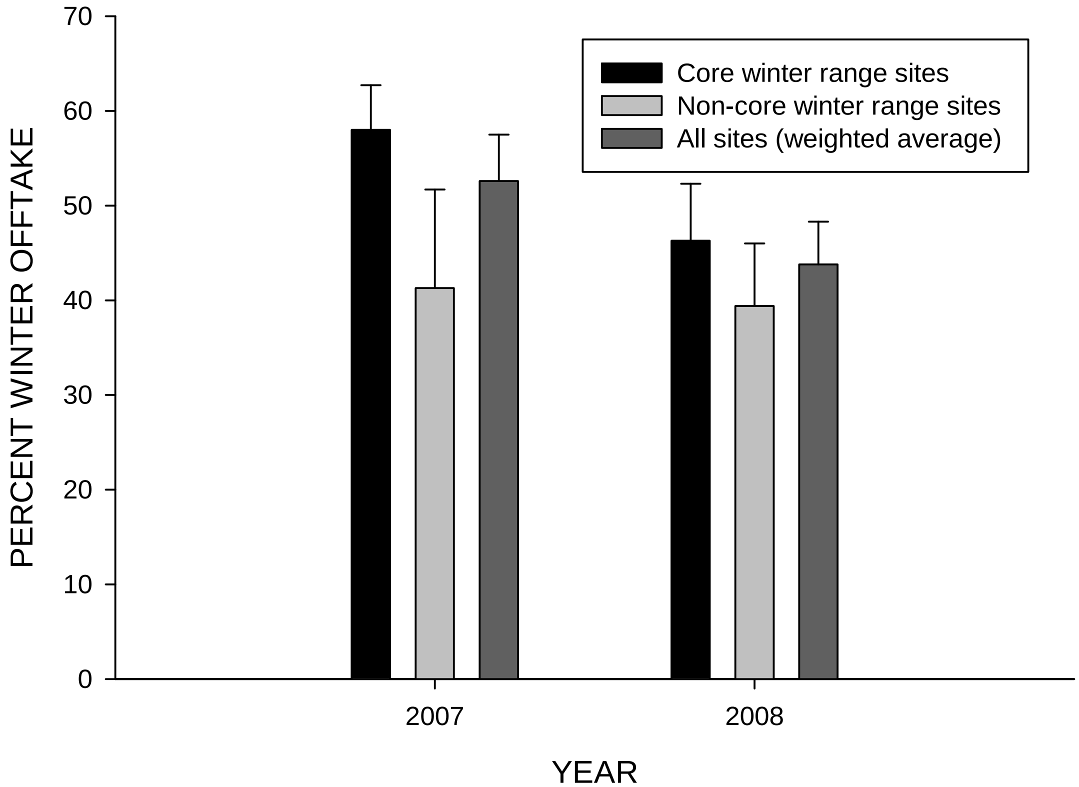


Figure 11. Percentage of annual winter offtake (consumption) of herbaceous plants on upland sites on the elk winter-range of Rocky Mountain National Park, Colo., 2007–2008.

Table 9. Mean winter herbaceous offtake on various upland vegetation types on elk winter-range in Rocky Mountain National Park, Colo., 2007–2008.

Upland vegetation category	Total number of sites	Number of core winter-range sites	Number of non-core winter-range sites	Mean herbaceous offtake 2007–2008
Upland herbaceous montane	7	5	2	68.0 ± 3.4
Ponderosa Pine graminoid	5	1	4	43.2 ± 8.6
Ponderosa Pine rocklands	1	1	0	57.5 ± 7.9
Ponderosa Pine shrublands	24	13	11	51.0 ± 3.9
Big sagebrush shrublands	3	2	1	16.9 ±10.8
Bitterbrush shrublands	2	0	2	41.0 ± 14.2
Undifferentiated shrublands	5	3	2	37.3 ± 12.4

Table 10. Sample-size tests using baseline data from upland and willow-monitoring sites in Rocky Mountain National Park, Colo.

			Change detection = 5 percent		Change detection = 10 percent	
			Power = 0.95 Sample size	Power = 0.9 Sample size	Power = 0.95 Sample size	Power = 0.9 Sample size
Upland n=20	Herbaceous Offtake	Core	18	15	7	7
		Non-core	25	21	8	7
Willow n=35	Height	Core	43	35	13	11
		Non-core	71	58	20	16
	Cover	Core	8	7	4	4
		Non-core	15	18	13	7
	Offtake	Core	8	7	4	4
		Non-core	9	8	5	4

Implementation of Monitoring

Monitoring of Existing Sites

Detailed protocols have been included to guide field staff in collecting monitoring data for each vegetation type (Appendices 1–3). Information on site locations and special instructions regarding grazing-cage placement at upland sites near cultural resources (intended to minimize site disturbance) are available from the park biologist in charge of the monitoring program. Sites should be monitored on the schedule set out in these protocols, with annual measurement of total annual willow and winter upland herbaceous offtake on a subset of sites, and sampling of aspen, upland shrub, and willow cover and height measures on a 5-year basis. As discussed above, there are two areas that could be removed from the sampling regime to reduce labor and analysis costs (table 11). In both cases, the reduced sampling effort will result in less-accurate results. The first change would be to measure shrub height and cover in willow areas using only the line-intercept method instead of both macroplot and line intercept. The macroplot-cover method measures cover on an areal rather than linear basis and should yield more accurate estimates and is therefore the best method. However, it is more time intensive and it could be sacrificed in years of poor funding. In years with adequate funding, both macroplot and line intercept cover measures should be continued to maintain continuity between sampling periods.

The second change that could be made to reduce effort would be an alteration to the method used to measure willow offtake. The DD3 method is preferable, as it is more accurate since the estimate is scaled based on productivity of browsed and unbrowsed shoots. This requires the additional collection of shoots late in the growing season each year and the development of annual species-specific regression equations. The DD2 method is less time intensive and could be used as the sole offtake measure if necessary based upon available funding. Both methods yield similar results in the baseline data analysis; however, the difference between methods appears to be greater at lower offtake levels with the DD2 method underestimating offtake. Further reductions of time and labor could be achieved by sampling only willow cover and height and no other shrub species in willow plots, but as noted previously, this would remove the ability to determine which type of community shifts were taking place in these willow areas. It should be kept in mind that the thresholds in table 1 were based upon baseline conditions calculated using the DD3 and macroplot cover and height methods. To interpret DD2 or line-intercept cover and height measures against thresholds, the thresholds should be recalculated from baseline DD2 and line-intercept data.

Table 11. Projected labor requirements for annual and 5-year sampling periods for the Rocky Mountain National Park elk-vegetation monitoring program. "Reduced sampling option" refers to line intercept for shrub cover and DD2 method for willow offtake.

Sample Period	Vegetation type	Task	Crew size	Season	Full sampling option		Reduced sampling option	
					# plots	Time	# plots	Time
Annual (all years)	Willow	Measure winter browsing	2	Spring	28	2 weeks	28	2 weeks
		Collect and weigh willow shoots	2	Late August		2 weeks		
	Upland	Clip and weigh winter offtake from grazing cages	2	Spring	20	2.5 weeks	20	2.5 weeks
		Set grazing cages for next winter	2	Fall	20	1 week	20	1 week
	All types	Data entry	1	Fall-Winter		5 weeks		3 weeks
		Data summarization and analysis	1	Winter		2 weeks		2 weeks
5-year sample Years: 2013 2018 2023 2028	Aspen	Stem demographics, sapling regeneration, photos	2	Summer	73	8 weeks	73	8 weeks
	Willow	Measure winter browsing	2	Spring	28	2 weeks	28	2 weeks
		Collect and weigh willow shoots	2	Late August		2 weeks		
		Macroplot, line intercept, plot photos	2	Late Spring-fall	91	8.5 weeks	91	5 weeks
	Upland	Clip and weigh winter offtake from grazing cages	2	Spring	20	2.5 weeks	20	2.5 weeks
		Set grazing cages for next winter	2	Fall	20	1 week	20	1 week
		Shrub line intercept, photos	2	Spring-Fall	50	4 weeks	50	4 weeks
	All types	Data entry	1	Fall-Winter		13 weeks		10 weeks
		Data summarization, analysis, reporting	1	Winter		8 weeks		8 weeks

Data Summarization and Analysis

Within 3–6 months of data collection, data should be entered into the database, quality assurance performed, and summary analyses conducted. This increases the probability that data discrepancies can be discovered and corrected while field staff are still available and able to recall sampling visits. It also allows for timely management action in response to vegetation indicators that show objectives are not being met. Each year, data summaries should be conducted to calculate annual offtake estimates (Appendix 7). Offtake data should be averaged for each site first before estimating average offtake for winter-range zones in the manner described in the "Establishment of Monitoring Sites and Collection of Baseline Data" section. Estimates for the entire winter-range should be weighted by the proportion of area in each winter-range zone. Repeat sampling at some sites for two years in a row allows the estimation of annual changes from a direct comparison at a sample point, which provides insight into interannual variation in offtake that might otherwise be masked by simply averaging all offtake measures in an elk winter-range zone. Analyses conducted on an annual basis should include:

- calculation of mean offtake (and standard error) for core and non-core upland herbaceous and willow;
- graphs of mean offtake and previous years' summary data for core and non-core upland and willow;
- analysis of trend for two-year averages of offtake for sites with repeat measures and comparison to annual averages over all measured sites.

Statistical analyses should be conducted by a biologist with a sound statistical background or by a statistician. While the statistical methods laid out in this document should be adequate to detect trends in the data over time, periodic review by a biometrician or statistician (perhaps after the 10-year sample) may be useful so that, if applicable, newly developed statistical methods might be applied to the data. A summary of the main statistical analyses to be performed is listed in table 12. Prior to any statistical analysis, exploratory data analysis should be performed to check for normality and homogeneity of variances. Appropriate transformations should be applied, particularly to percentage data (offtake and cover data). Analyses should be aimed at answering three main questions at each 5-yr sample point.

1. Analysis of trend: Has there been a change in the variables of interest from measurements at the time of site establishment (T1) and successive sample times (T2,T3) over the entire winter-range?
2. Change among management types: Are there differences between mean parameter estimates of the variables of interest for each management sub-group (core winter-range, non-core winter-range, and fenced)?
3. Analysis of sub-groups: Do the trends differ between management sub-groups? Were these differences evident at the beginning of the monitoring program or have they developed as the EVMP has been implemented?

Offtake, shrub cover, and shrub height data should be averaged for each site first before estimating average offtake for winter-range zones in the manner described in "Establishment of Monitoring Sites and Collection of Baseline Data" section. Estimates for the entire winter-range should be weighted by the proportion of area in each winter-range zone. Analysis of trend can be examined using repeated measures analysis of variance (ANOVA) or general linear models with contrasts between years. This analysis will compare the trend (slopes) between sites adjusting for

Table 12. Summary of statistical analyses to be conducted as part of the Rocky Mountain National Park elk-vegetation monitoring program. [ha, hectare; m, meters; ht, height; dbh, diameter at breast height QA/QC, quality assurance/quality control]

Objective	Parameter	Units or index	QA/QC/details	Scale of Analysis	Frequency for analysis of trend by site
Preventing loss of aspen clones.	Stem density by height	stems/ha	Stems < 2.5 m ht, < 2 cm dbh. Calculate percent sites suckering and regenerating.	Entire winter-range Core vs. non-core winter-range Fenced vs. unfenced core winter-range.	5 years
Distribution of stem diameters reflects ~75% small diameter, 20% medium diameter and 5% large diameter trees.	Distribution of stem diameters	%	Stems > 2 cm dbh only, small diameter stems = 2–10 cm dbh, medium diameter stems = 10–20 cm dbh, large diameter stems = > 20 cm dbh.		5 years
Increasing cover and height of riparian willow.	Cover of willows	%	0–100; in cases with overlapping canopies can be greater than 100	Entire winter-range Core vs. non-core winter-range Fenced vs. unfenced core winter-range	5 years
	Mean/SE Height of willows	m	Average of all willows intersected (line intercept method) or all willows in the site (macroplot method)		5 years
No increase in mean offtake on the winter-range.	Offtake, DD2	%	Based on equation 3 in Bilyeu and others (2007), range 0-100	Entire winter-range Core vs. non-core range	Annual
	Offtake, DD3	%	Based on equation 5 in Bilyeu and others (2007), range 0-100		Annual
Reduction of elk grazing on upland herbaceous.	Herbaceous offtake	%	Adjust for any values less than 0%	Entire winter-range Core vs. non-core winter-range	Annual
Maintenance of diversity of grazing levels.	Upland shrub cover	%	Average of all shrubs intersected (line intercept)		5 years

individual site differences. A mixed-model approach may be appropriate if violations of the assumptions of compound symmetry and independent covariance are violated. Because a number of factors may influence the response variables (for example, wetland type—wetland, bog, wet meadow, or dry meadow—may affect the rate at which willow cover changes over time), analysis of covariance may be appropriate if patterns related to secondary variables are observed in the exploratory data analysis. These site-characteristic data are collected at the outset of the study and at 5-yr intervals to account for any changes that might result due to changes in underlying hydrology of the site (for example, a flood event or beaver damming changes the course of the creek and causes a previously wet area to become dry).

Establishment of New Sites

Establishment of additional sites may be considered as needed to replace sites that have to be removed from monitoring for various reasons, to expand monitoring inside fences, or if additional treatments (vegetative restoration treatments, elk harassment, etc.) need to be examined. Establishment of new sites should be conducted following the protocols found in Appendices 4–6.

Cost and Labor Considerations

There will be many costs associated with operation of this monitoring program throughout its lifetime. These costs can be divided into two main groups: Materials and Equipment Costs and Labor Costs.

Material and Equipment Costs

We attempted to use materials that were as durable as possible so that frequent replacement would not be a necessity. However, the requirements of working within the regulations for scientific research in the park and a desire on the part of all parties to make our monitoring as aesthetically unobtrusive as possible meant that we selected some materials that will need to be replaced throughout the life of the program. It became apparent in the fall of 2008 that the current grazing cage design may be problematic. We had based the design on previous work in the park, but for that study, most cages were placed in willow areas where soils were more solid for driving in rebar stakes, thus anchoring the cages more firmly. At that time, only approximately 40 cages were placed and concentrated in 4 upland locations and another 60 cages were spread among 12 willow sites. Over the previous, 4-yr study, there were approximately 4 cages destroyed by elk (most because the wire welds broke) and no known incidents of animals becoming entangled in the cages. Apparently, with nearly 150 cages scattered among 47 locations, there are more opportunities for curious bull elk to encounter the cages and the results have been destructive to the cages and distressing and potentially dangerous to the elk, as well as costing park staff time and effort capturing an animal with a cage snared on his antlers. After only 2 yr, we have had a large number of cages destroyed or in need of much repair. The original plan for the cage design was to find something inexpensive, unobtrusive, and easily replaceable. We suggested using metal fencing t-posts instead of rebar, but the considerable cost and larger size made them undesirable. However, in light of recent events and loss of cages, the park asked that we revisit the issue of cage construction.

Three different designs could be considered (fig. 12), though all are more expensive to construct and more easily seen than the current design. These have all been used at other locations with success, including areas with bison and cattle (animals that are notoriously curious, larger than elk, and like to rub extensively). While these designs will be more costly than current designs, some of this cost could

Figure 12. Three alternative grazing-cage designs that might be used in Rocky Mountain National Park monitoring program. One uses 3×2-in mesh stainless steel fence and heavy gauge steel fencing t-posts (left). Another uses welded angle iron with 6×6-in steel mesh cattle fencing attached to the sides (center). The third has a welded rod frame in a trapezoid design with 2×3-in steel mesh cattle fencing attached to the sides (right).

be absorbed by only placing cages at the sites to be monitored each year, in which case only 60 cages would be needed each year, instead of 150. However, there would be additional time and labor expense as 30 cages would need to be completely removed from 20 sites each spring and transported to new sites for use in the fall. The designs would also be more visually obtrusive and many of the upland sites are highly visible to the public since most of the upland areas in the core winter-range are near roads and draw park visitors who wish to observe the elk.

The alternative to choosing a new grazing cage design would be to continue with the current design of using three rebar posts wrapped with cattle fencing with a chicken-wire top. These cages may need to be replaced a bit more frequently, but material costs are relatively cheap. The biggest tradeoff is whether the risk of animal entanglement is worth the cheap costs and less obtrusive design of the current cages.

Additional materials and equipment to be considered include the replacement of marker caps and/or rebar posts that are removed by humans or kicked from the ground by animals. Because of the 6-in (inch) length requirement set by the park for the marker posts, the corner markers in the willow sites are subject to frost heave and then to being knocked out of the ground by animals as they pass. Our first spring sampling found a few marker posts missing and a number out of the ground or nearly out. If the park management team reconsiders the requirements of marker length, replacement of the rebar markers with longer posts (12–18 in), in the willow sites at a minimum, would be a prudent action.

Other than the replacement or upgrading of existing equipment (measuring tapes, calipers, GPS units, digital cameras, etc), we do not foresee any other regular costs.

