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Response of a Depleted Sagebrush Steppe Riparian System to Grazing Control and Woody Plantings

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Research Summary

Conventional wisdom suggests that virtually all riparian areas respond quickly to improved management or to complete protection. To test this assumption a study was established along Pole Creek in the sagebrush steppe of eastern Oregon. Five management treatments were examined: (1) ungrazed and woody species planted, (2) ungrazed, (3) light to moderate spring grazing, (4) light to moderate fall grazing, and (5) heavy season-long grazing. These treatments were evaluated over a 7-year period and the response of riparian and upland plant communities, bird and small mammal populations, and stream channel characteristics compared.

Existing herbaceous plant species increased in growth and vigor under reduced grazing (ungrazed and moderate grazing treatments), but there was no measurable increase in occurrence of bank protecting rhizomatous wetland species. A fortuitous flood event occurring at the beginning of the study provided a favorable seedbed for willow establishment. These naturally established plants and those naturally establishing later benefitted from light to moderate spring grazing or from complete protection from grazing as compared to light to moderate fall grazing or heavy season-long grazing, although recovery was slowed by wild ungulate use. Significantly improved stands of cottonwood and willows developed where these species were artificially planted.

After 7 years, populations of nesting birds and small mammals did not differ among treatments. This lack of response was likely due to the limited habitat improvement that occurred during the study. Available literature suggests a much more varied bird community was present early in the twentieth century.

Stream channel shape (width/depth ratios) appeared to improve somewhat under reduced grazing pressure. However, the lack of rhizomatous grasslike species left the streambanks poorly protected. As a result, all treatments except those not subjected to grazing experienced an increase in width-depth ratios in the latter portion of the study under conditions of extended high stream flows resulting from snowmelt. Recovery of the degraded uplands and riparian zone of this watershed will apparently require many years, probably decades.

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Introduction

Since the mid-1800's, alteration of low-elevation streams of the sagebrush steppe by human activities, particularly livestock grazing, has frequently resulted in local loss of wetland plants (Kauffmann and Krueger 1984; Thomas and others 1979; US-GAO 1988) and animal species (Bock and others 1993; Saab and others 1995; Sedgwick and Knopf 1987). Riparian (stream-side) areas within the sagebrush ecosystem (see appendix A for plant scientific names) are particularly susceptible to livestock concentrations and grazing damage (Berry 1979). Defoliation, soil compaction, and floodplain water table subsidence, due to channel widening or downcutting, have resulted in loss of densely rooted sedges and rushes, as well as willows, cottonwoods, and other woody species (Armour and others 1994; Berry 1979; Kovalchik and Elmore 1992). Banks are left poorly protected and produce large quantities of sediment as they erode. They may be a major source of a stream's sediment load (Hansen 1971; Trimble and Mendel 1995). Negative effects of destabilized riparian areas on overall watershed stability, water quality, animal populations and habitat, human recreation, aesthetic, and economic uses have been extensively documented (Chaney and others 1990; Platts 1991; Saab and others 1995; US-GAO 1988).

Conventional wisdom and general observation suggest many degraded riparian areas recover quickly when stressful impacts, such as improper grazing, are removed (Chaney and others 1993; Krueper 1993). Skovlin (1984) suggested that, on average, a 75 percent recovery of fish and wildlife habitat conditions

could occur in approximately 5 years. However, Szaro and Pase (1983) found little response within a cottonwood-ash-willow association after 4 years of protection from grazing, and Knopf and Cannon (1982) reported 10 to 12 years were insufficient for riparian willow communities to recover from excessive grazing. The ability of streams, associated vegetation, and wildlife populations to recover naturally after reductions in grazing stress appear to be situation specific and related to site characteristics, degree of degradation, and availability of native plant materials (Krueper 1993; Shaw 1992).

Existing grazing management approaches, however, may not be capable of correcting cattle impacts on riparian habitats (Platts 1991) because response of riparian areas to grazing practices has been inconsistent (Kauffman and Krueger 1984). These inconsistencies may result because inadequate site-specific information is used in management design or because a variety of different procedures are often lumped under a single "practice" (Marlow and Pogacnik 1985). There are also problems associated with evaluating site potential, and therefore, difficulty in interpreting the degree of response to management changes.

In the current study, we examined the response of a depleted riparian ecosystem to five treatments applied over 7 years; (1) ungrazed/planted, (2) ungrazed, (3) light to moderate grazed in the spring, (4) light to moderate grazed in the fall, and (5) heavily grazed season-long. Data are presented on vegetation, bird, small mammal, and channel changes in response to the five treatments from 1987 to 1993. Further, success of woody plantings in the ungrazed/planted treatment is evaluated.

Study Area

The study was conducted in the Pole Creek drainage of the Poall Creek grazing allotment located in the eastern foothills of the Cottonwood Mountains in Malheur County, OR (44°15'N 117°35'W). Cattle graze the Poall Creek allotment from April 1 to September 30 in even years and from July 1 to October 31 in odd years (USDI-BLM 1982, 1987). Thus, although spring deferment occurred every other year, the allotment was grazed heavily each year.

Climate of the area is semiarid. Annual precipitation is 244 mm with 61 percent falling from October through March (USDC-NOAA 1986-1993). Annual temperature at Vale, OR, the nearest reporting station, is 10 °C; ranging from -3 °C in January to 23 °C in July. Soils are derived from a combination of basalt and rhyolite, varying from shallow and rocky soils on ridges to deep alluvial deposits in former wet meadows and sandy, gravelly, or cobbly deposits adjacent to stream channels and on flood plains. Upland slopes within the study pastures average 33 percent.

Pole Creek is perennial and spring-fed with a 2.5 to 3 percent gradient, sinuosity of 1.2, and a relatively uniform base flow of about 0.03 m³/s. Streamside elevation ranges from 880 to 975 m. Except for its low sinuosity, the stream approximates a Rosgen classification of C3b to C4b (Rosgen 1994). Loss of native riparian bank-stabilizing vegetation has resulted in widening and downcutting of the stream channel—in some cases to bedrock. The incised banks created by this process are 1 to 3 m or more in height. The narrow flood plain developing between the incised banks generally ranges from 10 to 30 m in width. Flood events overtopping the low active-channel banks of the developing flood plain typically result from snowmelt flows in late winter and from rainstorm events in summer.

The Pole Creek riparian system is considered less than stable because uplands are susceptible to severe erosion events during high intensity rainstorms (fig. 1), annual stream channel shifts, and limited protection provided by the current weedy streambank vegetation. Unstable sandbars are initially colonized by horsetail and speedwell species (see appendix A for plant scientific names). Sediments on low banks and terraces support Kentucky bluegrass and creeping bentgrass. Drier benches supporting exotic annuals grade into the sagebrush community.

A limited description of the area provided by Peck (1911), and remnant plants, logs, and seedlings suggest that previous to livestock grazing woody riparian communities may have included coyote willow, whip-lash willow, narrow-leaved cottonwood, and black cottonwood. Remnant shrubs associated with the riparian area include blue elderberry, Wood's rose, and common chokecherry. Although a large component of sedges and rushes, for example Nebraska sedge and Baltic rush, would also normally be expected in a riparian system such as Pole Creek (Crouse and Kindschy 1984; Griffiths 1903; Peck 1911), few are present.

Uplands within the watershed are steep (25 to 45 percent slopes). We would expect potential natural upland communities in this area to contain a substantial component of bluebunch wheatgrass, Sandberg's bluegrass, Thurber's needlegrass, needle-and-thread, and some bottlebrush squirreltail (Hironaka and others 1983). However, these plant communities have been substantially depleted. The majority of the upland sites currently support Wyoming big sagebrush/cheatgrass plant communities. A stiff sagebrush/Sandberg's bluegrass habitat type is restricted to rocky, basalt sites with shallow soils.



Figure 1—Erosional deposits in the riparian area following a high intensity thunderstorm (A), rilling on an upland site that occurred during the same storm (B).

Methods

Pasture Treatments

Ten experimental pastures ranging in area from 4.0 to 5.5 ha were established along a 5 km segment of Pole Creek in 1987. Five grazing treatments were applied from 1987 to 1993 in a completely randomized design with two replications. Treatments were; (1) ungrazed with plantings of woody species, (2) ungrazed, (3) spring grazing, light to moderate intensity, (4) fall grazing, light to moderate intensity, and (5) season-long, heavy grazing. All pastures except those grazed season-long were fenced to exclude domestic livestock, but not large native ungulates such as deer and elk. Pastures grazed season-long were unfenced and were grazed with the remainder of the allotment. They were located approximately 0.5 km from the nearest fenced pastures to avoid a water-gap concentration effect in their use. Spring (mid-May) and fall (early October) grazing treatments were applied by releasing four cow/calf pairs into each pasture for about 10 days. The treatment objective was to apply grazing pressure, but not to exceed 50 percent utilization by weight at streamside, particularly in Kentucky bluegrass and creeping bentgrass community types. The latter generally represented the most stable communities along the degraded riparian system. Some unplanned grazing occurred in the ungrazed treatments. Precipitation was measured at Brogan, OR, 3 km southeast of the study site.

Herbaceous Vegetation and Shrub Sampling

Eighty plots within the riparian area of each pasture were arranged on 20 variable-length transects with four 50 by 50 cm (0.25 m²) plots per transect. Transects transversed the stream, and end points were located inside perpendicular secondary banks, if present. In areas with sloping banks, the riparian area border (and end point of the transect) was defined as the point where the bank attained an elevation of 1 m above the normal summer stream surface. Upland vegetation was sampled on up to 100 plots located at 20 m intervals within a square 4 ha grid centered on the stream. This sampling grid provided a broad characterization of the upland pasture vegetation.

Canopy cover (Daubenmire 1959) was ocularly estimated for graminoids, forbs, and shrubs in each riparian or upland plot in 1987, 1990, and 1993. Maximum vegetative heights (not flower or seed head heights) were also recorded for graminoids, forbs, and shrubs. In addition, aboveground biomass was estimated by clipping current annual growth of shrubs and herbaceous vegetation to ground level on temporary 0.25 m² plots located adjacent to every tenth plot. Regression

relationships between biomass and the product of plant cover times vegetative height were used to estimate biomass values for all plots (Blankenship and Smith 1966).

Ocular estimates of percentage forage utilization by weight (Pechanec and Pickford 1937) were taken from each plot in grazed pastures following their respective grazing periods from 1987 to 1993. Utilization was estimated to the nearest 5 percent for graminoids, forbs, and shrubs. Six reference cages were placed in each grazed pasture to serve as a comparison for ocular estimates. Cages were relocated at the beginning of each grazing period. Average heights of residual plants within each plot were recorded for plant groups at the end of each grazing period, and in the case of spring grazed pastures, again at the end of each growing season from 1989 through 1993.

Natural Regeneration of Woody Riparian Plants

Natural willow recruitment and growth were evaluated annually in early October from 1987 through 1993 in each of the four treatments not planted with woody species (ungrazed, spring grazed, fall grazed, and season-long grazed). Twenty 5 m wide belt transects were placed perpendicular to the stream in each of the eight pastures receiving one of these treatments. Transect length varied to best encompass the corridor of stream-affected vegetation. Width of active and slack water and total length were recorded for each transect. Species, height, number of basal stems, distance from water, dominant understory plant species, substrate texture, and use by livestock or wildlife were recorded for each willow encountered in each belt transect. In the last year of the study all woody riparian plants in all treatments, including the ungrazed/planted treatment, were counted and stem diameters measured on 3 by 3 m plots centered over each of the eighty 0.25 m² riparian transect plots established for sampling herbaceous vegetation and small shrubs.

Woody Plantings

Willow and Cottonwood Plantings—Coyote willow and whiplash willow cuttings of current year's growth were harvested in August 1986 from the Willow Creek drainage about 8 km northeast of the experimental pastures. Cuttings were packed in coolers and transported to a commercial greenhouse where they were planted in 130 cm³ Leach Tubes and rooted. By May 1987, cuttings were well rooted, leafy, and actively growing. Stem heights at planting ranged from about 15 to 30 cm.

Willow cuttings of each species were planted on plots within the two ungrazed/planted pastures in May

1987. Plots were characterized by three separate plant communities and conditions; (1) undisturbed overbank areas with a thick Kentucky bluegrass sod, (2) overbank areas from which the Kentucky bluegrass sod was removed mechanically, and (3) recent depositional surfaces vegetated largely by species of speedwell and horsetail (speedwell community). Eight coyote willow and eight whiplash willow cuttings were planted randomly on approximately 1.7 m centers in each plot. Plot size and shape varied, depending on local distribution of plant communities, and ranged from about 5 by 20 m to 8 by 10 m. Planting bars made from 1.2 cm rebar were used to open planting holes as the substrate was generally gravelly or stony and highly compacted. Treatments were replicated three times.

Survival and height of each planted willow cutting was measured in June and August 1987. Survival, growth, and understory vegetation associated with each cutting were also assessed annually in October from 1987 through 1990 when the willows were considered established. Annual measurements included survival, height, maximum and minimum crown diameter, understory composition (percent cover by species within 1 m² willow-centered plots [Daubenmire 1959]), and a subjective estimate of use by livestock or big game.

Supplemental plantings of about 210 coyote willow and 230 whiplash willow cuttings were conducted in the riparian zone in each of the two ungrazed/planted pastures. Cuttings of each species were planted randomly on approximately 1.7 m centers throughout most Kentucky bluegrass and speedwell communities in these areas. Planting was interrupted by a high intensity rainstorm that uprooted, buried, or physically damaged some cuttings, necessitating partial replanting. Survival and height of the willows were measured in June and August 1987.

About 25 dormant rooted cuttings of narrow-leaved cottonwood were planted in each of the two ungrazed/planted pastures in March 1987. Cuttings propagated in 8-liter containers were purchased from a commercial nursery. Stem heights at planting ranged from 50 to 75 cm. Cuttings were planted on 1.7 m centers in Kentucky bluegrass communities not planted with

rooted willow cuttings. Survival and growth of 16 of these cottonwoods planted in four plots of four cuttings were monitored as described for the willow cuttings planted in experimental plots.

