Structural Resilience Of A Willow Riparian Community

To Changes In Grazing Practices

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ABSTRACT

Many studies have shown that the diversity of an avian community is partly regulated by structural aspects of woody vegetation. The objective of this study was to quantify the impact of cattle (Bos taurus) on the physical structure of a high-altitude willow (Salix spp.) community in Colorado. Cattle altered the size, shape, volume, and quantities of live and dead stems of bushes. In addition, cattle also influenced the spacing of plants and the width of a riparian tract. In contrast to studies that indicate fish habitats respond quickly to changes in grazing practices, terrestrial habitats respond slowly. The willow community tolerated heavy grazing pressures well initially, but recovered slowly when damaged.

INTRODUCTION

Overgrazing by livestock is considered the most widespread cause of deterioration of riparian systems on public lands (Carothers 1977, Cope 1979). Studies of riparian sites have revealed rapid deterioration (bank erosion, siltation, etc.) of fish habitats soon after the introduction of cattle, but rapid recovery of those habitats with the removal of the cattle (Platts 1979, Behnke and Raleigh 1979).

Terrestrial species, particularly birds, are responsive to the vertical diversity of vegetation structure (MacArthur 1964, MacArthur and MacArthur 1961), especially at riparian sites (Whitmore 1975, Anderson and Ohmart 1977). Strong relations between avian diversity and horizontal patchiness of the vegetation have also been reported (Karr and Roth 1971, Roth 1976). Quantitative information on the responsiveness of willow vegetation, a common riparian community, to grazing impacts is unavailable.

The present study investigates the early response of a willow community to removal of grazing. Combined with a known history of grazing on the study area, the results also provide information on long-term impacts of grazing systems on the structure of terrestrial wildlife habitats in willow communities.

We thank E. C. Patten and W. J. Wilson, Manager and Assistant Manager, respectively, Arapaho National Wildlife Refuge (NWR), for permission to work on the refuge, support of the study, and access to data on grazing history at the refuge. J. F. Ellis and J. P. Ward provided field and technical assistance, respectively. R. Engeman and J. L. Oldemeyer offered advice with statistical interpretations.

STUDY AREA

The study was conducted at the Arapaho NWR. The refuge is at 2,492 m elevation in an intermountain glacial basin (North Park) of Jackson County, Colorado (Figure 1). Mean annual precipitation is 23.2 cm and the growing season has only 46 frost-free days (Smith 1966).

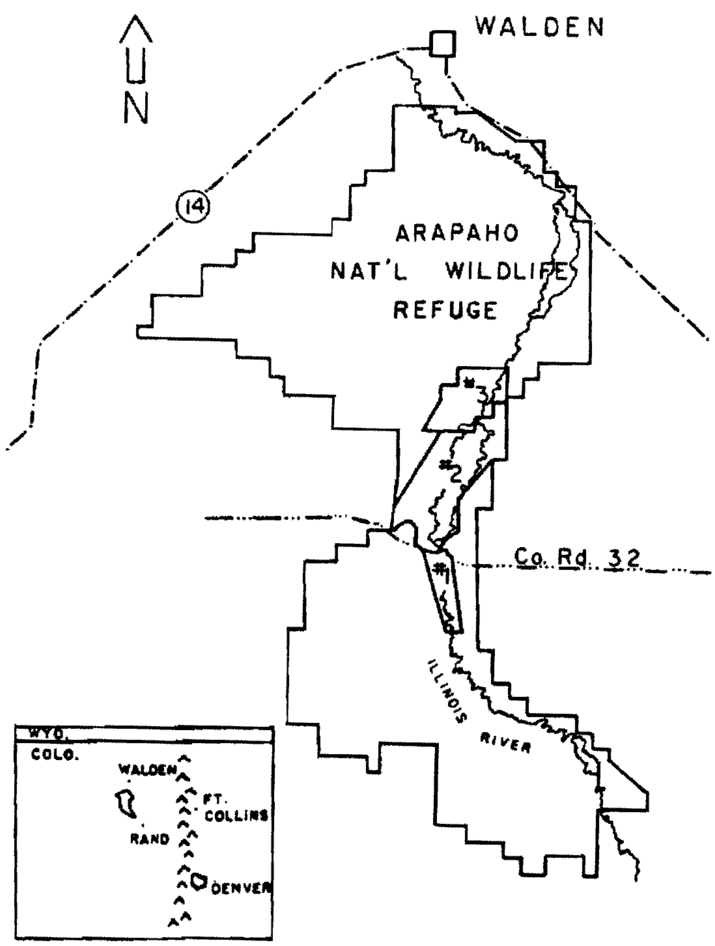

Figure 1. Location of experimental pastures on the Arapaho National Refuge, Jackson County, Colorado.

