Evaluation of tall willows (Salix spp.) within a livestock grazing allotment in southwest Montana

by Mark Edward Manoukian

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Range Science
Montana State University

Abstract:
The Long Creek Cattle Allotment has been grazed by domestic livestock from the late 1800s to the present time. For the last 28. years the 2200 ha allotment was usually grazed by 800 cow/calf pairs in a four pasture rest-rotation system from July 15 to October 15.

Concerns that historic and recent livestock management on the allotment had deteriorated Geyer (Salix geveriana Anderss.) and Booth (S. boothii Dom) willows along the three main tributaries were expressed in 1991. From the fall of 1991 to the fall of 1993, historic and current evaluations of Geyer and Booth willows were made.

Evaluations of the long-term trend of willow canopy cover along the three streams were made with the use of aerial photographs. Photographs taken of the allotment in 1942, 1965, and 1987 were compared using a dot count method. One hundred ninety-five stems were collected and aged to determine current demographics of willows within the four pastures.

Seasonal variation in the canopy volume of 380 willows was also quantified. Several environmental factors (including: beaver (Castor canadensis canadensis Kuhl), wild ungulate [moose (Alces alces shiras Nelson), elk (Cervus elaphis nelsoni Bailey), and deer (OdocoiIeus spp.)], and domestic livestock herbivory, as well as species of willow, initial willow size, and distance to surface water) were identified as potentially influencing the seasonal change in willow volume. Two ungulate exclosures were constructed to compare change in volume of willows protected from ungulate herbivory to willows not protected from ungulate herbivory. Additionally, the rate of willow development through clonal expansion was also compared inside and outside the exclosures.

Aerial photographs and stem demographics indicate that willows have and are regenerating under current management. Willow volume decreased in one exclosure and one pasture over the study period. These decreases were attributed to repeated beaver herbivory. It may take several years for these willows to return to their original size.

Clonal expansion appears to be slow inside and outside the exclosures. Historic or current domestic or wild ungulate browsing does not appear to be restricting willow growth or expansion within the Long Creek Allotment.

EVALUATION OF TALL WILLOWS (Salix Spp.) WITHIN A LIVESTOCK GRAZING ALLOTMENT IN SOUTHWEST MONTANA

by

Mark Edward Manoukian

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APPROVAL

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Mark Edward Manoukian

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date 5-6-94

Dedicated to my mother and father, Lorraine and Milt Manoukian.

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ABSTRACT

The Long Creek Cattle Allotment has been grazed by domestic livestock from the late 1800s to the present time. For the last 28 years the 2200 ha allotment was usually grazed by 800 cow/calf pairs in a four pasture rest-rotation system from July 15 to October 15. Concerns that historic and recent livestock management on the allotment had deteriorated Geyer (Salix geyeriana Anderss.) and Booth (S. boothii Dorn) willows along the three main tributaries were expressed in 1991. From the fall of 1991 to the fall of 1993, historic and current evaluations of Geyer and Booth willows were made.

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CHAPTER 1

INTRODUCTION

The Long Creek Cattle Allotment of the Beaverhead National Forest is located on the Centennial Divide, about 71 km southeast of Dillon, Montana. The allotment encompasses approximately 2200 ha, annual precipitation averages 480 mm and elevation averages 2300 m (Montana Agricultural Potentials System (MAPS) 1994). Upland vegetation is described as Artemisia tridentata Nutt./Festuca idahoensis Elmer. habitat type (Mueggler and Stewart 1980). Riparian vegetation is dominated by Salix geyeriana Anderss. (Geyer willow), S. boothii Dorn (Booth willow)/Carex spp. and Poa pratensis L. Both species of willows normally occur as multi-stemmed shrubs, greater than 3 m tall. The allotment is divided into four grazing pastures: Pole, Jones, Long Creek, and Lone Butte. Three main streams flow through the allotment; Pole Creek flows through the Pole Creek pasture, Jones Creek flows through the Jones Creek pasture (with only a small section flowing through the Lone Butte pasture) and Long Creek flows through Lone Butte pasture with only 0.8 km of the stream flowing through the southwest corner of the Long Creek pasture (Figure 1).

Domestic livestock grazing was unrestricted on the Centennial Divide with no allotment boundaries from 1911 to 1934 (Stellingwerf 1991). In 1935 the present Long Creek Allotment boundary was

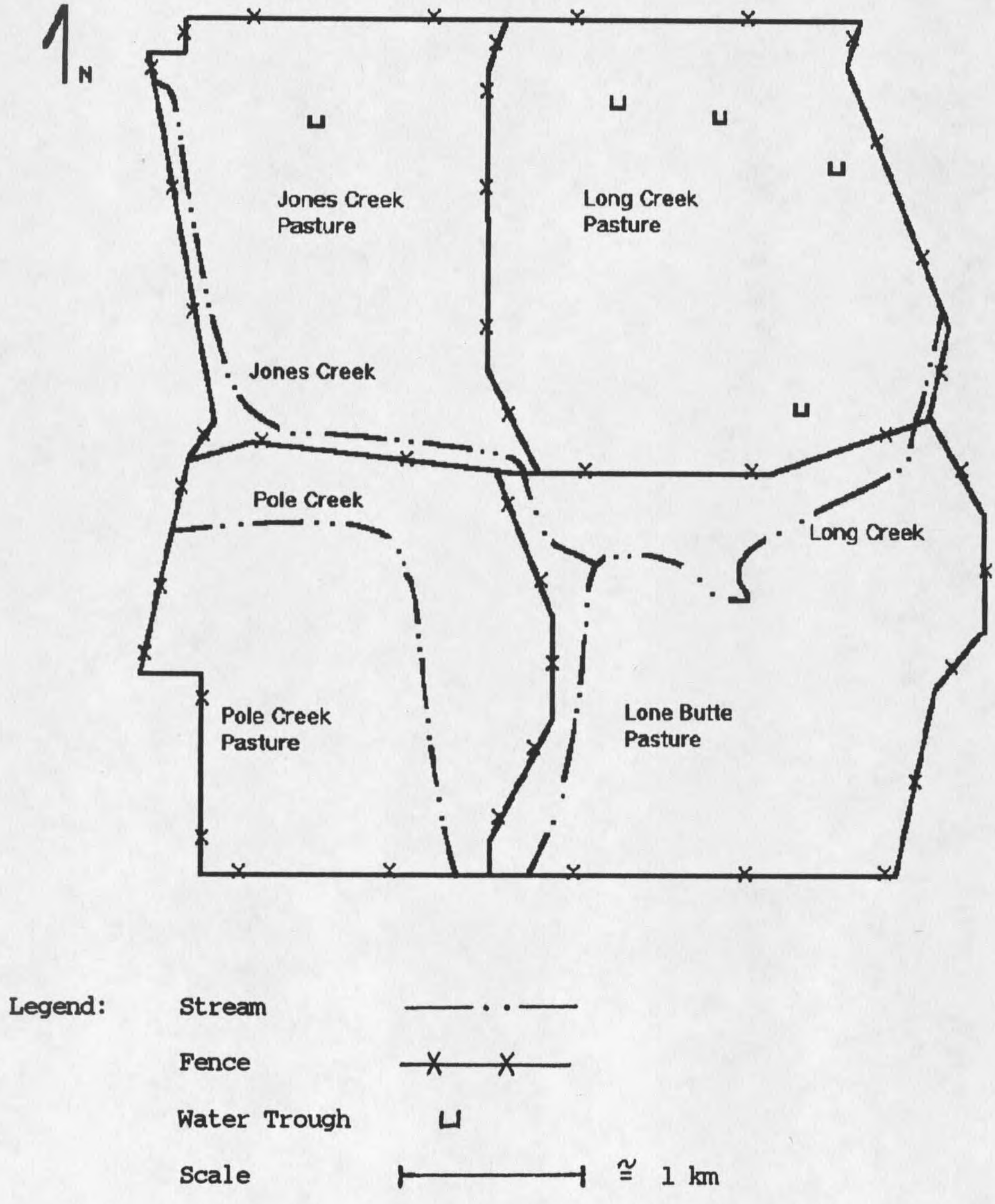


Figure 1. Location of pastures and main streams within Long Creek Allotment.

established. From 1935 to 1962, class of livestock and season of use varied from 535 cows and 75 horses to as many as 1,238 cows and 115 horses or 1,351 sheep and 120 horses. Season of use was June 1 to October 31 for horses and August 1 to October 31 for cattle and sheep (Stellingwerf 1991). In the early 1950s the current permittee, Matador Cattle Company, acquired the privileges to the allotment. In 1963 and 1964, when the Forest Service aerially applied 2, 4-D to control sagebrush, the allotment was not grazed by livestock. In 1965, the allotment was fenced into four pastures and a rest-rotation management system was established. Season of use was set at 90 days, from July 16 to October 15, for 800 cow/calf pairs. The grazing program was followed until 1986, when concerns of increasing sagebrush caused the permittee to voluntarily reduce the permit by 200 cow/calf pairs (Stellingwerf 1991).

In 1991, heightened concern for riparian areas within the Long Creek Allotment led to the development of a Memorandum of Understanding between the Beaverhead National Forest, Matador Cattle Co., and Montana State University (MSU) (Memorandum of Understanding 1991). In this memorandum, MSU agreed to implement a research project which would allow a graduate student to collect baseline riparian data, evaluate the grazing management program and to complete a Masters Degree.

The primary concern within the allotment was the historic and current status of tall willows (Salix spp.) (Resource Concepts, Inc. 1991). Manning and Padgett (1991) described tall willows as willows greater than 183 cm in height at maturity and low willows as less than 183 cm in height at maturity. The focus of this thesis was to: 1) determine the change in tall willow canopy cover over time 2) evaluate current population demographics of willow stems 3) monitor seasonal change in canopy volume of willows, and 4) monitor clonal expansion of willows.

