RECRUITMENT AND GROWTH OF PACIFIC WILLOW AND SANDBAR WILLOW SEEDLINGS IN RESPONSE TO SEASON AND INTENSITY OF CATTLE GRAZING

Nancy L. Shaw

ABSTRACT

The effect of cattle grazing treatments on recruitment and growth of Pacific willow (Salix lasiandra) *and sandbar willow* (S. exigua) *seedlings was monitored over a 4-year period on a degraded low-elevation stream in the sagebrush-steppe zone of eastern Oregon. Treatments included: (1) spring grazing, light-to-moderate intensity; (2) fall grazing, light-to-moderate intensity; (3) protection from cattle grazing; and (4) continued season-long, heavy to very heavy grazing (control). Density of Pacific willow seedlings did not vary among treatments or years. Increase in sandbar willow seedling density over time was similar for the spring grazing, fall grazing, and protected treatments, but declined over time in control pastures. Within species, seedling growth was similar in spring, fall, and protected pastures, exceeding that of controls. However, after 4 years of treatment, heavy deer browsing in all pastures prevented most seedlings from growing beyond the reach of grazing animals, thus establishment was not ensured.*

INTRODUCTION

Ribbonlike springfed streams (stringers) are a common feature of sagebrush-dominated landscapes in the Western United States. Damage to these streams and associated riparian areas from improper livestock grazing practices and other human activities has impaired watershed function, decreased biological diversity, and adversely impacted human economic and recreational activities both locally and downstream (Kauffman and Krueger 1984; Skovlin 1984; Thomas and others 1979). Improving a significant proportion of these streams presents a major challenge. Artificial rehabilitation is often costly, not always successful, and generally applied only to critical areas. The ability of streams and associated vegetation to recover naturally in the absence of livestock grazing or with altered grazing practices is situation specific and related to site characteristics, degree of degradation, availability of seed and vegetative material of native species adapted to the disturbances, and compatibility of management practices with recovery processes (Crouse and Kindschy 1984; Van Haveren and Jackson 1986). Factors such as wildlife use and presence of weedy species can have profound impacts on the rate, extent, and direction of recovery.

Recent research efforts have been directed toward developing a better understanding of changes in physical stream characteristics and the composition, structure, and productivity of riparian vegetation in response to protection from livestock grazing or to specific seasons and intensities of grazing (Clary 1990; Kauffman and others 1983a, b; Marlow and others 1989; Platts and others 1987). Improved knowledge of the autecology of major riparian plant species, particularly requirements for their establishment and seedling development as well as the response of individual species to grazing practices would contribute to this effort (Patton 1977).

Pacific willow (*Salix lasiandra*) and sandbar willow (*S. exigua*) are two of the most common woody riparian species at low- to mid-elevations within the sagebrush steppe. Pacific willow ranges in growth habit from multistemmed shrubs to tree-like forms. It resprouts following crown removal, but does not spread by suckering (Argus 1973; Haeussler and Coates 1986; Zasada 1986). Stands typically occur immediately adjacent to the water's edge on sites with high water tables year round (Brunsfeld and Johnson 1985; Uchytil 1989b). Sandbar willow is a short-lived, normally shrubby species that forms dense clonal thickets by production of shoots from buds on lateral roots (Argus 1973). It is highly tolerant of flooding and may occur below the high water line (Brunsfeld and Johnson 1985; Hansen and others 1988a). A widely adapted species, sandbar willow may be found bordering margins of rivers, streams, ponds, marshy areas, and irrigation ditches (Dorn 1977; Hansen and others 1988a; Stephens 1973; Uchytil 1989a; Youngblood and others 1985).

Pacific willow and sandbar willow provide streambank stabilization as well as cover and food for numerous wildlife species (Finch 1987; Hansen and others 1988a; Uchytil 1989a, b). Both rapidly colonize fresh alluvial deposits ranging from fine silt to sand and gravel (Dorn 1977; Hansen and others 1988a; Stephens 1973). The objective of this study was to examine recruitment and growth of Pacific willow and sandbar willow seedlings on a degraded low-elevation eastern Oregon stream of the sagebrush-steppe zone in response to season and intensity of cattle grazing.

Paper presented at the Symposium on Ecology and Management of Riparian Shrub Communities, Sun Valley, ID, May 29-31, 1991.

Nancy L. Shaw is Botanist, Intermountain Research Station, Forest Service, U.S. Department of Agriculture, Forestry Sciences Laboratory, Boise, ID 83702.

STUDY SITE

The study was conducted approximately 48 km northwest of Vale in Malheur County, OR. Pole Creek, a spring-fed, third-order tributary of the Malheur River, originates on the eastern slope of the Cottonwood Mountains. The stream is perennial with a rather uniform flow of about 1 cfs. Experimental pastures were installed along a portion of the stream passing through moderate to steep foothill terrain near the base of the mountains. Elevation within the study area ranges from 880 to 975 m. Climate is semiarid. Average annual temperature at Vale, the nearest reporting station, is 10 °C. Mean January temperature is –3 °C and mean July temperature is 23 °C. Average annual precipitation is 244 mm with 61 percent falling from October through March (USDC 1986-90). High intensity, short-duration rain storms are not uncommon in summer.