Shrubs—Dormant nursery stock of four native and one introduced nonsalicaceous shrub species commonly associated with the border of riparian areas were planted in the two ungrazed/planted pastures in March 1987 (table 1). Stock was purchased from commercial nurseries as the timeframe for planting precluded collection and propagation of local plant materials.

Shrubs were planted in plots on three aspects; (1) north slopes, (2) south slopes, and (3) flats. North and south aspect plots were located on incised, but sloping streambanks. Plots on the flats were located on low, dry benches within the flood plain. Plot sizes and shapes differed due to local variability in site conditions. All sites were dominated by scattered Wyoming big sagebrush with an understory of cheatgrass and other exotic annuals. Five seedlings of each shrub species were planted randomly on approximately 1.7 m centers in a grid within each plot. Each seedling was planted in the center of a 1 m² scalp mechanically cleared of vegetation. Planting holes were prepared using a tapered auger (USDA-FS 1988a). Each aspect treatment was replicated three times. Sixty additional seedlings of each shrub species were also planted in each of the two rehabilitation pastures on microsites deemed most appropriate for each species.

Plantings were evaluated as described for willows and cottonwoods planted in experimental plots. Contribution of planted willows, cottonwoods, and shrubs to community structure was estimated annually during the herbage and small shrub sampling in each pasture and through the woody plant sampling conducted in all pastures in 1993.

Birds and Small Mammals

The sampling grid for vegetation provided a framework for surveying breeding land birds and small mammals. Breeding birds were sampled in 4 ha grids in each pasture using the spot mapping method (International Bird Census Committee 1970). Seven or eight

Table 1—Native and introduced species of dormant containerized and bareroot nursery stock and height at time of planting in the ungrazed/planted pastures in March 1987.

Species	Common name	Local native	Planting stock	Stem height at planting
				cm
<i>Clematis ligusticifolia</i>	Western clematis	Yes	Container (4-liter)	Dies back
<i>Cornus stolonifera</i>	Red-osier dogwood	Yes	Bareroot	60
<i>Prunus virginiana</i>	Common chokecherry	Yes	Bareroot	45
<i>Rhus trilobata</i>	Squawbush	No	Container (4-liter)	10-15
<i>Rosa woodsii</i>	Wood's rose	Yes	Bareroot	45

visits were made to each pasture from May 1 to June 13 in 1987, 1990, and 1993. Each visit was conducted from 0630 to 1530. Beginning and ending points for surveys varied between visits to ensure unbiased site coverage. At the end of the sampling period, territories were mapped for each species. Clusters of observed breeding activity were studied to indicate approximate territories (International Bird Census Committee 1970). Fractional portions of territories established along pasture boundaries were included. The number of territories were determined for each species to provide an estimate of breeding bird pairs (territories per ha) by treatment. Species richness was also determined for each treatment.

Small mammals were trapped in a 1.6 ha grid in each pasture centered along the stream and including upland and riparian vegetation. Forty trap stations, placed 25 m apart, were established within each grid. Two Museum Special mouse traps and one Victor rat trap were set around each station. Traps were baited with a mixture of peanut butter and rolled oats during a 3 consecutive-night trapping period in each pasture. Trapping dates ranged from August 8 to September 11 in 1987, 1990, and 1993. Species, gender, and weight were determined for individuals trapped. Small mammal relative abundances (number per trap night) were estimated for each treatment and species richness determined.

Channel Morphology and Streambank Characteristics

Channel cross-section measurements were taken at each of the 20 transect locations per pasture in 1987, 1990, and 1993. Measurements included stream wetted width, wetted depth, and bank angle (Platts and others 1987). Stream shape (straight, concave, or convex) and stream stability (Kozel and others 1993) were also rated for each transect. Stream channel gradient was determined by survey instrument. For each plot on the riparian transects, texture of the soil surface, depth to a gravel (or coarser texture) layer, elevation above the water surface, and distance from the water's edge were recorded. Stream classification for the entire study reach was estimated from Rosgen (1994).

Gravimetric soil moisture samples from a depth of 0 to 15 cm were taken from every fifth plot in the upland and riparian sampling areas for pastures 1 and 6 in 1987, from all plots in the riparian areas of pastures 1, 3, 5, and 6 in 1988 to 1989, and from all plots along every other riparian transect in all pastures during late summer 1994.

Statistical Analysis

Analyses were based on individual grazing treatments and upon the following groupings of treatments;

(1) no grazing (ungrazed pastures with and without planting), (2) moderately grazed pastures (light to moderate spring or fall grazing), and (3) heavily grazed pastures (unfenced and grazed in conjunction with the surrounding allotment). Analyses of covariance were performed using a General Linear Model for quantitative characteristics of herbaceous and shrubby vegetation, bird and small mammal densities, and stream channel cross-section characteristics. The initial reading (1987) was used as a covariate to compensate for large initial variability among pastures due, in part, to a localized flood in May 1987. Analyses of utilization data were conducted without a covariate.

Because of the variability in streamside plant composition, particularly after 1987 floods, production and utilization analyses were made only on sample plots supporting sod-forming species as these areas appeared to have a greater potential to respond to grazing management. Sod-forming species included: creeping bentgrass, Kentucky bluegrass, common horsetail, and occasionally common threesquare, Baltic rush, and small-winged sedge. An average of 48 plots per pasture were used in these analyses.

Further analyses of vegetation data included an examination of the frequency of plots dominated by various species components. In the riparian area these included plots dominated by the entire group of sod-forming species, known as the "sod-former" group, as well as plots with sedge or rush dominants or sedge or rush presence only. Tests for upland areas included change in numbers of plots dominated by perennial bunch grasses (Sandberg's bluegrass, bottlebrush squirreltail, and occasionally bluebunch wheatgrass), those plots dominated by exotic bromes (primarily cheatgrass), those dominated by exotic forbs (such as pale alyssum, Canada thistle, stork's-bill, hornseed buttercup, and Jim Hill mustard, among others), and those dominated by sagebrush or rabbitbrush in response to the grazing treatments.

Native willow seedling recruitment and growth; survival and growth of planted willows, shrubs, and cottonwoods; and estimates of cover, litter, and bare ground on transplant plots were compared by treatments and years using two-way, repeated-measures analyses of variance. Means and standard errors ($\pm se$) are presented for shrub survival and growth measurements when low survival or loss of replications precluded statistical analyses. One-way analyses of variance were used to compare shrub and herbaceous understory cover by aspect for shrub plantings in 1990. Two-way analyses of variance by willow species and treatment were used to compare distance of naturally occurring willows from active water in 1990, and to compare the proportion of planted (1990) or naturally occurring willows (1993) growing beyond reach of wild ungulates.

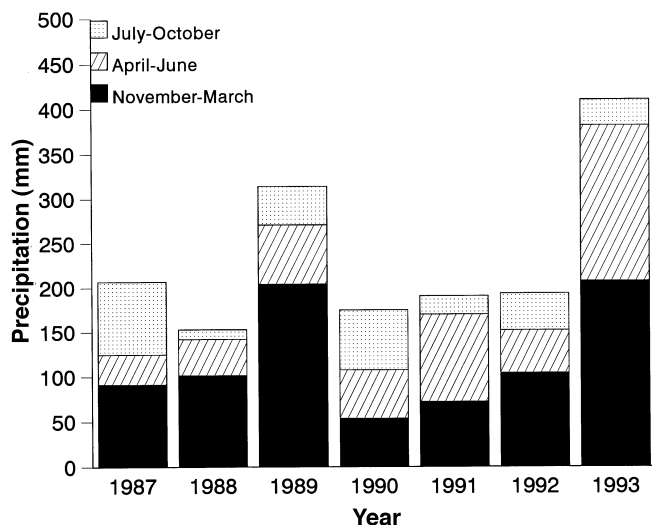


Figure 2—Seasonal and annual rainfall, Brogan, OR.

A protected Least Significant Difference (LSD) test at $P < 0.10$ was used to identify treatment differences when significance was indicated. P indicates the probability of a difference due to chance. In these analyses we defined the probability of a chance error of 10 percent or less as acceptable for a specific analysis. P 's of greater than 0.10 are also presented in the text so the readers can assess for themselves how likely or unlikely that a treatment effect had occurred. When data were not normally distributed square root and arc sine transformations were used for count and percent data, respectively.

Multiple regression was used to examine some specific relationships among streamside plant communities and various channel and streambank variables.

Environmental Conditions

Dry conditions prevailed during 1987 to 1988 and 1990 to 1992, with precipitation at Brogan ranging from 165 to 201 mm. Greater precipitation fell in 1989 (304 mm) and 1993 (421 mm) (fig. 2). Most years spring runoff did not cause severe flooding, but short-duration, high-intensity storms in May 1987, 1989, and 1991 and August 1987 and 1990 produced flash-flood conditions. Extended high stream flow in spring 1993 resulted in localized streambank erosion.

Results: Riparian Area

Ground Cover

With one exception, ground cover provided by different plant life forms, litter cover, and the amount of bare soil did not vary among individual treatments (table 2). Shrub cover was greater in the ungrazed/planted treatment compared to other treatments, with the difference attributed to the plantings. The percentages of graminoid cover ($P = 0.06$) and litter cover ($P = 0.07$) were higher, and of bare soil lower ($P = 0.06$) on the grouped ungrazed treatments. Forb cover did not vary significantly among treatments or treatment groups.

Table 2—Average 1990-1993 plant cover, litter, and bare soil on riparian sites supporting sod-forming vegetation as adjusted to the 1987 mean values.^a

Treatments	Graminoids	Forbs	Shrubs	Litter	Bare soil
----- Percent -----					
Individual treatment					
Ungrazed/planted	38.3a ^b	27.5a	19.5b	11.4a	5.0a
Ungrazed	40.3a	21.6a	1.5a	10.7a	6.7a
Spring grazed light to moderate	37.4a	33.2a	7.8a	8.5a	11.5a
Fall grazed light to moderate	36.5a	28.6a	5.0a	8.2a	12.8a
Season-long heavy	30.0a	34.5a	5.9a	11.4a	16.1a
P^c					
Among treatments	0.33	0.43	0.04	0.33	0.32
Interaction with years	0.91	0.60	0.29	0.10	0.83
Treatment group					
Ungrazed	39.3b	24.7a	11.2a	11.1b	5.8a
Moderately grazed	36.9a	31.0a	6.2a	8.4a	12.1b
Heavily grazed	30.0a	34.5a	5.9a	11.4b	16.1b
P					
Among groups	0.06	0.25	0.46	0.07	0.06
Interaction with years	0.67	0.55	0.82	0.01	0.50

^aTotal values may exceed 100 percent because of overlapping canopies.

^bValues in columns among treatments or treatment groups followed by different letters are significantly different at $P < 0.10$.

^cProbability value.

Herbaceous Vegetation

Substantial variability in initial conditions occurred within and among pastures due to heavy flooding the first spring and summer of the study (1987). After 7 years, some riparian areas still consisted of a braided stream flowing through dry gravel deposits. In such areas little improvement in riparian habitat conditions occurred under any grazing treatment. These areas were typically unvegetated or supported exotic annuals such as cheatgrass, common mullein, bull thistle, and common cocklebur. Species of the sod-former group, listed earlier, characterized the more stable riparian areas.

Forage Utilization—Average utilization rates of sod-formers (percent of weight removed) over the 1987-1993 period varied from 4 percent across all ungrazed pastures to 70 percent in heavily grazed pastures (table 3). Residual forage stubble heights, measured 1989 to 1993, were reduced approximately 80 percent by the heavy grazing treatment. Both utilization and residual stubble height illustrate substantial differences ($P < 0.01$) among grazing treatments in the riparian area of Pole Creek, although the response by treatment was not similar in every year because of 1991 unplanned grazing of ungrazed pastures (treatment $\times$ year interaction, $P < 0.01$).

Utilization rates for forbs between 1988 to 1993 were lower than for sod-forming plants (table 3). The range of weight removed was approximately 2 percent

to 19 percent and varied among treatments ($P < 0.01$). A strong reduction in utilization rates for forbs in the latter part of the study resulted in a significant interaction with years ($P < 0.01$).

Standing Crop Biomass—Both total herbage standing crop and that produced only by sod-formers differed among treatments ($P < 0.01$); standing crop on ungrazed/planted and ungrazed pastures was higher than on moderately grazed pastures, and all four treatments had higher standing crop than the heavily grazed pastures (table 4).

The greatest amount of increase in standing crop biomass through time (Treatment[T] $\times$ Years[Y], $P < 0.01$) occurred in pastures with the least amounts of grazing—an apparent increase in general vigor of existing plants (fig. 3). A similar, but less consistent, effect on forb biomass standing crop occurred in response to grazing intensity (table 4). The interaction with years was not significant ($P = 0.33$).

Herbaceous Species Composition—We examined the frequency of plots (Hyder and others 1966) whose cover was dominated by “desirable” species, that is, sod-forming species in general, and more importantly, rhizomatous wetland species as an indication of response to grazing. The number of plots dominated by sod-formers, listed earlier, did not vary by treatment ($P = 0.57$) and treatment means did not differ in their response to time (T $\times$ Y, $P = 0.99$) (table 5) (fig. 3). There was no apparent increase in frequency

Table 3—Average herbage utilization (1987-1993) and residual plant heights (1989-1993) on riparian sites supporting sod-forming species.

Treatments	Grazing use of sod-formers			Grazing use of forbs	
	Utilization	Stubble height		Utilization	Post season stubble height
		Post grazing	Post season		
	Percent	----- cm -----		Percent	cm
Individual treatment					
Ungrazed/planted	0.1a ^a	28.6d	28.6d	0.2a	29.0d
Ungrazed	8.4b	24.6c	24.6c	2.5a	18.0b
Spring grazed light to moderate	21.4c	14.3b	23.3c	5.9b	20.0c
Fall grazed light to moderate	42.4d	12.4b	12.4b	9.8c	13.5b
Season-long heavy	70.3e	5.2a	6.5a	18.7d	4.0a
<i>P</i> ^b					
Among treatments	<0.01	<0.01	<0.01	<0.01	<0.01
Interaction with years	<0.01	0.03	0.01	<0.01	0.74
Treatment group					
Ungrazed	4.2a	26.6c	26.6c	1.4a	23.5c
Moderately grazed	31.9b	13.4b	17.8b	7.8b	16.8b
Heavily grazed	70.3c	5.2a	6.5a	18.7c	4.0a
<i>P</i>					
Among groups	<0.01	<0.01	<0.01	<0.01	<0.01
Interaction with years	0.34	0.42	0.29	<0.01	0.91

^aValues in columns among treatments or treatment groups followed by different letters are significantly different at $P < 0.10$.