Results of this research will assess short and long-term trend in tall willows and provide a better understanding of the environmental factors restricting willow development. This information will add to the growing knowledge of riparian management and assist land managers in making future decisions regarding management of the Long Creek Allotment and other allotments in southwest Montana.

CHAPTER 2

FIFTY-ONE YEARS OF WILLOW DYNAMICS ON LONG CREEK ALLOTMENT

Introduction

Some reaches of the three main streams in the Long Creek Allotment support tall willows, whereas other reaches do not. While historic and recent livestock management was blamed as a factor restricting distribution of tall willows (Platts 1990), there may be alternative explanations (Resource Concepts, Inc. 1991). Therefore, management options were restricted because little is known about historical willow populations.

Long-term trends in willow community can be evaluated through aerial photography taken at different time periods (Batson et al. 1987). Added information on willow population demographics can be gained through stem age structure (Kavlachek 1991). If livestock grazing was the cause of reduced willow stature, excessive browsing by domestic livestock over a long time period should decrease willow canopy cover along streams, as identified from aerial photography. Furthermore, demographics of willow stems should depict suppression by cattle browsing. The objective of this study was to improve the understanding of long-term trend of willows on Long Creek Allotment by interpreting aerial photographs, and current status of willows by analyzing population structure.

Methods

Willow Canopy Cover

Three sets of aerial photographs spanning 45 years were used to determine the change in willow canopy cover along the three main streams in the Long Creek Allotment. Aerial photographs from 1942 were purchased from the National Photographic Archives, Atlanta, Georgia and photographs taken in 1965 and 1987 were purchased from the Soil Conservation Service Air Photo Field Office, Salt Lake City, Utah. Photographs were ordered at an enlarged scale of 1 cm : 121.92 m (paper size .965 m X .965 m).

The photo scale (1:121.92) was checked with a topographic map and features. Clear (.22 m X .28 m) acetate sheets were placed on individual photos, covering the length of each stream. Allotment and pasture boundaries were delineated on each set of acetate sheets. The area occupied by willows along each stream was traced onto the acetate overlays. Natural changes (breaks) in willow canopy cover were ocularly estimated and marked on the acetate sheets. A standardized dot grid template was then placed over the acetate sheets. The number of dots within the outlined willow area and number of dots touching willows were totaled for each cover canopy break (Tueller 1977). The total number of dots were divided into the number of dots touching willows. This approximated a percent canopy cover. To minimize sampling error, canopy cover estimates were stratified into one of the six cover classes (Daubenmire 1959) (Table 1). After calculating the percentage of the stream within a canopy cover class, the cover estimates were used to compare canopy along streams within a given year, and to estimate canopy cover changes at the three time periods.

Table 1. Daubenmire Cover Classes

Cover Class	Range of Coverage, %	Midpoint of Coverage Class, %
I	0-5	2.5
II	5-25	15.0
III	25-50	37.5
IV	50-75	62.5
V	75-95	85.0
VI	95-100	97.5

Another clean set of acetate sheets was placed over the photos. The stream channel, breaks in the canopy cover, and the associated cover classes were marked onto these clean acetate sheets. The length of stream within each pasture was measured from these stream channel acetate sheets with the use of a digitizer.

The digitizer used the Sigma Scan 3.10 program. Sigma Scan was calibrated to the scale of the photographs by tracing a known distance with an electronic pointer on an electronic pad. The pointer and pad were used to measure total length of each stream from the stream channel acetate sheets. Stream channels were re-measured on photos from each of the three years. The total length of individual cover classes was also measured from stream channel acetates. Stream length occupied by individual cover classes was divided by the total stream length. This calculation represented the percentage of stream occupied by the individual cover classes.

Stem Age

Five locations in each pasture, systematically distributed along the stream reaches, were selected as collection sites for willow stems.

Two average size willows, one each of Geyer (Salix geyeriana Anderss.) and Booth (S. boothii Dorn) were selected for stem aging at each location (willows were selected based on ocular size compared with other willows at the location).

The base of each willow was measured with a two meter ruler along a north-south axis. Five stems equally spaced along the axis were selected for removal. Prior to removal, height of individual stems was measured in centimeters and recorded. Each stem was cut at ground level. The narrowest diameter of each stem was measured to the nearest millimeter and recorded. Stems were shortened to 20 cm in length, permanently tagged, and transferred to Montana State University.

The end of the stem closest to the ground was shaved with a sharp knife to produce a smooth surface and dipped in water to help accentuate growth rings. Annual growth rings were counted under a 1 X 10 binocular microscope. One hundred fifty stems were collected and analyzed from Long Creek, Jones Creek, and Lone Butte pastures. Fifty stems were also collected from Pole Creek pasture however, due to lost data, only 45 stems were analyzed for Pole Creek pasture. Therefore, a total of 195 stems were analyzed.

Analysis

Willow Canopy Cover

Because canopy cover of the entire willow population along the three main streams was inventoried, the pasture canopy cover class estimates per stream reach were population statistics, rather than samples. No further analysis was required.

Stem Age

Multiple regression analyses were used to determine the correlation of species, stem height, and diameter on stem age by pasture. Also, linear regression analysis was used to determine the correlation between stem diameter and stem age for all 195 stems.

Results

Willow Canopy Cover

Canopy cover was less than 75% along all three streams. Therefore, canopy classes V and VI were omitted from the discussion.

The percentage of stream occupied by cover classes I and II in the Lone Butte and Pole Creek pastures decreased from 1942 to 1987 (Figure 2). These decreases have been off-set by an increase of cover class III in both pastures. Cover class IV in Lone Butte pasture varied from 21% in 1942, to 0% in 1965, to 18% by 1987. Cover class IV was never encountered in the Pole Creek pasture.

Cover class I in the Jones Creek pasture increased 7% during the 45 year period (Figure 2). Cover classes II and III remained relatively constant from 1942 to 1965 but changed considerably from 1965-87. During the later period, cover class II decreased while cover class III increased.

From 1942 to 1965 the percentage of stream occupied by cover class IV in the Long Creek pasture decreased from 90% to 0% (Figure 2). However, increases in cover classes II and III maintained the amount of willow cover. From 1965 to 1987 cover class II declined while class III occupied the entire stream reach.

Stem Age

Willow stem ages averaged 8, 9, 9, and 10 years for Lone Butte, Pole, Jones, and Long Creek pastures, respectively (Figures 3). Stem diameters from each pasture were correlated ($p < 0.0001$) to stem age (Table 2). Additionally, the linear regression of stem diameter and stem age for all 195 stems was correlated ($p < 0.0001$) and explained 67% of the variation (Table 2).

Table 2. Diameter and stem age regression equations by pasture.

Pasture	n	R^2	Equation
Lone Butte	50	66	Stem Age = 0.76 + 4.87 * Diameter
Pole Creek	45	57	Stem Age = 1.57 + 3.78 * Diameter
Jones Creek	50	60	Stem Age = 2.06 + 3.37 * Diameter
Long Creek	50	77	Stem Age = 2.59 + 3.37 * Diameter
All	195	63	Stem Age = 2.18 + 3.84 * Diameter

Discussion

Although photographs from 1942 did not precede introduction of domestic livestock to the Long Creek Allotment, they provided a quantifiable baseline of willow canopy cover along the main streams on the allotment. For purposes of research and management, this provided 45 years of trend data.

Analysis of aerial photographs indicated fluctuations in willow canopy cover along the three main streams within the Long Creek Allotment over 45 years. From 1942 to 1965 the majority of the stream reach of Long Creek within the Long Creek pasture changed from cover class IV to cover class II and III. Herbivory (by beaver, wild ungulates, domestic livestock), harsh climatic conditions, or herbicide drift from sagebrush control efforts in the early 1960s, or other

