2009

2009 Report : A Multi-Refuge Program to Evaluate the Effect of Ungulate Browsing on Habitat

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Introduction

Big game exclosures document that ungulates can alter habitat. These changes could be viewed in three ways. We could accept whatever happens without making a value judgment. This management strategy is sometimes referred to as “natural regulation.” Alternatively we could manage for the kind of habitat that can sustain maximum, healthy ungulate populations. Or, we could manage for the kind of habitat that can sustain other kinds of wildlife such as nesting birds. The habitat characteristics that results from the three alternatives can be markedly different.

This report describes the evaluation of ungulate browsing at six wildlife refuges in FWS Region 6 in 2009. The aim of evaluation was to determine if ungulate browsing occurred at an acceptable level, or not. Developing an objective means of making that distinction was part of the process. While evaluation was our focus, the report incorporates evaluation into a more comprehensive program of adaptive ungulate management. The intent is to illustrate how this could be done, and does not imply that such a program was implemented at the respective refuges. Given the brief amount of time spent at each refuge, the evaluations should be viewed as an indication of what would likely be found if more-intensive efforts were made. In addition, the report is intended to serve as a how-to guide for biologists wishing to independently develop adaptive management programs.

We based our evaluation on the attainment of a refuge management goal, and focused on the habitat required by birds that nest in trees and tall shrubs. The birds using that habitat ranged from the common yellow warbler to the endangered southwestern willow flycatcher. With respect to nesting birds, the goal is to fledge healthy young that can successfully migrate to their winter territory. While the birds are at the refuge, this involves the selection of nesting territory, pairing and nest building, egg laying, fledging, and development of young birds to a condition suitable for migration southward. The completion of these activities is dependent on habitat structure, with “structure” collectively referring to plant species composition, plant height, and stem density. Different species of birds prefer or require different habitat structures. If our management goal is to provide breeding habitat for one or more species of migratory birds, we must provide the appropriate habitat structure if we are to be successful.

Many other factors also influence habitat condition including plant succession, fire, disease, frost-kill, and changes in stream hydrology. This report focuses on detecting changes in habitat that are primarily caused by ungulate browsing.

The program has implications at both the refuge and regional levels. At the refuge level, the primary objective was to identify, at specific locations, changes that were primarily caused by ungulate browsing. With respect to attaining management goals, is habitat at that location relatively stable and acceptable, declining, or improving? If habitat is in a state of change, we estimated what the future habitat might look like. In some cases we identified factors that act in combination with browsing, factors that may exacerbate the rate of decline or retard (or prohibit) improvement in habitat condition. At the refuge level, emphasis was on habitat condition at given areas with respect to attaining the refuge's management goals.

At the regional level there is interest in the condition and management of individual refuges. But with the responsibility for allocating resources region-wide, there is also an interest in the management of the collection of habitats within the region. The region-wide comparison of individual areas is complicated by the fact that they differ in management goals, habitat structure, history of ungulate browsing, and history of the effects of that browsing. We provide a uniform context for comparing habitat conditions by classifying sites at each refuge into one of six stages of structural change, each stage having implications for the attainment of management goals. Because the stages are independent of plant species, the extent of change can be qualitatively compared across refuges. We also describe three factors that influence the rate of change from one stage to another. When paired with region-wide priorities of management goals, the classification may provide guidance for prioritizing management activities within the region.

At the level of the individual refuge, the process described in this report can be incorporated into a program of adaptive ungulate management that includes four components:

- **Management Goal:** Goals provide the basis for specifying a measurable management objective and a foundation for adaptive ungulate management. The management goal in this case: Provide habitat for birds that nest in trees and tall shrubs.

- **Management Objective:** Measureable management objectives provide the basis for evaluation. At each site being evaluated, we specified stem density and height characteristics suitable for attaining the management goal.

- **Evaluation:** Evaluation is the process of determining if the management objective is being attained. We determined if ungulate browsing would prevent the development of the target stem density and height characteristics specified by the management objective.

- **Ungulate Management:** These are the management actions necessary to attain the management objective. In this case, develop strategies to regulate the presence of ungulates to a level consistent with attaining the management goal of providing nesting habitat. This report does not address ungulate management issues.

The chapters in this report consist of the following:

- **Overview.** This chapter sets the stage with a simple description of key processes that produce habitat, a process that could be summarized as: Young plants grow to full height. It then describes three premises that were the foundation of our evaluations.

- **Concepts and Methods.** This is a detailed description of the concepts and methods that were used. They are presented in the form of eleven concepts, five of which are qualitative, six of which are quantitative.

- **Browse Evaluation as a Part of Adaptive Ungulate Management.** This chapter serves two purposes, the first being to incorporate browse evaluation as part of adaptive ungulate management. The second is to describe the sequence of activities a biologist would undertake in developing a program.

- **Introduction to the Refuge Chapters.** This chapter describes the general sequence of events that occurred at each refuge.

- **The refuge chapters.** These chapters serve two functions. First, they describe the effect of browsing at given locations in the respective refuges, and in some cases describe additional data that were collected. Second, the chapters provide different examples of browse evaluation.

- **Stages of Structural Trend.** Structural trend is classified into six stages: Stable, Early Stage of Structural Decline, Intermediate Stage of Structural Decline, Advanced Stage Structural Decline, Recovery of Structural Diversity, and Structure is Lost. Three factors influence the rate at which structure changes from one stage to another: Susceptibility, Resistance, and Resilience.

- **Refinement of Management Objectives.** Evaluation cannot occur without specifying a measureable habitat attribute, the management objective. In 2009, evaluation was based on rough quantitative estimates of stem density in a single height class: stems taller than 2.5 m. Improving our ability to specify desired habitat conditions will enhance our ability to evaluate the effect of ungulate browsing, and to successfully attain the management goal of providing nesting habitat. This chapter discusses how those refinements fit into the adaptive management process.

- **Appendix: Common and Scientific Names.** For ease of reading, common names are used throughout the report. The corresponding scientific names are described in this appendix.

- **Appendix: Datasheets: Landscape Level Survey, Measurement of Existing Conditions, and Existing Browsing Pressure.**

Overview of Approach

Aspen stands are important habitat for a variety of songbirds. Consider a hypothetical stand composed of aspens of various heights and ages. The diversity of heights produces multiple levels of foliage that provide nesting sites and feeding areas for a variety of birds. The trunks of older individuals provide additional feeding areas and nest sites for cavity nesters.

The stand is dynamic. Young trees grow taller and older trees die. If the structure is to be maintained, young trees must grow to full height to replace older trees that die. For a variety of reasons, age classes are likely not uniformly represented, so over time, gaps in age classes will likely affect the structure of the stand. Fire can cause a major gap in age classes by killing all above-ground stems.

Immediately after fire, the structure of the area (tall dead stems and short live suckers) will likely appeal to a different suite of bird species compared to that present before the fire. The pre-fire structure will not exist again until young aspens have grown to an appropriate range of heights. In this hypothetical example, assume that ungulates had no effect on the growth of young aspen. Decades after the fire, the stand will likely differ from the stand that was burned, with that difference being determined by the number of suckers that grew to full height. The resulting structure may or may not appeal to the suite of birds present before the fire. Because these differences (in structure and nesting populations) were not caused by ungulate browsing, they are not the subject of this report.

Ungulate browsing can prevent young plants from growing to full height. If, after the fire, all young aspen suckers were prevented by browsing from growing to full height, the aspen stand would be converted to a meadow-like condition. In this case, ungulate browsing would be the primary cause for the change in structure from a stand of trees to a meadow. If ungulate browsing prevents some—but not all—suckers from growing to full size, the result could be a stand of aspen trees, but one with a structure that is different compared to the structure that would be present in the absence of browsing.

At this point we emphasize that ungulate browsing is a natural phenomenon. We expect that our aspen stand will be browsed. Our task is to determine the point at which browsing alters structure to the point that management goals can no longer be attained.

Our approach to browse evaluation was based on three premises:

1: The structure of woody plant communities (species composition, stem density, stem height) is a critical factor in attaining the management goal of providing habitat for birds for birds that nest in trees and tall shrubs.

2: By preventing the height growth of young plants, ungulates can influence the structure of plant communities.

3: Ungulate browsing will be deemed excessive if browsing prevents the attainment of the management goal by its influence on plant community structure.

Premise 3 is a part of evaluation in that we specify how the data will be interpreted. The remaining part of the evaluation process is the collection and analysis of the required data. The objective distinction between an adverse effect (excessive browsing) and a benign effect is a critical aspect of evaluation. For that reason, we present an overview of the process at an early stage of the report.

The effect of browsing on structure is based on browsing pressure, a term that is often used loosely. For example, at a site with obvious ungulate impacts one might say, "The browsing pressure is high."

We use the term more precisely by defining Browsing Pressure to be the percent of plants that browsing prevents from growing through the browse zone. There are two types of browsing pressure: Existing Browsing Pressure and Threshold Browsing Pressure.

To measure the Existing Browsing Pressure we examine 20 plants that are between 50 and 150 cm tall (we measure to the base of current-year-growth). Using procedures described in the Concept and Methods chapter, we determine if browsing will likely prevent the height growth of any of the sampled plants. At the end of the measurements, we will have a result similar to the following: Browsing will likely prevent 70% of the young plants from growing through the browse zone. This percentage is the Existing Browsing Pressure at the site.

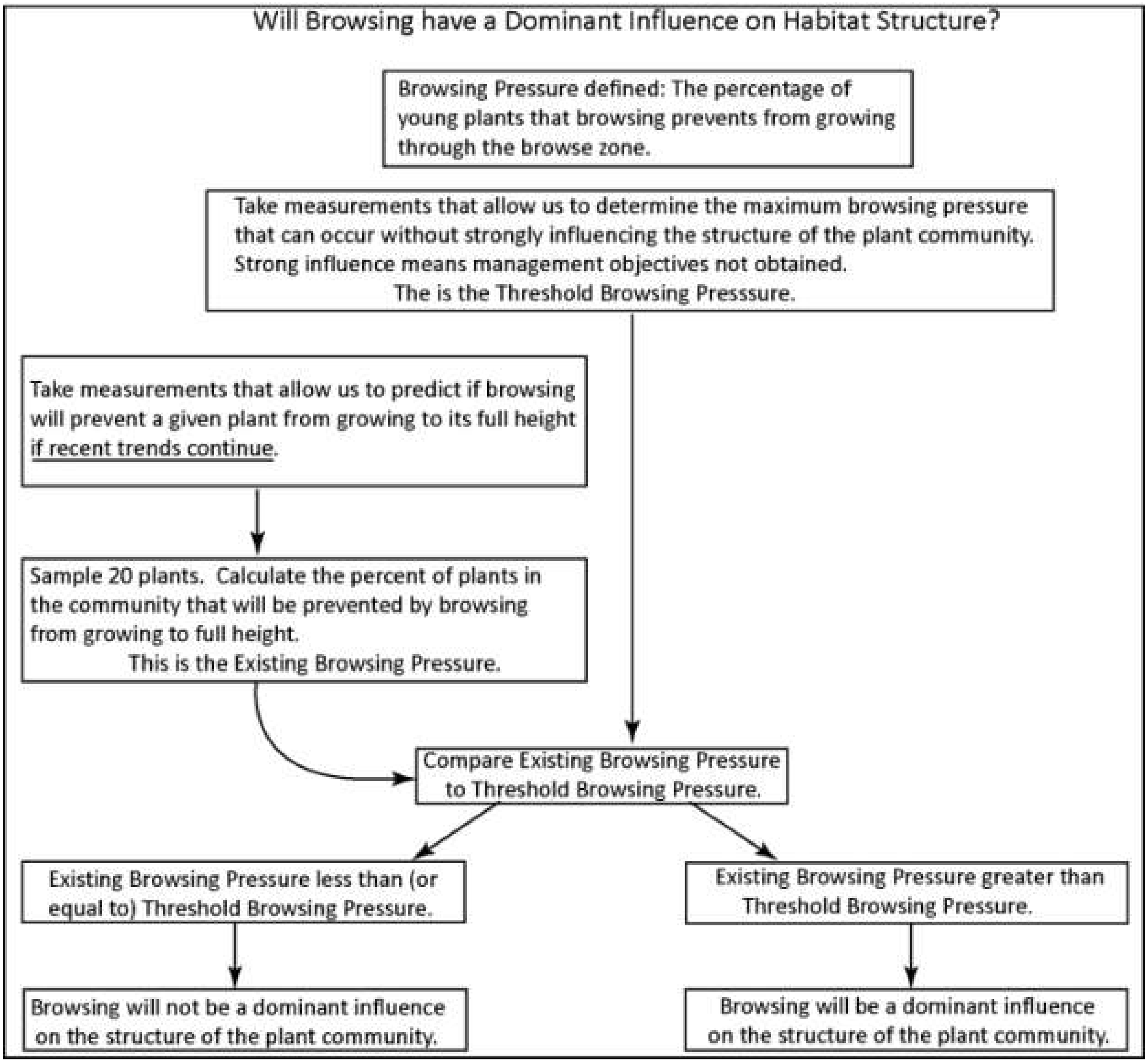
The ecologic significance of an Existing Browsing Pressure of 100% is obvious: if the condition exists long enough, the stand will disappear once the older individuals die. Because browsing would be the dominant influence causing the loss of stand structure, ungulate browsing would be deemed excessive. The ecologic significance of 0 % Existing Browsing Pressure is also obvious: browsing will have no effect.

But the ecologic significance of Existing Browsing Pressures between 1 and 99% is not obvious. A Threshold Browsing Pressure is calculated for each site to determine the point at which ungulate browsing will have an adverse effect on the structure of the community. At this point, we will not describe how Threshold Browsing Pressure is calculated, but a substantial effort is taken to make its calculation as objective as possible.

Evaluation consists of the comparison of the measured Existing Browsing Pressure to the calculated Threshold Browsing Pressure. If the Existing Browsing Pressure is less than (or equal to) the Threshold Browsing Pressure, ungulate browsing is not predicted to be a dominant influence on stand structure. If the Existing Browsing Pressure is greater than the Threshold Browsing Pressure, ungulate browsing is predicted to be a dominant influence on stand structure with respect to attaining management objectives. This comparison constitutes browse evaluation. The process is diagramed below.

A caveat: the data that are collected reflect how browsing affected the height growth of plants at a site in the recent past. Based on those data, we predict how browsing will likely affect the structure of the plant community in the future. The accuracy of this prediction is influenced by the extent to which those recent trends continue into the future.

Many factors can cause changes in trend. Ungulate populations can increase or decrease, climate and weather events can alter ungulate distribution, disease and climate can affect a plant's response to browsing. Adaptive management should be a repetitive process aimed at detecting changes in trends. We also acknowledge that predicting the future effect of ungulate browsing involves a degree of uncertainty. By repetition we can detect error and refine the accuracy of our predictions.



Browse zone

Throughout this report we refer to the "browse zone." This is the height-range within which ungulates browse. Several factors influence its upper and lower limits.

At the lower limit, three factors are important, two of which are related: 1) The time of year in which the stem is nipped, and 2) The height to which the stem had grown at the time the nipping occurred. Slow growing plants nipped early in the year will be browsed close to the ground, fast-growing plants nipped late in the year will be browsed at a greater height. Typical lower browse zone heights related to these factors ranges from 5 to 50 cm, and occasionally to as high as 75 cm.

The third factor influencing the lower limit is depth of snow at the time of browsing. For cattle, deer, and elk snow produces a lower limit that ranges from 20 to 50 cm. Because moose are better suited to occupy areas with deeper snow, the lower limit of their browse zone during mid-winter can range to about 1 m.

The upper limit of the browse zone is about 1.5 m for cattle and deer, and 2.5 m for elk and moose. While both elk and moose can reach higher than 2.5 m, they tend to browse at lower heights.

Species appropriate for evaluation

The use of the methods is limited to species that, under light browsing, are capable of growing through—or well into—the browse zone (1.5 to 2.5 meters high depending on the ungulate species that are present). Browsing often prevents such plants from growing taller than 20 to 50 cm, a height that is substantially different from their potential full height. Suitable species include many willows, aspen, cottonwood, and chokecherry. The methods are not appropriate for low-growing species such as sagebrush or bitterbrush.

The methods also require the use of bud scars to determine the effect of browsing on a complete annual increment of a stem. This excludes species having naked buds such as silver buffaloberry.

Concepts and Methods

In this multi-refuge program we were interested in the condition of browse plants that grew across a thousand acres or more. Assessing the condition of those plants occurred in two phases. The first was a **Landscape Level Survey** in which a broad area was rapidly traversed. After the Landscape Level Survey was completed, two sites were identified for more detailed examination. This more-detailed examination is referred to as **Monitoring**.

Eleven concepts were used: six are qualitative, five are quantitative. The Landscape Level Survey is based on qualitative concepts.

The quantitative concepts are used in monitoring to make predictions based on recent trends. More specifically, the objective of Monitoring is to predict if browsing likely will—or will not—have a dominant influence on stand structure. One qualitative concept (Browsing Level) is also used in monitoring.

The Qualitative Concepts

Concept 1: Preference (or Sensitivity) Gradient.

Ungulates prefer some browse species more than others. For example, Bebb willow, Geyer willow, alder, and spruce form a preference gradient that runs from highly-preferred to least-preferred. When browsing increases, the more-highly-preferred species are heavily consumed before less-preferred species. If the increase occurred in a community that contained the above species, Bebb willow would be first to be heavily used. At this point, Geyer willow might be lightly used; alder and spruce might not be used at all. A continued increase in browsing would cause heavy use of Geyer willow, with alder and spruce lightly used. Alder would be next, and finally spruce. We infer the existence of this preference gradient because we can find examples of the combinations described above.

In the above discussion, one species was assumed to be more highly preferred than another. However, it could be that an apparent difference in consumption is actually caused by differences in the ability of the plant to cope with browsing: both species may have been consumed equally, but one species being less able to recover from that consumption. In either case, browsing threatens the well-being of one species to a greater extent than the other, and the apparent difference in impact forms a gradient that can be used to assess browse condition.

Concept 2: Indicator Species. What species should we monitor?

A given plant community will likely contain several browse species, and often it would not be feasible to measure the effect of browsing on each. Fortunately a single, or relatively few, species can be used to describe the approximate effect of browsing on all other browse species. Four criteria guide the selection of indicator species: height, presence of bud scars, abundance, and preference. The plants must be capable of growing through—or well into the browse zone; the plants must produce bud scars that distinguish current-year-growth from growth that which occurred in previous years; the plants must be widely distributed across the area of interest.

By selecting an appropriate indicator species, we can accomplish the following. First, if we select a highly preferred species such as Bebb willow, and find its condition to be acceptable with respect to browsing, we can assume that the condition of all other species is acceptable. We will have documented that current browsing did not have a dominant effect on habitat structure. Second, we could use Bebb willow to document the earliest stage of habitat decline. Third, if habitat quality is in further decline, we can measure the magnitude of that decline by determining which species are heavily used and which are not. Are we at a midpoint of the browsing preference continuum where Geyer willow, but not alder is heavily browsed? Finally, we can document changes in habitat condition that occur due to management action. Species at the beginning stages of heavy use will also be most sensitive to changes in browsing pressure. For example, if alder is heavily browsed (but not spruce), we can expect a reduction in browsing pressure to be reflected by the growth of alder before we see a response in Geyer willow.

Concept 3: Indicator Sites. Where should we monitor?

In topographically diverse areas, some sites are more available to ungulates than others. Wind can influence the location of snowdrifts. Slope aspect can influence the rate of snowmelt. Ungulate behavior (migration, protective cover) can also influence use. Whether due to topography or behavior, some sites may be more heavily used than others. As in the case of indicator species, if we determine that browse conditions are acceptable at areas of heaviest use, we can assume that browse conditions are likely acceptable in areas that are less heavily used. If our aim is to assess browse conditions at the landscape level, we will attempt to monitor those parts of the landscape that are most exposed to browsing. These are indicator sites.

Concept 4: Potential Stature. How tall should a tree or shrub grow?

Potential stature is a concept used to distinguish the effect of browsing from other factors that may influence height growth. The concept allows us to deal with situations where, for reasons unrelated to browsing, plants do not grow to their expected height. In the absence of browsing, the mature individuals of a plant community grow to a stature that is determined by local conditions including climate, soil, slope, aspect, disease, and insect herbivory. We include in this list everything but browsing. We could refer to this height as “the potential stature in the absence of browsing at this local site,” or more simply as “potential stature.”

In a section below we describe a criterion that marks the prevention of height growth by browsing. (A plant will have a measured LD Index that is less than a threshold value.) If that criterion is met, the plant is deemed unlikely to grow to potential stature. Otherwise, the plant is deemed likely to grow to potential stature. We do not need to know the actual potential height in meters.

The concept of potential stature allows us to deal with situations where unfavorable environmental or physiologic conditions limit height growth. As long as the above mentioned criterion is not met, the plant is assumed to be growing to its potential stature even though unfavorable conditions prevent it from growing out of the browse zone. For example, an unbrowsed aspen sucker that dies from shading is presumed to have grown to its potential stature. An unbrowsed willow that has been topkilled by frost is presumed to be growing to its potential stature.

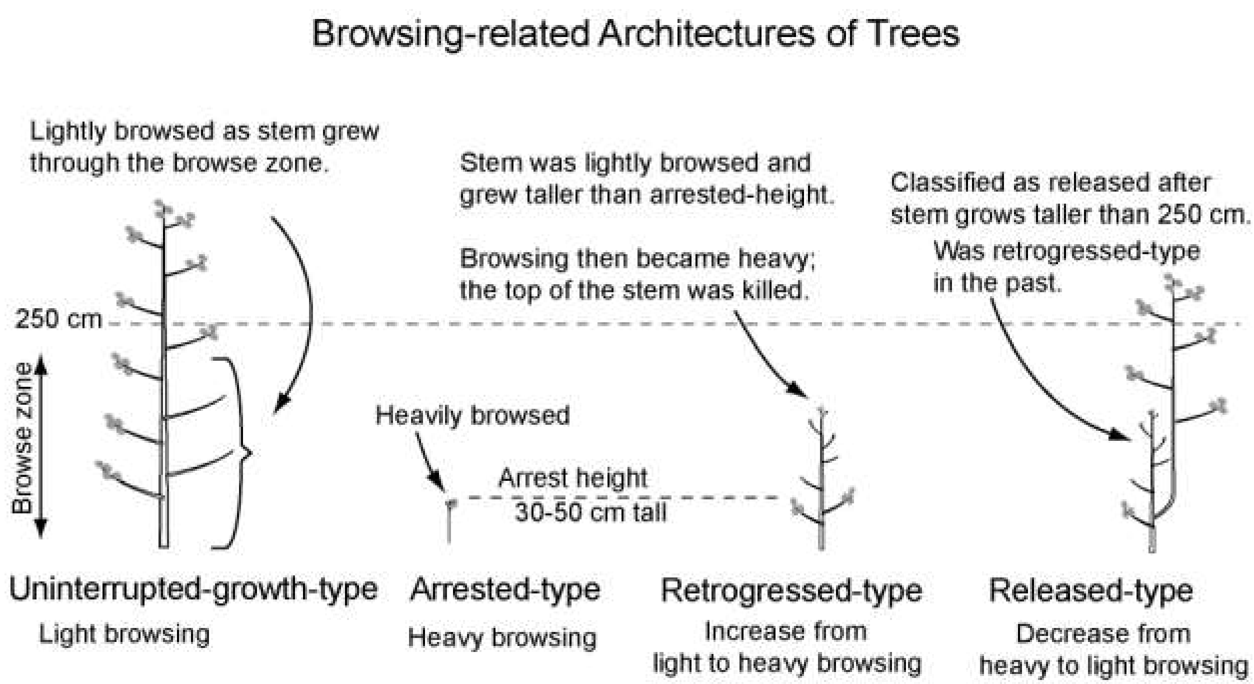
Concept 5: Browsing–related architectures: Ungulate topiary.

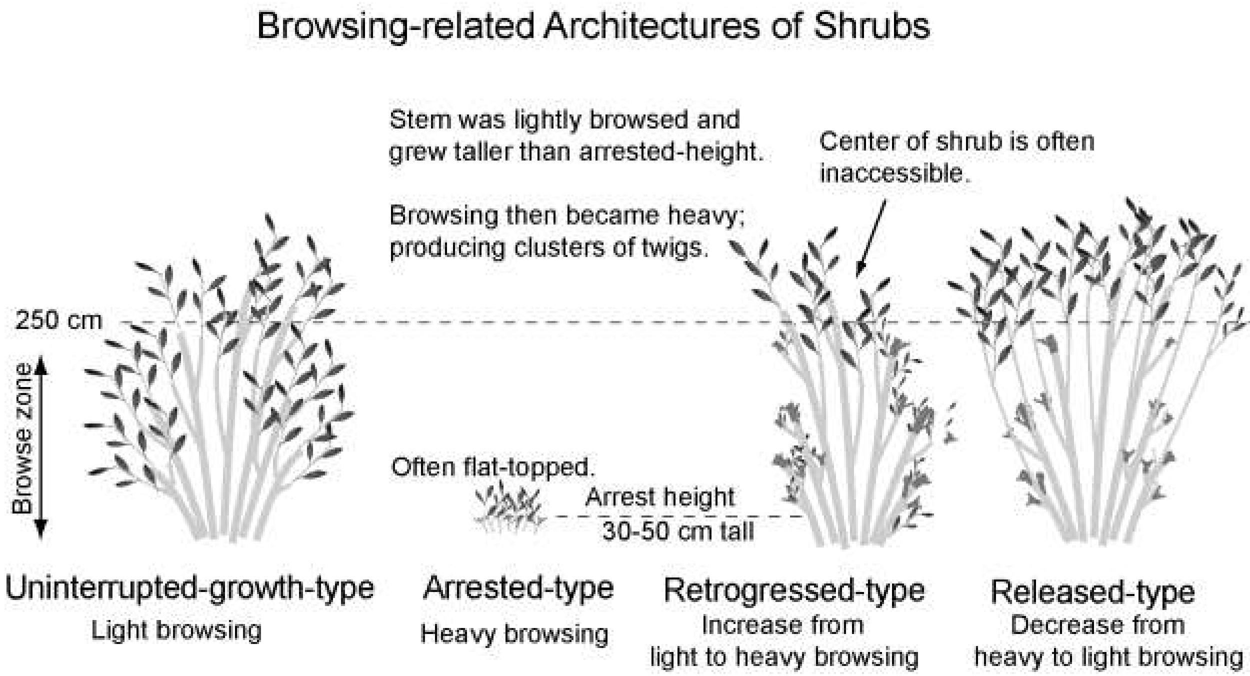
The degree to which a tree or shrub is browsed affects its shape. We refer to those shapes as browsing-related architectures. The architectures are produced during the time that the plant's terminal leader grows in or through the browse zone.

Four types of architectures document four browsing regimes.

- **Uninterrupted-growth-type** architecture is produced by light browsing.
- **Retrogressed-type** architecture is produced by an increase from light to heavy browsing
- **Arrested-type** architecture is produced by heavy browsing.
- **Released-type** architecture is produced by a decrease from heavy browsing to light browsing.

"Light" and "heavy" browsing are used in a broad sense. More precisely, the terms correspond respectively to Light-to-moderate and Intense as defined in Concept 6: Browsing Level. The broad terms allow us to describe the obvious effects of browsing without closely examining plants for the presence of diagnostic characteristics associated with Browsing Level.





Applications of Browsing Related Architectures

There are five principal applications:

- Describing the recent effect of browsing at a site.
- Reconstructing an approximate history of browsing.
- Identifying the preference gradient of different browse species.
- Selecting indicator species, and
- Selecting indicator sites.

A Landscape Level Survey is the application of the above activities at different locations across the landscape. A Landscape Level Survey should not be viewed as a study, but rather as a series of preliminary observations that provide guidance for future monitoring.

Recent effect of browsing. The presence of uninterrupted-growth-type individuals growing within the browse zone indicates that some individuals may likely grow to potential stature. If plants growing within the browse zone consist solely of arrested- and retrogressed-type individuals, browsing may be preventing growth through the browse zone, and browsing may be a dominant influence on plant community structure. Monitoring is used to determine if browsing is a dominant influence or not.

Reconstruct approximate history of browsing. Because the architectures mostly reflect the browsing conditions experienced by young plants, a community of plants of diverse age records a history of browsing. A community composed solely of uninterrupted-growth-type individuals records a history of light-to-moderate browsing. A community of old uninterrupted-growth type individuals and younger retrogressed- and arrested-type individuals records an early period of light browsing followed by an increase to heavy browsing.

Using the concept of Browsing Level (Concept 6), we can detect (and perhaps date) subtle changes in browsing. A willow community consisting of retrogressed- and arrested-type architectures indicates a history of light browsing followed by heavy browsing, the light browsing allowing the retrogressed-type plants to grow taller than arrest-height in their youth, the heavy browsing causing their retrogression and the development of arrested-type architectures in younger plants. Now suppose that lengths of unbrowsed stems grow from the tops of the retrogressed- and arrested-type plants. This growth would not result in released-type architecture until the plant was more than 250 cm tall. But the unbrowsed (or lightly browsed growth) documents a decrease in browsing. We may be able to age the lightly-browsed part of the stem and. for example, reconstruct the following history: light browsing, followed by heavy browsing (indicted by the retrogressed-type architecture), followed by five years of light browsing (indicted by five years of Light-to-moderately browsed stem growth).

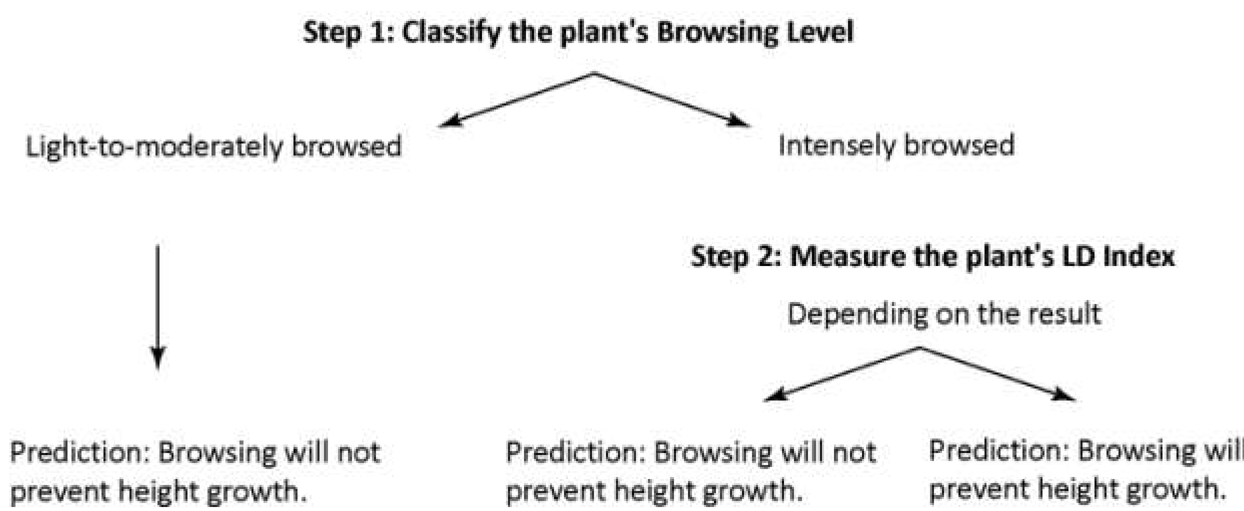
Preference gradient. In the course of conducting the landscape level survey, the preference gradient for the area should become apparent.

Selection of indicator species and indicator sites. Criteria for selecting an Indicator species were described in a section above (Concept 2). Criteria for selecting indicator sites were discussed as Concept 3.

Concept 6: Browsing Level.

We now begin to address a monitoring question: Will browsing prevent a given plant from growing to its potential stature?

The question is addressed in two steps. The first step—described in this section—is to classify the plant into one of two categories, either Light-to-moderately-browsed, or Intensely-browsed. If the plant is Light-to-moderately-browsed, we assume that browsing will not prevent height growth. If the plant is Intensely-browsed, we continue to the second step (Concept 7): the measurement of its LD Index. The diagram below summarizes how Browsing Level is used.



The remainder of this section consists of three parts. The first part describes the rationale behind the classification of Browsing Level. The second part describes the criteria for classifying the Browsing Level of both stems and plants. The purpose of these criteria is to foster consistency in classification. The third part addresses a complexity that could occur, the cause of which is introduced in the following section.

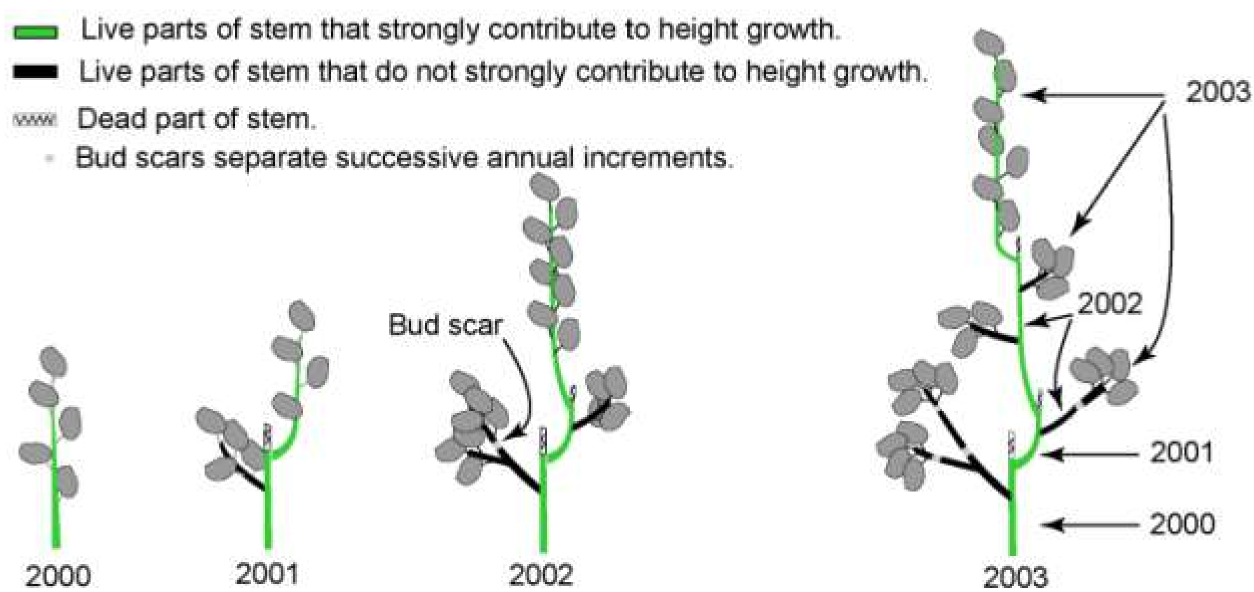
Part 1: The Rationale

Plants grow taller each year by adding new stem segments to stem segments that elongated in a previous year. A typical sequence is diagramed below. The classification of Browsing Level is based on how browsing disrupts that typical sequence.

The drawing below describes the growth of an aspen over four growing seasons. During the 2000 growing season, leaves were produced and buds formed at the base of the leaf petioles. When buds mature at the end of the growing season, each consists of an embryonic stem, complete with leaves, that is covered by bud scales. In temperate climates, buds typically remain dormant during the growing season in which they were produced. The following growing season, a bud can activate allowing the embryonic stem to elongate and its leaves to expand. Buds can also remain dormant, retaining the possibility to become active at a future time. Buds can die.

> NOTE: On occasion, buds activate the same year that they were produced. Immediately after activation, this condition is easy to detect because leaves are present on the current-year-growth stem segments. In later years, the double flush of growth may not be detectable without careful examination. This condition is addressed in Part 3: Dealing with the potential double flush of growth.

In the fall of 2000 the tip of our aspen was browsed, removing the uppermost two buds (the terminal bud and one lateral bud). In the 2001 growing season two lateral buds activated to produce two current-year-growth segments. While both are lateral branches, the uppermost segment (colored green) grew tallest, and so most strongly contributes to the plants growing taller. In the fall of 2001 the uppermost segment was browsed; the lower lateral branch was not.



In the 2002 growing season, four buds activated, three of which were lateral buds. Segments originating from lateral buds diverge from the older stem at an angle and are easy to identify. A single terminal bud activated from the lower branch that was not browsed in 2001. Current-year-growth developing from a terminal bud is a direct extension of the segment produced the previous year. Bud scars mark where one annual segment developed from the previous annual segment. The scars left by terminal buds may require close inspection to identify. In the 2003 growing season, six buds activated, three were lateral buds, three were terminal buds.

In the drawing on the previous page, the green-colored segments contribute most strongly to the plant's height growth. These are segments that often originate from the uppermost buds. In this example, each of those segments originated from lateral buds. If the aspen was not browsed, the uppermost current-year-growth would develop from the terminal bud.

Although the aspen above was repeatedly browsed, that browsing did not interrupt height growth; the plant grew taller. When classifying the Browsing Level of a plant, our aim is to determine whether or not browsing significantly interrupts height growth. The question is: What will we use as evidence of an interruption in height growth?

The chokecherry to the right was heavily browsed, producing a characteristic hedged appearance. Much of the upper stem was dead. Most would agree that this chokecherry was heavily browsed, and agree that browsing has interrupted—if not prevented—its height growth. This plant is an extreme example. Our aim is to detect, at an early stage, the possibility of a browsing-related interruption in height growth.

The rationale behind the classification: Mortality of the upper stem is an indication that browsing may prevent height growth. The classification is based on determining if browsing has caused the death of a plant part that would contribute strongly to its height growth.

In so far as possible, the aim is to establish criteria that result in a True or False outcome. When classifying a given plant, different observers should reach the same conclusion.

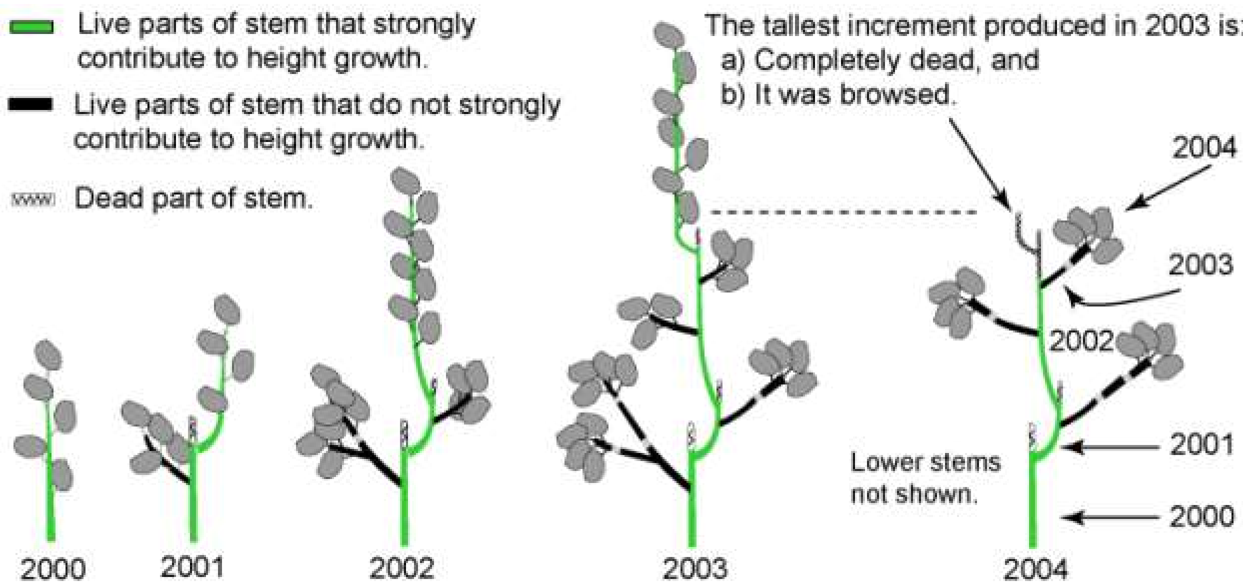
Part 2: Criteria for Classification of Browsing Level

A given plant may consist of one or more vertically-oriented stems, and many horizontally-oriented stems. Because we are concerned with height growth, we restrict our attention to those that are vertically oriented. (While horizontally-oriented stems can be similarly classified, those stems are not used to predict height growth.) Below are criteria for classifying the Browsing Level of individual stems.

A plant consists of one or more stems. In a later section we describe how to classify the Browsing Level of a plant based on an examination of its stems.

The drawing below describes an alternative fate for our plant in 2004. As in previous years, current-year-growth was browsed in the fall. But this time a substantial portion was removed. In the 2004 growing season, current-year-growth did not elongate from the tallest increment produced in 2003, and as a result, the entire increment died.

A lower 2003 increment did survive, and current-year-growth elongated from it in 2004. But the death of the tallest increment marks a temporary—perhaps long-lasting—interruption in height growth.

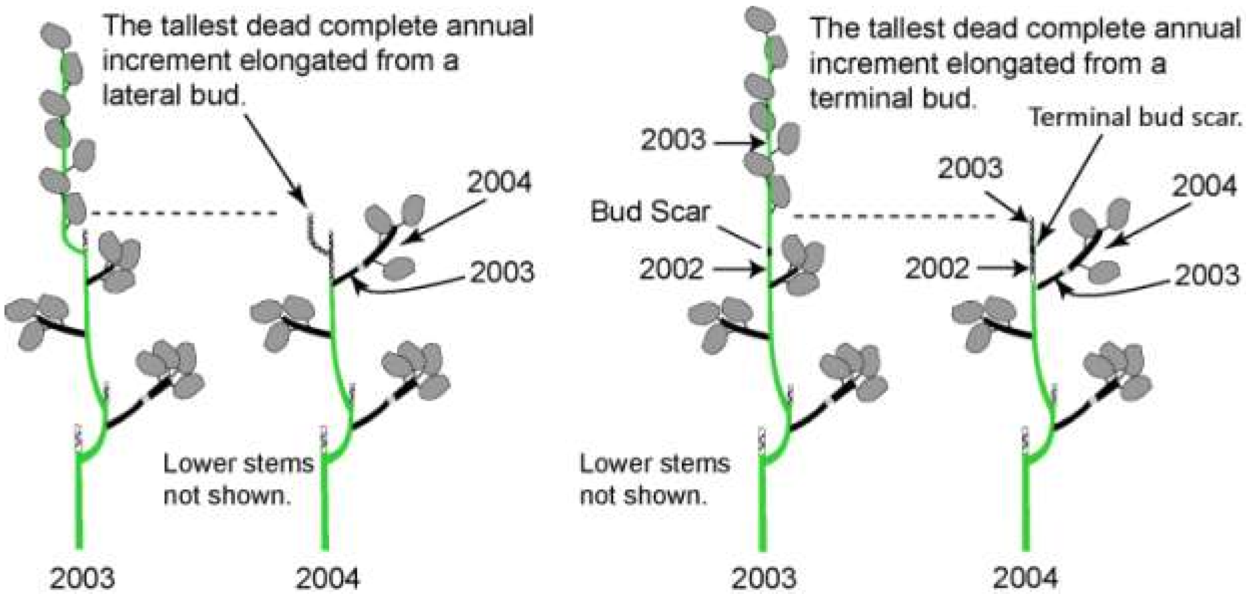


There are two categories of Browsing Level:

- Intense, and
- Light-to-moderate.

Intense Browsing. A stem is Intensely-browsed if browsing is believed to have caused the death of a complete annual increment that, if it had survived, could have strongly contributed to the stem's height growth. The increment must have been browsed.

Typically (but see comment below), the complete annual increment would have been the tallest increment at some point in the plant's life. Two situations are diagramed below.



Comment: The diagrams depict common growth patterns, but exceptions occur. In those cases, one must consider the intent of the classification: Determine if browsing has caused the death of a complete annual increment that, if it had survived, could have strongly contributed to the plant's height growth.

Light-to-moderate Browsing. A stem is Light-to-moderately-browsed if it lacks the characteristics of intense browsing. The aspen used in the example was not Intensely-browsed until the winter of 2003. In 2001 through 2003, browsing caused the death of parts of annual segments (the stem dies from the point where it was browsed to the base of the tallest current-year-growth). The partial death of an annual segment does not qualify as being Intensely-browsed.

Classifying the Browsing Level of plants.

The Browsing Level of a plant is determined by classifying the Browsing Level of its vertically-oriented stems. Trees typically have a single stem. However browsing, as well as other influences, may cause the vertical growth of multiple stems. If any vertically oriented stem is Intensely-browsed, the tree is classified as Intensely-browsed.

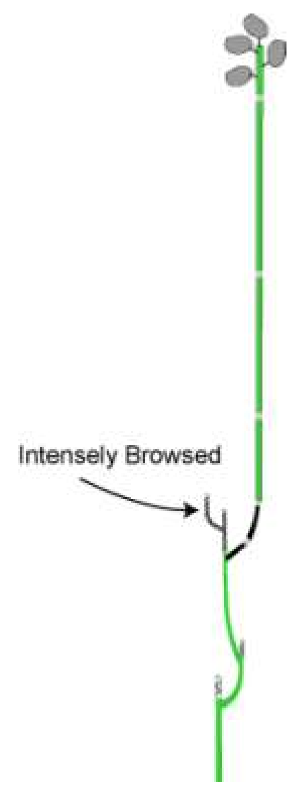
By definition, a shrub consists of multiple vertically oriented stems. If any of the shrub's vertically-oriented stems were Intensely-browsed (including stems that are completely dead), the shrub is classified as having been Intensely-browsed.

Once a plant is classified as Intensely-browsed it retains that classification for life. The Intense browsing could be a brief episode, such as that diagrammed below, or could be continual and prevent height growth.

How Browsing Level is used.

The application of Browsing Level was diagramed at the beginning of this section:

> We assume that a Light-to-moderately-browsed plant will grow to its potential stature.
>
> An Intensely-browsed plant *may* grow to its potential stature. The plant to the right was Intensely-browsed at a single point in its life. It was not browsed again, and appears likely to grow to its potential stature. The likelihood that it will do so is determined by measuring its LD Index which is described below as Concept 7.