Soils within the study site are derived from basalt and rhyolite. They range from shallow and rocky on ridges to deep alluvial deposits in former wet meadows and near the mouths of lateral drainages. Uplands support primarily a Wyoming big sagebrush/cheatgrass (*Artemisia tridentata* ssp. *wyomingensis/Bromus tectorum*) biotic climax. Associated overstory shrubs include squawapple (*Peraphyllum ramosissimum*), rubber rabbitbrush (*Chrysothamnus nauseosus*), and an occasional antelope bitterbrush (*Purshia tridentata*), spiny hopsage (*Grayia spinosa*), or Saskatoon serviceberry (*Amelanchier alnifolia*). Sandberg bluegrass (*Poa secunda*), bottlebrush squirreltail (*Sitanion hystrix*), and minor amounts of bluebunch wheatgrass (*Agropyron spicatum*) and Great Basin wildrye (*Elymus cinereus*) are present in the understory. A stiff sagebrush/Sandberg bluegrass (*Artemisia rigida/Poa secunda*) habitat type is restricted to rocky, basalt sites with shallow soils.

Loss of native bank-stabilizing riparian vegetation has resulted in heavy sediment loss and downcutting of the stream channel to bedrock along much of its length. Incised banks sometimes exceed 6 m in height, but are more commonly 1 to 3 m high. The narrow floodplain averages 10 to 30 m in width. Rock and fine- to coarse-textured sediment deposits occur at streamside. Saturated streambars are initially colonized by a field horsetail (*Equisetum arvense*) and water speedwell (*Veronica anagallis-aquatica*) community. These areas are often reworked by later floods. Low terraces with fine- to medium-textured sediments support Kentucky bluegrass (*Poa pratensis*) and redtop (*Agrostis alba*) communities. Drier sites support a number of pioneer species and introduced weeds including flannel mullein (*Verbascum thapsus*) and Scotch thistle (*Onopordum acanthium*). These herbaceous communities intergrade with upland sagebrush communities.

Remnant plants, logs, and seedlings suggest that before livestock grazing populations of woody riparian species along Pole Creek may have been similar to those now present on local streams with relatively healthy riparian areas. The willow family is represented by Pacific willow, sandbar willow, black cottonwood (*Populus trichocarpa*), and narrow-leaf cottonwood (*P. angustifolia*). Shrubs associated with the riparian area include blueberry elder (*Sambucus cerulea*), Woods rose (*Rosa woodsii*), common chokecherry (*Prunus virginiana melanocarpa*), syringa (*Philadelphus lewisii*), clematis (*Clematis ligusticifolia*), and red-osier dogwood (*Cornus stolonifera*). These shrubs are either heavily grazed or grow in locations inaccessible to livestock.

The Poall Creek grazing allotment comprises 1,829 ha. Approximately 66 percent is within the U.S. Department of the Interior, Bureau of Land Management, Vale District, while the remainder consists of State and private holdings (USDI 1982). The single-pasture community allotment is administered by the Bureau of Land Management and used by three permittees. Active preference is 589 AUM's (USDI 1987). Season of use is April 1 to September 30 in even years and July 1 to October 31 in odd years. Grazing is heavily concentrated along Pole Creek.

METHODS

Grazing treatments were applied to pastures installed along a 5-km segment of the stream. Treatments were: (1) spring grazing, light-to-moderate intensity; (2) fall grazing, light-to-moderate intensity; (3) protection from cattle grazing; and (4) season-long, heavy to very heavy use (control) (table 1). Pastures assigned spring, fall, and protected treatments were fenced to exclude livestock, but not big game. Application of spring and fall grazing treatments normally involved release of four cow/calf pairs into each pasture for approximately 10 days. Treatment duration was determined by monitoring forage utilization by weight at streamside, primarily in Kentucky bluegrass and redtop communities (Clary 1987, 1989). Cattle were excluded from protected pastures. Control pastures were not fenced. They were located approximately 0.5 km from the nearest fenced pastures to avoid a "water gap" concentration effect in their use. Control pastures were grazed with the remainder of the allotment as prescribed in the current Allotment Management Plan (USDI 1982, 1987). Treatments were applied in a completely randomized design with two replications.

Natural recruitment and growth of native woody riparian species were measured annually in early October from 1987 through 1990 on 20 belt transects (each 5-m wide)

Table 1—Grazing treatments applied at Pole Creek Experimental Pastures

Season of grazing	Stocking intensity[1]	Period of use (approximate)
Spring	Light/moderate	May 15-25
Fall	Light/moderate	October 10-20
Protected	Not grazed	—
Season long (control)	Heavy/very heavy	Even years: April 1 - September 30 Odd years: July 1 - October 31

[1]Based on forage utilization by weight at streamside: light = 20-35 percent, moderate = 36-55 percent, heavy = 56-75 percent, very heavy = >75 percent.

along the approximately 200-m stream segment within each pasture. Transects were placed perpendicular to the stream. Species, height, maximum and minimum crown diameters, number of basal stems and distance from water were recorded for each seedling. Use by livestock or wildlife was noted. Width of active and slack water and the band of stream-affected vegetation were determined for each transect. Precipitation was measured at Brogan, OR, approximately 3 km southeast of the study site, throughout the study period.

