REEVALUATION OF VEGETATIVE COVER CHANGES, EROSION, AND SEDIMENTATION ON TWO WATERSHEDS—1912-1983

Richard Stevens
E. Durant McArthur
James N. Davis

ABSTRACT

Watersheds A and B, on two adjoining depleted subalpine watersheds at the head of Ephraim Canyon, UT, have been under continuous study since 1912. Watershed A has been protected from grazing since 1920. This protection resulted in a rapid increase in plant cover on all but the more depleted areas. Although Watershed A is still in marginal condition, increase in plant cover has resulted in substantial reduction in runoff and sedimentation. In Watershed B, heavy grazing reduced ground cover and changed a fairly stable watershed to a serious flood-source area. Immediate control of summer runoff and sedimentation was achieved with disking, contour trenching, and seeding of grasses and leguminous forbs. Watershed B would now support controlled livestock use without producing runoff and erosion. Watershed stabilization can be much more rapidly accomplished using restoration techniques than long periods of nonuse. Both systems have a place, depending on the urgency of restoration and management objectives.

INTRODUCTION

Two small, depleted watersheds in Ephraim Canyon, UT, on the Great Basin Experimental Range, have been studied since 1912. Research in the watersheds has obtained information on the influence of herbaceous cover and litter on surface runoff, erosion, and sedimentation.

Watershed A has been closed to grazing since 1920, and no restoration techniques have been used to enhance cover. Watershed B was exposed to grazing and cover loss before 1952 when it was disked, trenched, and seeded. Management techniques in Watershed B have restored cover and stability to levels that will allow controlled grazing.

This paper outlines these two approaches to watershed restoration and their results in these two Ephraim Canyon watersheds by evaluating changes in cover type, erosion, and sedimentation in the years 1952, 1958, 1961, and 1983.

LOCATION

Two small complete watersheds named A and B, located in the head of Ephraim Canyon, Sanpete County, UT, have been under continuous study since 1912.

The two watersheds are located about 900 ft apart in a subalpine vegetative zone at 10,000-ft elevation on the crest of the Wasatch Plateau. Both watersheds are complete, separate, and isolated. Neither has a permanent stream. Watershed A average slope is 18.5 percent and occupies 11 acres. Watershed B average slope is 16.3 percent and covers 9 acres (Meeuwig 1960).

Ellison (1954) stated that heavy grazing and accelerated erosion have changed the characteristics of surface soil in much of the Wasatch Plateau subalpine zone. Forsling (1931) estimated that a few inches to as much as 3 ft of soil had been removed from Watersheds A and B prior to 1912. Soils are residual clay and clay loams derived from limestone and bituminous shales.

Precipitation varies considerably, but averages 36 inches annually, with the majority coming as snow (Price and Evans 1937). An average of 6 inches of rain falls during the summer growing season. During July and August high-intensity localized storms occur.

Prior to introduction of livestock in the 1880's Ellison (1954) characterized the subalpine community on the Wasatch Plateau. Seventy to 80 percent of the vegetation consisted of the following broadleaf species: small-leaf angelica (*Angelica pinnata*), Colorado columbine (*Aquilegia caerulea*), rhexia-leaved paintbrush (*Castilleja leonardii*), sulphur painted-cup (*C. sulphurea*), Oregon fleabane (*Erigeron speciosus*), wallflower (*Erysimum elatum*), oneflower helianthella (*Helianthella uniflora*), Utah peavine (*Lathyrus utahensis*), Porter ligusticum (*Ligusticum porteri*), tall bluebell (*Mertensia leonardii*), sweetanise (*Osmorhiza occidentalis*), leafy polemonium (*Polemonium foliosissimum*), low goldenrod (*Solidago ciliosa*), edible valeriam (*Valeriana edulis*), and western valerium (*V. occidentalis*). The remaining vegetation consisted of slender wheatgrass (*Agropyron trachycaulum*), nodding brome (*Bromus anomalus*), mountain brome (*B. carinatus*), oniongrass (*Melica bulbosa*), and mutton bluegrass (*Poa fendleriana*) with only a few shrubs, trees, and annuals.