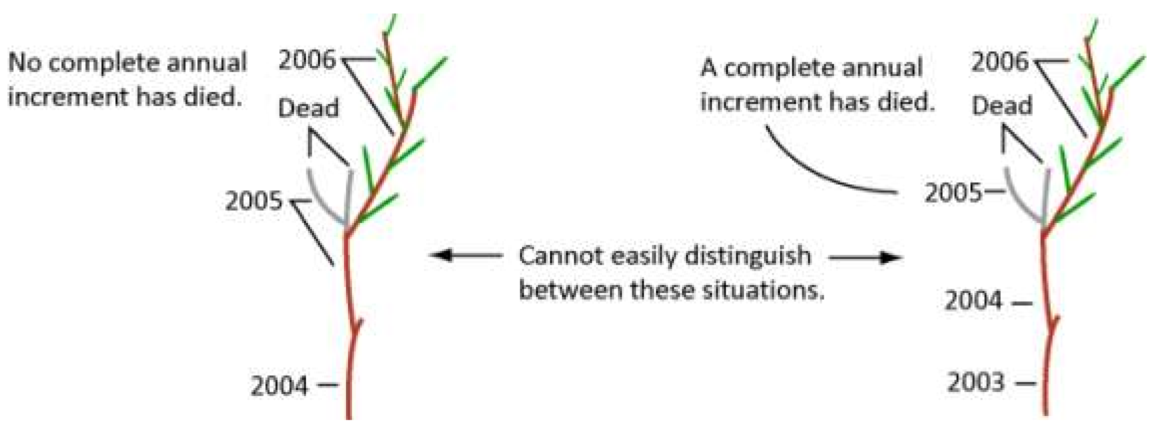


Part 3: Dealing with the potential double flush of growth

In our temperate region, the buds of most browse species typically overwinter in a dormant state. As a result, we are able to age stem segments based on their position along the stem axis. On occasion, buds elongate without undergoing a dormant state. During the current growing season, the situation is easy to detect because leaves are produced on both segments. In the diagram below, this phenomenon occurred in 2006. Once the leaves are shed, the condition is more difficult to detect.

When classifying Browsing Level, our aim is to identify the death of a complete annual segment. The diagram below illustrates the uncertainty that can occur given the potential double flush of growth. In the example to the left, a double flush occurred in 2005 (as well as 2006). No complete annual increment has died because part of the 2005 segment died and part remained alive. The plant in this example would not meet the criteria for Intense Browsing. In the example to the right there was no double flush of growth prior to 2006. Because the complete 2005 increment is dead and was browsed, the plant meets the criteria for being Intensely Browsed.

By inspecting the current-year-growth of shrubs we can get a sense of the frequency at which the double flush occurs. In the case of species we commonly monitor (chokecherry, Geyer willow, Booth willow, Bebb willow, and aspen), the frequency appears to be quite low, and the effect on the analysis negligible. For coyote willow however, the condition is fairly common.



By examining stem sections under the microscope it may be possible to distinguish between the above situations. But for the sake of practicality in monitoring, we assume that each segment represents an annual segment. Both situations abve would be classified as Intensely Browsed (the left one erroneously). If the double flush of growth is suspected (as it would be above), independent lines of evidence are used to infer the role of browsing. In some cases (such as at the first monitoring site at Baca: [MS2009-1]), the inferred role is strongly supported: tall coyote willows were browsed and are dying back to groundlevel. In other cases (such as at Alamosa MS2009-1), the role is less certain.

The Quantitative Concepts

Concept 7: LD Index

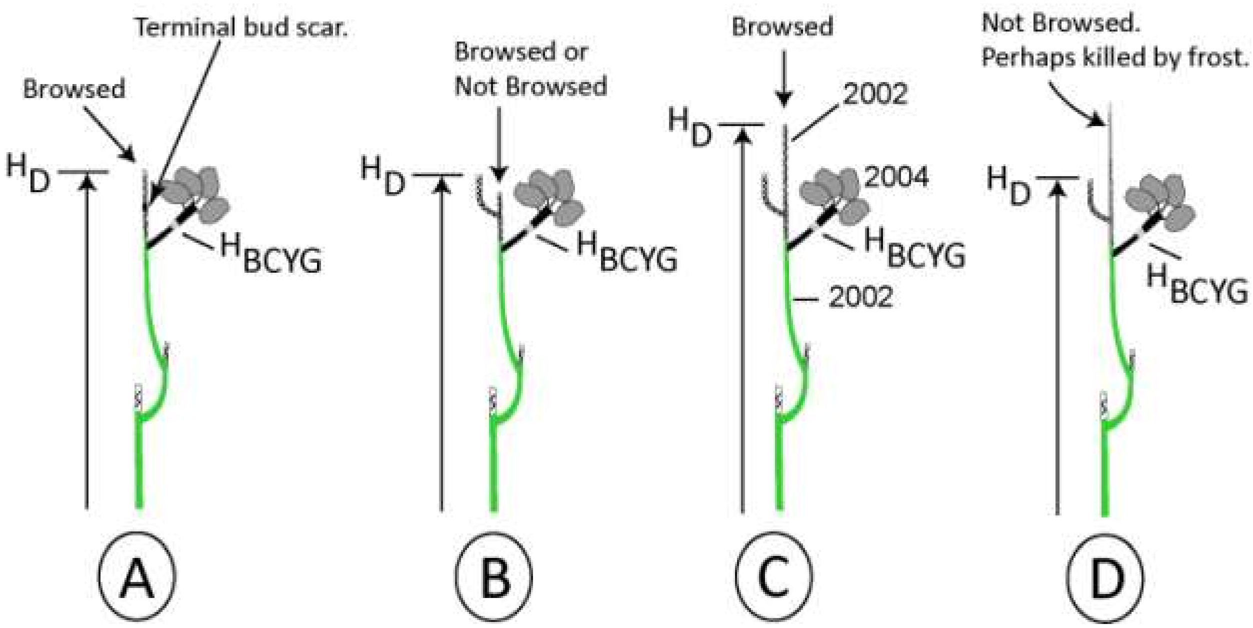
LD Index (Live-Dead Index) is a measure of height growth that occurred after a plant was Intensely-browsed.

How it is measured

LD Index is based on two measurements, the first being the height to the base of the tallest current-year-growth (H_{BCYG}).

> **It is important to note that plant height is measured to the base of current-year-growth. This minimizes complications that can arise if a stem is browsed after measurement.**

The second measurement is the height to the tip of the tallest stem having a dead, vertically oriented, complete annual increment that was browsed (H_D). The location of H_D is described in the diagram below.



Situation A is common: A complete annual increment that originated from a terminal bud is dead.

Situation B is also common: A complete annual increment that originated from a lateral bud is dead.

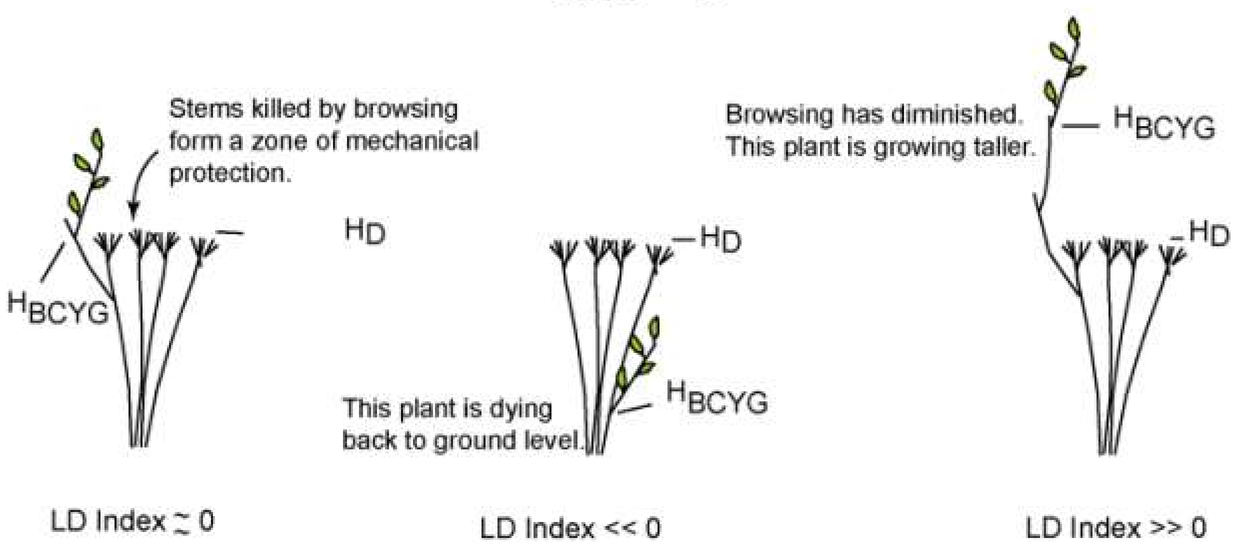
Situation C is not so common. The point to which H_D is measured is older than the browsed, dead lateral branch below. Ungulates typically do not browse below the mechanical protection of older stems. In this case, we assume that browsing played a role in the death of the tip of the stem.

Situation D is common in shrubs where taller stems are killed by frost. Younger shorter stems are then browsed. The absence of browsing on the tallest segment would be identified by the presence of a terminal bud. The presence of browsing on the lower segment would be identified by the absence of a bud and the exposure of the annual ring.

Calculation and Interpretation of LD Index

LD Index is calculated by subtracting the height of the tallest stem having a complete dead annual increment (H_D) from the height of the tallest live leader as measured to the base of current-year-growth (H_{BCYG}).

$$\text{LD Index} = H_{BCYG} - H_D$$



An LD Index of about zero indicates that current-year-growth is being browsed to the level of mechanical protection provided by stems and twigs that were killed by browsing. This indicates that browsing is preventing height growth. If the LD Index is substantially less than zero, the plant is dying back to ground level. In the case of trees, the death of the stem at ground level means the death of the plant. Because shrubs can produce additional stems from belowground, the plant will persist as long as additional stems can be produced. The arrested-type shrub diagramed above illustrates a succession of such stems. An LD Index substantially larger than zero indicates that the plant is growing taller after having been intensely browsed. A Threshold LD Index (Concept 8) is used to determine if the plant will likely grow to its potential stature.

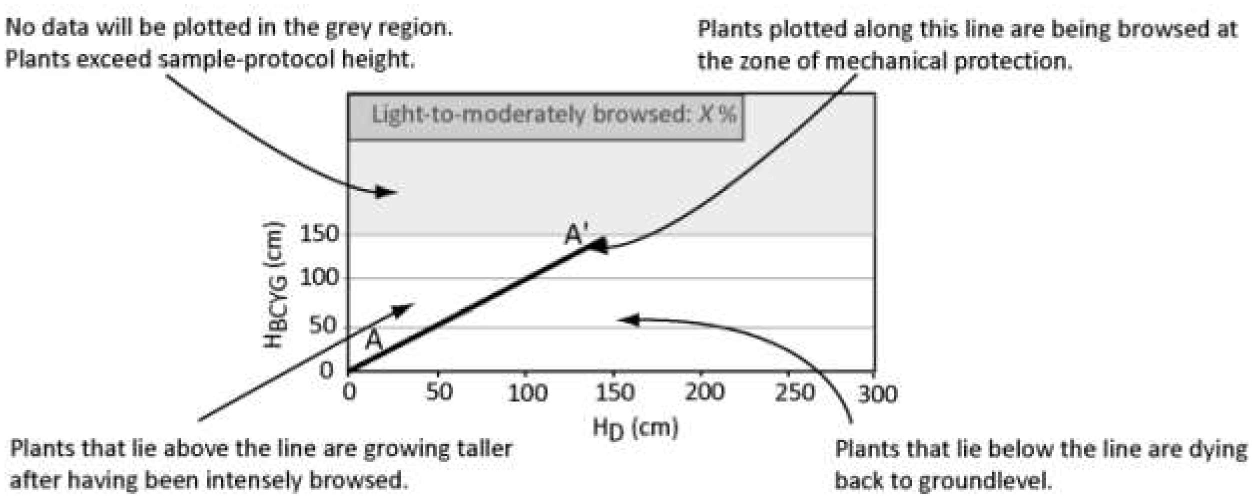
Limitations in the use of LD Index

The aim of the LD Index analysis is to predict whether or not a given plant will grow through the browse zone. There is one important limitation: Plants must be at least three years old to develop the characteristics of Intense Browsing.

This means that LD Index cannot be used to measure the effect of ungulate browsing immediately after fire when all plants are young. Immediately after the fire the likely future effect of browsing can be assessed by examining plants killed by fire for evidence of pre-fire levels of browsing . During the first five years following fire, an analysis of stem growth rate and lifespan will more accurately indicate the effect of browsing. A discussion of this analysis is beyond the scope of this report.

The Graphic Portrayal of Structural Trend With Respect to Browsing

Concept 8 (Threshold LD Index) sets the stage for determining if browsing will likely have a dominant influence on plant community structure. But before proceeding to that topic, we describe how the monitoring measurements can be used to graphically portray structural trend. In the course of monitoring, 20 plants are sampled; the plants must be less than 150 cm tall. (The sample protocol for height measurement is explained in Concept 11: Existing Browsing Pressure.) When Intensely-browsed plants are sampled, we measure the height to the base of the tallest current-year-growth (H_{BCYG}) and the height to the tip of the tallest, dead, browsed, complete annual increment (H_D). We plot H_D on the X-axis and H_{BCYG} on the Y-axis. Since H_D does not exist for Light-to-moderately browsed plants, we note the percent of plants that were Light-to-moderately browsed in the upper left hand corner of the graph. This type of graph will be used when describing structural trend later in this report.



Concept 8: Threshold LD Index

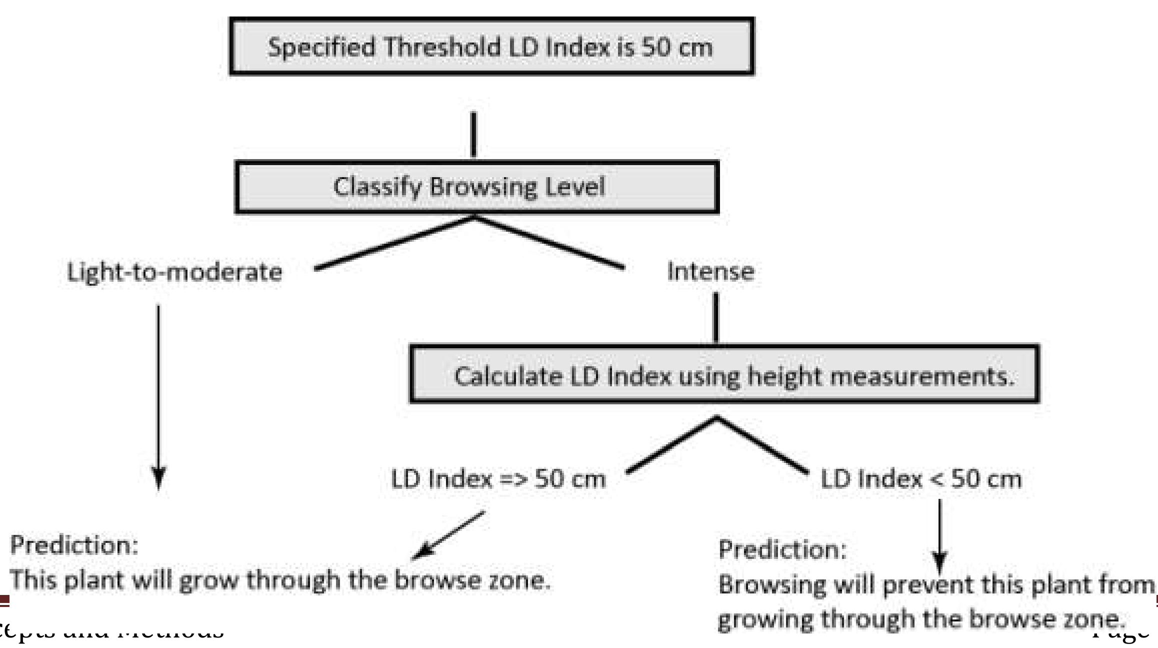
An LD Index of substantially greater than zero indicates the plant is growing taller after having been Intensely-browsed. The question is: How much greater than zero must an LD Index be to assume that the plant is likely to grow through the browse zone?

One approach to answering this question would be to mark plants having various LD Indexes, and track the height growth of those plants over time. The original LD Index would be the independent variable; the change in LD Index over time would be the dependent variable. In practice, there are two major problems with this approach.

- At some sites, the LD Index of all plants is less than, or very close to, zero. (One such site is described in this report: Arapaho National Wildlife Refuge MS2009-1.) Data cannot be collected for the analysis.

- The year-to-year change in stem growth (and thus LD Index) is clearly influenced by many variables. These include yearly changes in weather, disease, and insect herbivory. Perhaps more significantly, we cannot assume that ungulate herbivory has remained constant over the years. Our independent value is not truly independent.

In reality, Threshold LD Index is an estimate. The larger the number, the more certain we can be that the plant will likely grow through the browse zone. Specifying the Threshold LD Index value that was used should be part of reporting the results of the analysis. While this specification is subjective (something we have strived to avoid), it is no different than the specification of a statistical probability used in hypothesis testing. We used a Threshold LD Index of 50 cm.



Practical effect of estimating Threshold LD Index: What if our estimate is inaccurate?

The ultimate purpose of monitoring is to predict if browsing will affect the structure of the plant community. This is accomplished by sampling 20 plants and applying the concepts described below. We commonly encounter two situations:

- Ungulate browsing is currently heavy and it is visually apparent that browsing is preventing young plants from growing to their potential stature. In our experience, LD Index values will likely be less than (or close to) zero. The low LD Index values corroborate what is visually obvious.

- Ungulate browsing was once heavy, but has recently diminished to light. In our experience, changes in the height of plants in the community occur primarily due to the growth of young, Uninterrupted-growth-type plants into browse zone. As these plants become more common, they will be encountered during sampling, and will minimize the effect of Threshold LD Index regardless of value. This situation occurred at the National Elk Refuge MS2009-1 and 2.

The fact remains, an estimated Threshold LD Index is imperfect. We can use it to make predictions that are more or less accurate. Documenting the ultimate effect of browsing can only be accomplished by monitoring over a period of years.

Concept 9: Replacement Percentage

We now begin to address the question: Will browsing have a dominant influence on stand structure?

For a stand of plants to be sustained, young plants must grow through the browse zone to replace those that die. Replacement Percentage is the percent of young plants that must grow through the browse zone to maintain or produce the stem density of the parent stand.

Replacement Percentage varies by site and is influenced by the lifespan of the species and the age structure of the stand. Where young plants replace plants that die of old age, replacement can be largely incremental. On an annual basis, the incremental replacement rate could be very low. The highest replacement rate occurs when all plants must be simultaneously replaced due to an event such as fire.

Simultaneous replacement is used as the basis for assessing the potential effect of browsing on habitat structure for two reasons. First, the determination of simultaneous Replacement Percentage is much less complicated than the determination of incremental Replacement Percentage, and for that reason more appropriate for general monitoring. Second, all sites are potentially exposed to wildfire or prescribed fire. We base the determination of Replacement Percentage on the hypothetical occurrence of fire.

Replacement Percentage is calculated using two estimates of plant density. The first is the plant density that we desire to grow through the browse zone after a hypothetical fire. This is the **Target Density**. In the case studies described in this report, Target Density was calculated based on a hypothetical spacing between plants. Target Density could also be based on actual measurements of an existing stand.

The second estimate, the **Propagule Density**, is the density of plants that will be available after a hypothetical fire to grow through the browse zone and establish the target plant density. After fire, plants may be established from seed, root sucker, rhizome, or root crown depending on the species. Each of these sources is a propagule. The accuracy of the estimated Propagule Density could be relatively good (in the case of species that reproduce from root crowns, the density of which can be measured) to relatively poor (in the case of species that reproduce from root budding, rhizomes, or from seed).

Replacement Percentage is calculated by dividing the Target Density by the Propagule Density. In the following section, Replacement Percentage is used to determine Threshold Browsing Pressure: the point at which ungulate browsing will be a dominant factor in shaping the structure of the plant community.

It should be apparent that the calculated Replacement Percentage is a very rough estimate. But it provides a starting point for the objective interpretation of data as described in the following section.

Concept 10: Threshold Browsing Pressure

We define browsing pressure to be the percent of plants that are prevented by browsing from attaining their potential stature. A browsing pressure of 100% means that browsing prevents all plants from attaining potential stature. There are two types of browsing pressure: the Existing Browsing Pressure, which is measured (Concept 11), and the Threshold Browsing Pressure which is calculated.

Threshold Browsing Pressure describes the point at which browsing will affect stand structure. It is calculated by subtracting the Replacement Percentage from 100 percent.

Threshold browsing pressure = 100% - Replacement percentage

Because Threshold Browsing Pressure will be a rough approximation of actual conditions, it is fair to question the value of its use. Its value lies in the fact that it is a rational (i.e., reasoned—not arbitrary) criterion used to interpret data—to distinguish between an acceptable condition and an unacceptable condition (which is the goal of monitoring). The logic behind Threshold Browsing Pressure is understood: post-fire propagules are the source of a subsequent condition that browsing can influence. We can discuss the relative merits of the Target Density on which the Threshold Browsing Pressure was based. We can discuss the merits of an estimated Propagule Density, and if an actual fire occurs, measure an actual Propagule Density. Because we understand the basis for calculating the threshold condition at a site, we can refine its accuracy over time by periodically collecting and analyzing data. We acknowledge upfront that the threshold criterion is an estimate that is subject to change.

In contrast, the typical monitoring approach is to specify arbitrary criteria. Based on the recommendation of an external authority, we may specify that browse utilization should not exceed 35%, or that mean LD Index should be greater than 25 cm. Because we have not explicitly related these criteria to specified effects on habitat structure, we have no logical basis for making corrections in response to changes in habitat condition.

Concept 11: Existing Browsing Pressure

Existing Browsing Pressure is the percent of plants that, based on measurements, we predict will be prevented by browsing from growing to potential stature. To determine the effect of browsing on stand structure, we compare the Existing Browsing Pressure to the Threshold Browsing Pressure. If the existing browsing pressure is less than (or equal to) the threshold value, we predict that browsing will not have a dominant effect on the structure of the plant community. If the existing browsing pressure is greater than the threshold value, then browsing is predicted to have a dominant effect on stand structure.

In a previous section we described how Browsing Level and LD Index could be used to determine if browsing will prevent an individual plant from growing to potential stature. To determine the effect of browsing on the future structure of the plant community, we examine a sample of 20 plants along a line transect. At each point we measure the closest plant meeting either of the following criteria:

- Criterion 1: The plant is between 50 and 150 cm tall. Plants in this size range are attempting to grow through the browse zone to replace plants that die of old age or for other reasons. Such plants are usually tall enough to have been exposed to browsing, and are short enough to be available to all ungulate species.

  If plants taller than 150 cm are sampled, we exclude the effect of browsing by livestock and deer. This could potentially skew the results if both tall-browsing (elk and moose) and short-browsing (livestock and deer) ungulates are present. For example, suppose half of our sample consisted of plants that are taller than 150 cm, and half that are shorter. And suppose that we have a large population of deer (that can only reach up to 150 cm), and a relatively small population of elk (that can browse to more than 250 cm). We might find that 50 % of our sample—the plants that were taller than 150 cm—were growing through the browse zone. This could occur because deer do not browse above 150 cm, and that while the elk potentially could, their population size was relatively small. If we had restricted our sample to plants less than 150 cm, we might have found that browsing by deer prevents the height growth of all plants.

- Criterion 2: The plant is shorter than 50 cm tall, and is Intensely Browsed. Recall that our aim is not to describe the height of all plants in the community, but rather to determine if browsing prevents young plants from growing through the browse zone. The intense browsing of a short plant indicates that it may not grow into the 50-to-150-cm-tall browse zone. A Light-to-moderately Browsed short plant may not yet have been discovered or may be protected by snow.

(Protracted heavy browsing can kill all stems growing within the browse zone. As a result, the community could consist of short plants and tall plants that grew through the browse zone when browsing pressure was lighter. Alternatively, the community could consist solely of short plants, some of which are Intensely-browsed, some of which are Light-to-moderately browsed. The Intensely-browsed plants die before growing into the browse zone. The Light-to-moderately browsed plants eventually become Intensely-browsed.)

Based on the sample of 20 plants meeting the above criteria, we estimate the percent that will be prevented by browsing from growing through the browse zone. This is the percentage of plants having a measured LD Index that is less than the specified Threshold LD Index value. We refer to that percentage as the Existing Browsing Pressure.

Browse Evaluation as Part of Adaptive Ungulate Management

While our attention in 2009 was restricted to evaluating the effect of browsing, it is important to consider how the resulting information could be applied in the form of adaptive ungulate management. An adaptive management process is diagramed on the following page. It consists of four components:

- Management Goal
- Management Objective
- Evaluation
- Ungulate Management

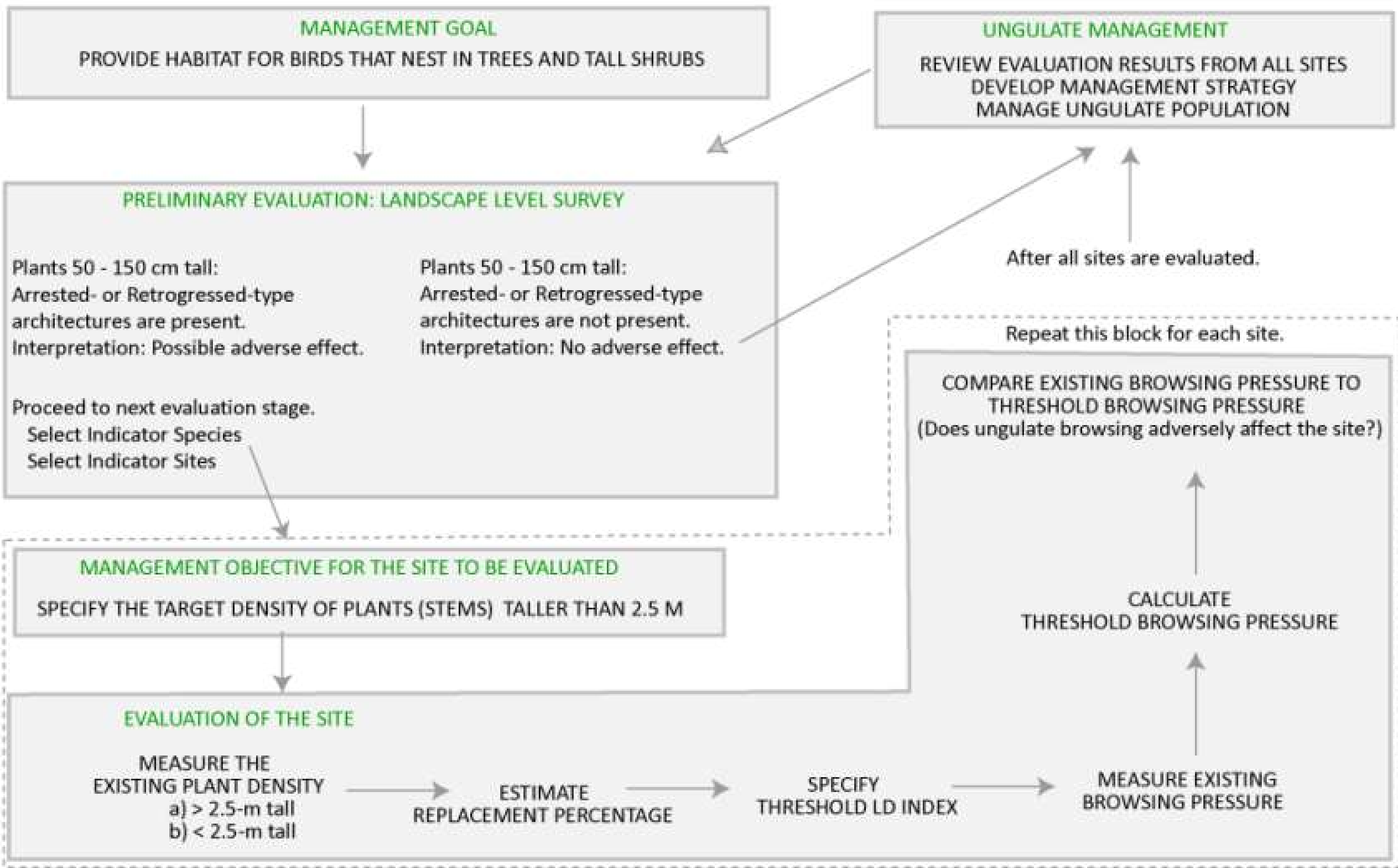
The Management Goal is the foundation. It is a broad statement of intent that reflects the mission of the Refuge system, relevant legislation and administrative orders, and planning documents such as Comprehensive Conservation Plans. In the 2009 program, we specified the following: P*rovide habitat for birds that nest in trees and tall shrubs.* Barring unusual circumstances, the Management Goal would remain constant.

In the context of adaptive ungulate management, the Management Goal is restricted to the effect that ungulates can have on habitat structure. The aim of the process is to prevent an ungulate-caused decline of nesting habitat. The process does not address other factors that influence habitat condition such as climate, hydrology, or disease. Complimentary management processes could be developed for such influences.

Adaptive management is an iterative process. Ungulate management strategies are periodically revised based on the effect that the ungulates are currently having on habitat structure. That current effect is determined by the Management Objective and Evaluation components. The ultimate aim of the Evaluation component is to determine if ungulate browsing is excessive, or not. There is no fixed target ungulate population size.

To maintain competency and continuity, some evaluation aspects should be conducted at the refuge each year. Ultimately, the effort expended will depend on available resources and perceived urgency. If ungulate populations are managed based on the data, several monitoring sites should be established.

Adaptive Ungulate Mangement Based on Habitat Goals



Preliminary Evaluation: Landscape Level Survey

The Landscape Level Survey is used to rapidly assess the effect of browsing across the refuge, and assist in the design of the monitoring program. The survey is based on the browsing-related architectures (Concept 5, page 12).

When the adaptive management program begins, a Landscape Level Survey is used to decide if more detailed measurements are required. If all plants between 50 and 150 cm tall have Uninterrupted-height-growth architecture, there is no point in quantitatively measuring the Existing Browsing Pressure; we know that it would be 0 %. With respect to browsing impacts, the management strategy would be based on the absence of browsing-related effects.

If arrested- or retrogressed type plants are present, sites should be selected for monitoring to determine if ungulate browsing is adversely affecting habitat structure. Landscape Level Survey data are used design the monitoring program: i.e., the selection of Indicator Species (Concept 2) and Indicator Sites (Concept 3).

The steps of the Landscape Level Survey are:

Prepare for the Survey

After considering which refuge plant communities contain trees and tall shrubs, a tentative survey route is planned using a map or photograph. In the 2009 program, we used National Agricultural Imagery Program (NAIP) photographs available through the Farm Service Agency (http://datagateway.nrcs.usda.gov/). Consider which of the refuge's browse species are likely to be highly preferred (Concept 1, p. 10), and the kinds of sites that are most exposed to browsing (Concept 3, p. 11). The planned route should include sites where highly-preferred, readily-browsed plants are present. If a site is protected from browsing by topography or fencing, a stop could be planned to document the approximate height to which plants grow under light browsing.

The survey is begun with a tentative route and possible stops. Most of the stops will likely be selected while traveling along the route.

A comment about site selection

The selection of sites along the route is subjective. We explicitly look for adverse effects due to heavy browsing. We also look for evidence of trends in browsing impacts: evidence of an increase or decrease in browsing.

If we were asked to document the effect of browsing across the refuge, our site selection would be random. Exposure to browsing across the refuge will vary depending on topography and other forms of mechanical protection. The degree to which plants are browsed across the refuge would depend on the proportion of protected areas compared to exposed areas. Random sampling would document that proportion.

Conduct the Landscape Level Survey

Traveling along the route, stop at the first Landscape Level Survey site. Before collecting data, quickly consider the following. What browse species are present? Is there an obvious difference in use between species? Does topography discourage use in parts of the site? Is there anything about the site's environment that would promote or inhibit plant growth? With this brief consideration, select one or more browse species, with special attention given to the most-highly preferred. Then mentally delineate an area where the species grows and is homogeneously exposed to browsing, with special attention given to areas of high exposure.

Record the browsing-related architectures of the selected species growing in the delineated area. In 2009 we recorded the architectures in four height classes: 1) < 50 cm, 2) 50 – 150 cm, 3) 150 – 250 cm, and 4) > 250 cm. Classification was assigned based on the height of the tallest stem, live or dead. The height classes correspond to: 1) plants that may be protected by snowcover, 2) plants accessible to all ungulate species, 3) plants accessible to elk and moose, and 4) plants that have grown out of the browse zone. (Elk and moose can reach above 250 cm, but typically browse stems that are lower.)

Note evidence of changes in browse use such as retrogressed- or released-type architectures. Are tall trees highlined? Are trunks scarred by gnawing? This would indicate an increase in browsing after the tree grew out of the browse zone. Do arrested- or retrogressed-type plants have stems that have been lightly browsed for the past few years? This would indicate that browsing has decreased.

Continue along the route selecting additional sites. Compare the current site to sites that were examined earlier along the route. Such comparisons may suggest the kind of sites that should be selected at other stops along the route. In the course of a day, 15 to 20 sites could easily be visited. A datasheet is provided in the Appendix to this report.

Interpret the Landscape Level Survey Data

Although the survey data are not quantitative, they do provide a perspective on three aspects: 1) the effect of current browsing, 2) the stage of structural trend (see Stages of Structural Trend: A Multi-Refuge Comparison, p. 160), and 3) the history of browsing (see Concept 5, p. 12).

With respect to the current effect of browsing, the architectures of plants in the 50-to-150 cm height class are most informative. If *all* plants at a site have Uninterrupted-growth-type architecture, browsing is not adversely affecting habitat. If Uninterrupted-growth-type *and* Arrested- or Retrogressed-type architectures are present, then browsing may or may not be having an adverse effect. Monitoring (described below) would be required to determine if browsing was having an adverse effect.

If all plants in the 50-to-150 cm height class have Arrested-or Retrogressed-type architecture, one could refine the interpretation by closer examination. Is there evidence of significant dieback on all Retrogressed-type plants in the 50-to-150-cm height range? If so, we would likely find that the Existing Browsing Pressure was 100% if we were to collect monitoring data.

On heavily browsed sites there may be no plants in the 50-to-150 cm height class and a mix of Uninterrupted-growth-type and Arrested-type plants in the < 50-cm height class. This characteristic is indicative of advanced structural decline. Using the sample protocol described later in this section, we would document an Existing Browsing Pressure of 100% if we were to collect monitoring data.

Select Monitoring Sites and Indicator Species

Rank the Landscape Level Survey sites by impact, and select two or more for monitoring. The Indicator Species should be highly preferred. Note that our aim is to document whether or not an adverse effect occurs on the refuge, and not to determine the extent to which that condition may occur across the refuge. The areal extent of heavily browsed sites will be considered in the course of developing an ungulate management strategy.

In Subsequent Years

The initial cycle through the process culminates with the development and implementation of an ungulate management strategy. The next cycle begins with a return to the Preliminary Evaluation phase. In some cases, the obvious presence of arrested- or retrogressed-type plants will indicate the need to proceed to monitoring. For that year, it might be decided that a formal survey was unnecessary and that the time should be devoted to monitoring. Over the years, additional sites could be added as deemed appropriate.

Monitoring: The Management Objective and Evaluation Components

The qualitative Landscape Level Survey provides a rapid, subjective assessment of possible browsing impacts at a site. Quantitative monitoring refines that assessment. More importantly, monitoring provides an *objective* basis for determining if ungulate browsing is excessive or not. This section describes the sequence of events that would occur at each site where quantitative data are collected. Each site involves the Management Objective and Evaluation components of the adaptive management process.

The species to be monitored are selected based on the Landscape Level Survey, and may vary from site to site. The number of monitored sites may vary from one to several. A single site provides insight into the effect of browsing, but would not provide a basis for ungulate management. If ungulate management is contemplated, extensive replication would be appropriate.

Delineate an area that is homogeneously exposed to browsing

Assess how topography or mechanical protection may influence exposure to ungulate browsing across the site to be monitored. Steep slopes can discourage ungulate access. Slope aspect (N, S, E, or W) can influence the depth, timing, and duration of snowdrifts.

Along a stream confined by steep banks, exposure to browsing could be influenced by several factors. When ungulates browse during snowfree periods, plants growing on the steep banks may be reached with difficulty, while plants growing on flatter areas (above the bank or at the bottom) are more accessible. In the immediate vicinity of streams, dense stands of mature shrubs may discourage use of younger plants. As snow begins to accumulate, a north-facing bank may be covered before a south-facing bank. The stream bottom may fill with snow. As a result, exposure to browsing is influenced both by topography and by the season in which browsing occurs. Each of these circumstances provides an opportunity to delineate an area that is homogeneously exposed to browsing.

To determine the effect of browsing, data should be collected from areas that are most exposed to browsing (Concept 3: Indicator Sites, p. 11). Areas that are protected from browsing by topography or snow should be avoided. Alternatively, to document the approximate height to which plants can grow under light browsing, protected areas could be sampled. Once a homogeneous area has been delineated, the following steps are accomplished.

Specify a Management Objective

A measurable Management Objective is specified for each monitored site. It is a statement of the desired habitat, and is specified in terms of the target density of stems (or plants) that are taller than 2.5 meters. It provides the basis for analyzing the monitoring data, and is the benchmark for determining if browsing occurs at an acceptable level, or not.

The Management Objective is considered at this point primarily for organizational reasons. In practice, its specification may occur later in the data analysis phase of Evaluation.

The following approaches could be used to develop a site's Management Objective:

- If the habitat at the site is believed to be in acceptable condition, its existing characteristics could be used. The measurement of these characteristics using a belt transect is described in the following section.
- A site's Management Objective could be based on habitat conditions measured elsewhere.

- The Management Objective could be based on hypothetical characteristics: the desired spacing between plants using the formula below.

$$Density = \frac{1}{Distance\ between\ plants^2}$$

Given the complexity of real habitat, the Management Objective is a crude approximation. Its refinement is discussed in the chapter *Target Conditions and the Attainment of Habitat Objectives* (p. 178).

Evaluation Component: Measure Existing Conditions

The measurement of existing conditions serves two purposes. First, measurements taken over a period of time can be used to track actual changes that occurred in habitat structure. Second, the data could possibly be used to specify a site's Management Objective.

At five of the six refuges in 2009, plants were classified into one of two height classes: those that were shorter than 2.5 m and those that were taller. The densities of plants in these height classes were used to specify the Management Objective and determine the Propagule Density (see Concept 9: Replacement Percentage, p. 26).

At Red Rock Lakes NWR the actual height of each willow in the belt transect was recorded. The density of plants in the < 2.5 m and > 2.5 m height classes were determined from these data. Time permitting, measurement of the actual height is preferred.

The method: Following the approach used during the Landscape Level Survey, delineate the boundary of a homogeneous stand. Determine appropriate dimensions for the belt transect. These dimensions may be limited by the size of the stand; in this case the density of the complete stand can be measured. In larger stands, the goal is to determine the smallest belt transect that will provide a relatively accurate measurement of density. In 2009 we used the following approach.

- Run a tape down the estimated length of the transect, and extend a tape perpendicular to that line. Estimate the required width of the belt. The selection of belt transect dimensions is subjective.

- Visually divide the transect into a series of blocks running down the length (e.g., 0 – 2 m, 2 – 4, …).

- Observe the approximate number of plants growing in cumulative blocks. (0-2 m, 0- 4 m...).

- Assess how plant density would change as successive blocks are added. A transect is of suitable minimum size if density is not substantially affected by the addition of another block. Err on side of larger transect areas.

- If there is a large difference in the density of tall and short plants, belt transects of different dimensions could be used.

- After the belt transect is laid out, collect data while walking along the tape, counting the individuals that grow in the succession of blocks.

Calculate Threshold Browsing Pressure (Concept 10, p. 27) Two examples are described in each of the six refuge chapters.

Measurements for Existing Browsing Pressure (Concept 11, p. 28)

Existing Browsing Pressure should be measured in a homogeneous area similar to where Existing Conditions were measured. Plants are selected for measurement along a line transect. The steps:

- Establish an imaginary line running from a fixed point at the site to a point located in the far distance (e.g., mountain top, tree).

- Based on the dimensions of the stand, estimate the maximum possible length of the line.

- Estimate the pace interval that would provide 20 points along the line. If the stand is small, multiple lines can be run.

- Walking toward the distant landmark, step the required number of paces and stop. The toe of the boot marks a point on the ground. Select the closest plant that meets either of the following criteria:
    - It is between 50 – 150 cm tall; it can be Intensely *or* Light-to-moderately Browsed (Concept 6: Browsing Level, p. 15), or
    - It is less than 50 cm tall *and* is Intensely Browsed. (Short Light-to-moderately browsed plants are not measured.)

  Note: Heights are measured to the base of current-year-growth. Because a plant's leaders vary in length, the tallest leader as measured to the base of current-year-growth is not necessarily the leader that extends to the tallest point of the plant.

  Note: The explanation for the sample height classes was described on page 28.

- Once the plant is selected, determine if it is Intensely-browsed or Light-to-moderately browsed. If it is Intensely-browsed identify the location of H_{BCYG} and H_D (see Concept 7: LD Index, p. 22). If it is Light-to-moderately browsed only H_{BCYG} will be measured.

- After the measurement points have been identified, extend the tape to the ground. If the plant is Intensely-browsed, record both heights without moving the tape. (Variation in local topography could cause differences in measurements if the tape was moved. (Because LD Index is based on the difference between measurements, the value is not dependent on the actual height.) If it is Light-to-moderately browsed, record H_{BCYG}.

- Record the length of current year growth (L_{CYG}) of the leader from which H_{BCYG} was measured. Note: L_{CYG} is not used in the evaluation. Short lengths of current-year-growth can be an indication of stress.

- After measurements have been recorded, return to the point on the line, step off the next pace interval, and repeat the selection and measurement process. Repeat until 20 plants have been measured.

Measurements in the Current Year

Repeat above steps as necessary for each Monitoring Site.

Specify Threshold LD Index (Concept 8, p. 25)

In 2009, a Threshold LD Index of 50 cm was used.

Data Analysis: Calculate Existing Browsing Pressure (Concept 11, p. 28).

The collected data can be entered into a spreadsheet to calculate Percent Intensely Browsed, mean LD Index, and Existing Browsing Pressure for each site. Existing Browsing Pressure is the percentage of plants having an LD Index that is less than the Threshold LD Index.

Evaluate Effect of Browsing for Site

Compare the Existing Browsing Pressure to the Threshold Browsing Pressure for each site. It is assumed that browsing will not be a dominant influence on habitat structure if the Existing Browsing Pressure is less than (or equal to) the Threshold Browsing Pressure. If the Existing Browsing Pressure is greater than the Threshold Browsing Pressure, browsing is deemed to have a dominant influence on habitat structure.

Ungulate Management Component

A review of the evaluation data will indicate if ungulate management is required to prevent a decline in habitat. This aspect was not undertaken in the 2009 multi-refuge program. Some common issues are highlighted below.

- Multiple ungulate species may be present. If livestock are present it may be possible to use exclosures to distinguish their use from that of wild ungulates.
- If multiple wild ungulate species are present, it will be necessary to partition the use by the respective species. This may require a dedicated study.
- Wild ungulates typically move across land management boundaries, both private and public. When management involves multiple parties, it may be desirable to discuss alternative management goals, and to coordinate browse evaluation across those boundaries.
- The actual regulation of ungulate number by harvest can be complicated.

Ungulate management issues are typically complex. A full discussion of management issues is beyond the scope of this report.

In Subsequent Years

The following year could begin with a Preliminary Evaluation as described in the section above.

The level of effort expended on monitoring will depend on resources and urgency. Trends can be documented by collecting site data annually. Annual monitoring trends, supplemented by repeat photography provide compelling evidence that an actual change is being documented (Keigley and Fager 2006). If time does not permit annual monitoring at each site, consideration should be given to collecting data at half the sites in one year, and at the remaining sites the following year. Data analysis would proceed as described above.

Ungulate management strategies would be reconsidered based on the new data.

Introduction to the Refuge Chapters

Each of the chapters follows a similar format, beginning with an overview of the refuge, a description of current and historic ungulate populations, habitat goals, and a brief description of the habitat type examined in 2009. The remainder of the chapter is divided into four parts: Landscape Level Survey, Monitoring, Additional Information, and a Summary of Findings.

Landscape Level Survey. The Landscape Level Surveys were conducted on the first day of field work. The route was selected by the respective refuge biologists. It is important to note that the areas were selected because they were of special interest to the biologists. For example, at the National Elk Refuge we only examined part of the northern half of the refuge. The Landscape Level Survey is not intended to characterize the effect of browsing across an entire refuge.

In the course of conducting the survey, the refuge biologists were trained in applying the structure-based approach. By the end of the first day, six or more Landscape Level Survey sites were described. Based on the browsing-related architectures that were observed, a general history of browsing is described. In some cases, the history inferred from the architectures was supplemented by examining stems for evidence of a recent decrease in browsing that was not reflected by the changes in architecture. A recent reduction in the browsing of Booth willow at Red Rock Lakes NWR is an example. By the end of the first day, Indicator Species and Indicator Sites were selected.

The National Elk Refuge provides an example of how a Landscape Level Survey can be used to document a Preference Gradient (Concept 1) and select Indicator Sites (Concept 2). Chokecherry and Geyer willow were found to be more highly preferred than aspen; chokecherry on south-facing slopes is likely the most sensitive indicator of ungulate impacts at the landscape level. However, management concerns led to the selection of aspen as the Indicator Species. The selection of aspen was fortuitous in that it documented a point raised in Concept 1: Less-preferred species respond to a reduction in browsing before more highly-preferred species.

Monitoring. Two sites were monitored at each refuge, and data were collected the second day. The objective of Monitoring was to determine if ungulate browsing likely had a dominant influence on the structure of the plant community at the respective site.

Each chapter contains two examples of the five steps that ultimately lead to a comparison of Existing Browsing Pressure to the Threshold Browsing Pressure.

Chapters also include a discussion on how the selected species affects the estimation of Propagule Density (see Concept 9). For example, the number of Geyer willow root crowns at the Arapaho NWR relatively accurately represents the propagules that would exist after fire. The number of aspen suckers at the National Elk Refuge is a somewhat less certain estimate of the number of suckers that would be present following fire. Because coyote willow propagates from root sprouts and can form diffuse thickets, the estimate of post-fire propagules at the Baca and Alamosa refuges is even less certain. In any case, the estimated propagule density provides a starting point for assessing the potential impact of browsing.