The study area made up portions of the refuge formerly known as the Allard ranch, having been purchased with Duck Stamp monies in July 1969. Our efforts concentrated on the Illinois River floodplain which was surrounded by sagebrush (Artemisia spp.) uplands. Species of willow (with respective canopy coverage) in the Illinois River drainage include Salix planifolia (24.6%), S. pseudocordata (16.3%), S. monticola (15.4%), S. subcoerulea (7.6%), and S. geyeriana (2.4%), based upon surveys conducted upstream from the refuge (R. A. Nowlin, personal communication). S. caudata also may occur on the refuge.

The Allard ranch contained pastures of 105, 351, and 219 ha at the time of purchase. Historically, pastures No. 1 and 2 were hay meadows, and were grazed only during the winter. Pasture 3 was used for summer seasonal grazing. From 1969 to 1977 all pastures were grazed each summer, and each pasture was rested for 2 years during that period (Table 1). In 1978 only pasture 3 was grazed and in 1979, only pasture 2. All pastures were rested in 1980. Thus pasture No. 2 was in its first year of rest, No. 3 in its second, and No. 1 in its fourth.

Table 1. Grazing history of experimental pastures at Arapaho National Wildlife Refuge, Jackson County, Colorado 1969-1980, expressed in animal unit months (AUMS) and animal unit months/hectare (AUMS/ha). The refuge was established in 1969.

Year	Pasture 1 (105 ha)		Pasture 2 (351 ha)		Pasture 3 (219 ha)	
	AUMS	AUMS/ha	AUMS	AUMS/ha	AUMS	AUMS/ha
1969	680	6.5	1197	3.4	764	3.5
1970	389	3.7	1580	4.5	703	3.2
1971	331	3.2	1792	5.1	720	3.3
1972	771	7.3	1280	3.7	608	2.8
1973	596	5.7	1422	4.1	0	0
1974	584	5.5	954	2.7	934	4.3
1975	0	0	1430	4.1	0	0
1976	777	7.4	0	0	750	3.4
1977	0	0	0	0	629	2.9
1978	0	0	148	0.4	524	2.4
1979	0	0	1482	4.2	0	0
1980	0	0	0	0	0	0

METHODS

During June and July 1980, we sampled vegetation at 50-m intervals along the Illinois River in each of the 3 pastures. At each interval a random distance perpendicular to the stream was measured to give a sample point for the vegetation inventory. This technique produced 120, 125, and 125 sample points for the 3 pastures.

For each random sampling point we recorded the width of the riparian tract as being 0-25, 26-50, 51-75, 76-100, or > 100 m, and the distance to the nearest willow bush (an index to density). The height and radius of the bush was also recorded. The number of branches hitting intercept lines divided into 1-dm intervals along N-S and E-W Cardinal directions (at a height 1/2 of the bush height) provided indices to the amount of live vs. dead material/bush. The bush was divided into quadrants by these cardinal directions, and for each quadrant we recorded distances from (1) outer edge of the bush to the outer edge of the nearest bush in that quadrant, (2) from the outer edge of that second bush to its basal center, and (3) the height of the outer bush. Also, at a point midway between the central bush and each outer bush we recorded the height at which the 2 bushes were closest (an index to bush shape) and obtained an index to the herbaceous vegetation biomass using the technique of Robel et al. (1970).