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Richard Stevens is Project Leader and Research Biologist, Great Basin Experiment Station, Utah Division of Wildlife Resources, Ephraim, UT 84627; E. Durant McArthur is Project Leader and Chief Research Geneticist, Shrub Sciences Laboratory, Intermountain Research Station, Forest Service, U.S. Department of Agriculture, Provo, UT 84606; James N. Davis is Research Biologist, Shrub Sciences Laboratory, Utah Division of Wildlife Resources, Provo, UT 84606.

Ellison (1954) also listed the following species that characterized depleted areas on the plateau: Louisiana sage (*Artemisia ludoviciana*), Richardson geranium (*Geranium richardsonii*), tarweed (*Madia glomerata*), Rydberg penstemon (*Penstemon rydbergii*), Letterman needlegrass (*Stipa lettermanii*), and common dandelion (*Taraxacum officinale*).

Local areas on the Wasatch Plateau have (and had in 1912) different proportions of these and other species. On open areas with deeper soils, tall forbs predominated.

Plant nomenclature follows Plummer and others (1977) and Welsh and others (1987).

METHODS

Vegetative cover of Watersheds A and B has been manipulated with sheep and cattle since 1912 (Forsling 1931; Keck 1972; Meeuwig 1960, 1970; Sampson and Weyl 1918; Stewart and Forsling 1931).

In 1912, Watershed A live cover had been depleted to 16 percent. This was mostly broadleaf herbs. Watershed B cover was reduced to about 40 percent, consisting of a mixture of broadleaf herbs and perennial grasses. Both watersheds were maintained at these levels of live vegetative cover with controlled grazing, using sheep, through eight seasons to 1919. In 1920, livestock were excluded permanently from Watershed A and the range has been allowed to recover naturally since then. From 1920 to 1930 Watershed B was maintained at about 40 percent cover by controlled grazing. By 1924, Watershed A had recovered to an average of about 40 percent cover, similar to that of Watershed B. Between 1924 and 1930 Watershed A cover remained at 40 percent and Watershed B was held to 40 percent. Starting in 1931 Watershed B was exposed to heavy grazing in an effort to reduce cover to the 1912 Watershed A level of 16 percent. This effect was accomplished by 1950. Late in the fall of 1952 Watershed B was disked, some contour furrows were installed on the steeper slopes and the area was seeded at a rate of 20 pounds to the acre. The seed mixture included smooth brome (*Bromus inermis*), meadow foxtail (*Alopecurus pratensis*), orchardgrass (*Dactylis glomerata*), mountain brome (*B. carinatus*), meadow brome (*B. erectus*), 'Nomad' alfalfa (*Medicago sativa*), mountain lupine (*Lupinus alpestris*), and cicer milkvetch (*Astragalus cicer*). Livestock have not grazed Watershed B since it was seeded.

Sediment catchment basins were constructed in 1914 at the lower end of each watershed to measure surface runoff and sedimentation. Larger basins were subsequently built to accommodate the larger volumes of soil that were being delivered (fig. 1).

Vegetative surveys have been made periodically since 1912. Surveys prior to 1951 only estimated or measured live cover. In the early years, the reconnaissance method was employed (Sampson and Weyl 1918). Forsling (1931) used the point method (Levy and Madden 1933) on permanently established transects. Sampling was done along six 98.5-ft transects per watershed in 1983. Ten quadrats (3.281 ft^2) per transect were placed at 3-m intervals along each transect beginning at the 0 point and alternating from the right to the left side of the survey tape. Cover was determined within each 3.281-ft^2 quadrat for each species using a procedure slightly modified from that described by Daubenmire (1959). The modification consisted of adding one extra cover class with a limit of 0 to 1 percent.