The monitoring sections of each chapter illustrate how structural trend can be graphically portrayed using the measured data. The graphic portrayal is paired with a corroborating photograph. Four examples were used to describe how structural trend was inferred from the data and photographs.

- Early stage of structural decline: Arapaho MS2009-2
- Intermediate stage of structural decline: Baca MS2009-1.
- Advanced stage of structural decline: Lost Trail MS2009-2
- Recovering structural diversity: National Elk Refuge MS2009-2

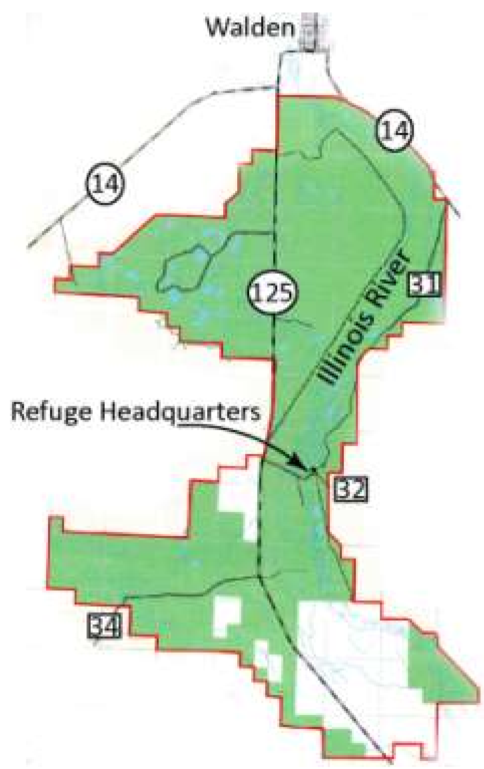
Additional Information. The Additional Information that is presented varies by refuge. At some refuges, samples were taken to more accurately reconstruct the history of browsing by counts of tree rings. It should be noted that the resulting history was typically based on a single sample, and is not the product of a systematic, formally-designed study. The resulting information provides a perspective on the kind of data that could potentially be attained. In one case (Alamosa NWR) there is speculation on the potential interaction between browsing and other factors. As above, the discussion is intended to stimulate a more comprehensive investigation.

Arapaho National Wildlife Refuge

Richard Keigley and Pam Johnson

Overview

The Arapaho National Wildlife Refuge (ARP), established in 1967, is located in north-central Colorado in a basin known as North Park. Prior to establishment of the refuge, water from the Illinois River and its tributaries was used to irrigate hay meadows. The irrigation created impoundments that were ideal waterfowl habitat. Willow communities adjacent to the Illinois River and its tributaries create habitat for Neotropical songbirds. Established under the Migratory Bird Conservation Act, the refuge is managed as habitat for migratory bird species. Since its establishment in 1967, the refuge has increased in size from 4,442 to 23,243 acres.



Ungulate Populations

Historic use. Prior to its establishment, the area was grazed by cattle and sheep.

Until the late 1980's elk were a rarity. By the late-1980's approximately 500 elk were common on and around the refuge from December to March. By the early 1990's, a resident herd of about 150 was established.

Current use. In recent years, 1,200 – 1,800 elk use riparian areas during the winter months. Approximately 20 moose (reintroduced in the late 1970's) use the riparian areas of the refuge.

Cattle are used under permit to manage refuge habitats. A small section north of the refuge headquarters and larger section to the south has not been grazed by cattle for approximately 30 years. The ungrazed sections total approximately 760 acres of riparian, meadow, and upland habitat.

General Habitat Goals

The goal for riparian habitat defined in the refuge CCP (2004):

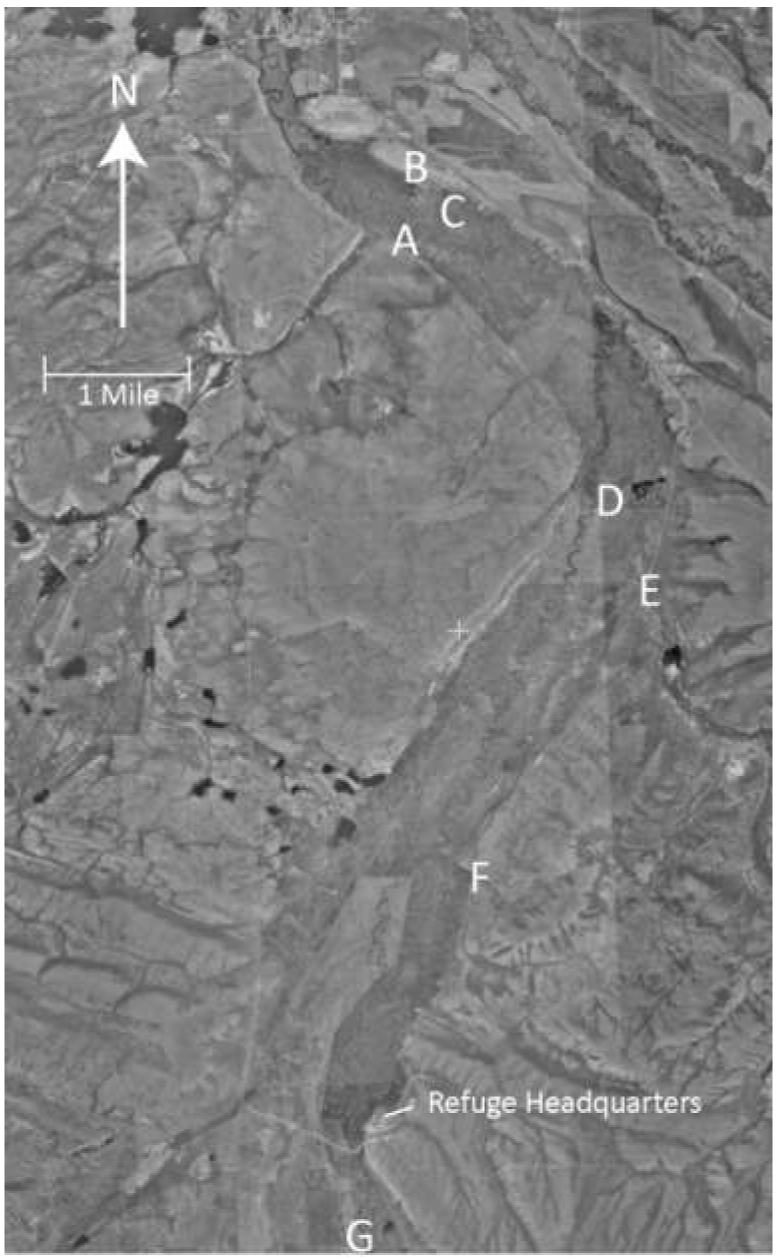
> To provide a riparian community representative of historical flora and fauna in a high valley of the southern Rocky Mountains to provide habitat for migratory birds, mammals, and river dependent species.

Habitat-types Addressed in 2009

Willow communities adjacent to the Illinois River.

2009 Landscape Level Survey

The index photograph below describes the location of landscape level surveys conducted by Pam Johnson and Richard Keigley on July 7 and 8, 2009. Six willow species are described. Due to the limited amount of time spent at each site, some willow species were likely overlooked. Particular attention was focused on locating individuals having Uninterrupted-growth-type architecture.



Site Descriptions

ARP LLS2009-A

NAD83: 40.70601° 106.27126°
Species: Various willow species.
Architectures:

- < 50 cm tall: Arrested-type Drummond willow.
- 50-150 cm tall: Arrested/Retrogressed-type Booth willow.
- 150-250 cm tall: None
- > 250 cm tall: Retrogressed-type Geyer, Booth, and Drummond.

Inferred browsing history: Light increasing to heavy.

The stand occupies a narrow corridor along the outside (eroding) bank of an Illinois River meander. Elk frequent the area in the winter; there is periodic grazing by cattle.

ARP LLS2009-B

NAD83: 40.70679° 106.27127°
Species: Various willow species.
Architectures:

- < 50 cm tall: Arrested-type Exigua.
- 50-150 cm tall: Arrested/Retrogressed-type Exigua and Booth.
- 150-250 cm tall: Arrested/Retrogressed-type Exigua.
- > 250 cm tall: Retrogressed-type Bebb.

Inferred browsing history: Light increasing to heavy.

The willows grow along a dike that forms an impoundment to the east, and along a drainage flowing northwest out of the impoundment. Elk frequent the area in the winter; there is periodic grazing by cattle.

ARP LLS2009-C

NAD83: 40.71178° 106.27127°
Species: Various willow species.
Architectures:

- < 50 cm tall: Arrested-type Geyer.
- 50-150 cm tall: Arrested/Retrogressed-type Planeleaf, Geyer, and Bebb.
- 150-250 cm tall: Arrested/Retrogressed-type Geyer
- > 250 cm tall: Retrogressed-type Geyer.

Inferred browsing history: Light increasing to heavy.

Willows at this site grow along relic channels of the Illinois River. The stand is approximately 60 m northeast of the active channel. Elk frequent the area in the winter; there is periodic grazing by cattle.

ARP LLS2009-D

NAD83: 40.67895° 106.24781°
Species: Various willow species.
Architectures:

- < 50 cm tall: Arrested-type Geyer.
- 50-150 cm tall: Arrested/Retrogressed-type Geyer.
- 150-250 cm tall: Arrested/Retrogressed-type Booth, Geyer, and Whiplash.
- > 250 cm tall: Retrogressed-type Geyer.

Inferred browsing history: Light increasing to heavy.

The stand is located on the inside of a current Illinois River meander bend. Elk frequent the area in the winter; there is periodic grazing by cattle.

ARP LLS2009-E

NAD83: 40.66890° 106.27207°
Species: Various willow species.
Architectures:

- < 50 cm tall: Uninterrupted-growth-type and Arrested-type Geyer; Uninterrupted-growth-type Planeleaf.
- 50-150 cm tall: Uninterrupted-growth-type Geyer.
- 150-250 cm tall: Retrogressed-type Geyer.
- > 250 cm tall:

Inferred browsing history: Light increasing to heavy.
The stand is located in a ditch on the east side of County Road 31, where snow likely accumulates, providing some protection from browsing. During the July 2009 survey, this was the only site where uninterrupted-growth type willow grew into the 50-to-150-cm height class. Elk frequent the area in the winter; there is periodic grazing by cattle.

ARP LLS2009-F

NAD83: 40.64173° 106.26568°
Species: Various willow species.
Architectures:

- < 50 cm tall: None.
- 50-150 cm tall: Arrested/Retrogressed-type Geyer.
- 150-250 cm tall: Retrogressed-type Geyer.
- > 250 cm tall: Retrogressed-type Geyer.

Inferred browsing history: Light increasing to heavy.

The stand is located in the interior of an Illinois River meander. Taller (older) plants appear to grow in relic channels that cross the interior of the meander. Young willows are becoming established between those channels. Elk frequent the area in the winter; there is periodic grazing by cattle.

This site was selected for monitoring.

ARP LLS2009-G

NAD83: 40.60665° 106.28056°
Species: Various willow species.
Architectures:

- < 50 cm tall: Arrested-type Planeleaf, Geyer, and Mountain.
- 50-150 cm tall: Arrested/Retrogressed-type Planeleaf, Geyer, Mountain, Booth, and Whiplash.
- 150-250 cm tall: Arrested/Retrogressed-type Geyer.
- > 250 cm tall: Retrogressed-type Geyer, Mountain, and Whiplash.

Inferred browsing history: Light increasing to heavy.

The stand is located in the interior of an Illinois River meander. Cattle were excluded from grazing approximately 30 years ago. Since that time, wild ungulates (moose and elk) have been the sole browsers. This site was selected for monitoring.

Vigorous current year growth obscures past heavy browsing. No browsed current-year-growth was observed, indicating that much of the browsing likely occurs in the fall and winter. A close-up of a browsed Geyer stem is shown in the photograph to the right.

An arrested-type Geyer is shown to the right.

Monitoring

ARP MS2009-1

NAD83: 40.64173° 106.26568° This is ARP LLS2009-F, a photograph of which is shown above.

Species monitored: Geyer willow.

Step 1: Specify target characteristics for plants greater than 2.5 m tall.

The target condition was based on attaining a density of mature Geyer willow shrubs spaced an average of 5 meters apart. Resulting density: 0.040 shrubs per square meter.

Step 2: Measure the existing density of plants that are greater than 2.5 m tall and the density of plants that are less than 2.5 m tall.

The existing density of shrubs > 2.5 m tall was measured in a 20-m-wide by 75-m-long belt transect. 13 shrubs were counted in this 1500 m^2 area.

The existing density of shrubs < 2.5 m tall was measured in a 20-m-wide by 75-m-long belt transect. 52 shrubs were counted in this 1500 m^2 area.

The resulting densities were:

Shrubs > 2.5 m: 0.009 per m^2
Shrubs < 2.5 m: 0.035 stems per m^2

Step 3: Estimate the Replacement Percentage.

Replacement Percentage is calculated by dividing the target shrub density by the number of propagules that would be present after a hypothetical fire. Each of the existing shrubs was assumed to represent a root crown that could serve as a propagule following fire. The total existing density of shrubs was used as an estimate of Propagule Density.

Replacement Percentage = 0.040 / 0.044 = 91%.

The target density of 0.04 shrubs per square meter would be attained if 91% of the existing root crowns produced shrubs that grew taller than 2.5 m.

Step 4: Calculate the threshold browsing pressure.

Threshold browsing pressure = 100 % - Replacement Percentage, or 9 %.
If browsing prevented up to 9 % of the young shrubs from growing through the browse zone, 91 % or more could potentially do so, and the target shrub density would be attained. Other factors could inhibit stand regeneration. Browsing will be deemed to be a dominant influence if the Existing Browsing Pressure exceeds the Threshold Browsing Pressure.

Step 5: Estimate a Threshold LD Index: The initial Threshold LD Index was set at 50 cm.

Step 6: Measure the Existing Browsing Pressure.

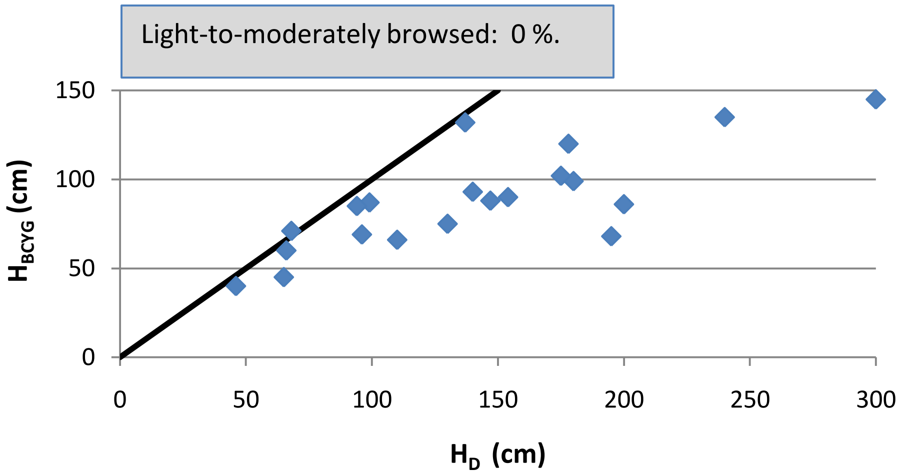
Obs	HBCYG	HD	LCYG	LD Index	Prevent?
1	90	154	6	-64	TRUE
2	93	140	1	-47	TRUE
3	132	137	13	-5	TRUE
4	71	68	2	3	TRUE
5	135	240	6	-105	TRUE
6	87	99	1	-12	TRUE
7	69	96	1	-27	TRUE
8	99	180	1	-81	TRUE
9	88	147	15	-59	TRUE
10	85	94	5	-9	TRUE
11	66	110	10	-44	TRUE
12	60	66	6	-6	TRUE
13	102	175	3	-73	TRUE
14	40	46	4	-6	TRUE
15	86	200	5	-114	TRUE
16	45	65	6	-20	TRUE
17	75	130	7	-55	TRUE
18	145	300	4	-155	TRUE
19	68	195	5	-127	TRUE
20	120	178	9	-58	TRUE
MEAN	**88**	**141**	**6**	**-53**	
SE	**6.4**	**14.4**	**0.9**	**10.1**	

Light-to-moderately-browsed: 0 %
Percent Intensely-browsed: 100 %
Existing Browsing Pressure: 100 %

Step 7: Compare Existing Browsing Pressure to Threshold Browsing Pressure.

The Existing Browsing Pressure (100 %) was greater than the Threshold Browsing Pressure (9 %), indicating that ungulate browsing will likely be a dominant factor affecting the future structure of this stand—if recent trends continue.

Structural Trend at Arapaho MS2009-1



The graph above plots the data that were collected to calculate Threshold Browsing Pressure. The height to the tallest dead, browsed annual increment is plotted on the X-Axis; height to the tallest base of current year growth is plotted on the Y-Axis. The solid line marks the point at which the two values would be equal. As this graph shows, the taller the shrub at the time of intense browsing (Measurements were restricted to those having an H_{BCYG} that was between 50 and 150 cm.), the greater the discrepancy between the height of H_{BCYG} and H_D.

Structure at Arapaho MS2009-1 is in an intermediate state of decline. Plants of intermediate height (age) are dying back to groundlevel.

The photograph on the following page visually corroborates the graphed data.

- The arrested-type shrub in the mid-foreground likely has an H_D of 50 to 60 cm; the height to base of the tallest current year growth is about the same height.

- The retrogressed-type shrub close to the background has an H_D close to 200 cm; the height to the tallest current year growth appears to be about 100 cm tall.

- The tall shrubs in the far background did not meet the sample protocol, and so were not measured. The interior of these shrubs was protected by the outer branches, and so could not be reached by ungulates. Stem grew through the interior to full height. There were no dead stems extending above the height of the tall, live stems. Where dead stems were present, their height was approximately the same as that of the tallest living stems. These stems are presumed to have died due to old age.

This combination of characteristics suggests the following. The tallest shrubs grew out of the browse zone under light browsing. These shrubs will persist until they die of old age, frost, disease, or are burned. Shrubs that had grown taller than arrest height, but shorter than 250 cm are especially vulnerable to browsing. The tallest stems of these shrubs are accessible for browsing. As these stems die due to browsing, the stems that replace them may not be mechanically protected from browsing. As a result, the shrubs die back to ground-level. The shortest shrubs are being maintained at that height by browsing. Shrubs that are currently about 50 cm tall will continue to look much as they do at present. Close examination will show that they consist of dead stems and live stems. The dead stems are typically only a few years old, indicating that browsing markedly shortens stem lifespan.

If this declining trend continues, the community will eventually consist of shrubs that are approximately 50 cm tall and shrubs that are taller than 250 cm. The density of the tall shrubs will be 0.009 per m^2; they will be spaced an average of 10 m apart.

ARP MS2009-2

NAD83: 40.60665° 106.28056° This is ARP LLS2009-G, a photograph of which is shown above.

Species monitored: Willow species diversity at this site was high. Planeleaf, Geyer, Mountain, Booth, and Whiplash were treated as a single, tall-growing willow entity.

Step 1: Specify target characteristics for plants greater than 2.5 m tall.

The target condition was based on attaining a density of mature willow shrubs spaced an average of 5 meters apart. Resulting density: 0.040 shrubs per square meter.

Step 2: Measure the existing density of plants that are greater than 2.5 m tall and the density of plants that are less than 2.5 m tall.

The existing density of shrubs > 2.5 m tall was measured in a 5-m-wide by 50-m-long belt transect. 4 shrubs were counted in this 250 m^2 area.

The existing density of shrubs < 2.5 m tall was measured in a 1-m-wide by 50-m-long belt transect. 29 shrubs were counted in this 50 m^2 area.

The resulting densities were:

Shrubs > 2.5 m: 0.016 per m^2
Shrubs < 2.5 m: 0.580 stems per m^2

Step 3: Estimate the Replacement Percentage.

Replacement Percentage is calculated by dividing the target shrub density by the number of propagules that would be present after a hypothetical fire. Each of the existing shrubs was assumed to represent a root crown that could serve as a propagule following fire. The total existing density of shrubs was used as an estimate of Propagule Density.

Replacement Percentage = 0.040 / 0.596 = 6.7%.

The target density of 0.04 shrubs per square meter would be attained if 6.7% of the existing root crowns produced shrubs that grew taller than 2.5 m.

Step 4: Calculate the threshold browsing pressure.

Threshold browsing pressure = 100 % - Replacement Percentage, or 93 %.
If browsing prevented up to 93 % of the young shrubs from growing through the browse zone, 7 % or more could potentially do so, and the target shrub density would be attained. Other factors could inhibit stand regeneration. Browsing will be deemed to be a dominant influence if the Existing Browsing Pressure exceeds the Threshold Browsing Pressure.

Step 5: Estimate a Threshold LD Index: Threshold LD Index was set at 50 cm.

Step 6: Measure the Existing Browsing Pressure.

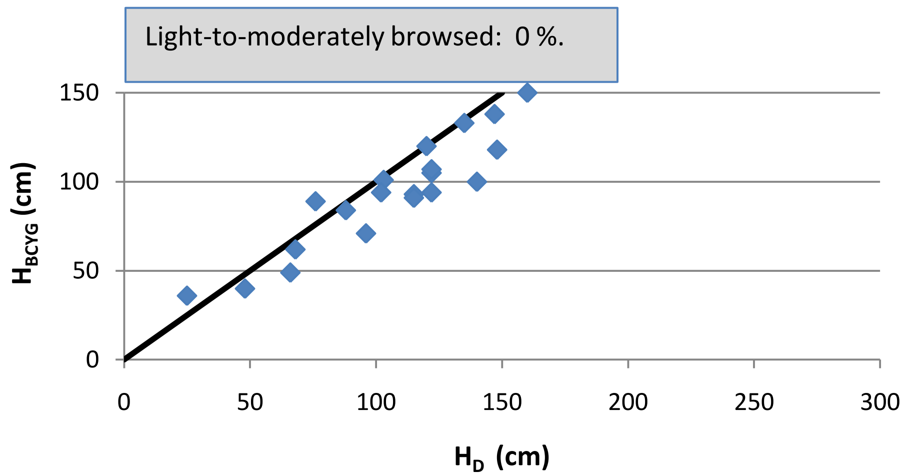
Obs	HBCYG	HD	LCYG	LD Index	Prevent?
1	133	135	5	-2	TRUE
2	49	66	6	-17	TRUE
3	100	140	6	-40	TRUE
4	71	96	9	-25	TRUE
5	93	115	4	-22	TRUE
6	40	48	7	-8	TRUE
7	36	25	7	11	TRUE
8	94	122	3	-28	TRUE
9	118	148	2	-30	TRUE
10	101	103	2	-2	TRUE
11	138	147	8	-9	TRUE
12	105	122	7	-17	TRUE
13	107	122	4	-15	TRUE
14	89	76	1	13	TRUE
15	94	102	2	-8	TRUE
16	150	160	3	-10	TRUE
17	84	88	5	-4	TRUE
18	120	120	7	0	TRUE
19	62	68	5	-6	TRUE
20	91	115	1	-24	TRUE
MEAN	**94**	**106**	**5**	**-12**	
SE	**6.9**	**7.9**	**0.5**	**3.0**	

Light-to-moderately-browsed: 0 %
Percent Intensely-browsed: 100 %
Existing Browsing Pressure: 100 %

Step 7: Compare Existing Browsing Pressure to Threshold Browsing Pressure.

At this site the Existing Browsing Pressure (100 %) was greater than the Threshold Browsing Pressure (93), indicating that ungulate browsing will likely be a dominant factor affecting the future structure of this stand—if recent trends continue.

Structural Trend at Arapaho MS2009-2



Structural trend is in an early stage of decline. All shrubs attempting to grow through the browse zone were Intensely Browsed. Most H_D and H_{BCYG} pairs fall on or just below the line marking the point where the two values are equal.

From a distance, it would appear that this stand has not been affected by browsing. Leafy stems are present at all heights. But if one examines the shrubs that are in reach of ungulates, one would find that the previous-year's-growth had been browsed to the zone of mechanical protection. The mechanical protection is provided by a thatch of dead twigs that lie just below the foliage on current-year-growth. Regardless of outward appearance, it is important to examine the region just below current-year-growth before concluding that a shrub is lightly browsed.

The situation at Arapaho MS2009-1 indicates what will happen if this trend continues.

- Stems will continue to grow unbrowsed in the interior of the tall willows (those more than 2.5-m tall). Those willows will persist until they die of old age, disease, frost, or are burned.

- The taller stems of shrubs of intermediate height will die.

- Shrubs that are currently about 50 cm tall will continue to look much as they do at present. Close examination of these shrubs will show that they consist of many dead stems and a few live stems. The live stems will be short-lived.

Additional Information

Assessing the Role of Wildlife

Because cattle have been excluded from ARP MS2009-G for approximately 30 years, the effect of browsing there is solely due to wild ungulates. At Sites A through F, cattle have been present to varying degrees for many decades. Elk were rarely seen prior to the late 1980s and moose numbers were low. At all sites, the browsing-related architectures indicate a recent history of light browsing followed by heavy browsing. During the period of light browsing, some willows grew well out of the browse zone. Cattle would have been present during this period of light browsing. At some point, browsing increased to a level that currently prevents willow height growth. Samples collected at Sites F and G date approximately when that increase occurred.

The sampled shrubs had grown part-way through the browse zone under light browsing. When browsing increased, height growth ceased. Dieback of the upper canopy produced the retrogressed-type architecture. The onset of heavy browsing can be dated using methods described in Keigley et al. (2003).

To date the change in Browsing Level, we must find a stem that elongated prior to the increase in browsing. The stem cannot have been mechanically protected from browsing. (If a stem is mechanically protected, the date of initial browsing reflects the date that the stem grew above the zone of mechanical protection.) To date the year of increase, part of the stem must be alive. The stem in the photo on the following page was collected from a shrub at Site F. Under light browsing, the shrub grew to a height of about 160 cm, after which, browsing increased preventing further height growth.

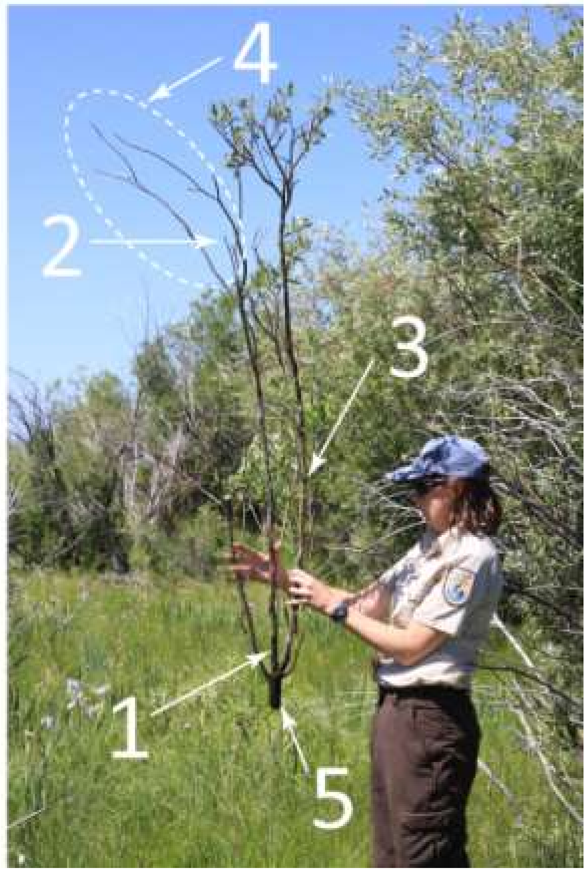
1) Vertical orientation at base marks initial elongation of the stem.

2) The stem grew to this height before it was browsed.

3) The initial stem branched at the base. Current-year-growth produced by this branch allowed the stem to survive the death of older segments.

4) After being browsed for a few years, the part of the stem that initially elongated died. The entire segment likely died at the same time. Evidence: There are no branches midway down the stem to sustain it after the upper branches died.

5) Because the base of the stem remained alive, we can approximately date the events described above.

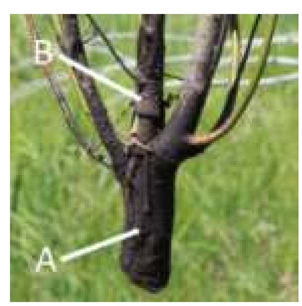


The first step in reconstructing the browsing history is to determine the total age of the stem. This is obtained by counting the number of annual rings in a section taken at point A. This stem was 20 years old.

We determine the year of elongation using the following formula:
Elongation Year =Year the section was taken – The stem's age + 1.
This stem elongated for the first time in 1990.

We assume that the stem grew from A through point B in the same year. Therefore, the stem grew through point B in 1990.

The next step is to determine the number of years it took to grow from point B to the point at which the stem was browsed the first time. This is done by counting the number of annual rings in sections taken at points B (in the photo above) and C (in the photo to the right), and subtracting C from B. If the same number of rings were counted in both B and C, the stem would have grown to point C in the same year that it initially elongated. In this case, the age at B was 11 years, and the age at C was 9 years, indicating it took 2 years to grow from point B to point C.

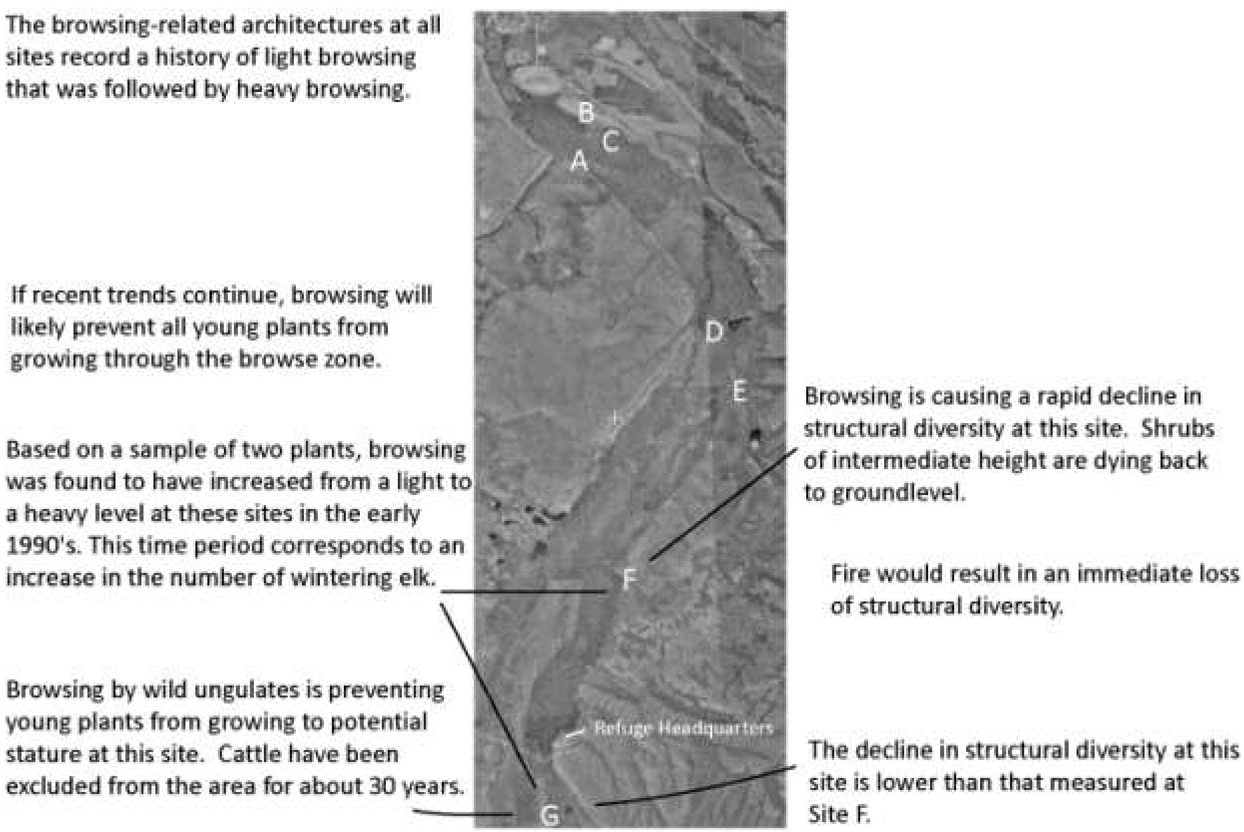


To obtain the year that the stem reached C, we add that period to the initial year of elongation: the stem reached C in 1992. The stem was browsed for the first time in 1992 or 1993. The initial segments lived for 11 years before dying back to near ground level.

A similar analysis of the stem collected at ARP MS2009-G also yielded a date of initial browsing of 1992. These dates roughly correspond to the period in which the number of wintering elk increased within the refuge.

This history was based on two samples, and is only intended to be a preview of what might result if a more-detailed study was undertaken.

Summary of Findings at Arapaho National Wildlife Refuge



National Elk Refuge

Richard Keigley and Eric Cole

Overview

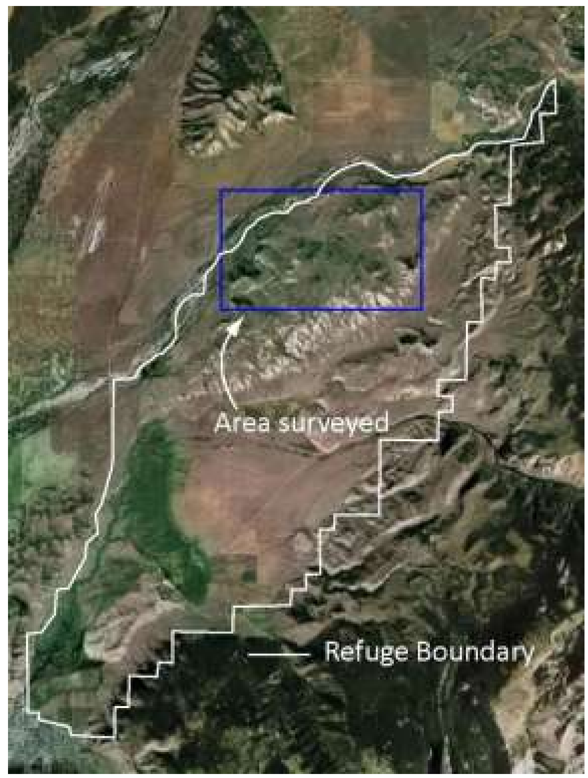
To reduce mortality in the Jackson, Wyoming area, the winter feeding of elk began in 1910. In 1912 the US government appropriated funds to purchase and maintain a winter game range now known as the National Elk Refuge. The refuge is roughly divided into northern and southern halves. Feeding operations are restricted to the southern half.

Ungulate Populations

Current use. Approximately 7,000 elk winter on the refuge, most which remain on the feedground in the south. There is negligible elk use during the summer. Approximately 800 bison and 30 – 50 bighorn sheep winter on the southern half of the refuge.

Ungulates that summer on the refuge include: 5 - 20 moose and 20 -50 mule deer.

Historic use. Livestock were present from the 1880's until establishment of the refuge in 1912. By the 1930's, all livestock use was eliminated as private parcels were sold to the refuge.



General Habitat Goals

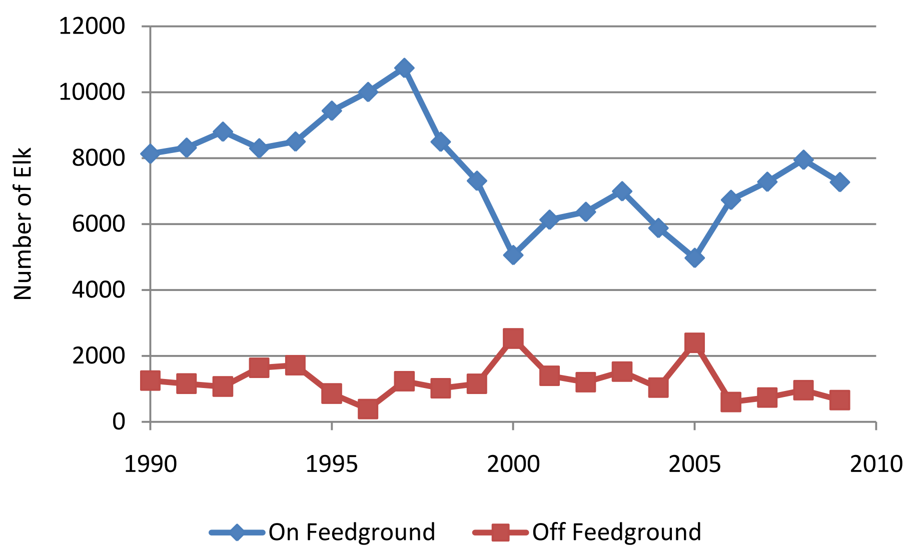
The habitat conservation goal for the refuge is to, "Provide secure, sustainable ungulate grazing habitat that is characterized primarily by native composition and structure within and among plant communities and that also provides for the needs of other native species." (2007 Final Bison and Elk Management Plan and Environmental Impact Statement for the National Elk Refuge / Grand Teton National Park / John D. Rockefeller, Jr., Memorial Parkway.) Habitat within the refuge includes wetland and riparian communities, grasslands, shrublands, and forests. The impact of elk on the southern half of the refuge is described in *Imperfect Pasture: A Century of Change at the National Elk Refuge in Jackson Hole, Wyoming* (Bruce Smith, Eric Cole, and David Dobkin. 2004. Grand Teton Natural History Association, Moose, WY). Mountain shrublands, narrowleaf cottonwood, willow, and aspen have been markedly affected.

Habitat-types Addressed in 2009

Three habitat types were examined: aspen, chokecherry, and willow. The survey and monitoring in 2009 were restricted to the northern half of the refuge where ungulate density is lower compared to than on the southern half of the refuge. *Imperfect Pastures* describes four factors for the difference in ungulate number:

- Lush vegetation adjacent to the southern area of the refuge attracts ungulates,
- Winter feeding occurs in the south,
- Snow accumulates to lesser depths in the south than in the Gros Ventre Hills to the north, and
- Elk have been consistently hunted on the northern two thirds of the refuge since the 1950's. Beginning in 2007, smaller numbers of hunters have also been allowed on the south end of NER with limited range weapons (archery, muzzle loading black powder, and shotguns).

The annual February census graphed below indicates the general elk population trends. The Off Feedground group includes elk wintering on the NER, and elk immediately east of NER on Forest Service land. Because the census is taken in February, the survey data do not reflect elk use in the late fall and early winter period.



2009 Landscape Level Survey

The index photograph below describes the location of landscape level surveys conducted by Eric Cole and Richard Keigley on June 23 and 24, 2009. The location of the survey area is delineated in the photo on page 58.

Site Descriptions

NER LLS2009-A

NAD83: 43.59571° -110.69186°
Species: Aspen
Architectures:

- < 50 cm tall: Uninterrupted-growth type.
- 50-150 cm tall: Uninterrupted-growth type and Arrested/Retrogressed-type.
- 150-250 cm tall: Arrested/Retrogressed-type.
- > 250 cm tall: Uninterrupted-growth-type; these are mature tree-size individuals.

Inferred browsing history: Light increasing to heavy, then decreasing to light.

The stand consists of two age classes: old and young. The old class consists of tree-size individuals. The smallest basal diameter in this group was about 20 cm suggesting (at the time of the survey) an age on the order of 50 – 100 years. (A core taken from a similar-sized individual at NER LLS2009-J indicates an age closer to 100 years.) The young age class consists of suckers and saplings that grow within the browse zone. The oldest of these individuals is likely less than 20 years old. We saw no live individuals in the 20 to 100 year age class (ages are approximate).

The uninterrupted-growth-type architecture of the older trees documents a period (or periods) of light browsing. These tree-size individuals were highlined after they grew through the browse zone; their lower trunks are scarred by ungulate gnawing.

The young age class consists of arrested/retrogressed-type and uninterrupted-growth-type individuals. The arrested/retrogressed-type individuals document a period of heavy browsing. The uninterrupted-growth-type individuals in the 50 to 150 cm height class indicate that browsing recently diminished.

The existing stand recorded an early period of light browsing and a late period of heavy browsing that diminished to light browsing. There is circumstantial evidence suggesting that the intervening period included episodes of heavy browsing. The highlining of aspen trees was not recent, nor was the scarring caused by the gnawing of bark. Dead arrested/retrogressed-type individuals found at the site may have grown during this intervening period.

The goal of this survey was to determine recent trends at various points across the landscape. Recent trends at this site were heavy browsing a few years ago, followed by light browsing which has persisted into the present.

NER LLS2009-B

NAD83: 43.59710° -110.69083°
Species: Geyer willow
Architectures:

- < 50 cm tall: None.
- 50-150 cm tall: Arrested-type.
- 150-250 cm tall: Retrogressed-type.
- > 250 cm tall: Retrogressed-type.

Inferred browsing history: Light increasing to heavy.

The early period of light browsing is indicated by the retrogressed type individuals that were taller than 250 cm. These individuals would have likely grown to that height having uninterrupted-growth type architecture. The conversion of those individuals to retrogressed-type architecture indicates an increase in browsing, as does the presence of retrogressed-type individuals in the 150 – 250 height class.

In contrast to the aspen stand nearby (NER LLS2009-A), the following evidence indicates that these shrubs have not experienced a period of markedly lower browsing. Some arrested-type shrubs were approximately 50 – 60 tall, with the tallest live stems being roughly at the same height as the tallest intensely-browsed, dead stems. Under light browsing, live stems could be expected to grow substantially taller than the intensely- browsed, dead stems.

NER LLS2009-C

NAD83: 43.58673° -110.68344°
Species: Aspen
Architectures:

- < 50 cm tall: Uninterrupted-growth-type and arrested-type
- 50-150 cm tall: Arrested/Retrogressed-type.
- 150-250 cm tall: Arrested/Retrogressed-type.
- > 250 cm tall: Uninterrupted-growth- type.

Inferred browsing history: Light increasing to heavy, then decreasing to light.

The tree-size aspen with uninterrupted-growth-type architecture indicate an early period of light browsing. The arrested/retrogressed-types indicate heavy browsing. Although we found no uninterrupted-growth type individuals in the 50 to 150 cm size class, the growth of stems on Intensely-browsed aspen suggests that browsing has diminished. An example is shown on the photograph to the right.

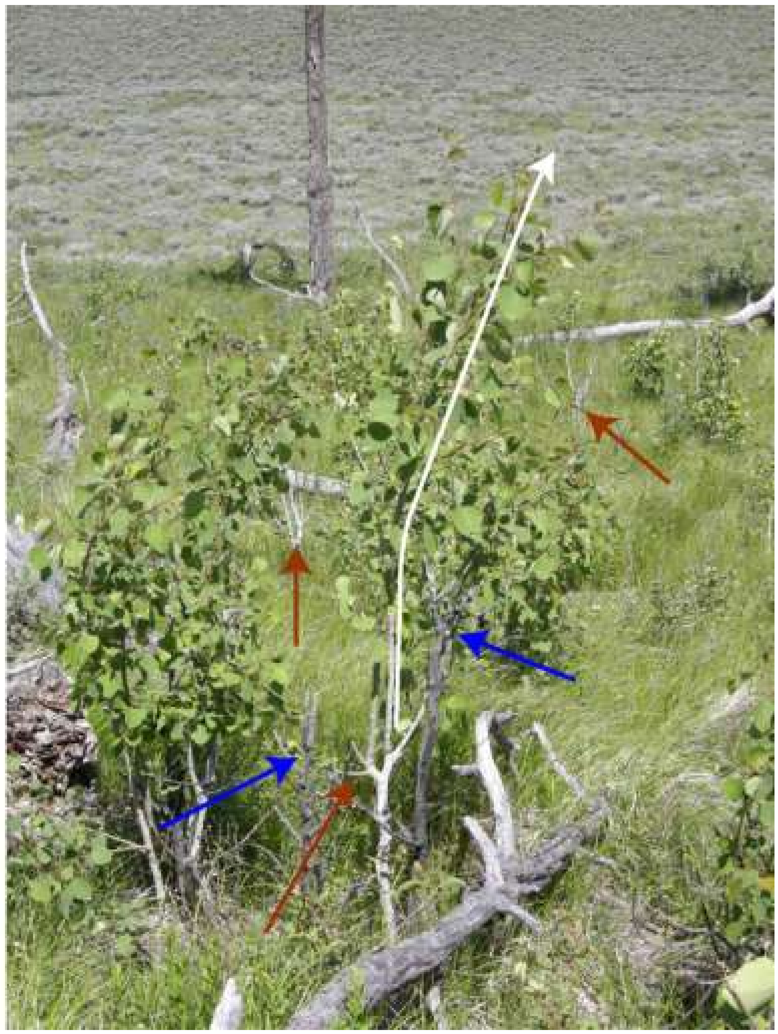
As at NER LLS2009-A, the recent trend at this site was heavy browsing followed by light browsing.

1) The oldest stems were dead; many lacked bark. These stems had been heavily browsed.
Examples are marked:

Close up of retrogressed-type individual at right center of photograph.

2) The older segments of live stems were also heavily browsed.
Examples are marked:

3) The youngest segments of live stems were lightly browsed.
A white arrow markes one example.



NER LLS2009-D

NAD83: 43.59240° -110.67633°
Species: Aspen and Chokecherry

Aspen Architectures:

- < 50 cm tall: Uninterrupted-growth-type.
- 50-150 cm tall: Arrested/ Retrogressed-type, Uninterrupted-growth-type.
- 150-250 cm tall: Uninterrupted-growth-type.
- > 250 cm tall: Uninterrupted-growth-type.

Inferred browsing history: Light increasing to heavy, then decreasing to light.

The architectures indicate the three-part history seen at Sites A and C above. At this point in the survey it seemed apparent that, over the past few years, browsing had diminished across a broad area of the landscape. The principal difference between sites was the vigor of uninterrupted-growth-type plants. At Site A there were uninterrupted-growth-type individuals in the 50 to 150 cm height class; at Site C there were no uninterrupted-growth-type individuals (but robust stem growth on arrested/retrogressed-type plants); at Site D there were uninterrupted-growth-type individuals in the 50 to 150 and 150 to 250 cm height classes.

Chokecherry Architectures:

- < 50 cm tall: Uninterrupted-growth-type, Arrested-type.
- 50-150 cm tall: Arrested/Retrogressed-type.
- 150-250 cm tall: None.
- > 250 cm tall: None.

Inferred browsing history: Light increasing to heavy.

The architectures indicate a two-part history. The retrogressed-type individuals in the 50-to-150 cm height class indicate an early period of light browsing, that was followed by an increase in browsing. A retrogressed-type individual can be seen on the left side of the photograph. Arrested-type individuals in the <50-cm height class corroborate the current period of heavy browsing.