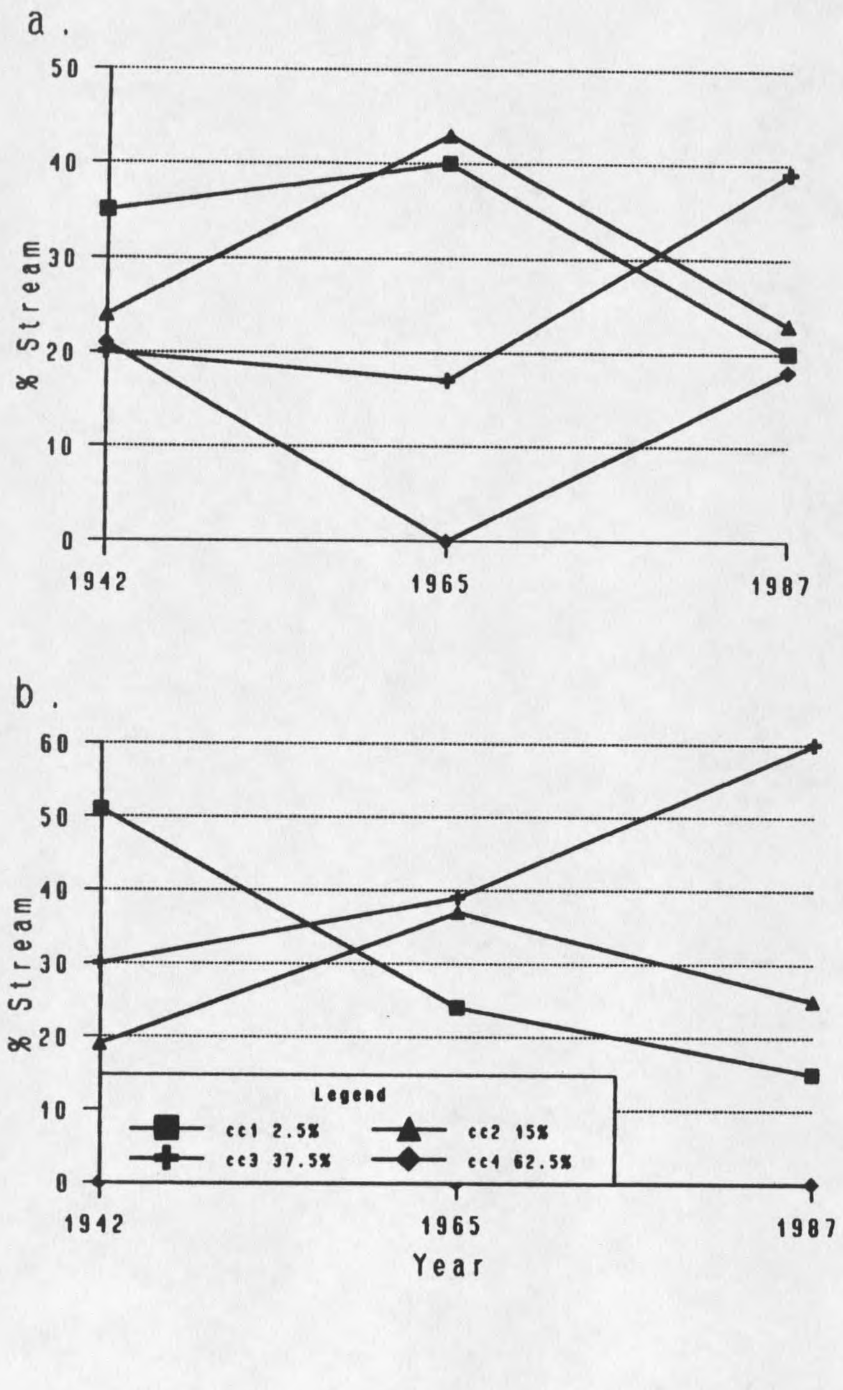


Figure 2. Percent of stream occupied by different canopy classes at three time periods for a. Lone Butte pasture and b. Pole Creek pasture

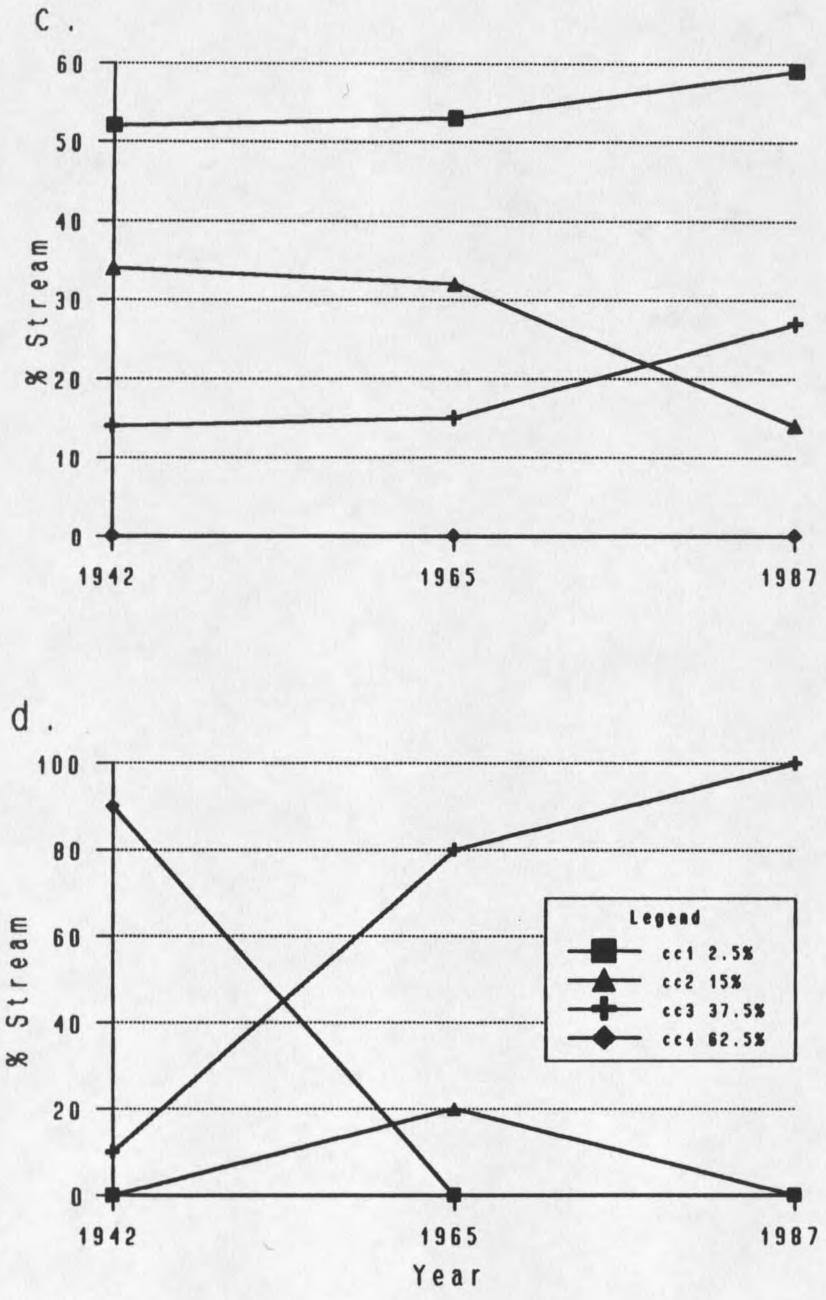
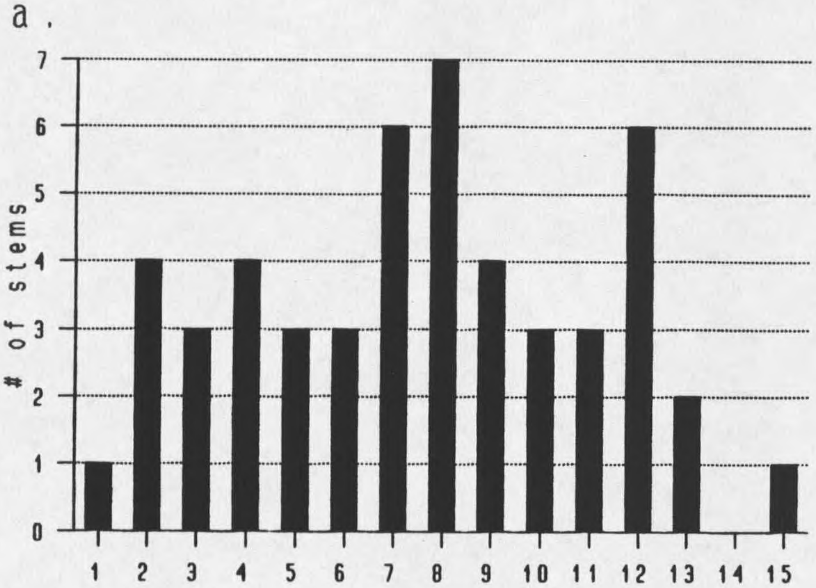


Figure 2. (Contd) Percentage of stream occupied by the different canopy classes at three time periods for c. Jones Creek pasture and d. Long Creek pasture



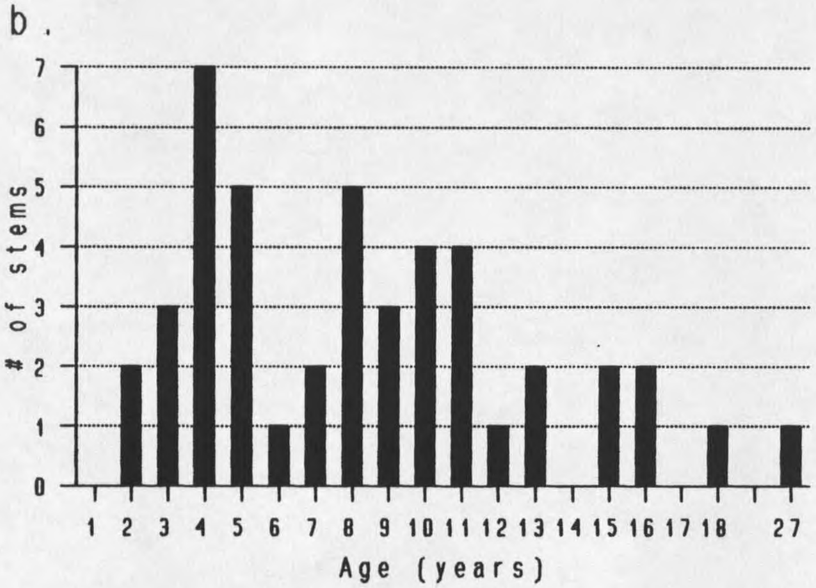
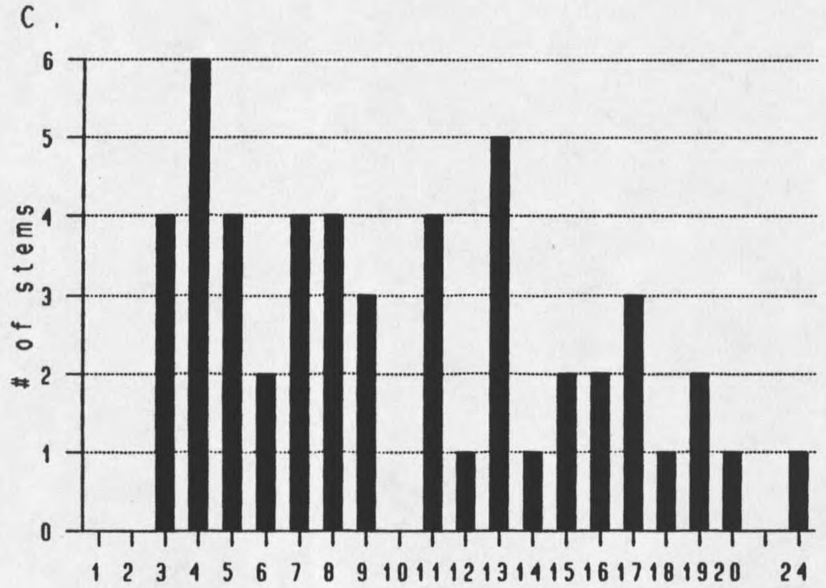