^bProbability value.

Table 4—Average 1990-1993 herbaceous standing crop on riparian sites supporting sod-forming species as adjusted to the 1987 mean values.

Treatments	Herbaceous biomass		
	Total	Sod-formers	Forbs
	----- g/0.25 m ² -----		
Individual treatment			
Ungrazed/planted	72.8c ^a	55.6c	17.2b
Ungrazed	72.1c	59.4c	12.7ab
Spring grazed			
light to moderate	60.2b	43.4b	16.8b
Fall grazed			
light to moderate	57.7b	41.1b	16.6b
Season-long			
heavy	31.6a	23.6a	7.0a
<i>P</i> ^b			
Among treatments	<0.01	<0.01	0.10
Interaction	<0.01	<0.01	0.35
with years			
Treatment group			
Ungrazed	72.5c	57.7c	14.8b
Moderately grazed	59.0b	42.3 b	16.7b
Heavily grazed	31.6a	23.6a	7.0a
<i>P</i>			
Among groups	<0.01	<0.01	0.04
Interaction			
with years	<0.01	<0.01	0.33

^aValues in columns among treatments or treatment groups followed by different letters are significantly different at $P < 0.10$.

^bProbability value.

of sod-formers related to reduced grazing stress. Likewise, numbers of plots dominated by members of the wetland families Cyperaceae and Juncaceae (such as sedges, bulrushes, and rushes), expected to dominate on wet streamside areas, did not differ ($P = 0.96$) among treatments (table 5). However, when all plots that contained any occurrence of Cyperaceae or

Juncaceae were considered for grouped treatments, a modest improvement trend was noted in the herbaceous composition of the streamside areas related to grazing treatment ($P = 0.09$). The presence of wetland species increased on ungrazed pastures compared to those with moderate or heavy grazing. The proportion of forbs in the biomass composition averaged 30 percent. It did not vary significantly among treatments ($P = 0.43$) and showed no trend of response to treatment through time ($T \times Y$, $P = 0.55$) (fig. 4).

Woody Plants

Naturally Regenerating Willows—In 1987 only a few small, heavily browsed willows grew within the study area. Scattered seed-producing willows occurred downstream with the nearest, a whiplash willow, growing about 0.5 km below the pastures. Additional seed sources may be present several kilometers above the study area at the head of the watershed. Some naturally occurring willows in the pastures responded to treatments and began producing seed by 1990.

New willow seedlings were observed during each year of the study. Most seedlings established on open, saturated sediment surfaces; sediments supporting speedwell or horsetail species; or in slack water. Scattered seedlings were observed along dry channels and in Kentucky bluegrass communities. In 1993, about 95 percent of all naturally occurring willows grew within 1.6 m of active water.

Willow density fluctuated over time with contrasting trends developing for coyote willow and whiplash willow. Few coyote willow seedlings established in 1987, but their density increased from 1987 to 1989, remaining generally stable through 1993 ($P = 0.01$) (fig. 5). Over the 7-year period, coyote willow density varied significantly with treatment and was greatest ($P = 0.04$) in spring-grazed pastures, intermediate in



Figure 3—Change in plant vigor, but not in species composition 1987 (A) to 1993 (B) in an ungrazed pasture.

Table 5—Number of plots on which at least 25 percent of the cover was occupied by sod-formers or by Cyperaceae/Juncaceae, and number of plots where Cyperaceae/Juncaceae were present (n = 80). Average of 1990-1993 as adjusted to the 1987 mean values.

Treatments	Sod-formers dominated	Cyperaceae or Juncaceae dominated	Cyperaceae or Juncaceae present
----- Number/pasture -----			
Individual treatment			
Ungrazed/planted	41.8a ^a	4.6a	8.3a
Ungrazed	52.5a	3.1a	11.3a
Spring grazed light to moderate	45.1a	2.9a	5.7a
Fall grazed light to moderate	42.2a	2.9a	4.7a
Season-long heavy	42.3a	2.7a	4.3a
<i>P</i> ^b			
Among treatments	0.57	0.96	0.33
Interactions with years	0.99	0.62	0.74
Treatment group			
Ungrazed	46.8a	3.8a	9.8b
Moderately grazed	43.2a	2.9a	5.2a
Heavily grazed	42.3a	2.7a	4.3a
<i>P</i>			
Among groups	0.68	0.87	0.09
Interaction with years	0.87	0.84	0.40

^aValues in columns among treatments or treatment groups followed by different letters are significantly different at $P \leq 0.10$.

^bProbability value.

ungrazed pastures, and least in pastures grazed season-long. Density in fall-grazed pastures was statistically similar to density in both the ungrazed pastures and pastures grazed season-long.

Although new seedlings emerged each year, large numbers of whiplash willow seedlings emerged in 1987, possibly due to good seed availability and the presence of fresh sediments deposited following a high-intensity storm in May, shortly before June seed

dispersal (fig. 5). Whiplash willow density generally declined through 1991, with no significant changes occurring from 1991 to 1993 ($P = 0.02$). Ungrazed and moderately grazed pastures supported greater seedling densities than pastures grazed season-long ($P = 0.02$).

Height of each willow species increased gradually over time, with the greatest increase occurring in 1993, a wet year ($P < 0.01$) (fig. 5). During the 7-year period, willow seedling height was significantly greater



Figure 4—A forb-dominated site in a spring-grazed pasture that demonstrated no trend toward establishment of wetland sod-forming species, 1987 (A) to 1993 (B).

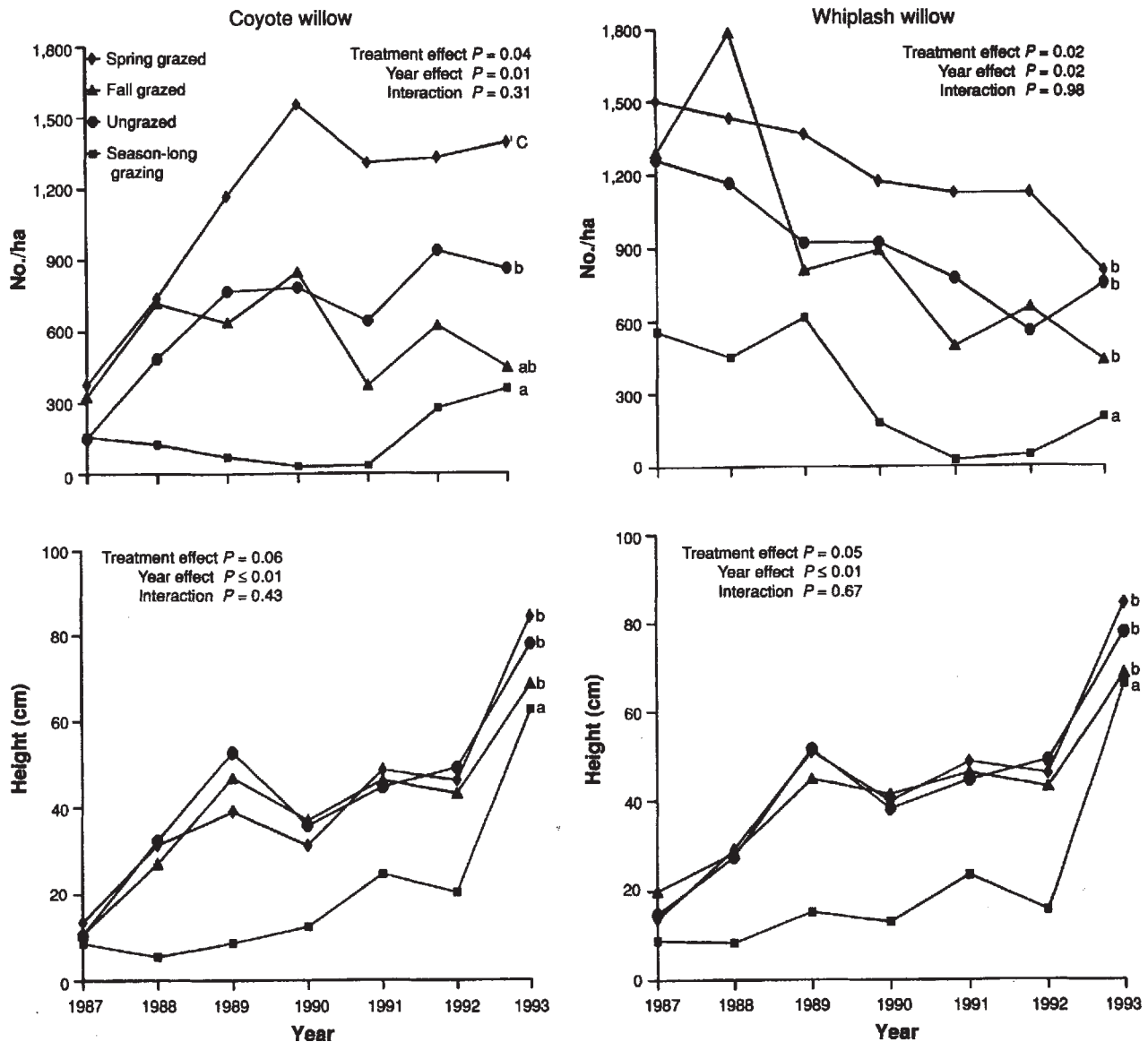


Figure 5—Density and height of naturally regenerating coyote willow and whiplash willow in 1987 to 1993 by grazing treatment. Treatments followed by different letters are significantly different at $P \leq 0.10$.

in ungrazed or moderately grazed pastures compared to those grazed season-long ($P = 0.06$ [coyote willow]; $P = 0.05$ [whiplash willow]). By October 1993, however, an average of 8 percent of naturally establishing willows exceeded 1.5 m in height with no difference among treatments or between species. Thus the upper portion of most crowns remained within reach of large browsing animals.

Number of basal stems for coyote willow increased from 1.6 in 1987 to 3.0 in 1993 ($P < 0.01$), and from 1.1 to 3.7 ($P < 0.01$) for whiplash willow. Over this period, crown diameter increased from 12 to 27 cm ($P < 0.01$) for coyote willow and from 11 to 46 cm ($P < 0.01$) for whiplash willow with no differences among treatments for either species.

Planted Willows and Cottonwoods—A total of 93 percent of all coyote willow cuttings and 92 percent of all whiplash willow cuttings planted survived in mid-June 1987, about 1 month following planting. First-year survival of all planted coyote willow declined to 68 percent and whiplash willow to 66 percent by mid-August 1987.

Over the 4-year period, survival of both coyote willow and whiplash willow in experimental plots was significantly greater in cleared Kentucky bluegrass plots and undisturbed speedwell communities compared to undisturbed Kentucky bluegrass communities ($P = 0.02$ [coyote willow and whiplash willow]) (fig. 6). About 16 percent of each willow species died during the first growing season. An additional decline of about 20

percent occurred in 1988 ($P < 0.02$ [coyote willow and whiplash willow]), but survival remained stable thereafter through 1990.

Height of coyote willow increased about 6 times ($P < 0.01$) and crown diameter 12 times ($P < 0.01$) from 1987 to 1990 (fig. 6), however, these variables were not influenced by site conditions ($P = 0.38$ [height]; $P = 0.35$ [crown]). By 1990, whiplash willow heights and crown diameters varied significantly with the three site conditions and were greatest in the cleared Kentucky bluegrass plots, intermediate in the undisturbed

speedwell communities, and smallest in undisturbed Kentucky bluegrass communities where no increase in height or crown diameter occurred over the 4-year period ($P = 0.02$ [T x Y interaction for height]; $P < 0.01$ [T x Y interaction for crown]) (fig. 6).