Data for each variable were summarized by pasture and tested relative to meeting assumptions for Analysis of Variance. We tested for homogeneity of variances using the residual plot technique (Draper and Smith 1967:90-91) and for normality of variances using the half-normal probability plot of residuals (Zahn 1975). Both of these techniques are graphical methods of appraising patterns of variability. Based on these tests we concluded that both assumptions were violated for most of our variables. We used the Kruskall-Wallis Distribution-Free test for evaluating differences in variables among the pastures. We tested differences between pair combinations of pastures using the Dunn Large Sample Approximation for calculating multiple comparisons (Dunn 1964). We tested the data on width of riparian using contingency tables.

We anticipated that grazing may influence the variability in many of the measured variables. For each random stake we calculated a standard deviation for those variables which were measured on the central bush and 4 outlying bushes, plus the 4 measurements/sampling point for height of separation and herbaceous biomass. These standard deviations were tested with the Kruskall-Wallis and Dunn Approximation techniques as above.

RESULTS

The analyses were designed to quantify changes in (1) the structure of individual bushes, (2) the horizontal and vertical patterning of the community, and (3) variability in these parameters within each pasture. The following discussion is based on comparisons among and between pastures (Table 2).

BUSH STRUCTURE

The structure of individual willow bushes was significantly different among pastures. Bushes were larger, both in height and radius, in pasture 3 but not significantly different in size between pastures 1 and 2.

We noted that grazing practices often removed lower branches from larger bushes. This affected the shape and, most importantly, foliage

Table 2. Comparison of willow bush structure, community structure, and structural variability between and among the 3 experimental pastures at Arapaho National Wildlife Refuge.

Variable	n			Mean rank difference			χ^2
Pasture(s):	1	2	3	1:2	1:3	2:3	(approximation)
Bush Structure							
Height	549	597	549	15.1	210.0*	194.9*	63.6*
Radius	550	597	549	26.2	122.6*	148.8*	29.6*
Foliage Volume	209	248	258	38.1	220.9*	182.8*	40.7*
No. Live Stems	115	126	122	36.0*	57.6*	21.6	18.1*
No. Dead Stems	115	126	122	6.5	63.9*	57.4*	27.1*
Community Structure							
Stake-Willow Distance	114	126	122	1.7	32.6	34.2*	8.3*
Willow-Willow Distance	545	583	538	23.9	69.4	93.3*	11.2*
Height Interspersion	115	126	122	16.4	71.8*	55.4*	30.9*
Herbaceous Height	545	583	537	0.6	67.8*	67.2*	7.2*
Structural Variability							
S.D. of Height	115	126	122	19.2	79.5*	60.3*	37.5*
S.D. of Foliage Volume	115	126	122	6.2	53.9*	47.8*	19.1*
S.D. of Willow-Willow Distance	115	126	122	8.5	12.5	21.0	2.5
S.D. of Herbaceous Height	115	126	122	22.9	17.1	40.0*	9.1*

* $P < 0.05$

volume of a bush. We assumed that a willow bush was the shape, and contained the volume, of a hemisphere and we used the height from the ground at which 2 adjacent bushes were closest together as an index to the quantity of foliage removed. Since the height of bushes was different among pastures, we restricted the analysis to bushes which were > 2 m. As with the measures of bush size, the volume of foliage removed was different among pastures, and was significantly greater in pasture 3.

Willow bushes within the pastures also varied in the quantities of live and dead material. Bushes in pasture 1 had more live branches/bush than in the other pastures. Bushes in pasture 3 had more dead branches. Bushes in pasture 2 were intermediate in both of these comparisons.

COMMUNITY STRUCTURE

At each of the randomly located stakes we arbitrarily classified the width of the willow community. Riparian width was significantly different among pastures ($\chi^2 = 210.0$; $\underline{P} < 0.01$). We were unable to statistically test differences between pairs of pastures, but concluded that the riparian community was substantially narrower in pasture 3 than either of the other pastures. These conclusions are based on comparison of frequencies and percentages of occurrence for the various width intervals in each pasture (Table 3).

We calculated 4 measures of community structure. The distance from a randomly located stake to the nearest willow bush and the distance between a willow bush and its nearest neighbor in each quadrant were treated as indices to bush density. The 2 indices provided us similar results: densities differed significantly among pastures. Between pastures, bushes in pasture 3 were significantly further apart (at lower densities) than in pasture 2. The comparison of pasture 3 to pasture 1 approached statistical significance ($\underline{P} = 0.06$ and $\underline{P} = 0.07$, respectively). Since the Kruskall-Wallis test is conservative, we interpreted these differences as having biological significance.