Labor Costs

Labor will be an ever-increasing cost throughout the duration of this monitoring plan. The majority of the work (field sampling and data entry) in this monitoring program can be completed by minimally skilled technicians or interns with training and close supervision, or alternatively, more skilled technicians working independently. Data summarization should be performed by a skilled technician supervised by a biologist, or by a biologist. Data analysis should be performed by a biologist with some statistical background, by a biometrician, or by a statistician. Since future budgets are unknown and the program is quite labor-intensive (and therefore costly), particularly at the 5-yr sampling interval, we have included a reduced sampling option (table 11). This reduced option would scale back field time by two weeks for a two-person crew (four person-weeks total) plus an additional two weeks of data entry time for a total of six person-weeks of reduction for annual samples. At the 5-yr intervals, this reduced sampling option reduces field time by 5.5 weeks of field time (11 person-weeks), and three weeks of data-processing time for a total of 14 person-weeks reduction. The reduced sampling option would remove use of the production-weighted diameter difference method (DD3) to calculate willow offtake and would only use the line-intercept method without the macroplot method to estimate willow height and cover. The tradeoff for this reduced sampling option is less accurate willow offtake and cover data. An additional 3 weeks of field time (6 person-weeks) could be eliminated by removing the Kawuneechee Valley aspen sites and extra winter-range aspen sites from sampling. Further time reductions (a decrease of an additional 8–10 person weeks) could be achieved by eliminating the shrub cover measurements in upland areas and measuring only willow species cover in willow plots. This further reduction would come at the expense of knowing: (1) whether elk grazing was causing changes in upland sites from grass-dominated to shrub-dominated communities (or the reverse) and (2) determining if potential change in willow communities was to grass-dominated meadows, shrubby meadows, or birch-alder (*Betula-Alnus*) communities.

Conclusion

The success of any monitoring program is dependent upon the commitment of the managing entity to fully support and implement the program. The decision of when to make changes in elk or vegetation management because the objectives of the EVMP are not being met lies with the Park. Only those closely involved with managing Park resources have the ability to determine whether the data collected through this monitoring program indicate substantial and acceptable (or unacceptable) changes to vegetation conditions in these key communities. It is also the responsibility of those managing Park resources to respond appropriately with Park management. Park staff also have the knowledge of extenuating circumstances (localized weather events, prescribed or natural fire events, human disturbances, etc.) which could influence the data collected as part of this monitoring program and how to interpret those data in light of the specific circumstances occurring in the park. Periodic review and analysis of summary data collected in this monitoring program by an independent biologist (with strong statistical skills) or statistician could provide objectivity and new insight into interpretation of the monitoring data and could also take advantage of advances in statistics, remote sensing, GIS, and other technologies that may develop over the proposed 20-yr time frame of this monitoring program.

Acknowledgments

This project was funded by Rocky Mountain National Park. We appreciate the support and assistance of J. Visty, C. Yost, and R. Thomas of Rocky Mountain National Park. D. Binkley, W. Romme, D. Cooper, E. Gage, Colorado State University; D. Johnston, Colorado Division of Wildlife; and P. Geissler, U.S. Geological Survey–Fort Collins Science Center (USGS–FORT), provided valuable feedback during development of the monitoring protocols. I. Ashton, National Park Service Inventory and Monitoring Program; and P. Geissler, and C. Melcher, USGS–FORT, provided insightful reviews of the draft monitoring plan. G. Miller, Rocky Mountain National Park, improved the field protocols with many helpful comments. We were assisted in the field by Student Conservation Association interns K. Holland, S. Sink, A. Terway, B. Carroll, L. Holtrop, and T. Putt. R. Waltermire, USGS–FORT assisted with cost estimates for remote imagery. We also thank K. Schoenecker of USGS–FORT for advice, logistical and administrative support, and review of early proposals.

References Cited

Baker, W.L., Munroe, J.A., and Hessl, A.E., 1997, The effects of elk on aspen in the winter range of Rocky Mountain National Park: Ecography, v. 20, p.155–165.

Berry, J., Decker, D., Gordon, J., Heitschmidt, R., Huff, D., Knight, D., Romme, W., and Swift, D., 1997, Science-based assessment of vegetation management goals of elk winter range—Rocky Mountain National Park: Fort Collins, Colo., Colorado State University Environment and Natural Resources Policy Institute, 16 p.

Bilyeu, D.M., Cooper, D.J., and Hobbs, N.T., 2007, Assessing impacts of large herbivores on shrubs—Tests of scaling factors for utilization rates from shoot-level measurements: Journal of Applied Ecology, v. 44, p.168–175.

Binkley, D., 2008, Age distribution of aspen in Rocky Mountain National Park: Forest Ecology and Management, v. 255, p. 797–802.

Bonham, C.D., 1989, Measurements for terrestrial vegetation: New York, John Wiley and Sons, 338 p.

Canfield, R.H., 1941, Application of the line interception method in sampling range vegetation: Journal of Forestry, v. 39, p. 388–394.

Kaye, M.W., Stohlgren, T.J., and Binkley, D., 2003, Aspen structure and variability in Rocky Mountain National Park, Colorado, USA: Landscape Ecology, v. 18, p. 465–486.

Olmsted, C.E., 1997, Twenty years of change in Rocky Mountain National Park elk winter range aspen: Greeley, Colo., University of Northern Colorado, 45 p.

Peinetti, H.R., 2000, Riparian willow dynamics and their interaction with environmental and biological factors in the elk winter range of Rocky Mountain National Park (Colorado) - a multiscale analysis. PhD. Dissertation, Colorado State University, Ft. Collins, Colo., 194 p.

Peinetti, H.R., Kahlkan, M., and Coughenour, M.B., 2002, Long-term changes in willow spatial distribution in Rocky Mountain National Park: Landscape Ecology, v. 17, p. 341–354.

Salas, D., Stevens, J., and Schulz, K., 2005, Rocky Mountain National Park, Colorado, 2001-2005 Vegetation Classification and Mapping: U.S. Bureau of Reclamation Technical Memorandum 8560-05-02, 146p.

SAS Institute, 2003, SAS Version 9.1 statistical analysis software: Cary, N.C., SAS Institute Incorporated.

Singer, F.J. and Zeigenfuss, L.C., comps., 2002, Ecological evaluation of the abundance and effects of elk herbivory in Rocky Mountain National Park, Colorado, 1994-1999: U.S. Geological Survey Open-File Report 02–208, 268 p.

Stevens, D.R., 1980, The deer and elk of Rocky Mountain National Park—A ten year study: National Park Service Report ROMO-N-13, 162 p.

Stevens, J.E., J. Lemly, and R. Thomas, 2005, Dichotomous key to the plant associations of Rocky Mountain National Park: Fort Collins, Colo., Colorado State University, Colorado Natural Heritage Program, 49 p.

Stohlgren, T.J., 2001, Rocky Mountain National Park long-term monitoring plan: Estes Park, Colo., Rocky Mountain National Park, 137 p.

Suzuki, K., Suzuki, H., Binkley, D., and Stohlgren, T.J., 1999, Aspen regeneration in the Colorado Front Range—Differences at local and landscape scales: Landscape Ecology, v. 14, p. 231–237.

Urquhart, N.S., and Kincaid, T. M.,1999, Designs for detecting trend from repeated surveys of ecological resources: Journal of Agricultural, Biological, and Environmental Statistics, v. 4, p. 404-414.

U.S. Department of the Interior, 2007, Elk and vegetation management plan, Rocky Mountain National Park, Colorado: Washington D.C., National Park Service, unpaged, accessed December 17, 2010, at *http://www.nps.gov/romo/parkmgmt/elkveg_mgmt_plan_feis.htm*.

U.S. Department of the Interior, 2008, Record of decision, Final environmental impact statement, Elk and vegetation management plan, Rocky Mountain National Park, Colorado: Washington D.C., National Park Service, 21 p., accessed online December 17, 2010, at *www.nps.gov/romo/parkmgmt/upload/rod_evmp_signed_2-15-08.pdf*.

Zeigenfuss, L.C., Singer, F.J., and Bowden, D., 1999, Vegetation responses to natural regulation of elk in Rocky Mountain National Park: Biological Science Report USGS/BRD/BSR—1999-0003: Denver, Colo., U.S. Government Printing Office, 23 p. [Also in F.J. Singer, and Zeigenfuss, L.C., comps., 2002, Ecological evaluation of the abundance and effects of elk in Rocky Mountain National Park, Colorado, 1994-1999: U.S. Geological Survey Open-File Report 02–208.]

Zeigenfuss, L.C., Singer, F.J., Williams, S.A., and Johnson, T. L., 2002, Influences of herbivory and water on willow in elk winter range: Journal of Wildlife Management, v. 66, p.788–795.

Appendix 1: Rocky Mountain National Park Elk-Vegetation Monitoring Program Aspen Monitoring Protocol

The following steps outline the process of visiting and sampling the aspen-monitoring sites as part of the Rocky Mountain National Park elk-vegetation monitoring program. All site locations and special instructions are with the park biologist in charge of the monitoring program and should be acquired from this individual. *Italic* type indicates the name of datasheet to be filled out. Sample datasheets can be found at the end of this appendix. Sampling of all aspen-monitoring sites should be conducted once every 5 yr starting in 2013 (repeated in 2018, 2023, and 2028). Sampling should be conducted during summer, preferably when the majority of annual growth has already occurred and before elk begin browsing to any great extent in the fall. Photos should be taken any time an event of interest occurs at a site (for example, tree falls into site, ground torn up by animals/humans, etc.). Nothing should be removed from any site except for approved plant samples listed on your research permit. A general schematic of aspen-monitoring plot design can be found in figure 1.1.

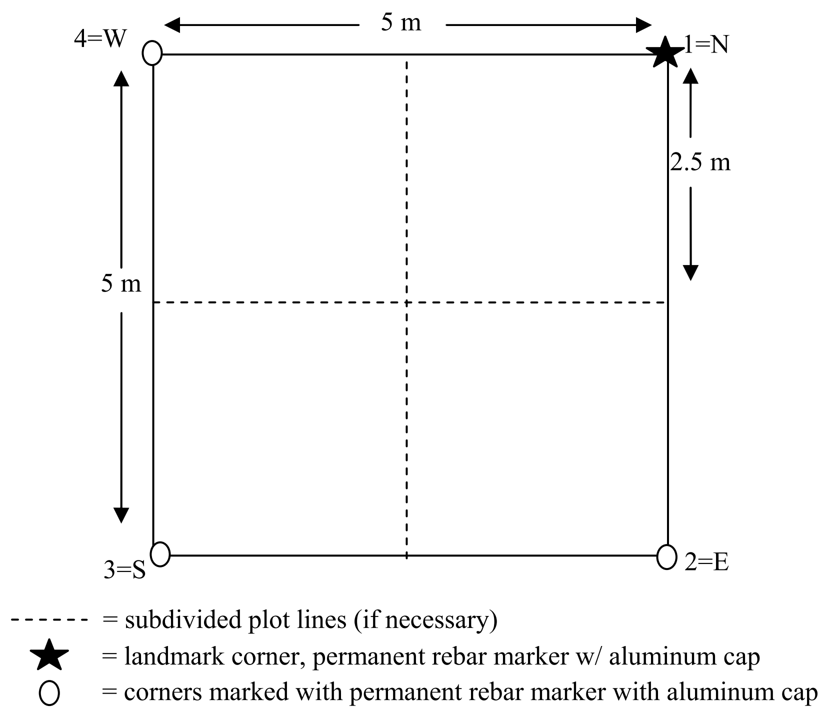


Figure 1.1. Diagram of aspen-monitoring plot layout for the Rocky Mountain National Park elk-vegetation monitoring program.

1. Gather equipment and supplies

FOR ALL FIELD WORK

- Research permit
- Radio pack set
- Protocol, data sheets, pens, clipboard, notebook
- Hammer or mallet for pounding in loose site markers (a rubber mallet will help prevent damage to the marker labeling)

- Metal detector (may be needed to find site corners)
- 2 tape measures at least 25 m in length for plot layout (pre-measured lengths of chain or string can also be used to speed the process)
- Chaining pins or other stakes for holding down tape measure/strings (10)
- Compass (set current declination prior to each field season from info at *http://www.ngdc.noaa.gov*)
- Handheld GPS unit and spare batteries
- 2 pieces of 6-in (inch) rebar to replace wooden stakes if necessary (if approval is granted in the future (because of problems with frost heaving of site markers), these rebar pieces may be changed to 1 ft (foot) in length or longer)
- 2 aluminum survey marker caps imprinted with "ELK-VEG MONITOR—NPS-DO NOT DISTURB—ROMO STUDY 06013" to replace wooden stakes if necessary
- Diameter tape (tape that converts circumference to diameter)
- 1-2 small metric tape measures (for measuring sucker height)
- Digital camera with extra batteries
- List of site locations (see park biologist in charge of monitoring program)

FOR REFERENCE PHOTO POINT

- Laminated placard (light, not white) with following information:

ROMO EVMP SITE___________ DATE _________ CORNER_____

- dry erase marker
- wipes or cloth to clean placard

2. Navigate to the site using GPS and UTM (Universal Transverse Mercator) coordinates on list provided by park biologist in charge of monitoring program. Be sure to have WAAS (Wide Area Augmentation System) enabled on the GPS to increase accuracy (although this will shorten battery life). Site corners are marked with rebar stakes with aluminum caps pounded flush with the ground and imprinted with "ELK-VEG MONITOR—NPS-DO NOT DISTURB—ROMO STUDY 06013". Each cap has the site number (AC # or ANC#) and the cardinal direction of that corner. If corner stakes have heaved partially out of the ground, pound back into place. Direction of landmark corner (corner #1) in relation to rest of the plot is noted in table 1.1. In the earlier part of the study, we labeled corners 1–4 instead of the cardinal directions, so some of the corner stakes might still have this labeling: 1=N, 2=E, 3=S, 4=W. If all four plot corners cannot be found easily, use chaining pins to temporarily hold the tape at located plot corners and lay out measuring tapes between these corners to determine rough location of missing corners. Use metal detector to locate missing corners in these areas. Each side of the plot should measure 5 m and the diagonal should measure 7.07 m (fig. 1.1). Any corner that has come completely out of the ground should be replaced in the ground after using a compass and tape measure to determine correct corner location (90° angle, 5 m between replaced corner and adjacent corner markers). Due to changes in the protocols over the period of initial site establishment, it is possible that some plots that originated in 2006 have two rebar corners and two corners marked with wooden stakes. If this is the case, replace wooden corner stakes with rebar stakes capped with aluminum caps described above and stamped with the site and corner numbers. Once all four corners have

been located and the outline of the plot determined, dissect plot into four quarters by placing tape measures or cord across the mid-section of each line (fig. 1.1). This will make it easier to measure and account for all trees in the plot. When there are a limited number of suckers in the plot, it may not be necessary to subdivide the plot for an accurate count.

3. *Rocky Mountain National Park Elk-Vegetation Monitoring Project—Aspen Monitoring Data Sheet*. Begin filling out the site information on the data sheet
   - Site name/number: letter and numeric combinations: A(aspen)+ NC(noncore) or C(core) + individual number. For example, ANC4 would be aspen, noncore site 4.
   - Fenced?: identify whether the site is located inside an elk-proof fence (Y/N).
   - Date: full date including year (mm/dd/yyyy).
   - Observers: last name of those observing, measuring, and recording data.
   - Site coordinates: this should have the easting and northing coordinates in UTM NAD83 zone 13N. Record the true bearing (corrected for declination) to each corner from the landmark stake.
   - GPS accuracy: record GPS error in meters.
   - General comments: record general site locations, directions, and additional information to help relocate the plot (distance and bearing from trail or other landmarks), events that have happened such as fires, excessive wind damage, etc.
   - Slope (percent): record the percent slope of the site.
   - Aspect: record the general site aspect (flat, N, NE, E, SE, S, SW, W, NW).
   - Elevation: record the elevation in meters as reported on the GPS.
   - Soil type/wetness: record general information on how wet or dry the site is—dry hillslope, wet meadow, wet streamside, etc.
   - Riparian or upland: record whether the aspen stand surrounding the plot is generally riparian or upland in nature.
   - Bark scarring: categorize the degree of bark scarring caused by elk on the aspen trees by circling the percentage of the trunk below 2.5 m height which is scarred: 0–25 percent, 25–50 percent, 50–75 percent, or 75–100 percent.
   - Animal sign: record any signs (scat, browse, tracks, sightings, beaver dams, food caches, or cuttings) of elk, mule deer, moose, or beaver at the site.
   - Trees and sapling counts: using a diameter tape, determine aspen trunk diameter at 1.4 m height (this measure is known as dbh, or diameter at breast height) and using a telescoping measuring rod (if necessary), determine whether the height of the tree is greater than, less than, or equal to 2.5 m.
   - Tally the number of live and dead aspen trees greater than 2.5 m tall in 2 cm dbh classes ranging from 0–2 cm dbh to 32–34 cm dbh. Live and dead trees should be tallied separately. Any and all trees greater than 34 cm dbh should be pooled and a single tally each recorded for live and dead categories. Trees greater than 2.5 m tall with a dbh less than 2 cm should be uncommon, but a space has been provided if this condition is observed.
   - Tally the number of trees less than or equal to 2.5 m tall in each height class listed below. Tally separately for live and dead trees in each of the following categories:
     - 0–50 cm height
     - 51–100 cm height
     - 101–150 cm height
     - 151–200 cm height

- 201–250 cm height.