Use of both willow species by wild ungulates was evaluated as moderate for all three planting conditions in 1987 and 1988, light to moderate in 1989, and moderate to heavy in 1990. Thirty-two percent of the planted coyote willow grew beyond reach of browsing animals (greater than 1.5 m height) by 1990, compared

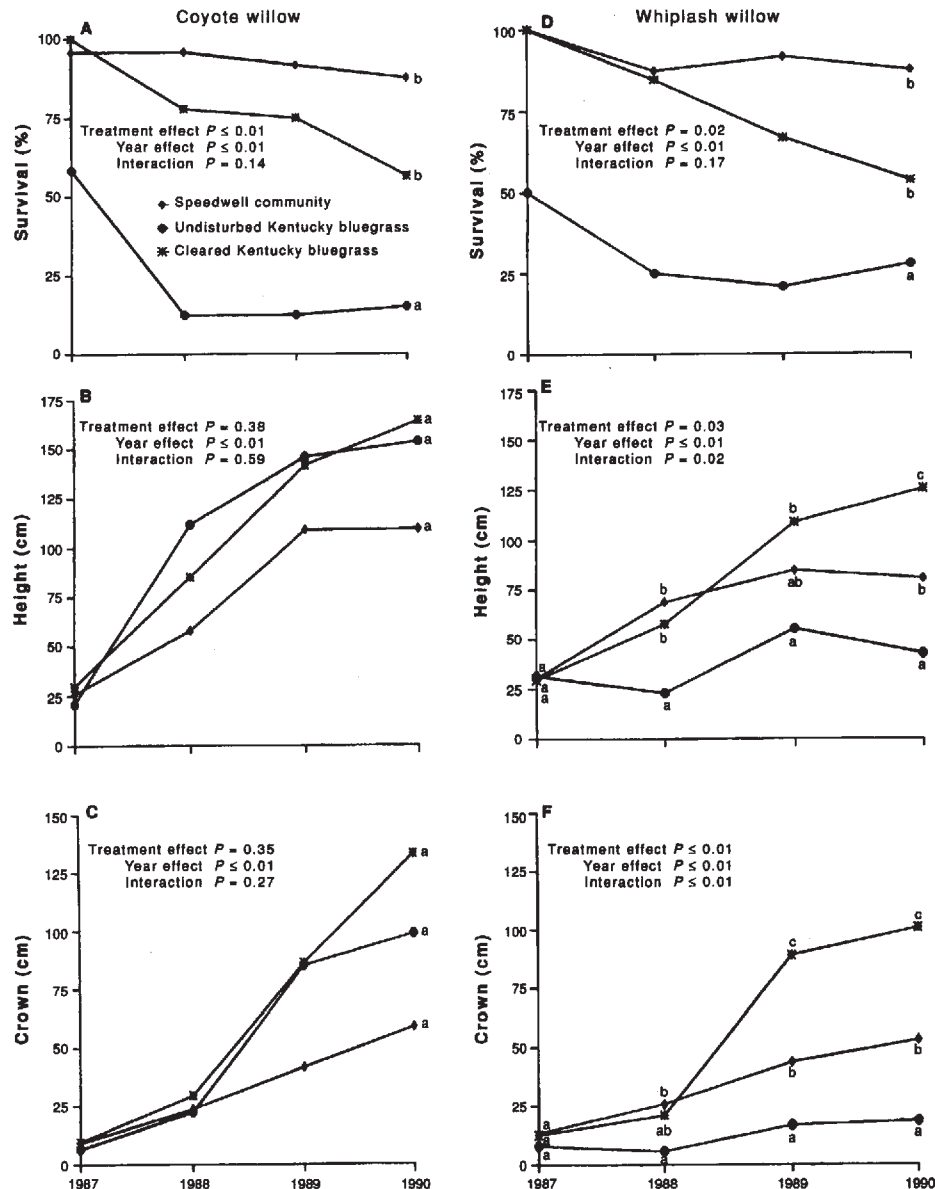


Figure 6—Survival and growth (1987 to 1990) of coyote willow and whiplash willow cuttings planted in the ungrazed/planted pastures in May 1987 as influenced by plant community and site preparation. A-D: Treatments followed by different letters are significantly different at $P \leq 0.10$. E-F: Within years, treatment means with different letters are significantly different at $P \leq 0.10$.

Table 6—Willow cover, understory plant cover, and bare soil (1987 and 1990) on 1-m² plots planted with rooted willow cuttings in May 1987 as influenced by plant community and site preparation.

Cover category	Plant community and site preparation		
	Kentucky bluegrass	Speedwell	
	Cleared	Undisturbed	undisturbed
----- Cover (percent) -----			
Bare ground/rock			
1987	33B ^a b	7Aa	8Aa
1990	9Aa	11Aa	17Aa
Litter			
1987	7Aa	10Aa	10Aa
1990	37Bb	41Bab	24Ba
Graminoids			
1987	13Aa	49Ab	29Aa
1990	36Ba	45Ab	26Aa
Forbs			
1987	48Bb	33Ba	47Bb
1990	13Aa	9Aa	29Ab
Woody species			
1987	2Aa	1Aa	2Aa
1990	18Bb	6Ba	10Ba

^aValues within cover category and plant community and site preparation followed by different upper case letters are significantly different at $P < 0.10$.

^bValues within cover category and year followed by different lower case letters are significantly different at $P < 0.10$.

Table 7—Average density, frequency, and stem diameter in 1993 of both naturally occurring and planted willows and cottonwoods within the riparian area ($n = 80$).

Treatments	Stem		
	Density	Frequency	Diameter
	Number/ha	Plots/pasture	cm
Individual treatment			
Ungrazed/planted	7,400b ^a	29.0c	2.3b
Ungrazed	2,700a	14.5b	0.8a
Spring grazed	3,400a	18.2bc	0.7a
light to moderate			
Fall grazed	600a	6.0a	0.8a
light to moderate			
Season-long	400a	6.0a	0.9a
heavy			
P^b			
Among treatments	0.05	0.02	0.03
Treatment group			
Ungrazed	5,000a	20.8b	1.6a
Moderately grazed	2,000a	11.0ab	0.8a
Heavily grazed	400a	5.0a	0.9a
P			
Among groups	0.14	0.10	0.29

^aValues in columns among treatments or treatment groups followed by different letters are significantly different at $P < 0.10$.

^bProbability value.

to 12 percent for whiplash willow. A significantly greater proportion of the two willow species (41 percent) exceeded 1.5 m in height in the cleared Kentucky bluegrass plots in 1990, compared to 12 percent in the undisturbed Kentucky bluegrass and speedwell communities.

Understory cover provided by graminoids, primarily Kentucky bluegrass, was significantly greater in the undisturbed Kentucky bluegrass community compared to the cleared Kentucky bluegrass plots and speedwell communities in 1987 and 1990 (table 6). Following 4 years of protection from grazing, Kentucky bluegrass cover increased 2.8 times in the cleared Kentucky bluegrass plots, but remained unchanged in the undisturbed Kentucky bluegrass and speedwell communities.

Ninety-four percent of the narrow-leaved cottonwood survived by 1990. Tree height increased from 69 cm in 1987 to 190 cm in 1990 ($P < 0.01$), and crown diameter increased from 49 cm in 1987 to 160 cm in 1990 ($P < 0.01$).

When all riparian woody plants, both naturally occurring and planted, were examined in 1993, total woody stem densities, stem frequencies, and stem diameters were higher on planted treatments than on other treatments (table 7; fig. 7). Stem frequencies were higher on ungrazed and spring-grazed treatments than on fall and season-long grazed treatments.

Results: Upland Area

Herbaceous Vegetation and Small Shrubs

Much of the upland area within the study pastures consisted of steep slopes, averaging about 33 percent. Although significant differences occurred in utilization rates of grasses ($P < 0.01$) the mean utilization on these upland slopes was low, even on pastures grazed season-long (table 8). The limited differences in degree of utilization of the uplands were also reflected in the relative similarity of residual plant heights (table 8). Significant interactions with years occurred because of variation in annual utilization intensities.

Standing crop biomass of upland graminoids differed among treatments ($P = 0.03$) and treatment groups ($P = 0.01$) (table 9). As a group, ungrazed plots supported higher graminoid biomass in uplands than other treatments. Further, percentage canopy cover of graminoids, forbs, and shrubs was higher and bare soil lower on ungrazed and light to moderately grazed treatments as compared to the season-long heavily grazed treatment (table 10).

No differences were detected in the frequency of various predominant plant composition components in the upland sites during the 7 years of grazing treatments (table 11).

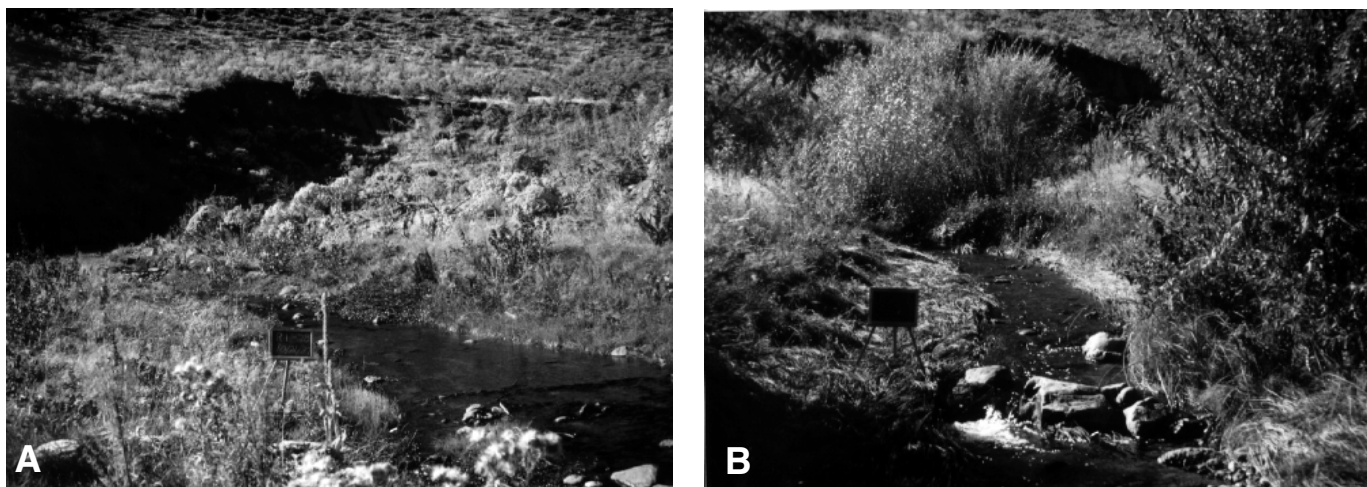


Figure 7—Typical view of willow response in ungrazed/planted pastures, 1987 (A) to 1993 (B).

Table 8—Average utilization (1987-1993) and residual plant heights (1989-1993) of pasture uplands.

Treatments	Utilization rates			Plant heights		
	Graminoids	Forbs	Shrubs	Graminoids	Forbs	Shrubs
	----- Percent -----			----- cm -----		
Ungrazed/planted	—	—	—	—	—	—
Ungrazed	—	—	—	—	—	—
Spring grazed light to moderate	8.3a ^a	3.2b	0.3a	12.7b	9.6a	44.8a
Fall grazed light to moderate	9.7b	2.1a	0.0a	12.1a	11.6b	45.6a
Season-long heavy	16.1c	2.4ab	0.2a	11.8a	13.0c	43.0a
<i>P</i> ^b						
Among treatments	<0.01	0.05	0.15	0.05	<0.01	0.84
Interaction with years	<0.01	<0.01	0.24	<0.01	<0.01	0.13

^aValues in columns followed by different letters are significantly different at $P < 0.10$.

^bProbability value.

Table 9—Upland mid-summer 1990-1993 standing crop biomass as adjusted to the 1987 mean values.

Treatments	Graminoids	Forbs	Shrubs	Total
	----- g/0.25 m ² -----			
Individual treatment				
Ungrazed/planted	12.6c ^a	11.1b	15.8a	39.5a
Ungrazed	11.3c	6.8a	17.6a	35.7a
Spring grazed light to moderate	7.6ab	7.3a	18.0a	32.9a
Fall grazed light to moderate	10.3bc	7.6a	15.2a	33.1a
Season-long heavy	6.7a	5.7a	14.0a	26.4a
<i>P</i> ^b				
Among treatments	0.03	0.10	0.49	0.13
Interaction with years	0.33	0.95	0.95	0.90
Treatment group				
Ungrazed	11.9b	8.9a	16.6a	37.4b
Moderately grazed	9.1a	7.4a	16.7a	33.2b
Heavily grazed	6.7a	5.7a	14.0a	26.4a
<i>P</i>				
Among groups	0.01	0.13	0.35	0.01
Interaction with years	0.16	0.94	0.85	0.53

^aValues in columns among treatments or treatment groups followed by different letters are significantly different at $P < 0.10$.

^bProbability value.

Table 10—Average 1990-1993 upland plant canopy cover, litter, and bare soil as adjusted to the 1987 mean values.

Treatments	Graminoids	Forbs	Shrubs	Litter	Bare
----- Percent -----					
Individual treatment					
Ungrazed/planted	33.3a ^a	14.3a	18.6ab	22.2a	25.8ab
Ungrazed	36.9a	12.2a	21.9c	20.5a	19.8a
Spring grazed light to moderate	31.7a	13.2a	21.4c	20.9a	26.5b
Fall grazed light to moderate	34.9a	12.1a	20.8bc	23.1a	23.9ab
Season-long heavy <i>P</i> ^b	24.4a	10.5a	16.7a	21.4a	33.4c
Among treatments	0.16	0.12	0.04	0.73	0.04
Interaction with years	0.80	0.49	0.61	0.66	0.70
Treatment group					
Ungrazed	35.0b	13.2b	20.3b	21.3a	22.9a
Moderately grazed	33.4b	12.9b	21.1b	22.0a	25.0a
Heavily grazed <i>P</i>	24.4a	10.5a	16.7a	21.4a	33.4b
Among groups	0.03	0.07	0.03	0.89	0.01
Interaction with years	0.49	0.65	0.59	0.97	0.60

^aValues in columns among treatments or treatment groups followed by different letters are significantly different at $P < 0.10$.

^bProbability value.

Table 11—Number of upland plots on which at least 25 percent of the cover was occupied by designated vegetation components (n = 80). Average for 1990-1993 as adjusted to the 1987 mean values.

Treatments	Herbaceous layer			Shrub layer	
	Perennial grass dominated ^a	Exotic brome dominated	Exotic forb dominated	Sagebrush dominated	Rabbitbrush dominated
----- Number /pasture ^b -----					
Individual treatment					
Ungrazed/planted	25.7a ^c	59.9a	24.2a	51.6a	7.4a
Ungrazed	27.2a	64.6a	17.3a	57.9a	12.8a
Spring grazed light to moderate	26.4a	66.9a	24.2a	57.0a	16.6a
Fall grazed light to moderate	32.7a	58.2a	15.9a	69.9a	9.8a
Season-long heavy <i>P</i> ^d	31.4a	59.8a	8.9a	59.2a	14.4a
Among treatments	0.47	0.32	0.29	0.23	0.16
Interaction with years	0.77	0.58	0.67	0.92	0.98
Treatment group					
Ungrazed	26.5a	62.3a	19.7a	54.3a	9.8a
Moderately grazed	29.4a	62.4a	20.2a	63.0a	12.7a
Heavily grazed <i>P</i>	31.4a	59.8a	8.9a	59.2a	14.4a
Among groups	0.39	0.86	0.11	0.24	0.22
Interaction with years	0.60	0.71	0.29	0.73	0.95

^aContributed at least 25 percent of the plant cover.

^bBased on 100 upland plots.

^cValues in columns among treatments or treatment groups followed by different letters are significantly different at $P < 0.10$.

^dProbability value.

Woody Plantings

Dry conditions from October 1986 through October 1987 (fig. 2) reduced shrub establishment and growth during the first growing season. During this period, following mid-March planting, no precipitation fell until early May. About 50 percent of May precipitation and all August precipitation fell during two short-duration (<0.5 hr) high-intensity rainstorms.