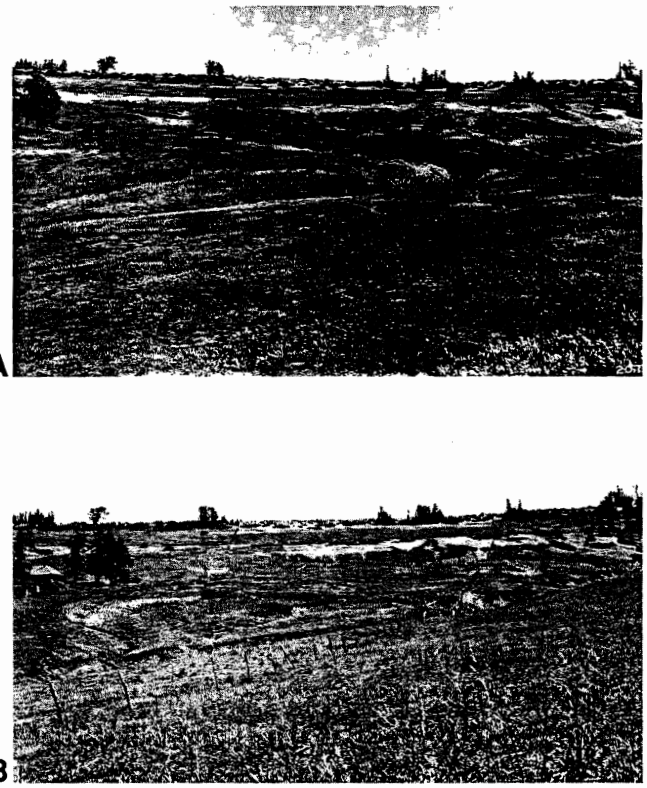

Figure 1—Overall view of Watershed B and buildings over sediment catchment basins in: (A) the fall of 1924 and (B) following grazing treatment in 1946.

Analysis of variance with the Student-Neman-Keuls multiple range test was used on the 1957, 1961, and 1983 data.

RESULTS

1912 to 1920—Using sheep, Watershed A vegetative cover was maintained at about 16 percent (fig. 2) and Watershed B cover at about 40 percent. During this period, Watershed A produced six times as much runoff and five times as much sediment as Watershed B (table 1). This period of study was summarized by Sampson and Weyl (1918).

1921 to 1923—Sheep were used to maintain Watershed B at 40 percent cover. Sheep were excluded from Watershed A, and its herbaceous cover recovered from 16 percent to about 30 percent by 1923 and up to 40 percent by 1924. Vegetative recovery on most of Watershed A was fairly rapid, resulting in considerably less runoff and sediment. The more severely depleted steep area, however, showed little improvement (fig. 2). Even with vegetative improvement, Watershed A produced almost three times as much surface runoff and sediment as Watershed B (table 1).

1924 to 1930—Watershed A was ungrazed and cover persisted at 40 percent. Watershed B was grazed to maintain 40 percent cover (fig. 1). Vegetative composition on the two watersheds was somewhat different; B had considerably