Figure 3. Population demographics of willow stems within a. Lone Butte pasture (n=50) and b. Pole Creek pasture (n=45)



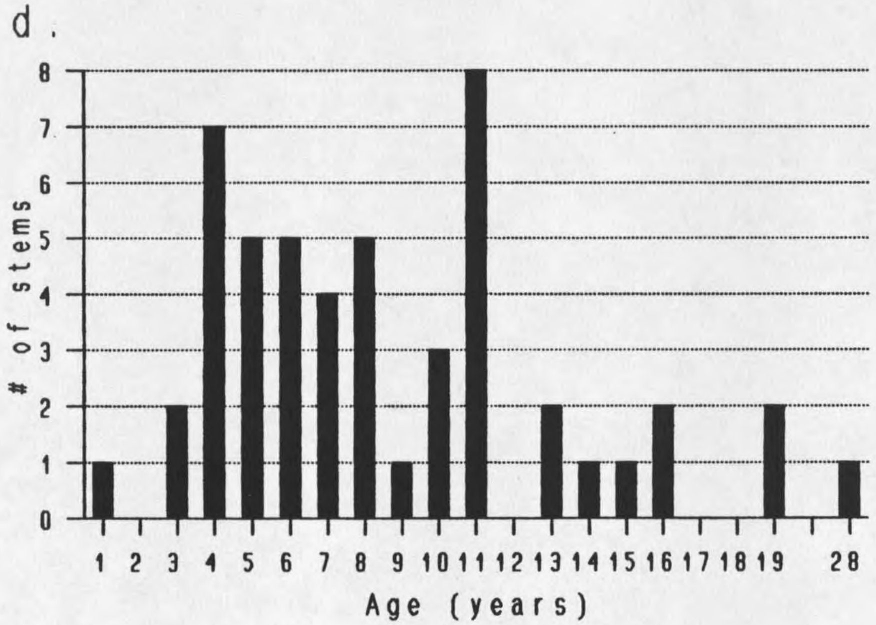


Figure 3. (Contd) Population demographics of willow stems within c. Jones Creek pasture (n=50) and d. Long Creek pasture (n=50)

environmental factors may have contributed to this change. However, photo interpretation did not provide information on the cause of change.

The fluctuations in percentage of stream occupied by the four different cover classes were indicative of a dynamic natural system. Only one pasture, Jones Creek, showed an increase in cover class I. Cover class II generally declined while class III increased. Cover class IV remained constant in Lone Butte pasture but declined in Long Creek pasture.

The apparent uniformity in willow cover indicates willow replacement equaled willow loss. In other words, willow stems continued to regenerate under 28 years of rest-rotation management and environmental conditions. If management and/or environmental conditions were suppressing regeneration, the populations would have been dominated by older individuals with few young individuals. Additionally, there would have been an increase in the percentage of stream reach occupied by cover class I.

Population structure of willow stems also indicated a rapid turnover rate in stems. Ninety percent of the willow stems sampled were younger than 16 years. Therefore, near complete turnover in willow stems may have occurred three times during the 1942 to 1993 period. A complete turnover every 15 years on the Long Creek Allotment is similar to Geyer and Booth stem senescence (15 to 20 years) in central Oregon (Kavlachek 1991). Begin and Payette (1991) suggested turnover occurred from 10 to 14 years for Planeleaf willow (_S. planifolia_ Pursh) along a Quebec lake shore in Canada. Thus, natural turnover may explain the fluctuations in cover classes from 1942 to 1987 on Pole, Jones, and Long Creek.

The Long Creek Allotment has a frost free period of 10 to 30 days with nearly 80% of the annual precipitation falling in the form of snow (MAPS 1994). In late October 1991, approximately 380 mm of snow fell over a five day period. When snowfall ceased, the temperature dropped to 30° C below zero. Several clumps of willows averaging 2 m in height were bent over by the snow and frozen to the ground. Conditions such as these could damage stems on the perimeter of willow clumps, and while they do not occur every year, they can impact large areas and potentially hundreds of young stems. Thus, these conditions combined with winter wind patterns may be factors restricting tall willows establishment along exposed stream reaches within the allotment. Begin and Payette 1991, suggested winter conditions restricted willow development along a lake shore in Canada.

CHAPTER 3

RESPONSE OF WILLOWS TO HERBIVORY AND OTHER ENVIRONMENTAL FACTORS

Introduction

Willow use by domestic and wild ungulates is a major concern of land managers (Chadde and Kay 1991). Browsing of Geyer (Salix geyeriana Anderss.) and Booth willows (S. boothii Dorn) by domestic livestock within the Long Creek Allotment was identified as inhibiting the growth and development of tall willows (Platts 1990). To understand the ecology of willows within the allotment, we evaluated the effects of beaver (Castor canadensis canadensis Kuhl) herbivory, wild ungulate browsing [moose (Alces alces shiras Nelson), elk (Cervus elaphus nelsoni Bailey), and deer (Odocoileus spp.)], species of willow, initial willow size, distance to water, and cattle browsing on growth of tall willows. Results should provide an understanding of the relationship between environmental factors and willow size.

Methods

Treatment

A grazing management program developed by Resource Concepts, Inc. for Long Creek Allotment was implemented in 1991. The primary objective of the program was to improve riparian vegetation in Lone Butte and Pole Creek pastures. This was to be accomplished by resting Lone Butte and

Pole Creek pastures for consecutive years (Table 3). The Long Creek Allotment was normally grazed from July 15 through October 15. Thirty-day grazing periods were planned for each pasture. The grazing schedule was believed to be consistent with two criteria: 1) 50% use (dry weight) of upland vegetation over 50% of the pasture, and 2) minimum 80 mm stubble height in riparian areas at the end of the grazing or growing season (whichever occurred last). This thesis covers the first three years of the monitoring program.

Table 3. A five-year grazing system designed for the Long Creek Allotment and implemented in 1991.

	Pastures			
Year	Lone Butte	Pole Cr.	Jones Cr.	Long Cr.
1991	Rest	First	Mid	Late
1992	Rest	First	Late	Mid
1993	First	Rest	Mid	Late
1994	First	Rest	Late	Mid
1995	Rest	First	Mid	Late

Measurements

We analyzed change in willow volume instead of individual twig length. This provided information on the entire shrub rather than one or a few stems.

Crowns of most willows within the allotment have an elliptical shape. Therefore, we used the mathematical relationship to calculate volume of an ellipse (Creamer 1991) to estimate willow volume:

Volume = Height X (3.14 [Minor axis /2] X [Major axis /2])

In the fall of 1991, 75 willows were systematically selected along the main streams in the four pastures of the Long Creek Allotment. Because of the short stream reach (0.8 km) in the Long Creek pasture, the first 75 willows from the bottom of the fence upstream were selected. Sample size was determined by calculating the coefficient of variation between independent volume measurements (Snedecor and Cochran 1989). Selected willows were permanently tagged with numeric aluminum tags and sprayed with florescent paint at the base of each plant to aid identification.

In July 1991, ungulate exclosures were built in Pole Creek and in Lone Butte pastures to determine the biological potential of tall willows in the absence of ungulate browsing. All willows (approximately 40) within each exclosure were painted and permanently tagged with numeric aluminum tags for identification.

The decision to monitor willows using the volume method occurred in late summer 1991. Willows within the four pastures were initially tagged and measured in the fall (post-grazing) of 1991. Deep snow and cold temperatures prevented the 1991 tagging and measuring of willows in the exclosures. Therefore, initial measurements were recorded in the spring of 1992.

To monitor the effects of grazing, willow volume in the pastures grazed in early and mid-summer was measured in the spring (soon after snow melt), before grazing, after grazing, and fall (fall was considered to be when the cattle left the allotment after October 15). Measurements from post-grazing to fall were made to account for any post-grazing growth. Volume in the late-grazed pasture was measured three times annually: spring (soon after snow melt) and before grazing and after grazing. Growth after October 15 was unlikely in the late-grazed pasture. Measurements in the two exclosures and rested pasture were recorded in the spring and fall only.

In addition to the volume measurements, "willow use" by each kind of herbivore (cattle, big game, or beaver) was recorded for each collection period. Browsing by cattle or big game was ocularly estimated and recorded as a percentage of current year's growth (cyg). Beaver use was ocularly estimated as a percent of total willow volume removed. Cattle use was separated from big game use by considering the period of cattle use (i.e. if use was observed before cattle entered the pasture, it was attributed to wild ungulates). We did not determine which species of big game (moose, elk, or deer) browsed the willow.

The effect of distance to surface water on willow volume was also monitored. We assumed that willows furthest from the creek would potentially be water stressed during late summer. Additionally, beaver activity could raise or lower the water table over a short time period, affecting willow growth. Therefore, distance from the base of the willow to surface water was measured during each data collection period.

Analysis

The data were analyzed using the general linear models (GLM) procedure in SAS (SAS 1985). Multiple regression analyses were used to evaluate the influence of several environmental factors on changes in willow volume. The P value for level of significance was set at $P \leq 0.10$. The regression model for willow volume change was:

Willow Volume Change = f(S, IV, D, L, W, B)

Where:

S = species of willow
IV = initial volume of willow
D = distance to surface water
L = cattle use
W = wildlife use
B = beaver use

Changes in willow volume were calculated on a percent volume and on an actual volume basis. Percent volume was logical because smaller willows (willows < 2.0 m) have a greater growth potential than larger willows on a relative basis. Additionally, willows less than 2 m were within browsing reach of ungulates, and could have been reduced more than large willows. By analyzing percent volume, the initial size of the individual willow was considered:

$$\frac{\text{current willow volume} - \text{initial willow volume}}{\text{initial willow volume}} \times 100$$

Change in willow volume was also measured in cubic meters (m^3). This analysis reflected an absolute change in willow volume:

current willow volume - initial willow volume

Outliers from each data set, positive and negative, were deleted using the Grubbs and Beck (1972) test for outlying observations at the upper 10% level. A different standard deviation value was calculated for percent volume and actual volume change, generating different outliers. Percent volume and actual volume change data sets were reanalyzed with the outlying observations deleted.