Plant density and growth data within and between years were analyzed by analysis of variance (ANOVA). Mean comparisons were made using Fisher's Least Significant Difference (FLSD). Comparisons between years were analyzed as a split plot using conservative degrees of freedom. Significance was noted at the $p \leq 0.05$ level.

RESULTS

Precipitation was erratic throughout the study period. The long-term average precipitation for Vale, the nearest reporting station, is 251 mm (USDC 1986-90) (fig. 1). Average annual precipitation at Brogan from 1986 to 1990 was 226 mm. Brogan rainfall for the 1988-89 water year was 124 percent of normal for Vale but ranged from 67 to 82 percent of the Vale average in the remaining 3 years.

Winter snowpacks and spring runoff on Pole Creek were very light throughout the study period. Spring runoff generally peaked in early March. Intense, short-duration summer rain storms exceeding 20 mm in less than 1 hour occurred in May and August 1987, May and September 1989, and August 1990. These storms caused flash floods that produced sheet erosion and gullying on uplands and severe scouring in and along the stream.

A large number of Pacific willow and sandbar willow seedlings emerged in all treatments during the summer of 1987, possibly because a May flash flood left fresh deposits of saturated sediments along the stream prior to willow seed maturation and dispersal. These deposits were devoid of competing vegetation and provided excellent seedbed conditions for willows. Willow seedlings emerged within a narrow band along the stream, primarily on streambars. They also occurred on saturated sediments colonized by field horsetails and water speedwell and in slack water. Seedlings were not observed in Kentucky bluegrass or redtop communities. In 1990 average distance of seedlings from water, 136 cm for Pacific willow and 90 cm for sandbar willow, did not differ among treatments for either willow species.

Density of Pacific willow seedlings did not respond to treatments or time over the 4 years of study. Analysis of 1990 data alone also failed to distinguish differences among treatments. Density of Pacific willow seedlings averaged over all years and treatments was 1,018/ha of stream-affected vegetation.

Analysis of changes in density of sandbar willow seedlings over time revealed a significant two-way interaction between treatments and years (fig. 2). There was a trend for seedling density in reduced spring grazing, fall grazing, and protected pastures to increase over time, with the rate of increase greatest for spring-grazed pastures. Density decreased over time in control pastures.

Changes in seedling height were similar for both willow species (figs. 3, 4). Significant differences were distinguished among main-effect means for both time and treatments. Height of seedlings in reduced grazing pastures exceeded controls. Mean height differed for each year of treatment with maximum heights measured in 1989.

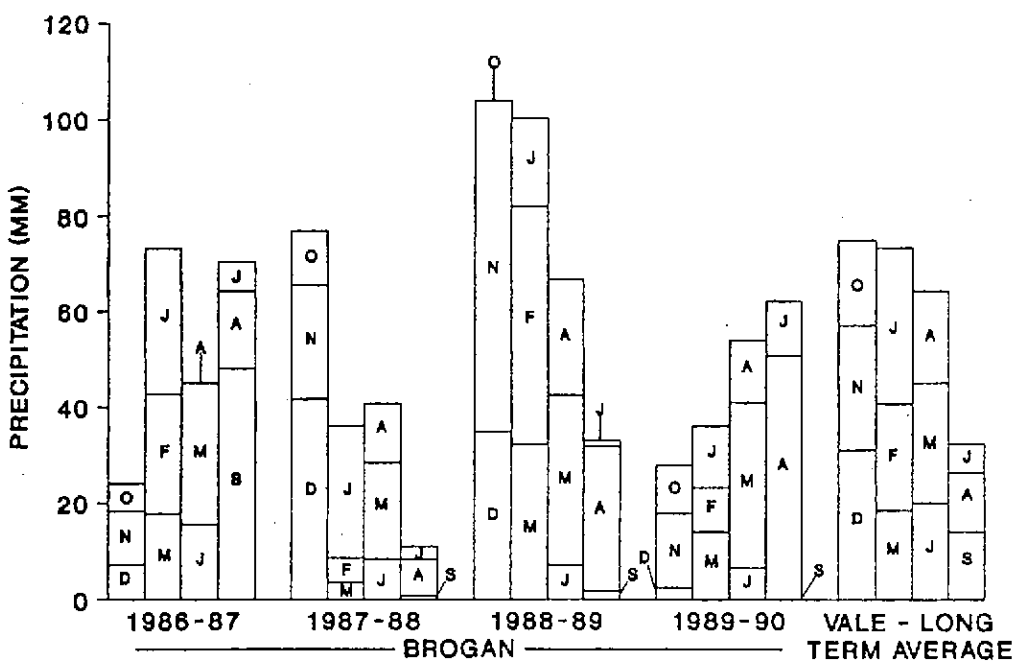


Figure 1—Monthly precipitation, Brogan, OR, October 1986 through September 1990 (author's data) and long-term mean monthly precipitation, Vale, OR (USDC1986 to 1990).