The photograph above shows aspen and chokecherry growing side-by-side at NER LLS09-D. The aspen stem was largely unbrowsed; the adjacent chokecherry plants were heavily browsed. This suggests that chokecherry may be more-highly-preferred than aspen, and raises the question: When did the retrogressed-type chokecherry plants grow taller than arrest height (e.g., those on the left side of the photograph on the preceding page)? If the above interpretation is correct, that growth would not have occurred when the retrogressed-type aspen were being Intensely-browsed.

NER LLS2009-E

NAD83: 43.59798° -110.67588°
Species: Aspen
Architectures:

- < 50 cm tall: Arrested-type (many dead).
- 50-150 cm tall: Arrested/Retrogressed-type, Uninterrupted-growth-type.
- 150-250 cm tall: Arrested/Retrogressed-type.
- > 250 cm tall: Uninterrupted-growth-type.

Inferred browsing history: Light increasing to heavy, then decreasing to light.

The individual to the right was aged using bud scars. It elongated for the first time in 2005, and was not browsed at any time during its life. Light browsing during this five-year period was documented at other sites.

The plant was 86 cm tall (measured to the base of current-year-growth); current-year-growth was 3 cm long. The relatively low vigor of aspen growing at this site contrasts with the high vigor of aspen growing at the following site.

NER LLS2009-F

NAD83: 43.59957° -110.66008°
Aspect: Northeast-facing (60°)
Species: Aspen and Chokecherry

Aspen Architectures:

- < 50 cm tall: Uninterrupted-growth-type, Arrested-type.
- 50-150 cm tall: Arrested/ Retrogressed-type, Uninterrupted-growth-type.
- 150-250 cm tall: Arrested/Retrogressed-type Uninterrupted-growth-type.
- > 250 cm tall: Uninterrupted-growth-type, Released-type.

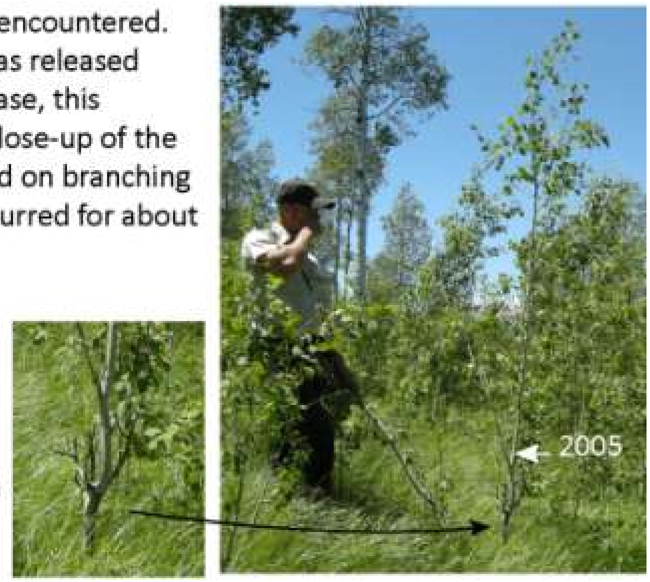
Inferred browsing history: Light increasing to heavy, then decreasing to light.

As in sites A, C, D, and E above, the tree-sized uninterrupted-growth-type individuals document a period of light browsing. The retrogressed-type individuals document relatively recent heavy browsing; the uninterrupted-growth type in the 50 to 150 and 150 to 250 cm height class document the current period of light browsing.

Relatively few released-type individuals were encountered. Under protocol, an individual is not classified as released until it grows taller than 250 cm. Prior to release, this individual had arrested-type architecture. A close-up of the lower part of the aspen is shown below. Based on branching at the base, the heavy browsing may have occurred for about five years after the stem first elongated.

Release began in 2005.

This individual is indicative of the vigorous growth that occured at NER LLS2009-F. There also many robust uninterrupted-growth type individuals in the 150 to 250 cm height class.



Site NER LLS2009-F was selected as a monitoring site.

Chokecherry Architectures:

- < 50 cm tall: Uninterrupted-growth-type, Arrested-type.
- 50-150 cm tall: Arrested/Retrogressed-type, Uninterrupted-growth-type.
- 150-250 cm tall: Arrested/Retrogressed-type.
- > 250 cm tall: Released-type.

Inferred browsing history: Light increasing to heavy, then decreasing to light.

Compared to other sites, chokecherry at NER LLS2009-F grew with unusual vigor. A dead retrogressed-type individual is shown at the left side of the photograph. Uninterrupted-growth-type chokecherry can be seen to the right.

NER LLS2009-G

NAD83: 43.60270° -110.65595°
Species: Aspen
Architectures:

- < 50 cm tall: Uninterrupted-growth-type, Arrested-type
- 50-150 cm tall: Arrested/Retrogressed-type, Uninterrupted-growth-type.
- 150-250 cm tall: Arrested/Retrogressed-type, Uninterrupted-growth-type.
- > 250 cm tall: Uninterrupted-growth-type. (One eight years old; most 50 to 100.)

Inferred browsing history: Light increasing to heavy, then decreasing to light.

Uninterrupted-growth type individuals in the 50 to 150, 150 to 250, and > 250 height classes indicates robust growth, although not as robust as NER LLS2009-F.

NER LLS2009-H

NAD83: 43.60166° -110.65470°
Aspect: South-facing (180°)
Species: Chokecherry
Architectures:

- < 50 cm tall: Uninterrupted-growth-type, Arrested-type.
- 50-150 cm tall: Arrested/Retrogressed-type.
- 150-250 cm tall: None.
- > 250 cm tall: None.

Inferred browsing history: Heavy.

This chokecherry stand is heavily browsed. This site is 0.3 miles northeast of Site F where chokecherry grew vigorously. The difference in aspect at the sites is one factor that could contribute to differences in vigor. Wind and exposure may cause snow to drift, and by doing so afford protection to browse plants as ungulates move onto the winter range.

NER LLS2009-I

NAD83: 43.59628° -110.63555°
Aspect: NW-facing.
Species: Aspen
Architectures:

- < 50 cm tall: Uninterrupted-growth-type.
- 50-150 cm tall: Arrested/Retrogressed-type, Uninterrupted-growth-type.
- 150-250 cm tall: Arrested/Retrogressed-type, Uninterrupted-growth-type.
- > 250 cm tall: Released-type, Uninterrupted-growth-type.

Inferred browsing history: Light increasing to heavy, then decreasing to light.

A released-type individual is shown to the right. Release began in 2005.

NER LLS2009-J

NAD83: 43.60041° -110.66086°
Aspect: N-facing.
Species: Aspen
Architectures:

- < 50 cm tall: Uninterrupted-growth-type.
- 50-150 cm tall: Arrested/Retrogressed-type, Uninterrupted-growth-type.
- 150-250 cm tall: Uninterrupted-growth-type.
- > 250 cm tall: Released-type, Uninterrupted-growth-type.

Inferred browsing history: Light increasing to heavy, then decreasing to light.

The architectures at this site document a history similar other sites. The presence of uninterrupted-growth-type individuals in all height classes indicates robust growth.

This site is located 110 m northwest of Site F. When viewed from a distance (prior to surveying), the site appeared to be less vigorous than Site F. Because of its close proximity to Site F, NER LLS2009-J was added as survey site. It was also selected as a monitoring site.

Monitoring

NER MS2009-1

NAD83: 43.60041° -110.66086° This is NER LLS2009-J, a photograph of which is shown above.

Species monitored: Aspen

Step 1: Specify target characteristics for plants greater than 2.5 m tall.

The target condition was based on attaining a density of mature aspen stems spaced an average of 2 meters apart. Density was calculated as: $1 / (\text{Spacing})^2$. Resulting density: 0.25 stems per square meter.

Step 2: Measure the existing density of plants that are greater than 2.5 m tall and the density of stems that are less than 2.5 m tall.

At the location selected for monitoring, relatively few young plants grew in the vicinity of tree-size individuals. A tape was run down the boundary between young plants and older trees. The density of tree-sized individuals was measured on one side of the tape, the density of young plants on the other. Note that the existing stem density of tree sized individuals was not used to calculate the target stem density.

The existing density of stems > 2.5 m tall was measured in a 10-m-wide by 40-m-long belt transect. 19 stems were counted in this 400 m^2 area.

The existing density of stems < 2.5 m tall was measured in a 3-m-wide by 40-m-long belt transect. 64 stems were counted in this 120 m^2 area.

The resulting stem densities were:

> 2.5 m: 0.05 stems per m^2

< 2.5 m: 0.53 stems per m^2

Step 3: Estimate the Replacement Percentage.

Replacement Percentage is calculated by dividing the target stem density by the number of propagules that would be present after a hypothetical fire. The existing density of stems shorter than 2.5-m-tall was used as estimate of Propagule Density.

Replacement Percentage = 0.25 / 0.53 = 47%.

The target density of 0.25 stems per square meter would be attained if 47 % of the propagules grew to tree stature. This is rough approximation based on current information. The sucker density after an actual fire would likely be much different.

Step 4: Calculate the threshold browsing pressure.

Threshold browsing pressure = 100 % - Replacement Percentage, or 53 %. If browsing prevented up to53 % of the propagules from growing through the browse zone,47 % or more could potentially do so, and the target stem density would be attained. Other factors could inhibit stand regeneration. Browsing will be deemed to be a dominant influence if the Existing Browsing Pressure exceeds the Threshold Browsing Pressure.

Step 5: Estimate a Threshold LD Index. The initial Threshold LD Index was set at 50 cm.

Step 6: Measure the Existing Browsing Pressure.

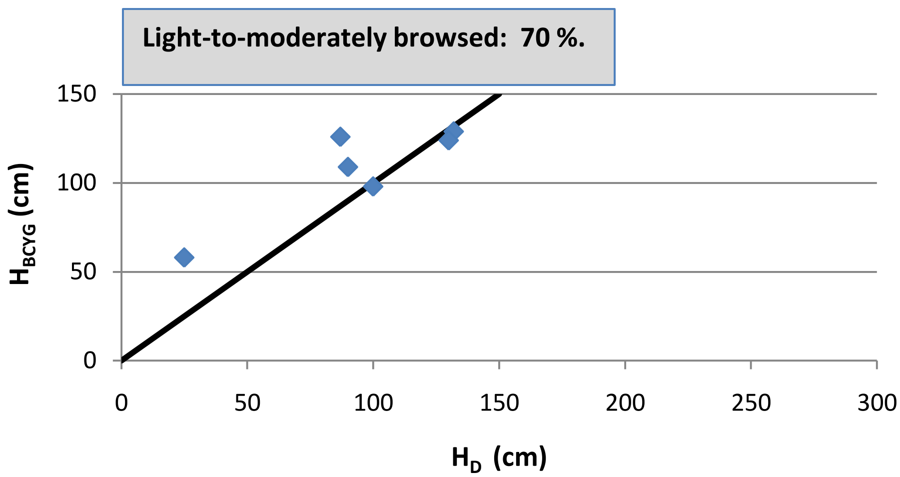
Obs	HBCYG	HD	LCYG	LD Index	Prevent?
1	123		17	NA	FALSE
2	129	132	16	-3	TRUE
3	124	130	2	-6	TRUE
4	126	87	3	39	TRUE
5	98	100	1	-2	TRUE
6	114		18	NA	FALSE
7	109	90	1	19	TRUE
8	58		8	NA	FALSE
9	122		10	NA	FALSE
10	148		15	NA	FALSE
11	68		1	NA	FALSE
12	106		1	NA	FALSE
13	74		2	NA	FALSE
14	101		1	NA	FALSE
15	105		15	NA	FALSE
16	100		11	NA	FALSE
17	58	25	9	33	TRUE
18	102		10	NA	FALSE
19	94		6	NA	FALSE
20	98		3	NA	FALSE
MEAN	**103**	**94**	**8**	**13**	
SE	**5.3**	**15.9**	**1.4**	**8.1**	

Light-to-moderately-browsed: 70 %
Percent Intensely-browsed: 30 %
Existing Browsing Pressure: 30 %

Step 7: Compare Existing Browsing Pressure to Threshold Browsing Pressure.

At this site the Existing Browsing Pressure (30 %) was less than the Threshold Browsing Pressure (53 %), indicating that ungulate browsing would likely not be a dominant factor affecting the future structure of this stand—if recent trends continue.

Structural Trend at NER MS2009-1



Structural trend is improving. At this site, all improvement is due to growth of young light-to-moderately browsed aspen into the browse zone. Although some Intensely-browsed plants had grown taller, none had an LD Index greater than the Threshold Value of 50 cm. See NER MS2009-2 for a discussion of improving structural trend.

In the area occupied by the young plants, the present stem density is 0.53 /m^2. At an Existing Browsing Pressure of 30 %, 70 % of these stems are predicted to grow through the browse zone producing a density of 0.37 stem per m^2. At this density, stems would be spaced approximately 1.6 m apart. Factors such as climate and disease will influence the actual stand density.

NER MS2009-2

NAD83: 43.59957° -110.66008° This is NER LLS2009-F, a photograph of which is shown above.

Species monitored: Aspen

Step 1: Specify target characteristics for plants greater than 2.5 m tall.

The target condition was based on attaining a density of mature aspen stems spaced an average of 2 meters apart. Density was calculated as: 1 / $(\text{Spacing})^2$. Resulting density: 0.25 stems per square meter.

Step 2: Measure the existing density of plants that are greater than 2.5 m tall and the density of stems that are less than 2.5 m tall.

The existing density of plants > 2.5 m tall was measured in a 10-m-wide by 50-m-long belt transect. 33 stems were counted in this 500 m2 area.

The existing density of plants < 2.5 m tall was measured in a 2-m-wide by 22-m-long belt transect. 21 stems were counted in this 44 m2 area.

The resulting densities were:

> 2.5 m: 0.07 stems per m^2
< 2.5 m: 0.48 stems per m^2

Step 3: Estimate the Replacement Percentage.

Replacement Percentage is calculated by dividing the target stem density by the number of propagules that would be present after a hypothetical fire. The existing density of stems shorter than 2.5-m-tall was used as estimate of Propagule Density.

Replacement Percentage = 0.25 / 0.48 = 52 %.

The target density of 0.25 stems per square meter would be attained if 47 % of the propagules grew to tree stature. This is rough approximation based on current information. The sucker density after an actual fire would likely be much different.

Step 4: Calculate the Threshold Browsing Pressure.

Threshold browsing pressure = 100 % - Replacement Percentage, or 48 %. If browsing prevented up to 48 % of the propagules from growing through the browse zone,52 % or more could potentially do so, and the target stem density would be attained. Other factors could inhibit stand regeneration. Browsing will be deemed to be a dominant influence if the Existing Browsing Pressure exceeds the Threshold Browsing Pressure.

Step 5: Estimate a Threshold LD Index. The initial Threshold LD Index was set at 50 cm.

Step 6: Measure the Existing Browsing Pressure.

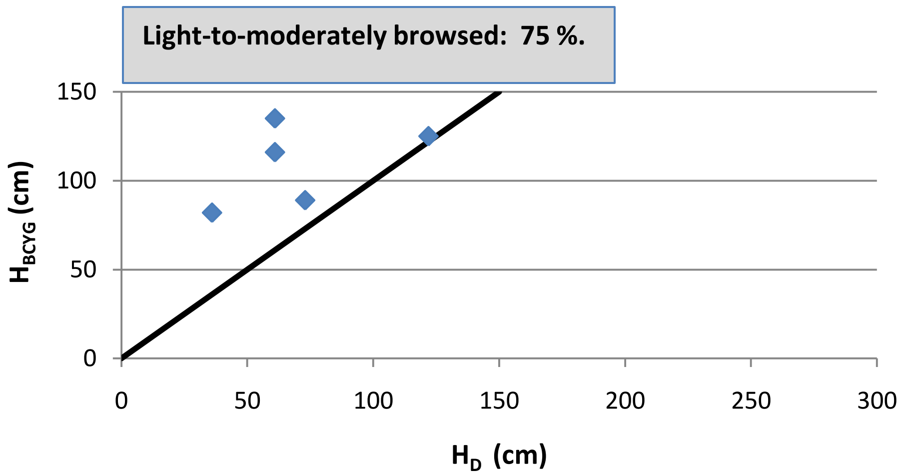
Light-to-moderately-browsed: 75 %
Percent Intensely-browsed: 25 %
Existing Browsing Pressure: 15 %

Obs	HBCYG	HD	LCYG	LD Index	Prevent?
1	86		14	NA	FALSE
2	89	73	5	16	TRUE
3	82	36	1	46	TRUE
4	121		6	NA	FALSE
5	79		3	NA	FALSE
6	83		18	NA	FALSE
7	127		11	NA	FALSE
8	75		6	NA	FALSE
9	116	61	4	55	FALSE
10	125	122	7	3	TRUE
11	104		3	NA	FALSE
12	135	61	15	74	FALSE
13	106		14	NA	FALSE
14	110		1	NA	FALSE
15	119		3	NA	FALSE
16	124		9	NA	FALSE
17	125		8	NA	FALSE
18	149		14	NA	FALSE
19	50		17	NA	FALSE
20	101		2	NA	FALSE
MEAN	**105**	**71**	**8**	**39**	
SE	**5.5**	**14.2**	**1.2**	**13.0**	

Step 7: Compare Existing Browsing Pressure to Threshold Browsing Pressure.

At this site the Existing Browsing Pressure (15 %) was less than the Threshold Browsing Pressure (48 %), indicating that ungulate browsing would likely not be a dominant factor affecting the future structure of this stand—if recent trends continue.

Structural Trend at NER MS2009-2

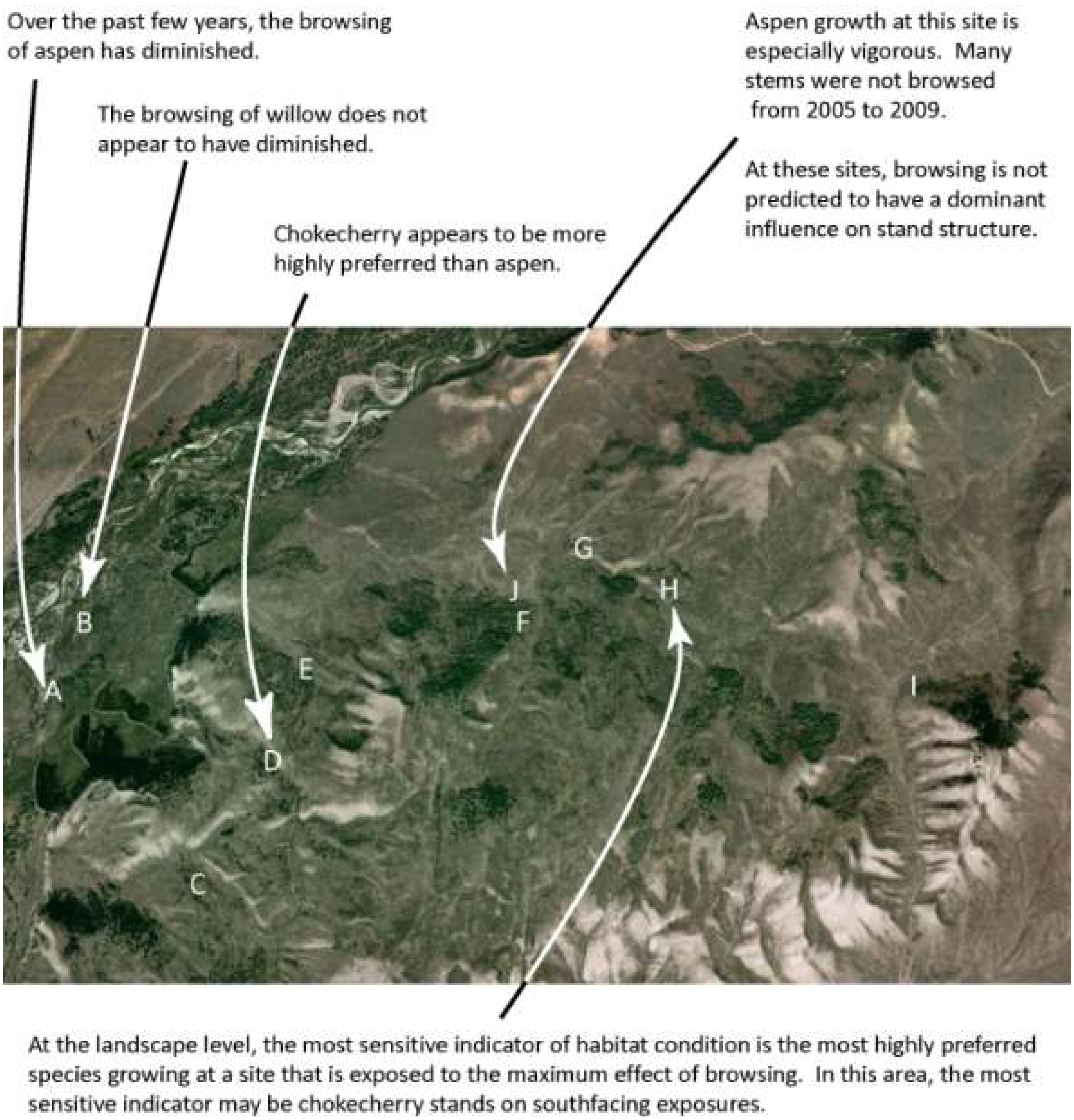


Structural trend is improving. Most of the improvement is due to the growth of young Light-to-moderately browsed plants (75 % of those sampled). Some improvement is due to the height-growth of plants that were Intensely-browsed in the past (i.e., those having LD Indexes that were greater than 50 cm; this was 10 % of the sampled plants). The released-type plant pictured in NER LLS2009-F is an example of this kind of growth. (Note that the pictured plant would have exceeded the height specified by the measurement protocol and would not be measured.) By examining the stem of such plants we determined that growth into browse zone had occurred since 2005.

In many cases (including NER MS2009-1), the improvement in trend is exclusively due to the growth of young Light-to-moderately browsed plants. Where plants have been stressed by browsing and then protected from browsing (as with the construction of a big game exclosure), it is not uncommon for Intensely-browsed plants to have LD Indexes of about zero, and nearby have Light-to-moderately browsed plants growing vigorously into the browse zone.

The present density of all stems is 0.54 /m^2. At an Existing Browsing Pressure of 15 %, 85 % of these stems are predicted to grow through the browse zone producing a density of 0.50 stem per m^2. At this density, stems would be spaced approximately 1.5 m apart. Factors such as climate and disease will influence the actual stand density.

Summary of Findings

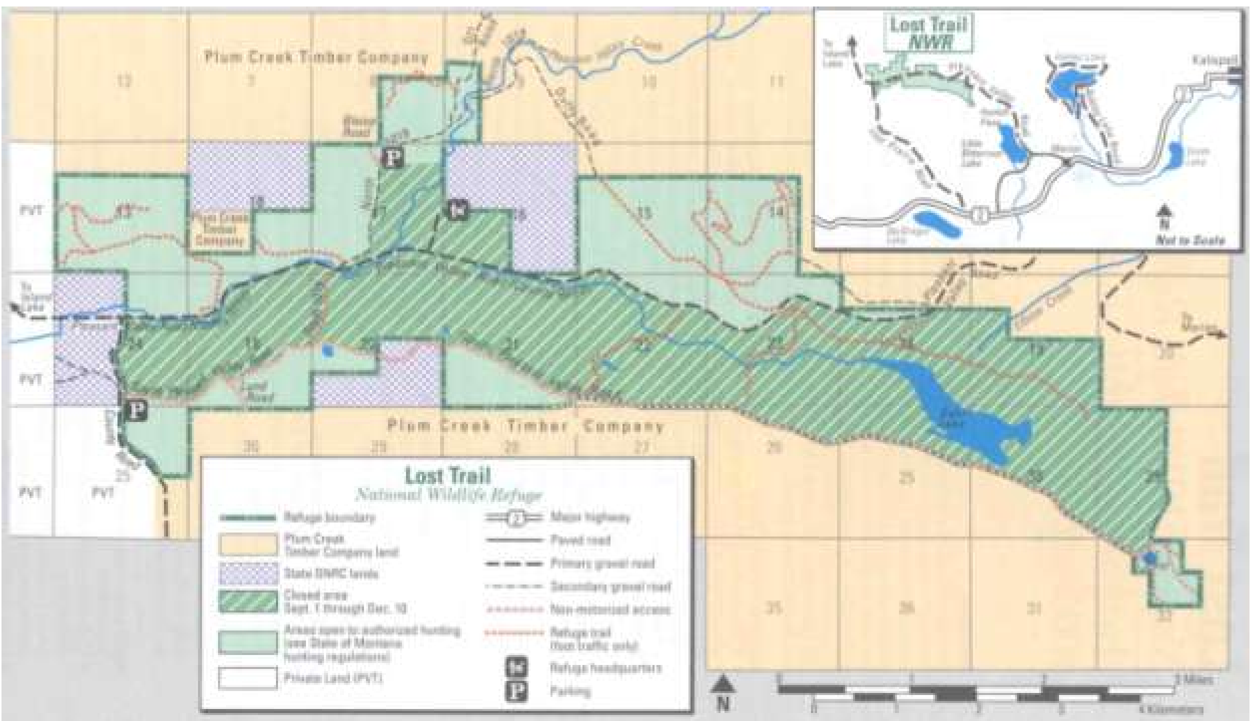


Lost Trail NWR

Richard Keigley and Lynn Verlanic

Overview

Lost Trail National Wildlife Refuge (NWR) is located in northwest Montana, in the west-central portion of Flathead County in the drainage known as Pleasant Valley. The 9,225 acre Refuge was acquired in August 1999. Prior to acquisition, Refuge lands were privately owned and managed as a cattle and horse ranch known as Lost Trail Ranch. Plant communities within the refuge include wetland and riparian communities, grasslands, shrublands, and forests.



Ungulate Populations

Current use. The refuge is winter range for approximately 350 elk that occupy the south-facing slope north of the county road. Approximately 20 to 30 elk are resident year round. Approximately 5 moose are present in the spring, summer, and fall. A small number of white-tail deer and mule deer are also present.

Historic use. The Lost Trail Ranch was heavily stocked year-round with cattle. The presence of livestock may have discouraged use by wild ungulates. Cattle were removed by 2000. Use by wild ungulates may have subsequently increased due to the absence of livestock.

General Habitat Goals

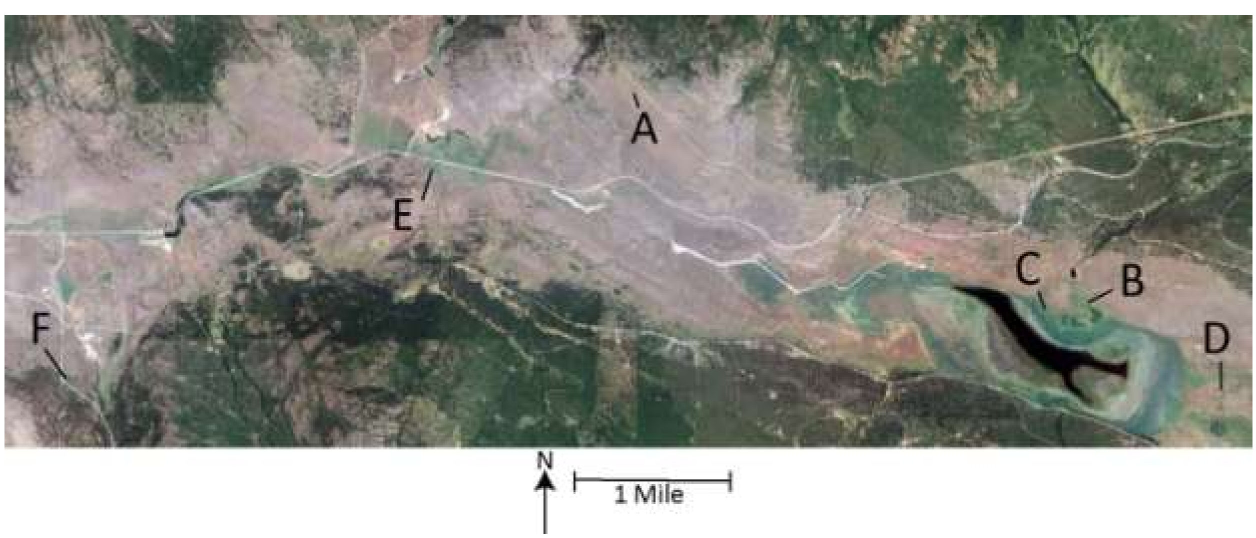
Habitat goals are defined in the Lost Trail NWR Comprehensive Conservation Plan. The assessment of existing conditions and restoration of appropriate habitat are two components (p. 57). With respect to that restoration, the past effects of cattle ranching and the current impacts of wildlife are two aspects that should be considered when developing management strategies.

Habitat-types Addressed in 2009

Two types were examined: aspen and willow.

2009 Landscape Level Survey

Data were collected June 16, 2009 by Lynn Verlanic and Richard Keigley, assisted by Skyler Kincaid. The photograph below describes the location of six Landscape-Level Survey sites (A – F). Pleasant Valley runs through the central part of the photo.



Site Descriptions

LTR LLS2009-A

NAD83: 48° 11.523 N 114° 53.164 W
Topographic Position: South-facing slope.
Species: Aspen
Architectures:
< 50 cm tall: Uninterrupted-growth-type and Arrested-type (see p. 9).
50-150 cm tall: Uninterrupted-growth-type, Arrested-type, and Retrogressed-type.
150-250 cm tall: A single Retrogressed-type.
> 250 cm tall: none.

Inferred browsing history: Light increasing to heavy, decreasing to light.

Live stems were aged by bud scars. Basal stem diameter was taken into consideration for stems too old to be reliably aged by bud scars. The oldest live stems appear to be about 10 - 12 years old. A single downed trunk is evidence that aspen once grew to tree stature under light browsing.

The oldest live stems were hedged by browsing soon after they elongated. This could have occurred before livestock were removed from the area. This south-facing slope is currently used as winter range by elk. Younger stems are browsed. The presence of uninterrupted-growth type individuals indicates that some aspen may grow through the browse zone. The question is: Will a sufficient number of stems grow through the browse zone to establish the desired habitat conditions? This stand was selected as a monitoring site.

LTR LLS2009-B

NAD83: 48° 10.284 N 114° 49.350 W
Topographic Position: Valley bottom.
Species: Aspen
Architectures:

- < 50 cm tall: Uninterrupted-growth-type and Arrested-type.
- 50 - 150 cm tall: none.
- 150 -250 cm tall: none.
- > 250 cm tall: Uninterrupted-growth-type trees.

Inferred browsing history: Light increasing to heavy.

The live, tree-size stems were approximately 15 cm in diameter. The stems were not aged by counting annual rings; a rough estimate was based on stem diameter. The youngest live stems to grow through the browse zone appear to be on the order of 30-to-40 years old. The uninterrupted-growth type architecture indicates that, when these stems grew through the browse zone, browsing was relatively light. The highlining of these trees indicates that after the stems grew through the browse zone, browsing increased.

There were many short, dead, browsed suckers, some of which would be classified as Intensely-browsed: A living stem has a complete annual increment that is dead and was browsed. This condition requires a minimum of three years to develop. Other stems appear to have died within a year or two of elongation. Growth regulators produced by the parent aspen stems could play a role in the mortality of these stems. However, the intense browsing of suckers some distance from the stands suggests that browsing is the dominant factor.

The absence of individuals in the 50-to-150 cm height class suggests that browsing has been heavy for a number of years, perhaps extending to the time that the youngest tall stem grew through the browse zone. Because browsing has prevented suckers from growing taller than 50 cm, it appears that this site is more heavily browsed than Site A described above, where suckers have recently grown well into the browse zone.

LTR LLS2009-C

NAD83: 48° 10.137 N 114° 49.657 W
Topographic Position: Valley bottom.
Species: Geyer and Bebb willow.
Architectures:

- < 50 cm tall: none.
- 50 - 150 cm tall: none.
- 150 – 250 cm tall: Retrogressed-type.
- > 250 cm tall: Retrogressed-type.

Inferred browsing history: Light increasing to heavy.

The stand is approximately 80 meters north of Dahl Lake. Bebb and Geyer willow were present.

A longer-range view of the area is shown in the photo to the right. The measured stand was part of an elongate arc of willow that was approximately 500 m long. The willows may mark an old shoreline of Dahl Lake, stream channel, or ditch.

Surrounding the willows is a dense stand of reed canarygrass. On June 16, 2009 there was approximately 10 cm of standing water. In places the thatch of reed canarygrass was thick enough to allow for dry passage through the standing water.

The retrogressed-type architecture is evidence of light browsing that allowed the willows to grow through the browse zone, followed by heavy browsing. Some willows have the mushroom-type shape indicative of rubbing by livestock.

The absence of willows less than 150-cm-tall indicates that this willow stand is not regenerating. Three factors could play a role:

- When the seeds disperse in mid-June, the area is covered by standing water. Moist, exposed mineral soil provides the optimum willow seedbed. Because these seeds remain viable for only a few days, they are an unlikely source of regeneration when the area becomes drier later in the growing season.

- If hydrologic conditions were such that seeds could germinate, the dense stand of reed canarygrass would inhibit the growth of seedlings. The dense thatch of lodged reed canarygrass would also inhibit vegetative propagation from the root crown or by branch layering.

- The heavy browsing of aspen nearby (LTR LLS2009-B and LTR LLS2009-D) indicates that browsing would likely prevent the height growth of regenerating willow.

LTR LLS2009-D

NAD83: 48° 9.851 N 114° 48.069 W
Topographic Position: Valley bottom.
Species: Aspen
Architectures:

- < 50 cm tall: Uninterrupted-growth-type and Arrested-type.
- 50 - 150 cm tall: none.
- 150 – 250 cm tall: none.
- > 250 cm tall: Uninterrupted-growth-type trees.

Inferred browsing history: Light increasing to heavy.

This stand is a little over a mile east of Site B. The situation appears to be similar: Browsing is preventing height growth. The clumps in the foreground are young, heavily-browsed aspen.

LTR LLS2009-E

NAD83: 48° 11.074 N 114° 54.882 W
Topographic Position: Valley bottom.
Species: Geyer and Bebb willow
Architectures:

- < 50 cm tall: Uninterrupted-growth-type and Arrested-type.
- 50-150 cm tall: Arrested-type.
- 150 – 250 cm tall: Retrogressed-type.
- > 250 cm tall: Retrogressed-type.

Inferred browsing history: Light increasing to heavy.

The tall retrogressed-type shrubs in the background grow along the side of a ditch. These shrubs are relatively old. The short shrubs in the foreground are relatively young. The age of stems was determined by examining bud scars. The older stems associated with the short shrubs were on the order of 8 years of age. Willow is expanding away from the parent shrubs adjacent to the ditch. The plants are apparently being established from seed. Conifers are establishing in the same area.

The presence of arrested- and retrogressed-type architectures is evidence that browsing could be a major influence on height growth. This site was selected for monitoring.

LTR LLS2009-F

NAD83: 48° 9.868 N 114° 57.918 W
Topographic Position: Valley bottom; at base of north-facing slope.
Species: Aspen and Serviceberry
Architectures (both species):

- < 50 cm tall: Uninterrupted-growth-type and Arrested-type.
- 50 - 150 cm tall: Uninterrupted-growth-type, Arrested-type, and Retrogressed-type.
- 150 – 250 cm tall: (not recorded).
- > 250 cm tall: Uninterrupted-growth-type.

Inferred browsing history: Light increasing to heavy.

Although the retrogressed-type plants indicate an increased in browsing, the presence of uninterrupted-growth-type aspen in the 50-to-150 cm height class suggests that browsing has had less of an impact at this site compared to its influence at sites A, B, and D. Serviceberry at this site (seen in the foreground) was extremely hedged, however browsing appears to have diminished in recent years.

Monitoring

LTR MS2009-1

Location: NAD83 : 48° 11.523 N 114° 53.164 W
(Same as LTR LLS2009-A)

Species monitored: Aspen

Step 1: Specify target characteristics for plants greater than2.5 m tall.

The target condition was based on attaining a density of mature aspen stems spaced an average of 2 meters apart. Density was calculated as: 1 / $(\text{Spacing})^2$. Resulting density: 0.25 stems per square meter.

Step 2: Measure the existing density of plants that are greater than 2.5 m tall and the density of stems that are less than 2.5 m tall.

Existing plant density was measured in 1-m-wide X 19-m-long belt transect. No plants > 2.5 m tall were present; there were 46 plants that were < 2.5 m tall.

- > 2.5 m: 0.0 stems / m^2
- < 2.5 m: 2.3 stems / m^2

Step 3: Estimate the Replacement Percentage.

Replacement Percentage is calculated by dividing the target stem density by the number of propagules that would be present after a hypothetical fire. The existing density of stems shorter than 2.5-m-tall was used as estimate of Propagule Density.

Replacement Percentage = 0.25 / 2.4 = 10 %.

The target density of 0.25 stems per square meter would be attained if 10 % of the propagules grew through the browse zone.

Step 4: Calculate the threshold browsing pressure.

Threshold browsing pressure = 100 % - Replacement Percentage, or 90 %. If browsing prevented up to 90 % of the propagules from growing through the browse zone, 10 % or more could potentially do so, and the target stem density would be attained.

Step 5: Estimate a Threshold LD Index.

The initial Threshold LD Index was set at 50 cm.

Step 6: Measure the Existing Browsing Pressure.

Obs	HBCYG	HD	LCYG	LD Index	Prevent?
1	75	78	11	-3	TRUE
2	73	50	8	23	TRUE
3	69	45	22	24	TRUE
4	140	89	10	51	FALSE
5	120	104	18	36	TRUE
6	89		18	NA	FALSE
7	68	106	25	-17	TRUE
8	68	46	21	22	TRUE
9	75		19	NA	FALSE
10	74		10	NA	FALSE
11	52		11	NA	FALSE
12	67	46	28	6	TRUE
13	68	67	1	0	TRUE
14	60		13	NA	FALSE
15	50	78	9	-18	TRUE
16	49	37	11	13	TRUE
17	47	36	16	13	TRUE
18	88	74	7	-27	TRUE
19	86		5	NA	FALSE
20	82		8	NA	FALSE
MEAN	**75**	**66**	**14**	**9**	
SE	**5.4**	**6.8**	**1.6**	**6.2**	

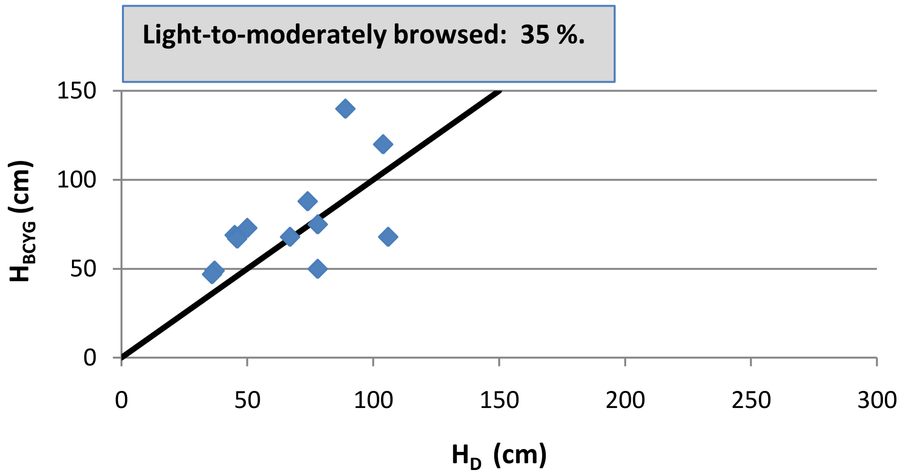
Light-to-moderately-browsed: 35 %
Percent Intensely-browsed: 65 %
Existing Browsing Pressure: 60 %

Step 7: Compare Existing Browsing Pressure to Threshold Browsing Pressure.

The regulation of browsing pressure is based on a comparison of the Existing Browsing Pressure with the Threshold Browsing Pressure. At this site the Existing Browsing Pressure (60%) was less than the Threshold Browsing Pressure (90%), indicating that ungulate browsing will likely not be a dominant factor affecting the future structure of this stand.

Structural Trend at LTR MS2009-1

Structure at this site is in an improving trend. Light-to-moderately browsed plants are growing into the browse zone. Some Intensely-browsed plants are gaining height.



Predicted Stand Density if Present Trend Continues

The present total stem density is 2.4 /m^2. At an Existing Browsing Pressure of 60%, 40% of these stems are predicted to grow through the browse zone producing a density of 1 stem per m^2. At a density of 1 stem per m^2, stems would be spaced approximately 1 m apart. Factors such as climate and disease will influence stand density.

LTR MS2009-2

Location: NAD83: 48° 11.074 N 114° 54.882 W
(Same as LTR LLS2009-E)

Species monitored: Geyer willow

Step 1: Specify target characteristics for plants greater than2.5 m tall.

The target condition was based on attaining a density of shrubs spaced an average of 2 meters apart. Density was calculated as: 1 / $(\text{Spacing})^2$. The resulting density is: 0.25 stems per square meter.

Step 2: Measure the existing density of plants that are greater than 2.5 m tall and the density of stems that are less than 2.5 m tall.

Clusters of stems were treated as individuals. The density of clusters was measured in a 2-m-wide X 50-m-long belt transect. No stem clusters > 2.5 m tall were present; there were 57 stem clusters that were < 2.5 m tall.

- > 2.5 m: 0 stems / m^2
- < 2.5 m: 0.57 stems / m^2

Step 3: Estimate the Replacement Percentage.

The existing density of stem clusters in all height classes was used as estimate of Propagule Density.

Replacement Percentage = Target Density / Propagule Density, or 0.25 / 0.57 = 44 %.

The target density of 0.25 stems per square meter (shrubs spaced 2 meters apart) would be attained if 44 % of the propagules grow through the browse zone.

Step 4: Calculate the threshold browsing pressure.

Threshold browsing pressure = 100 % - 44 % = 56 %.

Step 5: Estimate a Threshold LD Index. The initial Threshold LD Index was set at 50 cm.

Step 6: Measure the Existing Browsing Pressure.

Obs	HBCYG	HD	LCYG	LD Index	Prevent?
1	52	10	2	42	TRUE
2	47	58	4	-11	TRUE
3	37	63	3	-26	TRUE
4	78	68	3	10	TRUE
5	53		4	NA	FALSE
6	49	38	3	11	TRUE
7	40	47	5	-7	TRUE
8	63	66	3	-3	TRUE
9	87	70	4	17	TRUE
10	66	64	1	2	TRUE
11	50	56	4	-6	TRUE
12	54	52	2	2	TRUE
13	60	47	2	13	TRUE
14	66	52	2	14	TRUE
15	64	40	1	24	TRUE
16	76	56	4	20	TRUE
17	63	58	5	5	TRUE
18	73	68	4	5	TRUE
19	57		2	NA	FALSE
20	75	60	4	15	TRUE
MEAN	**61**	**54**	**3**	**7**	
SE	**2.9**	**3.4**	**0.3**	**3.6**	

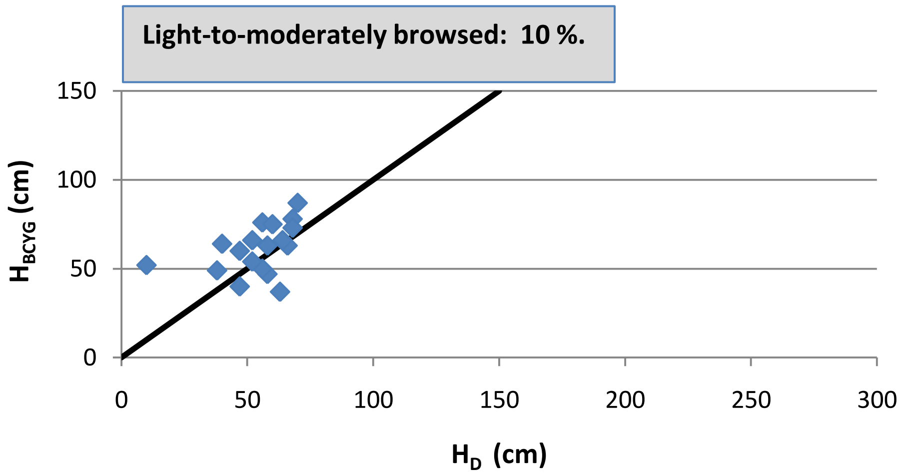
Light-to-moderately-browsed: 10 %
Percent Intensely-browsed: 90 %
Existing Browsing Pressure: 90 %

Step 7: Compare Existing Browsing Pressure to Threshold Browsing Pressure.

At this site the Existing Browsing Pressure (90%) was greater than the Threshold Browsing Pressure (56 %), indicating that ungulate browsing would likely be a dominant factor affecting the future structure of this stand.