It was believed comparison of data among pastures may be influenced by willow size. To determine willow size in each pasture, willow volumes from the spring of 1992 were stratified into five size classes (0-3, 4-6, 7-9, 10-12, and >12 m^3). These stratifications were then combined for willows in all of the pastures. Results of the combined pasture stratification were pooled into two classes (0-6 and >9 m^3) and into two subsets (percent and actual volume change). Percent and actual volume change from spring 1992 to fall 1992 were determined for all small willows (0-6 m^3) and for all large willows (>9 m^3).

Linear regression analyses were used to determine the relationship between percent and actual volume change from these two subsets.

Results

The majority of willows in each pasture were in the 0-3 m^3 size class (Table 4). Results of the linear correlation of percent and actual volume change indicated a high positive correlation of 88% for large willows (>9 m^3) and only a moderate positive correlation of 55% for small willows (0-6 m^3) (Table 5).

Table 4. Stratification of willows into five size classes by pasture and all pastures combined.

Size	Percentage of Willows				
Class m^3	Lone Butte	Pole Cr.	Jones Cr.	Long Cr.	All Pastures
0-3	56.5	41.2	54.3	59.2	52.9
3-6	21.7	16.2	22.9	9.9	17.6
6-9	7.2	7.4	11.4	7.0	8.3
9-12	4.3	7.4	2.9	7.0	5.4
>12	10.1	27.9	8.6	16.9	15.8

Table 5. Stratification of willows into two size classes for all pastures.

Size Class m^3	Percentage of willows
0-6	76.9
>9	23.1

Complete results of multiple regression analyses for percent and actual volume for pastures and exclosures including: R^2s, significant factors, slope of estimate for significant factors, and actual model statements are shown in Tables 19-24 of the Appendix. Results of species significance are shown in Tables 25-30 of the Appendix.

Mean R^2s for percent and actual volume change regression analysis were 15% and 17%, respectively. Although these values were low, the measurement technique was able to detect seasonal changes in willow volume. When beaver herbivory was significant in the Lone Butte pasture (Table 19, Appendix) and exclosure (Table 23, Appendix), R^2 values tended to be higher.

Of the 32 regression analyses, initial volumes were significant 10 times when analyzed using percent volume (Tables 19-24, Appendix). These results indicated smaller willows changed more than large willows. Conversely, initial volumes were significant in 16 of the 32 data sets when analyzed using actual volume change (m^3). Results indicated larger willows changed more than smaller willows in 12 of the 16 data sets (Tables 19-24, Appendix).

Grazed/Rested Pastures

An estimated 10% beaver use (by volume) decreased percent willow volume and actual willow volume in the Lone Butte pasture over the 1991-92 winter (Table 6). Lone Butte pasture was rested from cattle grazing in 1992 and willows increased 44% or 0.88 m^3 in volume.

Beaver use (19% by volume) over the winter of 1992-93 and high spring flows in 1993 reduced volumes 39%, or by -2.32 m^3. Willows reduced in volume over the winter responded the following growing season by increasing 112% in volume, or an increase of 0.71 m^3. An estimated 26% cattle use of current year's growth (cyg) occurred during 21 days of grazing in July-August 1993 (Table 6). However, willows increased 8% during this time period or 0.08 m^3 in volume. Seven percent beaver use from post-grazing to fall reduced willow volume. For cumulative total change from fall 1991 to fall 1993 percent volume increased while actual volume decrease (Table 6).

Table 6. Mean and Standard Error change in willow volume (percent and actual) within Lone Butte pasture 1991-1993.

Measurement Period	% Volume Change	Actual Change m^3
W'91-92	-22(±4)	-.71(±.23)
Sp-F'92	43(±8)	.88(±.22)
W'92-93	-39(±4)	-2.32(±.24)
Sp-PG'93	112(±35)	.71(±.17)
G'93	8(±5)	.08(±.14)
PoG-F'93	-9(±5)	-.46(±.17)
Cumulative Total	93	-1.82

F = Fall
G = Grazed
PG = Pre-Grazed
PoG = Post-Grazed
Sp = Spring
W = Winter

In the Pole Creek pasture, percent willow volume increased 17% from spring to pre-grazing 1992, while actual willow volume decreased 0.01 m^3 (Table 7). Willows decreased by 8% or 0.21 m^3 during 23 days of cattle grazing, which removed 29% of the current year's growth during July-August 1992. Willows not browsed and/or willows stimulated from browsing, increased in volume 15% or 0.96 m^3 from post-grazing to fall. Willows decreased 11% or 1.40 m^3 during the winter of 1992-93. The Pole Creek pasture was not grazed in 1993 and willows in that pasture increased 25% or 0.71 m^3. For cumulative total change, willow volumes (percent and actual) increased from fall 1991 to fall 1993 (Table 7).

Willows increased over the winter of 1991-92 and continued to increase through spring in the Jones Creek pasture. Three percent beaver use and 11% cattle use over 28 days of grazing, in September-October 1992, reduced willow volume 3%, while actual volume increase 0.09 m^3 (Table 8).

Table 7. Mean and Standard Error change in willow volume (percent and actual) within Pole Creek pasture 1991-1993.

Measurement Period	% Volume Change	Actual Change m^3
W'91-92	19($\pm$6)	0.96($\pm$.42)
Sp-PG'92	17($\pm$6)	-0.01($\pm$.37)
G'92	-8($\pm$3)	-0.21($\pm$.30)
PoG-F'92	15($\pm$4)	0.96($\pm$.30)
W'92-93	-11($\pm$4)	-1.4($\pm$.46)
Sp-F'93	25($\pm$5)	0.71($\pm$.43)
Cumulative Total	57	1.01

Table 8. Mean and Standard Error change in willow volume (percent and actual) within Jones Creek pasture 1991-1993.

Measurement Period	% Volume Change	Actual Change m^3
W'91-92	99($\pm$12)	0.46($\pm$.21)
Sp-PG'92	18($\pm$7)	0.21($\pm$.20)
G'92	-3($\pm$4)	0.09($\pm$.19)
W'92-93	-20($\pm$4)	-0.76($\pm$.14)
Sp-PG'93	45($\pm$8)	0.58($\pm$.10)
G'93	5($\pm$4)	0.22($\pm$.10)
PoG-F'93	-7($\pm$3)	-0.26($\pm$.11)
Cumulative Total	137	0.54

F = Fall
G = Grazed
PG = Pre-Grazed
PoG = Post-Grazed
Sp = Spring
W = Winter

Willow volume in Jones Creek decreased by 20% or 0.76 m^3 during the winter of 1992-93 (Table 8). Using percent volume change, this decrease resulted from 5% beaver use and high spring flows. Using actual volume change, this decrease resulted from spring flows, beaver, and 7% big game browsing (cyg). Although utilization by cattle was 10%

(cyg), willows increased 5% or 0.22 m^3 during the 28-day grazing period in August-September 1993. From post-grazing to fall, willow volumes decreased 7% or 0.26 m^3. Percent and actual volume change cumulative totals indicated an increase from fall 1991 to fall 1993 (Table 8).

In Long Creek pasture, willow volumes increased 19% during the winter of 1991-92 (Table 9). However, actual volumes indicated a decreased 0.33 m^3 . During 26 days of cattle grazing in August-September 1992, willow utilization was 12% (cyg) which decreased willow volume by 23% or 0.00 m^3 (no net change). Cattle browsing did not explain the decrease when analyzed using percent volume but did explain the no net change when using actual volume.

Table 9. Mean and Standard Error change in willow volume (percent and actual) within Long Creek pasture 1991-1993.

Measurement Period	% Volume Change	Actual Change m^3
W'91-92	19(+5)	-0.33(±.23)
Sp-PG'92	27(±6)	0.44(±.34)
G'92	-23(±3)	0.00(±.21)
PoG-F'92	10(±2)	0.12(±.20)
W'92-93	-28(±3)	-1.07(±.25)
Sp-PG'93	91(±10)	1.80(±.29)
G'93	-29(±3)	-.96(±.24)
Cumulative Total	67	0.0

F = Fall
G = Grazed
PG = Pre-Grazed
PoG = Post-Grazed
Sp = Spring
W = Winter

Willows in Long Creek pasture were reduced by 28% or 1.07 m^3 during the 1992-93 winter (Table 9). Percent volume change indicated 2% beaver use decreased willow volume, while actual volume change indicated willows closer to the stream were reduced from high spring runoff. Willow volume decreased during the grazing season 29% or 0.96 m^3, but the 11% estimated cattle use over the 28 days of grazing in September-October 1993 did not explain the decrease. From fall 1991 to fall 1993, cumulative percent volume change increased while actual volume did not change (Table 9).

Exclosures

Willow volumes in the Lone Butte exclosure increased 61% or 0.06 m^3 from the spring to fall of 1992 (Table 10). Willow volumes decreased during the winter of 1992-93. Thirty-two percent beaver use decreased willow volumes from spring to fall 1993. Cumulative change for percent volume increased while actual volumes decreased (Table 10).

Table 10. Mean and Standard Error change in willow volume (percent and actual) within Lone Butte exclosure 1992-1993.