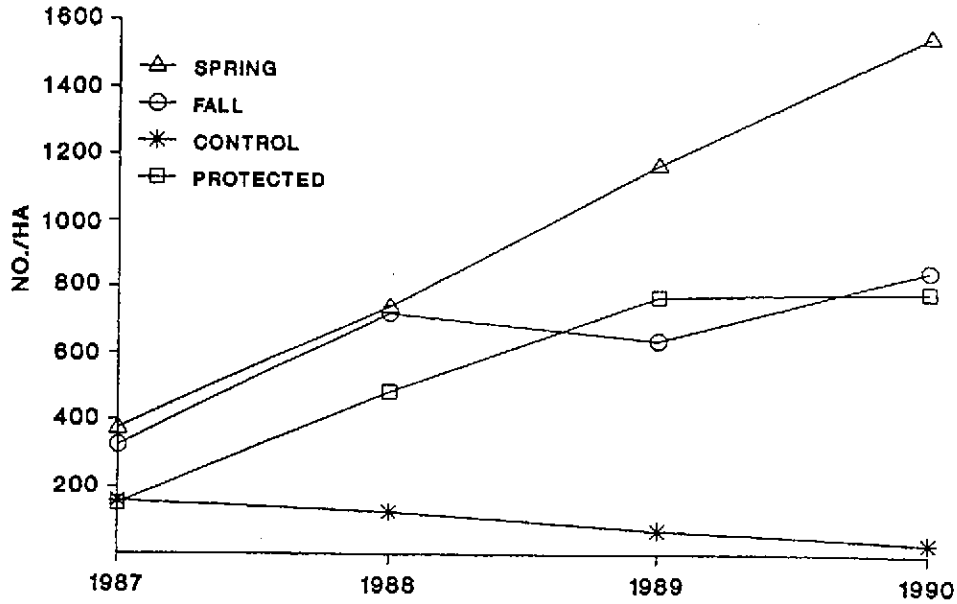


Figure 2—Sandbar willow seedling density by treatment, 1987 to 1990, Pole Creek Experimental Pastures.

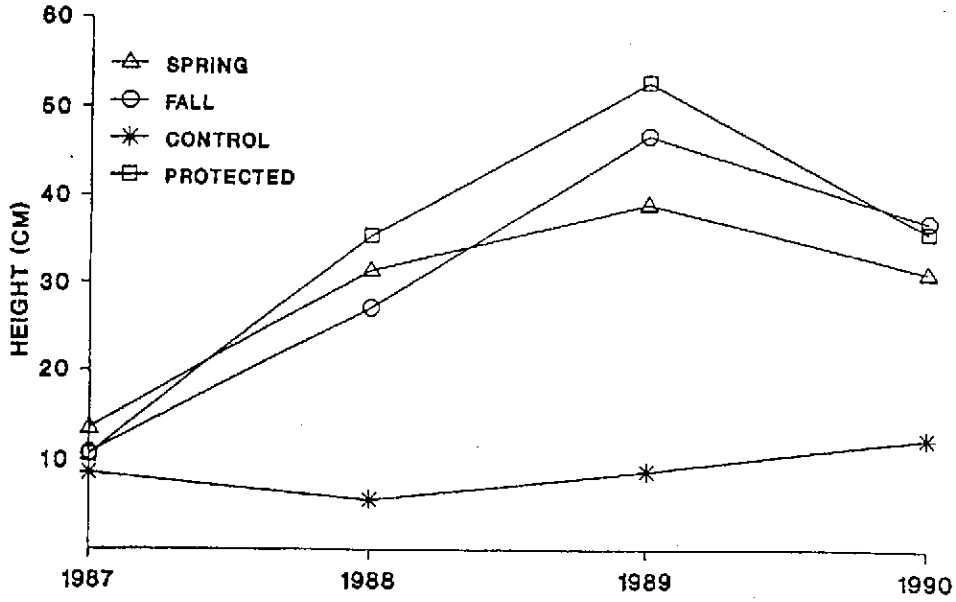


Figure 3—Sandbar willow seedling height by treatment, 1987 to 1990, Pole Creek Experimental Pastures.

Sediment deposits and burial of some seedlings by a flash flood just prior to sampling in 1990 may have affected measurements. In 1990 mean height of each species did not exceed 50 cm for any treatment due to heavy browsing by deer in protected pastures and deer and livestock in reduced-grazing pastures. Until seedling height exceeds 150 to 170 cm, available forage is entirely within reach of grazing animals; the ability of seedlings to survive to maturity is uncertain. In 1990, fewer than 5 percent of the willow seedlings in restricted grazing pastures exceeded 100 cm in height (table 2). All seedlings in control pastures were less than 50 cm tall.