Structural Trend at LTR MS2009-2

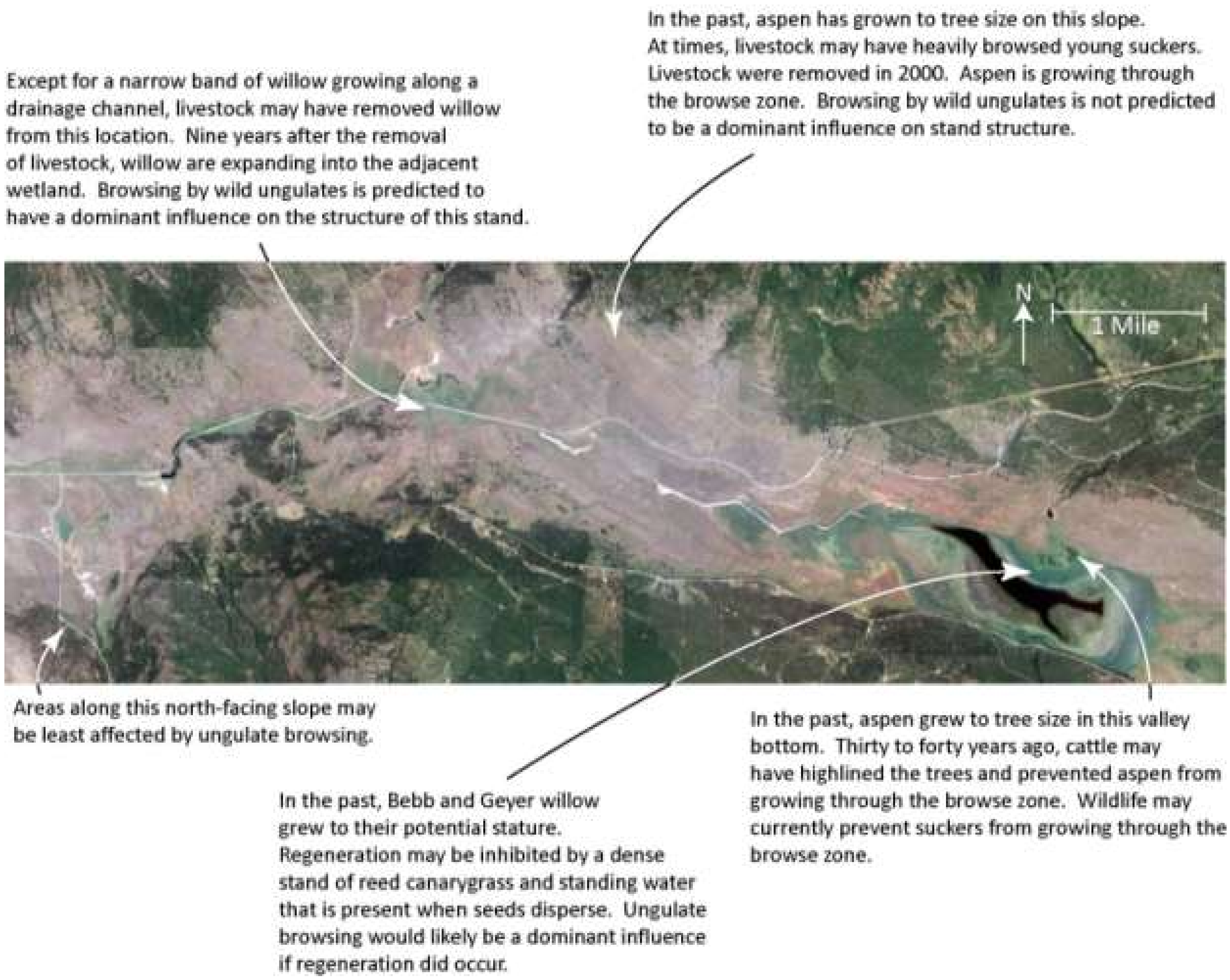
Structure is in a declining trend. Intensely-browsed plants are not significantly growing taller.



Predicted Stand Density if Present Trend Continues

The present total stem density is 0.5 /m^2. At an Existing Browsing Pressure of 90%, 10% of these stems are predicted to grow through the browse zone producing a density of 0.05 stem per m^2. At a density of 0.05 stem per m^2, stems would be spaced approximately 4 m apart. Factors such as climate and disease will influence stand density.

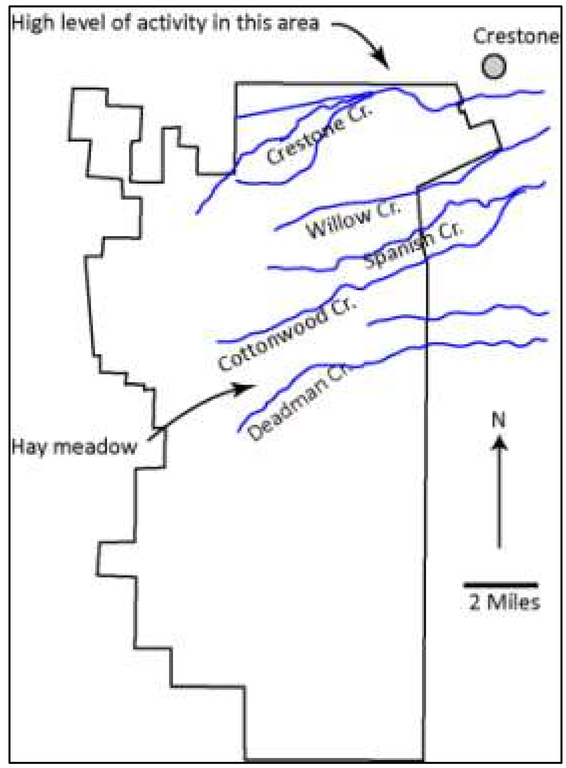
Summary of Findings



Baca National Wildlife Refuge

Richard Keigley, Ron Garcia and Scott Miller

Overview



The 92,500 acre Baca National Wildlife Refuge was authorized in 2000. Prior to establishment of the refuge, the area was acquired in 1860 by the heirs of Luis Maria Baca as a replacement grant for the original Vegas Grandes Land Grant which was located in New Mexico. Locally and in Colorado it has been known and referred to as the Baca Grant. After an early period of gold mining, the area became a cattle ranch, with intense activity on what is now the refuge portion of the original grant. Until the time that the land was acquired by the U.S. government this activity has continued at varying degrees. That activity has had an influence on current habitat condition. Five creeks run through the northeast part of the refuge, two of which were visited in 2009: Crestone Creek to the north and Deadman Creek to the south. Hay meadows between drainages were, and continue to be, irrigated by diversions and hay was (and still is) harvested where appropriate. The harvesting of hay has had an impact on current habitat condition. Since 2004 cattle and haying operations have ceased along riparian corridors. However, hay continues to be harvested in wet meadows.

Ungulate Populations

Current use. The area is winter range to approximately 2,000 - 4,000 elk; in addition, approximately 750 - 1,000 elk summer on the refuge. Cattle are locally present during fall months on wet meadows, but have been fenced from immediate riparian corridors.

Historic use. Elk were only sporadically present prior to the mid-1980s. Cattle grazed throughout until 2004.

General Habitat Goals

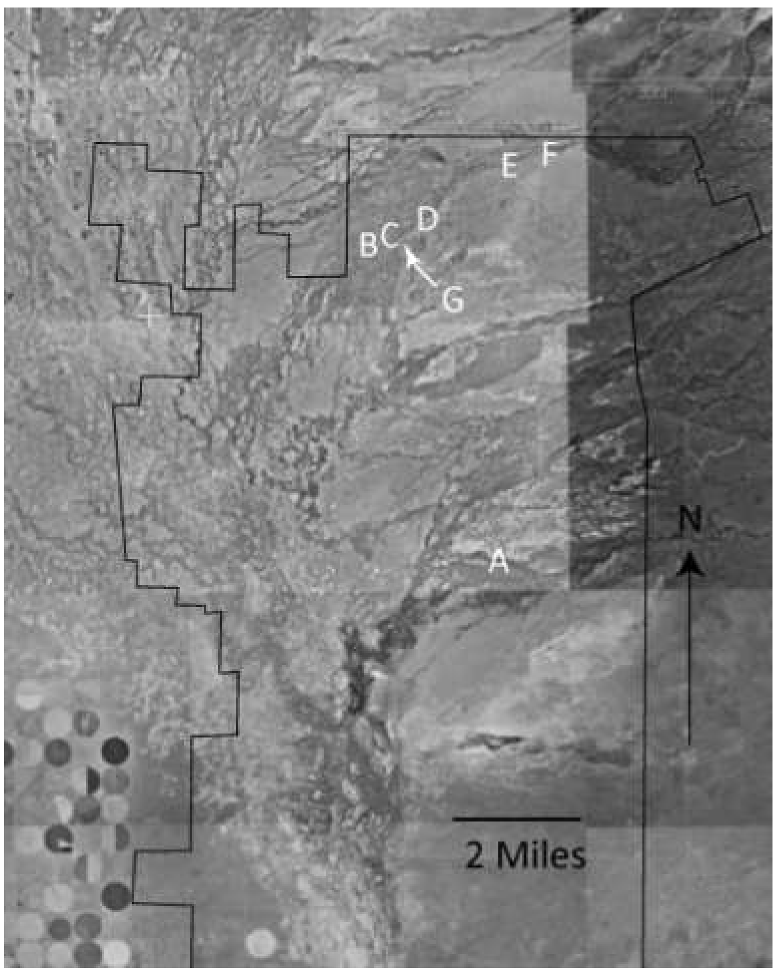
The purpose of the refuge is to restore, enhance and maintain wetland, upland, riparian and other habitats for wildlife, plants, and fish species that are native to the San Luis Valley. Management emphasizes migratory bird conservation.

Habitat-types Addressed in 2009

Riparian trees and shrubs.

2009 Landscape Level Survey

The Landscape Level Survey was conducted July 21, 2009. Seven sites were surveyed.



Site Descriptions

BACA LLS2009-A

NAD83: 37.87609° N 105.76807°W
Topographic Position: Deadman Creek
Species: Willow spp.: Yellow, Whiplash, and Coyote
Architectures:

- < 50 cm tall: U-type Coyote willow.
- 50-150 cm tall: none.
- 150-250 cm tall: none.
- > 250 cm tall: Live Yellow and Whiplash willow.

There were carcasses of dead willows.

Inferred browsing history: Light increasing to heavy.

Ed Clayton, irrigator on the Baca Ranch for 30 years, was the source of the following information:

> For as long as anyone could remember, a dense stand of willow grew along the Deadman Creek drainage. The willows grew so densely that it was difficult to operate machinery within the stands. The practice was to maintain a 5 to 6 foot corridor adjacent to the creek. Each year, young willows would expand up to 12 feet from the creek. They were mowed to prevent them from expanding into the hay meadows.
>
> Elk began showing up in the 1980s; the population exploded in the 1990s. Elk began killing willows. As the willows died, the carcasses would fall. The area where the willows died was mowed; the carcasses were baled along with the hay and removed from the area. Within 20 years, most evidence of the dense willow stand had disappeared. During this time cattle were present, and no change had occurred in the water regime.
>
> Elk tended to avoid areas of human activity. The most intense activity occurred in the northeast part of the refuge in an area referred to as the Purebred Cattle Headquarters Area (Purebred Area).

The Landscape Level Survey documented differences in willow condition that correspond to the distance away from high activity. Of the areas visited, Deadman Creek was farthest from the Purebred Area.

A single live, young willow was found (Coyote willow). The plant was two years old and approximately 50 cm tall to the tip of current year growth. The first year's growth had been browsed to about 15 cm above ground level.

The marked reduction of mature willow has all but eliminated a seed source in this area. Given the lack of seeds, reproduction is primarily due to root sprouts. The root system will likely decline if stems continue to be killed. If the willow community is to be restored in the Deadman Creek drainage, consideration should be given to protecting the few plants that survive.

BACA LLS2009-B

NAD83: 37.95664° N 105.81699°W
Topographic Position: Crestone Ditch.
Species: Willow spp.: Yellow, Whiplash, and Coyote in the vicinity.
Architectures:

- < 50 cm tall: none.
- 50-150 cm tall: none.
- 150-250 cm tall: none.
- > 250 cm tall: none.

Inferred browsing history: Light increasing to heavy.

With respect to the Purebred Area (where intense ranching activity occurred), this is the most distant of four willow sites on Crestone Ditch and Creek. There were many carcasses of plants presumed to be Coyote willow. Some of the carcasses were about 2.5 m tall. Hydrologic conditions at this point on the Crestone Ditch are similar to conditions at other points along the ditch. Because willows grow vigorously at two of those points (in an exclosure at LLS site D and in adjacent fenced site that is described below in this chapter), it is presumed that willows at BACA LLS2009-B were not killed by changes in hydrology. Observations at BACA LLS2009 sites C and G (described below) and data collected at BACA MS2009-1 indicate that willows are in marked decline due to browsing. That decline is occurring because, for the past few years, browsing has prevented all young willows from growing through the browse zone. The willows at site B grew to 2.5 meters tall when browsing was lighter compared to the current heavy level that was documented at the aforementioned sites. Prior 2005 (the year that cattle were first excluded from the riparian corridor), these willows could have been browsed by cattle and elk. It is unlikely that these 2.5-m-tall willows were less than four years old at the time of death, so it was concluded that these willows grew through the browse zone prior to 2005 while cattle were present. The elk population has markedly increased over the past 25 years. Over those 25 years there would be a corresponding increase in elk-related browsing. In a Sidebar later in this chapter, we describe direct evidence that elk are currently responsible for preventing the height growth of young plants. In addition to this direct evidence, there is circumstantial evidence that elk are responsible. Namely, sites that were more distant from the intense activity at the Purebred Area are more impacted by browsing compared to sites adjacent to that area. Elk would tend to avoid areas of high activity. Given that these and other willows grew through browse zone for many years when cattle were present, given that these willows have morphologic evidence of heavy browsing, and given that elk currently heavily browse young plants, it seems logical to conclude that elk were responsible for the death of this stand.

BACA LLS2009-C

NAD83: 37.95807 N 105.81408°W
Topographic Position: Valley bottom.
Species: Willow spp.: Yellow, Whiplash, and Coyote
Architectures:

- < 50 cm tall: Uninterrupted-growth-type, Arrested-type.
- 50-150 cm tall: Arrested/Retrogressed-type; the dead extending to 4-meters tall.
- 150-250 cm tall: Retrogressed-type; the dead extending to 4-m tall.
- > 250 cm tall: Retrogressed-type.

Inferred browsing history: Light increasing to heavy.

Based on the line of reasoning described above, these willows grew through the browse zone while livestock were present. Since livestock have been removed, the current heavy browsing that produced the arrested-type architecture is likely due to elk.

Willow is attempting expand into the adjacent hay meadow. Hay mowing has likely prevented willows from expanding to their full potential distribution. It is possible that willow could occupy wide corridors adjacent to drainages.

BACA LLS2009-D

NAD83: 37.96191° N 105.80601°W
Topographic Position: Valley bottom.
Species: Willow spp.: Yellow, Whiplash, and Coyote
Architectures:

- < 50 cm tall: Uninterrupted-growth-type.
- 50-150 cm tall: Uninterrupted-growth-type, Arrested/Retrogressed-type.
- 150-250 cm tall: Uninterrupted-growth-type, Arrested/Retrogressed-type.
- > 250 cm tall: Retrogressed-type.

Inferred browsing history: Light browsing increasing to heavy, decreasing to light.

Site D is inside a big game exclosure that was constructed in 2006. Stems were aged by bud scars. The beginning of vigorous growth corresponds with the construction of the exclosure. The implications of this growth are described in a sidebar below.

BACA LLS2009-E

NAD83: 37.98071° N 105.77106°W
Topographic Position: Valley bottom.
Species: Narrowleaf cottonwood.
Architectures:

- < 50 cm tall: Arrested-type.
- 50-150 cm tall: Arrested/Retrogressed-type.
- 150-250 cm tall: none.
- > 250 cm tall: Uninterrupted-growth type.

Inferred browsing history: Light increasing to heavy.

The cottonwoods were not aged. With a basal circumference of 40 cm, the youngest trees may be on the order of 50 years old. These trees grew to full height while cattle were present. Since livestock have been removed, the current heavy browsing appears to be due to elk.

This site was selected for monitoring (BACA MS2009-2).

BACA LLS2009-F

NAD83: 37.98400° N 105.75703°W
Topographic Position: Valley bottom.
Species: Willow spp.: Yellow, Whiplash, and Coyote
Architectures:

- < 50 cm tall: Uninterrupted-growth-type, Arrested-type.
- 50-150 cm tall: Uninterrupted-growth-type, Arrested/Retrogressed-type.
- 150-250 cm tall: Retrogressed-type.
- > 250 cm tall: Retrogressed-type.

Inferred browsing history: Light increasing to heavy.

Of the willow sites monitored, this site was closest to the Purebred Area. From a distance, the willows appear to be lightly browsed. However, stems are intensely browsed, and plants are likely in an early stage of decline.

BACA LLS2009-G

NAD83: 37.95827° N 105.81355°W
Topographic Position: Valley bottom.
Species: Willow spp.: Whiplash, and Coyote
Architectures:

- < 50 cm tall: Uninterrupted-growth-type, Arrested-type.
- 50-150 cm tall: Arrested/Retrogressed-type.
- 150-250 cm tall: Retrogressed-type.
- > 250 cm tall: Retrogressed-type.

Inferred browsing history: Light increasing to heavy.

This stand (selected as BACA MS2009-1) is located between the dead willow stand (Site B) and the relatively vigorous willow stand near the Purebred Area (Site F). The site was added to the survey because a greater number of young plants were present, making the stand more appropriate for monitoring.

Sidebar 1: Dating the onset of heavy browsing near BACA LLS09-G

The willows shown in the photograph to the right grow a few meters south of the exclosure on the Crestone Ditch. Browsing appears to have increased from light to heavy in about 1999.

The evidence: Tall willow stems were light-to-moderately browsed as they grew through the browse zone. Young stems are now intensely browsed. The youngest tall stem to grow through the browse zone would document approximately when browsing increased from light to heavy.

The 3-cm-diameter stem held by Ron Garcia (left) was cut and sectioned for aging. Because of heart rot, the section was taken at about 1.5 m above the ground. Eleven annual rings were counted; this stem grew to that height in 1999.

Young shoots grew at the base of the taller stems. Browsing has prevented these shoots from growing taller than about 50 cm. There is no reason to believe that the production of young shoots occurred only in recent years. It is likely that shoots attempted to grow through the browse shortly after 1999, but were prevented by browsing from doing so. We conclude that browsing increased from light to heavy in approximately 1999.

This is a date based on a sample of one. But if the age / diameter relationship of the sampled stem is similar to that of other stems, the analysis of other stems would likely yield similar approximate dates.

Sidebar 2: Evidence that Browsing by Elk is Responsible for the Decline of Willow

The photo to the right was taken outside the big game exclosure constructed in 2006. The fence can be seen behind the tall willows. As described in Sidebar 1, these willows last grew through the browse zone in about 1999. Since that time, browsing has prevented further height growth.

Two lines of evidence indicate that elk are responsible, the first of which relates to timing, the second relates to the response of willow inside the big game exclosure.

Timing. There are several stands of tall willows growing along the Crestone Ditch. Although the age of these tall shrubs was not determined, there is no reason to believe that growth to more than 2.5 meters tall is a recent phenomenon. It seems likely that some willows grew taller than 2.5 m tall throughout the two-decade period prior to 1999, the approximate year in which height-growth ceased due to browsing. Cattle were present throughout that period. Over that same period (i.e., 1979 to 1999) the elk population increased markedly.

Both cattle and elk were present in 1999 when height growth ceased due to browsing. But for the following reason, elk are believed to be primarily responsible for the increase in browsing. In 2005 cattle were excluded from the riparian corridor. With the exception described below (inside an exclosure), there is no corresponding willow height growth that dates to the removal of cattle. Both the monitoring data collected at BACA MS2009-1 and observations made during the landscape level survey indicate that browsing has prevented height growth after cattle were removed. Elk were the only ungulate present.

As described in the BACA LLS2009-B section above, willows are dying along a ditch that carries water year round. Under this circumstance, the mortality or failure to grow tall cannot be attributed to changes in hydrology.

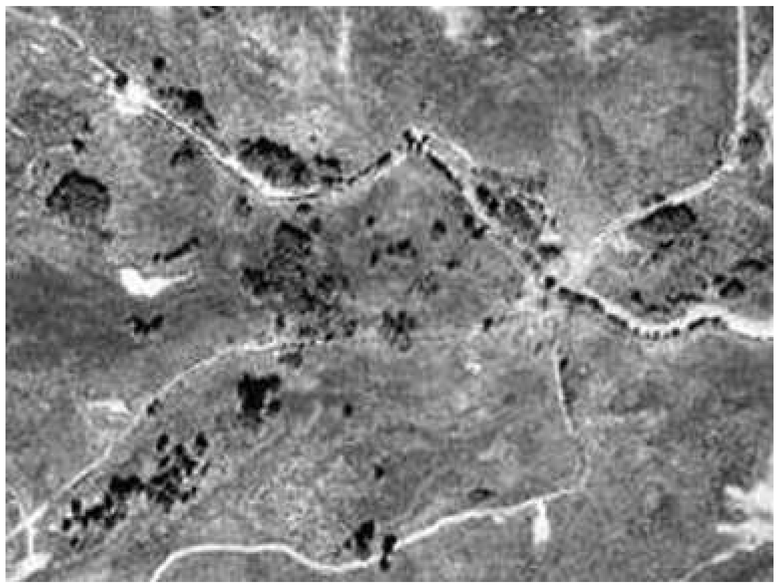
Response of willows inside the big game exclosure. The photograph to the right shows the flush of growth that occurred inside the exclosure seen in the photograph above. This exclosure was constructed in 2006. With just a few years of protection from browsing, willows have responded vigorously. The exclosure provides direct evidence that browsing by elk currently prevents young willows from growing tall.

Sidebar 3: Evidence that Elk Browsing Led to the Near-elimination of Willow along Deadman Creek.

At the beginning of this chapter we presented an anecdotal account by irrigator Ed Clayton describing how elk led to the elimination of willow along Deadman Creek. The account could be summarized as: willows had grown in the drainage for as long as anyone can remember, up until the 1980s elk were scarce, elk markedly increased after the mid-1980s, by the early 1990s willows were killed by browsing and rubbing, and the dead stems were removed during hay production operations.

The account raises the following questions:

- Has willow abundance been markedly reduced?
- If so, what were the respective roles of:
  - Cattle
  - Elk
  - Hay mowing and baling



Abundance. A comparison of aerial photographs taken in 1998 (upper photo) and 2009 (lower photo; FSA NAIP) documents that willow distribution has diminished. For example, at the center-right of the October 5, 1998 photo, shadows are cast by willows lining the creek. There is no evidence of these willows in the August 2, 2007 photo.

The abundance of willows declined over the period 1997 to 2009.
At the present time we do not have aerial photography prior to 1998.

Sidebar 3 Continued

Role of cattle. Tall willows are visible in the 1998 aerial photo and in the 2009 photo shown to the right. Based on the size of the canopy of the willows in the background, these willows are a few to several decades old. It is reasonable to assume that these willows are more than 25 old, and grew out of the browse zone before elk were present.

Cattle have been present for many decades. As these willows grew through the browse zone, cattle were almost certainly present. Browsing by cattle did not prevent these willows from growing through the browse zone.

The willows in the background do show evidence of livestock impacts. Two of the willows have a mushroom-shaped base that is a typical sign of livestock rubbing. To develop a mushroom shape, a shrub must be large enough to present resistance when rubbed against. With this resistance, stems and bark are removed as cattle rub against the shrub. A young shrub would be flexible and bend in response to rubbing. This is another line of evidence indicating that these shrubs are some decades old, and grew through the browse zone when cattle were present, but elk were not.

The dead willows in the foreground appear to be somewhat younger than the willows behind. When alive, these willows would have been more flexible than the mushroom-shaped willows in the background. If rubbed up against by a cow, such a willow would bend. Large-diameter stems have been broken off approximately 50 to 100 cm above the ground. This breakage could have been caused by elk antler thrashing. Some stems show evidence of browsing-related hedging. Current heavy elk browsing has been documented elsewhere in this report. The appearance of the dead, browsed willows is similar to that of the carcasses present along the Crestone Ditch (Site B).

Hay mowing and baling. According to Ed Clayton, much of the evidence of the willow stand was removed by mowing and baling operations. This raises the possibility that the death of the willows was caused by mowing and baling alone, or mowing and bailing in combination with elk. However, the photo to the right shows dead willows that have been browsed and broken by elk. These willows were neither mowed nor baled.

Conclusion. Willows grew through the browse zone while cattle were present. Cattle impacted willows to a degree by rubbing. When the elk population increased, browsing and rubbing increased as well and killed most of the willows present. Much of the evidence of the stand has been removed by mowing and baling.

Monitoring

BACA MS2009-1

NAD83 : 37.95827° N 105.81355°W
(Same as BACA LLS2009-G)

Species monitored: *Salix exigua (*Coyote willow). Whiplash willow was not included in the sample.

Step 1: Specify target characteristics for shrubs greater than 2.5 m tall.

Clusters of stems are treated as individual shrubs. Because Coyote willow root sprouts and forms thickets, the target condition is an approximate characterization. The target condition was based on attaining a density of mature clusters of shrubs spaced an average of 2 meters apart. Density was calculated as: 1 / $(\text{Spacing})^2$. Resulting density: 0.25 shrubs per square meter.

Step 2: Measure the existing density of shrubs that are greater than 2.5 m tall and the density of shrubs that are less than 2.5 m tall.

As above, clusters of stems were treated as individual shrubs. Existing density was measured in a 4-m-wide by 30-m-long belt transect. 14 shrubs > 2.5 m tall were present; there were 57 shrubs that were < 2.5 m tall.

- **> 2.5 m: 0.1 shrubs / m^2**
- **< 2.5 m: 0.5 shrubs / m^2**

Step 3: Estimate the replacement percentage.

Replacement percentage is calculated by dividing the target shrub density by the number of propagules that would be present after a hypothetical fire. The existing density of live clusters of stems was used as estimate of Propagule Density. Because Coyote willow root sprouts, this is a rough estimate.

Replacement Percentage = 0.25 /0.6 = 42 %.

The target density of 0.25 stems per square meter would be attained if 42 % of the propagules grew through the browse zone.

Step 4: Calculate the threshold browsing pressure.

Threshold browsing pressure = 100 % - Replacement Percentage, or 58 %. If browsing prevented up to 58 % of the propagules from growing through the browse zone, 42 % or more could potentially do so, and the target stem density would be attained.

Step 5: Estimate a Threshold LD Index.

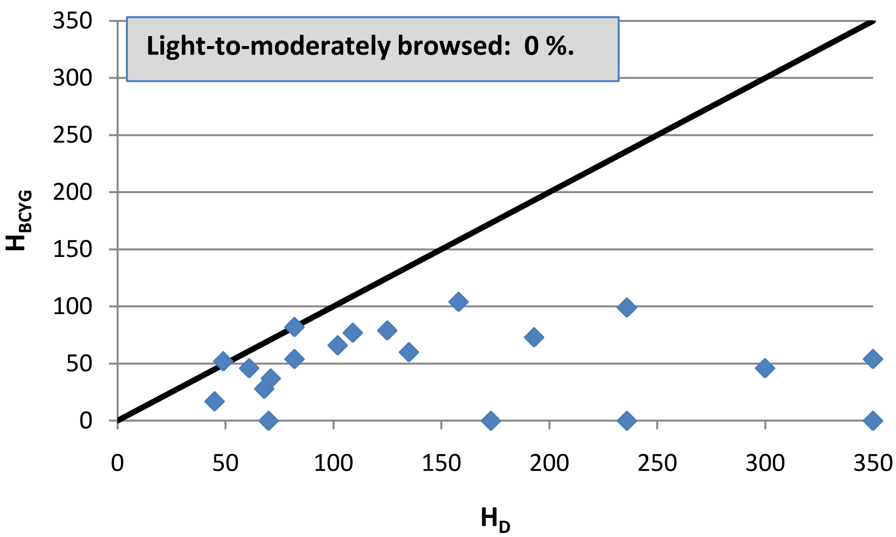
Threshold LD Index was set at 50 cm.

Step 6: Measure the Existing Browsing Pressure.

Obs	HBCYG	HD	LCYG	LD Index	Prevent?
1	60	135	1	-75	TRUE
2	73	193	10	-120	TRUE
3	0	173	94	-173	TRUE
4	46	300	12	-254	TRUE
5	0	350	98	-304	TRUE
6	54	350	1	-350	TRUE
7	28	68	27	-14	TRUE
8	82	82	4	-54	TRUE
9	46	61	2	21	TRUE
10	0	70	86	-24	TRUE
11	104	158	4	-158	TRUE
12	0	236	56	-132	TRUE
13	37	71	7	-71	TRUE
14	17	45	22	-8	TRUE
15	54	82	13	-65	TRUE
16	52	49	7	5	TRUE
17	77	109	21	-57	TRUE
18	99	236	17	-159	TRUE
19	66	102	17	-3	TRUE
20	79	125	18	-59	TRUE
MEAN	**47**	**150**	**26**	**-103**	
SE	**7.6**	**21.9**	**7.0**	**23.3**	

Light-to-moderately browsed: 0 %
Percent Intensely browsed: 100 %
Existing Browsing Pressure: 100 %

Structural trend is in an intermediate stage of decline. Retrogressed-type plants are present; the LD Index the taller plants (as measured to H_D) is strongly negative indicating a level of dieback.



Step 7: Compare Existing Browsing Pressure to Threshold Browsing Pressure.

The regulation of browsing pressure is based on a comparison of the Existing Browsing Pressure with the Threshold Browsing Pressure. At this site the Existing Browsing Pressure (100%) was greater than the Threshold Browsing Pressure (58 %), indicating that ungulate browsing will likely be a dominant factor affecting the future structure of this stand.

Predicted Stand Density if Present Trend Continues

If the present trend continues, all Coyote willows will die. The stand will resemble BACA LLS2009-B.

BACA MS2009-2

Location: NAD83 :
(Same as BACA LLS2009-E)

Species monitored: *Populus angustifolia* (Narrowleaf cottonwood).

Step 1: Specify target characteristics for trees greater than2.5 m tall.

The target condition was based on the existing density of mature trees at the site. Target density is 0.06 trees / m^2. (See Step 2 below.)

Step 2: Measure the existing density of stems that are greater than 2.5 m tall and the density of stems that are less than 2.5 m tall.

Existing stem density was measured in a 5-m-wide by 14-m-long belt transect. 4 stems were > 2.5 m tall; 24 stems were < 2.5 m tall.

- **> 2.5 m: 0.06 stems / m^2**
- **< 2.5 m: 0.34 stems / m^2**

Step 3: Estimate the Replacement Percentage.

Replacement percentage is calculated by dividing the target stem density by the number of propagules that would be present after a hypothetical fire. The existing density of young cottonwood (i.e., those shorter than 2.5-m-tall) was used as estimate of Propagule Density.

Replacement Percentage = 0.06 / 0.34 = 18 %.

The target density of 0.06 trees per square meter would be attained if 18 % of the propagules grew through the browse zone.

Step 4: Calculate the Threshold Browsing Pressure.

Threshold browsing pressure = 100 % - Replacement Percentage, or 82 %. If browsing prevented up to 82 % of the young cottonwoods from growing through the browse zone, 18 % or more could potentially do so, and the target tree density would be attained.

Step 5: Estimate a Threshold LD Index.

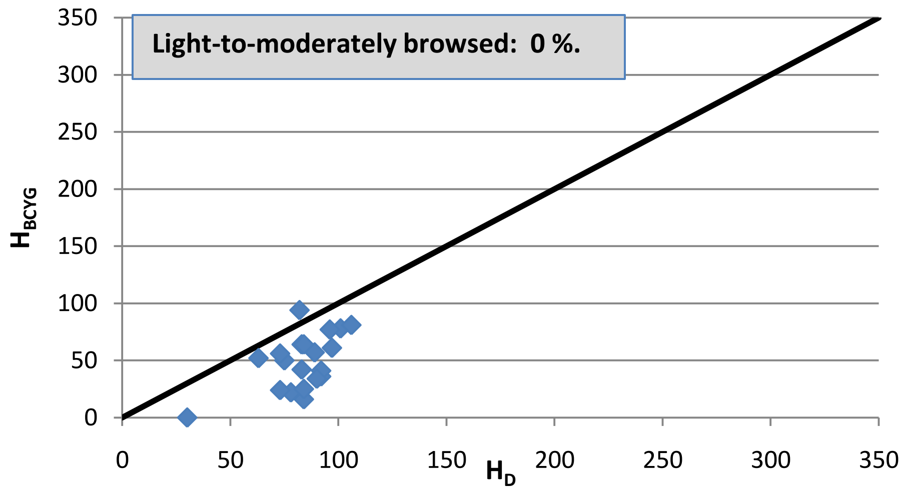
Threshold LD Index was set at 50 cm.

Step 6: Measure the Existing Browsing Pressure.

Obs	HBCYG	HD	LCYG	LD Index	Prevent?
1	57	89	13	-32	TRUE
2	16	84	2	-68	TRUE
3	61	97	35	-36	TRUE
4	0	30	64	-30	TRUE
5	36	92	1	-56	TRUE
6	22	78	1	-56	TRUE
7	25	84	14	-59	TRUE
8	50	75	2	-25	TRUE
9	52	63	12	-11	TRUE
10	78	101	7	-23	TRUE
11	81	106	3	-25	TRUE
12	64	83	3	-19	TRUE
13	41	92	25	-51	TRUE
14	34	90	11	-56	TRUE
15	77	96	2	-19	TRUE
16	94	82	4	12	TRUE
17	56	73	2	-17	TRUE
18	42	83	4	-41	TRUE
19	64	84	53	-20	TRUE
20	24	73	5	-49	TRUE
MEAN	**49**	**83**	**13**	**-34**	
SE	**5.5**	**3.6**	**4.0**	**4.5**	

Light-to-moderately browsed: 0 %
Percent Intensely browsed: 100 %
Existing Browsing Pressure: 100 %

With respect to cottonwood less than 150 cm tall, structure is in an advanced stage of decline. Young cottonwoods are dying back to groundlevel.



Step 7: Compare Existing Browsing Pressure to Threshold Browsing Pressure.

The regulation of browsing pressure is based on a comparison of the Existing Browsing Pressure with the Threshold Browsing Pressure. At this site the Existing Browsing Pressure (100%) was greater than the Threshold Browsing Pressure (82 %), indicating that ungulate browsing will likely be a dominant factor affecting the future structure of this stand.

Predicted Stand Density if Present Trend Continues

In the absence of fire, the structure of this site will change slowly. The mature, tall trees may live to 100 years old or more; young cottonwoods will be prevented from growing taller than 50 to 100 cm.

Summary of Findings

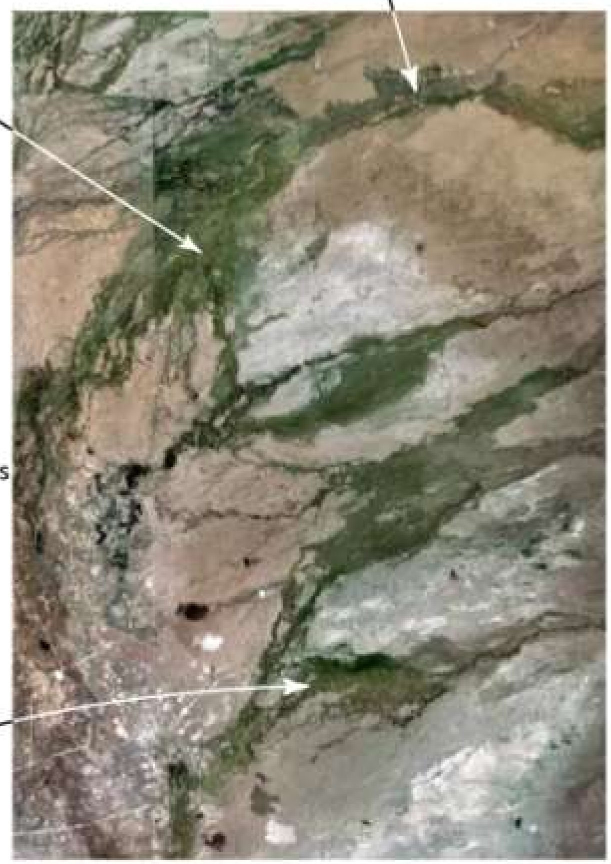
Riparian trees and shrubs grew to full stature when cattle were present. When the elk population began to increase in the late-1980's , browsing subsequently increased as well.

Currently browsing prevents the height growth of all young trees and shrubs.

This was a site of high human activity associated with cattle ranching. Elk avoided this area. The highest quality habitat occurs here.

Based on the data collected and on an eyewitness account, increased elk numbers have contributed to the elimination of a stand of willow along the Crestone Ditch. Evidence of this stand remains in the form of carcasses.

Nearby stands are in decline.



The distribution of willow has been restricted by hay mowing. The potential area of willow habitat is unknown.

It is conceivable that the refuge could have large areas of high quality habitat for Neotropical songbirds.

There is evidence that a dense stand of willow once grew along Deadman Creek.

It is apparent that browsing likely due to increased elk has killed nearly all willows in this area over a 20-year period.

Evidence of the willow community has been removed by ranching operations.

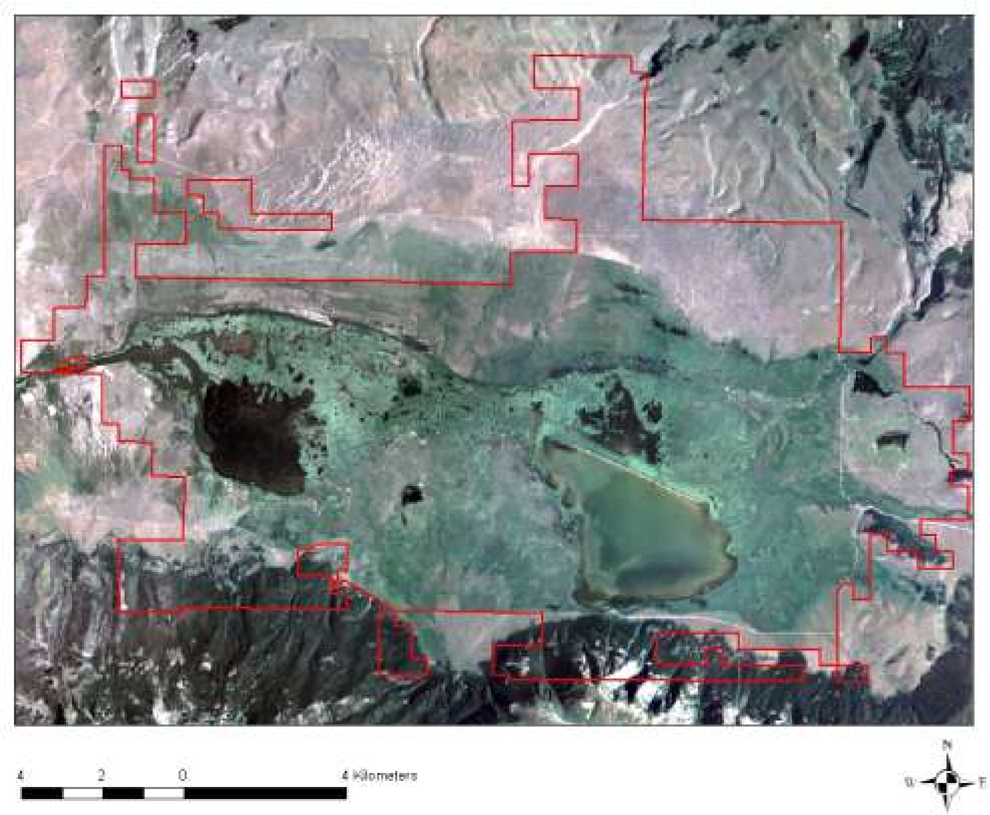
Once the Coyote willow root system dies, these willows may be extirpated from the lower Deadman Creek drainage.

Red Rock Lakes National Wildlife Refuge

Richard Keigley and Jeffrey Warren

Overview

Red Rock Lakes NWR is located in the Centennial Valley of southwest Montana, within the Greater Yellowstone Ecosystem (GYE) and part of the furthest headwaters of the Missouri River drainage. The Refuge ranges from 6600 to 9400 feet in elevation along the Continental Divide, resulting in a diversity of habitats largely unrivaled by other refuges in the contiguous United States – 57 vegetation associations have been mapped to date. The Refuge also encompasses the largest wetland complex in the GYE; nearly half of the 50,000 acre Refuge is wetland habitat. The scale and quality of the wetlands associated with the Red Rock lakes, along with the last known breeding population of trumpeter swan in North America, provided the impetus for creation of the Refuge in 1935. Additionally, the extensive willow-dominated riparian habitat on the Refuge supports one of the highest density wintering moose populations in the Northern Rocky Mountains and a diversity of breeding migratory landbird species.



Ungulate Populations

Current use. The Centennial Valley (CV) in southwest Montana contains the largest wetland complex in the Greater Yellowstone Ecosystem, and the associated willow communities support one of the highest-density wintering Shiras moose populations in the Northern Rocky Mountains. The Refuge, situated in the eastern extent of the valley, encompasses most of these communities, including approximately 2,000 acres of willow-dominated riparian habitat. The latter is believed to provide winter habitat for the majority of the moose population within Montana Fish, Wildlife and Parks (MFWP) hunting district 334 (HD 334). Winter surveys conducted by MFWP between 1966 and 2009 show that the total number of moose wintering on the Refuge has increased throughout the period surveyed, from a low of 25 in 1966 to a high of 135 in 2008. Concurrently, the elk population increased in southwestern Montana (Gravelly Elk Management Unit [EMU]). The elk population in the Gravelly EMU, which includes the CV, doubled during 1985–2004 (Montana Fish Wildlife & Parks 2004). Increased use of Refuge riparian habitats during this period by elk has also been anecdotally noted. The amount of browsing pressure in Refuge riparian habitats that is attributable to moose and to elk is therefore unknown.

Historic use. The Centennial Valley has been grazed by livestock since the late 1800s. Sheep were the predominant livestock in the valley through the early 1900s. The refuge began excluding riparian habitats from livestock grazing beginning in the 1970s, with the major riparian habitats excluded from grazing by the late 1980s.

General Habitat Goals

Willow riparian habitat goals are directed at 3 primary target species or groups of species – migratory landbirds, moose, and Arctic grayling. For the purpose of this study only the former 2 will be discussed. Objectives in the CCP relevant to this study are to 1) "maintain at least 2000 acres of willow dominated riparian habitat at moderate to low browse levels for greater than eighty wintering Shiras moose…", 2) "maintain at least 500 acres of moderate to dense (>40% canopy cover) willow riparian habitat to benefit breeding migratory songbirds, spawning Arctic grayling, and native ungulates…", and 3) "maintain low to moderate browse levels… within willow habitats for the maintenance of willow volume, canopy cover, and structural heterogeneity…".

Habitat-types Addressed in 2009

Willow dominated riparian habitats were investigated. Willow communities on the Refuge occur along riparian corridors and within a large fen along the southern and eastern edge of Upper Red Rock Lake. Riparian willow communities are dominated by Booth's and Drummond's willow, both tall-statured (> 2 m in height) willow species. Geyer willow and Bebb willow are also well represented. The fen is a mosaic of short-statured shrubs (< 2 m in height), dominated by Wolf's willow, with shrubby cinquefoil codominating in smaller patches, and tall willow communities co-dominated by Bebb willow and Booth's willow, with lesser amounts of Geyer willow.

2009 Landscape Level Survey

The Landscape Level Survey was conducted July 28, 2009. Seven sites were surveyed. Their locations are indicated on the index photograph below.

Site Descriptions

RRL LLS2009-A

NAD83: 44.61622 N° -111.63235 W°

Topographic Position: Confined corridor of Red Rock Creek (See Landscape Level Survey Index Photo).

Species: Booth willow, Bebb willow

Architectures:

- < 50 cm tall: None seen.
- 50-150 cm tall: Arrested/Retrogressed type.
- 150-250 cm tall: Arrested/Retrogressed type.
- > 250 cm tall: Arrested/Retrogressed type.

Based on visual appearance, structural diversity at this site is high. Although there is evidence that heavy browsing occurred at some time in the past, current observations do not suggest that structure is in decline.

All plants examined had arrested- or retrogressed-type architecture. Some retrogressed-type individuals grew out of the browse zone when browsing was light. At some time in the past, browsing increased to a level that caused arrest and retrogression. Intense browsing along the perimeter of the tall shrubs is evidence of that increase. We did not encounter a case where intensely browsed stems had subsequently grown taller than 2.5 m, so no shrub was classified as having released-type architecture. However, we did encounter many instances of stems that were not browsed (or were lightly browsed) for the past few years. Based on an examination of bud scars, stem segments that elongated from 2003 through 2009 were lightly browsed. This recent reduction in browsing was encountered at other Landscape Level Survey Sites.

The apparent absence of individuals less than 50 cm tall suggests that recruitment is currently limited. Given the reduction in browsing that appears to have occurred over the past few years, such individuals should have grown tall enough to be visually apparent.

Inferred browsing history: The architectures indicate a history of light increasing to heavy; stem growth since 2003 indicates a reduction in browsing.

RRL LLS2009-B

NAD83: 44.62462 N° -111.65853 W°

Topographic Position: Red Rock Creek corridor. This site is less confined than RRL LLS2009-A which is located 1.3 miles to the southeast.

Species: Planeleaf, Bebb, Mountain, Geyer, Booth willow.

Architectures:

- < 50 cm tall: Arrested-type.
- 50-150 cm tall: Arrested/Retrogressed type.
- 150-250 cm tall: Arrested/Retrogressed type.
- > 250 cm tall: Arrested/Retrogressed type.

Willow at this site grew on a saturated, peaty substrate. Based on visual appearance, structural diversity is not as high compared to structure at RRL LLS2009-A. Note the predominance of short shrubs in the photo above. In addition, the presence of dead stems extending above live shrub canopy suggested that structural diversity was in decline. This site was selected for monitoring (RRL MS2009-1). Of the species that were present, Bebb willow appeared to be most heavily browsed, and was selected as the indicator species.

Inferred browsing history: The architectures indicate a history of light increasing to heavy; stem growth since 2003 indicates a modest reduction in browsing.

RRL LLS2009-C

NAD83: 44.60490 N° -111.65648 W°

Topographic Position: Gentle gradient of Battle Creek drainage approximately 1.8 miles east of Upper Red Rock Lake.

Species: Geyer and Bebb willow

Geyer willow architectures:

- < 50 cm tall: Arrested-type.
- 50-150 cm tall: Arrested/Retrogressed type.
- 150-250 cm tall: Arrested/Retrogressed type.
- > 250 cm tall: Arrested/Retrogressed type.

Bebb willow architectures:

- < 50 cm tall: None.
- 50-150 cm tall: Arrested-type.
- 150-250 cm tall: None.
- > 250 cm tall: None.

As at RRL LLS2009-A, there is evidence of a reduction in browsing that began about 2004. All of the live stems in the Geyer willow to the right were relatively young, and were lightly browsed since 2004. The shrub is classified as having retrogressed-type architecture due to the presence of relatively young, dead, browsed stems; the premature mortality of those stems was likely due to browsing.

Inferred browsing history: The architectures indicate a history of light increasing to heavy; stem growth since 2004 indicates a reduction in browsing.

RRL LLS2009-D

NAD83: 44.58922 N° -111.67473 W°

Topographic Position: Gentle gradient of Tom Creek drainage approximately 1.1 miles southeast of Upper Red Rock Lake.

Species: Booth, Geyer, Planeleaf, and Bebb willow.

Architectures:

- < 50 cm tall: Arrested-type.
- 50-150 cm tall: Arrested/Retrogressed type.
- 150-250 cm tall: Arrested/Retrogressed type.
- > 250 cm tall: Arrested/Retrogressed type.