Measurement Period	% Volume Change	Actual Change m^3
Sp-F'92	61($\pm$36)	0.06($\pm$.11)
W'92-93	-16($\pm$6)	-0.15($\pm$.08)
Sp-F'93	-19($\pm$7)	-0.30($\pm$.09)
Cumulative Change	26	-0.39

F = Fall
G = Grazed
PG = Pre-Grazed
PoG = Post-Grazed
Sp = Spring
W = Winter

Willow volumes increased from spring to fall 1992 and over the winter of 1992-93 in the Pole Creek exclosure (Table 11). From spring to fall 1993, actual volumes decreased 0.04 m^3, while percent volumes increased 22%. Cumulative results indicated willow volume increased (percent and actual) in the Pole Creek exclosure (Table 11).

Table 11. Mean and Standard Error change in willow volume (percent and actual) within Pole Creek exclosure 1992-1993.

Measurement Period	% Volume Change	Actual Change m^3
Sp-F'92	19($\pm$4)	0.93($\pm$.27)
W'92-93	2($\pm$4)	0.10($\pm$.38)
Sp-F'93	22($\pm$14)	-0.04($\pm$.27)
Cumulative Change	43	0.99

F = Fall
G = Grazed
PG = Pre-Grazed
PoG = Post-Grazed
Sp = Spring
W = Winter

Discussion

In 7 of 64 regression analyses species of willow was significant (Tables 25-30, Appendix). Results indicated one species of willow changed more than the other during that measurement period. However, no differentiation between response of Geyer willows and Booth willows was observed. Additionally, cattle, beaver, or big game did not prefer one species over the other. Variation between the two species in the Pole Creek pasture was a result of the difference in numbers of willows sampled, 9 for Geyer and 60 for Booth willow (Table 27, Appendix).

Correlation of percent and actual volume change for large willows (>9 m^3) was high, 88%, while only moderate (55%) for small willows (0-6 m^3). This indicated that either variable was appropriate for large willows but possibly less appropriate for small willows. Because most of the willows sampled (76.9%) were small may explain the different results for percent and actual volume changes.

For example, in the Lone Butte pasture cumulative percent volume change was a positive 93% whereas actual volume change indicated a decrease of 1.82 m^3 (Table 6). Methodology used to calculate percent willow volumes were biased to favor increases over decreases. Willows can increase greater than 100% of their initial size but can only be reduced to 100% of initial size. This was particularly the case when willows were reduced in excess of 50% by volume.

Consider a willow reduced from a height of 2.0 m to 0.5 m while minor and major axes length remain unchanged. Percent volume analysis would indicate a decrease of 75%. If this same willow grew from 0.5 m to 1.5 m it increased 300% yet had not returned to its initial height of 2.0 m. The percent volume analysis would suggest the willow was better after the decrease than before. However, the net volume change of the willow had been reduced. Actual willow volume measurement correctly indicated that the willow has not returned to its initial volume.

Also, percent volume unevenly weighted the increase of small willows over large willows. Small willows, less than 1 m in height, did not have to grow much to increase more than 100% of their initial size. Actual willow volume analyses were more reflective of the actual change of individual willows. For these reasons, the following discussion focuses on actual volume and not on percent volume.

Actual volume analyses indicated large willows changed more than small willows. This was particularly the case in the Lone Butte pasture, which could be attributed to beaver harvesting large willows for dams. Additionally, the magnitude of change was potentially greater for a 20 m^3 willow than a 0.05 m^3 willow.

In general, from the fall of 1991 to the fall of 1993, willows in the Pole and Jones Creek pastures increased in volume while willows in the Long Creek pasture remained the same size. In 1993, cattle browsing and physical damage, and spring runoff were the main factors holding willows to no net change (0.0 m^3) in willow volume within the Long Creek pasture. Because of fence location in relationship to topography cattle were funneled into this corner of the allotment. More importantly, a short reach of Long Creek which provided most of the flowing water in the pasture is located in this corner. These conditions could have seriously reduced willow volumes. However, this 0.8 km stream reach contains a dense stand of multi-sized willows.

Although Long Butte pasture was rested from livestock for two consecutive years, willows in the Lone Butte pasture decreased in volume over the study period (Table 6). This loss is attributed to beaver herbivory which was most active during winters (Table 12). Additionally, in the summer of 1993 beavers were rebuilding dams that washed-out in the spring flows.

Table 12. Mean ocular estimates of beaver herbivory (by volume) and cattle and big game herbivory (current year's growth) on willows by season, pasture, and exclosure.

Pasture	Season of use	Herbivore	Estimated use (%)
Lone Butte	winter'91-92	beaver	10
	winter'92-93	beaver	19
	July-Aug.'93	cattle	26
	Oct.'93	beaver	7
Pole Creek	July-Aug.'92	cattle	29
Jones Creek	Sep.-Oct.'92	cattle	11
		beaver	3
	winter'92-93	beaver	5
		big game	7
	Aug.-Sep.'93	cattle	10
Long Creek	Aug.-Sep.'92	cattle	26
		cattle	11
	winter'92-93	beaver	2
Exclosure			
Lone Butte	June-Oct.'93	beaver	32

Beaver herbivory in the Lone Butte pasture was also evident in the ungulate exclosure. While cattle and big game were excluded by the exclosure, beaver were able to swim up the creek and enter the exclosure. Willows in the exclosure decreased 0.39 m^3 from beaver herbivory (Table 10). Willows in the Pole Creek exclosure did not receive any beaver use and increased 0.99 m^3 (Table 11).

Hall (1960) suggested willows could not withstand more that two consecutive years of beaver herbivory. Repeated herbivory of willow stems reduce photosynthetic material and deplete carbohydrate reserves which are stored in the second-year wood of some shrubs (Coyne and Cook 1970). Therefore, if beaver remain in the area, willows are expected to decline in the future.

Cattle use within the Long Creek Allotment did not exceed 50% (cyg) over the study period. Responses were not dramatic and willow growth was not restricted. Likewise, 250 cow/calf pairs grazing in Oregon for 48 and 53 days for each of two years did not excessively use shrubs (Roath and Krueger 1982). Based on Shaw's (1991) research, season-long grazing was detrimental to sandbar willow (S. exigua Nutt.) seedlings, whereas seedling establishment under spring, fall grazed, and protected treatments were similar under light/moderate stocking density. The grazing strategy initiated in 1991 to improve willow growth on the Long Creek Allotment has been successful in three of four pastures.

Continued monitoring of actual willow volume on the Long Creek Allotment is needed. Beaver activity in Lone Butte pasture is likely reducing carbohydrate reserves. These willows could further be suppressed by future beaver or ungulate herbivory. Additional monitoring is needed to assess willow trend and to provide a better understanding of the length of time needed to recover from herbivory.

CHAPTER 4

CLONAL EXPANSION OF WILLOWS

Introduction

One form of willow propagation is clonal expansion. Clones expand by forming horizontal root system and sending up vertical shoots (ramet) (Douglas 1989). Ramets are connected to the parent plant, and probably have a higher survival rate than seedlings (Legere and Payette 1981).

We examined the rate at which Geyer (Salix geyeriana Anderss.) and Booth (S. boothii Dorn) willows expand through ramet production in grazed and ungrazed exclosures. By knowing the rate of expansion of willows in grazed versus ungrazed areas, managers could better estimate the time it takes to re-establish willows through grazing management.

Methods

There were two criteria for selecting willows for clonal expansion monitoring: 1) willows had to be within four meters of the stream 2) each willow was easily identified as an individual plant. Five willows, in the Lone Butte, Pole, Jones, and Long Creek pastures and five willows in the Pole Creek exclosure were systematically selected along the length of the stream for monitoring (only four willows fit the criteria for selection in the Lone Butte exclosure thus only four willows were monitored). Based on the size of the shrub, two to four permanent 0.25 m^2 plots were established in each of the cardinal coordinates of the clump. Depending on the size of the individual willow, plots were established so that 5, 10, or 20 cm of the sample frame extended from the perimeter into the shrub (Figure 4). The outer

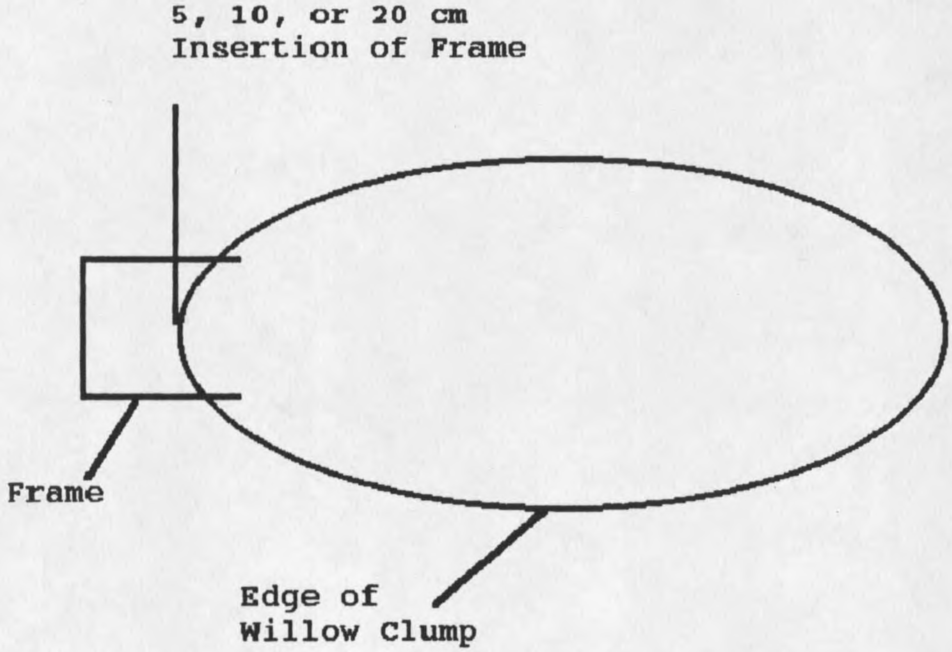


Figure 4. Example of clonal expansion sampling plot.

edges of each plot were permanently marked by driving 10 cm long nails (with washers) into the ground. Nails were driven until washers touched the ground and were painted for identification.