4. Four digital photos should be taken of the plot— one from each corner. Using a dry erase marker and the pre-printed placard of laminated colored paper, write the plot name/number, date, and the corner number (N, E, S, W) from which the photo is taken. The placard should be placed in the plot or held on the edge of the photo field to identify the photo. Using a dry erase marker to write the information on the placard and allows the placard to be wiped clean and reused for each photo.
5. When all data collection is complete, remove measuring tapes and temporary markers. Double check to be sure that all rebar is pounded flush to the ground before leaving site at end of visit.
6. Data entry and reduction.
   - Copy data sheets when they are complete (including weights). Put originals into binders by direction of the biologist in charge of elk management. Archive copies in a separate location in case of loss of originals.
   - Download digital photos from camera as soon as possible, print as 4×5-in, and store with original data sheets. Archive electronic images as directed by the biologist in charge of elk management and the monitoring program.
   - Data entry: Enter data into database as directed by biologist in charge of elk-management and vegetation-monitoring program.

Table 1.1. Location information for aspen sites to be monitored every 5 years (2013, 2018, 2023, 2028) as part of the Rocky Mountain National Park elk-vegetation monitoring program. [m, meters; km, kilometers]

Unique site	Date established	Corner location	Comments General	directions
AC1	8/8/2006	NE	corner 3 was moved towards the middle of the plot because the true point is on a rock	Park at West Horseshoe Park. Walk across Hwy 34 through the meadow about 150 m.
AC2	9/1/2009	N		Park before Alluvial Fan in lot with corral
AC3	8/30/2007	SE		.
AC4	8/9/2006	SW	corner 2 was moved towards the middle of the plot due to landing on a rock, corner 3 was moved slightly out of the plot due to landing on a rock	Park at West Horseshoe Park. Walk across Hwy 34 and into the meadow about 100 m. Then walk up the hill about 50 m.
AC5	9/12/2009	N		Park near Fan Lake Exclosure. West across valley and up hillside
AC6	8/9/2006	N	corner 2 was moved slightly out of the plot due to a large boulder, corner 3 was moved towards the center due to rock, stake 1 has pin just to the outside of the stake	Park at West Horseshoe Park. Walk across Hwy 34. Walk away from the road about 150 m and up the hill about 200 m
AC7	11/6/2006	N		Park near turnoff to Moraine Park campground. Site is on north side of road ~ 25 m.
AC8	11/13/2008	S		.
AC9	8/9/2006	N	corner 3 was not hammered in all the way due to tree root	Park in West Horseshoe Park. Walk across Hwy 34 and up the hill about 50 m.
AC10	10/24/2006	SW		~25 m south of Fern Lake Rd.
AC11	10/20/2006	SW		Park in West Horseshoe Park. Point is southwest ~250 m.
AC12	8/10/2006	N		Fern Lake Road ~100 m from main lot, ~70 m south.
AC13	11/6/2006	S		Park at west Alluvial Fan lot. Point is south across Fall River ~450 m.
AC14	8/9/2006	N		Park in West Horseshoe Park. Walk across Hwy 34 and up the hill about 50 m and away from the road about 100 m.
AC15	9/12/2009	N		Park near Fan Lake Exclosure. West across valley and up hillside.
AC16	10/20/2006	NE		Drive behind Bighorn Ranger Station near Fall River Entrance ~1/2 mile, ~ 20 m west of road.
AC17	11/7/2006	NW		Park on Fern Lake Rd at bathroom lot. ~50 m uphill behind bathroom.
AC18	11/6/2006	NE		Park at end of Beaver Meadows Rd. Follow signs to

Unique site	Date established	Corner location	Comments	General directions
				Moraine Park for ~1 km. Site is ~60 m east of trail.
AC19	10/24/2006			
AC20	10/25/2006	SW		
AC21	7/23/2007	NW		
AC22	9/1/2009	N		
AC23	9/1/2009	.		Large stand at southwest end of Horseshoe Park
AC24	9/1/2009	N		Moraine Park near turn for campground
AC25	9/1/2009	S		Horseshoe Park
AC26	9/1/2009	N	Three cottonwood in plot, likely P. angustifolia, possibly P. balsamifera. One 0-50 cm tall, one 50-100 cm tall, one 2-4 cm dbh > 2.5m tall	Fern Lake Road.
AC27	9/1/2009	N	Lots of cottonwood. Four 0-50cm tall, two 51-100cm tall, two 101-150 cm tall, two 151-200cm tall, and three 201-250cm tall.	Fern Lake Road.
AC28	7/23/2007	NE		
AC29	9/1/2009	N	Lots of P. balsamifera? Three 101-150cm tall, two 151-200cm tall in plot.	Fern Lake Road.
AC30	7/20/2007	SE	bones ~3 meters away from 1st landmark	
AC31	8/30/2007	NE		
AC32	8/30/2007	SE		
AC33	8/30/2007	N		
AC35	9/1/2009	N	.	Little Horseshoe Park
AC36	9/1/2009	N	Only N & S markers were placed. Real photo has circle around plot number and is listed as AC38.	Horseshoe Park stand.
AC37	8/20/2007	.		
AC38	9/1/2009	N	Cottonwoods in the area. Only N & S corners are marked.	
AC39	9/1/2009	N	Only N was marked.	
AC40	9/1/2009	N	Only E & W markers were placed	Just north of Fan Lake Exclosure.
AC41	9/1/2009	N	Only N & S corners were marked. No E marker due to big rock	Park near Fall River Entrance. Up drainage to north behind Ranger Station.
AC44	5/6/2008	NE		
AC45	5/6/2008	NE		
AC60	11/8/2009	N		Beaver Meadows
AC61	11/8/2009	N		Moraine Park near museum, road goes through site.
AC62	11/8/2009	.		Hondius Park
AK1	9/26/2007	N		

Unique site	Date established	Corner location	Comments	General directions
AK2	9/26/2007	S		
AK3	9/27/2007	SE		
AK4	9/27/2007	SSW		
AK5	10/4/2007	SE		
AK6	10/4/2007	N		
AK7	10/5/2007	S		
AK8	10/5/2007	NW		
ANC1	6/21/2007	SW		
ANC2	6/20/2007	N		
ANC3	11/13/2008	.		
ANC4	7/19/2007	SE	Several 0–2cm dbh, but > 2.5 m tall.	
ANC5	11/13/2008	.	game trail	
ANC6	11/14/2008	N		
ANC7	7/2/2007	.		
ANC8	7/2/2007	NE		
ANC9	11/14/2008	E		
ANC10	7/19/2007	NE		
ANC11	6/19/2007	SE		
ANC13	7/5/2007	N		
ANC15	8/8/2006	NW	stake for corner 3 was moved towards center due to large rock	
ANC16	6/19/2007	SW		
ANC17	7/19/2007	W		
ANC18	6/20/2007	SW		
ANC19	7/2/2007	SE		
ANC21	6/21/2007	NE		
ANC22	11/14/2008	.	coordinates pts 3 and 4 off likely due to loss of GPS signal reception	
ANC23	8/10/2006	.		Site most easily reached from stables at YMCA of Rockies.

Rocky Mountain National Park Elk-Vegetation Monitoring Program
Aspen Monitoring Data Sheet

Plot name/number:__________________ **Date:** ________________
Observers:_______________________________________
Plot Coordinates: *UTM NAD83* **Accuracy (m):** ____________

Corner	Easting	Northing	Location of landmark corner	Bearing from landmark
#1 (landmark)				
#2				
#3				
#4				

General Comments:

Site Characteristics:
Slope %:______________**Aspect:**______________**GPS elevation(m):**________________
Soil Type/Wetness:_______________________________ **Site type:** riparian / upland
Bark scarring (circle one): 0–25% 25–50% 50–75% 75–100%

Animal Species: (elk, deer, moose, beaver)	**Animal Sign:** (scat, browse, tracks, sightings)

Trees (Stems > 2.5 m tall dbh)

DBH (cm)	alive	dead
0–2		
2–4		
4–6		
6–8		
8–10		
10–12		
12–14		
14–16		
16–18		
18–20		
20–22		
22–24		
24–26		
26–28		
28–30		
30–32		
32–34		
>34		

Saplings (stems < 2.5 m tall)

Height (cm)	alive	dead
0–50		
51–100		
101–150		
151–200		
201–250		

additional comments:

Appendix 2: Rocky Mountain National Park Elk-Vegetation Monitoring Program Willow Monitoring Protocol

The following protocol outlines the process for visiting and sampling willow-monitoring sites as part of the Rocky Mountain National Park elk-vegetation monitoring program. All site locations and special instructions are with the park biologist in charge of the monitoring program and should be acquired from this individual. *Italic* type indicates the name of datasheet to be filled out. Sample datasheets can be found at the end of this appendix. Description of general site characteristics, reference photos, and macroplot and line intercept measures of shrub cover should be performed at all sites at time of site establishment and once every 5 yr (during summer) according to the timetable set out in table 2.1. Willow sites scheduled for browse measures require individual site visits in spring of the sampling year to measure winter browse consumption following the timetable set out in table 2.1. Sites should be sampled in spring prior to leafout and onset of new growth, or if not possible, before new growth has advanced to any great extent. This pre-growth timeframe is typically from mid-April to mid-May in these sites. Additionally, willow shoot samples for building biomass regressions for calculating offtake should be collected in late August/early September each year in an attempt to capture the timeframe: (1) after the majority of annual growth has occurred and (2) prior to the onset of elk browsing in fall. Photos should be taken any time an event of interest occurs at a site (for example, tree falls into site, ground torn up by animals/humans, etc.). Nothing should be removed from any site except for approved plant samples listed on the research permit. A general schematic of willow-monitoring plot design can be found in figure 2.1.

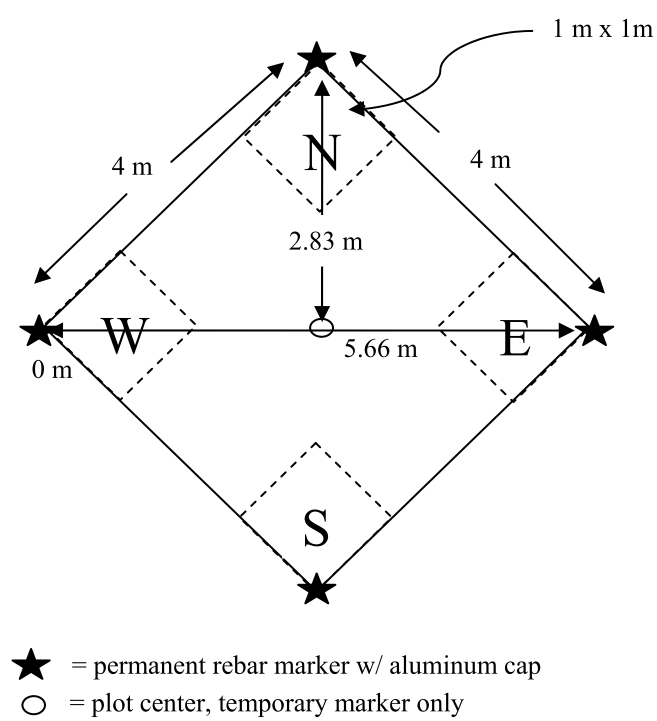


Figure 2.1. Diagram of willow-monitoring plot layout for the Rocky Mountain National Park elk-vegetation monitoring program.

1. Gather equipment and supplies

FOR ALL FIELD WORK

- Research permit
- Radio pack set
- Protocol, data sheets, pens, clipboard
- Handheld GPS unit and spare batteries
- Metal detector (may be needed to find site corners)
- Hammer or mallet (for pounding in loose site markers), wood pad to protect engraved aluminum caps
- Digital camera
- Willow ID key
- Voice recorder (if working alone)
- List of site locations (see park biologist in charge of monitoring program)

FOR MACROPLOT AND LINE INTERCEPT SAMPLING

- 2 tape measures at least 25 m in length for macroplot and intercept line delineation
- 5 m tape measure and/or meter stick for plant heights
- 10 Chaining pins or other stakes for holding down tape measure
- Height pole for measuring heights of tall plants
- Compass set to proper declination (check current declination prior to each field season at *http://www.ngdc.noaa.gov*)

FOR BROWSE SAMPLING

- Survey flags for temporarily marking microplot corners,
- Digital or dial calipers with metric units graduated to 0.5 mm (millimeters)
- Small metric tape measure (2–5 m) or ruler

FOR SHOOT COLLECTIONS

- Small paper bags (lunch bag size) and small coin envelopes
- Clippers

FOR REFERENCE PHOTO POINT

- Laminated placard (light, not white) with following information:

ROMO EVMP SITE___________ DATE _________ CORNER_____

- dry erase marker
- wipes or cloth to clean placard

2. Navigate to the site using GPS and UTM coordinates on list provided by park biologist in charge of monitoring program. Be sure to have WAAS enabled on the GPS to increase accuracy (although this will shorten battery life). Site corners are marked with rebar stakes with aluminum caps pounded flush with the ground imprinted with "ELK-VEG MONITOR—NPS-DO NOT DISTURB—ROMO STUDY 06013". Each cap has the site number (WC # or WNC#) and the cardinal direction of that corner (N, E, S, W). If corner stakes have heaved partially out of the ground, push back into place.
3. If all four plot corners cannot be found easily, use chaining pins to temporarily hold the tape at located plot corners and lay out measuring tapes between these corners to determine the rough location of missing corners. Use metal detector to locate missing corners in these

areas. Each side of the plot should measure 4 m and the diagonal should measure 5.66 m (fig. 2.1). Any corner that has come completely out of the ground should be replaced in the ground after using a compass and tape measure to determine correct corner location (90° angle, 4 m between replaced corner and adjacent corner markers (see site establishment protocol)). The technique known as double-chaining is effective and efficient if two corners are found. Extend the tape measure 8 m between opposite corners, or 9.66 m (4 m + 5.66 m) between adjacent corners. Tighten the slack tape in the direction of the missing corner—the 4 m mark will be at the correct angle and distance of the missing corner.

4. *Rocky Mountain National Park Elk-Vegetation Monitoring Program—Willow Monitoring Data—Site Characterization Data Sheet*. The information on this sheet is gathered when a site is established and once every 5 yr according to the schedule found in table 2.1. Dimensional variables shall be in metric units.

   - Site number: letter and numeric combinations—W(willow)+ NC(noncore) or C(core) + individual number. For example, WNC4 would be willow, noncore site 4.
   - Fenced? (Y/N): specify if the site is inside an exclosure.
   - Location: general location of the site (for example, Horseshoe Park, Hidden Valley, etc).
   - Observers: last name of those observing, measuring, and recording data.
   - Date: full date including year (mm/dd/yyyy).
   - Dominant willow type: determine the dominant type of willow existing on the plot at the time of the survey (for further detail see Peinetti, 2000). All sites should have some willow in the immediate area, if not in the actual plot, at the time of establishment, unless otherwise noted.

- Ecosystem type: using the wetland key below, identify the site as: fen, riparian, marsh, or wet meadow. If the site does not appear to fit any of these wetland types because xeric conditions predominate (areas where hydrologic regime has changed over time) then choose dry meadow.

1	1a. Soils organic[1]		**Fen**
	1b. Soils mineral		Go to 2
	2	2a. Site adjacent to and hydrologically connected to stream or river by surface-water flows on timescales of years to decades	**Riparian**
		2b. Site lacks surface water connection to stream or river[2]	Go to 3
		3 3a. Sites formed in depressions or basins and subject to inundation on relatively frequent basis; vegetation dominated by annual or perennial grasses and sedges; water tables highly variable on both a seasonal and inter-annual basis; hydrologic regimes may be influenced by precipitation and snow-melt, surface water inputs, or groundwater.	**Marsh**
		3b. Sites found on both slopes and basins but rarely if ever inundated; vegetation dominated by perennial grasses, sedges, rushes, or shrubs such as willows (*Salix* spp.); water tables variable but rarely to surface; hydrologic regimes predominantly groundwater or, at high elevations, snow-melt driven; surface water inputs relatively unimportant.	**Wet meadow**

[1]Soils classified as Histosols, where at least 40 cm (16 in) of the upper 80 cm (32 in) is organic material with an organic carbon content (by weight) of 12 to 18 percent, or more, depending on the clay content of the soil. Organic soils may be primarily muck (sapric), mucky peat (hemic), or peat (fibric material).

[2]Sites may share a seasonal subsurface connection to streams; however, sites are topographically isolated from all but extreme magnitude flood events (for example, those with a recurrence interval greater than 100 yr).

- Predominant herbaceous species: record the scientific name for the one or two most common herbaceous species observed at the site.
- Beaver presence: identify any signs of recent beaver activity in the site, including dams, food caches, fresh cuttings, fresh tracks or droppings, sightings of beaver, or if no activity was observed.
- UTM coordinates: UTM easting and northing coordinates of site center and each marked corner—be sure the GPS unit is set at UTM NAD83 .
- GPS error (m): record the GPS error at the time of the recording of the UTM coordinates.
- General comments: General information about events that have taken place at site (fires, floods, human disturbance, etc,) or additional directions to help find a difficult site to locate.

5. Two digital photos should be taken of the plot. One from the north corner looking south, the other from the south corner looking toward the north. A placard of laminated colored paper (light, but not white), with the plot name/number, date, and the location of the photo (for example, north if photo is taken from the north corner) should be placed in the plot to identify the photo.