From a distance the shrubs in the above photograph appear to have experienced an uneventful history of growth.

However, much of the foliage of this Planeleaf willow is current-year-growth that extends above a dense thatch of dead, heavily-browsed twigs. This indicates that, at the end of the growing season, current-year-growth is browsed to the zone of mechanical protection provided by the thatch of dead stems.

Bebb willow is heavily browsed into a hedge-like shape. The current-year growth of this willow is shorter compared to the current-year-growth of the Planeleaf willow on the previous page. The tall shrub to the left is a Geyer willow.

From the height and general appearance of these species, we infer the following preference gradient: Bebb willow is more highly preferred by ungulates than Planeleaf willow; Planeleaf is more highly preferred than Geyer willow.

Inferred browsing history: The architectures indicate a history of light increasing to heavy; stem growth of some species since 2004 indicates a reduction in browsing.

This site was selected as Monitoring Site 200902. Bebb willow was selected as the indicator species.

RRL LLS2009-E

NAD83: 44.9257 N° -111.70518 W°

Species: Aspen

Architectures:

- < 50 cm tall: Arrested-type.
- 50-150 cm tall: Arrested/Retrogressed type, and Uninterrupted-growth-type.
- 150-250 cm tall: Uninterrupted-growth-type.
- > 250 cm tall: Uninterrupted-growth-type.

Many years ago, aspen grew to tree stature when browsing was light. At some point, browsing increased to a level that prevented the height growth of young plants. Over a period of years the tall stems died. The presence of young uninterrupted-growth type individuals indicates that browsing has diminished. However, some young suckers have died. Stands that have declined to the extent of this one may respond slowly to a reduction in browse use.

Inferred browsing history: Light increasing to heavy, then decreasing.

RRL LLS2009-F

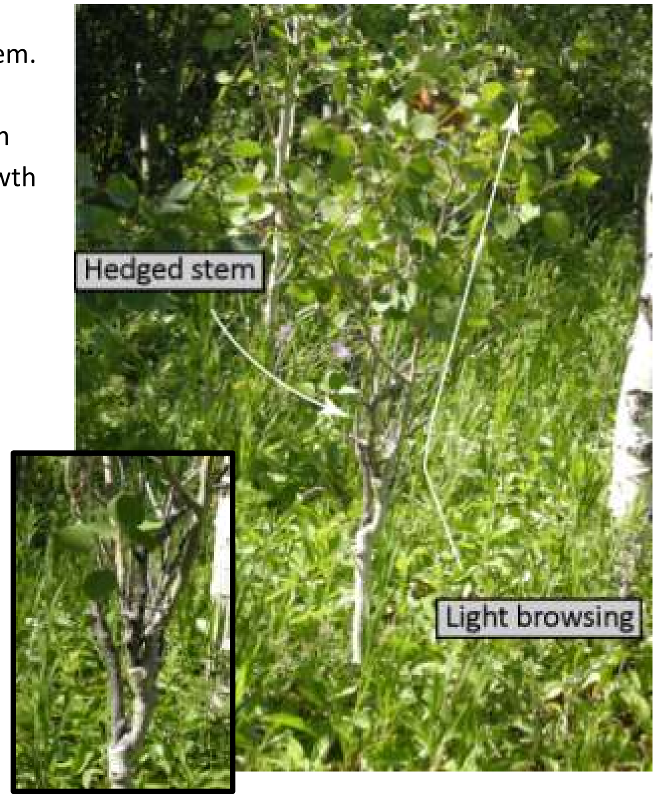
NAD83: 44.59300 N° -111.72924 W°

Species: Aspen

Architectures:

- < 50 cm tall: Arrested-type.
- 50-150 cm tall: Arrested/Retrogressed type, and Uninterrupted-growth-type.
- 150-250 cm tall: Uninterrupted-growth-type.
- > 250 cm tall: Uninterrupted-growth-type.

The aspen to the right was heavily browsed for several years, producing a gnarly hedged lower stem. As at Site E, a reduction in browsing has allowed stems to grow through the browse zone. The stem on the right side of this aspen began vigorous growth in 2004.



Of the different species examined during the Landscape Level Survey, three had grown into the browse zone: Aspen, Geyer willow, and Booth willow.

One species had failed to grow into browse zone: Bebb willow.

And one species was intermediate: Planeleaf.

Inferred browsing history: The architectures indicate a history of light increasing to heavy, then decreasing.

RRL LLS2009-G

NAD83: 44.60700 N° -111.80778 W°

Topographic Position:

Species: Geyer and Bebb willow.

Architectures:

- < 50 cm tall: Arrested-type.
- 50-150 cm tall: Arrested/Retrogressed type.
- 150-250 cm tall: Arrested/Retrogressed-type.
- > 250 cm tall: Retrogressed-type.

Browsed, dead stems in interior of this shrub result in classification as retrogressed-type shrub. However, there were stems that were not browsed since they elongated in 2004.

Inferred browsing history: The architectures indicate a history of light increasing to heavy; stem growth since 2004 indicates a reduction in browsing.

Monitoring

RRL MS2009-1

NAD83 : 44.62462 N° -111.65853 W°
(Same as RRL LLS2009-B)

Species monitored: Bebb willow

Step 1: Specify target characteristics for Bebb willow shrubs greater than 2.5 m tall.

The target density was based on attaining a community of tall willows spaced 3 m apart.

The approach taken at Red Rock Lakes MS2009-1 and MS2009-2 2 differed from that taken at Arapaho MS2009-2. All three sites contained multiple species of willows capable of growing taller than 2.5 meters. At Arapaho, the willows were treated as a single entity. At Red Rock Lakes we used a single Indicator Species: Bebb willow. We calculated the necessary parameters according to the proportion of Bebb willow in the community.

The Target Density at RRL MS2009-1 was based on measurements taken in a 10-by-60 m belt transect that contained five willow species capable of significant height growth: Planeleaf, Bebb, Mountain, Geyer, and Booth. The total density of all species was 4.62 shrubs per square meter; the density of Bebb willow was 1.28 shrubs per square meter. 28 % of the shrubs were Bebb willow.

The density of shrubs at this site is extremely high. The average distance between patches was about 0.5 meters. Over half the shrubs were less than 50 cm tall. In part, the short stature was due to browsing; in part stature at this site could be influenced by environmental factors. We adopted the 3-meter spacing as a means of assessing the effect of browsing on height growth. As it will be seen below, the Threshold Browsing Pressure at this site was very high: 98 %.

The Target Density of Bebb willow (0.03 shrubs per square meter) was calculated as follows:

- Based on a spacing of 3 m, the resulting Target Density of all willows would be 0.11 shrubs per square meter.

$$Density = \frac{1}{Distance\ between\ plants^2}$$

- Since the combined Existing Density of willows shrubs of all species capable of growing taller than 2.5 m was 4.62 shrubs per square meter, the target spacing of 3 m would be attained if 2.4 % of the existing shrubs grew to 2.5 m tall:
  0.11 / 4.62 = 2.4 %

- As a component of the community, the Target Density of Bebb willow would be 0.03 shrubs per square meter:
  2.4 % X 1.28 shrubs / m^2 = 0.03 shrubs / m^2.

Step 2: Measure the existing density of Bebb willow shrubs that are greater than 2.5 m tall and the density of shrubs that are less than 2.5 m tall.

Note that this step refers only to the Bebb willow component of the community. Clusters of stems were treated as individual shrubs. Existing density was measured in a 10-m-wide by 60-m-long belt transect. There were no shrubs > 2.5 m tall; 77 were < 2.5 m tall.

- > 2.5 m: 0 shrubs / m^2
- < 2.5 m: 1.28 shrubs / m^2

Step 3: Estimate the Replacement Percentage.

Replacement percentage was based on a hypothetical fire scenario. Following such a fire, it was assumed that sprouts could elongate from each existing shrub. The target density of 0.03 shrubs per square meter would be attained if 2.3% of the existing shrubs produced post-fire shrubs that grew taller than 2.5 m.

Step 4: Calculate the Threshold Browsing Pressure.

The Threshold Browsing Pressure is 98 %.

Step 5: Specify a Threshold LD Index.

Threshold LD Index was set at 50 cm.

Step 6: Measure the Existing Browsing Pressure.

Percent Light-to-moderately browsed:
0 %

Percent Intensely Browsed:
100%

Existing Browsing Pressure:
100 %

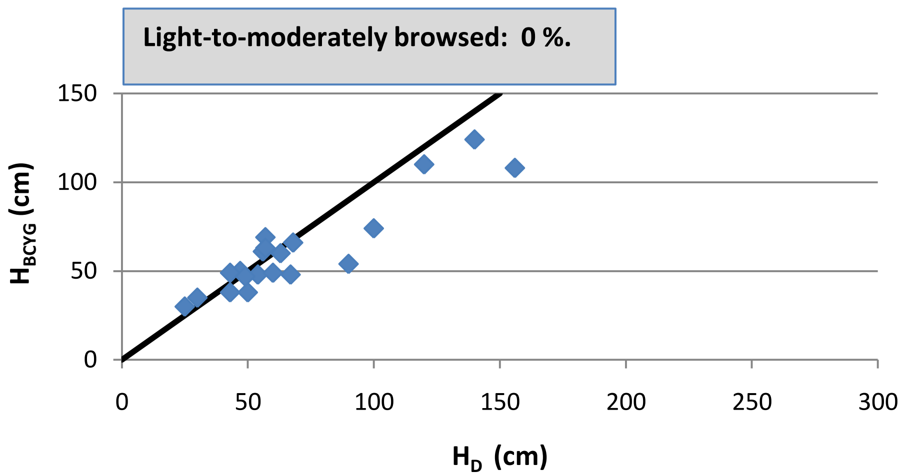
Obs	HBCYG	HD	LCYG	LD Index	Prevent?
1	30	25	9	5	TRUE
2	66	68	3	-2	TRUE
3	50	47	5	3	TRUE
4	48	67	1	-19	TRUE
5	110	120	22	-10	TRUE
6	124	140	13	-16	TRUE
7	60	63	20	-3	TRUE
8	48	54	23	-6	TRUE
9	38	50	4	-12	TRUE
10	49	43	10	6	TRUE
11	47	49	3	-2	TRUE
12	108	156	35	-48	TRUE
13	69	57	15	12	TRUE
14	38	43	15	-5	TRUE
15	54	90	13	-36	TRUE
16	61	56	1	5	TRUE
17	74	100	3	-26	TRUE
18	35	30	2	5	TRUE
19	49	60	22	-11	TRUE
20	63	57	10	6	TRUE
MEAN	**61**	**69**	**11**	**-8**	
SE	**6.1**	**7.9**	**2.1**	**3.4**	

Step 7: Compare Existing Browsing Pressure to Threshold Browsing Pressure.

The Existing Browsing Pressure of 100 % was greater than the Threshold Browsing Pressure of 98 %.

Predicted Stand Density if Present Trend Continues

Structural trend is in the intermediate stage of decline. Changes in structure that have occurred over the past 40 years are described later in this chapter.



RRL MS2009-2

NAD83 : 44.58900 N° -111.67756 W° (The belt transect ran approximately south to north; these are the coordinates of the zero point.)
(Same as RRL LLS2009-D)

Species monitored: Bebb willow. Planeleaf and Booth were also measured.

Step 1: Specify target characteristics for Bebb willow shrubs greater than 2.5 m tall.

As at RRL MS2009-1, the target density was based on attaining a willow community of tall willows spaced 3 m apart. The density was based on measurements taken in a 10-by-100 m belt transect that contained four willow species capable of significant height growth: Planeleaf, Bebb, Geyer, and Booth. The target density of Bebb willow is specified to be 0.006 shrubs per square meter and was calculated as follows:

- Based on a spacing of 3 m, the resulting target density of all willows would be 0.11 shrubs per square meter.

$$Density = \frac{1}{Distance\ between\ plants^2}$$

- The combined existing density of willows capable of growing taller than 2.5 m was 0.51 shrubs per square meter. (See Existing Density below.)

- The target spacing of 3 m would be attained if 22 % of the existing shrubs grew to 2.5 m tall (0.11 / 0.51 = 22 %)

- Based on the existing proportion of Bebb willow in the community (5.8 %), the target density of Bebb willow is 0.006 shrubs per square meter.
  5.8 % X 0.11 shrubs / m^2 = 0.006 shrubs / m^2.

At a density of 0.006 shrubs per square meter, Bebb willow would spaced approximately 13 meters apart.

Step 2: Measure the existing density of Bebb willow shrubs that are greater than 2.5 m tall and the density of shrubs that are less than 2.5 m tall.

Clusters of stems were treated as individual shrubs. Existing density was measured in a 10-m-wide by 100-m-long belt transect. There were 4 shrubs > 2.5 m tall; 47 were <= 2.5 m tall.

- > 2.5 m: 0.04 shrubs / m^2
- < 2.5 m: 0.47 shrubs / m^2

Step 3: Estimate the Replacement Percentage.

Replacement percentage was based on a hypothetical fire scenario. Following such a fire, it was assumed that sprouts could elongate from each existing Bebb willow shrub. The target density of 0.006 Bebb willows per square meter would be attained if 20 % of the existing Bebb willows grew taller than 2.5 m.

0.03 (current density) / 0.006 (target density) = 20 %

Step 4: Calculate the Threshold Browsing Pressure.

The Threshold Browsing Pressure is 80 %.

Step 5: Specify a Threshold LD Index.

Threshold LD Index was set at 50 cm.

Step 6: Measure the Existing Browsing Pressure.

Percent Light-to-moderately browsed:
0 %

Percent Intensely Browsed:
100%

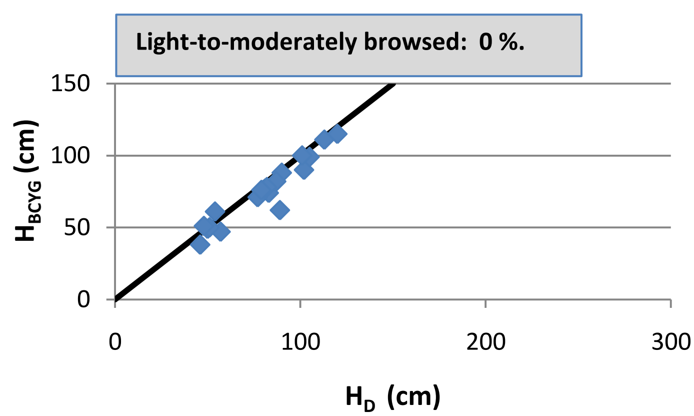
Existing Browsing Pressure:
100 %

Obs	HBCYG	HD	LCYG	LD Index	Prevent?
1	74	83	8	-9	TRUE
2	90	102	9	-12	TRUE
3	76	80	5	-4	TRUE
4	71	77	2	-6	TRUE
5	62	89	3	-27	TRUE
6	49	50	2	-1	TRUE
7	47	57	12	-10	TRUE
8	38	46	4	-8	TRUE
9	99	105	16	-6	TRUE
10	100	101	1	-1	TRUE
11	88	90	5	-2	TRUE
12	50	51	1	-1	TRUE
13	61	54	3	7	TRUE
14	77	81	2	-4	TRUE
15	82	87	1	-5	TRUE
16	115	120	4	-5	TRUE
17	78	82	7	-4	TRUE
18	76	79	2	-3	TRUE
19	51	48	2	3	TRUE
20	111	113	1	-2	TRUE
MEAN	**48**	**80**	**5**	**-5**	
SE	**4.9**	**5.0**	**0.9**	**1.5**	

Step 7: Compare Existing Browsing Pressure to Threshold Browsing Pressure. The Existing Browsing Pressure of 100 % was greater than the Threshold Browsing Pressure of 80 %.

Predicted Stand Density if Present Trend Continues

Structural trend is in the intermediate stage of decline.



Additional Information

In this section we attempt to relate long-term ungulate population trends to changes in the structure of willows. Some of the earliest detailed information is found in Dorn (1969). Dorn describes the historic moose population as follows:

> Moose were observed in the Centennial Valley shortly after 1900 but were not numerous until after 1940. A conspicuous increase occurred about 1950 (Banko 1951 cited by Dorn).
>
> Over-utilization of browse resulted from the population increase on the refuge around 1950 (Banko 1951 cited by Dorn). A die-off of willows occurred shortly after from unknown causes.
>
> The refuge was open to hunting in 1952 when the moose population was about 60 animals. A total of 128 moose were killed over eight successive seasons. At the time Dorn's study in 1968/1969, the population at peak use was about 55 animals.
>
> Dorn concluded that the winter population appeared to be approaching the carrying capacity of the range.

Dorn's report provides snapshots of early moose numbers. Moose surveys in Hunting District 334 provide a perspective on long-term trend. Over the period 1966 to 2008, moose wintering on the refuge increased from 25 to 135. The elk population has increased as well. It is clear that ungulate number has increased markedly in the past sixty years, from near zero to the low 100s. Paradoxically, the documented high point of this trend (135 moose in 2008) occurred during what we describe as a period when browsing was reduced (since about 2003/2004).

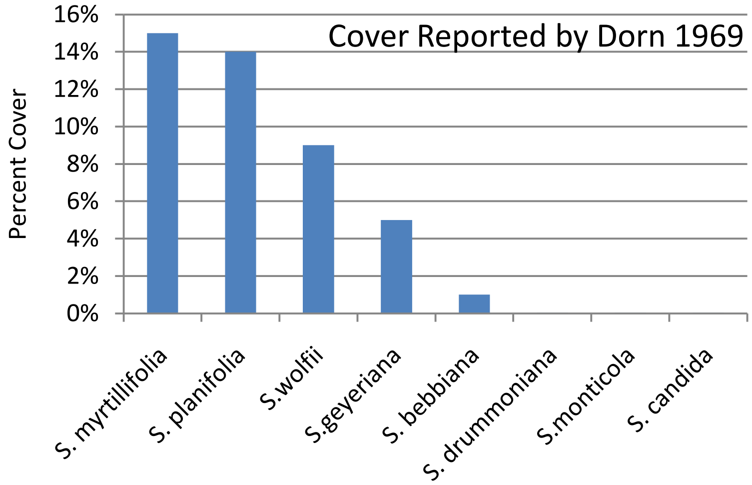
At the time much of the population increase occurred, the area suitable for browsing was relatively fixed. The increase in animals would have resulted in a concurrent increase of the density of animals. It was noted that this increase had an adverse effect on browse condition when moose number was low (about 60) in comparison to recent numbers.

In 2003, the land area suitable for foraging may have increased markedly. In August 2003 the Winslow Fire burned approximately 13,500 acres of conifer forest. Beginning in 2004, a flush of new growth would have provided a new source of forage. We do not have data to document that ungulates dispersed away from their prior foraging ground. But the period of light browsing that began about that time could be explained by such dispersal.

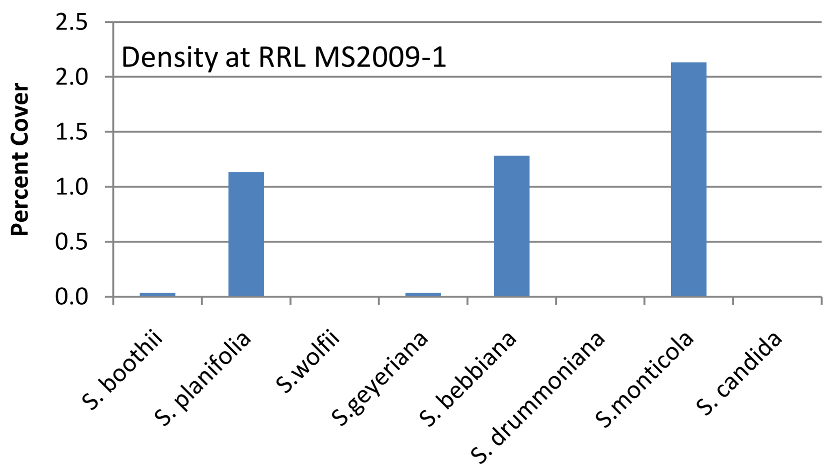
Dorn described two willow characteristics: cover and height. Because we did not collect cover data, we cannot make that comparison. We can compare the long-term differences in willow height.

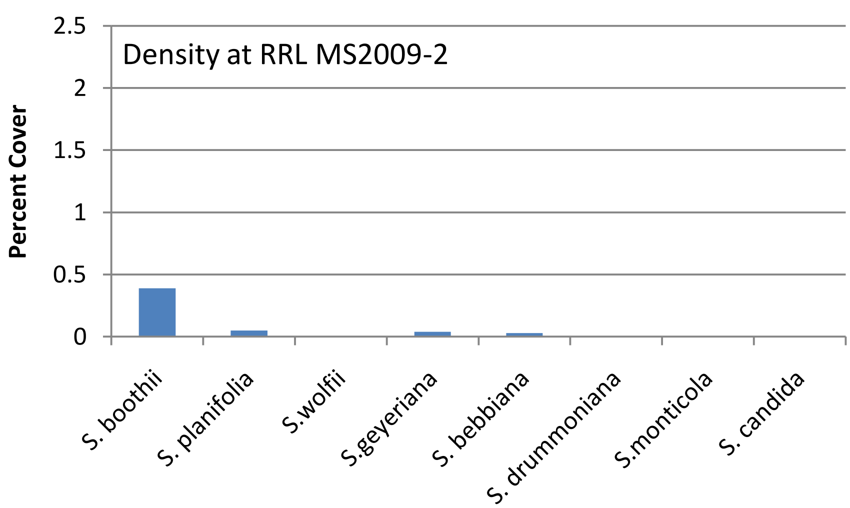
Dorn classified vegetation into eight types, one of which was the "willow type." The areas of RRL MS2009-1 and 2 were both mapped by Dorn as being willow type. Dorn described five species of willow in that vegetation type.

Abundance. A graph on the following page describes Dorn's reported cover data.



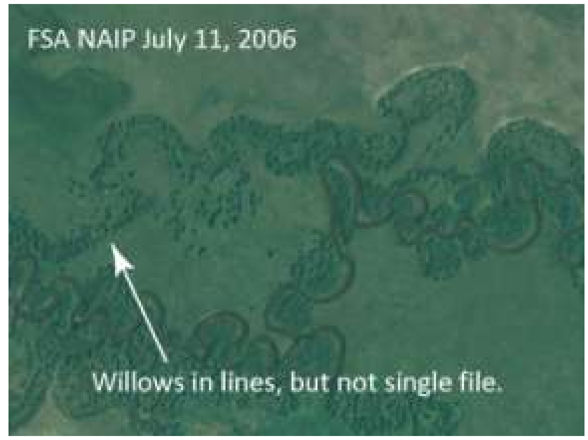
Our measure of abundance (Density) is not exactly comparable to cover. However, the data do provide an indication of relative differences in abundance. We refer to *S. myrtillifolia* as *S.boothii*. Because it does not grow taller than 2.5 meters, we did not measure the density of Wolf willow; it was abundant. TheY-axis scales are similar so that differences between sites can be visually compared.





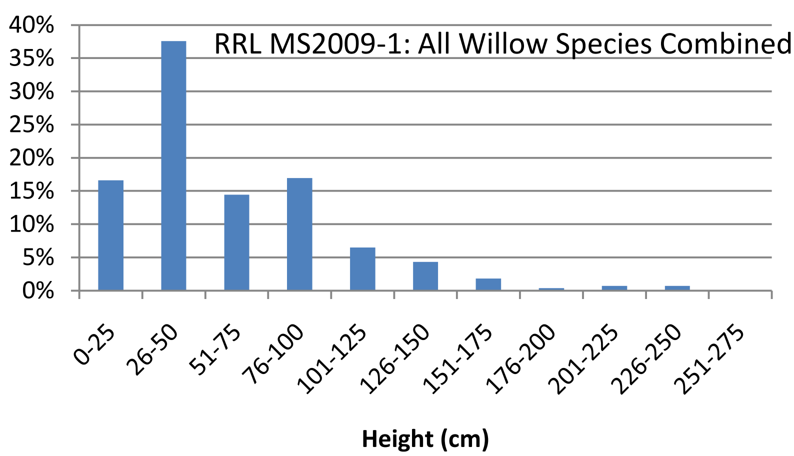
The relative differences in density at RRL MS2009-2 are somewhat similar to differences reported by Dorn. RRL MS2009-1 differs markedly from both Dorn's data and our data at MS2009-2. Some of differences may be due to site conditions.

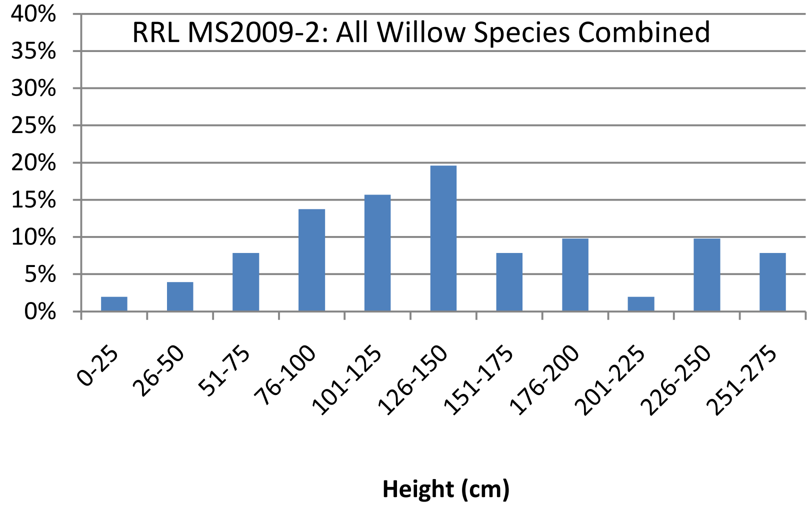
Red Rock Creek meanders through the photograph to the right. Willows grow along the bank of the active channel. A line of willows the in upper part of the photo mark the position of a relic channel. Willow grows on both sides of the channel, forming a belt that varies in width. RRL MS2009-2 is associated with a creek (Tom Creek); the willows formed a wide belt adjacent to the creek.



At RRL MS2009-1, tall willows mark the perimeter of a topographic depression. The peaty substrate of the depression was saturated. The tall willows may mark the perimeter of a pond or wetland that has since filled, becoming dry enough to support willows in the interior. The difference in species could reflect environmental tolerance or differences in colonization strategies.

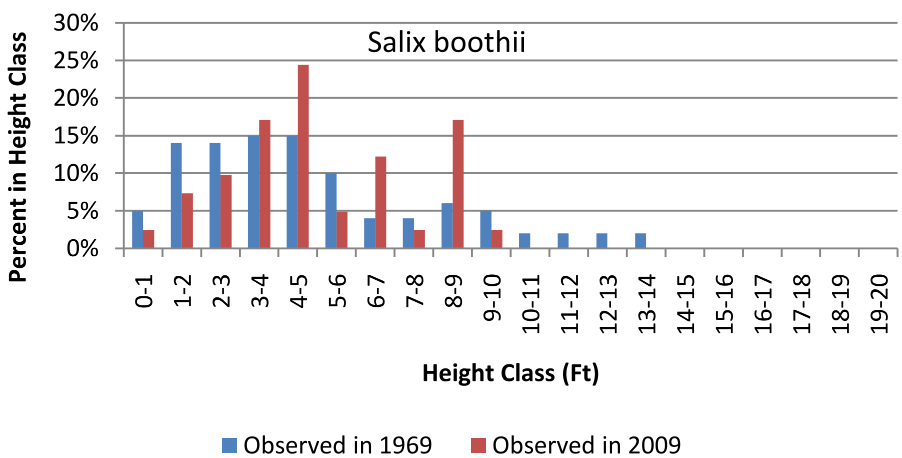
Height comparisons between sites measured in 2009. Frequency distributions of the heights of all tall-growing willows are shown below. The scales of the Y-Axis are similar for comparison. There were marked differences in height as well as the differences in density described above.

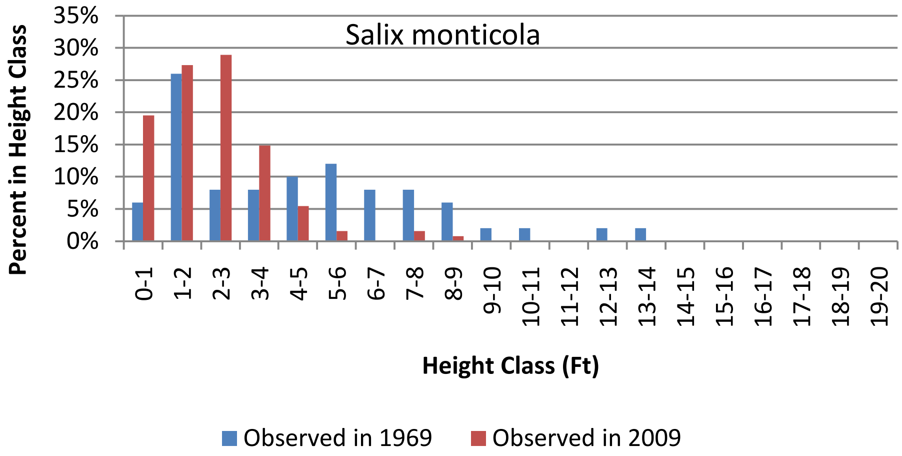


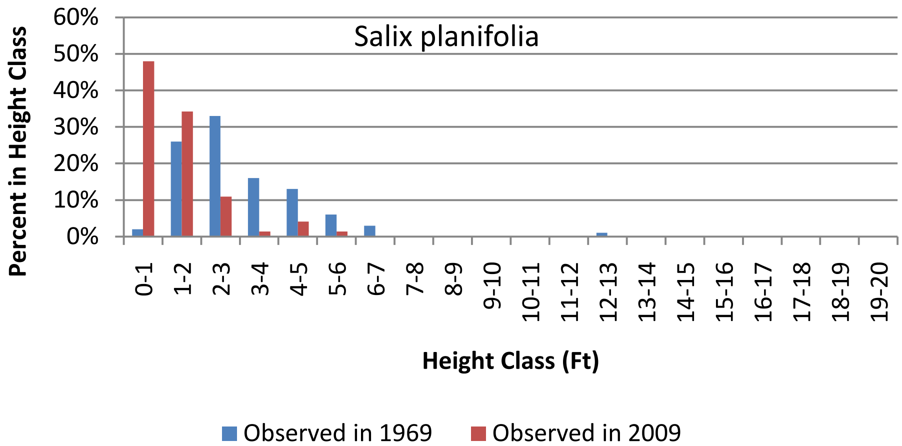


Height comparisons between sites measured in 2009 and Dorn's 1969 data.

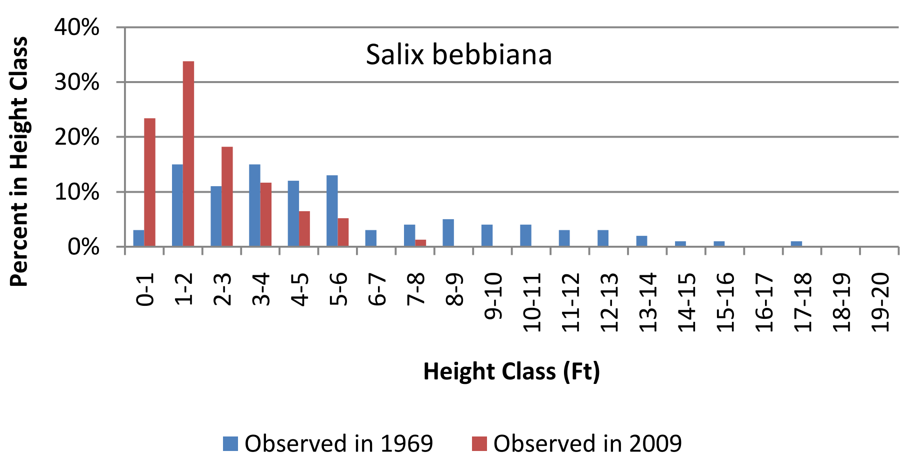
Dorn measured the height of willows adjacent to his line transects. By comparing those heights with heights measured in 2009, we gain a perspective on how structure has changed in the past forty years. To correspond with Dorn's protocol, our metric measurements were converted to feet. Data from both monitoring sites were pooled.







At RRL MS2009-1 we saw what were believed to be carcasses of large Bebb willow. We were especially interested in changes in Bebb willow because of its high palatability. To increase our sample size, Gina Pasini took additional measurements at 28 random locations for a total sample of 205 additional measurements. When pooled with data from MS-1 and 2, the total size was 285.



With respect to all species, it appears that there has been a marked reduction in height. Over the forty year period, structural diversity at Red Rock Lakes NWR has diminished.

Alamosa National Wildlife Refuge

Richard Keigley and Scott Miller

Overview

The Alamosa National Wildlife Refuge is located southeast of Alamosa in south-central Colorado. The 11,169 acre refuge was approved for acquisition in 1962 by the Migratory Bird Conservation Committee as a sanctuary for migratory birds. Prior to establishment, the area was managed for cattle ranching; irrigation ditches were constructed to irrigate meadows for the production of livestock forage. After establishment, similar irrigation practices continued in order to provide wetland habitat. Much of the refuge is located on the historic floodplain of the Rio Grande River, the hydrologic characteristics of which have been altered by diversion of water upstream. The refuge provides habitat for a variety of wildlife including the endangered southwestern willow flycatcher. This report focuses on the nesting habitat required by that species.

Ungulate Populations. The formation on elk number was provided by Ron Rivale, Colorado Department of Wildlfie.

Historic use. Livestock grazed on the refuge until 1993. Prior to 1997 there were no known elk observations. In 1998 300 elk entered the southern end of the refuge during hunting season; some left after the end of the season. In 1999 400 elk moved into the area. By 2000 400 elk were present in vicinity of the refuge.

Current use. Trespass grazing by a small number of cattle occasionally occurs. The current resident elk herd is estimated to be 350.

General Habitat Goals

Comprehensive Conservation Plan Goal 8: *Enhance the Rio Grande corridor and its tributaries on Refuge lands to provide habitat for river, riparian-dependent, and other wetland species.*

Habitat-types Addressed in 2009

Coyote willow (*Salix* exigua) communities growing adjacent to the Rio Grande River.

Willow shrublands within the refuge were found to support a breeding population of willow flycatcher that is presumed to be the endangered southwestern willow flycatcher (Colorado Natural Heritage Program 2009). Most of the nesting sites were associated with Coyote willow, the most abundant of the willow species occurring on the refuge. The desired nesting habitat consists of relatively dense riparian vegetation located near standing water or saturated soil. A study along the Rio Grande in New Mexico indicates a preference for nest sites located in the mid-canopy layer between 3 and 6 m in height (USDI 2007).

2009 Landscape Level Survey

The Landscape Level Survey was accomplished on September 30, 2009 by Scott Miller and Richard Keigley. Six sites were described.

Site Descriptions

ALAMOSA LLS2009-A

NAD83: 37.35037° N 105.74689° W
Species: Coyote willow.
Architectures:

- < 50 cm tall: Uninterrupted-growth type.
- 50-150 cm tall Arrested/Retrogressed-type.
- 150-250 cm tall: Retrogressed-type.
- > 250 cm tall: Retrogressed-type.

Inferred browsing history: Light increasing to heavy.

Two height classes can be seen in the upper photograph. In the mid-background of that photo (and in the photo to right) are willows that have grown taller than 2.5 meters. Among the stand of tall willows were dead stems that were 2.5 cm or more in diameter. Stems were not cut for aging, but based on a comparison with a stem cut at ALAMOSA LLS2009-E, stems of this size may be on the order of 20 years old. Weathered dead stems of similar diameter lay on the ground. The dense thicket of live and dead tall stems, combined with the weathered stems on the ground, suggested that willow was present at this location for many years.

Based on the data presented in USDI (2007), the tall willows likely provide superior nesting habitat for the southwestern willow flycatcher compared to the shorter adjacent willows.

In the mid-foreground of the upper photograph and in the photo to the right are willows that have grown to about 1 m tall. Many were dead. Live stems were estimated to be approximately 4 to 5 years old. Compared to the adjacent stand of tall willows, the stand currently provides inferior willow flycatcher habitat. The mortality of young plants raises questions as to whether this stand will attain the structural development of its older neighbor.

To further explore the potential effect of browsing, this site was selected for monitoring (Alamosa MS2009-1).

ALAMOSA LLS2009-B

NAD83: 37.36075° N 105.76243° W
Species: Coyote willow.
Architectures:

- < 50 cm tall: Uninterrupted-growth-type.
- 50-150 cm tall: Uninterrupted-growth-type.
- 150-250 cm tall: Uninterrupted-growth-type.
- > 250 cm tall: None.

Inferred browsing history: Light.

Willow stems were of fairly uniform height, most ranging from 1.75 to 2 meters tall. Based on stem diameter and bud scars, the live stems were estimated to be on the order of 5 to 10 years old—the live stems of this stand are similar in age. Since their establishment, these stems were lightly browsed.

Beaver had cut and removed virtually all older stems. An arrow points to a beaver-cut stem in the photo to the right. Sixteen beaver-cut stems were counted in this photograph. Based on diameter, the beaver-cut stems were similar in age to the live stems.

ALAMOSA LLS2009-C

NAD83: 37.36149° N 105.76314° W
Species: Coyote willow.
Architectures:

- < 50 cm tall: Uninterrupted-growth type.
- 50-150 cm tall: Arrested / Retrogressed-type, Uninterrupted-growth type.
- 150-250 cm tall: Retrogressed-type.
- > 250 cm tall: Retrogressed-type.

Inferred browsing history: Light increasing to heavy.

The stand consists of tall willows in the background (3 meters or more tall) and shorter willows in the foreground (about 1.5 m meters tall). The tall willows are clearly older than the shorter willows.

With respect to the short willows, the individual stems were relatively young. Many were dead.

The tall willows would provide good flycatcher habitat; the short willows would provide inferior habitat.

ALAMOSA LLS2009-D

NAD83: 37.37017° N 105.76771° W
Species: Coyote willow.
Architectures:

- < 50 cm tall: Uninterrupted-growth type, Arrested-type.
- 50-150 cm tall: Arrested / Retrogressed-type.
- 150-250 cm tall: Retrogressed-type.
- > 250 cm tall: None.

Inferred browsing history: Light increasing to heavy.

The stand was approximately 50 m from the active Rio Grande channel (a bank can be seen in the distance in the photograph on the preceding page).

The live stems in the foreground are relatively young (approximately 5 years). Many had died before growing taller than one meter. Some dead stems were lightly browsed. Others were intensely browsed, but the incidence of browsing appeared to be relatively low. Beaver had cut stems at some time in the past.

Carcasses of willows that had grown to about 2 m tall were lying on the ground. By the time these willows died, they had grown substantially taller than the willows that recently died.

From aerial photographs it can be seen that this site was located in a relic channel that existed when the Rio Grande floodplain was braided. This carcass may have descended from individuals that were established in that channel.

ALAMOSA LLS2009-E

NAD83: 37.38017° N 105.77366° W
Species: Coyote willow.
Architectures:

- < 50 cm tall: Arrested-type
- 50-150 cm tall: Arrested / Retrogressed type.
- 150-250 cm tall: Retrogressed-type
- > 250 cm tall: Retrogressed-type.

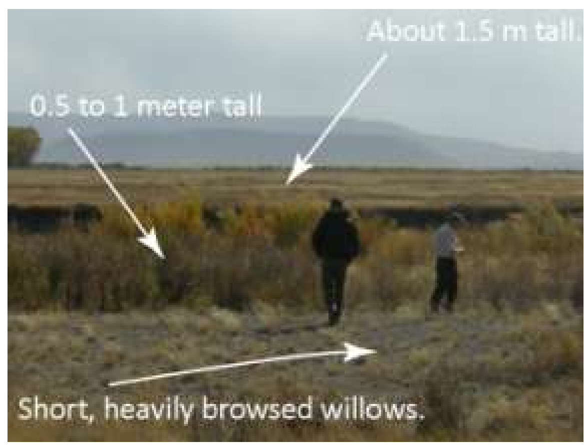
Inferred browsing history: Light increasing to heavy.

The tallest willows consisted of a small patch that can be seen to right of the photograph on the preceding page. The characteristics of other stands are discussed on the following page.

The remaining willows can be roughly classified into four groups. Adjacent to the Rio Grande was a stand of young willows. The establishment of this stand is discussed at the end of the chapter.

Willows that were approximately 1.5 m tall willows grew higher on the bank. These are seen in background of the photograph to the right. A stand of 0.5 to 1-m tall willows is in the mid-foreground. These willows were heavily browsed; many were dead. On the exposed bar in foreground were short (about 0.3 meters tall), very heavily browsed willows.

This site was selected for monitoring (Alamosa MS2009-2).



ALAMOSA LLS2009-F

NAD83: 37.43061° N 105.78864° W
Species: Coyote willow.
Architectures:

- < 50 cm tall: Uninterrupted-growth type
- 50-150 cm tall: Uninterrupted-growth type; Arrested / Retrogressed-type.
- 150-250 cm tall: Uninterrupted-growth type.
- > 250 cm tall: Uninterrupted-growth type.

Inferred browsing history: Light increasing to heavy.

This stand is on the northeast side of the Rio Grande, which flows to the southeast. The part of the stand seen in the photograph above was very lightly browsed; only uninterrupted-growth type individuals were seen. This part of the stand would provide excellent flycatcher habitat.

Browsing did occur on the southwest side of the stand adjacent to the Rio Grande, where a few Arrested / Retrogressed type individuals were seen. The individuals in the photograph to the right are about 1 to 1.5 meters tall.

Also on the southwest side of the stand was a patch of dead willow.

Monitoring

ALA MS2009-1

NAD83: 37.35037° 105.74689° This is ALAMOSA LLS2009-A.

Species monitored: Coyote willow.

Step 1: Specify target characteristics for plants greater than 2.5 m tall.

The target condition was based measurements taken in the stand of tall willow at Alamosa MS2009-1 (the measurement is described in Step 2). Resulting density: 0.5 patches per square meter, which would result in patches spaced about 1.4 meters apart.

Step 2: Measure the existing density of plants that are greater than 2.5 m tall and the density of plants that are less than 2.5 m tall.

No tall willow grew within the stand of short plants north of the fence. The existing density of shrubs < 2.5 m tall was measured in a 2-m-wide by 27-m-long belt transect. 29 patches were counted in this 54 m^2 area.

The resulting densities were:

Shrubs > 2.5 m: 0 per m^2
Shrubs < 2.5 m: 0.5 patches per m^2

Step 3: Estimate the Replacement Percentage.

Replacement Percentage is calculated by dividing the target shrub density by the number of propagules that would be present after a hypothetical fire. Each patch was assumed to represent a a propagule following fire. The total existing density of patches was used as an estimate of Propagule Density. Because Coyote willow root sprouts, this is a very rough estimate.

Replacement Percentage = 0.5 / 0.5 = 100 %.

The target density of 0.5 patches per square meter would be attained if 100 % of the existing patches produced shrubs that grew taller than 2.5 m.

Step 4: Calculate the threshold browsing pressure.

Threshold browsing pressure = 100 % - Replacement Percentage, or 0 %.

Step 5: Estimate a Threshold LD Index.

The initial Threshold LD Index was set at 50 cm.

Step 6: Measure the Existing Browsing Pressure.

Obs	HBCYG	HD	LCYG	LD Index	Prevent?
1	101	102	16	-1	TRUE
2	137	174	6	-37	TRUE
3	93	100	3	-7	TRUE
4	140	136	3	4	TRUE
5	69	65	1	75	FALSE
6	130	138	6	-69	TRUE
7	114	121	5	9	TRUE
8	149	153	10	-39	TRUE
9	112	144	4	5	TRUE
10	85	102	22	10	TRUE
11	73	93	6	-8	TRUE
12	138	136	12	-63	TRUE
13	137	132	20	6	TRUE
14	139	97	10	40	TRUE
15	101	102	5	37	TRUE
16	60	64	5	37	TRUE
17	98	99	1	-39	TRUE
18	122	125	30	-27	TRUE
19	69	95	1	27	TRUE
20	27	102	49	-33	TRUE
MEAN	**109**	**114**	**11**	**-4**	
SE	**6.5**	**6.3**	**2.7**	**8.2**	

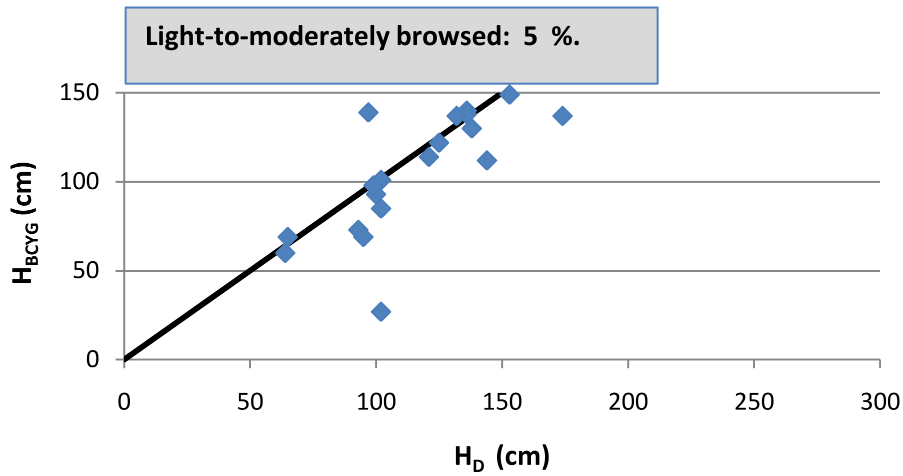
Light-to-moderately-browsed: 0 %
Percent Intensely-browsed: 100 %
Existing Browsing Pressure: 95 %

Step 7: Compare Existing Browsing Pressure to Threshold Browsing Pressure.

The Existing Browsing Pressure of 95% was greater than the Threshold Browsing Pressure of 0 %. Based on this analysis, it could be concluded that browsing was the dominant factor influencing stand structure. However, other factors also affect stand structure. It appears likely that browsing and hydrologic factors are co-dominant influences.

Predicted Stand Density if Present Trend Continues

Structure at this site is in a declining trend. Most intensely browse plants are not growing taller. If browsing was dominant influence the density of stems taller than 2.5 m would be 0.025 stems per square meter (5% of 0.5 stems per square meter). The patches would hypothetically be spaced 6 meters apart. But it appears that hydrologic influences also affect this stand. The future density will likely be 0 stems per square meter.



ALAMOSA MS2009-2

NAD83: 37.38017° 105.77367°

Species monitored: Coyote willow.