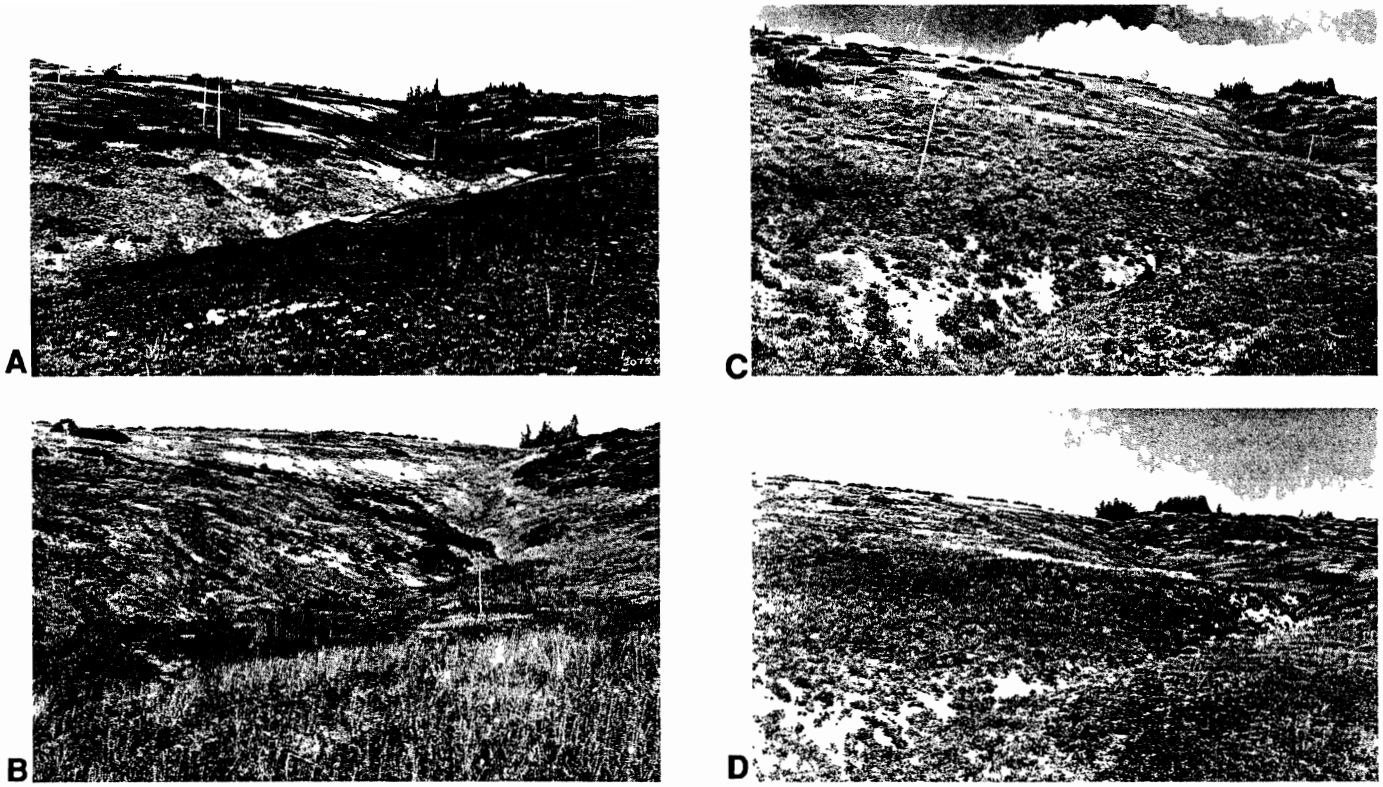

Figure 2—Watershed A in: (A) 1915, (B) 1924, (C) 1940, and (D) 1958.

more perennial forbs and bunchgrasses than A. Watershed A also had steeper areas that were fairly bare and subject to erosion. Forsling (1931) and Stewart and Forsling (1931) summarized work up to 1931.

1931 to 1952—It was felt that the influence of herbaceous cover on surface runoff and erosion could be determined more conclusively if plant cover on Watershed B was reduced to Watershed A's percent cover in 1912 (Meeuwig 1960). During this period Watershed A was ungrazed, and cover remained at 40 percent (fig. 2). Watershed B was heavily grazed by sheep (no grazing during World War II, 1942-45) to reduce plant cover to about 16 percent. This reduction in plant cover resulted in Watershed B producing an average 25 percent more runoff and 40 percent more sediment than Watershed A in 1951. Runoff and sedimentation on A decreased during these years (table 1). Reduction in plant cover and resulting increase in erosion and runoff on Watershed B substantiates the importance herbaceous cover has on watershed stabilization.

1953 to 1957—No grazing occurred on Watershed A. Vegetative cover remained at about 40 percent; most plants were broadleaf herbs (fig. 2). Very little sedimentation has come off A since 1953 (table 1). There has, however, been some summer runoff associated with summer storms. To determine how effective revegetation efforts are in reducing erosion and runoff Watershed B was plowed, furrowed on the steeper slopes, and seeded during the fall of 1952 (fig. 3). The 1952 treatment on Watershed B produced three major results: (1) no summer runoff or sedimentation after 1953, (2) vegetative community changed from basically a broadleaf herb to a strong grass stand, and (3) gully systems that were prominent were broken up by disking, trenching, and seedling establishment (fig. 3).

Prior to the 1952 restoration treatment on Watershed B, broadleaf herbs accounted for two-thirds of the total vegetative cover. Species in order of abundance in 1952 are given in table 2. Six years following treatment only 6 percent of the vegetative cover consisted of broadleaf herbs, with Louisiana sage being the major forb species. Seeded species made up 90 percent of the vegetation. Meeuwig (1960) summarized data from 1912 to 1958.

1958 to 1983—No grazing occurred on either watershed. As shown in table 3, vegetative cover on Watershed A remained nearly the same until 1983 when it increased significantly. On Watershed B, cover significantly increased in both 1961 and 1983. There was a significant difference in percent vegetative cover between Watersheds A and B in 1958 but no difference between watersheds in 1961 and 1983.