6. *Rocky Mountain National Park Elk-Vegetation Monitoring Program—Willow Monitoring Data— Macroplot Data Sheet*. The information on this sheet is gathered once every 5 yr according to the schedule found in table 2.1. Record the site, location, observer, and date information. For each shrub whose canopy intersects the 4 m × 4 m macroplot, record the following information:
    - Species code: record species of plant being measured using a four-letter code based on first two letters of the genus and first two letters of species. Commonly used codes provided at bottom of datasheet.
    - Percent of plant in plot: estimate the percent of plant being recorded that falls within the macroplot (4 m × 4 m plot).
    - Canopy diameters: record the diameter across the widest axis of the plant's live canopy and the diameter perpendicular to the widest axis to the nearest 5 cm.
    - Maximum height: record the maximum live height of the plant to the nearest 5 cm.
    - Height to tallest bud scar: record the height to the tallest bud scar (point at end of previous year's growth and beginning of current year's growth) to the nearest 5 cm.
    - Microplot ID: for willow only that intersects a 1-m x 1-m microplot, note the microplot id (N, E, S, W).
    - Stems in microplot: record the total number of willow stems intersecting the microplot.
7. *Rocky Mountain National Park Elk-Vegetation Monitoring Project—Willow Monitoring—Line Intercept Data*. The information on this sheet is gathered once every 5 yr according to the schedule found in table 2.1. A 5.66-m tape should be laid out between the west and east corners of the macroplot (fig. 2.1). Record the site, location, observer, and date information. Conduct a line intercept transect, from west to east, measuring all shrubs (willows plus any other shrub species) along the length of the 5.66 m. Gaps of less than 5 cm are considered continuous canopy cover (fig. 2.2).

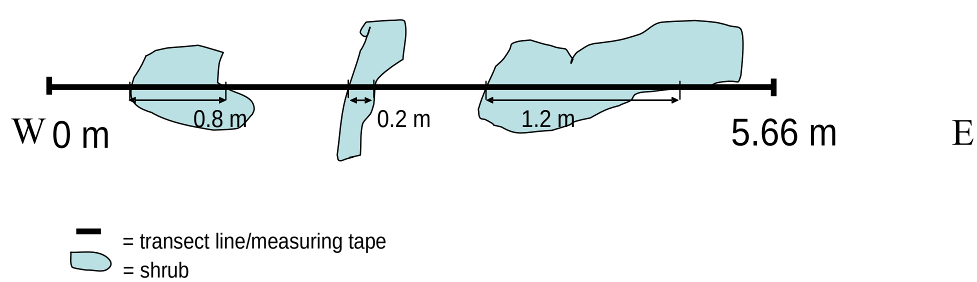


Figure 2.2. Diagram of layout of line intercept plot used in the Rocky Mountain National Park elk-vegetation monitoring program.

If a plant canopy intersects the line in more than one location, only one height is recorded for whole plant, not for individual sections of the plant. For each shrub encountered along the line, record:

- Species code: record species of plant being measured using a four-letter code based on first two letters of the genus and first two letters of species. Commonly used codes are provided on the data sheet.

- Intercept length: using another measuring tape, record the length to the nearest 0.1 m from the western edge where the shrub canopy first intersects the 5.66 m tape line to where the eastern edge of the shrub canopy intersects the line.
- Height: record height to the nearest 5 cm of the shrub (not necessarily on the intercept line).
- Browsing: record whether the plant has been browsed by ungulates (Y/N).

8. *Rocky Mountain National Park Elk-Vegetation Monitoring Project—Microplot Willow Browsing Data Sheet*. Measure along macroplot sides for 1 m from each permanent corner and mark with a survey flag. Mark fourth corner of microplots at 1.42 m from the permanent macroplot corners along tapes that bisect the macroplot from north (1.42 m on tape 1) to south (4.24 m on tape 1) and west (1.42 m on tape 2) to east (4.24 m on tape 2). Record the site, location, fenced, observer, and date information. Using plants whose canopies intersect the microplots (1 m x 1 m), select 3–5 stems per plant, measuring 10–12 stems per willow species, if available. A stem is identified as the portion of an individual willow plant that emerges from the ground surface. If 10 stems per species cannot be located using plants in each of the four microplots, then more stems should be selected from plants in the macroplot that fall outside the microplots. Items Microplot ID through Shoot sampling ratio below (shaded in datasheet) need only be recorded once for each stem. For each marked stem record:
   - Microplot ID: record which of the 4 microplots is being measured. N=North, E=East, S=South, W=West.
   - Plant ID Number: this is a number assigned to each plant where stems will be measured for browsing.
   - Stem Count: total number of stems on plant.
   - Species Code: record species of plant being measured using a 4 letter code based on first 2 letters of the genus and first 2 letters of species.
   - Stem ID: this is a letter (A,B,C, . . .) assigned to each individual stem measured.
   - Shoot sampling ratio: determine the shoot ratio that you will be sampling by estimating total shoot count on the stem. To ensure an unbiased sample of shoots, you should follow the method described in fig. 2.3. A shoot is defined as a single section of current year's growth. When sampling in early spring, shoots are the previous season's growth. As long as measures are made before the commencement of new shoot extension in spring, there should be no confusion on this matter. In fig. 2.3, the lightest gray areas are the shoots. The darker areas are growth from previous seasons. If a stem is large with a high number of shoots, the subsampling method should shift accordingly. Plants with less than 50 shoots can use a sampling ratio of 3 (measure every third shoot), but stems with 51–100 shoots should use a sampling ratio of 5 (measure every fifth shoot). For 101–250 shoots, use a sampling ratio of 10; for stems with greater than 250 shoots a sampling ratio of 20.

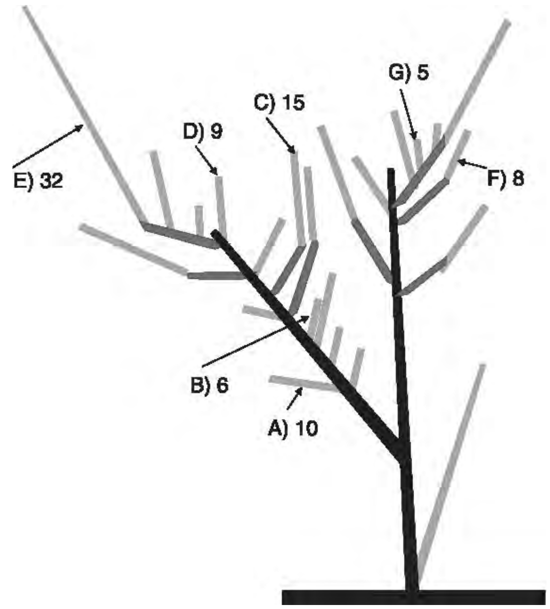


Figure 2.3. Diagram illustrating shoot-sampling protocol for a stem (from Bilyeu and others 2007, used with permission of the author). Letters indicate the order of measurements; numbers indicate lengths in centimeters. To represent adequately the shoot size distribution in this example, choose a sampling ratio of 3 (which means recording measurements on every third shoot encountered as you work apically from the base of the stem), accommodating side branches by sampling the lowest branches first. Here, seven measurements are made, with two shoots apical of the last shoot sampled. The count of shoots is then calculated as 7 × 3 + 2 = 23. If four of the seven measured shoots were browsed, along with the two apical of the last shoot sampled, then the count of browsed shoots is estimated as 4 × 3 + 2 = 14, and the count of unbrowsed shoots as 3 × 3 + 0 = 9.

For each sampled shoot (based on the shoot-sampling methods above), record:

- Additional shoot: check this box if this shoot is additional beyond those counted when using the shoot ratio. For example, if there are 28 shoots on the plant, you would measure every third shoot plus one more for a total of 10 shoots (9 measured shoots x 3 [shoot ratio] = 27 + 1 additional measured shoot). If the total number of shoots was 52, then 12 shoots would be measured (10 measured shoots x 5 [shoot ratio]=50 + 2 additional measured shoots).
- Browsed?: indicate whether the shoot is browsed (B) or unbrowsed (U).
- Diameter at base of shoot: using a digital or dial caliper, measure the basal diameter to the nearest 0.05 millimeters of the shoot at the base of the current year's growth. Be careful not to squeeze the calipers shut too tightly causing damage and an inaccurate measure.
- Diameter at tip of shoot: for unbrowsed shoot, use a digital or dial caliper to measure the tip diameter (to the nearest 0.05 mm) below the swelling of the apical bud of the shoot. For a browsed shoot, use calipers to measure the shoot diameter (in millimeters) at point of browsing.
- Shoot length: measure the length to the nearest 0.5 cm of the shoot from the base of current year's growth to tip.

When sampling is complete, be sure to fill in Page __ of __ information for all sheets from a site.

9. Shoot Collections: Each year in late summer, select 50 unbrowsed shoots of each willow species found in the microplots from plants outside the monitoring sites for each of the six major sampling areas: Hallowell Park-Glacier Creek, Moraine Park, Beaver Meadows, Hidden Valley, Horseshoe Park-Endovalley, and Cow Creek. Table 2.2 indicates the distribution of willow species based upon baseline data collection. Shoots collected from each site/species should cover a range of sizes and canopy locations (upper, lower, inner canopy, outer canopy) from several different plants. If additional species appear in the monitoring plots over time, shoots should be sampled from these species as well so that offtake data is complete. Place each clipped shoot in an envelope marked with the following information:
    - Sample area
    - Date
    - Species
    - Diameter at base of shoot (mm)
    - Diameter at tip of shoot (mm)
    - Length of shoot (cm)
10. Check to be sure all data sheets are complete.
11. Gather tapes and remove temporary markers and survey flags.
12. Drying and weighing willow shoot samples—*Rocky Mountain National Park Elk-Vegetation Monitoring Project—Willow Shoot Data for Biomass Regressions*. Drying of clipped vegetation samples should commence within a day of collection. Dry bagged samples in a drying oven set at 55°C for 48 hours. If oven space is not available right away and if the clipped material is already dry, store loosely in paper bags in a well-ventilated location. Record shoot weights with and without leaves along with species, diameter, and length information on data sheet.
13. Data entry and reduction
    - Copy data sheets when they are complete (including weights). Put originals into binders by direction of biologist in charge of elk management. Archive copies in a separate location in case of loss of originals.
    - Download digital photos from camera as soon as possible, print as 4×5-in, store with original data sheets. Archive electronic images as directed by the biologist in charge of elk management and the monitoring program.
    - Data entry: Enter data into database as directed by biologist in charge of elk management and vegetation-monitoring program.

Table 2.1. Schedule for site visits to willow-monitoring sites and location of site marker along transect line and declination corrected bearing of the transect line. * Denotes baseline sampling in 2009–10, not to be sampled with group 1 in following years.

Site	Fenced? (Y=Yes N=No P=Planned)	Winter offtake sampling structure					Macroplot/line-intercept sampling years: 2013 2018 2023 2028
		Group 1 years sampled: 2010 2015 2020 2025	Group 2 years sampled: 2011 2016 2021 2026	Group 3 years sampled: 2012 2017 2022 2027	Group 4 years sampled: 2013 2018 2023 2028	Group 5 years sampled: 2014 2019 2024 2029	
WC1	Y						X
WC2	Y						X
WC3	Y						X
WC4	Y						X
WC5	N		X	X			X
WC6	Y						X
WC7	Y						X
WC8	Y						X
WC9	Y						X
WC10	Y						X
WC11	Y						X
WC12	N				X	X	X
WC13	N	X	X				X
WC14	N	X	X				X
WC15	N			X	X		X
WC16	Y						X
WC17	N				X	X	X
WC18	N			X	X		X
WC19	N		X	X			X
WC20	N	X				X	X
WC21	N	X				X	X
WC22	N		X	X			X
WC23	N			X	X		X
WC24	Y						X
WC25	Y						X
WC26	Y						X
WC27	Y						X
WC28	Y						X
WC29	P	*					X
WC30	N	X				X	X
WC31	N				X	X	X
WC32	N		X	X			X
WC33	N				X	X	X
WC34	N	X	X				X
WC35	N	X				X	X
WC36	N		X	X			X
WC37	P	*					X
WC38	N	X	X				X
WC39	N	X				X	X

Site	Fenced? (Y=Yes N=No P=Planned)	Winter offtake sampling structure					Macroplot/line-intercept sampling years: 2013 2018 2023 2028
		Group 1 years sampled: 2010 2015 2020 2025	Group 2 years sampled: 2011 2016 2021 2026	Group 3 years sampled: 2012 2017 2022 2027	Group 4 years sampled: 2013 2018 2023 2028	Group 5 years sampled: 2014 2019 2024 2029	
WC40	P	*					X
WC41	P	*					X
WC42	Y						X
WC43	N		X	X			X
WC44	N			X	X		X
WC45	N	X				X	X
WC46	N	X	X				X
WC47	N	*			X	X	X
WC48	N	*			X	X	X
WC49	N	*			X	X	X
WC50	N	X	X				X
WC51	N	*		X	X		X
WC52	N	*		X	X		X
WC53	P	*					X
WC54	N	*		X	X		X
WC55	N	X	X				X
WC56	N	*	X	X			X
WC57	N	X				X	X
WNC1		X	X				X
WNC2			X	X			X
WNC3		X	X				X
WNC4		X	X				X
WNC5		X	X				X
WNC6			X	X			X
WNC7		X	X				X
WNC8			X	X			X
WNC9				X	X		X
WNC10					X	X	X
WNC11				X	X		X
WNC12					X	X	X
WNC13				X	X		X
WNC14			X	X			X
WNC15				X	X		X
WNC16					X	X	X
WNC17		X	X				X
WNC18			X	X			X
WNC19					X	X	X
WNC20		X				X	X
WNC21				X	X		X
WNC22					X	X	X
WNC23		X				X	X
WNC24			X	X			X
WNC25				X	X		X
WNC26		X				X	X

Site	Fenced? (Y=Yes N=No P=Planned)	Winter offtake sampling structure					Macroplot/line-intercept sampling years: 2013 2018 2023 2028
		Group 1 years sampled: 2010 2015 2020 2025	Group 2 years sampled: 2011 2016 2021 2026	Group 3 years sampled: 2012 2017 2022 2027	Group 4 years sampled: 2013 2018 2023 2028	Group 5 years sampled: 2014 2019 2024 2029	
WNC27					X	X	X
WNC28		X				X	X
WNC29		X	X				X
WNC30			X	X			X
WNC31		X				X	X
WNC32		X				X	X
WNC33					X	X	X
WNC35				X	X		X

Table 2.2. Summary of locations, willow species, and sample sizes of shoots that should be collected late each summer as part of the Rocky Mountain National Park elk-vegetation monitoring program. [SAGE, *Salix geyeriana*; SAMO, *Salix monticola*; SAPL, *Salix planifolia*; SABE, *Salix bebbiana*; SALA, *Salix lasiandra*; SAPE, *Salix petiolaris*; SADR, *Salix drummondiana*]

Sample Area	Species to be sampled	# shoots sampled of each/species	Total # of shoots to collect
Endovalley-Horseshoe Park	SAGE, SAMO, SAPL	50	150
Beaver Meadows	SAGE, SAMO, SAPL	50	150
Moraine Park	SABE, SAGE, SAMO, SAPL	50	200
Cow Creek	SADR, SAGE, SALA, SAMO, SAPE, SAPL	50	300
Hallowell Park-Glacier Creek	SAGE, SAMO, SAPL	50	150
Hidden Valley	SAGE, SAMO, SAPL	50	150
TOTAL			1100

Rocky Mountain National Park Elk-Vegetation Monitoring Project
Willow Monitoring Data—Site Characterization

Site #:____________Fenced (Y/N)? __________
Location:______________________________________
Observer(s):_____________________________________Date (mm/dd/yyyy):______________

Dominant Willow Type (circle one): *no willow* (meadow /no willow evident) *tall* (> 2.5 m ht (height))
intermediate (1.5–2.5 m ht) *short-young* (< 1.5 m ht, no dead stems, many colored stems)
short-old (< 1.5 m ht, larger crown w/ some dead stems, few young, colored stems)
sapling (< 50 cm ht, largest stem < 5 mm diameter at base, small crown, no lignification)

Ecosystem Type (circle one): fen riparian marsh wet meadow dry meadow

Predominant Herbaceous Species:
____

Current or Recent Beaver Presence (circle all that apply):
dam food cache cuttings tracks/droppings animal sighting none

Site corner UTM locations (NAD83): Site center_____________________
GPS error (m)___________
N _________________________________E___________________________________
S _________________________________W___________________________________

Comments____
____
____
____
____

Rocky Mountain National Park Elk-Vegetation Monitoring Project
Willow Monitoring Data—Macroplot Data

Site #:______________Location:_______________________Observer(s):______________________Date (mm/dd/yyyy):__________

Species code	% of plant in plot	Canopy diameters (cm)	Height (cm)	Height to tallest bud scar	Micro-plot ID	# stems in micro-plot	Species code	% of plant in plot	Canopy diameters (cm)	Height (cm)	Height to tallest bud scar (cm)	Micro-plot ID	# stems in micro-plot