Crown development on seedlings of both willow species has also been severely limited by cattle and wildlife use (table 3). Lateral spread by new shoots has been almost nonexistent. By 1990 Pacific willow seedlings averaged only 1.6 and sandbar willow 1.2 basal stems, with no significant differences among treatments. Treatments did impact crown diameter. Mean crown diameter of Pacific willow and sandbar willow seedlings under reduced grazing treatments was 130 and 66 percentgreater than respective controls.

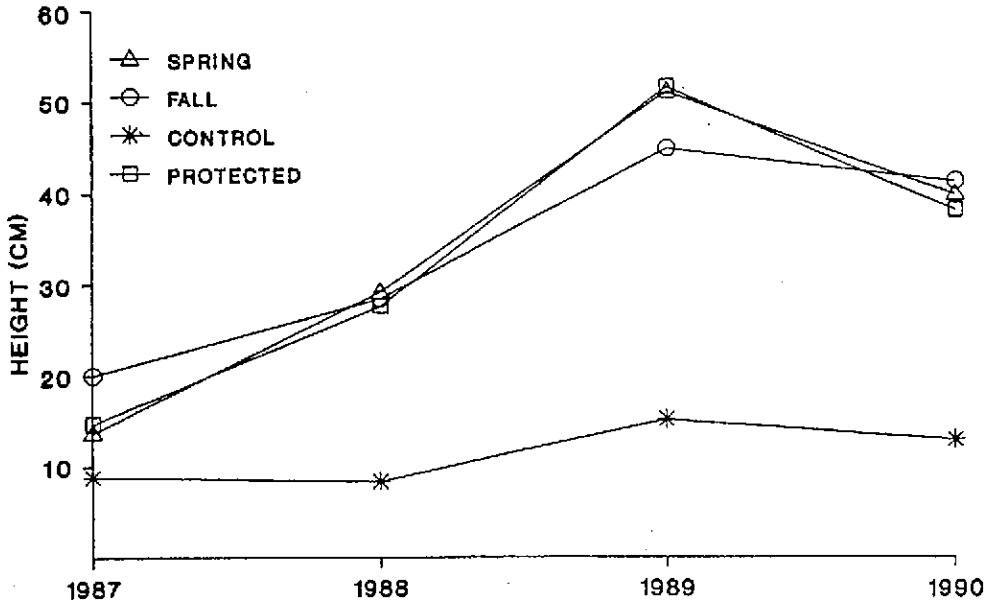


Figure 4—Pacific willow seedling height by treatment, 1987 to 1990, Pole Creek Experimental Pastures.

DISCUSSION

Pacific willow and sandbar willow are common along streambanks and quickly invade disturbed areas. Seeds are likely transported by wind and water from plants higher on the watershed or by wind from downstream plants. Offsite plants can be important seed sources (Uchytil 1989a, b). Very few seed-bearing willows occurred within the 5-km section of Pole Creek that includes the experimental pastures. However, new seedlings were observed each year in pastures with reduced grazing treatments. By 1990, average willow seedling density in these pastures was 2,054/ha of stream-affected vegetation, significantly exceeding the 212 seedlings/ha mean for control pastures that were grazed with the surrounding allotment.

Zasada (1986) commented that establishment of woody species on disturbed sites is related to stochastic events and availability of suitable microsites for germination and establishment. Seeds of Pacific willow and sandbar willow can be transported for considerable distances, but remain viable for only a short period, perhaps only 1 week. Moist mineral soils and light are required for germination (Hansen and others 1988a). Only those seeds that quickly encounter fresh sediment deposits or other saturated soil surfaces exposed to light and free of dense competing vegetation have an opportunity to germinate and establish. Consequently, germination and establishment are related to effects of grazing treatments on availability of suitable microsites as well as season and intensity of use of willow seedlings and competing vegetation. Variability in seed production from year to year, drought conditions, erratic summer flood events, and inherent differences in microsite availability within and between pastures with the

Table 2—Height distribution of Pacific and sandbar willows by grazing treatment, October 1990, Pole Creek Experimental Pastures

Species / Height class	Grazing treatment: Spring	Fall	Protected	Control
	Percent			
Salix lasiandra				
≤50 cm	73.0	68.8	70.4	100
51-100 cm	23.5	31.2	28.3	—
101-150 cm	3.4	—	1.3	—
Salix exigua				
≤50 cm	86.0	81.2	82.4	100
51-100 cm	13.3	17.5	15.8	—
101-150 cm	0.6	1.3	1.8	—

Table 3—Mean number of basal stems and mean crown diameters of Pacific willow and sandbar willow seedlings by grazing treatment, October 1990, Pole Creek Experimental Pastures

Grazing treatment	*Salix lasiandra* Basal stems	*Salix lasiandra* Crown diameter	*Salix exigua* Basal stems	*Salix exigua* Crown diameter
	No.	cm	No.	cm
Spring	1.7	[1]28.0a	1.5	18.2a
Fall	1.6	28.1a	1.5	21.8a
Protected	1.4	26.0a	1.5	22.3a
Control	1.5	11.9b	1.0	12.5b

[1]Within columns, means followed by the same letter do not differ ($p < 0.05$).

same grazing treatment are among factors not quantified in this study that may have had major impacts on willow seed and seedling distribution and survival.