Table 3. Frequency comparison of the width of the willow riparian community for study pastures at Arapaho National Wildlife Refuge.

Pasture	Riparian Width (m)				
	0-25	26-50	51-75	76-100	>100
1	3	3	8	28	73
2	16	3	9	8	90
3	65	31	13	8	5

Many wildlife species select the interspersion of structural features for habitats. As an index to height interspersion of willow bushes in the community, we calculated the difference in range of bush heights recorded at each of the randomly located stakes. Again, differences were significant among pastures, and pasture 3 had the greatest mean range in bush heights.

The height of herbaceous cover also varied among pastures; pasture 3 had less cover than either pasture 1 ($P = 0.07$) or pasture 2 ($P = 0.06$). Herbaceous cover was similar in pastures 1 and 2.

STRUCTURAL VARIABILITY

The diversity of many wildlife communities increases with structural variability of the vegetative community. We examined the structural variability of selected parameters by calculating the standard deviation of measurements recorded at each of our randomly located stakes, and tested those values with the same nonparametric techniques.

Variability in the height of bushes and the index to foliage volume removed from bushes differed among pastures. The calculation of the index to foliage volume removed was not restricted to large bushes as before since we wanted an index to the total willow community and small vs. large bushes are a major component of that variability. As in tests for structural similarities, differences in variability of structural measures were significantly greater in pasture 3 than in pastures 1 and 2, which were similar.

Although the pastures differed in estimates of bush densities, variability in density (interbush distance) was comparable among and between pastures. The structure of the herbaceous layer, however, varied. Comparisons between pastures showed the difference was only significant when pasture 2 was compared with pasture 3.

DISCUSSION

This study was designed to monitor the response of a high-altitude willow community to the removal of grazing by domestic cattle. Measurements of most structural parameters, however, failed to detect a single significant trend among pastures rested from grazing 1, 2, and 4 years. Contrarily, the analyses revealed that the pastures in their first and fourth year of "recovery" were virtually identical, whereas the pasture (No. 3) in its second year of rest differed in almost every structural parameter.

Analyses of bush structure indicated that pasture 3 was a decadent willow stand. The bushes were larger in that pasture, and they contained fewer live branches and more dead branches than in pastures 1 and 2. The greater variability in bush size, which normally indicates a more diverse community, actually was due to large proportions of very large and very small bushes in pasture 3. Distribution histograms (Figure 2) of height intervals for pastures 1 and 2 approached normality, being skewed slightly to the right. The distribution of heights in pasture 3 was bimodal; the major peak occurred in the middle of the range of values with a secondary peak among smaller height classes.

In pasture 3, comparisons of community structure and variability did not particularly indicate decadence, but rather, a community which had experienced a major or prolonged disturbance relative to pastures 1 and 2. The woody riparian community in this pasture was narrower and less dense than in pastures 1 and 2. Although inconclusive, data on the herbaceous community indicated a tendency towards greater patchiness, apparently from different historical use of the pasture.