Species Codes

Geyer's willow	*Salix geyeriana*=SAGE	River birch or water birch	*Betula occidentalis*=BEOC
Plane-leaf willow	*Salix planifolia*=SAPL	Bog birch or resin birch	*Betula glandulosa*=BEGL
Mountain or Park willow	*Salix monticola*=SAMO	Thin-leaf alder	*Alnus incana*=ALIN
Blue-stem or Drummond's willow	*Salix drummondiana*=SADR	Twinberry honeysuckle	*Lonicera involcrata*=LOIN
Bebb willow	*Salix bebbiana*=SABE	Shrubby cinquefoil	*Dasiphora fruticosa*=DAFR
Whiplash willow	*Salix lasiandra*=SALA	Whitestem gooseberry	*Ribes inerme*=RIIN
Meadow willow	*Salix petiolaris*=SAPE	Wax currant	*Ribes cereum*=RICE
Delicious raspberry	*Rubus deliciosus*=RUDE	Grayleaf red raspberry	*Rubus idaeus*=RUID

Rocky Mountain National Park Elk-Vegetation Monitoring Project
Willow Monitoring Data—Line-Intercept Data

Site #:_________________________________Location:________________________________
Observer(s):____Date (mm/dd/yyyy):__________

Line Intercept Data (5.66-m line):

Species Code	Intercept length (m)	Max Height (cm)	Browse (Y/N)

Species Code	Intercept length (m)	Max Height (cm)	Browse (Y/N)

Species Codes:

Geyer's willow	*Salix geyeriana*=SAGE
Plane-leaf willow	*Salix planifolia*=SAPL
Mountain or Park willow	*Salix monticola*=SAMO
Blue-stem or Drummond's willow	*Salix drummondiana*=SADR
Bebb willow	*Salix bebbiana*=SABE
Whiplash willow	*Salix lasiandra*=SALA
Meadow willow	*Salix petiolaris*=SAPE
River birch or water birch	*Betula occidentalis*=BEOC
Bog birch or resin birch	*Betula glandulosa*=BEGL
Thin-leaf alder	*Alnus incana*=ALIN
Twinberry honeysuckle	*Lonicera involcrata*=LOIN
Shrubby cinquefoil	*Dasiphora fruticosa*=DAFR
Whitestem gooseberry	*Ribes inerme*=RIIN
Wax currant	*Ribes cereum*=RICE
Delicious raspberry	*Rubus deliciosus*=RUDE
Grayleaf red raspberry	*Rubus idaeus*=RUID

Rocky Mountain National Park Elk-Vegetation Monitoring Project
Microplot Willow Browsing Data

Site #:____________________________Location:____

Fenced?_________Observer(s):____

Date (mm/dd/yyyy):_______________ Page____ of ______

Microplot Data: Items in gray need only be filled out once for each marked stem.

Micro-plot (N, E, S, W)	Plant ID #	Species code	Total stem count	Stem ID letter	Shoot ratio	Additional shoot? (check if Yes)	Browsed? B/U	Diameter at base of shoot (mm)	Diameter at tip of shoot (mm)	Shoot length (cm)

Rocky Mountain National Park Elk-Vegetation Monitoring Project
Willow Shoot Data for Biomass Regressions

Sample area	Species code	Diameter at base of shoot (mm)	Diameter at tip of shoot (mm)	Shoot length (cm)	Shoot weight without leaves (g)

Appendix 3: Rocky Mountain National Park Elk-Vegetation Monitoring Program Upland-Herbaceous Site Monitoring Protocol

The following steps outline the process of visiting and sampling the upland-herbaceous-monitoring sites that are part of the Rocky Mountain National Park elk-vegetation monitoring program. All site locations and special instructions are with the park biologist in charge of the monitoring program and should be acquired from this individual. *Italic* type indicates the name of datasheet to be filled out. Sample datasheets can be found at the end of this appendix. The sampling of general site characteristics, reference photos, and line-intercept measures of shrub cover should be performed at all sites once every 5 yr during summer according to the timetable set out in table 3.1. Only those sites scheduled for sampling in a given year should be measured for winter offtake (consumption) in spring each year following the timetable set out in table 3.1. Winter offtake measures should be collected prior to green-up of new growth each year, and if not possible, before such green-up has advanced to any great extent. Green-up typically occurs between late March and late April in these sites. Placement of grazing cages for monitoring of winter consumption should be conducted in late August-early September—ideally after the peak growing season, but before elk herds arrive on the winter range and begin to graze to any great extent. Photos should be taken any time an event of interest occurs at a site (for example, tree falls into site, ground torn up by animals/humans, etc.). Nothing should be removed from any site except for approved plant samples listed on the research permit. A general schematic of upland-monitoring plot design can be found in figure 3.1.

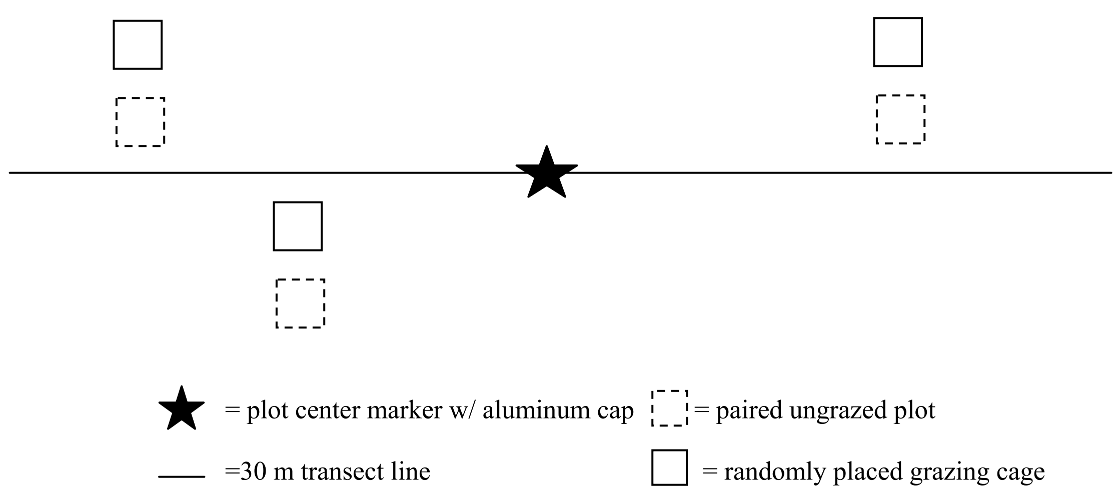


Figure 3.1. Schematic of upland-vegetation-monitoring plot design.

1. Gather equipment and supplies

FOR ALL FIELD WORK

- Research permit
- Radio pack set
- Protocol, data sheets, pens, clipboard, notebook
- Handheld GPS unit and spare batteries
- Compass set to proper declination (check current declination prior to each field season at *http://www.ngdc.noaa.gov*)
- Metal detector (may be needed to find site center)
- Hammer or mallet (for setting cages in August through September)
- Digital camera with extra batteries
- Maps
- Pliers, bailing wire (for cage repair)
- List of site locations (to be supplied by park biologist in charge of monitoring program)

FOR LINE INTERCEPT

- Tape measure (longer than 30 m)
- 4 chaining pins or stake to hold ends of tape
- Clinometer
- Five-meter tape measure and meter stick for plant heights
- Vegetation ID key: Stevens, J.E., J. Lemly, and R. Thomas, 2005, Dichotomous key to the plant associations of Rocky Mountain National Park: Fort Collins, Colo., Colorado State University, Colorado Natural Heritage Program, 49 p.

FOR REFERENCE PHOTO POINT

- Laminated placard (light, not white) with following information:

  ROMO EVMP
  SITE___________
  DATE _________
  DIRECTION_____

- dry erase marker
- wipes or cloth to clean placard

FOR PLOT CLIPPIPNG & COLLECTION

- 0.25-m^2 (square meters) steel circular clipping rings (usually kept in the wildlife cache—look like a steel ring divided into quarters)
- Scissors, shears, or other clippers appropriate for clipping grasses (2 per crew member)
- Small paper bags (lunch-bag size) and small coin envelopes (42 per site) , stapler or rubber bands, Sterilite container for storage
- Nitrile gloves (for clearing scat from plot)
- Sharpie® marker for labeling bags

2. Navigate to the site center using GPS and UTM coordinates on list provided by park biologist in charge of monitoring program. Be sure to have WAAS enabled on the GPS to increase accuracy (although this will shorten battery life). Site center is a rebar stake with aluminum cap pounded flush with the ground imprinted with "ELK-VEG MONITOR—NPS-DO NOT DISTURB—ROMO STUDY 06013" and the plot number. The presence of grazing cages at a site should indicate that you are in the correct overall location. The metal detector may be useful for locating plot center.

3. *Rocky Mountain National Park Elk-Vegetation Monitoring Program—Upland Site Characterization Data Sheet*. The information on this sheet is gathered once every 5 yr according to the schedule found in table 3.1. Dimensional variables shall be in metric units.
   - Site name/number: letter and numeric combinations—U(upland)+ NC(noncore) or C(core)+ individual number. For example, UNC4 would be upland, noncore site 4.
   - Location: general description of the location (for example, Moraine Park, Beaver Meadows, etc.).
   - Date: full date including year (mm/dd/yyyy).
   - Start time: time starting plot.
   - E.T.: end time—time work was finished.
   - # persons: size of field crew making measurements.
   - Observers: last name of those observing, measuring and recording data.
   - Site coordinates: UTM easting and northing coordinates of site center if different from table 3.1—be sure the GPS unit is set at UTM NAD83 zone 13, WAAS-enabled.
   - GPS error: record error on GPS in meters.
   - General comments: additional information (for example, distance and bearing from landmarks) to help in future relocations, information about events at site (slides, fires, etc.).
   - From site center record:
     - Slope (percent) using clinometer.
     - Aspect (flat, N, NE, E, SE, S, SW, W, NW) for later comparison with data derived from Digital Elevation Models (DEMs).
   - Elevation: record reading from GPS in meters (if GPS is set for statute to help in navigation with vehicle, use conversion of 3.281 ft=1 m).
   - Site characteristics: as described on data sheet. Animal signs (scat, tracks, presence, excavations) should be limited to ungulates that may graze in the area and burrowing animals that might affect herbaceous plants or bury site markers. Be sure to identify species of ungulate.
   - Dominant vegetation type: record which one of these general vegetation types you observe at the site based on the Dichotomous Key to the Plant Associations for Rocky Mountain National Park (Stevens and others, 2005). Choices are: Herbaceous Upland Montane (MU4), Shrub-Upland-Lower Montane-Bitterbrush (MU142), Shrub-Upland-Lower Montane-Undifferentiated (MU14), Shrub-Upland-Big Sagebrush (MU141), Ponderosa Pine-Graminoid (MU34), Ponderosa Pine-Rockland (MU35), and Ponderosa Pine-Shrubland (MU36).
   - Shrub cover (line intercept): using the capped rebar site marker as an anchor point, stretch a 30-m tape along the true compass bearing listed in table 3.1 for the site (see figure 3.2). True bearing is magnetic bearing plus or minus declination. It is best to use a compass with the declination preset. The Marker Point Location column in table 3.1 specifies the position of the site center marker on this 30 m transect:
     - middle: Place the 15-m mark on the tape on the site center marker, extend the tape 15 m in the true bearing given in table 3.1, and 15 m along the back bearing (bearing minus 180 degrees) using compass set to the correct declination.
     - west or east: place the west or east end of the 30-m tape on the site center marker and extend the tape 30 m along the true bearing given in table 3.1.

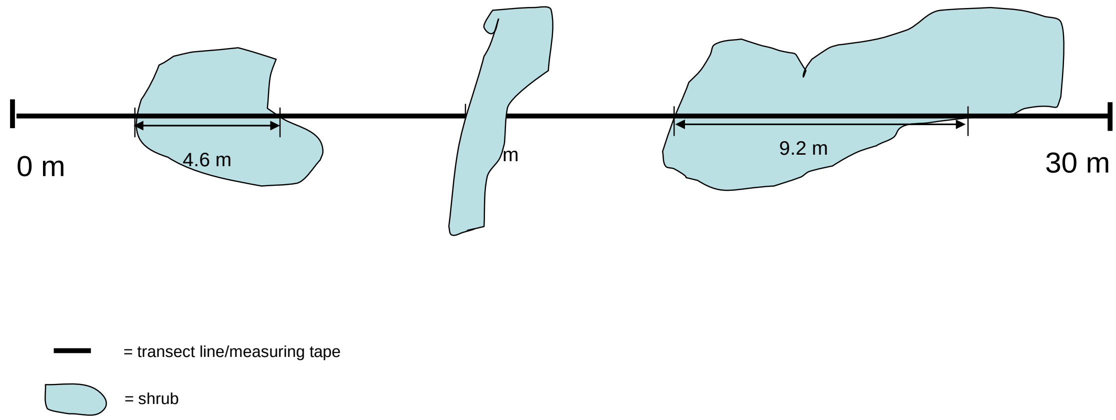


Figure 3.2. Schematic diagram of line-intercept method to measure upland shrub cover.

- Along the 30-m line, conduct a line-intercept plot, measuring all live shrubs along the length of the line. For each shrub encountered along the line, record:
  - Species: four letter identification codes should be used for each shrub species, based on the first two letters of the genus and the first two letters of the species (for example, *Artemisia tridentata*=ARTR, *Purshia tridentata*=PUTR, *Chrysothamnus nauseosus*=CHNA, etc).
  - Intercept length: distance along the tape to nearest 0.1 m where the outer edges of the shrub canopy intersect the line (see figure above).
  - Height: maximum height of the shrub (not necessarily on the intercept line) to nearest 0.05m.

4. Take 2 digital photos from the site center and looking in opposite directions along the transect line. Place the laminated placard with the site name/number, date, and the direction of the photo (for example, N if photo is taken looking north from site location point) within the photo field.
5. *Rocky Mountain National Park Elk-Vegetation Monitoring Program—Upland Herbaceous Offtake Data Sheet*. These measures shall be gathered annually according the schedule outlined in table 3.1. Each site has three grazing-exclusion cages. The objective here is to collect comparable data from the 0.25-m^2 (clipping ring) plots outside (available for fall/winter grazing) and inside the exclusion cages.

   Uncaged plot: (Do first to minimize your influence) The uncaged plot should be 3–5 m from the caged plot to reduce the influence of the cage on the uncaged plot (trailing/trampling that may occur along the edge of the cage, snow deposition on one side of the cage, etc). Select a general location south of the caged plot with similar slope/aspect, overstory/exposure, species composition, and soil characteristics. If the area to the south of the caged plot is unusable, select the first suitable location found (in priority order) to the west, north, or east. All attempts should be made to not trample either study plot. Be sure that each pair of plots has the same quadrat/cage number and that no other pair in that site has the same numbers.

   Caged plot: Place 0.25-m^2 steel circular quadrat in the center of the area protected by a grazing cage.

   Record the following information on the data sheet:

- Site name/number: letter and numeric combinations—U(upland) + NC(noncore) or C(core) + individual number. For example, UNC4 would be upland, noncore site 4.
- Clipped by: last names of observers doing the clipping.
- Date: full date including year (mm/dd/yyyy) plot was clipped.
- Weighed by: last name of observers conducting the weighing.
- Date: full date including year (mm/dd/yyyy) samples were weighed.
- Cover class: for each 0.25-m^2 plot, inside and outside the grazing exclusion cage, first (before clipping) visually assess and record percent coverage of the previous growing season's vegetation and other categories listed on the data sheet. Be sure to record zeroes. The clipping ring is divided into 4 quadrants (each 25 percent) to aid this assessment (observer mentally "compresses" categories into one or more quadrants and can generally assess as ½ (12.5 percent), ¼ (6.25 percent), 1/8 (3.125 percent) of a quadrant. For categories that are present but less than roughly 2 percent, enter "T" (for trace). The values should total 100 percent, although the presence of overhanging shrubs could potentially increase this number to greater than 100 percent.
- Clipping and collecting: At each 0.25-m^2 plot, clip biomass at ground level and sort by category (sub-shrub, forbs, graminoids, other not-litter). Litter is considered to be non-rooted dead and down plant material in the plot and is not collected. Rooted plants which appear to be gray, in contact with the soil, and more than one season old are also considered to be litter. Litter should not be confused with plant material produced the previous season which is now standing dead and should be collected as graminoids or forbs—these plants will appear yellow, brown, or tan in color.

  When clipping vegetation, if a category is not present and not collected, be sure to enter a zero for that category in the weighing section of the data form. This prevents confusion as to whether the sample was misplaced or non-existent. When clipping in the spring, be sure to remove from the sample any new green growth that is from the current year's production. The spring sample is only designed to measure winter plant consumption by ungulates and therefore no new growth should be included.

  Definitions of plant categories and which types to collect (clip) are as follows:
  - Graminoids: includes grasses and grass-like plants such as rushes (*Juncus* spp.) and sedges (*Carex* spp.). Collect only previous season's growth and remove current season's green growth from clippings.
  - Forbs: collect only previous season's growth and remove current season's green growth from clippings.
  - Sub-shrubs: predominantly low-growing (less than 20 cm) herbaceous plants with woody stems and basal branches—includes such plants as fringed sage (*Artemisia frigida*), Oregon grape (*Mahonia repens*), and Kinnikinnik (*Arctostaphylos uva-ursi*). Clip all parts of subshrubs, woody as well as the previous year's herbaceous growth.