Step 1: Specify target characteristics for plants greater than 2.5 m tall.
The target density was based on attaining patches of willows spaced 2 meters apart. The resulting density would be 0.25 stems per square meter.

Step 2: Measure the existing density of plants that are greater than 2.5 m tall and the density of plants that are less than 2.5 m tall.

There were no willows taller than 2.5 m. The existing density of shrubs < 2.5 m tall was measured in a 2-m-wide by 60-m-long belt transect. 108 clusters of stems were counted in this 60 m^2 area.

The resulting densities were:

Shrubs > 2.5 m: 0 per m^2
Shrubs < 2.5 m: 1.8 patches per m^2

Step 3: Estimate the Replacement Percentage.

Replacement Percentage = Target Density / Propagule Density, or 0.25 / 1.8 = 14 %.

Step 4: Calculate the threshold browsing pressure.

Threshold Browsing Pressure = 100 % - 44 % = 66 %/

Step 5: Estimate a Threshold LD Index.

Threshold LD Index was set at 50 cm.

Step 6: Measure the Existing Browsing Pressure.

Obs	HBCYG	HD	LCYG	LD Index	Prevent?
1	69	100	5	-31	TRUE
2	84	129	30	-45	TRUE
3	66	57	1	9	TRUE
4	81	122	8	-41	TRUE
5	50	66	19	-16	TRUE
6	59	102	31	-43	TRUE
7	77	142	25	-65	TRUE
8	102	105	3	-3	TRUE
9	112	156	25	-44	TRUE
10	65	53	16	12	TRUE
11	78	108	26	-30	TRUE
12	37	113	31	-76	TRUE
13	43	112	60	-69	TRUE
14	70	126	25	-56	TRUE
15	44	92	13	-48	TRUE
16	86	87	25	-1	TRUE
17	44	65	16	-21	TRUE
18	66	50	4	16	TRUE
19	40	41	37	-1	TRUE
20	19	80	32	-61	TRUE

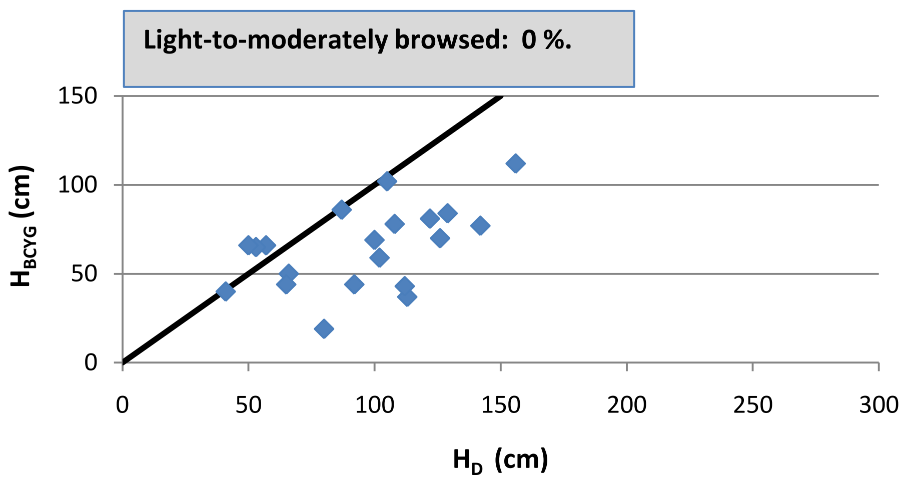
Light-to-moderately-browsed: 0 %
Percent Intensely-browsed: 100 %
Existing Browsing Pressure: 100 %

Step 7: Compare Existing Browsing Pressure to Threshold Browsing Pressure.

The Existing Browsing Pressure of 100 % was greater than the Threshold Browsing Pressure of 66 %. Based on this analysis, it could be concluded that browsing was the dominant factor influencing stand structure, but hydrology may play a major role in the decline of this stand.

Predicted Stand Density if Present Trend Continues

This stand is predicted to disappear. What little structure existed is in an intermediate stage of decline.



Additional Information and Discussion

The analysis above documented that browsing is associated with the death of complete annual increments of stems. If this occurred at a level that prevented height growth, we could (using criteria defined for each site) conclude that browsing was having a dominant effect on the structure of the plant community.

But as we noted during the Landscape Level Survey, lightly browsed plants of similar height (and presumed age) are dying. The mortality of young willows is extensive. The stand to the upper right is on the west side of the Rio Grande, approximately 50 m northwest of 37.3838° N 105.7747° W. The stand was about a meter above the water surface level of the Rio Grande.

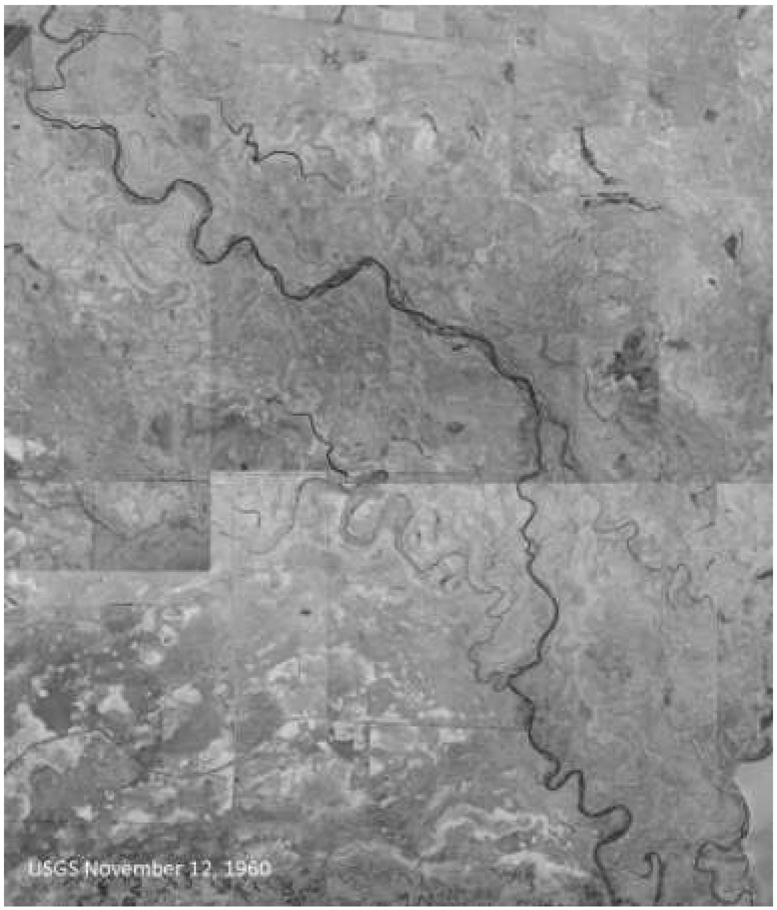
All plants in the stand above (live or dead) were young—only a few years old. No willows had survived long enough to grow more than about a meter tall. The fact that these willows became established for even a few years is evidence that, if post-establishment circumstances were appropriate, the site could potentially support a stand of tall willows. Below we will show the flood event that likely established this stand was exceeded many times in the past, yet there is no evidence that willows became established and survived for an extended period of time. And because large numbers of ungulates have only been present since about 1998, ungulate herbivory does not explain the lack of tall willow on this site.

Our data do suggest that browsing is having an effect on height growth. But given the historic lack of growth at sites such as that above, there appears to be other factors that significantly influence the growth of willows. If we are to partition the effect of browsing from those other factors, we need to identify those factors.

Hydrology is one possibility. The flow of the Rio Grande River is highly regulated. The diversion of water for irrigation has had two influences:

- Morphology: Prior to flow regulation the Rio Grande floodplain consisted of braided channels. Since flow regulation, the Rio Grande has been largely confined to a single channel that has been relatively stable over several decades. Based on aerial photographs taken in 1960, the Rio Grande channel has remained relatively stable for at least 70 years. Photographs showing the channel location in 1960 and 2005 are shown on the following page.

- Annual discharge: Prior to flow regulation the Rio Grande would be expected to have had a peak discharge associated with spring runoff. After flow regulation, peak annual discharge can potentially occur at any time of year.


USGS November 12, 1960


FSA NAIP June 27, 2005

Willow establishment and survival is closely tied to stream hydrology. With the possible exception of beaver-transported cuttings, the initial establishment of Coyote willow at a site is from seed. The seeds are viable for only a few days, and must germinate on a moist mineral soil. A typical establishment scenario involves seed dispersal in late June as spring flooding diminishes. The retreating floodwater produces a moist substrate. If that substrate is mineral, the conditions are suitable for germination. Establishment occurs if root growth can keep pace with the declining soil moisture. For the next several years, the plant grows taller and the roots grow deeper. Individual Coyote willow stems are relatively short-lived. But once firmly established by seed at a site, a willow stand can persist by vegetative reproduction for many decades. We will show that many stands on the Alamosa NWR are likely more than 70 years old.

To summarize, there are three requirements:

- Seeds must be deposited on a moist mineral substrate.
- After deposition they must remain in place long enough to germinate and survive the initial growing season, and
- After that initial growing season, they must continue to survive.

The section below describes observations that relate hydrology to the three requirements described above. A case will be made below that the first two requirements are being met, and that the third requirement may be the limiting factor.

In the course of our survey we did not age willow stems by cutting sections and counting annual rings. We did approximately age stems by counting bud scars. Those approximate ages are used in the discussion that follows, recognizing that a rigorous corroboration is required.

Three cohorts are referred to:

- A cohort of two-year old stems,
- A cohort of stems that are approximately five years old, and
- A cohort of ten-year old stems.

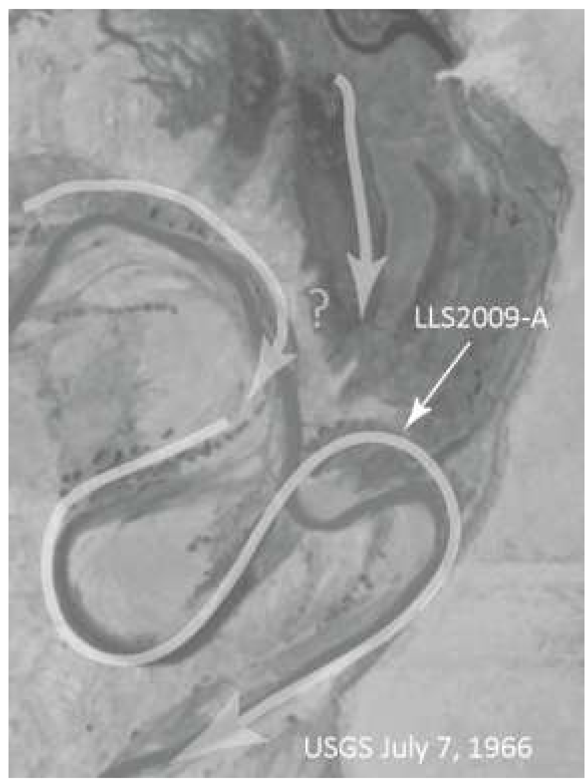
In addition, we refer to “old, tall stands.” These are stands that were established long enough ago that some stems have died of old age, and younger stems have grown within the canopy to replace them. Such stands are 3-meters or more tall, they are comprised of plants having stems that are up to 3 cm diameter, and they have a dense canopy. The photographs of Alamosa LLS2009-A (presented in the LLS section) show one such stand. These stands are also large enough to be visible in aerial photography.

Some stands of tall willow are associated with relic channels.

When viewed from groundlevel, willow communities appear to be patches that are scattered randomly in the vicinity of the Rio Grande. But from aerial photographs it can be seen that many stands are associated with relic channels. Some relic channels were clearly produced by the migration of the current Rio Grande channel. In the FSA NAIP 2006 photo to the right, stands labeled A, B and C are examples. In other cases, the relic channels are part of the braided system that existed historically.

Some stands of tall willow were established many years ago. Few stands of tall willow have been established since that time.

The photo to the right was taken July 7, 1966. The stands labeled B and C in the 2006 photograph above were present in 1966. The stand of tall willows at Alamosa LLS2009-A was also present in 1966. In the 2006 photograph, there is a small patch of willow at the southernmost end of oxbow. These willow stands were present in 1966.



Given their size in the 1966 photograph, these stands were likely established several years before 1966.

Stand B and the stand at LLS site A were likely established when the Rio Grande occupied the channel indicted by the lower arrow. The upper arrows indicate alternative upstream channel configurations.

When comparing the plants visible in the 2006 photo to the plants visible in 1966 photo, it appears that very few new stands of willow have been established in the past 40 years. Given the large size of the plants in the 1966 photo, the period of relative non-establishment is likely much longer.

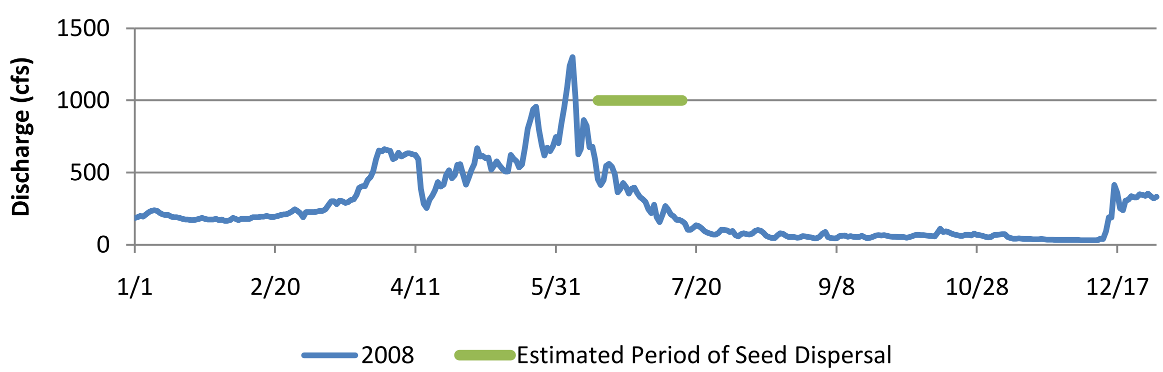
There appear to be frequent opportunities for establishment from seed.

In this section we document that seedling establishment does occur, and examine the discharge conditions that are favorable and unfavorable for deposition and establishment. We then describe an approach for determining the frequency of favorable events in the past.

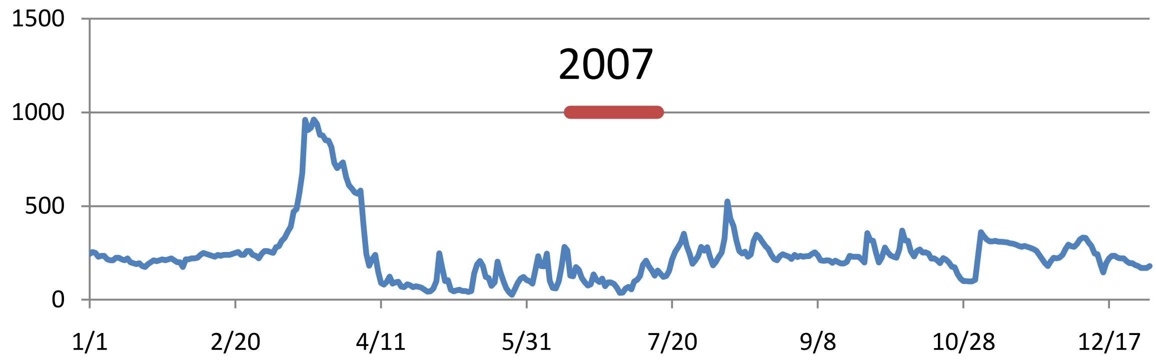
At Alamosa LLS2009-E we found 2-year old willows about 10 meters from water's edge on October 1, 2009. Seeds that were deposited in 2008 survived the growing season and continued to grow in 2009.

The willow in the photograph was aged based on branching. No leaves can be seen on the basal stem segment; arrows point to multiple branches off the one-year old segment. Although older Coyote willows routinely produce a second flush of growth it seems unlikely that a seedling that germinated in late-June would do so. If branching is to be used for aging seedlings, this interpretation should be confirmed.

Based on the scenario described above, flow conditions in 2008 were favorable for establishment. The discharge hydrograph for 2008 is shown below (Station: Rio Grande near Alamosa). Toward the end of June, water receded allowing seeds to be deposited on the moist mineral substrate. This satisfies the first requirement: opportunity for deposition. From late-June to the end of October stage did not increase. This period of low water allowed seedlings to become established before the next flood event, thus satisfying the second requirement: germination and establishment in the initial growing season. In December 2008 stage began to increase.

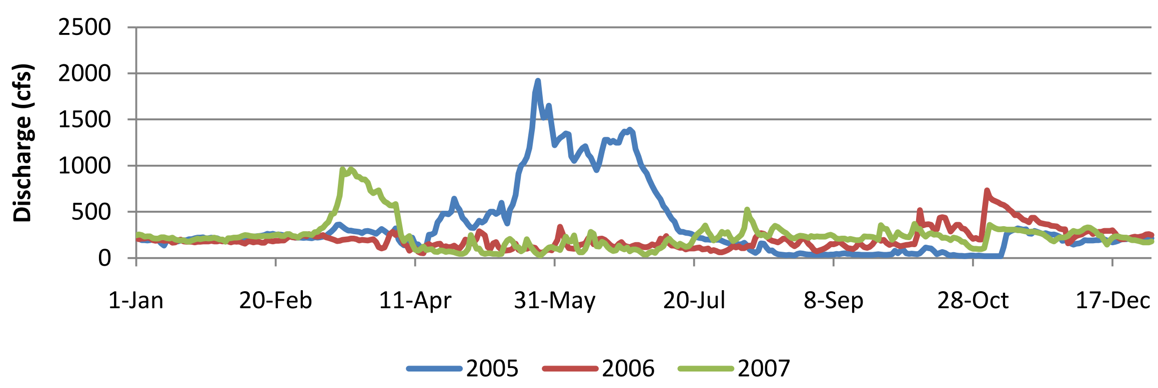


The 2007 hydrograph illustrates a sequence that is not conducive to seedling establishment. Seeds would likely be dispersed during the time indicated by red bar. Even if seeds were deposited during a low discharge stage during that period, the seedling would not have time to germinate and develop roots strong enough to resist the increase in discharge that occurred later in that period. In this case, the first requirement might be satisfied, but not the second.



A comparison of 2005, 2006, and 2007 illustrates the effect of regulated flow of the Rio Grande. In 2005 peak discharge occurs during the period associated with spring runoff. As in 2008, this timing could result in successful seedling establishment.

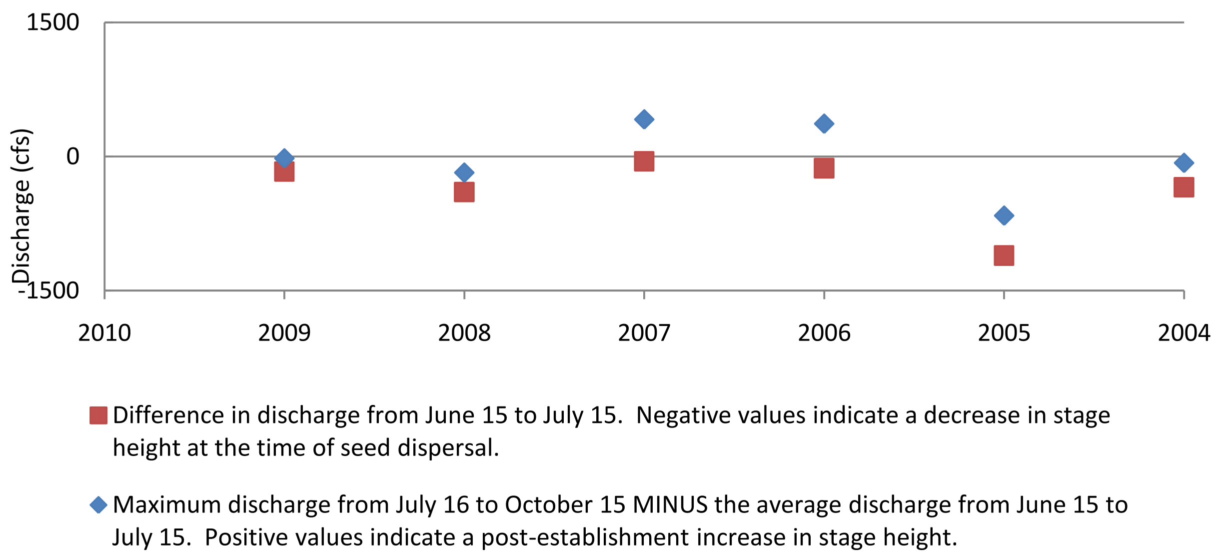
In 2006 peak discharge occurred in November; in 2007 peak discharge occurred in March. In both years, discharge was consistently very low during the period of seed dispersal. Any seeds that were deposited would be subject to removal by small fluctuations in discharge.



An Approach for Determining the Frequency of Favorable Events

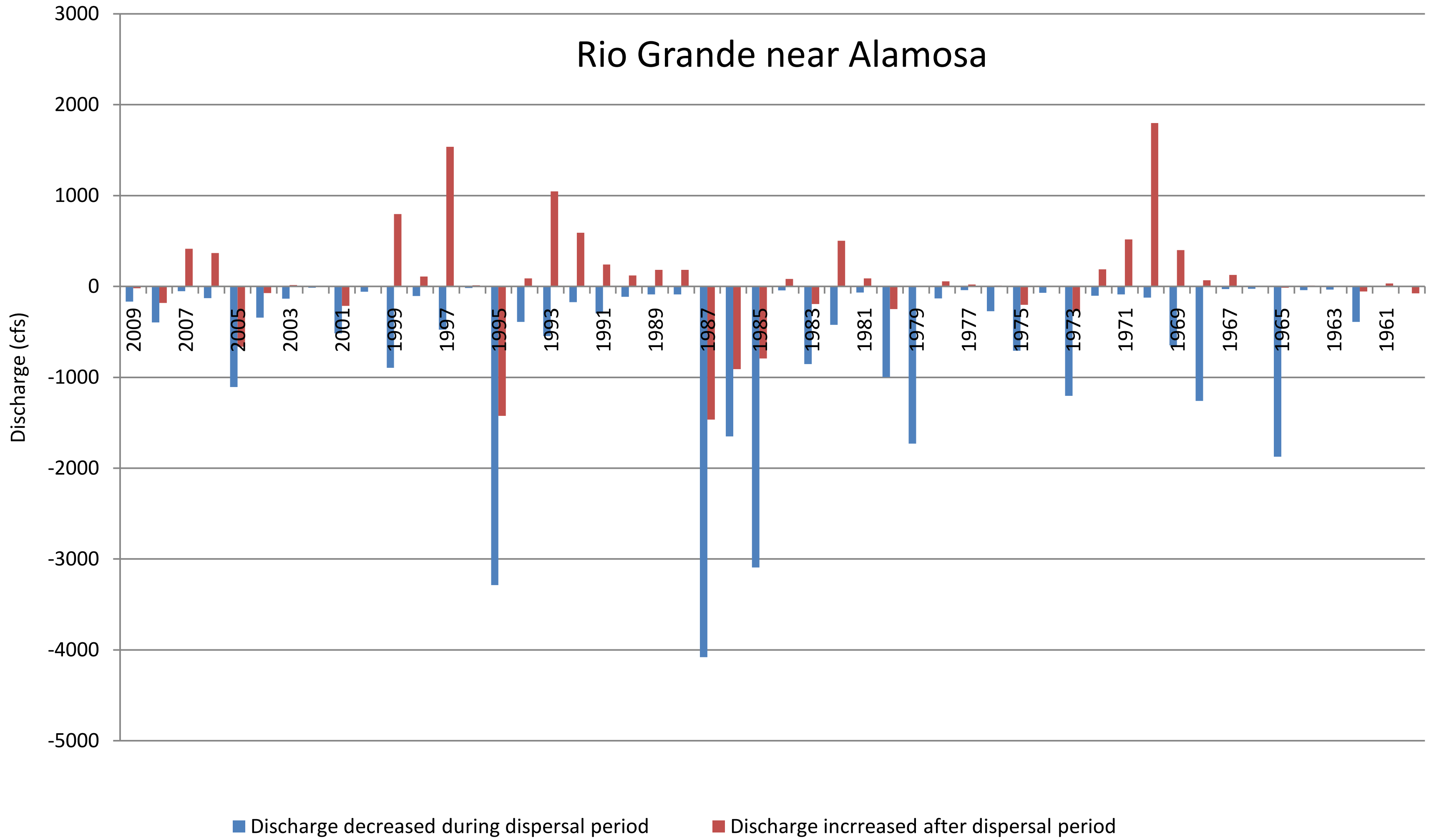
Discharge data for the Rio Grande River near Alamosa are available for the period 1912 through the present. (The accuracy of that record may vary with advances in measurement technology.) A method for assessing the opportunity for seeding establishment is described in the graph below. The assessment occurs in two stages.

The first stage is to determine if a receding flow occurred as seeds were dispersing. In the graph below, red square markers plot this stage. The plotted value was calculated by determining the maximum discharge that occurred during period June 15 to July 15, and subtracting that maximum value from the discharge that occurred on July 15. Red square markers below zero indicate that discharge declined over the June 15 – July 15 period, potentially allowing seeds to be deposited.



The second stage is to determine if discharge remained low after July 15, allowing the deposited seeds to germinate and become established during the initial year. The plotted value was calculated by determining the maximum discharge that occurred from July 16 to October 15, and subtracting from that value the mean discharge that occurred over the June 15 to July 15 period. Blue diamond markers below zero indicate that discharge did not increase. For example, in 2005 (graphed on the previous page) the mean discharge between June 15 and July 15 was 946 cfs; the maximum daily discharge from July 16 to October 15 was 284 cfs; 284 – 946 = - 663 cfs. The highest probability of seed deposition and establishment occurs when both markers are substantially below zero.

The graph on the following page describes an analysis of the period 1960 to 2009. During that 48 year period, the criteria (negative values in both cases) were met in nineteen years. However, in some of those years some values were very close to zero, nearly failing to meet the criteria.


Rio Grande near Alamosa
Discharge (cfs)
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
2009
2007
2005
2003
2001
1999
1997
1995
1993
1991
1989
1987
1985
1983
1981
1979
1977
1975
1973
1971
1969
1967
1965
1963
1961
Discharge decreased during dispersal period
Discharge incrreased after dispersal period

The condition in 2008 could be viewed as representing the minimum favorable conditions. Based on that minimum threshold, favorable conditions for seed deposition and seed germination and survival the initial year have occurred 11 times since 1960.

Because we do not know the relationship between discharge and stage height at given locations, we cannot place the potential establishment cohorts at a specified height above the river. At LLS2009-E, the 2-year old plants were located about 10 meters from the river on October 1, 2009. We did not measure the height of this surface, but it was likely on the order of 25 cm above Rio Grande on that date. The relationship between discharge and stage height will vary from place to place depending on channel morphology.

A ten-year old willow would correspond to the 2001 event, and be located on a somewhat higher surface compared to plants established in 2008. A five-year old cohort would correspond with the 2005 event which would have occurred on an even higher surface. Very high surfaces could have been inundated in 1995, 1987, 1986, and 1985. Alternatively, higher discharge could spread laterally, causing seeds to be deposited farther from the main channel.

The FSA NAIP photograph taken June 27, 2005 provides evidence of the extent to which floods will occupy relic channels. On the date the photograph was taken, the discharge was 1,370 cfs. Peak discharge at 1,920 cfs occurred on May 25. At 1370 cfs, the channel marked C was partially inundated.

Referring back to the pair of 2005 / 1966 photographs shown above, the channel marked B appears to have been recently wetted. What appears to be herbaceous vegetation has greened.

While the area is not shown in the photograph to the right, water appears to have entered the channel leading to stand A in the previous photograph.

If the substrate of these areas was mineral, there would be a moist site appropriate for willow seed germination and establishment each time Rio Grande flood stage receded to 1,370 cfs in late June as willow seeds were dispersing.

Over the period 1960 to 2009, there appear to have been 11 opportunities for willow seeds to have been deposited and survive through the initial year. The location of that establishment would depend on the location of the water’s edge when seeds were dispersing. Examination of the 1966 and 2006 photographs indicate that, if this occurred, those stands did not develop to maturity. The current widespread mortality of young plants may indicate the fate of plants established in the past.

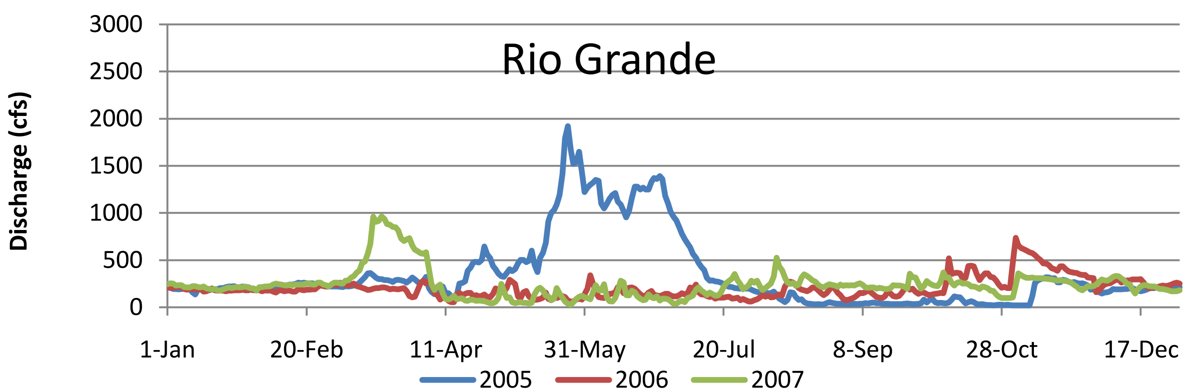
Why are young willows dying after being established?

The death of willows after establishment could potentially be related to the regulated flow of the Rio Grande. As shown above, water diversion can cause peak discharge to occur at any time of year. In many years, peak flow does not correspond to spring runoff. It could be that some sites depend on recurrent high discharge to maintain adequate soil moisture during the growing season.

Immediately after germination, a willow seedling must develop a root system capable of following soil moisture as flooding recedes. By the end of the first year, roots may develop to a shallow depth. When the young plant begins its second growing season, soil moisture could be provided by two sources. Precipitation during the preceding months would provide some moisture. Deeper soil moisture may be provided by high stream discharge during spring runoff. A willow could be initially sustained by precipitation-derived moisture. If seasonal flooding occurred, roots could then follow the soil moisture as the flooding recedes. Repeated over a number of years, roots could reach a level where soil moisture was reliable.

This section explores the possible effect of flow regulation by examining the frequency of inundation. As described above, some tall willow stands may have initially become established when streams were not regulated. Mature stands could have had well-developed root systems, and may have been able to adapt to flow regulation. It is the younger stands that hypothetically could be affected by intermittent reduced flow.

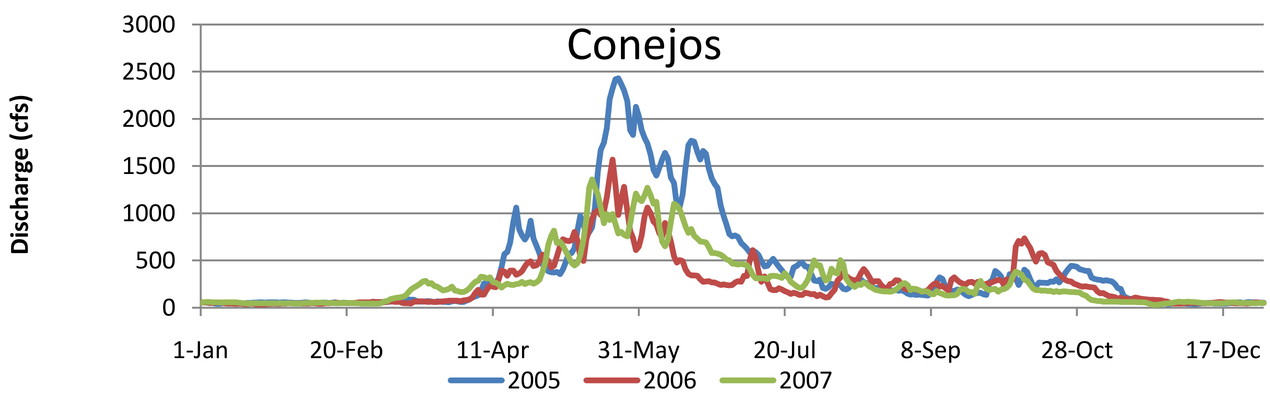
An example is shown below. Given the modestly high discharge in 2005, seedlings could have been deposited on an upper terrace. For the next two years, those plants would not have benefited from water derived from a flood stage. Discharge did increase during the spring of 2008, perhaps providing some relief. But two years of growth depending primarily on surface moisture could have hypothetically stressed these plants.



To determine the effect of regulated flow, we need to compare regulated rivers to natural flowing rivers in close proximity. No appropriate comparison can be made in the vicinity of the refuge. We can however compare flows in two regulated streams, and if the extent of that regulation is substantially different, examine the differences in willow communities.

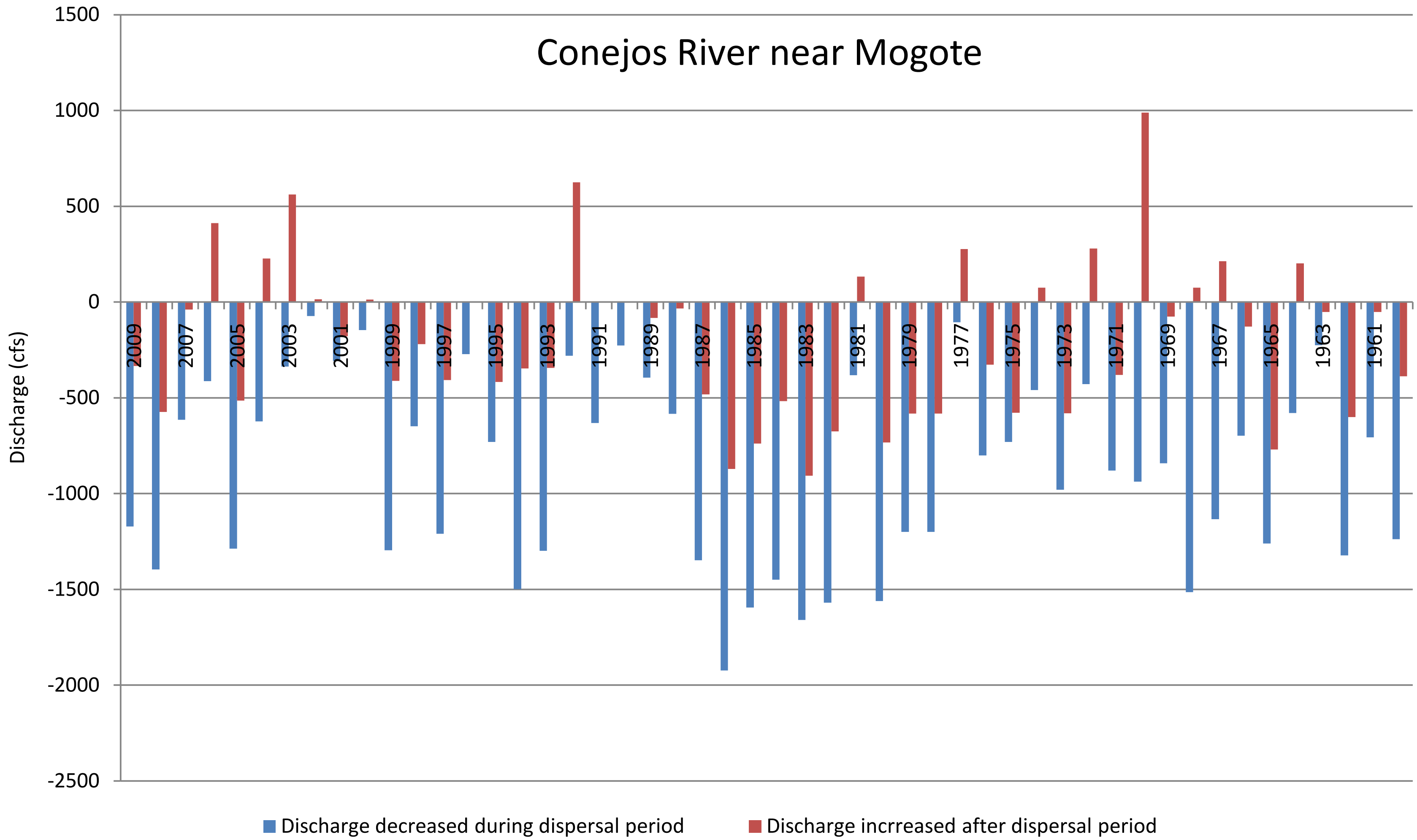
The hydrograph below is from the Conejos River gauge station near Mogote, CO (CONMOGO). The site is located about 30 miles southwest of LLS2009-1. Like the Rio Grande, the Conejos is heavily used for agriculture, and for this reason is not a natural flowing river. The period 1960 to 2008 is compared below. With a mean annual discharge of 308 cfs, more water annually flows through the Conejos compared to the Rio Grande with a corresponding annual mean of 226 cfs.

Discharge is plotted for 2005, 2006, and 2007. In each of those years there was a substantial increase in discharge during the growing season. In each of the three years there would have been appropriate conditions for: 1) seed deposition, 2) germination if the substrate was mineral, and 3) survival over the initial growing season. In 2006 and 2007, an increase in discharge would have increased the soil moisture available to plants that were established in 2005.



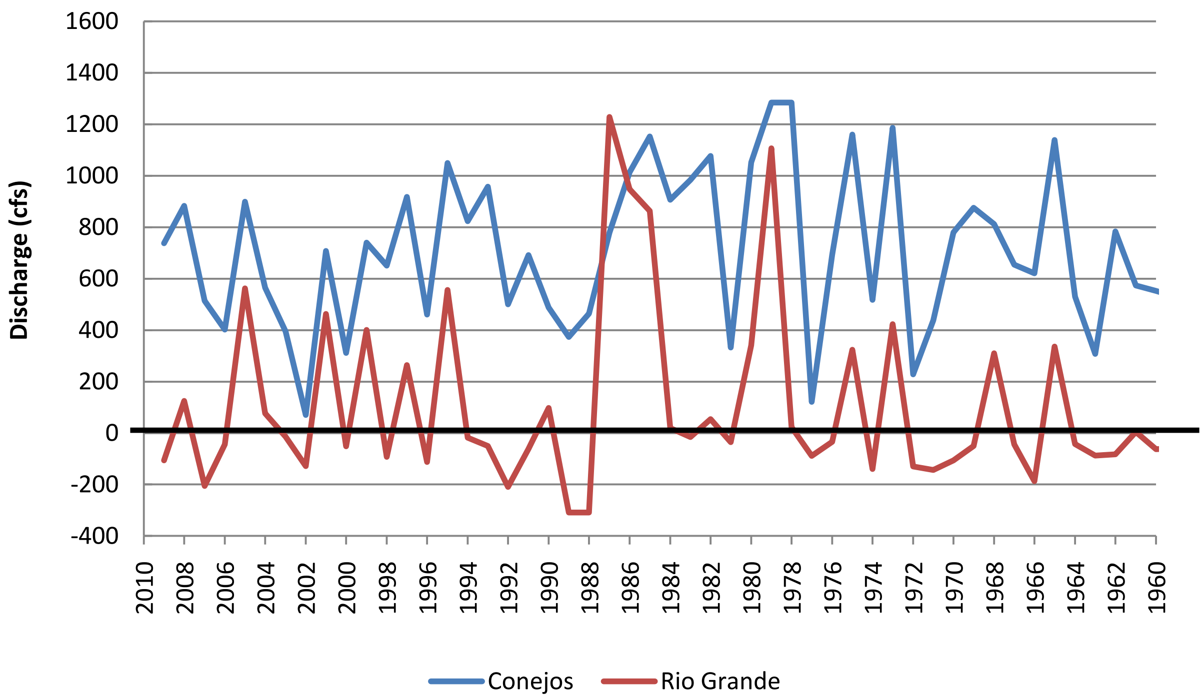
The successive years of inundation did not occur consistently on the Conejos. In some years, conditions were not appropriate for seedling establishment. In some years, flood discharge was followed by low flow during the growing season. However, an analysis identical to that run for the Rio Grande suggests that conditions on the Conejos are hypothetically more favorable for seed deposition, initial survival, and long-term survival of willow. Germination would vary by the local type of substrate.

The graph on the following page describes the frequency conditions that are hypothetically appropriate for seed deposition and initial survival over the period 2009 – 1960. In 35 of the 48 years, the test criteria were strictly met. Using the same threshold condition that was used on the Rio Grande, in 33 years hydrologic conditions were favorable for the deposition and survival of willows the first year.


Conejos River near Mogote
Discharge (cfs)
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
2009
2007
2005
2003
2001
1999
1997
1995
1993
1991
1989
1987
1985
1983
1981
1979
1977
1975
1973
1971
1969
1967
1965
1963
1961
Discharge decreased during dispersal period
Discharge incrreased after dispersal period

There appears to be a much higher probability of seed deposition and (if seeds germinate on an appropriate substrate) initial establishment on the Conejos River. Long-term survival is the third requirement to produce a mature stand. The graph below describes the change in discharge in winter/early spring to discharge that occurred during growing season which was taken to be May 1 through July 31. The values plotted on the graph were calculated as the average occurring from May 1 to July 31 subtracted from the average occurring from February 1 to April 30. Negative values mean that discharge during the growing season was lower than the discharge during late winter / early spring.

For example, in 2007 on the Rio Grande, mean discharge from February 1 to April 30 was 341 cfs. The mean discharge from May 1 to July 31 was 136 cfs. Discharge during the growing season was 206 cfs less than the discharge during late winter / early spring.



Values on the Conejos are all above zero, and are typically above 400 cfs. Values on the Rio Grande are often below zero, and seldom above 400 cfs. The analysis indicates that the Conejos recharges subsurface moisture more frequently compared to the Rio Grande.

The frequent occurrence of increased discharge during the growing season could allow young willows to survive long enough to develop root systems that reach a depth where soil moisture is consistent.

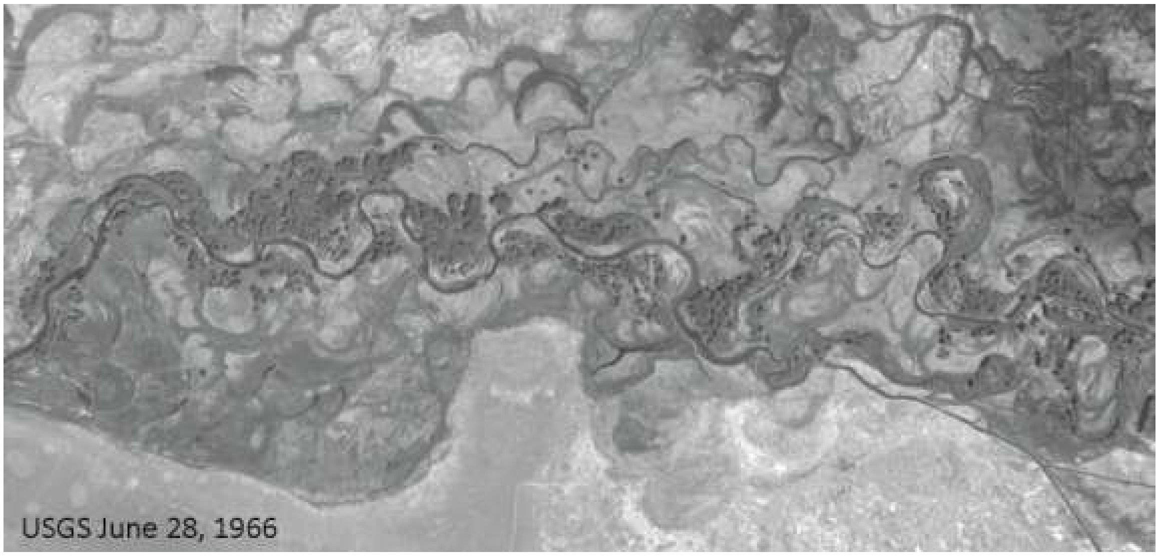
Based on the exercise above, it appears the Conejos has discharge characteristics that, compared to the Rio Grande, more appropriately meet the requirements for the establishment of mature, tall willow stands. There is a higher frequency of conditions appropriate for seed deposition and survival the initial year. There is also higher discharge during the growing season which hypothetically could provide more reliable soil moisture for developing root systems. The areal extent to which this happens on the respective rivers is dependent on the type of substrate: mineral soil is required for optimum germination.

Above we have described hydrologic differences between the two rivers, and explained the hypothetical effect these differences could have on willow communities. The next step would to examine differences in the willow communities on the two rivers, and based on those observations develop testable hypotheses. Even after differences are noted, we are a long way from documenting the actual effect of hydrology on willows.

In this section we have described two types of willow observations: plants we have seen from the ground, and plants that are visible on aerial photographs. We have referred to the widespread mortality of young willows on the Rio Grande. We saw these plants on the ground; they cannot be seen on aerial photographs. We did not visit the Conejos, so we cannot say whether or not similar widespread mortality occurred there. Quantifying the mortality of young plants at these two rivers would be a candidate for study.

We can examine willow condition at both sites using aerial photography. The condition of willows at one location on the Rio Grande was described above. The stands of tall willows visible in the 2006 photograph were also visible in the 1966 photograph. The stands are old; virtually no new stands of tall willows were established.

Based on the hypothetical model described above, on the Conejos we would expect that stands of tall willow periodically developed. If we were to compare aerial photographs we would expect to find substantial changes over time. Below we compare aerial photographs taken in the vicinity of Pike's Stockade located on the Conejos River 5 miles southwest from the location of the above paired photographs of Rio Grande. One set of photographs was taken on June 28, 1966, the other on June 27, 2005.