Heavy browsing to this point has severely restricted vertical development as well as lateral spread of willow seedlings. Those few willows within the watershed that have grown out of reach of browsing animals rapidly develop spreading crowns, but new sprouts continue to be removed at ground level. Vertical and lateral development create bands of dense, well-rooted plants that bind the streambank, trap sediment, and improve physical characteristics of the stream and its associated riparian area, and provide habitat critical for improving faunal diversity along the stream and within the surrounding watershed (Finch 1987; Lindauer 1983; Thomas and others 1979).

Very little is known about the relative palatability of Pacific willow, sandbar willow, or their subspecies. Kufeld and others (1973) and Van Dersal (1938) reported that Pacific willow is highly palatable to mule deer in summer, but receives little use in winter. Sampson and Jesperson (1963) considered it to be of little value to livestock in California. However, Hansen and others (1988b) reported loss of vigor and plants from excessive use of Pacific willow by livestock in Montana. Van Dersal (1938) described sandbar willow as highly palatable to livestock, but not deer. Both willow species receive heavy use by elk and beaver (Gaffney 1941; Kindschy 1985; Kufeld 1973; Mozingo 1987; Patten 1968).

Browsing of both willow species was extremely heavy in all pastures along Pole Creek due to the extremely degraded condition of riparian areas along the stream, drought conditions prevailing throughout much of the study period, and the resulting scarcity of succulent vegetation. Consequently, differences in deer and cattle preference for the two species have not been distinguished. Additional years of study are required to determine whether willow seedlings of either species are capable of growing out of reach of browsing animals and develop normal growth habits.

CONCLUSIONS

Although there were almost no mature willows within the Pole Creek study area, seed dispersal from offsite plants was adequate to provide reasonable seedling densities of both Pacific willow and sandbar willow in all but the control pastures. Thus, disturbed riparian sites, particularly those that are heavily grazed, should be examined carefully for presence of new seedlings to determine whether the areas may recover naturally or whether artificial revegetation may be required.

After 4 years of treatment, density and growth of willow seedlings were greater in pastures with spring or fall grazing or protected from cattle grazing compared to season-long grazing (control) pastures. A similar pattern has been observed with respect to condition of streamside herbaceous communities and physical characteristics of the stream channel (Clary 1991).

Additional time will be required to allow full expression of any differences in response of willow seedlings to applied grazing treatments at Pole Creek and to determine whether willows subjected to any of these treatments are capable of growing beyond the reach of livestock and wildlife. Flash floods have seriously impacted seedling establishment and survival. The study pastures are small and subject to concentrated wildlife use. However, they are comparable in area to many riparian improvement projects, planting sites, and demonstration areas. Alterations in management plans at the watershed level may be necessary to dilute wildlife impacts and enhance rapid recovery of woody riparian species.

ACKNOWLEDGMENTS

I wish to thank the U.S. Department of the Interior, Bureau of Land Management, Vale District, Vale, OR, for providing study sites, pasture maintenance, and coordinating grazing treatments; permittees of the Poall Creek Grazing Allotment for providing cattle for grazing treatments; and members of the U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Riparian-Stream Ecosystems Project for their contributions to various aspects of this study.

REFERENCES

Argus, George W. 1973. The genus *Salix* in Alaska and the Yukon. Publications in Botany, No. 2. Ottawa, ON: National Museums of Canada, National Museum of Natural Sciences. 279 p.

Brunsfeld, Steven J.; Johnson, Frederic D. 1985. Field guide to the willows of east-central Idaho. Bull. 39. Moscow, ID: University of Idaho, College of Forestry, Wildlife and Range Sciences, Forest, Wildlife and Range Experiment Station. 82 p.

Clary, Warren P. 1987. Livestock effects on riparian vegetation and adjoining streambanks. Study Plan 4202-1-3. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 22 p. + appendices.

Clary, Warren P. 1989. Brief review of vegetation plot results on Pole Creek and Willow Creek. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. n.p.

Clary, Warren P. 1990. Differences in vegetation biomass and structure due to cattle grazing in a northern Nevada riparian ecosystem. Res. Pap. INT-427. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 8 p.

Clary, Warren P. 1991. Brief summary of 1990 general vegetation and stream channel results, Pole Creek, OR. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. n.p.

Crouse, M. R.; Kindschy, R. R. 1984. A method for predicting riparian vegetation potential of semi-arid rangelands. In: Proceedings; 1984 Pacific Northwest range management short course; range watersheds, riparian zones, and economics: interrelationships in management and use; Corvallis, OR. Corvallis, OR: Oregon State University. 83 p.

Dorn, Robert D. 1977. Willows of the Rocky Mountain States. Rhodora. 79: 390-429.

Finch, Deborah M. 1987. Bird-habitat relationships in subalpine riparian shrublands of the central Rocky Mountains. In: Troendle, Charles A.; Kaufmann, Merrill R.; Hamre, R. H.; Winokur, Robert P., tech. coords. Management of subalpine forests: building on 50 years of research: Proceedings of a technical conference; 1987 July 6-9; Silver Creek, CO. Gen. Tech. Rep. RM-149. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 167-172.