  Place sorted clipped plant material in paper bags, labeled with:
  - ROMO EVM (stands for Rocky Mountain NP Elk Vegetation Monitoring)
  - full date (MM/DD/YYYY)
  - site name/number (for example, UC20 or UNC1, etc.)
  - quadrat/cage number (1–3), whether IN or OUT (use different colored labeling for IN vs. OUT bags)

    - bag contents (category as listed on data sheet)
- Storage of cages: when clipping is complete, store cages on sites—securely staked in a group on the edge of a clearing or away from center of site until fall when the cages will be relocated.

6. Drying and weighing: the drying of clipped vegetation samples should commence within a day of collection. Dry bagged samples in a drying oven set at 55°C for 48 hr—longer if samples are exceptionally wet when collected. If oven space is not available right away and if the clipped material is already dry, store loosely in paper bags in well-ventilated location. After plant samples are dried, weigh contents of each bag by placing in a tared pan on a scale (balance). Measure dry weight of sample in the bag to the nearest 0.01 g and record this weight on the bag and on the associated data sheet. Return data sheets to the biologist in charge of this monitoring program after weights are recorded.
7. Relocating cages in fall: Relocate the cages at the appropriate sites following the timetable in table 3.1 each fall (late August/early September before elk presence on the winter range increases to winter concentration levels). Remember that the dates in table 3.1 are for the year the sites will be sampled, therefore in fall 2009, the Group 2 sites to be sampled in spring 2010 should have cages set. Using a random number table (table 3.2), select a random compass bearing to determine direction from the site-center point and a random number of full paces (between 1 and 100) to travel in that direction. If the distance or direction to locate a cage places the cage out of the upland vegetation type, first halve the original distance. If the cage location is still outside the vegetation type, pick a new random direction and distance. If site is UC14, UC18, or UC20, be sure to follow the special instructions to protect cultural resources—acquire photos for cage placement at these sites from park biologist in charge of monitoring program. Cages should be located no more than 125 m from the site center to prevent the possibility of overlap with other upland monitoring sites. If cages are not easily visible from the site center due to topography or trees, note location of cages on the data sheet (bearing and distance from center). Grazing cages should be staked to the ground using three 4-ft lengths of rebar placed approximately equidistant along the cage perimeter, woven through the fencing mesh, and hammered at least 1ft into the ground. In this manner, the rebar will not protrude above the height of the cage. A 4-ft square of chicken wire should be placed over the top of each cage to prevent elk grazing over the top of the cage. The chicken wire should be crimped around the edge of the top of the cage and fixed in place with 2–3 shoat or pig rings. Use bailing wire to connect the cage to each length of rebar in one or two places. Two or three 6-in u-shaped landscaping staples may be used to additionally hold the bottom strand of fence wire to the ground to prevent elk from nosing under the cage, though their usefulness is limited in loose, gravel soils.
8. Data entry and reduction
    - Copy data sheets when they are complete (including weights). Put originals into binders by direction of the biologist in charge of elk management. Archive copies in a separate location in case of loss of originals.
    - Download digital photos from camera as soon as possible, print as 4×5-in, store with original data sheets. Archive electronic images as directed by the biologist in charge of elk management and the monitoring program.
    - Data entry: Enter data into database as directed by the biologist in charge of elk management and vegetation monitoring program.

Table 3.1. Schedule for site visits to upland-monitoring sites and location of site marker along transect line and declination-corrected bearing of the transect line.

Site	Winter offtake sampling structure (herbaceous clipping in April of sampling year)					Line-intercept sampling years: 2013 2018 2023 2028	Marker point location	Bearing of line from true north	General comments
	Group 1 years sampled: 2009 2014 2019 2024	Group 2 years sampled: 2010 2015 2020 2025	Group 3 years sampled: 2011 2016 2021 2026	Group 4 years sampled: 2012 2017 2022 2027	Group 5 years sampled: 2013 2018 2023 2028				
UC1	X	X				X	middle	241	.
UC2		X	X			X	middle	164	.
UC3	X				X	X	middle	104	.
UC5				X	X	X	middle	264	.
UC8	X	X				X	middle	262	.
UC9			X	X		X	middle	160	.
UC11		X	X			X	middle	124	.
UC12			X	X		X	middle	268	~5 m off horse trail
UC13				X	X	X	middle	260	.
UC14	X				X	X	middle	208	.
UC16	X	X				X	middle	254	.
UC17		X	X			X	middle	206	~10 m off road
UC18			X	X		X	west	308	~3 m off trail
UC19			X	X		X	middle	268	~3 m from road
UC20				X	X	X	middle	184	.
UC21		X	X			X	middle	310	.
UC24		X	X			X	middle	268	.
UC25			X	X		X			
UC26				X	X	X	middle	142	.
UC28	X				X	X	middle	210	.
UC29	X	X				X			
UC31	X	X				X	middle	182	.
UC34	X				X	X	middle	272	.
UC35				X	X	X	middle	254	.
UC36	X				X	X	middle	94	.
UNC2	X	X				X	middle	78	

Site	Winter offtake sampling structure (herbaceous clipping in April of sampling year)					Line-intercept sampling years: 2013 2018 2023 2028	Marker point location	Bearing of line from true north	General comments
	Group 1 years sampled: 2009 2014 2019 2024	Group 2 years sampled: 2010 2015 2020 2025	Group 3 years sampled: 2011 2016 2021 2026	Group 4 years sampled: 2012 2017 2022 2027	Group 5 years sampled: 2013 2018 2023 2028				
UNC4	X	X				X	middle	254	.
UNC5			X	X		X	middle	244	.
UNC6		X	X			X	middle	271	.
UNC8			X	X		X	.	.	.
UNC9	X	X				X	middle	12	.
UNC10			X	X		X	NW end	152	.
UNC14		X	X			X	middle	260	.
UNC16	X				X	X	middle	358	.
UNC21	X	X				X	N end	180	.
UNC22		X	X			X			
UNC24			X	X		X	9.5 m	12	Extends 20.5 m at 12° and 9.5 m at 192°
UNC27				X	X	X	middle	186	.
UNC30	X				X	X			
UNC32	X	X				X	middle	66	.
UNC34		X	X			X	middle	202	.
UNC38				X	X	X	middle	264	.
UNC40				X	X	X	middle	12	
UNC41		X	X			X			
UNC42			X	X		X	middle	198	
UNC49	X				X	X	middle	82	
UNC50	X				X	X		.	
UNC60				X	X	X	middle	78	.

Table 3.2. Random-number table. With eyes closed, drop a pencil anywhere on the page to indicate a starting place in the table. If single-digit random numbers are needed, use the last digit of the number you started on as your first random number and proceed down the column to the bottom of the page and then to the top of the next column, and so on. Ignore duplicates and record zero (0) as ten (10). If two-digit random numbers are needed, use last 2 digits of starting number and proceed as above. If looking for bearing, use last 3 digits and only choose numbers less than or equal to 360.

13962	70992	65172	28053	02190	83634	66012	70305	66761	88344
43905	46941	72300	11641	43548	30455	07686	31840	03261	89139
00504	48658	38051	59408	16508	82979	92002	63606	41078	86326
61274	57238	47267	35303	29066	02140	60867	39847	50968	96719
43753	21159	16239	50595	62509	61207	86816	29902	23395	72640
83503	51662	21636	68192	84294	38754	84755	34053	94582	29215
36807	71420	35804	44862	23577	79551	42003	58684	09271	68396
19110	55680	18792	41487	16614	83053	00812	16749	45347	88199
82615	86984	93290	87971	60022	35415	20852	02909	99476	45568
05621	26584	36493	63013	68181	57702	49510	75304	38724	15712
06936	37293	55875	71213	83025	46063	74665	12178	10741	58362
84981	60458	16194	92403	80951	80068	47076	23310	74899	87929
66354	88441	96191	04794	14714	64749	43097	83976	83281	72038
49602	94109	36460	62353	00721	66980	82554	90270	12312	56299
78430	72391	96973	70437	97803	78683	04670	70667	58912	21883
33331	51803	15934	75807	46561	80188	78984	29317	27971	16440
62843	84445	56652	91797	45284	25842	96246	73504	21631	81223
19528	15445	77764	33446	41204	70067	33354	70680	66664	75486
16737	01887	50934	43306	75190	86997	56561	79018	34273	25196
99389	06685	45945	62000	76228	60645	87750	46329	46544	95665
36160	38196	77705	28891	12106	56281	86222	66116	39626	06080
05505	45420	44016	79662	92069	27628	50002	32540	19848	27319
85962	19758	92795	00458	71289	05884	37963	23322	73243	98185
28763	04900	54460	22083	89279	43492	00066	40857	86568	49336
42222	40446	82240	79159	44168	38213	46839	26598	29983	67645
43626	40039	51492	36488	70280	24218	14596	04744	89336	35630
97761	43444	95895	24102	07006	71923	04800	32062	41425	66862
49275	44270	52512	03951	21651	53867	73531	70073	45542	22831
15797	75134	39856	73527	78417	36208	59510	76913	22499	68467
04497	24853	43879	07613	26400	17180	18880	66083	02196	10638
95468	87411	30647	88711	01765	57688	60665	57636	36070	37285
01420	74218	71047	14401	74537	14820	45248	78007	65911	38583
74633	40171	97092	79137	30698	97915	36305	42613	87251	75608
46662	99688	59576	04887	02310	35508	69481	30300	94047	57096
10853	10393	03013	90372	89639	65800	88532	71789	59964	50681
68583	01032	67938	29733	71176	35699	10551	15091	52947	20134

Rocky Mountain National Park Elk-Vegetation Monitoring Program
Upland Site Characterization Data Sheet

Site name/number: ___________________ Location:_____________________________
Date (mo/da/yyyy): _____________ Start: ______ E.T. _______ # Persons ___________
Observers: ____

Site Coordinates: *UTM NAD83* GPS make/model: ___________
Easting____________________Northing_____________________Error (m)_________

General Comments:

Slope %:_______________Aspect_______________GPS elevation (m)____________________

Site Characteristics:
Soil Type/Wetness (wet/dry; rocky, sandy, clay, loam, etc):_________________________________

Animal Signs: Spp. Evidence

Vegetation type:_____________________________________

Shrub cover: *line-intercept method* Marker Point Location (if different from table 3.1):______
Bearing (if different from table 3.1):_______

Species	**Intercept length (m)**	**Height (m**		**Species**	**Intercept length (m)**	**Height**

Rocky Mountain National Park Elk-Vegetation Monitoring Program
Upland Herbaceous Offtake Data Sheet

Site name/number _______________ Clipped by___________________________
Date____________/20____
Weighed by_____________________________Date__________________

Life Forms (standing dead)	Quadrat OUTSIDE Cage Weight (g)				Quadrat INSIDE Cage Weight (g)		
	1	2	3		1	2	3
Graminoids				Graminoids			
Forbs				Forbs			
Sub-Shrubs				Sub-Shrubs			
Other				Other			

Cover Class	Quadrat OUTSIDE Cage % cover			Cover Class	Quadrat INSIDE Cage % cover		
	1	2	3		1	2	3
Bare Ground				Bare Ground			
Litter				Litter			
Grams				Grams			
Forbs				Forbs			
Cactus				Cactus			
Shrub				Shrub			
Sub-shrub				Sub-shrub			
Rock				Rock			
Scat				Scat			
Moss				Moss			
Hole				Hole			
Other				Other			

UTM (NAD83) location of stored cages: Easting______________Northing______________
Comments:____
____

NOTE: IF NO COLLECTION MADE OF A CATEGORY, ENTER A "0" IN THE WEIGHT COLUMN

Appendix 4: Rocky Mountain National Park Elk-Vegetation Monitoring Program Aspen Monitoring Site-Establishment Protocol

The following steps outline the process of establishing aspen-monitoring sites as part of the RMNP elk-vegetation monitoring program. **Boldface** type indicates the name of an associated monitoring protocol. *Italic* type indicates the name of datasheet to be filled out. Plot establishment should be conducted during summer, preferably when the majority of annual growth has already occurred and before elk begin browsing to any great extent in the fall. Nothing should be removed from any site except for approved plant samples listed on the research permit.

1. Using a GIS (geographic information system) program, randomly select potential sites from available aspen areas. If new sites are desired within aspen fences, use GIS software and current fence and vegetation maps to identify the fenced areas that need to be monitored, and use a random-point generator to select points within the fences. You should buffer the fenceline so that the points fall at least 5 m from the fence. If the sites need to be selected from aspen area outside the fence, use a map of projected aspen vegetation to determine area to select from. Be sure to buffer the fence by 10 m so that plots won't fall in areas where elk may trail along the fenceline and cause excessive trampling or herbivory and so that plots won't fall in areas where there may be disturbance caused by fence building. All intended sample locations should be checked with NPS cultural-resources staff to ensure cultural-resources compliance.
2. Gather equipment
    - Research permit
    - Radio pack set
    - Protocol, data sheets, pens, clipboard
    - Hammer or mallet for pounding in site markers
    - 2 tape measures at least 25 m in length for plot layout
    - 4 pieces of 6-in length rebar (if approval occurs in the future because of problems with frost heaving of site markers, these rebar pieces may be changed to 1 ft in length or longer)
    - 4 aluminum survey marker caps imprinted with "ELK-VEG MONITOR—NPS-DO NOT DISTURB—ROMO STUDY 06013"
    - Metal die kit
    - 10 chaining pins or other stakes for holding down tape measure
    - Compass (declination should be set to appropriate number)
    - Handheld GPS unit and spare batteries
    - Diameter tape (tape that converts circumference to diameter)
    - Digital camera

- Laminated placard (light, not white) with following information:

ROMO EVMP SITE___________ DATE _________ CORNER_____

- dry erase marker
- wipes or cloth to clean placard

3. Locate the plot using GPS. Be sure to have WAAS enabled on the GPS to increase accuracy (although this will shorten battery life). The site should be surveyed to be sure it is the correct vegetation type—predominantly aspen—and to be sure that placing the plot using that point will not lead to the majority of the plot lying in a vegetation type other than aspen. The plot should be located within the stand of aspen so as not to include edge or mixed conifer/aspen areas. Conifer in the understory of a stand with an aspen overstory is acceptable. Assess whether there are any other conflicts (roads, trails, picnic areas, campgrounds, or other human impacts) which may make the site unacceptable for use in the monitoring study. If the plot center needs to be moved, move the plot 10 m in the cardinal direction that will put it in the aspen vegetation type. If a 10 m move does not result in successfully locating a plot center in the target vegetation type, moving an additional 10 m toward the vegetation type may be attempted. If this second attempt at relocation does not succeed in achieving an appropriate plot location, abandon this point and move to another. If cultural artifacts or indications of cultural resource issues are identified, discontinue work and contact park cultural resources staff before proceeding. Do not remove any artifacts, or animal, plant, or geologic material unless approved on the research permit for this project.
4. A 5-m × 5-m square plot should be located as close to the random point as possible. Assign an unused site number. Do not reuse numbers if a previous site has been discontinued. The plot should be marked with rebar stakes in each corner. All corners should have UTM coordinates marked with a GPS set to NAD83 projection. The starting point for the plot should be determined as the landmark corner and its coordinates and general direction/location (that is, southeast corner or south corner) in relation to the rest of the plot should be noted on the data sheet.
5. From the landmark corner (#1), stretch a 25-m tape 5 m along a line that will ensure the plot falls within the stand. Place a rebar marker stake at the 5-m point. This is corner #2. Run another tape at a 90° bearing for 5 m from the first tape to make the second side and also mark corner (#4) with a stake. To mark the last corner (#3), take bearings 90° from corners #2 and #4 and run a tape 5 m from each of these corners. If the meeting point does not appear square, either by bearing line or by 5-m distance along the line, remeasure corners #2 and #4 to ensure the last corner is placed as accurately as possible. Trueing of the corners can also be achieved by running a tape 7.07 m across the diagonal from corner #1 to corner #3 and from corner #2 to corner #4. Put in a rebar stake at the final corner. Leave tape measures in place until finished measuring the plot (fig. 4.1).
6. Dissect plot into four quarters by placing tape measures or cord across the mid-section of each line (fig. 4.1). This will make it easier to measure and account for all trees in the plot.