Beginning in the spring 1992, the number of live stems between the edge of the shrub and the open area within the frame were counted. Counts were repeated in the fall 1992, and in the spring and fall 1993. A metal detector was used to relocate plots. If a stem was outside the original shrub perimeter, it was considered expanding.

Analysis

Mean and standard error of live stems per sample period for pastures and exclosures were calculated (Table 13-18). Additionally, the density of stems (m^2) for each willow were reported.

Results

Two willow stems were found to be clonally expanding over the study period. They were willow number 5 in Pole Creek pasture, fall 1993 (Table 14) and willow number 1 in Jones Creek pasture, fall 1993 (Table 15). Clonal expansion was not detected in the remaining 27 willows.

Beaver (Castor canadensis canadensis Kuhl) herbivory during the winter 1992-93 decreased stem counts in the Lone Butte pasture (Table 13). High spring flows in spring 1993 possibly stimulated the sprouting of willow number 5 in the Pole Creek pasture (Table 14).

Table 13. Lone Butte pasture clonal expansion.

Willow Number	Mean and Standard Error of Stem Count				Mean # Stems/m²
	Spring'92	Fall'92	Spring'93	Fall'93	
1	4.0(.71)	4.0(.71)	4.0(.71)	4.0(.71)	80
2	5.3(.66)	5.3(.66)	4.5(.83)	4.5(.83)	49
3	3.5(.35)	3.5(.35)	3.5(.35)	3.5(.35)	140
4	7.8(.24)	7.8(.24)[a]	5.0(.94)[b]	5.0(.94)	64
5	3.0(.71)	3.0(.71)	3.0(.71)	3.0(.71)	100

Table 14. Pole Creek pasture clonal expansion.

Willow Number	Mean and Standard Error of Stem Count				Mean # Stems/m²
	Spring'92	Fall'92	Spring'93	Fall'93	
1	3.5(1.06)	4.0(1.41)	5.0(1.41)	4.5(1.77)	85
2	4.3(.52)	4.3(.52)	4.0(.46)	3.8(.43)	41
3	5.5(1.13)	6.3(1.36)	6.3(1.36)	6.3(1.36)	61
4	6.0(.71)	6.0(.71)	6.0(.71)	6.0(.71)	120
5	5.3(.52)	4.3(.24)	4.8(.31)	4.0(.20)	48

[a]Willows with different superscript letters had different stem counts (Standard Errors do not overlap between observations).

Physical damage by cattle during the summer of 1992 decreased stem count for willow number 1 in the Jones Creek pasture (Table 15). Severe wildlife browsing (> 100% current year's growth) of willow number 1, over winter 1992-93, killed some large interior stems. This caused new stems to sprout from the base of the plant. By the fall 1993, one stem was found to be clonally expanding. Beaver herbivory during the winter 1992-93, reduced stem counts for willows 3 and 4 (Table 15). No clonal expansion was observed in the Long Creek pasture over the two years of monitoring.

Table 15. Jones Creek pasture clonal expansion.

Willow Number	Mean and Standard Error of Stem Count				Mean # Stems/m²
	Spring'92	Fall'92	Spring'93	Fall'93	
1	7.5(.49)[a]	6.5(.43)[b]	6.5(.49)	6.0(.66)	66
2	7.0(.85)	7.5(.35)[a]	5.0(1.41)[b]	5.0(1.41)	123
3	4.5(.60)	4.5(.60)[a]	3.0(.41)[b]	3.0(.41)	38
4	10.7(1.95)	10.7(1.95)[a]	6.0(.33)[b]	6.0(.33)	83
5	9.0(1.20)	9.0(1.20)	7.7(1.07)	7.7(1.07)	84

Table 16. Long Creek pasture clonal expansion.

Willow Number	Mean and Standard Error of Stem Count				Mean # Stems/m²
	Spring'92	Fall'92	Spring'93	Fall'93	
1	4.0(1.41)	4.0(1.41)	4.0(1.41)	4.0(1.41)	80
2	5.5(.60)	4.3(.47)	4.8(.55)	4.0(.88)	47
3	12.0(.71)	12.0(.71)	12.0(.71)	12.0(.71)	240
4	5.7(.84)	4.7(.84)	3.7(1.17)	3.7(1.17)	44
5	8.5(1.06)	8.5(1.06)	8.0(0.0)	8.0(0.0)	165

[a]Willows with different superscript letters had different stem counts (Standard Errors do not overlap between observations).

Stem counts for willow number 2 in the Lone Butte exclosure was reduced by beaver herbivory over the winter 1992-93. Additionally, the nails for willow number 2 were apparently removed by a rodent in the fall 1993 (Table 17). No clonal expansion was observed in the Pole Creek exclosure over the study period.

Table 17. Lone Butte exclosure clonal expansion.

Willow Number	Mean and Standard Error of Stem Count				Mean # Stems/m^2
	Spring'92	Fall'92	Spring'93	Fall'93	
1	2.0(.71)	2.0(.71)	2.0(.71)	2.0(.71)	40
2	4.0(0.0)	4.0(0.0)[a]	2.5(1.06)[b]	LOST	70
3	4.8(.75)	4.8(.75)	5.3(.75)	5.3(.83)	50
4	5.0(2.12)	5.0(2.12)	6.0(2.12)	6.0(2.12)	110

Table 18. Pole Creek exclosure clonal expansion.

Willow Number	Mean and Standard Error of Stem Count				Mean # Stems/m^2
	Spring'92	Fall'92	Spring'93	Fall'93	
1	4.0(.20)	4.0(.20)	4.0(.20)	4.3(.31)	41
2	4.0(.35)	4.0(.35)	4.0(.35)	4.3(.31)	41
3	6.0(.79)	6.0(.79)	6.0(.79)	6.0(.79)	60
4	7.0(.71)	7.0(.71)	7.0(.71)	7.0(.71)	140
5	2.5(1.06)	2.5(1.06)	2.5(1.06)	3.5(.35)	55

[a]Willows with different superscript letters had different stem counts (Standard Errors do not overlap between observations).

Discussion

Sediment, up to 20 cm deep, deposited around the base of willows covered washers and nails making relocation of plots difficult, even with a metal detector. Additionally, construction of beaver ponds caused bank slumping which moved some plots in Lone Butte pasture. Movement of plot by beaver activity made willow stem counts difficult.

Two of the 27 plots exhibited clonal expansion during the four measurement periods. These small increases indicate that willows within the Long Creek Allotment expand slowly, possibly a result of the short growing season and competition from herbaceous vegetation. Flooding events that bend over then cover existing stems with sediment may have better chances of vegetatively expanding than horizontal root systems. However, these events are episodic and may require more than two years to observe.

CHAPTER 5

SUMMARY

Livestock management within the Long Creek Allotment has not restricted tall willow growth or development since 1942 as indicated by aerial photographs and stem age demographics. Additionally, clonal expansion rates inside and outside of exclosures were similar. Severe winter conditions and competition from herbaceous vegetation may be restricting further expansion of willows.

Actual willow volume increased or was maintained in the Pole, Jones, and Long Creek pastures. Repeated beaver herbivory reduced willows in the Lone Butte pasture. Actual volume reduction occurred during a three year period, in which the pasture was rested from cattle grazing for two years. Beaver herbivory in the Lone Butte exclosure also reduced willow volume while willows in the Pole Creek exclosure increased, with no beaver activity over the study period.

Use of willows by beaver within the Lone Butte pasture may continue until the population declines or resources are depleted and beavers move to other areas occupied by willows. Because aerial photography and willow stem age indicate healthy willows, this volume reduction may be short-term. However, willows reduced by beaver are within browsing reach of domestic and wild ungulates. Future browsing may further suppress willows, requiring several years for willows to recover. Additional monitoring to assess trend of willows and to quantify herbivory impacts is recommended.

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APPENDIX
MULTIPLE REGRESSION RESULTS

Table 19. Mean and Standard Error multiple regression results for Lone Butte pasture.

Season	R^2	%Change	Si	E	R^2	Change m^3	Si	E
W'91-92	37	-22(±4)	B S	-	24	-.71(±.23)	B S W	- -
Sp-F'92	15	43(±8)	B IV	- -	8	.88(±.22)		
W'92-93	47	-39(±4)	B D IV	- + +	73	-2.32(±.24)	B D IV	- + -
Sp-PG'93	4	112(±35)			22	.71(±.17)	B IV	- +
G'93	16	8(±5)	L	-	25	.08(±.14)	S D IV L	 + - -
PoG-F'93	14	-9(±5)	B	-	14	-.46(±.17)	B IV	- -
Cumulative Change		93				-1.82		

%Change = Percent Volume Change
Change m^3 = Volume Change m^3
Si = Significant Factors
E = Slope of Estimate
B = Beaver
D = Distance to Water
F = Fall
G = Grazed
IV = Initial Volume
L = Livestock
PG = Pre-Grazed
PoG = Post-Grazed
S = Species of Willow
Sp = Spring
W = Wildlife

Actual Model Statements

W'91-92 %Change = S D B W IV
Change m^3 = S D B W IV
Sp-F'92 %Change = S D B W IV
Change m^3 = S D B W IV
W'92-93 %Change = S D B W IV
Change m^3 = S D B W IV
Sp-PG'93 %Change = S D B IV
Change m^3 = S D B IV
G'93 %Change = S D B L IV
Change m^3 = S D B L IV
PoG-F'93 %Change = S D B IV
Change m^3 = S D B IV
Sp-F'93 %Change = S D B L IV
Change m^3 = S D B L IV

Table 20. Mean and Standard Error multiple regression results for Pole Creek pasture.