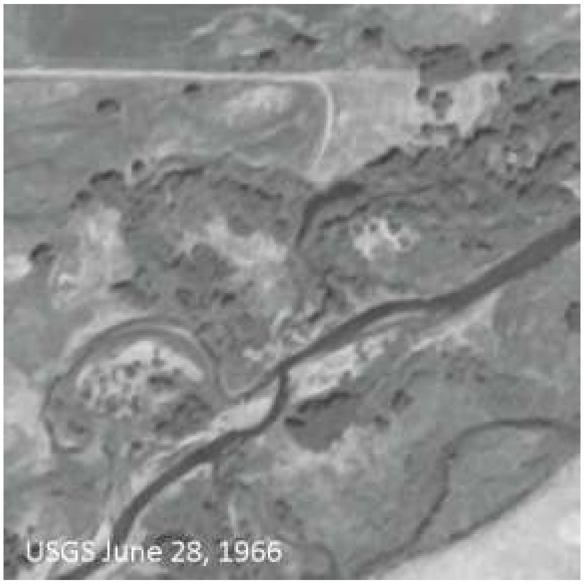


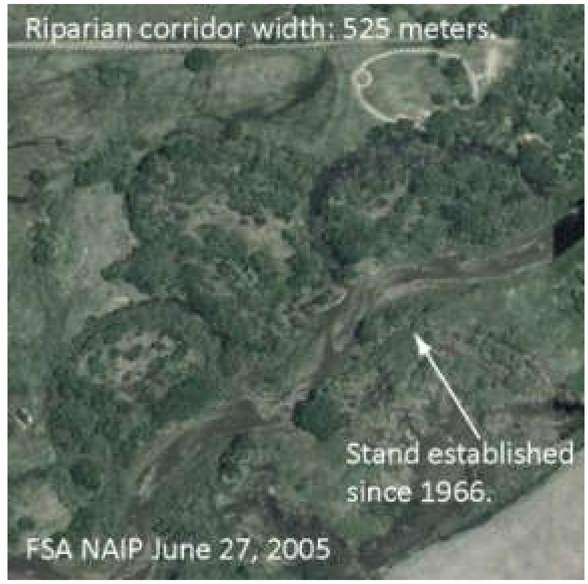
The left edge of the photographs is about 630 meters east of Pike's Stockade. The channel has changed relatively little over the past 40 years. With close inspection, a few small areas of new establishment can be seen in the 2005 photograph. Similar establishment has occurred adjacent to the Rio Grande channel.

Channel migration produces a mineral substrate suitable for establishment. The relative stability of the channel at this location may limit the areal extent of mineral substrate.

What distinguishes this site from any location on the Rio Grande is width. At this location, willows occupy a band approximately 400 meters wide. While the lineation of initial establishment is visible, large areas have filled in to create a relatively uniform willow cover.

Pike's Stockade can be seen in the upper right of the photographs below. In the 1966 photograph, the Conejos has created a mineral substrate as the channel migrated. New stands of willows were established by 2005. Willows occupy a corridor 525 meters wide at this point.





New stands are being established at some sites on the existing channel of the Rio Grande. The stand marked below is one example. As on the Conejos, channel stability likely limits the areal extent of mineral substrate.

On the Rio Grande within the Alamosa NWR there are a very few locations (primarily in the northern half) where willow stands are up to 150 meters wide. At those areas willows grow in narrow, well-defined lines along relic channels. The sparsely populated stands in the southern part of the refuge was shown in the paired photographs above and at the beginning of this section (LLS2009-A).

Confinement of the Rio Grande channel likely varies modestly within the refuge. In areas where the channel is somewhat confined, there have been at least four opportunities for Coyote willow to become established well above the height reached in 2005. In areas where the channel is somewhat less confined, those same events created opportunities for Coyote willow to become established further from the existing channel. The fact that willows are restricted to a narrow belt close to the existing channel suggests that soil moisture is limiting. A comparison with the Conejos suggests that low growing season discharge may be responsible for that limitation. This interpretation is not viewed as an explanation, but rather as a model that could be tested.

The Role of Browsing

Browsing does appear to have an effect on the height growth of young plants. However, there are other factors that appear to have limited willow distribution over a long term by causing the death of young willows. Changes in hydrology over the century could play an important role. If the currently level of browsing continues, the effect of browsing will be superimposed on whatever has caused the long-term decline in willow.

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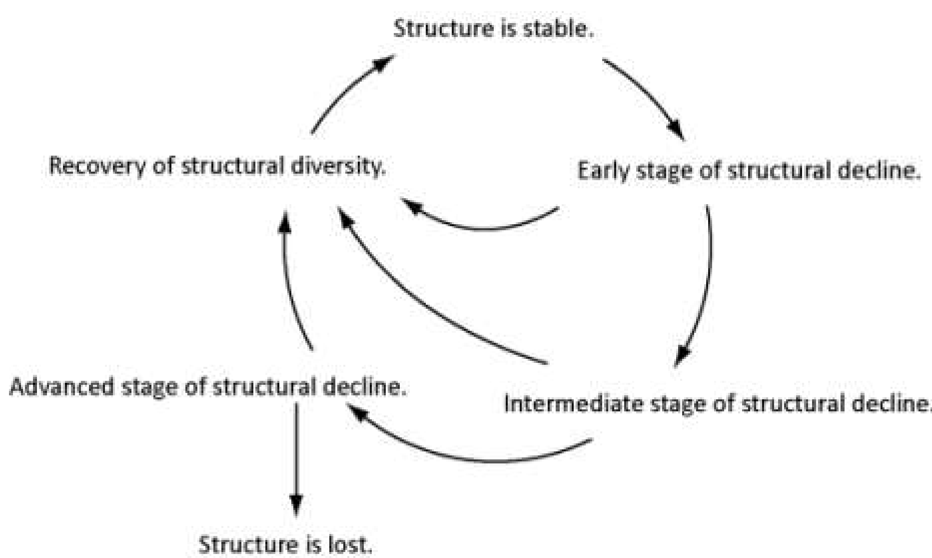
USDI. 2007. Vegetation quantification of southwestern willow flycatcher nest sites. Rio Grande from La Joya to Elephant Butte Reservoir Delta, New Mexico 2004-2006. Bureau of Reclamation. Denver, CO.

Stages of Structural Trend: A Multi-Refuge Comparison

Each refuge chapter describes implicit evidence that habitat structure is in a constant state of change, some of which is in response to ungulate browsing. This chapter describes a means of classifying the browsing-related trends that have occurred, and describes factors that influence the rate of change. The trends of respective browse species are classified separately. In a given area, species may differ with respect to their stage of structural trend.

At the level of the individual refuge, the approach can be used to assess how browsing may affect the attainment of management goals. Will nesting opportunities be diminished? Could predation be increased? At what rate can we expect change to happen? Is there an urgent need for mitigation? Is there opportunity for restoration? At the Regional level, the approach provides a uniform means of comparing habitat condition among refuges that differ in species composition. Such comparisons may be useful when comparing the urgency of needs among refuges.

Structural trend is classified into six stages diagrammed below. Classification can be based on Landscape Level Survey observations or on data collected during Monitoring. Existing Browsing Pressure controls the transition from the Structure is Stable Stage to the Early Stage of Decline, and from any stage of decline to the Recovery stage. The *rate* at which trends change is influenced by three factors: susceptibility, resistance, and resilience.



Below we describe the criteria for classification based on both Landscape Level Survey observations and on Monitoring data. We then describe four cases that were documented in the 2009 field season: Early, Intermediate, and Advanced stages of Structural Decline, and Recovery of Structural Diversity. Two examples were not seen during in 2009: Structure is Stable, and Structure is Lost (one site was very close to meeting the criteria for the latter).

After describing the classification process, we discuss the three factors that influence rate of change, and describe examples of each that were encountered in 2009. Finally, we describe the stage and rate of structural trend for each site that was monitored, and discuss the management implications.

Criteria for Classifying Stage of Structural Trend That Occur Due to Browsing

Notes. This following description occasionally refers to plant heights that are near the upper limit of the browse zone. For simplicity, that upper limit is assumed to be 250 cm. The actual limit of the browse zone will depend on the ungulate species that are present.

The term dieback can be applied at the stem or plant level. At the level of the stem, dieback refers to the death of its upper part. At the plant level, dieback refers to the death of its upper region. Because shrubs produce multiple stems, the dieback of stems does not necessarily result in the dieback of the shrub. We use the term to describe mortality at the plant level. Dieback is associated with a negative LD Index.

Some stages express structural trend as a graph of H_{BCYG} on $H_{D.}$ The reader is encouraged to refer to page 24 for an explanation of that graph.

Structural Trend is Stable

Architectures and Description: In its unequivocal expression, all plants growing within the browse zone have uninterrupted-growth-type architecture. The community consists of plants of diverse heights. The structure of the site will change in response to factors other than browsing. If Arrested-type plants are present, it would be necessary to measure Existing Browsing Pressure and calculate a Threshold Browsing Pressure to distinguish between the Stable stage and the Early Stage of Structural Decline.

Graph of H_{BCYG} on H_D: Does not apply (but see above); Light-to-moderately browsed plants have no H_D.

Habitat implications: None that are related to browsing.

Early Stage of Structural Decline

Architectures and Description: Plants growing within the browse zone exhibit the following characteristics:

- Arrested- and retrogressed-type plants are present.
- H_{BCYG} varies and ranges from close to ground-level to the upper limit of the browse zone.
- Visual evidence of dieback is absent.

When the Early Stage is fully developed, all plants growing within the browse zone have either arrested- or retrogressed-type architecture. Plants that are taller than 250 cm may have retrogressed-type architecture (shrubs) or uninterrupted-growth type architecture (trees).

During the growing season, current-year-growth extends above the dead stems that were previously killed by browsing. From a distance there is no evidence that the stand has been browsed. The effect can only be seen by examining the condition that exists below the current-year-growth.

At the beginning of the early stage of decline, shorter plants (50 – 100 cm) tend to be browsed first; taller plants are more likely to be lightly browsed and have uninterrupted-growth-type architecture. Over time, all plants become intensely-browsed. At the fully developed Early Stage, all individuals in the 50 to 250 size class are browsed to the zone of mechanical protection, but dieback is not significant.

If browsing diminishes, the early stage of recovery will be marked by the entry of young Light-to-moderately browsed plants into the browse zone.

Graph of H_{BCYG} on H_D: The LD Index of all intensely-browsed plants is about zero. Because plants can have live foliage throughout the browse zone, the plotted H_{BCYG} data can potentially range from zero to 150 cm (the maximum H_{BCYG} measured under the sample protocol). And because the LD Index of all plants is approximately zero, the points on the graph will lie along the full length of the diagonal line marking the equality of H_{BCYG} and H_D.

The percentage of Light-to-moderately browsed plants can range from relatively large (at the beginning of the Early Stage of Structural Decline) to zero (when the Early Stage is fully developed).

Habitat implications: At this stage of decline habitat implications may be relatively minor, at least with respect to plant height. Because browsing promotes branching, the stem density of arrested- and retrogressed-type plants will be greater than that of uninterrupted-growth-type plants. These differences may influence the availability and selection of nest sites.

Intermediate Stage of Structural Decline

Architectures and Description: Plants growing within the browse zone exhibit the following characteristics:

- All have either arrested- or retrogressed-type architecture.
- H_{BCYG} varies and ranges from close to ground-level to about the lower half of the browse zone.
- Dieback is evident from a distance.

Plants approximately 50-cm tall have arrested-type architecture. Taller shrubs have retrogressed-type architecture. When the Intermediate Stage is well developed, extensive dieback is occurring in mid-sized plants (i.e., those with H_D ranging from about 1.5 to 2.5 meters tall).

In the early part of the Intermediate Stage of Structural Decline, shrubs taller than 250 cm will also have retrogressed-type architecture, but dieback may not be significant. Trees taller than 250 cm may have uninterrupted-growth-type architecture.

Graph of H_{BCYG} on H_D: Individuals with short H_D (perhaps 50 to 75 cm) will have LD Index close to zero; the data will cluster along the lower end of the diagonal line marking equivalency of H_{BCYG} and H_D. Dieback is greater in individuals with taller H_D, and the LD Index of such plants will be substantially less than zero. Data describing plants with large H_D will fall into the lower right quarter of the graph. There are no Light-to-moderately browsed plants.

Habitat implications: The habitat provided by shrubs that have grown out of the browse zone remains relatively unchanged. The habitat provided by mid-height plants is highly altered. Nesting opportunities in the 1 – 2.5 meter height range are diminished. With the elimination of foliage, visual exposure in this height range may increase predation.

The impact on nesting birds in the area will be influenced by the proportion of tall retrogressed-type shrubs (which do not have extensive dieback) to short-retrogressed-type shrubs (which do have extensive dieback).

Advanced Stage of Structural Decline

Architectures and Description: There may be no plants with H_{BCYG} within the browse zone, all living plants consisting of retrogressed-type shrubs or uninterrupted-growth type trees that are taller than the upper limit of the browse zone. If there are plants with H_{BCYG} within the browse zone:

- All have either arrested- or retrogressed-type architecture.
- H_{BCYG} is limited to the lower limit of the browse zone.
- There may or may not be visual evidence of dieback. In the early part of the advanced stage, visual evidence exists. In the latter part of the advanced stage, the visual evidence may disappear due to decay. Fire can also eliminate visual evidence of dieback.

Graph of H_{BCYG} on H_D: Arrested-type plants will be clustered at the base of the diagonal line. If they are present, retrogressed-type plants will be graphed along the bottom of the graph.

Habitat implications: The loss of living mid-sized trees and shrubs will radically alter habitat characteristics. Some mid-to-high level nesting sites will remain available as long as the tall uninterrupted-growth type trees and tall retrogressed-type shrubs survive.

Recovery of Structural Diversity

Description: Three characteristics mark recovery of structural diversity:

- There is evidence that browsing affected structure in the past. That evidence could consist of individuals having arrested-, retrogressed-, or released-type architectures.

- There are light-to-moderately browsed plants growing in the browse zone.

- There is evidence that browsing has diminished. This evidence could be in the form of individuals having released-type architecture, or an apparent reduction in the browsing of arrested- or retrogressed-type individuals. (This characteristic is needed to distinguish recovery from the early stage of decline.)

Graph of H_{BCYG} on H_D: Recovery due to the growth of young uninterrupted-growth type individuals will be indicated by a substantial percentage of light-to-moderately browsed plants shown in the upper left corner of the graph. Recovery due to the resumption of growth by intensely browsed plants will be indicted by data points that lie above the diagonal line. Because sample selection is limited to plants that are less than 150 tall, released-type plants will not be represented on the graph. (Plants are not classified as released until they have grown taller than 250 cm.)

Habitat implications: Nesting sites in all height zones are increasing.

Structure is Lost

All visual evidence of the live community is missing. Evidence of its previous existence consists of carcasses of plants or anecdotal accounts.

Stages of Structural Decline: Summary of Characteristics
Based on Observation of Individuals Growing Within the Browse Zone

	Architectures	**Range of H_{BCYG} within the Browse Zone**	**Visual Evidence of Dieback within the Browse Zone**
Structure is Stable	Uninterrupted-growth type	Throughout browse zone	No
Early Stage of Decline	Arrested- and Retrogressed-type	Throughout browse zone	No
Intermediate Stage of Decline	Arrested- and Retrogressed-type	Lower half of browse zone	Highly apparent
Advance Stage of Decline	Arrested-and Retrogressed-type	Lowest part of browse zone	Possibly
Recovery of Structural Diversity	Uninterrupted-growth-, Arrested- and Retrogressed-type	Throughout browse zone	Possibly
Loss of Structural Diversity	None	None present	Possibly

Early Stage of Structural Decline

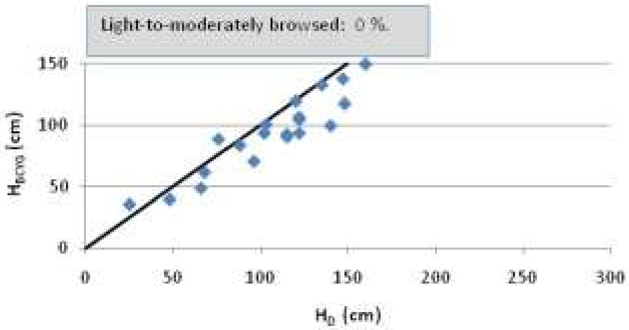
Arapaho MS2009-2

Classification based on visual appearance. Willow shrubs of various ages were present, and ranged in height from very short to more than 3-meters tall.

From a distance there is no evidence of dieback. Superficially, the structural trend of this stand appears to be stable.

But if we look beneath the current-year-growth, we see that all shrubs have either arrested- or retrogressed-type architecture.

The presence of arrested- and retrogressed-type individuals in combination with the absence of die back places this site in the early stage of structural decline.



Classification based on monitoring data. All shrubs were Intensely-browsed. The existing browsing pressure was 100%.

The data points roughly parallel the diagonal line that indicates plants are being browsed to the zone of mechanical protection. This was documented visually by the absence of dieback extending above the live canopy.

Because many of the data points fall somewhat below the diagonal line, this site is will likely enter the intermediate stage of decline in the near future.

Intermediate Stage of Structural Decline

Baca MS2009-1

Classification based on visual appearance.

All coyote willows attempting to grow through the browse zone had arrested- or retrogressed-type architecture. Dieback was significant; examples can be seen in the vicinity of the vehicle.

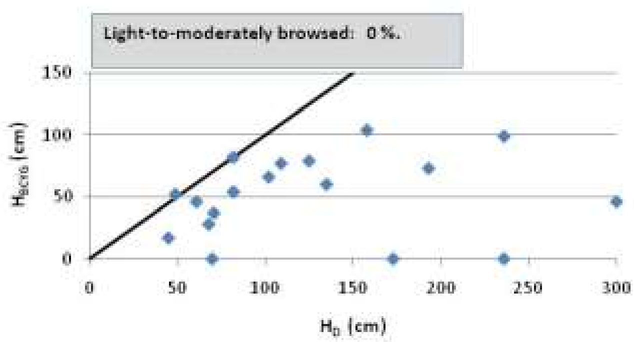
This site is placed in the intermediate stage of structural decline by the presence of arrested- and retrogressed-type individuals in combination with the extensive dieback of the taller retrogressed-type plants.

Note: Also see Arapaho MS2009-1 for another example of the intermediate stage of structural decline.

Classification based on monitoring data.

All shrubs were Intensely-browsed. The existing browsing pressure was 100%.

Ninety percent of the data points lie below the line, with many occupying the far lower-right region of the graph. These points correspond to the visually apparent dieback such as that seen in the vicinity of the vehicle above.



Advanced Stage of Structural Decline

(Perhaps entering recovery)

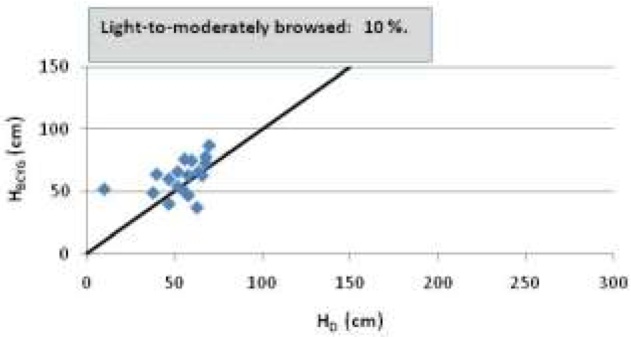
Lost Trail MS2009-2

Classification based on visual appearance. A long-term trend to an advanced stage of structural decline can be inferred, but there is evidence of possible recovery.

The willows in the background grew to about 3-m tall when browsing was light. The growth of young willow in the foreground indicates that this area is appropriate for willow growth, yet no live tall willow or willow carcasses are present. We know that this foreground area was heavily grazed by livestock for many years. Prior to the presence of livestock, a willow community likely grew there. After livestock were introduced, past evidence of the community was obliterated.

This site is classified into the advanced stage of structural decline based on the presence of tall retrogressed type shrubs (up to 3 meters), the presence of short (young) arrested- and uninterrupted-growth type individuals, in combination with the absence of mid-sized individuals.

Classification based on monitoring data.



The existing browsing pressure at this site was 90 %. The growth of those willows may reflect the removal of cattle in 2000. Current browsing is by native ungulates.

An advanced stage of structural decline is indicated by the clustering of data points along the base of the diagonal line, in combination with the absence of individuals taller than 75 cm.

The two Light-to-moderately browsed plants suggest that the stand may be entering the recovery stage. However, those individuals were relatively short (53 and 57 cm, respectively); snow may have protected these plants from browsing.

Recovering Stage of Structural Diversity

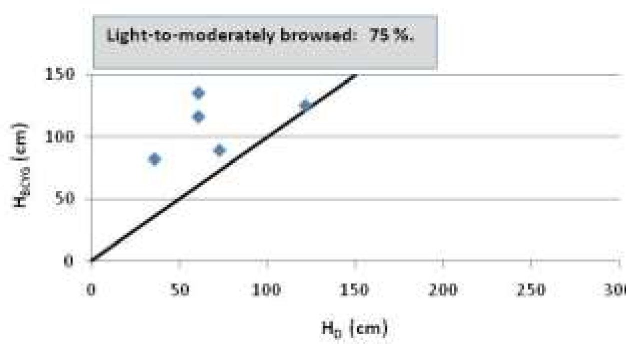
National Elk Refuge MS2009-2

Classification based on visual appearance.

Although they are not apparent in the photo to the right, arrested- and retrogressed-type plants were common. At one time this community was in an intermediate stage of structural decline. In recent years there has been robust growth of young uninterrupted-growth-type aspen. The growth of these young uninterrupted-growth type plants, in combination with older arrested- and retrogressed-type plants places this site in the recovering stage of structural diversity.

Classification based on monitoring data.

The existing browsing pressure at this site was 15 %. In this graph, recovery is mostly indicated by the fact that 75 % of the plants were light-to-moderately browsed. Some of the Intensely-browsed plants lie substantially above the diagonal line. Two of those plants are predicted to grow through the browse zone.



Factors Influencing the Rate of Change

The transition from one stage to another is determined by browsing pressure. In the unequivocal Stable Stage of Structural Trend, the Existing Browsing Pressure is zero. If browsing pressure increases, browsing will begin to influence stand structure. Threshold Browsing Pressure was used to determine when browsing will become a dominant influence with respect to the attainment of management objectives.

When Existing Browsing Pressure increases to 100%, we begin transitioning through the Early, Intermediate, and Advanced stages of structural trend, and perhaps to the stage where structure is lost. If the Existing Browsing Pressure diminishes to less than 100%, Recovery will begin. The *rate* at which transitions occur is influenced by three factors:

- **Susceptibility:** The likelihood that a plant will be selected for consumption.
- **Resistance:** The ability of a plant to withstand browsing and other ungulate impacts.
- **Resilience:** The ability of a plant to recover from the effects of browsing.

To an extent, the existence of the three factors is based on simple logic. In part, we observed examples in the course of our field work.

Susceptibility

Susceptibility is influenced by topography, adjacent vegetation and ungulate preference for some species over others. Mechanical protection by topography and protection by adjacent plants can be factors at all stages of decline. At locations where plants are fully exposed to browsing, preference is important in the early part of an increase in browsing and in the course of recovery.

Based on field observations, the species observed in 2009 could be classified into three categories of susceptibility as influenced by ungulate preference:

High susceptibility: Bebb willow, chokecherry.

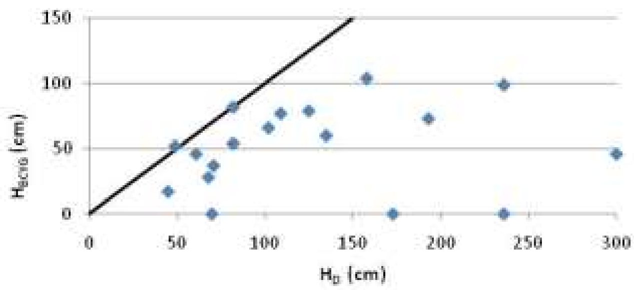
Moderate susceptibility: Aspen, other willow species.

Low susceptibility: Conifers (Seen, but not sampled.)

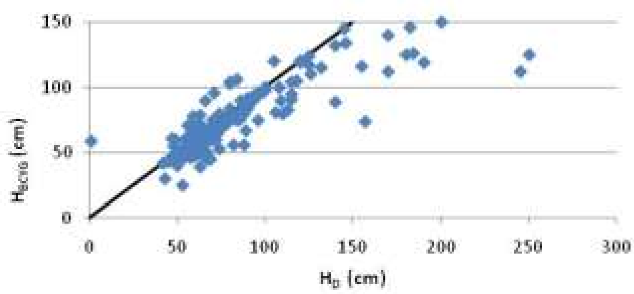
Resistance

Data collected at the Baca and Red Rock Lakes NWRs appear to document marked differences in the resistance of Bebb and Coyote willow.

Baca NWR. Based on the graph below, Coyote willow at the Baca NWR is in a marked state of structural decline.



Red Rock Lakes NWR. Bebb willow is also in a state of structural decline. However, the extent of die-back is not as pronounced as the die-back documented in the Coyote willow graph above.



If we assumed that all other factors were equal, the data graphed above indicate that Coyote willow is more prone to dieback compared to Bebb willow. But other factors are not equal. Bebb willow is more highly preferred by ungulates compared to Coyote willow. And willows at Red Rock Lakes have been exposed to heavy browsing substantially longer than the willows at Baca. (At Red Rock Lakes heavy browsing was noted in the early 1950s; at Baca, heavy browsing was not noted until the late-1980s.)

Based on these known browsing histories, Bebb willow is clearly more resistant to the effects of browsing compared to Coyote willow. The following characteristics may explain the differences in resistance:

- **Growth habit**.
  - The growth habit of a Bebb willow is multi-stemmed (see photo above). The dense thatch of stems protects young stems growing in the interior of the shrub.
  - Coyote willow (while it may grow in patches) tends to be single-stemmed. The single stem affords less protection to young stems from browsing, and is more exposed to mechanical damage due to antler thrashing.
- **Lifespan.**
  - A Bebb willow stem can live for several decades; shrubs can potentially have a very long lifespan.
  - An individual Coyote willow stem appears to be short-lived (perhaps up to 20 years).
- **Protective bark.**
  - Older Bebb willows produce a thick, protective layer of bark.
  - The bark of Coyote willow is relatively thin.

The difference in the extent of dieback was not due to differences in the elongation of current-year-growth. The mean length of current year growth of the sampled Coyote willows was 26 cm (n = 20), the mean length of current-year-growth of Bebb willow was 9.6 cm (n = 205). For various reasons, Bebb willow is more resistant to structural change than Coyote willow.

The species observed in 2009 were tentatively classified into three categories:

High Resistance: Bebb willow, mature aspen with large diameter stems.

Moderate Resistance: Other mature willows, mature chokecherry.

Low Resistance: Mature Coyote willow, other young willows, young chokecherry, young aspen.

Resilience

Resilience could be affected by many factors. If protracted browsing physiologically stresses a community, that community may respond less rapidly to a reduction in browsing compared to a community that was not stressed. Resilience may also be affected by factors unrelated to browsing. At Alamosa NWR, changes in hydrology due to management of the Rio Grande may prevent the re-establishment of tall Coyote willow communities should those communities decline.

We tentatively classified resilience into two categories: High and Low. Sites were placed in the Low category if there were obvious indications that recovery might be limited by environmental conditions.

A Comparison of Structural Trend Between Refuges

The stages of structural trend and the descriptions of susceptibility, resistance, and resilience provide a means of comparing refuges with different plant communities. When considered in combination with management priorities, the stages and associated factors could be used to prioritize the allocation of resources within the region. The description below is an example of how a comparison could be made between the refuges that participated in the 2009 multi-refuge program. No management objectives were included. In no way is this comparison intended to imply prioritization of management needs of in FWS Region 6.

In the following descriptions, the state of structural trend was based on the condition of two characteristics: 1) the extent of dieback within the browse zone, and 2) the distribution of foliage within the browse zone. The classification criteria were summarized in a table above. The description of Susceptibility, Resistance, and Resilience was based on the rationales developed in the preceding section.

Arapaho NWR

Both of the monitored sites at Arapaho NWR were in browsing-related structural decline, MS2009-1 in the Intermediate Stage, MS2009-2 in the Early Stage. Habitat at both sites consisted of willow shrubs of diverse height, some of which have grown to 3 to 4 meters tall. At MS2009-1, there has been a browsing-related dieback that has caused a reduction in foliage between 50 and 250 cm. Some dead stems in this zone had not been browsed, indicating that other factors have also played a role. Extensive dieback was not evident at MS2009-2. The presence of arrested-type willows indicates that, at present, browsing is a dominant influence at both sites.

Both communities are considered to be moderately susceptible to being browsed. At MS2009-1 browsing-related dieback within the browse zone has been relatively rapid. These shrubs have only been exposed to browsing by wild ungulates for the past 20 years. By protecting young shoots within their interior, the tall willows at the site should be able to resist decline for an extended period. For that reason, the site was classified as having moderate resistance to decline. However, habitat characteristics will change markedly as live foliage diminishes within the browse zone.

With an absence of visible dieback, MS2009-2 was classified as being in the early stage of decline. Unless browsing diminishes, this site is predicted to eventually transition to the Intermediate Stage. The cause in the difference in both sites is not known. Snow accumulation may be a factor.

Resilience at both sites was classified as high. Although hydrologic factors may influence the distribution of willows at a small scale (e.g., with respect to meander bends), there is no apparent reason why vigorous willow communities could not exist under conditions of light or moderate browsing.

National Elk Refuge

It should be emphasized that we examined communities in the northern half of the refuge, where conditions differ substantially from those on the winter feedground to the south.

Both of the monitored sites were in a state of recovery that appears to have begun circa 2005, a date that approximately corresponds with the establishment of a wolf den nearby. Chokecherry observed during the landscape level survey was in an Intermediate (LLS2009-D) to Advanced (LLS2009-H) stage of structural decline as a result of ungulate browsing. The Advanced Stage at LLS2009-H was indicated by the uniform low height of chokecherry plants.

Because mature aspen stems are relatively long-lived (several decades), the sites that were monitored were classified as highly resistant to structural decline. The robust recovery is evidence that the stand is highly resilient.

Lost Trail NWR

The aspen stand at MS2009-1 was classified as being in a state of recovery. If present trends continue, a dense stand of trees will be present in the future. The aspen were classified as having moderate susceptibility—other species (such as chokecherry) are more highly preferred. Because this stand consists solely of young aspen, it was classified as having a low structural resistance. If browsing should increase, the structure of this stand would rapidly decline. The stand was classified as being highly resilient.

The willow stand at MS2009-2 was classified as being in an Advanced Stage of decline, but possibly entering recovery. The advanced decline was inferred from the fact that the site clearly can support willow growth (it currently does), yet mature willow were absent. Given that the area was heavily stocked with cattle until 2000, the probable cause of that absence is understandable. The willows were classified as being moderately susceptible. Given the fact that young conifers (with low susceptibility) are also growing in the area, the moderate susceptibility of willows could mean that the area will be converted to a conifer stand in the future. Because of their young age, the willows were classified as having low resistance. The recruitment of young individuals indicates that the site has high resilience. The high resilience at MS2009-2 contrasts with that at LLS2009-C where reed canarygrass may limit willow reproduction and establishment.

Baca NWR

The Coyote willow stand at MS2009-1 was in the Intermediate Stage of Structural Decline. Foliage was present at diverse heights, but dieback was occurring within the browse zone. The willows were classified as being moderately susceptible to being browsed. The mature Coyote willow was classified as having low resistance to browsing. The low resistance of Coyote willow was based on the virtual elimination of the stand along Deadman Creek over a 20 year period. Based on the presence of young willows at MS2009-1, the area is believed to have high resilience. Given that willows once grew vigorously along Deadman Creek, resilience at that site may also be high. Ground water near the surface may compensate for the intermittent flow of the creek.

The cottonwood stand at MS2009-2 was classified as being in an Advanced Stage of decline. The site was placed in the advanced stage because all foliage within the browse zone occurs in the lower region. Susceptibility is moderate. The site has high structural resistance due to the mature trees. Even if heavy browsing persists, the structure provide by those trees will exist for decades.

Baca offers an exceptional management opportunity. For many decades, hay production has prevented willows from growing outside of narrow corridors. The presence of young willows growing in the meadows indicates that the corridor could be expanded. The extent of potential willow habitat is unknown.

Red Rock Lakes NWR

At MS2009-1 there was evidence of dieback, however most plants were browsed close to the zone of mechanical protection. The site was classified as being in the early stage of structural decline, but entering the intermediate stage. With little visible evidence of dieback, MS2009-2 was classified as being in the early stage of decline. While other willow species show evidence of some structural recovery in the past few years, Bebb willow did not.

Bebb willow is classified as being highly susceptible to being browsed, but mid- and older-aged shrubs are highly resistant to the effect of browsing. That resistance could explain why the sites are in the early stage of decline, yet heavy browsing by moose has been reported for 60 years.

The classification into the early stage of structural decline was based on the minimal evidence of dieback. However, a comparison of our 2009 data with data in a 1969 report by Robert Dorn indicates that structure has declined markedly over the past four decades. In 1969 Bebb willow reportedly grew to 18-feet tall; in 2009 the tallest Bebb was about 8-feet tall. Some large Bebb carcasses lie on the ground. But most of the visible evidence of that prior structure has been lost.

Two points are drawn from the above comparison. First, the loss of evidence of the extent of structural decline demonstrates the need to periodically document the resource condition, and to store that data in a way that will be available to future generations. There were prescribed fires conducted in the willow fen in the 70s and/or 80s to 'rejuvenate decadent willows'. Those 'decadent' willows were likely the evidence of structural decline that are now absent.

Second, the high structural resistance of mid-sized Bebb willows can mask the extent of structural decline. At Red Rock Lakes, the high resistance of Bebb willow allows foliage to be distributed throughout the browse zone, resulting in classification to the Early (entering Intermediate)Stage of decline. These Bebb willows provide nesting opportunities throughout the browse zone. But while foliage survived throughout the full range of the browse zone on young and middle-aged plants, older (taller) individuals died, presumably for reasons unrelated to browsing. Nesting opportunities in the height range of 8 to 18 feet were lost. The implication: while Bebb willow is a sensitive indicator of heavy browsing (due to its high susceptibility), it may be a less sensitive indicator of the rate at which structure is declining. Other willow species may provide a better indication of change in structural trend within the browse zone.

Resilience of willow at Red Rock Lakes is presumed to be high. In part, this resilience may result from regular sources of moisture along the riparian corridors and within the broad, spring-fed wet areas. In part, resilience may result from the deep snowcover that provides protection from browsing for much of the fall, winter, and spring.

Alamosa NWR

MS2009-1 was placed in the Early Stage of decline. While some dieback had occurred, most of the plants were being browsed at a level close to the base of current-year-growth. One sampled plant was light-to-moderately browsed. MS2009-2 was placed in the Intermediate Stage of decline. Dieback was apparent on most of the plants; all were Intensely-browsed. Coyote willow was classified as being moderately susceptible to being browsed.

As described above, Coyote willow has low resistance to the effect of browsing; the low resistance was attributed to its single-stemmed growth habit, the short lifespan of stems, and thin bark (i.e., compared to Bebb willow).

Other factors likely contribute to Coyote willow's vulnerability at Alamosa NWR. There is extensive mortality of young willows that appear to have been lightly browsed. As described in the Alamosa chapter, this mortality could be a result of hydrologic factors. Without the construction of big game exclosures, it would be difficult to distinguish between browsing and other factors.

The resilience of Coyote willow was classified as low. For reasons explained in the Alamosa chapter, Coyote willow at the Alamosa NWR has a questionable future, with or without ungulate browsing.

Summary of Trend by Refuge

Site	Stage	Susceptibility	Resistance	Resilience
Arapaho NWR MS2009-1	Intermediate Stage of Decline	Moderate	Moderate	High
Arapaho NWR MS2009-2	Early Stage of Decline	Moderate	Moderate	High
National Elk Refuge MS2009-1	Recovery of Structural Diversity	Moderate	High	High
National Elk Refuge MS2009-2	Recovery of Structural Diversity	Moderate	High	High
Lost Trail NWR MS2009-1	Recovery of Structural Diversity	Moderate	Low	High
Lost Trail NWR MS2009-2	Advanced Stage of Decline (Early stage of recovery?)	Moderate	Low	High
Baca NWR MS2009-1	Intermediate Stage of Decline	Moderate	Low	High
Baca NWR MS2009-1	Advanced Stage of Decline	Moderate	High	High
Red Rock Lakes NWR MS2009-1	Early Stage of Decline (Entering Intermediate)	High	High	High
Red Rock Lakes NWR MS2009-2	Early Stage of Decline	High	High	High
Alamosa NWR MS2009-1	Early Stage of Decline	Moderate	Low	Low
Alamosa NWR MS2009-2	Intermediate Stage of Decline	Moderate	Low	Low

Target Conditions and the Attainment of Habitat Objectives

To recap, evaluation requires that we have a benchmark condition to distinguish between two kinds of habitat: those where we believe management objectives can be attained and those where they cannot. At each monitored location, we defined that benchmark by specifying a Target Condition that was then used to calculate a Threshold Browsing Pressure. The effect of browsing was then determined by comparing the measured Existing Browsing Pressure to the calculated Threshold Browsing Pressure.

With two exceptions, how we interpret the effect of browsing is completely dependent on how we specify the Target Condition. Those exceptions are when the Existing Browsing Pressure is either 0 % or 100 %. In the 2009 field season, the Existing Browsing Pressure was 100% at seven of the twelve monitored sites. At those sites, if browsing continues at its current level, nesting habitat will eventually disappear.

At the remaining five sites, Existing Browsing Pressure ranged from 1 % to 99 %, where interpretation of the measurement is less certain. Some plants were predicted to grow through the browse zone, so structure would not be completely lost. Our interpretation of the effect of browsing at those sites depended on how we specified the Target Condition. We could have erred, being over- or under-conservative with respect to the effect of browsing. If we specified—and attained—an accurate Target Condition, we would produce diverse nesting habitat while supporting a maximum ungulate population. While specifying a totally accurate Target Conditions is unlikely, improving the accuracy of our evaluations is a worthwhile endeavor.

The need for accuracy raises issues relating to data resolution (the attributes) and the manner in which the values were derived (where we obtained the values). In 2009 the Target Condition was defined by specifying the desired density of plants that are at least 2.5 meters tall. Because we only distinguished between plants that were taller or shorter than 2.5 meters, our data had low resolution. Given that we are attempting to provide the complex habitat structure necessary to meet diverse breeding requirements for a variety of bird species, it would be fair to ask if Target Condition should not be specified with greater resolution. Why not describe the desired density of plants at a variety of heights such as 1 meter tall, 2 meters, and 3 meters?

In 2009, values used to specify the Target Condition were obtained in two ways. In two cases, the target density was based on measurements of existing reference communities, which were assumed to provide adequate nesting habitat. In ten cases, the target density was based on an estimated spacing of plants believed to provide diverse habitat structure for nesting birds. Regardless of whether the Target Condition was derived by measurement or estimation, it would be fair to question how well it reflected the bird's habitat preferences.

A variety of studies document the characteristics of habitats used by nesting birds. Such studies raise two questions:

- Could the habitat-description protocols used in such studies be used to specify a Target Condition?
- If a study was conducted at a given refuge, should that information be used to specify a Target Condition?

Habitat Description Protocols

Studies at Arapaho NWR document the relationship between habitat and breeding birds (Knopf and Sedgwick 1988, 1992; Sedgwick and Knopf 1992). With respect to specifying Target Condition, the studies make two important points.

First, successful breeding by a single species requires multiple habitat structures in close proximity. This structural variability supports various activities including singing, nesting, foraging, and protection from predation. Where multiple species are present, each would have distinct structural preferences.

Second, the description of habitat structure can be complex. At the simplest level, these studies report the mean habitat characteristics across unit areas: mean cover, density, and height. At a more complex level, the studies report how these characteristics vary spatially across the area, such as the heights and distances between adjacent bushes. Shrub volumes were measured; the numbers of live stems were counted.

The kinds of data reported by Knopf and Sedgwick document the relationship between birds and habitat at a point in time. Similar protocols could be used in the Evaluation Component when describing the Existing Condition. But most of these data cannot be used to specify a Target Condition, a condition that pertains to a *future* point in time. Given the data we collect, we have no way of predicting the heights of two adjacent bushes in twenty years.

Research data at the coarser level could be used. For nesting willow flycatcher, Sedgwick and Knopf (1992) report a mean plant density of 367.2 plants per hectare, or 0.03672 plants / m^2. On average, these plants would be spaced 5.2 meters apart. For nesting yellow warbler, Knopf and Sedgwick (1992) report a density of 0.0428 plants / m^2, which on average would be spaced 4.8 meters apart. In 2009 in the vicinity of the above studies, we measured a mean density of .044 plants / m^2, which (when values are rounded) were also spaced an average of 4.8 meters apart. When calculating the Threshold Browsing Pressure for this site, we recognized the coarse nature of the data and rounded our spacing to the nearest meter (plants 5 meters apart), for a mean density of 0.040 plants / m^2. Each of these measurements could have been used to calculate the Threshold Browsing Pressure with the following result:

- Based on the measured density: TBP would be 0 %.
- Based on 5-meter spacing: TBP was 9 %.
- Based on willow flycatcher data from Sedgwick and Knopf (1992): TBP would be 17 %.
- Based on yellow warbler data from Knopf and Sedgwick (1992): TBP would be 0 %.

Can research-type habitat description protocols be used to specify Target Condition? The answer is a qualified yes. Given the way Target Condition is used (i.e., to calculate Threshold Browsing Pressure), we are limited to specifying a mean density across part of the landscape. Because we are predicting a future condition, we will not know the exact heights of the plants that will be present. We can only distinguish between plants that have grown out of the browse zone which we assumed to be 2.5 meters (or potentially could do so) and plants that likely will not grow out of the browse zone.

The densities measured by Knopf and Sedgwick were very similar to the densities we measured in 2009, and could have been used to specify a Target Condition. The four Threshold Browsing Pressures described above ranged from 0 to 17 %. Because the Existing Browsing Pressure was 100 %, these differences are irrelevant at the present time. Subtle differences in Threshold Browsing Pressure will become relevant if Existing Browsing Pressure is reduced to values that approach the 0 to 17 % range. As described in the section below, the value of increasing the accuracy of Threshold Browsing Pressure based on habitat measurements at a particular site is uncertain.

Should Target Condition be Based on Research Study Data?

The studies by Knopf and Sedgwick offer a wealth of data, but do they document the *optimum* habitat preferences by yellow warblers and willow flycatchers? The study area was not a pristine willow community. Prior to the establishment of the refuge in 1967, the area was grazed by cattle and sheep. It is possible that that prior agricultural use had an effect on habitat structure. If so, the studies by Knopf and Sedgwick document how birds preferentially used parts of an altered landscape. Birds do breed in the area, so the conditions provide an indication of habitat requirements. But we cannot be certain that if habitat conditions were different, nesting densities might be greater.

Refining the Accuracy of Target Condition

The refuge areas examined in 2009 could be placed into two categories: those that had examples of usable habitat and those that did not. Using structural trend terminology, areas in the early and intermediate stage of structural decline (or areas entering recovery from those stages) have evidence that can serve as a starting point for specifying Target Condition, while those in the Advanced Stage do not.

Areas in the Early and Intermediate Stage of Structural Decline. The areas at Arapaho NWR are examples. Under this circumstance, the following approach could be taken:

- Use existing measurements for specifying the Target Condition.
- Explore the possibility that the habitat was altered.
- Make a list of the bird species for which the habitat is to be managed.
- Search the literature for information on the habitat selection of target species. Modify the target condition if warranted.
- Document trends in bird use. While a declining trend may be primarily due to factors unrelated to the refuge (e.g., reduced survival on winter grounds), the possibility exists that declines may be due to conditions on the refuge. Recruitment of birds breeding in refuge habitats is the ultimate measure of management objective success.

Areas in the following stages: Advanced Stage of Structural Decline, Recovering from Advanced Decline, or Structure is Lost. Areas at Lost Trail and Baca NWR are examples. In these cases, there is no usable habitat present on which to base a Target Condition. The following approach could be taken:

- Make a list of the bird species for which the habitat is to be managed.
- Specify a Target Condition based on 2-meter spacing (0.25 plants / m^2), a value that is believed to be conservative. At this mean density, some plants will be clustered and there will be open spaces greater than 2 meters across.
- Search the literature for information on the habitat selection of target species. Modify the target condition if warranted.
- Document trends in bird use. A positive trend in bird use would be evidence of habitat improvement.

We should be aware that multiple bird species are present, and that those species will have different habitat preferences (even if we don't know what those preferences exactly are). Depending on management objectives, one or a few of those bird species may be deemed more important than others. If so, the preferences of those species would be weighted accordingly. If multiple bird species are to be managed for, it could be that one of those species is more sensitive to changes in habitat than other species. If habitat conditions are managed to provide for the sensitive species, the requirements of other species will likely be met as well.

Specifying a Target Condition is a necessary part of evaluation. Although we are limited in our ability to accurately specify this condition, the process of trying to increase its accuracy will increase our awareness of the link between the birds we are managing for and the habitat they require.

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Appendix I: Scientific and Common Names

Birds

Yellow warbler .... *Dendroica petechia*

South western willow flycathcer .... *Empidonax traillii extimus*

Vegetation

Alder.. *Alnus spp*

Aspen .... *Populus tremuloides*

Bebb willow.. *Salix bebbiana*

Booth willow .... *Salix boothii*

Chokecherry .... *Prunus virginiana*

Coyote willow, Sandbar willow .... *Salix exigua*

Dogwood... *Cornus stolonifera*

Drummond willow .... *Salix drumondiana*

Geyer willow .... *Salix geyeriana*

Mountain willow .... *Salix monticola*

Narrowleaf cottonwood .... *Populus angustifolia*

Planeleaf willow .... *Salix planifolia*

Spruce .... *Picea spp*

Whiplash willow .... *Salix lucida*

Wolf willow .... *Salix wolfii*

Yellow willow .... *Salix lutea*

Datasheet: Landscape Level Survey LLS ______________________

Refuge: ______________ Date: _______ Observers: ____ Sheet ___ of ___

Stop	GPS Coordinates NAD83 preferred	Photo #	Species	< 50 cm	50 – 150 cm	150 - 250 cm	> 250 cm

Datasheet: Existing Stem Density

Refuge: ____________ **Date:** _____________ **Observers:** ____________________________

Site Identifier: ___________________ **Photo Number:** _______________ **Species:** __________

GPS: ____ **Datum:** _______

Dimensions of belt transect for plants < = 250 cm: __________ **W** __________ **L**

Dimensions of belt transect for plants > 250 cm: __________ **W** __________ **L**

<= 250 cm

Length	Number

<= 250 cm

Length	Number

> 250 cm

Length	Number

> 250 cm

Length	Number

Datasheet: Existing Browsing Pressure

Refuge: _____________ **Date:** ______________ **Site Identifier:** ________________

	H_{BCYG}	H_D	L_{CYG}
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