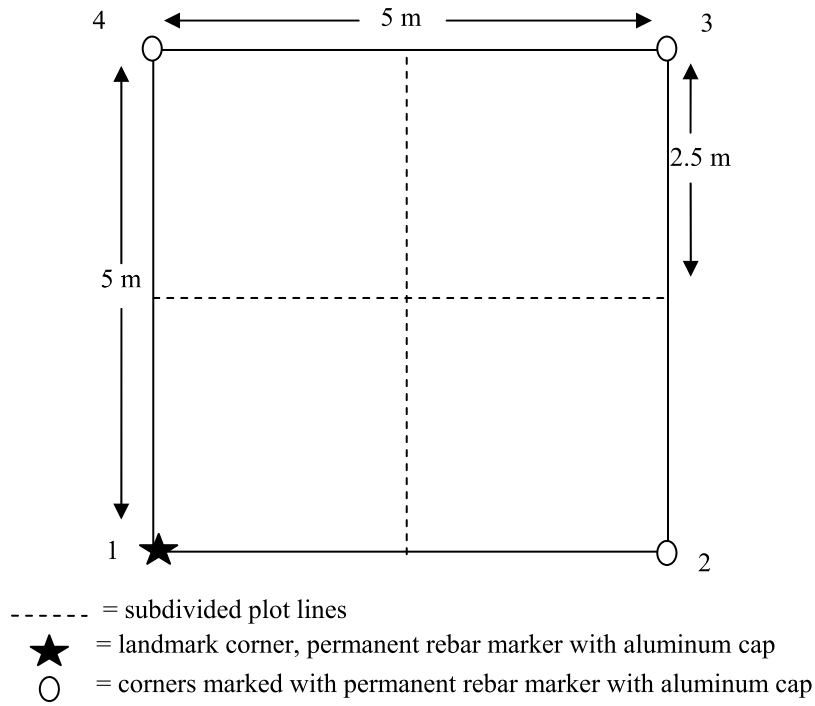


Figure 4.1. Diagram of aspen monitoring plot layout for the Rocky Mountain National Park elk-vegetation monitoring program.

7. Once the plot has been laid out, Proceed to **Rocky Mountain National Park Elk-Vegetation Monitoring Program—Aspen Site Monitoring Protocol** (Appendix 2), step 3, data sheet titled *Rocky Mountain National Park Elk-Vegetation Monitoring Project—Aspen Monitoring Data Sheet* .
8. Aluminum caps should be placed on top of each piece of rebar that mark the corners. These caps should have the following information imprinted on them: "ELK-VEG MONITOR—NPS-DO NOT DISTURB—ROMO STUDY 06013". The plot name/number and the corner number will need to be added at the time of plot establishment using a die-stamping kit. Rebar should be hammered in such that the cap is flush with the ground.
9. When all data collection is complete, remove measuring tapes and temporary markers. Double check to be sure that all rebar is pounded flush to the ground before leaving the site at the end of the visit.

Appendix 5: Rocky Mountain National Park Elk-Vegetation Monitoring Program Willow Monitoring Site-Establishment Protocol

This protocol outlines the procedures for selecting and establishing willow-monitoring sites as part of the RMNP elk-vegetation monitoring program. **Boldface** type indicates the name of an associated monitoring protocol. *Italic* type indicates the name of datasheet to be filled out. Plot establishment should be conducted during summer, preferably when the majority of annual growth has already occurred and before elk begin browsing to any great extent in the fall. Nothing should be removed from any site except for approved plant samples listed on the research permit.

1. Using a GIS program, randomly select potential sites from available willow areas. If new sites are desired within willow fences, use GIS software and current fence and vegetation maps to identify the fenced areas that need to be monitored and use a random-point feature to select points within the fences. You should buffer the fenceline so that the points fall at least 5 m from the fence. If the sites need to be selected from willow area outside the fence, use a map of projected willow vegetation to determine area to select from. Again, be sure to buffer the fence to a distance of 10 m so that plots won't fall in areas where elk may trail along the fenceline and cause excessive trampling or herbivory and so that plots won't fall in areas where there may be disturbance caused by fence building. All intended sample locations should be checked with NPS cultural-resources staff to ensure cultural-resources compliance.
2. Gather equipment needed to establish plot
    - Research permit
    - Radio pack set
    - Protocol, data sheets, pens, clipboard
    - Hammer or mallet for pounding in site markers
    - 2 tape measures at least 25 m in length for plot layout
    - 4 pieces of 6-in length rebar (if approval occurs in the future because of problems with frost heaving of site markers, these rebar pieces may be changed to 12–18-in length or longer)
    - 4 aluminum survey marker caps imprinted with " ELK-VEG MONITOR—NPS-DO NOT DISTURB—ROMO STUDY 06013"
    - Metal die kit
    - 10 chaining pins or other stakes for holding down tape measure
    - Compass (check current declination prior to each field season at *http://www.ngdc.noaa.gov*)
    - 12 survey flags for marking microplot corners
    - Handheld GPS unit and spare batteries
    - Digital camera
    - Laminated placard (light, not white) with following information:

ROMO EVMP SITE___________ DATE _________ CORNER_____

- dry erase marker
- wipes or cloth to clean placard

3. Navigate to desired plot center using GPS unit and coordinates of randomly selected points. Be sure to have WAAS enabled on the GPS to increase accuracy (although this will shorten battery life). Survey site to be sure it is the correct vegetation type (willow) and to be sure that placing the plot using that center point will not lead to the majority of the plot lying in a vegetation type other than either willow, other riparian shrub interspersed with willow, or meadow interspersed with willow. If the plot center needs to be moved, move the plot 10 m in the cardinal direction that will put it in the willow vegetation type. If a 10-m move does not result in successfully locating a plot center in the target vegetation type, moving an additional 10 m toward the vegetation type may be attempted. If this second attempt at relocation does not succeed in achieving an appropriate plot location, abandon this point and move to another. If the general area does not appear to have the potential to support willow (for example, the area is too dry, dead willow exist but indications that the water regime has changed and no longer will support willow, or no sign of willow in the general area (not just the plot area)) then proceed to another random point. If cultural artifacts or indications of cultural resource issues are identified, discontinue work and contact park cultural resources staff before proceeding. Do not remove any artifacts, or animal, plant, or geologic material unless approved on the research permit for this project.
4. Set a stake to temporarily mark the plot center. Assign an unused site number. Do not reuse numbers if a previous site has been discontinued. Site corners will be marked with rebar stakes with aluminum caps pounded flush with the ground imprinted with "ELK-VEG MONITOR—NPS-DO NOT DISTURB—ROMO STUDY 06013". Use metal die kit to additionally stamp four caps of these caps with the site number (WC # or WNC#) and the cardinal direction of each corner (N,E,S,W). This can be done ahead of time, if desired.
5. Using a compass with declination appropriately set, draw out the measuring tape end on a bearing due north for 2.83 m. Pin the end of the tape with chaining pin. Place permanent rebar marker at same point as chaining pin. This is the N corner of the plot.
6. From this north corner marker, proceed 5.66 m due south through the center with the tape spool. Mark end with chaining pin and permanent rebar marker. This is the S corner of the plot.
7. Return to plot center (2.83 m along the tape). Pull the tape end of the second tape 2.83 m due west and mark the W corner of the plot with a chaining pin to hold tape and a permanent rebar marker.
8. Proceed 5.66 m due east through the plot center with the tape spool, mark the E corner of the plot with a chaining pin and a permanent rebar marker.
9. Use additional tapes or cord to connect the 4 corners of the macroplot (4-m × 4-m plot), keeping tapes as straight as possible. Each side should measure 4 m between adjacent corners. If not, redo steps 3–6 as needed to "square" the plot.
10. Measure along macroplot sides for 1 m from each permanent corner and mark with a survey flag. Mark the fourth corner of microplots at 1.42 m from the permanent macroplot corners along tapes that bisect the macroplot from north (1.42 m on tape 1) to south (4.24 m on tape 1) and from west (1.42 m on tape 2) to east (4.24 m on tape 2). The distance between each adjacent survey flag should be 1 m. If it is not, redo until microplot is square.

11. The plot should now be laid out with one 4-m × 4-m macroplot with four permanent rebar corner markers and one temporary center marker, one 5.66 m transect line running from the west to the east corner, and four 1-m × 1-m microplots located in each corner of the macroplot. The plot should also have one permanent corner marker and three survey flag corner markers each (see fig. 5.1).
12. Place appropriate stamped aluminum caps on each rebar corner.
13. Proceed to **Rocky Mountain National Park Elk-Vegetation Monitoring Program Willow Monitoring Protocol** (Appendix 3), Step 4, and complete information on all four data sheets (*Site Characteristics, Macroplot Data, Line Intercept*, and *Browse Data*).
14. When all data collection is complete, remove measuring tapes, temporary center marker, and temporary survey flags. Double check to be sure that all rebar is pounded flush to the ground before leaving site at end of visit.

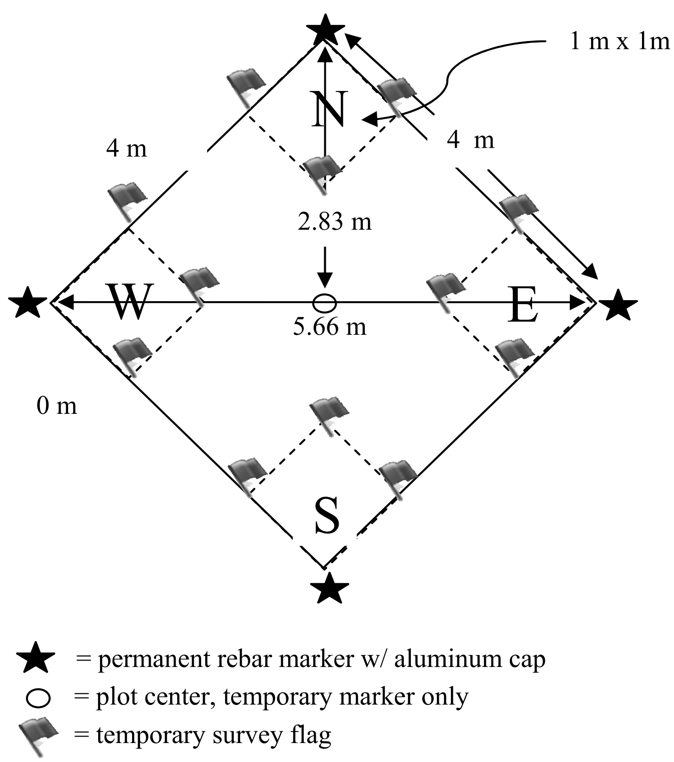


Figure 5.1. Diagram of willow-monitoring plot layout for the Rocky Mountain National Park elk-vegetation monitoring program.

Appendix 6: Rocky Mountain National Park Elk-Vegetation Monitoring Program Upland Herbaceous Site-Establishment Protocol

The following steps outline the process of establishing upland herbaceous monitoring sites that are part of the RMNP elk-vegetation monitoring program. **Boldface** type indicates the name of an associated monitoring protocol. *Italic* type indicates the name of datasheet to be filled out. Plot establishment should be conducted during summer, preferably when the majority of annual growth has already occurred and before elk begin browsing to any great extent in the fall. Nothing should be removed from any site except for approved plant samples listed on the research permit.

1. Using a GIS program, randomly select potential sites from available upland areas. Site locations should be in NAD83 projection. Areas delineated as Herbaceous Upland Montane (MU4), Shrub-Upland-Lower Montane-Bitterbrush (MU142), Shrub-Upland-Lower Montane-Undifferentiated (MU14), Shrub-Upland-Big Sagebrush (MU141), Ponderosa Pine-Graminoid (MU34), Ponderosa Pine-Rockland (MU35), and Ponderosa Pine-Shrubland (MU36) on the Rocky Mountain National Park Vegetation Map are eligible for consideration as upland-monitoring sites. All intended sample locations should be checked with NPS cultural-resources staff to ensure cultural-resources compliance. A suitable site must be a minimum of 250 m from any other established site to allow ample room for movement of grazing cages without site overlap.
2. Gather equipment and supplies
   - Research permit
   - Radio pack set
   - Protocol, data sheets, pens, clipboard
   - Handheld GPS unit and spare batteries
   - Hammer or mallet (for setting cages in August through September)
   - ½-in diameter rebar marker post, 6-in length (if permitted in future, 12–18-in posts should be used), one per site
   - Compass (check current declination prior to each field season at *http://www.ngdc.noaa.gov*)
   - 5 chaining pins or other stakes for holding down tape measure
   - Aluminum survey marker caps imprinted with " ELK-VEG MONITOR—NPS-DO NOT DISTURB—ROMO STUDY 06013" (one per site)
   - Metal die stamping kit
   - Digital camera
   - Laminated placard (light, not white) with following information:

ROMO EVMP SITE___________ DATE _________ DIRECTION_____

   - dry erase marker
   - wipes or cloth to clean placard
   - 3 grazing cages—these can be any design that is unobtrusive and at least 1 m tall with at least a 1-m area under the cage. Current design uses 39-in ht cattle fencing, three ½-in or

greater diameter rebar posts, and a chicken-wire top. The cattle fencing is cut to enclose a 1-m diameter circle (roughly 3.5 m length of fencing) and then bent into a circle and the fencing ends attached to the rebar posts with shoat rings. Three 1.5 m rebar posts are woven thru the wire and then driven into the ground until the top of the post is flush or below the top profile of the cage. Rebar can be attached to fencing with baling wire, if desired. A piece of chicken wire is then attached to the top with shoat rings, or wire crisscrossed over the top to prevent elk from leaning over the top to graze taller grasses. To prevent elk from nosing up under them, cages may be further staked to the ground using landscape staples or rebar bent into hooks or "u" shape. See figure 6.1 for examples.

Figure 6.1. Photo of grazing cage design currently being used in elk-vegetation monitoring program.

3. Navigate to the site center using GPS and UTM coordinates (NAD83 projection). Be sure to have WAAS enabled on the GPS to increase accuracy (although this will shorten battery life). Evaluate site to determine if it is one of the upland vegetation types listed above and described in the Dichotomous Key to the Plant Associations for Rocky Mountain National Park (Stevens and others, 2005). If the plot center needs to be moved, move the plot 10 m in the cardinal direction that will put it in the upland vegetation type. If a 10 m move does not result in successfully locating a plot center in the target vegetation type, moving an additional 10 m toward the vegetation type may be attempted. If this second attempt at relocation does not succeed in achieving an appropriate plot location, abandon this point and move to another. If the general area does not appear be an upland site (for example, lands in the middle of a lodgepole pine forest or wet meadow) then proceed to another random point and report discrepancies with the park vegetation map to park GIS coordinator. If cultural artifacts or indications of cultural resource issues are identified, discontinue work and contact

park cultural resources staff before proceeding. Do not remove any artifacts or animal, plant, or geologic material unless approved on the research permit for this project.

4. Assign an unused site number to the site based on the following naming convention: UC=Upland Core, UNC=Upland Non-Core + unique id number. Do not re-use numbers of discontinued sites. Stamp the assigned number onto an aluminum marker cap and place cap on rebar marker stake and drive marker stake into the ground until it is flush with the ground surface.
5. Proceed to **Rocky Mountain National Park Elk-Vegetation Monitoring Program—Upland Site Monitoring Protocol**—step 3*, Rocky Mountain National Park Elk-Vegetation Monitoring Program—Upland Site Characterization Data Sheet* (Appendix 1).
6. When all measurements are completed and grazing cages are placed, gather and remove all tape measures and temporary markers before leaving the site. Double check to be sure you have used the GPS to record the location of the site center marker, in case you changed the position from the original site.

Appendix 7: Rocky Mountain National Park Elk-Vegetation Monitoring Program Willow Monitoring Offtake Calculation Protocol

This protocol outlines the procedures for calculating landscape-scale willow browse offtake estimates from raw data collected from individual stems at willow-monitoring sites as part of the Rocky Mountain National Park (RMNP) elk-vegetation monitoring program. The term “offtake” in this document refers to the percentage of the current year’s shoot growth that is removed by browsing ungulates (primarily elk in RMNP).

Two methods of measuring ungulate browsing on willow were incorporated into the willow-monitoring protocols. The “stem-scaled diameter difference method” (also called the DD2 method in Bilyeu and others, 2007) calculates offtake as the difference between diameter at base of current year’s growth and at browse point scaled by the number of shoots browsed on the entire stem (equation 7-1).

$$DD2 = \left(\frac{b}{b+u}\right) \times \left(\frac{D_p - D_t}{D_b - D_t}\right) \tag{7-1}$$

where

b, the number of browsed shoots on the stem;
u, the number of unbrowsed shoots;
D_p, shoot diameter at the point of browsing;
D_t, the average diameter of unbrowsed shoot tips; and
D_b, the diameter at the base of the shoot.

This method of estimating browse levels was used in previous studies in Rocky Mountain National Park, (Singer and Zeigenfuss, 2002) and the thresholds identified in the Elk Vegetation Management Plan (U.S. Department of the Interior, 2007) were based upon these methods.

In recent years, Bilyeu and others (2007) developed a novel method for scaling browse estimates to account for elk preference for larger, more productive shoots. The “production-weighted diameter difference method” (DD3) recommended by Bilyeu and others (2007) accounts for the fact that elk often browse more productive shoots, and the method estimates the percentage of biomass removed based upon shoot size of browsed and unbrowsed shoots (equation 7-2).

$$DD3 = \left(\frac{b \times B}{b \times B + u \times U}\right) \times \left(\frac{D_p - D_t}{D_b - D_t}\right) \tag{7-2}$$

where

B, average pre-browse mass of browsed shoots; and
U, the average mass of unbrowsed shoots.

Variables *B* and *U* are estimated using regression equations which predict mass from diameter at base of shoot and shoot length measures from species-specific samples of unbrowsed shoots collected the previous fall.

Currently, the RMNP Elk-Vegetation Monitoring Plan calls for only measuring browse offtake in spring because the majority of browsing presently occurs over winter, but also recognizes that measurements of summer offtake may be necessary in the future if increasing numbers of elk begin to summer on the current elk winter range on the east side of the park. The steps outlined in this protocol are appropriate for estimating browse offtake in both seasons as long as field measurements are taken at the end of the summer growing season to assess summer browsing.