By 1990, shrub cover within scalps averaged 8 percent and did not vary among aspects (table 12). Height of each shrub species averaged less than 0.5 m (fig. 8; table 13) and was comparable to height of nearby Wyoming big sagebrush plants. For the shrub species planted, October 1990 survival was below 50 percent for four upland shrubs (table 13); it exceeded 50 percent only for squawbush (fig. 8). Consequently, statistical comparisons of survival and growth among aspects were made only for this species. Scalps on flats supported significantly greater herbaceous cover (43 percent) compared to north- or south-facing slopes, which supported 18 percent cover. Herbaceous cover was dominated by annual grasses, primarily cheatgrass.

Squawbush—Survival varied significantly among aspects. Survival was greatest on flats, intermediate on south-facing slopes, and least on north-facing slopes ($P < 0.01$) (fig. 8). About 22 percent of the squawbush planted failed to survive the 1987 growing season. Another 22 percent were lost by October 1989 ($P = 0.09$). Height and crown development over the 4 year period did not differ by aspect ($P = 0.42$ [height]; $P = 0.68$ [crown]). Plant heights and crowns did not change from October 1987 to October 1988, but crown

Table 12—Fourth year (1990) bare soil, understory plant cover, shrub cover, and total vegetative cover on 1 m² shrub transplant-centered scalps^a in the ungrazed/planted pastures as influenced by aspect.

Cover category	Aspect		
	Flats	North facing	South facing
----- Cover (percent) -----			
Bare ground	16a ^b	39ab	68b
Litter	39a	32a	15a
Rock	0a	1a	1a
Grasses			
Annuals	34c	6b	T ^c a
Perennials	5a	12a	Ta
Forbs	4a	1a	3a
Shrubs	3a	8a	12a
Total vegetative cover	47b	21a	15a

^aScalps were mechanically cleared of competing vegetation immediately prior to planting in March 1987.

^bValues within cover category followed by different letters are significantly different at $P < 0.10$.

^cT = trace.

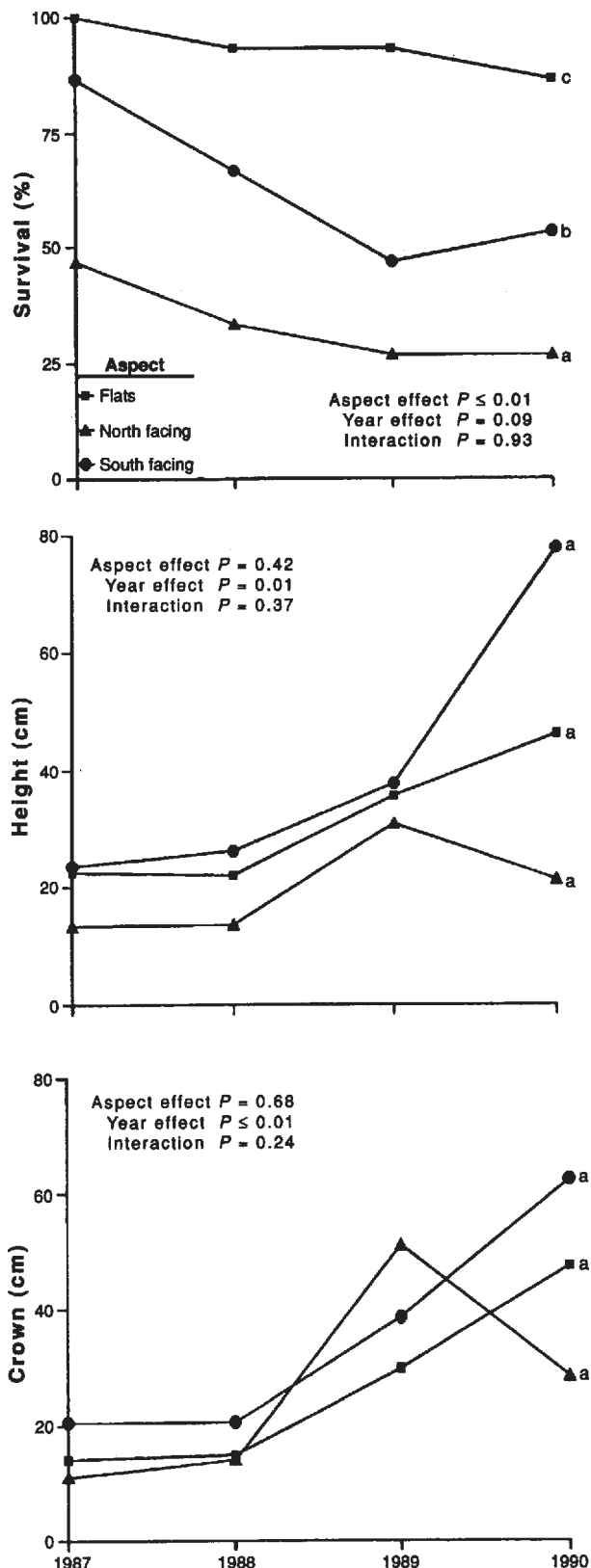


Figure 8—Survival and growth (1987 to 1990) of squawbush seedlings planted in the ungrazed/planted pastures in March 1987 as influenced by aspect. Treatments followed by different letters are significantly different at $P \leq 0.10$.

Table 13—Survival, height, and crown development (1987 to 1990) for four upland shrubs planted in the rehabilitation pastures in March 1987 as influenced by aspect.

Species Aspect	Year			
	1987	1988	1989	1990
Western clematis				
	----- Survival (percent) -----			
North facing	0	0	0	0
South facing	40 (± 20) ^a	33 (± 18)	33 (± 18)	20 (± 11)
Flats	47 (± 18)	47 (± 18)	33 (± 18)	40 (± 12)
	----- Crown ^b (cm) -----			
North facing	—	—	—	—
South facing	52 (± 18)	70 (± 35)	84 (± 51)	226 (± 127)
Flats	27 (± 4)	48 (± 9)	120 (± 8)	188 (± 33)
Red-osier dogwood				
	----- Survival (percent) -----			
North facing	20	0	0	0
South facing	20	0	0	0
Flats	27 (± 18)	0	0	0
	----- Height (cm) -----			
North facing	63	—	—	—
South facing	77	—	—	—
Flats	50 (± 4)	—	—	—
	----- Crown (cm) -----			
North facing	9	—	—	—
South facing	18	—	—	—
Flats	9 (± 1)	—	—	—
Common chokecherry				
	----- Survival (percent) -----			
North facing	27 (± 13)	0	0	0
South facing	27 (± 13)	7 (± 7)	7 (± 7)	7 (± 7)
Flats	27 (± 13)	7 (± 7)	7 (± 7)	33 (± 7)
	----- Height (cm) -----			
North facing	49 (± 14)	—	—	—
South facing	56 (± 0)	58	25	4
Flats	40 (± 5)	8	23	33 (± 10)
	----- Crown (cm) -----			
North facing	7	—	—	—
South facing	9 (± 1)	56	20	7
Flats	5	4	27	11 (± 6)
Wood's rose				
	----- Survival (percent) -----			
North facing	33 (± 7)	13 (± 11)	13 (± 7)	13 (± 7)
South facing	40 (± 19)	13 (± 7)	7 (± 7)	13 (± 11)
Flats	33 (± 18)	33 (± 18)	33 (± 18)	27 (± 13)
	----- Height (cm) -----			
North facing	56 (± 12)	17	33 (± 13)	18 (± 5)
South facing	46	38 (± 14)	71	45
Flats	55 (± 18)	49 (± 6)	54 (± 4)	48 (± 6)
	----- Crown (cm) -----			
North facing	14 (± 7)	17	25 (± 6)	16 (± 5)
South facing	13 (± 3)	24 (± 10)	33	45
Flats	15 (± 1)	17 (± 2)	40 (± 1)	40 (± 3)

^aStandard errors were calculated when plants survived in two or three replications of a treatment.

^bCrown, but no height data is provided as the species is a vine.

diameter increased in 1989 and height increased in 1990 ($P = 0.01$ [height]; $P < 0.01$ [crown]).

Western Clematis—No plants survived the 1987 growing season on north-facing slopes (table 13); a total of 60 percent mortality occurred on south-facing slopes and 53 percent on flats. Average crown spread of plants surviving in October 1990 exceeded 2 m.

Red-Osier Dogwood—Mortality of red-osier dogwood planted on the three aspects ranged from 73 to 80 percent in 1987 (table 13). Surviving plants exhibited little new growth; none survived the 1988 growing season.

Common Chokecherry and Wood's Rose—Survival and growth patterns were somewhat similar for these two species (table 13). By 1990, survival of common chokecherry did not exceed 33 percent on any aspect while survival of Wood's rose did not exceed 27 percent. Height and crown diameters did not exceed 0.5 m for either species.

Results: Birds and Small Mammals

During the three sampling periods (1987, 1990, 1993), a total of 24 bird species established breeding territories within the five grazing treatments (table 14). Territories were not recorded for transient species, wide-ranging raptors, and residents with few observations, although species' presence was noted within each treatment (appendix B). Species richness ranged from 14 in the pastures that were grazed season-long to 18 in the fall-grazed treatment, with nine species common to all treatments (table 14). Average breeding pair (territory) densities over the three sampling periods did not differ significantly ($P = 0.70$), but ranged from 19 in pastures grazed season-long to 25 in both ungrazed/planted pastures and fall-grazed pastures. Intermediate densities were reported for spring-grazed and ungrazed treatments (table 14). Of the 9 species common to all treatments, Brewer's blackbirds (bird scientific names listed in table 14 and appendix B) were most common ($2.6 [\pm 0.34 = 1 \text{ se}]/\text{ha}$) and California quail were least common ($0.03 [\pm 0.06]/\text{ha}$) birds nesting in the study area. Combined for all species, no significant differences in bird densities occurred among treatments ($P = 0.70$), but differences were significant among years ($T < 0.001$).

Eight species of small mammals were trapped during August 1987, 1990, and 1993 (table 15). Four species (deer mouse, Great Basin pocket mouse, western harvest mouse, and vagrant shrew [mammal scientific names listed in table 15]) were common to all treatments. Deer mice were the most commonly captured animal (920 individuals across all treatments and years), while least chipmunks were rarely

trapped—three individuals across all treatments and all years) (table 15). Total small mammals trapped over the three periods ranged from 192 individuals in pastures grazed season-long, to 303 individuals in ungrazed/planted pastures. Species richness (6 or 7) was similar among treatments (table 15). Small mammal densities did not differ among treatments ($P = 0.42$); however, the interaction with year ($T \times Y$, $P = 0.03$) and the year effect ($P < 0.001$) were significant.

The relative abundances of deer mice differed among years ($P < 0.001$), but did not differ among treatments ($P = 0.56$). Further, a significant treatment by year interaction ($T \times Y$, $P = 0.10$) indicated that the treatments did not respond in a similar manner each year. Average abundances of Great Basin pocket mice differed ($P = 0.06$) among treatments for all years, with the highest abundances reported for the spring grazed treatment. In addition, a significant decline ($P = 0.10$) in mean captures of pocket mice occurred in the ungrazed/planted treatment in 1993. The treatment-year interaction ($T \times Y$, $P = 0.01$) was significant.

Results: Stream Channel

Stream channel conditions did not respond to the treatments in a consistent manner. The stream course shifted annually in some locations. High intensity summer rainstorms initiated upland erosion, debris flows, and stream channel scouring (fig. 1). Some sections of the stream had channel changes appearing almost annually on aerial and ground level photographs taken between 1979 through 1993. This constant state of flux probably increased the difficulty in classifying the stream type (Rosgen 1994). A decreased sinuosity from that expected for similar streams and a flood plain in the early stages of recovery from down-cutting contribute to a combination of characteristics slightly different, perhaps, than might be expected for less impacted streams.

Width-depth ratios did not differ among individual treatments ($P = 0.53$) (table 16). However, there was a significant interaction between time and width-depth ratios of the three treatment groups—no grazing, moderate grazing, and heavy grazing ($P = 0.06$). The width-depth ratio showed a decreasing trend in the ungrazed treatment group for the latter portion of the study period (1990 to 1993) that was not evident in the other two treatment groups (fig. 9). The streambank conditions of the grazed pastures deteriorated during the extended snowmelt runoff of 1993. There was no evidence for a specific change over time among treatment groups for stream depth alone ($P = 0.64$) or stream width alone ($P = 0.13$).

Bank angles showed little average difference among treatments (table 16). A significant interaction with time ($P = 0.09$), and an examination of the means suggest a greater trend toward improvement in the

Table 14—Breeding bird densities (territories/1.0 ha^a) during 1987, 1990, and 1993.