Percent rock (table 3) between 1958, 1961, and 1983 did not significantly change within either watershed or between watersheds. Litter (table 3) percent did not change on Watershed A between 1958, 1961, and 1983. On Watershed B there were significant decreases between 1958, 1961, and 1983. Watershed B, however, had significantly more litter than Watershed A in 1958, 1961, and 1983. Amount of bare ground did not change on Watershed A or B from 1958 through 1961. However, both watersheds had significantly less bare ground in 1983 than

Table 1—Grazing treatments, average percent live plant, litter cover, and average annual summer storm runoff and sediment production for Watersheds A and B, 1915 to 1983 (1915 to 1958 data from Meeuwig [1960])

Year	Grazing treatment	Average percent cover			Average annual summer ft³/ac/yr	
		Live plant	Litter	Total	Sediment	Runoff
		Watershed A				
1915-20	heavy use	16			134	913
1921-23	no use	30			105	922
1924-30	no use	40			24	362
1931-45	no use	40			20	445
1946-50	no use	40			3	64
1951	no use	44	12	56	3	63
1952	no use	40			16	291
1953[1]	no use	40			60	1,662
1957	no use	40	16	56	T	2
1958	no use	37	17	54	T	17
1961	no use	33	19	52	0	0
1983	no use	53	15	68	0	0
		Watershed B				
1915-20	med. use	40			25	153
1921-23	med. use	40			37	260
1924-30	med. use	40			10	171
1931-45		30			29	556
1931-41	heavy use					
1942-45	no use					
1946-50	heavy use	16			36	288
1951	heavy use	14	6	20	102	396
1952[2]	heavy use	15			100	1,376
1953	no use	30			6	553
1957	no use	33	28	61	0	0
1958	no use	25	32	57	0	0
1961	no use	31	26	57	0	0
1983	no use	41	22	63	0	0

[1]Summer storm intensity was the greatest recorded on the watersheds. Intensity of 2.2 inches/h for a 20-minute period.

[2]In October of 1952 Watershed B was disked, trenched on steeper slopes, and seeded to a mixture of grasses and forbs.

Figure 3—Watershed B in: (A) fall 1952 following disking, trenching, and seeding, (B) August 1953 following the highest intensity storm ever recorded and (C) 1954, two growing seasons following seeding.

in 1958 or 1961. There was no difference in percent bare ground between watersheds in any of the 3 years.

The five most abundant species, in order of abundance as determined by percent cover, changed more on Watershed A than on Watershed B (table 2). Watershed A had more species than did Watershed B in all years (table 4). Watershed A had considerably more forbs and fewer grass species than did Watershed B.

In 1958 only 17 ft³/acre of summer runoff and no sediment came off Watershed A. No runoff or sediment was measured off Watershed A in 1961 and 1983, or Watershed B in 1958, 1961, and 1983.

Vegetative cover was closely associated with amount of precipitation on Watersheds A and B. Average water year precipitation on the watersheds over 56 years (1927 through 1983) is 35.95 inches. Precipitation in 1958 (37.79 inches) and 1961 (37.70 inches) was close to average and considerably lower than 1983 (51.72 inches) precipitation. Vegetative cover was significantly higher on A and B in 1983 than in either 1958 or 1961.

CONCLUSIONS

Runoff and sedimentation on Watersheds A and B are closely associated with vegetative and litter cover. The same associations have also been determined in a number of vegetative types (Dadkhah and Gifford 1990; Gifford 1973, 1985; Meeuwig 1960, 1970; Osborn 1956; Packer 1951; Ward and Bolton 1991; Ward and others 1990; Williams and others 1969, 1972). Infiltration rate and amount of infiltration have also been demonstrated to be positively affected by cover and litter (Blackburn 1973; Orr 1957; Pearse and Wooley 1936; Renard 1970).