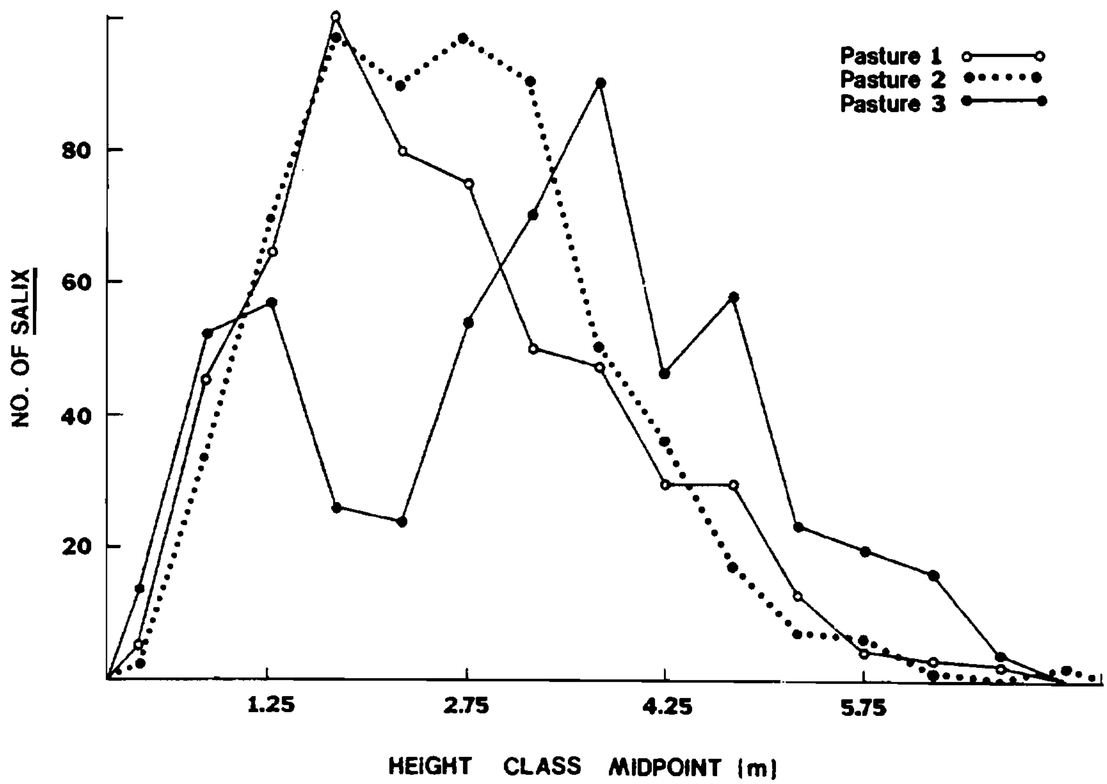

Figure 2. Distribution of height intervals of willow bushes in pastures 1-3, Arapaho National Wildlife Refuge, 1980.

The conclusion of differential disturbance was initially confusing, because the pastures had similar grazing treatments over a 12-year period. However, the foliage volume index, which was calculated only on larger (older) plants, still followed the differential pattern seen among pastures for other structural variables. This observation implied that pastures 1 and 2 were managed differently than pasture 3 under the ownership of the Allard ranch before refuge establishment.

Examination of the grazing practices of the Allard ranch revealed that pastures 1 and 2 historically were hay meadows which were grazed in winter, and pasture 3 was seasonally grazed in summer. In North Park, riparian sites often fill with snow in winter which preclude cattle from entering the woody vegetation. The cattle likely would spend less time in the willow in winter anyway since they are fed supplementally and would not seek shade under the bushes as they do in summer. The "notching" of larger bushes in pasture 3 appeared to be the consequence of both grazing and mechanical breakage of the lower branches by cattle seeking shade in summer. These explanations of the observed patterns in willow structure concur with

Severson and Boldt (1978), who concluded that grazing pressures on woody vegetation are greater in summer than winter.

The significance of our study, however, relates to how the willow community responded to the 2 changes in grazing practices: (1) recovery from a similar 12-year history of grazing with removal of cattle for up to 4 years, and (2) recovery from different historical grazing patterns with 12 years of similar treatments. The similarity of pastures in their first and fourth years after removal of grazing indicated that the willow communities were in good condition and capable of tolerating heavy grazing pressures, at least initially. Alternatively, the dramatic differences observed in the bush and community structures of pasture 3 indicated that willow communities which are in poor condition are slow to respond to changes in grazing practices, including total removal of cattle. Duff (1978) hinted at this slow response when he reported willow growth of 50 cm after 4 years of protection from grazing in Utah. In contrast to the studies cited earlier which indicate fish habitats change rapidly with the introduction or removal of cattle into riparian tracts, terrestrial wildlife habitats respond slowly. Terrestrial habitats are more resilient to changes in grazing practices.

Our study quantitatively supports 2 speculations by Myers (1981). First, 10-12 years is insufficient time for a willow riparian community to recover from a history of excessive grazing. Second, it is more difficult to improve a damaged or poor condition riparian habitat than it is to maintain a good riparian habitat while grazing a site. It follows that studies of riparian systems should be careful that historical grazing practices do not obscure the results of experimental evaluations of grazing impacts.

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