Species	Ungrazed/ planted			Ungrazed			Spring grazed light to moderate			Fall grazed light to moderate			Season-long heavy		
	1987	1990	1993	1987	1990	1993	1987	1990	1993	1987	1990	1993	1987	1990	1993
American kestrel <i>Falco sparverius</i>	—	—	—	0	0.2	0.2	—	—	—	0	0	0.1	—	—	—
American robin* ^b <i>Turdus migratorius</i>	0.4	0.3	0	0.5	0.5	0	0.4	0.4	0.1	0.6	0.3	0.2	0.5	0.5	0.3
Black-billed magpie <i>Pica pica</i>	0	0	0.1	—	—	—	—	—	—	—	—	—	—	—	—
Brewer's blackbird* <i>Euphagus cyanocephalus</i>	5.8	4.2	0.7	4.5	2.8	0.5	4.1	1.9	0.8	4.0	3.7	1.3	2.8	2.3	0
Brewer's sparrow <i>Spizella breweri</i>	—	—	—	—	—	—	—	—	—	0	0	0.2	—	—	—
California quail* <i>Callipepla californica</i>	0	0	0.1	0	0	0.1	0	0	0.1	0	0	0.1	0	0	0.1
Empidonax flycatchers <i>Empidonax</i> spp.	—	—	—	—	—	—	—	—	—	0	0.3	0	—	—	—
European starling <i>Sturnus vulgaris</i>	—	—	—	—	—	—	—	—	—	0	0.10	0	—	—	—
Killdeer* <i>Charadrius vociferus</i>	0.6	0.2	0	0.4	0.2	0	0.6	0.5	0	0.6	0.2	0	0.4	0.5	0
Lark sparrow* <i>Chondestes grammacus</i>	0.3	0.2	0.2	0.2	0.10	0.2	0.4	0.5	0.2	0.3	0	0.3	0.2	0	0.2
Loggerhead shrike* <i>Lanius ludovicianus</i>	0.10	0.2	0.03	0	0.1	0	0	0.1	0	0.1	0	0	0.03	0.3	0.2
Lazuli bunting <i>Passerina amoena</i>	0	0	0.4	0	0	0.4	—	—	—	0	0.1	0.1	—	—	—
Mourning dove* <i>Zenaida macroura</i>	0.2	0.3	0.1	0.3	0.4	0.2	0.2	0.4	0.1	0.3	0.3	0.1	0.2	0.4	0.2
Northern flicker <i>Colaptes auratus</i>	—	—	—	0.1	0	0.1	0	0.1	0.1	0.1	0.1	0.1	0.03	0	0
Northern oriole* <i>Icterus galbula</i>	0.4	0.5	0.2	0.3	0.5	0.3	0.4	0.6	0.2	0.5	0.5	0.2	0.4	0.5	0
Rock wren <i>Salpinctes obsoletus</i>	—	—	—	0.3	0.3	0.4	0.1	0.1	0.2	0	0.2	0	0.2	0	0.2
Rufous-sided towhee <i>Pipilo fuscus</i>	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0	0
Red-winged blackbird <i>Agelaius phoeniceus</i>	0	0.7	0	0	0.2	0	0	0.5	0	—	—	—	—	—	—
Rough-winged swallow <i>Stelgidopteryx serripennis</i>	0	0.2	0.1	—	—	—	0	0.2	0	0.2	0.4	0.2	0.6	0.6	0.4
Song sparrow <i>Melospiza melodia</i>	0	0.5	0	—	—	—	—	—	—	—	—	—	—	—	—
Spotted sandpiper <i>Actitis macularia</i>	0	0.2	0.1	—	—	—	0	0.2	0	0.2	0.4	0.2	0	0.1	0
Vesper sparrow <i>Poocetes gramineus</i>	—	—	—	—	—	—	0.2	0	0	—	—	—	—	—	—
Violet-green swallow <i>Tachycineta thalassina</i>	—	—	—	0	0.2	0	—	—	—	—	—	—	—	—	—
Western meadowlark* <i>Sturnella neglecta</i>	0.8	0.8	0.7	0.7	0.9	0.8	0.9	0.8	0.8	1.0	0.9	0.9	0.8	0.7	0.7
Total no. territories/ha/yr	8.6	8.3	2.7	7.3	6.4	3.2	7.3	6.3	2.6	7.9	7.5	4.0	6.3	5.9	2.3
Average no. territories/ treatment/ha (±1 se)	6.5 (±1.05)			5.6 (±0.84)			5.4 (±0.91)			6.5 (±0.85)			4.8 (±0.86)		
<i>P</i> (for all species' territories combined)															
Among treatments	0.70														
Interaction with years	0.60														
Species richness/treatment	15			15			15			18			14		

^aArea occupied by breeding pair as defined as a territory.

^bSpecies common to all treatments are denoted by an asterisk.

Table 15—Small mammal relative abundances (number/trap night) during 1987, 1990, 1993. The total individuals represent the total number of individuals summed across all treatments and all years by species.

Species	Ungrazed/ planted			Ungrazed			Spring grazed light to moderate			Fall grazed light to moderate			Season-long heavy		
	1987	1990	1993	1987	1990	1993	1987	1990	1993	1987	1990	1993	1987	1990	1993
Ord kangaroo rat <i>Dipodomys ordi</i> Total individuals (7)	1.0	0.7	0.3	—	—	—	—	—	—	0.3	0	0	—	—	—
Least chipmunk <i>Eutamias minimus</i> Total individuals (3)	—	—	—	—	—	—	0	0.3	0	—	—	—	0.3	0.3	0
Montane vole <i>Microtus montanus</i> Total individuals (9)	0.3	1.0	0	0.3	0	0	0	0.3	0.3	0.3	0	0.3	—	—	—
Deer mouse ^a <i>Peromyscus maniculatus</i> Total individuals (920)	32.7	56.3	0.7	21.3	28.0	1.0	16.7	39.3	0.7	22.0	37.7	0.7	18.0	27.0	4.7
Great basin pocket mouse* <i>Perognathus parvus</i> Total individuals (161)	0.7	3.0	1.7	1.0	3.7	8.0	1.0	3.0	9.7	1.3	2.3	6.3	0.3	5.3	6.3
Western harvest mouse* <i>Reithrodontomys megalotis</i> Total individuals (19)	0.7	0	0.7	0.3	0.3	2.0	0.7	0	0	0.3	0.3	0.3	0	0	0.7
Vagrant shrew* <i>Sorex vagrans</i> Total individuals (7)	0	0.7	0.3	0	0.3	0	0	0.3	0	0	0.3	0	0	0	0.3
Golden-mantled ground squirrel <i>Spermophilus lateralis</i> Total individuals (4)	0.3	0	0	0	0	0.3	—	—	—	—	—	—	0	0.7	0
Total individuals/yr/ trap night	35.7	61.7	3.7	23.0	32.3	11.3	18.3	43.3	10.7	24.3	42.7	7.7	18.7	33.3	12
Average no. individuals/ treatment/trap night (+1 se)	33.7 (+3.11)			22.2 (+1.87)			24.1 (+2.39)			24.9 (+2.42)			21.3 (+1.91)		
<i>P</i> (for all species' densities- combined)															
Among treatments	0.42														
Interaction with years	0.03														
Species richness/treatment	7			6			6			6			6		

^aSpecies common to all treatments are denoted by an asterisk.

Table 16—Average Pole Creek stream width, depth, width-depth ratio, and bank angle.

Treatments	Width	Depth	Width-depth ratio	Bank angle
	----- cm -----			Degrees
Individual treatment				
Ungrazed/planted	172.5a ^a	13.7a	16.7a	148.5a
Ungrazed	161.3a	12.0a	19.3a	142.9a
Spring grazed light to moderate	171.8a	11.8a	18.1a	148.0a
Fall grazed light to moderate	148.7a	12.5a	14.1a	147.8a
Season-long heavy	183.0a	10.6a	19.8a	149.1a
<i>P</i> ^b				
Among treatments	0.70	0.54	0.53	0.85
Interaction with years	0.41	0.80	0.19	0.14
Treatment group				
Ungrazed	170.5a	12.9a	17.9a	145.8a
Moderately grazed	162.2a	12.3a	16.3a	148.1a
Heavily grazed	183.0a	10.6a	19.8a	149.1a
<i>P</i>				
Among groups	0.77	0.27	0.53	0.82
Interaction with years	0.13	0.64	0.06	0.09

^aValues in columns among treatments or treatment groups followed by different letters are significantly different at *P* < 0.10.

^bProbability value.

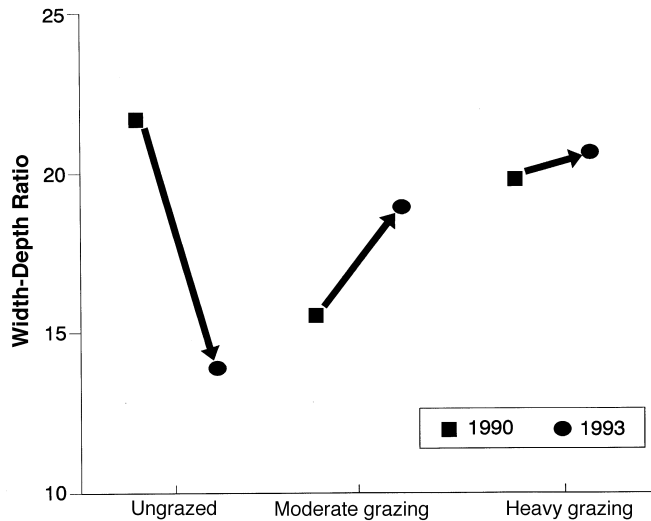


Figure 9—Interaction graph of stream width-depth ratio versus years by grazing intensity.

ungrazed and moderately grazed pastures as compared to the heavily grazed pastures.

Several attempts were made to identify additional relationships among a variety of streamside and channel variables with the intent of reducing uncontrolled data variance in plant biomass and stream channel characteristics. While some significant relationships were present, they had limited predictive value.

Discussion

Pole Creek, which transverses public and private lands, has been subjected to grazing, most likely intensive grazing, since settlement in the 1860's (Malheur County Historical Society 1988) as was much of the Great Basin and interior Northwest (Griffiths 1903; Renner 1936). Historically, Pole Creek, located near a local population center, was one of the few surface water sources (thus aggravating the influence of grazing), and provided an early-day local travel route. Early in the twentieth century, erosion in the Pole Creek drainage was apparently severe at times. A bridge (or bridges) spanning the lower end of Pole Creek was flooded and buried in sediment as many as five times (Mr. Lenard Cole [deceased] as told to Burrell B. Lovell 1991). This past erosional history, current erosional events, and depleted upland plant communities suggest that upland as well as riparian areas need improvement. An interdependency exists between watershed condition and health of riparian areas. Increases in soil compaction, and decreases in plant cover and soil surface litter, are a common result of heavy cattle use. Reduced water infiltration capacities of the surrounding uplands and an increase in

animal trails can greatly increase overland flow and eroded material moving into riparian areas (fig. 1) (Trimble and Mendel 1995). Thus, reduced condition of the surrounding upland slopes, acting to increase sediment-laden flows and stream erosive power, can greatly impact riparian areas (DeBano and Schmidt 1989; Kovalchik and Elmore 1992).

Plant Response

The post-settlement history of human and livestock impacts on Pole Creek has contributed to a loss of wetland plant species. A major component of sedges and rushes would normally be expected in a riparian system such as Pole Creek (Crouse and Kindschy 1984; Griffiths 1903; Peck 1911). The best indication of herbaceous plant response to grazing treatment appeared to be the frequency of plots (Hyder and others 1966) dominated by "desirable" species, that is, sod-forming species in general, and more importantly, rhizomatous wetland species. Even though the sod-former group was dominated by species adapted to disturbance (United States Department of Agriculture, Forest Service 1988b), a change in frequency of these species related to differences in grazing stress was not apparent. In addition, frequency of plots dominated by sedges, rushes, and similar wetland species was only 3 to 4 percent across all treatments, even though most of the study area was under no grazing or carefully controlled grazing for 7 years. Availability of sedges and rushes within much of this stream system seems limited at present. A similar historic depletion of riparian woody plants, such as willows and cottonwoods, has also occurred along Pole Creek (Shaw and Clary 1995). Other riparian-stream systems in the Intermountain Region have experienced similar depletions (Chaney and others 1990).

During our study, natural recovery of coyote willow and whiplash willow populations was affected by season and intensity of cattle grazing. Willow density and growth were generally enhanced by no or moderate grazing compared to heavy grazing. Greater densities in the spring-grazed compared to the ungrazed pastures may have been related to availability of microsites. Trampling along streambanks during spring grazing is generally limited, but may have created some microdisturbances favorable for germination and establishment of willows as seed was dispersed shortly after spring grazing each year. Lower densities in the fall-grazed pastures and pastures grazed season-long may be related to heavy use and trampling damage within the riparian area (Kovalchik and Elmore 1992).

Several additional biotic and abiotic factors affected natural willow recovery in all pastures. Composition of recovering willow populations may have reflected

availability of seed from offsite sources as willow seeds are not banked in soil (Brinkman 1974). Seeds of both coyote and whiplash willow remain viable for only a few days or weeks, thus only those that are quickly dispersed to favorable microsites will germinate (Brinkman 1974). Saturated sediments deposited by high-intensity storms prior to seed dispersal provided favorable microsite conditions (light, moisture, reduced vegetative competition) for establishment of both willows in some years. Flooding at any season, however, also uprooted, buried, or otherwise damaged many small seedlings.

Both planted willow species, coyote willow and whiplash willow, are well-adapted to low elevation riparian disturbances. Both are early successional species, colonizing recent sediment deposits (Argus 1973; Hansen and others 1988; Youngblood and others 1985). Both spread from seeds carried by wind or water, and occasionally from small twigs or branches that wash downstream. Although whiplash willow exhibits an upright, multi-stemmed growth habit, coyote willow spreads from root sprouting, forming dense thickets capable of catching sediments during flooding (Argus 1973; Zasada 1986).

Deer browsing in all pastures throughout the growing season severely reduced willow development each year. Ability of willows to grow beyond the reach of browsers is essential if recovering stands are to mature, produce seed, and contribute to riparian functioning. On Pole Creek, few native willows attained such heights in 7 years, even with protection from cattle grazing. Kovalchik (1987, 1992) found willows on well-drained sites averaged up to 0.4 m per year in height growth under shorter growing seasons. With the longer growing season at Pole Creek, we would expect a greater net height growth in the absence of browsing.

Although browsing reduced the rate of planted willow development, planting did provide a means of more rapidly establishing stands that grow beyond the reach of browsing animals than did natural regeneration. Reduced grazing or temporary protection from cattle grazing throughout the Pole Creek watershed might permit initiation of willow recovery over a larger area, thus diluting deer use. This, in turn, could result in more rapid height development of the naturally recovering willow stands. By 1990, more than three times as many coyote willows (shrubby habit) had grown out of reach of browsing animals (greater than 1.5 m height), when compared to whiplash willows (tree-like growth habit) in the experimental plots. This may be related to a number of factors including differences in growth rates, adaptability to the planting site, and palatability to livestock or wild ungulates (Argus 1973; Hansen and others 1988). In addition, the interior stems of developing coyote willow thickets may be afforded some protection from browsing.