Season	R^2	%Change	Si	E	R^2	Change m^3	Si	E
W'91-92	4	19(±6)			4	.96(±.42)		
Sp-PG'92	12	17(±6)	IV S	-	25	-.01(±.37)	IV	-
G'92	26	-8(±3)	L	-	9	-.21(±.30)	L	-
PoG-F'92	8	15(±4)	IV	-	3	.96(±.30)		
W'92-93	4	-11(±4)			8	-1.4(±.46)	IV	-
Sp-F'93	8	25(±5)			20	.71(±.43)	B IV	- -
Cumulative Change		57				1.01(±.38)		

%Change = Percent Volume Change
Change m^3 = Volume Change m^3
Si = Significant Factors
E = Slope of Estimate
B = Beaver
D = Distance to Water
F = Fall
G = Grazed
IV = Initial Volume
L = Livestock
PG = Pre-Grazed
PoG = Post-Grazed
S = Species of Willow
Sp = Spring
W = Wildlife

Actual Model Statements

W'91-92 %Change = S D W B IV
Change m^3 = S D W B IV
Sp-PG'92 %Change = S D IV
Change m^3 = S D IV
G'92 %Change = S D L IV
Change m^3 = S D L IV
PoG-F'92 %Change = S D IV
Change m^3 = S D IV
Sp-F'92 %Change = S D L IV
Change m^3 = S D L IV
W'92-93 %Change = S D W B IV
Change m^3 = S D W B IV
Sp-F'93 %Change = S D B IV
Change m^3 = S D B IV

Table 21. Mean and Statndard Error multiple regression results for Jones Creek pasture

Season	R^2	%Change	Si	E	R^2	Change m^3	Si	E
W'91-92	5	99(±12)			8	.46(±.21)		
Sp-PG'92	4	18(±7)			1	.21(±.20)		
G'92	28	-3(±4)	B D L	- - -	8	.09(±.19)	B	-
W'92-93	24	-20(±4)	B D	- +	27	-.76(±.14)	B D IV W	- + - -
Sp-PG'93	12	45(±8)	IV S	-	23	.58(±.10)	IV	+
G'93	9	5(±4)	D	-	6	.22(±.10)		
PoG-F'93	6	-7(±3)	S		6	-.26(±.11)		
Cumulative Change		137(±5)				.54(±.15)		

%Change = Percent Volume Change
Change m^3 = Volume Change m^3
Si = Significant Factors
E = Slope of Estimate
B = Beaver
D = Distance to Water
F = Fall
G = Grazed
IV = Initial Volume
L = Livestock
PG = Pre-Grazed
PoG = Post-Grazed
S = Species of Willow
Sp = Spring
W = Wildlife

Actual Model Statements

W'91-92 %Change = S D B W IV
Change m^3 = S D B W IV
Sp-PG'92 %Change = S D W IV
Change m^3 = S D W IV
G'92 %Change = S D L B IV
Change m^3 = S D L B IV
Sp-F'92 %Change = S D W L B IV
Change m^3 = S D W L B IV
W'92-93 %Change = S D W B IV
Change m^3 = S D W B IV
Sp-PG'93 %Change = S D W IV
Change m^3 = S D W IV
G'93 %Change = S D L IV
Change m^3 = S D L IV
PoG-F'93 %Change = S D IV
Change m^3 = S D IV
Sp-F'93 %Change = S D W L IV
Change m^3 = S D W L IV

Table 22. Mean and Standard Error multiple regression results for Long Creek pasture.

Season	R^2	%Change	Si	E	R^2	Change m^3	Si	E
W'91-92	18	19($\pm$5)	IV W	- -	32	-.33($\pm$.23)	IV	-
Sp-PG'92	4	27($\pm$6)			2	.44($\pm$.34)		
G'92	19	-23($\pm$3)	IV	+	13	.00($\pm$.21)	D L	+ -
PoG-F'92	10	10($\pm$2)	IV	-	8	.12($\pm$.20)	IV	-
W'92-93	13	-28($\pm$3)	B IV	- +	33	-1.07($\pm$.25)	D IV	- -
Sp-PG'93	13	91($\pm$10)	IV	-	31	1.80($\pm$.29)	D IV	+ +
G'93	8	-29($\pm$3)			5	-.96($\pm$.24)		
Cumulative Change		67($\pm$5)				0($\pm$.25)		

%Change = Percent Volume Change
Change m^3 = Volume Change m^3
Si = Significant Factors
E = Slope of Estimate
B = Beaver
D = Distance to Water
F = Fall
G = Grazed
IV = Initial Volume
L = Livestock
PG = Pre-Grazed
PoG = Post-Grazed
S = Species of Willow
Sp = Spring
W = Wildlife

Actual Model Statements

W'91-92 %Change = S D W IV
Change m^3 = S D W IV
Sp-PG'92 %Change = S D W IV
Change m^3 = S D W IV
G'92 %Change = S D L IV
Change m^3 = S D L IV
PoG-F'92 %Change = S D IV
Change m^3 = S D IV
Sp-F'92 %Change = S D L IV
Change m^3 = S D L IV
W'92-93 %Change = S D W B IV
Change m^3 = S D W B IV
Sp-PG'93 %Change = S D IV
Change m^3 = S D IV
G'93 %Change = S D L IV
Change m^3 = S D L IV
Sp-F'93 %Change = S D L IV
Change m^3 = S D L IV

Table 23. Mean and Standard Error multiple regression results for Lone Butte exclosure.

Season	R^2	%Change	Si	E	R^2	Change m^3	Si	E
Sp-F'92	7	61(±36)			35	.06(±.11)	B IV	- -
W'92-93	10	-16(±6)			6	-.15(±.08)		
Sp-F'93	45	-19(±7)	B IV	- -	35	-.30(±.09)	B IV	- -
Cumulative Change		26(±16)				-0.39(±.09)		

Table 24. Mean and Standard Error multiple regression results for Pole Creek exclosure.

Season	R^2	%Change	Si	E	R^2	Change m^3	Si	E
Sp-F'92	16	19(±4)	IV	-	2	.93(±.27)		
W'92-93	17	2(±4)	S		3	.10(±.38)		
Sp-F'93	14	22(±14)	IV	-	15	-.04(±.27)	IV	-
Cumulative Change		43(±7)				0.99(±.31)		

%Change = Percent Volume Change
Change m^3 = Volume Change m^3
Si = Significant Factors
E = Slope of Estimate
B = Beaver
D = Distance to Water
F = Fall
G = Grazed
IV = Initial Volume
L = Livestock
PG = Pre-Grazed
PoG = Post-Grazed
S = Species
Sp = Spring
W = Wildlife

Actual Model Statements

Lone Butte Control

Sp-F'92 %Change = S D B IV
Change m^3 = S D B IV
W'92-93 %Change = S D B IV
Change m^3 = S D B IV
Sp-F'93 %Change = S D B IV
Change m^3 = S D B IV

Pole Creek Control

Sp-F'92 %Change = S D IV
Change m^3 = S D IV
W'92-93 %Change = S D IV
Change m^3 = S D IV
Sp-F'93 %Change = S D IV
Change m^3 = S D IV

Table 25. Mean and Standard Error multiple regression results (percent volume change) for Lone Butte pasture by species.

Season	Spp	R^2	n	%Change	Si	E
W'91-92	Sabo	56	47	-22(±3)	B W	- -
	Sage	16	21	-25(±10)		

Table 26. Mean and Standard Error multiple regression results (actual volume change) for Lone Butte pasture by species.

Season	Spp	R^2	n	Change m^3	Si	E
W'91-92	Sabo	45	46	-1.11(+.23)	B IV	- -
	Sage	23	23	-.16(±.43)	IV	+
G'93	Sabo	23	52	.25(±.19)	D L IV	+ - -
	Sage	79	21	-.33(+.06)	B D L IV	- + - -

Table 27. Mean and Standard Error multiple regression results (percent volume change) for Pole Creek pasture by species.

Season	Spp	R^2	n	%Change	Si	E
Sp-PG'92	Sabo	11	9	-6(±8)		
	Sage	11	60	20(±7)	IV	-

%Change = Percent Volume Change
Change m^3 = Volume Change m^3
Si = Significant Factors
Spp = Species
E = Slope of Estimate
B = Beaver
D = Distance to Water
F = Fall
G = Grazed
IV = Initial Volume
L = Livestock
n = Number of Willows
PG = Pre-Grazed
PoG = Post-Grazed
Sp = Spring
W = Wildlife

Table 28. Mean and Standard Error multiple regression results (percent volume change) for Pole Creek exclosure by species.

Season	Spp	R^2	n	%Change	Si	E
W'92-93	Sabo	15	12	12($\pm$78)		
	Sage	8	18	-6($\pm$5)		

Table 29. Mean and Standard Error multiple regression results (actual volume change) for Jones Creek pasture by species.

Season	Spp	R^2	n	Change m^3	Si	E
W'91-92	Sabo	40	27	1.11($\pm$.43)	IV	-
	Sage	48	38	.05($\pm$.09)	B IV	- -

Table 30. Mean and Standard Error multiple regression results (percent volume change) for Jones Creek pasture by species.

Season	Spp	R^2	n	%Change	Si	E
Sp-PG'93	Sabo	13	32	56($\pm$15)	IV	-
	Sage	10	43	36($\pm$8)	IV	-
PoG-F'93	Sabo	1	31	-.90($\pm$3)		
	Sage	1	43	-12($\pm$4)		

%Change = Percent Volume Change
Change m^3 = Volume Change m^3
Si = Significant Factors
Spp = Species
E = Slope of Estimate
B = Beaver
D = Distance to Water
F = Fall
G = Grazed
IV = Initial Volume
L = Livestock
n = Number of Willows
PG = Pre-Grazed
PoG = Post-Grazed
Sp = Spring
W = Wildlife