Before using this protocol, first collect and process willow measurement data as described in steps 8–13 of the **Rocky Mountain National Park Elk-Vegetation Monitoring Program Willow Monitoring Protocol (Appendix 2)**. The following steps should be performed after data has been entered into an appropriate digital spreadsheet or database and quality assurance has been performed to assure the accuracy of data entry. Table 7.1 provides a sample datasheet with example data for the purpose of illustrating the calculation steps described in this protocol.

Table 7.1. Example data for estimating stem-level browse offtake. (N, north; S, south; E, east; W, west; M, middle; mm, millimeters; cm, centimeters; g, grams)

Site ID	Microplot Location (N, S, E, W, M)	Plant ID#	Species Code	Total Stem Count	Stem ID Letter	Shoot Ratio	Addtional shoot (check if yes)	Measured shoot browsed (B) or unbrowsed (U)?	Diameter at base of shoot (mm)	Diameter at tip of shoot (mm)	Shoot length (cm)	Estimated shoot weight (g)
WC13	E	1	SAMO	26	A	3	.	U	1.3	0.8	3.5	0.036159
WC13	E	1	SAMO	26	A	3	.	U	2.0	.9	7	0.191284
WC13	E	1	SAMO	26	A	3	.	B	1.1	.5	2.5	0.014286
WC13	E	1	SAMO	26	A	3	.	U	1.0	.5	6	0.019771
WC13	E	1	SAMO	26	A	3	.	U	1.5	.5	7.5	0.091861
WC13	E	1	SAMO	26	A	3	.	U	1.0	.5	4.5	0.014271
WC13	E	1	SAMO	26	A	3	.	U	1.3	1.0	6	0.050807
WC13	E	1	SAMO	26	A	3	.	U	1.2	.8	5.5	0.036134
WC13	E	1	SAMO	26	A	3	.	U	1.0	.8	3.5	0.011101
WC13	E	1	SAMO	26	A	3	.	U	2.1	1.2	10.0	0.257988
WC13	E	1	SAMO	26	A	3	.	B	2.0	1.5	13.5	0.279852
WC13	E	1	SAMO	26	B	3	.	U	2.2	.7	17.5	0.412087
WC13	E	1	SAMO	26	B	3	.	U	2.3	1.0	17.0	0.439775
WC13	E	1	SAMO	26	B	3	.	U	1.8	1.1	13.0	0.216625
WC13	E	1	SAMO	26	B	3	.	B	1.9	1.2	6.5	0.161640
WC13	E	1	SAMO	26	B	3	X	U	2.8	1.0	29.0	0.948053
WC13	E	1	SAMO	26	C	3	.	U	1.8	1.1	7.5	0.150451
WC13	E	1	SAMO	26	C	3	.	U	3.5	.7	35.5	1.595636
WC13	E	1	SAMO	26	C	3	X	B	3.8	3.0	17.0	1.181852
WC13	E	1	SAMO	26	D	3	.	B	2.8	2.8	0	0.318976
WC13	E	1	SAMO	26	D	3	.	U	2.0	1.8	11.5	0.250811
WC13	E	1	SAMO	26	D	3	.	U	1.4	0.7	5.5	0.060821
WC13	E	1	SAMO	26	D	3	.	B	2.0	1.3	8.5	0.210231
WC13	E	1	SAMO	26	D	3	X	U	2.4	.8	18.0	0.497758

1. The finest level of data acquired is from shoot-level measurements. These are the measures described in step 8 of the **Rocky Mountain National Park Elk-Vegetation Monitoring Program Willow Monitoring Protocol (Appendix 2)**. Total browsed and unbrowsed shoot counts are calculated for each stem by multiplying the shoot ratio for the stem by the sum count of all the measured browsed and unbrowsed shoots respectively on an individual stem of a plant with the exception of those marked as additional shoots. An individual stem is identified in table 7.1 by the columns headed *site #*, *microplot location*, *plant ID #*, and *stem ID letter* (for example, WC13-E-1-A is an individual stem). The group [browsed (*B*) or unbrowsed (*U*)] that the individual shoot belongs to is identified in the data sheet in the column, *Measured shoot browsed (B) or unbrowsed(U)?*(table 7.1). After tallying those shoots any additional shoots which were measured for each browse category (browsed and unbrowsed) are added as single count shoots. After calculating the stem-level browsed and unbrowsed total shoot counts, these two totals can be summed to calculate a total stem shoot count.

   Using the example data in table 7.1, plant #1 at site WC13-E had 4 sampled stems (A, B, C, and D). Stem A was sampled using a shoot ratio of three (every third shoot on the stem was measured). Eleven shoot diameter and length measurements were collected. Nine of these measurements were from unbrowsed shoots and none of these were marked as additional shoots. Therefore we applied the shoot ratio of three to the nine sampled shoots to determine the total number of unbrowsed shoots on the stem (9×3=27). Measurements were collected from two browsed shoots and none of these were marked as additional shoots, so the shoot ratio of three is applied to these two browsed samples to determine total number of browsed shoots (2×3=6). Total shoot count for this stem is the sum of unbrowsed plus browsed shoots (27+6) for a total of 33 shoots per stem.

   Stem B had three unbrowsed shoots sampled using a shoot ratio of 3 (3×3=9), plus one unbrowsed shoot that was marked an additional shoot (meaning there was not a total number of shoots on the stem that was divisible by the shoot ratio of three and that an additional shoot had to be sampled). This additional shoot is added to the unbrowsed shoot count of nine unbrowsed shoots for a total of ten unbrowsed shoots (9+1=10). There was one measured browsed shoot with a shoot ratio of three for a total of three browsed shoots (1×3=3). The total shoot count is 10+3=13.

   For stem C, there were two unbrowsed shoot measurements with a shoot ratio of three (2×3=6) with no additional unbrowsed shoots. There was one additional shoot measurement (which was a browsed shoot) for a total browsed shoot count of one. Total shoot count is 6+1=7.

   For stem D, two unbrowsed shoots were sampled using a shoot ratio of three (2×3=6) plus one additional unbrowsed shoot for a total of seven unbrowsed shoots (6+1=7). There were two browsed shoots sampled with a shoot ratio of three for total of six browsed shoots (2x3=6). Total number of shoots is 6+7=13.

2. Calculate percent of shoots browsed (also called percent leader use).
   a. Calculate percent of shoots browsed per stem. This is simply the number of browsed shoots (b) divided by the total shoot count ($b+u$) and then converted to a percentage (equation 7-3).

$$\%\_browsed\_shoots = \left(\frac{b}{b+u}\right) \times (100) \tag{7-3}$$

   Using example data from table 7.1, the percent browsed shoots
   for stem A is (6/33)×100=18.2%;
   for stem B is (3/13) ×100=23.1%;
   for stem C is (1/7) ×100=14.3%; and
   for stem D is (6/13)×100=46.2%.

   b. Calculate percent of shoots browsed per site. This is the average percent browsed shoots for all stems measured at a site.

   Using the example data: (18.2%+23.1%+14.3%+46.2%)/4=25.4 %.

   Species-specific percent browsed shoots can also be calculated at this point, if desired, by averaging across all measured stems of each species at a site. This might be of interest if needed to verify whether observed declines of one species of willow might be linked to browsing preference for that willow species.

3. Calculate the average proportion of shoot consumed per stem. Knowing the average diameter of unbrowsed shoot tips is necessary to determine the proportion of an individual shoot consumed. This average tip diameter is then used to determine the proportion of a shoot consumed (DD1) for all browse shoot measurements on a stem using equation 7-4,

$$DD1_{stem} = \left(\frac{D_p - D_t}{D_b - D_t}\right) \tag{7-4}$$

where
D_p, shoot diameter at the point of browsing;
D_t, the average diameter of unbrowsed shoot tips; and
D_b, the diameter at the base of the shoot.

There are some cases where no unbrowsed shoots were measured on an individual stem and thus an average unbrowsed tip diameter (D_t) for the stem cannot be calculated. In this case, an average unbrowsed tip diameter for all the stems of a particular species within a site is calculated (D_{tsite}) and then substituted for D_t. If there were no unbrowsed shoots of a species found within an individual site, then an average unbrowsed shoot tip can be calculated from all shoot measurements of that species (D_{tsp}) that were collected from other willow-monitoring sites measured within the same year and this average is substituted for D_t. In these cases the calculation for DD1stem becomes:

$$DD1_{stem} = \left(\frac{D_p - D_{tsite}}{D_b - D_{tsite}}\right) \text{ and } DD1_{stem} = \left(\frac{D_p - D_{tsp}}{D_b - D_{tsp}}\right) \text{ respectively.}$$

where

D_p; shoot diameter at the point of browsing;
D_{tsite}; the average diameter of unbrowsed shoot tips for a particular species within a site;
D_{tsp}; the average diameter of all unbrowsed shoot tips for a particular species; and
D_b; the diameter at the base of the shoot.

In some cases, the measured diameter at point of browsing (D_p) is smaller than the average diameter of unbrowsed shoot tips (D_t)—this results in a negative proportion of shoot consumed and thus underestimates offtake. If D_{tsite} or D_{tsp} are smaller than D_p, these estimates should be used to replace D_t. In a similar manner, proportions greater than 1 (cases where the diameter at point of browsing is larger than the shoot basal diameter) are converted to 1 since the current year's growth can be no more than 100 percent browsed (proportion of 1).

For the example data,

Stem A: D_t=0.78
Stem B: D_t =0.95
Stem C: D_t =0.9
Stem D: D_t =1.1
D_{tsite}=(0.78+0.95+0.9+1.1)/4=0.93
D_{tsp}=1.0 (calculated using data not found in example)

Stem A has 2 browsed shoots and $DD1_{shoot}$=(0.5-0.78/2-0.78) and (1.5-0.78/2.0-0.78)=(-0.23 and 0.59). Substitution with D_{tsite} and D_{tsp} still results in a negative proportion removed, so the first $DD1_{shoot}$ estimate for this stem is deleted from the data set and the remaining shoot measure is used, thus $DD1_{stemA}$=0.59.

Stem B has 1 browsed shoot and $DD1_{stemB}$=(1.2-0.95/1.9-0.95)=0.26

Stem C has 1 browsed shoot and $DD1_{stemC}$=(3.0-0.9/3.8-0.9)=0.72

Stem D has 2 browsed shoots and $DD1_{stemD}$=(2.8-1.1/2.8-1.1) and (1.3-1.1/2.0-1.1) or (1.0 +0.22)/2=0.61

4. Calculate DD2 offtake for each stem. The DD2 offtake method (Bilyeu and others, 2007) calculates offtake at the stem level by multiplying percent of shoots browsed per stem by average proportion of shoot removed (equation 7-5).

$$DD2_{stem} = \left(100 \times \frac{b}{b+u}\right) \times DD1_{stem} \qquad (7\text{-}5)$$

For the example data:

$DD2_{stemA}$=18.2%×0.59=10.7%
$DD2_{stemB}$=23.1%×0.26=6.0%
$DD2_{stemC}$=14.3%×0.72=10.3%
$DD2_{stemD}$=46.2%×0.61=28.2%

5. Calculate $DD2_{site}$ by averaging all $DD2_{stem}$ measures. Using the example data yields:

   (10.7+6.0+10.3+28.2)/4=13.8%.

6. Determine shoot mass regressions as first step to estimating DD3 offtake. Products of some steps of the DD2 calculation are used in calculation of DD3 offtake estimate. The DD3 offtake estimate accounts for the preferential browsing of larger shoots by elk and scales the offtake estimate accordingly. This preference was demonstrated by Bilyeu and others (2007) and was also found using the Rocky Mountain National Park Elk Vegetation Monitoring Program baseline data (see “Baseline Condition—Willow,” p. 28). Unbrowsed shoots of a variety of sizes from each species must be collected each year in the late summer/fall (when more unbrowsed shoots are readily available) in order to build regressions for determining shoot mass based upon shoot basal diameter and length. The shoot size and weight information collected in **Rocky Mountain National Park Elk-Vegetation Monitoring Program Willow Monitoring Protocol (Appendix 2, step 12)** is necessary to continue with the DD3 calculation. Shoot weights without leaves should be used in creating regression equations. Shoots collected for developing the regressions apply to offtake measures taken in spring of the following year (for example, shoots collected in fall 2009 are used to calculate DD3 for spring 2010). If summer offtake will be calculated, shoots collected in fall of the year are applied to shoot measurements taken at the end of summer of the same year (for example, shoots collected in fall 2009 are used to calculate summer DD3 for summer 2009).

   Several regression models used to estimate shoot weight from shoot basal diameter and length for each willow species were assessed using the baseline data and data collected in 2010. Comparisons between regression lines showed interannual differences, so data should be collected on a year-by-year basis whenever possible.

   Shoot mass regressions relating the square root of mass to shoot basal diameter and shoot length were found to provide the best relationship (equation 7.6; r^2 (the coefficient of determination) range from 0.83–0.98 with the majority greater than 0.95). R^2 improved when regressions were individually fit to the seven main locations (Beaver Meadows, Cow Creek, Horseshoe Park [including Endovalley], Hidden Valley, Hallowell Park, Moraine Park, and Kawuneechee Valley) where monitoring sites were located. However, this resulted in minimal change in the final values for DD3 for the entire winter range and for core and non-core winter ranges individually. Therefore, while it is recommended to gather shoot samples for building regressions across all locations, samples can be pooled across locations for each species regression. This pooled regression takes the form:

$$\sqrt{shoot\ mass} = \beta_0 + (\beta_1 \times\ basal\ shoot\ diameter) + (\beta_2 \times\ shoot\ length) \qquad (7\text{-}6)$$

7. Using the appropriate regression equation with species-specific y-intercept (β_0) and coefficients (β_1 and β_2), estimate the pre-browse shoot weight for each measured shoot. Then average the pre-browse shoot weights to get a mean pre-browse shoot weight for both browsed (B_{stem}) and unbrowsed (U_{stem}) shoots for each stem.

   Using the data from *Salix monticola* (SAMO) shoots collected in the area near site WC13, the following equation was developed with β_0, β_1, β_2 terms.

   $$\sqrt{shoot\ mass} = -0.22664 + (0.28265 \times basal\ shoot\ diameter) + (0.01410 \times shoot\ length)$$

   When applied to the data in table 7.1 this regression equation yields the estimated shoot weights listed in the final column of the table 7.1. If these shoot weights are averaged, we get the following mean browsed and unbrowsed shoot weights for each stem.

   B_{stemA}=0.147 g U_{stemA}=0.079 g
   B_{stemB}=0.162 g U_{stemB}=0.504 g
   B_{stemC}=1.182 g U_{stemC}=0.873 g
   B_{stemD}=0.265 g U_{stemD}=0.270 g

8. Calculate $DD3_{stem}$. Total shoot counts estimated in step 2 of this protocol and the $DD1_{stem}$ estimates from step 5 of this protocol are used to calculate $DD3_{stem}$ following equation 7-7.

   $$DD3_{stem} = \left(100 \times \left(\frac{b_{stem} \times B_{stem}}{b_{stem} \times B_{stem} + u_{stem} \times U_{stem}}\right)\right) \times DD1_{stem} \qquad (7\text{-}7)$$

   Using the example data this yields:

   $$DD3_{stemA} = \left(100 \times \left(\frac{6 \times 0.147}{(6 \times 0.147) + (27 \times 0.079)}\right)\right) \times 0.59 = 17.3\%$$

   $$DD3_{stemB} = \left(100 \times \left(\frac{3 \times 0.162}{(3 \times 0.162) + (10 \times 0.504)}\right)\right) \times 0.26 = 2.3\%$$

   $$DD3_{stemC} = \left(100 \times \left(\frac{1 \times 1.182}{(1 \times 1.182) + (6 \times 0.873)}\right)\right) \times 0.72 = 13.3\%$$

   $$DD3_{stemD} = \left(100 \times \left(\frac{6 \times 0.265}{(6 \times 0.265) + (7 \times 0.270)}\right)\right) \times 0.61 = 27.9\%$$

9. Calculate $DD3_{site}$ by averaging all stems in a site:

   $DD3_{site}$=(17.3% + 2.3% + 13.3% + 27.9%)/4=15.2%

10. Calculate $DD2_{site}$ and $DD3_{site}$ for all sites in the core and all sites in the non-core winter range to get $DD2_{core}$, $DD2_{non\text{-}core}$, $DD3_{core}$, and $DD3_{non\text{-}core}$ estimates. These estimates can be compared to determine whether significant differences between core and non-core willow winter range willow offtake exists.

11. Calculate $DD2_{winter\_range}$ and $DD3_{winter\_range}$. A weighted average for the entire winter range is calculated for each offtake method. At the outset of the study, weighting was based on the percentage of willow area falling within core and non-core winter range. At the outset of the monitoring, the 87.2 percent of the entire elk winter range willow area was located on the core winter range and the non-core winter range contained the remaining 12.8 percent of all winter range willow.

Publishing support provided by:
Denver Publishing Service Center

For more information concerning this publication, contact:
Center Director, USGS Fort Collins Science Center
2150 Centre Ave., Bldg. C
Fort Collins, CO 80526-8118
(970) 226-9398

Or visit the Fort Collins Science Center Web site at:
http://www.fort.usgs.gov/