Although willows planted in cleared scalps within the Kentucky bluegrass communities grew rapidly, recovery of Kentucky bluegrass within the scalps and a lack of suitable microsites within the community may preclude natural regeneration. Naturally occurring willow seedlings were rarely observed within this community during the study, but coyote willow transplants planted in cleared scalps did spread by root sprouting. Widening of the riparian zone as a result of stream recovery over time could increase the area available for natural willow regeneration.

Good survival was obtained by planting narrow-leaved cottonwood cuttings rooted in 4-liter containers directly into Kentucky bluegrass sod. Narrow-leaved cottonwood is a pioneer species in fresh sediment deposits and is adapted to dry riparian situations and fluctuating water tables (Hansen and others 1988; Youngblood and others 1985). Initial disease problems, heavy browsing by deer, and possible competition with Kentucky bluegrass, likely slowed development of planted cottonwoods. However, rapid growth in 1989, a relatively wet year, permitted most trees to grow beyond reach of browsing animals.

Planting success for transplanted, nonsalicaceous shrubs was likely limited by a number of factors. Limited precipitation during the season of establishment likely contributed to shrub mortality in 1987. Microsites favorable for establishment within the flood plain were limited due to frequent flooding that uprooted some shrub seedlings. Erosion and dry soil conditions on the incised banks also reduced establishment. Survival on north slopes was especially low due to their steep, rocky nature. Moderate to heavy browsing by deer throughout each growing season restricted shrub development, particularly for Wood's rose, common chokecherry, and red-osier dogwood (Shaw 1990). In addition, the planting stock purchased may not have been well-adapted to the site.

The greater survival of squawbush compared to the other four shrub species was attributed to the ability of this species to grow in dry areas and its generally low palatability to cattle (Dayton 1931; USDA-FS 1988b). Although not found growing in the Pole Creek drainage, squawbush does occur along the course of the Snake River and its tributaries in Idaho and on dry, rocky areas in southeastern Oregon (Mozingo 1986).

Western clematis, a shrub native to the Pole Creek watershed, is also adapted to dry situations (Wasser 1982); plants surviving to 1990 were large and vigorous, providing considerable cover. Western clematis seedlings were observed growing near mature, seed-producing transplants on open, south-facing slopes in 1993 (Shaw 1993). Whether seedlings of the other shrubs will be able to establish on the dry slopes or with competition from invasive annuals on the flats remains to be seen.

In addition to the native shrub species planted, remnant mature and decadent plants of several other shrub species occur within the Pole Creek drainage (appendix A). Reestablishing populations of these species would substantially improve both the biological and structural diversity of the riparian zone, providing niches for a variety of other organisms (Swenson 1957; Thornburg 1982; Wasser 1982; Welch and Andrus 1977). Many of these species, however, do not spread readily from seed or grow rapidly (Thornburg 1982; Wasser 1982). Consequently, spot plantings in appropriate sites along the length of the stream, and temporary protection from browsing to insure their establishment may be necessary. Planting efforts, however, may be more successful after watershed recovery increases the availability of suitable microsites for each species (Briggs and others 1994).

Wildlife Response

Historical changes in habitat conditions at Pole Creek have likely contributed to alterations in bird species composition and densities. Peck (1911) described the bird community of Pole Creek as a place where “both species and individuals were abundant.” Although livestock had been in the area for nearly 50 years previous to Peck’s survey (Malheur County Historical Society 1988), his 1911 account remains valuable as a comparison with respect to the 85 years of grazing since that time. Lark and vesper sparrows were reported as “abundant” or “plentiful” in the sagebrush communities (Peck 1911), but today both species are rarely observed in uplands surrounding Pole Creek. Song sparrows, warbling vireos, and yellow warblers, all species that nest in riparian areas, are virtually nonexistent today, but specifically noted as present throughout the breeding season by Peck (1911). The current comparatively depauperate nesting bird community is possibly a result of changes in both upland and riparian habitat conditions during this century. Earlier discussions in this paper suggest substantial vegetation changes have occurred.

Reduction in grazing during this 7-year study changed the vegetation little, and thus resulted in few responses by the bird community. Had treatments increased vegetation structure substantially and enhanced composition, we would have expected ground and shrub nesting species to increase, particularly in the ungrazed (Anderson and others 1989; Hunter and others 1989; Krueper 1993) and fall-grazed treatments (Kauffman and others 1982; Knopf and others 1988; Saab and others 1995; Sedgwick and Knopf 1987). Other studies have demonstrated that fall grazing appears to have the least impact on numbers of migratory birds during the breeding season in the short term (Saab and others 1995). Over the long-term, however, early fall grazing could result in degradation of willow

and other shrub communities to herbaceous communities (Kovalchik and Elmore 1992; Uresk and Paintner 1985) and the subsequent loss of shrub-nesting birds.

The cumulative impacts of livestock grazing along Pole Creek were reflected in the species composition and densities of small mammals. Rodent populations in all pastures were dominated by deer mice, a species known to occupy many vegetation types and conditions (Zeveloff 1988). Other grazing studies have reported limited deer mouse response to treatment effects (Medin and Clary 1990; Oldenmeyer and Allen-Johnson 1988; Samson and others 1988), and positive (Kauffman and others 1982; Moulton 1978; Schultz and Leininger 1991) or negative (Medin and Clary 1989; Rucks 1978) responses of deer mice to grazing disturbances. Deer mice densities did not significantly differ among treatments, although densities in pastures grazed season-long seemed generally depressed relative to others. In 1993, densities of deer mice dropped significantly in all pastures. This dramatic decline may have been influenced by unusually high rainfall during the previous spring and winter (fig. 2) or an encroaching full-moon during the time of trapping. A full moon phase can reduce activity levels of small mammals (Zeveloff 1988), however, Great Basin pocket mice were most numerous during this same time period.

Montane voles were rare on Pole Creek. Voles require high amounts of herbaceous cover (especially grasses) before resident breeding populations can be established (Birney and others 1976), conditions apparently not met at Pole Creek. By contrast, high densities of mountain voles were reported in ungrazed riparian vegetation in shrub-steppe habitats of Idaho (Medin and Clary 1990).

Channel Morphology and Streambank Response

Streambank stability in many small meadows is highly dependent upon the permeation and strength of underground structures (roots and rhizomes) of wetland plants. Among herbaceous plants, sedges and rushes provide this protective stability while species such as Kentucky bluegrass are much less effective (Dunaway and others 1994; Manning and others 1989; Platts and Nelson 1989). Under severe grazing pressure, streams that tend to be laterally unstable are usually characterized by widened channels, frequent channel realignments, and poorly vegetated banks and floodplains (Trimble and Mendel 1995; Van Haveren and Jackson 1986)—conditions rather similar to those at Pole Creek. Although, in most instances, these trends are expected to reverse quickly after improvement in grazing management (Armour and others 1994), average channel form changed little during this study. However, a significant interaction of treatment and years suggested that even carefully controlled grazing

may have reduced streambank stability in comparison with no grazing. Myers and Swanson (1995) reported a similar result. Instability of many stream segments and the apparent susceptibility of the streambanks to erosion during high snow melt streamflows can be largely attributed to the lack of highly rhizomatous bank-protecting wetland species and the low condition of the surrounding watershed. A lack of consistent association of in-channel characteristics with such variables as soil depth, stream gradient, streambank cover, and frequency of woody species was interpreted as additional evidence of an unstable riparian/watershed system.

Conclusions

Past grazing practices likely altered habitat conditions to a point that a wide range of grazing treatments (including no grazing) for 7 years resulted in few differential responses by plants or animals. The limited changes that occurred in these plant and animal communities suggest a need for long-term recovery and perhaps additional efforts to revegetate riparian habitats. Natural recovery of native riparian vegetation once occurring along the margins of the riparian area may be extremely slow, even with reductions in cattle grazing because of deterioration in physical conditions of the stream during the last 150 years, dominance of exotic annuals within the riparian area, and loss of native seed sources. Spot plantings of native herbaceous species, particularly sedges and rushes, and more extensive shrub plantings may be needed to expedite vegetation recovery, particularly in highly disturbed areas.

Careful consideration is required, however, if the appropriate plant materials are to be effectively matched to the site conditions of individual stream reaches. For example, in high gradient reaches, adapted willows and other woody riparian plants are capable of binding coarse substrates together, while some sedges, rushes, and grasses are better adapted to sites with more gentle gradients where they stabilize fine-textured substrates (Swanson and Meyers 1994). In some circumstances, heavy woody materials could possibly increase erosive processes under high flows by increasing local turbulence (Trimble and Mendel 1995). Because of the expense of revegetating streamside areas, perhaps the most cost effective initial strategy on many streams with gravelly-cobbly substrates, such as Pole Creek, would be to focus on grazing management approaches that foster the development of willow communities to provide initial streambank stability and sediment retention.

Addressing the continuing causes of site degradation is perhaps the most important long-term factor in achieving successful riparian rehabilitation (Briggs

and others 1994). The attraction of the green vegetation, low gradient topography, and proximity to water in the riparian zone (Ames 1977) was the dominant factor affecting livestock distribution under virtually all situations included in this study. Recovering natural vegetation and plantings require protection from excessive grazing or browsing until they are well established. Otherwise, few benefits will accrue. The alternative would likely be a long and unsure recovery period, raising doubts as to whether this riparian system would regain the stability and productivity of earlier years.

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Appendix A—Pole Creek Plant List^a

Graminoids

<i>Agropyron cristatum</i> (L.) Gaertn.	Crested wheatgrass
* <i>Agropyron spicatum</i> (Pursh)	Bluebunch wheatgrass
Scribn. & Smith ^b	
<i>Agrostis stolonifera</i> L.	Creeping bentgrass
<i>Bromus commutatus</i> Schrad.	Meadow brome
<i>Bromus japonicus</i> Thurb.	Japanese brome
<i>Bromus tectorum</i> L.	Cheatgrass
* <i>Carex</i> spp. —immature	Sedge
* <i>Carex microptera</i> Mack.	Small-winged sedge
* <i>Deschampsia elongata</i> (Hook.) Munro	Slender hairgrass
* <i>Eleocharis palustris</i> (L.) R. & S.	Common spike-rush
* <i>Elymus cinereus</i> Scribn. & Merr.	Giant wildrye
* <i>Festuca idahoensis</i> Elmer	Idaho fescue
<i>Festuca rubra</i> L.	Red fescue
* <i>Juncus acuminatus</i> Michx.	Tapered rush
* <i>Juncus balticus</i> Willd.	Baltic rush
* <i>Juncus ensifolius</i> Wikst.	Dagger-leaf rush
* <i>Muhlenbergia asperifolia</i> (N. & M.)	Alkali muhly
Parodi	
* <i>Oryzopsis hymenoides</i> (R. & S.)	Indian ricegrass
Ricker	
<i>Poa ampla</i> Merr.	Big bluegrass
<i>Poa bulbosa</i> L.	Bulbous bluegrass
* <i>Poa juncifolia</i> Scribn.	Alkali bluegrass
<i>Poa pratensis</i> L.	Kentucky bluegrass
* <i>Poa sandbergii</i> Vasey	Sandberg's bluegrass
<i>Polypogon monspeliensis</i> (L.) Desf.	Rabbitfoot polypogon
* <i>Scirpus microcarpus</i> Presl	Small-fruit bulrush
* <i>Scirpus pungens</i> Vahl	Common threesquare
* <i>Sitanion hystrix</i> (Nutt.) J. G. Smith	Bottlebrush squirreltail
* <i>Stipa comata</i> Trin. & Rupr.	Needle-and-thread
* <i>Stipa thurberiana</i> Piper	Thurber's needlegrass

Forbs

* <i>Achillea millefolium</i> L.	Yarrow
ssp. <i>lanulosa</i> (Nutt.) Piper	
* <i>Agoseris grandiflora</i> (Nutt.) Greene	Large-flowered agoseris
* <i>Allium acuminatum</i> Hook.	Tapertip onion
<i>Alyssum alyssoides</i> L.	Pale alyssum
* <i>Amaranthus californicus</i> (Moq.) Wats.	California amaranth
* <i>Amsinckia menziesii</i> (Lehm.) Nels. & Macbr.	Small-flowered fiddleneck
* <i>Amsinckia retrorsa</i> Suksd.	Rigid fiddleneck
* <i>Amsinckia tessellata</i> Gray	Tesselate fiddleneck
* <i>Antennaria microphylla</i> Rydb.	Rosy pussy-toes
* <i>Artemisia ludoviciana</i> Nutt.	Herbaceous sagebrush
var. <i>latiloba</i> Nutt.	
* <i>Aster chilensis</i> Nees	Common California aster
* <i>Aster eatonii</i> (Gray) Howell	Eaton's aster
* <i>Aster frondosus</i> (Nutt.) T. & G.	Short-rayed aster
* <i>Astragalus cusickii</i> Gray	Cusick's milk-vetch
* <i>Astragalus purshii</i> Dougl.	Woolly-pod milk-vetch
* <i>Balsamorhiza sagittata</i> (Pursh) Nutt.	Arrowleaf balsamroot
* <i>Blepharipappus scaber</i> Hook.	Blepharipappus

(con.)

Appendix A—(Con.)