Gaffney, W. S. 1941. The effects of winter elk browsing, South Fork of the Flathead River, Montana. Journal of Wildlife Management. 5: 427-453.

Haeussler, S.; Coates, D. 1986. Autecological characteristics of selected species that compete with conifers in British Columbia: a literature review. Victoria, BC: Canadian Ministry of Forests, Information Services Branch. 180 p.

Hansen, Paul L.; Chadde, Steve W.; Pfister, Robert D. 1988a. Riparian dominance types of Montana. Misc. Publ. 49. Missoula, MT: University of Montana, School of Forestry, Montana Forest and Conservation Experiment Station. 411 p.

Hansen, Paul L.; Chadde, Steve; Pfister, Robert; [and others]. 1988b. Riparian site types, habitat types, and community types of southwestern Montana. Missoula, MT: University of Montana, School of Forestry, Montana Riparian Association. 140 p.

Kauffman, J. Boone; Krueger, W. C. 1984. Livestock impacts on riparian ecosystems and streamside management implications...a review. Journal of Range Management. 37: 430-437.

Kauffman, J. Boone; Krueger, W. C.; Vavra, M. 1983a. Effects of late season cattle grazing on riparian plant communities. Journal of Range Management. 36: 685-691.

Kauffman, J. Boone; Krueger, W. C.; Vavra, M. 1983b. Impacts of cattle on streambanks in northeastern Oregon. Journal of Range Management. 36: 683-685.

Kindschy, Robert R. 1985. Response of red willow (*Salix lasiandra*) to beaver use in southeastern Oregon, USA. Journal of Wildlife Management. 49: 26-28.

Kufeld, Roland C. 1973. Foods eaten by the Rocky Mountain elk. Journal of Range Management. 26: 106-113.

Kufeld, Roland C.; Wallmo, O. C.; Feddema, Charles. 1973. Foods of the Rocky Mountain mule deer. Res. Pap. RM-111. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 31 p.

Lindauer, Ivo E. 1983. A comparison of the plant communities of the North Platte and Arkansas River drainages in eastern Colorado. The Southwestern Naturalist. 28: 249-259.

Marlow, Clayton B.; Olson-Rutz, Kathrin; Atchley, Jennifer. 1989. Response of a southwest Montana riparian system to four grazing management alternatives. In: Gresswell, Robert E.; Barton, Bruce A.; Kershner, Jeffrey L., eds. Practical approaches to riparian resource management—an educational workshop; 1989 May 8-11; Billings, MT. Billings, MT: U.S. Department of the Interior, Bureau of Land Management: 111-116.

Mozingo, Hugh N. 1987. Shrubs of the Great Basin: a natural history. Reno, NV: University of Nevada Press. 342 p.

Patten, D. T. 1968. Dynamics of the shrub continuum along the Gallatin River in Yellowstone National Park. Ecology. 49: 1107-1112.

Patton, D. R. 1977. Riparian research needs. In: Johnson, R. R.; Jones, D. A., tech. coords. Importance, preservation and management of riparian habitat: a symposium. Gen. Tech. Rep. RM-43. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 80-82.

Platts, William S.; Armour, Carl; Booth, Gordon D.; [and others]. 1987. Methods for evaluating riparian habitats with applications to management. Gen. Tech. Rep. INT-221. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 177 p.

Sampson, Arthur W.; Jespersen, Beryl S. 1963. California range brushlands and browse plants. Berkeley, CA: University of California, Division of Agricultural Sciences, California Agricultural Experiment Station, Extension Service. 162 p.

Skovlin, Jon M. 1984. Impacts of grazing on wetlands and riparian habitat: a review of our knowledge. In: Natural Research Council/National Academy of Sciences. Developing strategies for rangeland management. Boulder, CO: Westview Press: 1001-1103.

Stephens, H. A. 1973. Woody plants of the North Central Plains. Lawrence, KS: The University Press of Kansas. 530 p.

Thomas, Jack Ward; Maser, Chris; Rodiek, Jon E. 1979. Wildlife habitats in managed rangelands—the Great Basin of southeastern Oregon, riparian zones. Gen. Tech. Rep. PNW-80. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 18 p.

Uchytil, Ronald J. 1989a. *Salix exigua*. In: Fischer, William C., compiler. The Fire Effects Information System [Data base]. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Intermountain Fire Sciences Laboratory. Magnetic tape reels; 9 track; 1600 bpi, ASCII with Common LISP present.

Uchytil, Ronald J. 1989b. *Salix lasiandra*. In: Fischer, William C., compiler. The Fire Effects Information System [Data base]. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Intermountain Fire Sciences Laboratory. Magnetic tape reels; 9 track; 1600 bpi, ASCII with Common LISP present.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration. 1986-1990. Climatological data Oregon. Asheville, NC: National Climatic Data Center. Vols. 92-96. n.p.

U.S. Department of the Interior, Bureau of Land Management, Vale District. 1982. Poall Creek allotment management plan 0103. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. n.p.

U.S. Department of the Interior, Bureau of Land Management, Vale District. 1987. Poall Creek allotment evaluation. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 3 p.

Van Dersal, William R. 1938. Native woody plants of the United States, their erosion-control and wildlife values. Washington, DC: U.S. Department of Agriculture. 362 p.

Van Haveren, B. P.; Jackson, W. L. 1986. Concepts in stream riparian rehabilitation. In: Transactions of the 51st North American Wildlife and Natural Resources Conference: 280-289.

Youngblood, Andrew P.; Padgett, Wayne G.; Winward, Alma H. 1985. Riparian community type classification of eastern Idaho-western Wyoming. R4-Ecol-85-01. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region. 78 p.

Zasada, J. 1986. Natural regeneration of trees and tall shrubs on forest sites in interior Alaska. In: Van Cleve, K.; Chapin, F. S., III; Flanagan, P. W.; [and others], eds. Forest ecosystems in the Alaska taiga: a synthesis of structure and function. New York: Springer-Verlag: 44-73.

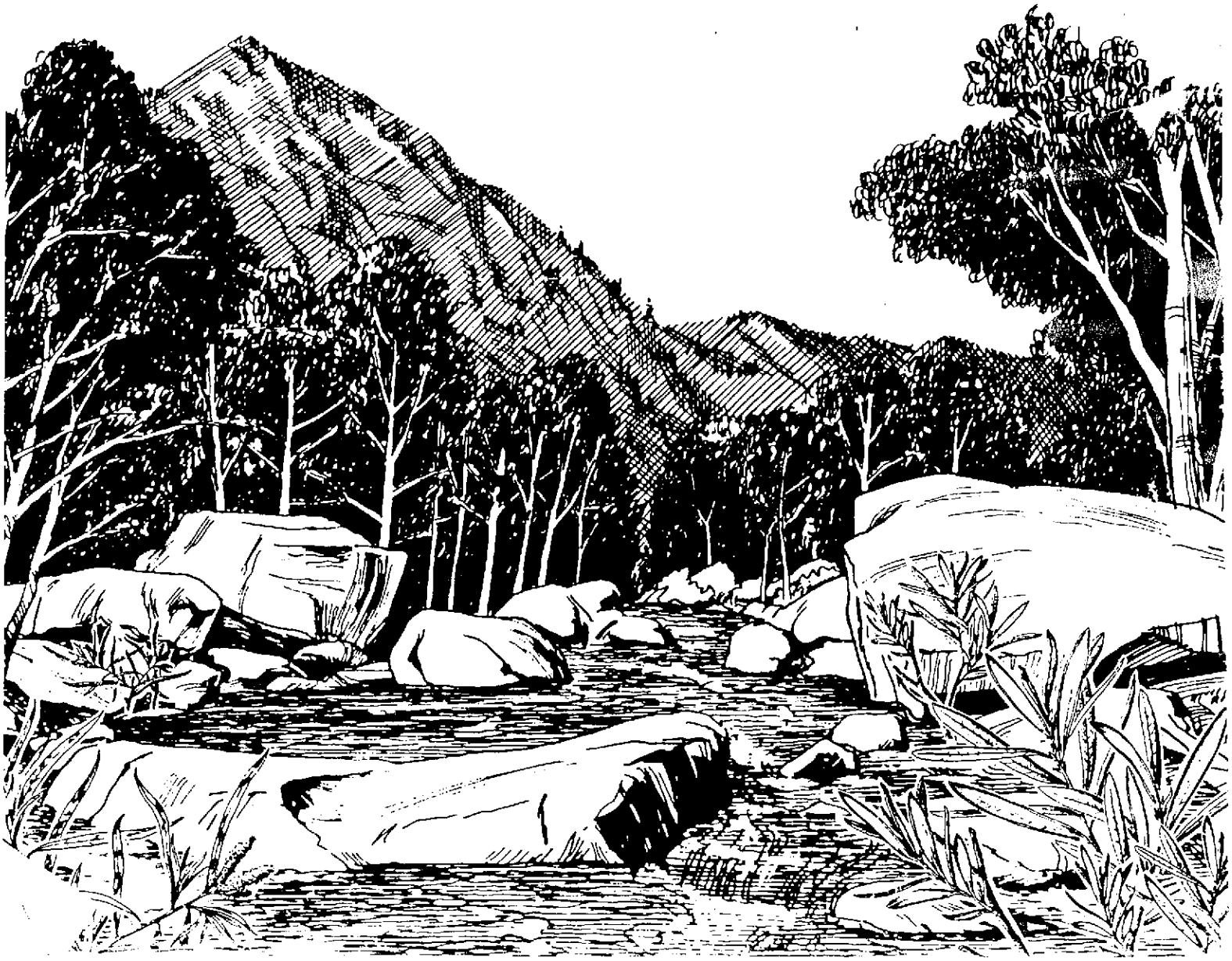
MASTER COPY

United States
Department
of Agriculture

Forest Service

**Intermountain
Research Station**

General Technical
Report INT-289

August 1992

Proceedings—Symposium on Ecology and Management of Riparian Shrub Communities