* <i>Boisduvalia stricta</i> (Gray) Greene	Brook spike-primrose
* <i>Calochortus macrocarpus</i> Dougl.	Sagebrush mariposa
* <i>Camissonia boothii</i> (Dougl.) Raven ssp. <i>alyssoides</i> (H. & A.) Raven	Alyssum-like evening-primrose
* <i>Castilleja chromosa</i> A. Nels.	Desert paintbrush
* <i>Chaenactis douglasii</i> (Hook.) H. & A.	Hoary chaenactis
<i>Chenopodium album</i> L.	Lambsquarter
<i>Chorispota tenella</i> (Pall.) DC.	Chorispota
<i>Cirsium arvense</i> (L.) Scop.	Canada thistle
<i>Cirsium vulgare</i> (Savi) Tenore	Bull thistle
* <i>Cleome serrulata</i> Pursh	Rocky Mountain bee plant
* <i>Collomia grandiflora</i> Dougl.	Large-flowered collomia
* <i>Collomia linearis</i> Nutt.	Narrow-leaf collomia
<i>Convolvulus arvensis</i> L.	Field morning-glory
* <i>Conyza canadensis</i> (L.) Cronq.	Canada fleabane
* <i>Cryptantha pterocarya</i> (Torr.) Greene	Winged cryptantha
* <i>Delphinium nuttallianum</i> Pritz.	Upland larkspur
* <i>Descurainia pinnata</i> (Walt.) Britt.	Western tansymustard
* <i>Descurainia sophia</i> (L.) Webb	Flixweed
* <i>Epilobium watsonii</i> Barbey	Watson's willow-herb
* <i>Equisetum arvense</i> L.	Common horsetail
* <i>Equisetum laevigatum</i> A. Br.	Smooth scouring-rush
* <i>Erigeron linearis</i> (Hook.) Piper	Line-leaf fleabane
* <i>Erigeron pumilus</i> Nutt. ssp. <i>intermedius</i> Cronq.	Shaggy fleabane
* <i>Eriogonum ovalifolium</i> Nutt.	Oval-leaved eriogonum
* <i>Eriogonum umbellatum</i> Torr.	Sulfur buckwheat
* <i>Eriogonum vimineum</i> Dougl. var. <i>vimineum</i>	Broom buckwheat
* <i>Eriophyllum lanatum</i> (Pursh) Forbes var. <i>integrifolium</i> (Hook.) Smiley	Oregon sunshine
<i>Erodium cicutarium</i> (L.) L'Her.	Stork's-bill
* <i>Euphorbia serpyllifolia</i> Pers.	Thyme-leaf spurge
* <i>Galium aparine</i> L.	Cleavers
* <i>Gayophytum diffusum</i> T. & G.	Spreading gayophytum
* <i>Helianthus annuus</i> L.	Common sunflower
* <i>Iliamna rivularis</i> (Dougl.) Greene	Streambank globemallow
<i>Lactuca serriola</i> L.	Prickly lettuce
<i>Lepidium perfoliatum</i> L.	Clasping peppergrass
* <i>Lomatium triternatum</i> (Pursh) Coul. & Rose	Nine-leaf lomatium
* <i>Lupinus arbustus</i> Dougl.	Spur lupine
<i>Malva neglecta</i> Wallr.	Dwarf mallow
<i>Marrubium vulgare</i> L.	Horehound
<i>Medicago lupulina</i> L.	Hop clover
<i>Medicago sativa</i> L.	Alfalfa
<i>Melilotus officinalis</i> (L.) Pallas	Common yellow sweet-clover
* <i>Mentzelia albicaulis</i> Dougl.	Small-flowered mentzelia
* <i>Mentzelia laevicaulis</i> (Dougl.) T. & G.	Blazing-star mentzelia
* <i>Mimulus guttatus</i> DC.	Yellow monkey-flower
* <i>Montia perfoliata</i> (Donn) Howell	Miner's lettuce
* <i>Navarretia minima</i> Nutt.	Least navarretia
<i>Onopordum acanthium</i> L.	Scotch thistle

(con.)

Appendix A—(Con.)

* <i>Penstemon</i> spp.	Penstemon
* <i>Penstemon speciosus</i> Dougl.	Showy penstemon
* <i>Perideridia bolanderi</i> (Gray) Nels. & Macbr.	Bolander's yampah
* <i>Phacelia heterophylla</i> Pursh	Varileaf phacelia
* <i>Phacelia linearis</i> (Pursh) Holz.	Threadleaf phacelia
* <i>Phlox longifolia</i> Nutt. var. <i>stansburyi</i> (Torr.) Gray	Long-leaf phlox
<i>Plantago major</i> L.	Common plantain
* <i>Potentilla biennis</i> Greene	Biennial cinquefoil
<i>Ranunculus cymbalaria</i> Pursh	Shore buttercup
<i>Ranunculus testiculatus</i> Cranz	Hornseed buttercup
<i>Rumex crispus</i> L.	Curly dock
* <i>Rumex salicifolius</i> Weinm. var. <i>triangulivalvis</i> Danser	Willow dock
<i>Salsola kali</i> L.	Russian thistle
* <i>Scutellaria angustifolia</i> Pursh	Narrow-leaved skullcap
* <i>Senecio hydrophiloides</i> Rydb.	Sweet-marsh butterweed
<i>Sisymbrium altissimum</i> L.	Jim Hill mustard
<i>Solanum dulcamara</i> L.	Climbing nightshade
<i>Solanum nigrum</i> L.	Black nightshade
* <i>Solidago canadensis</i> L.	Canada goldenrod
<i>Taraxacum officinale</i> Weber	Common dandelion
<i>Thlaspi arvense</i> L.	Field pennycress
<i>Trifolium fragiferum</i> L.	Strawberry clover
<i>Trifolium repens</i> L.	Dutch clover
* <i>Trifolium variegatum</i> Nutt.	White-tip clover
* <i>Triteleia grandiflora</i> Lindl.	Douglas' brodiaea
* <i>Typha latifolia</i> L.	Common cat-tail
* <i>Urtica dioica</i> L.	Stinging nettle
<i>Verbascum thapsus</i> L.	Common mullein
* <i>Veronica americana</i> Schwein.	American brooklime
<i>Veronica anagallis-aquatica</i> L.	Water speedwell
* <i>Viola</i> spp.	Violets
* <i>Xanthium strumarium</i> L. var. <i>canadense</i> (Mill.) T. & G.	Common cocklebur
Trees and Shrubs	
* <i>Amelanchier alnifolia</i> Nutt.	Western serviceberry
* <i>Artemisia rigida</i> (Nutt.) Gray	Stiff sagebrush
* <i>Artemisia tridentata</i> Nutt. var. <i>tridentata</i>	Great Basin big sagebrush
* <i>Artemisia tridentata</i> Nutt. var. <i>wyomingensis</i> (Beetle & A. Young) S. L. Welsh	Wyoming big sagebrush
* <i>Chrysothamnus nauseosus</i> (Pall.) Britt.	Gray rabbit-brush
* <i>Chrysothamnus viscidiflorus</i> (Hook.) Nutt.	Green rabbit-brush
* <i>Clematis ligusticifolia</i> Nutt.	Western clematis
* <i>Cornus stolonifera</i> Michx.	Red-osier dogwood
<i>Elaeagnus angustifolia</i> L.	Russian olive
* <i>Eriogonum microthecum</i> Nutt. var. <i>microthecum</i>	Slenderbush buckwheat

(con.)

Appendix A—(Con.)

* <i>Grayia spinosa</i> (Hook.) Moq.	Spiny hopsage
* <i>Juniperus occidentalis</i> Hook.	Western juniper
* <i>Peraphyllum ramosissimum</i> Nutt.	Squaw apple
* <i>Philadelphus lewisii</i> Pursh	Syringa
* <i>Populus angustifolia</i> James	Narrow-leaved cottonwood
* <i>Populus trichocarpa</i> T. & G.	Black cottonwood
* <i>Prunus virginiana</i> L.	Common chokecherry
* <i>Purshia tridentata</i> (Pursh) DC.	Bitter-brush
<i>Rhus trilobata</i> Nutt.	Squawbush
* <i>Ribes aureum</i> Pursh	Golden currant
<i>Rosa canina</i> L.	Dog rose
* <i>Rosa woodsii</i> Lindl.	Wood's rose
* <i>Salix amygdaloides</i> Anderss.	Peach-leaf willow
* <i>Salix ?lasiolepis</i> Benth.	Arroyo willow
* <i>Salix exigua</i> Nutt. ssp. <i>exigua</i>	Coyote willow
* <i>Salix lasiandra</i> Benth.	Whiplash willow
var. <i>caudata</i> (Nutt.) Sudw.	
* <i>Salix lemmonii</i> Bebb	Lemmon's willow
* <i>Salix lutea</i> Nutt.	Yellow willow
* <i>Sambucus cerulea</i> Raf.	Blue elderberry
* <i>Tetradymia glabrata</i> Gray	Little-leaf horsebrush

^aScientific nomenclature has been derived from Barneby (1989), Cronquist (1994), Cronquist and others (1972, 1977, 1984), and Hitchcock and Cronquist (1973). The use of common names has followed practices employed by Hitchcock and Cronquist (1973) and in a few cases locally utilized names furnished by Findley (1995).

^bNative species are denoted with an asterisk.

Appendix B—Presence of Transient Bird Species, Wide-Ranging Raptors, and Residents With Few Observations by Grazing Treatment for 1987, 1990, 1993

Species	Ungrazed/ planted			Ungrazed			Spring grazed light to moderate			Fall grazed light to moderate			Season-long heavy		
	1987	1990	1993	1987	1990	1993	1987	1990	1993	1987	1990	1993	1987	1990	1993
American goldfinch <i>Carduelis tristis</i>	+	+	+	+	+		+	+		+					
American kestrel <i>Falco sparverius</i>			+				+	+	+	+					+
Barn swallow <i>Hirundo rustica</i>	+			+	+			+	+	+	+			+	+
Black-billed magpie <i>Pica pica</i>				+	+								+		
Belted kingfisher <i>Ceryle alcyon</i>					+				+	+					
Brown-headed cowbird <i>Molothrus ater</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Black-headed grosbeak <i>Pheucticus melanocephalus</i>				+						+					
Brewer's sparrow <i>Spizella breweri</i>			+	+	+		+	+	+					+	+
Chipping sparrow <i>Spizella passerina</i>		+	+		+				+						+
Chukar <i>Alectoris chukar</i>	+		+	+	+		+		+	+		+	+		+
Cliff swallow <i>Hirundo pyrrhonota</i>										+					
Cooper's hawk <i>Accipiter cooperii</i>			+												
Common nighthawk <i>Chordeiles minor</i>		+		+	+			+		+				+	+
Common poorwill <i>Phalaenoptilus nuttallii</i>	+									+					
Common raven <i>Corvus corax</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Eastern kingbird <i>Tyrannus tyrannus</i>										+	+				
Empidonax flycatchers <i>Empidonax</i> spp.	+	+	+	+	+	+	+	+					+		
European starling <i>Sturnus vulgaris</i>			+				+						+	+	
Ferruginous hawk <i>Buteo regalis</i>								+							
Golden-crowned kinglet <i>Regulus satrapa</i>			+												
Golden-crowned sparrow <i>Zonotrichia atricapilla</i>												+			
Golden eagle <i>Aquila chrysaetos</i>	+			+	+		+		+	+	+	+	+		
Green-winged teal <i>Anas crecca</i>														+	
Hermit thrush <i>Catharus guttatus</i>			+												+
House wren <i>Troglodytes aedon</i>					+				+		+				
Lewis' woodpecker <i>Melanerpes lewis</i>			+		+										+
Lazuli bunting <i>Passerian amoena</i>				+				+	+				+		+
Mallard <i>Anas platyrhynchos</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

(con.)

Appendix B—(Con.)

Species	Ungrazed/ planted			Ungrazed			Spring grazed light to moderate			Fall grazed light to moderate			Season-long heavy		
	1987	1990	1993	1987	1990	1993	1987	1990	1993	1987	1990	1993	1987	1990	1993
MacGillivray's warbler <i>Oporornis philadelphia</i>			+						+		+	+			+
Nashville warbler <i>Vermivora ruficapilla</i>			+												
Northern flicker <i>Colaptes auratus</i>	+														
Northern harrier <i>Circus cyaneus</i>				+	+		+	+	+			+			
Osprey <i>Pandion haliaetus</i>			+												
Prairie falcon <i>Falco mexicanus</i>					+								+		
Ruby-crowned kinglet <i>Regulus calendula</i>	+	+		+							+	+			+
Ring-necked pheasant <i>Phasianus colchicus</i>	+														
Rock wren <i>Salpinctes obsoletus</i>	+														
Rufous-sided towhee <i>Pipilo fuscus</i>							+			+					
Red-tailed hawk <i>Buteo jamaicensis</i>				+						+	+				
Red-winged blackbird <i>Agelaius phoeniceus</i>										+	+		+	+	
Say's phoebe <i>Sayornis saya</i>									+						
Song sparrow <i>Melospiza melodia</i>										+					
Spotted sandpiper <i>Actitis macularia</i>				+											
Sharp-shinned hawk <i>Accipiter striatus</i>		+		+	+		+				+	+			
Swainson's hawk <i>Buteo swainsoni</i>				+					+	+					
Turkey vulture <i>Cathartes aura</i>	+		+	+	+	+		+	+	+	+		+		
Vesper sparrow <i>Pooecetes gramineus</i>	+	+		+	+					+	+		+		
Violet-green swallow <i>Tachycineta thalassina</i>	+							+		+	+		+	+	
Warbling vireo <i>Vireo gilvus</i>											+				
White-crowned sparrow <i>Zonotrichia leucophrys</i>		+	+	+	+	+		+	+		+	+		+	+
Western kingbird <i>Tyrannus verticalis</i>	+		+	+		+	+		+	+	+		+	+	
Wilson's warbler <i>Wilsonia pusilla</i>			+								+				+
Yellow warbler <i>Dendroica petechia</i>		+	+												
Yellow-rumped warbler <i>Dendroica coronata</i>		+	+		+	+			+	+	+	+	+	+	+

Clary, Warren P.; Shaw, Nancy L.; Dudley, Jonathan G.; Saab, Victoria A.; Kinney, John W.; Smithman, Lynda C. 1996. Response of a depleted sagebrush steppe riparian system to grazing control and woody plantings. Res. Pap. INT-RP-492. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 32 p.

To find out if a depleted riparian system in the sagebrush steppe of eastern Oregon would respond quickly to improved management, five management treatments were applied for 7 years, ranging from ungrazed to heavily grazed treatments, including in some cases, planting of woody species. While the results varied, all treatments were too limited to significantly restore the damaged areas within the 7-year span. Although some improvements were made in woody plant densities, little meaningful change occurred in the frequencies of herbaceous wetland plants, densities of small wildlife, or stream channel morphology. We concluded the restoration would take many years, possibly decades, without increased revegetation efforts and continued reductions in grazing in this riparian system damaged over 150 years.

Keywords: livestock grazing, riparian restoration, *Salix lasiandra*, *Salix exigua*, *Poa pratensis*, *Agrostis stolonifera*, small wildlife, stream channel

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