Early work on Watersheds A and B (Meeuwig 1960) demonstrated that as cover increases runoff and sedimentation

Table 2—Percent cover of principal species on Watersheds A and B, 1952, 1958, 1961, and 1983

Species	Watershed A			Watershed B			
	1958	1961	1983	1952	1958	1961	1983
Achillea millefolium	[1]1.4[a]	0.9[a]	14.2[a]		0.4[a]	0.3[a]	7.7[b]
			[2](1)	(1)			(3)
Agropyron trachycaulum	2.8[a]	2.3[a]	6.6[b]		2.8[a]	2.4[ab]	0.6[b]
	(3)	(4)	(5)		(4)	(4)	
Alopecurus pratensis					3.8[a]	4.6[a]	0.0[b]
					(3)	(3)	
Aster foliaceus	2.6[a]	0.5[a]	5.7[b]		0.0[a]	0.0[a]	2.5[b]
	(4)						
Artemisia ludoviciana	2.4[a]	2.0[a]	7.3[b]		0.7[a]	1.2[a]	3.3[b]
	(5)	(5)	(4)			(5)	
Bromus inermis					7.0[b]	12.1[a]	14.2[a]
					(1)		(1)
Dactylis glomerata					1.9[b]	0.6[a]	0.5[a]
					(5)		
Eriogonum umbellatum	2.4[a]	2.0[a]	0.1[a]				
	(5)	(5)					
Geranium fremontii	1.9[a]	2.0[a]	2.5[a]				
		(5)					
Lesquerella utahensis				(2)			
Ligusticum porteri	1.7[a]	1.4[a]	0.7[a]				
Lupinus alpestris	2.2[a]	3.8[a]	5.8[a]		0.4[a]	0.3[a]	4.3[b]
		(1)					(5)
Medicago sativa					0.7[a]	1.2[a]	0.0[a]
						(5)	
Penstemon rydbergii	1.6[a]	1.7[a]	4.1[a]				
Phleum pratense					0.1[a]	0.1[a]	9.1[b]
				(5)			(2)
Poa pratensis	0.9[a]	0.2[a]	5.6[b]		0.1[a]	0.0[a]	2.0[b]
Pseudocymopterus montanus					0.2[a]	0.5[a]	2.0[b]
Ribes montigenum	3.0[a]	2.4[a]	0.0[a]		0.4[a]	0.2[a]	0.0[a]
	(2)	(3)					
Stipa lettermanii	0.8[a]	1.3[a]	9.8[b]		4.2[a]	5.7[a]	4.6[a]
			(2)	(4)	(2)	(2)	(4)
Taraxacum officinale				(3)			
Viguiera multiflora	4.0[a]	3.5[a]	8.1[b]		0.2[a]	0.4[a]	3.0[b]
	(1)	(2)	(3)				

[1]Numbers in a watershed within the same line followed by the same letters are not significantly different at ($P < 0.05$).

[2]Numbers in parentheses signify the top five plant species, in order of percent cover, for 1952 (before treatment), 1958, 1961, and 1983.

decrease. When cover decreases the reverse occurs. The forb community of Watershed A has not been grazed since 1920. It took at least 34 years for Watershed A to be stabilized to the point where vegetation and litter were sufficient to intercept and detain surface moisture with no runoff or sedimentation occurring. All runoff and sedimentation was stopped on Watershed B in 1 year with an artificial restoration treatment that included seeding with stabilizing perennial grasses and forbs. The highest intensity storm ever recorded on the Watersheds occurred the summer (1953) following disking, trenching, and seeding of Watershed B. Even with 33 years of protection from grazing, Watershed A produced 60 ft^3/acre of sediment and 1,662 ft^3/acre of runoff water from the storm. The freshly disturbed and seeded Watershed B only produced 6 ft^3/acre of sediment and 553 ft^3/acre of runoff water from the same storm.

Difference in percent vegetative cover on Watersheds A and B was not significant ($P > 0.05$) in 1961 and 1983. There was, however, considerable difference in vegetative community composition; A consisted mainly of forbs that do not produce much in-place litter and B supported primarily grasses that produce much more in-place litter. Difference in the type and amount of litter produced between the watersheds is reflected in significantly greater amounts of cover on Watershed B in 1958, 1961, and 1983 than on Watershed A.

Meeuwig (1960), reporting on the condition of the watersheds in 1958, concluded that Watershed A was in marginal condition and would deteriorate if subjected to more than light grazing and that Watershed B appeared to be stable enough to support some degree of controlled grazing. In our judgment, conditions of the watersheds in 1961 and 1983 remained similar to 1958 conditions with respect to animal-carrying capacity and soil stability.

Riparian areas are directly affected by upland site conditions. Management that may include no grazing, limited grazing, or artificial restoration can stabilize erosive areas and reduce sedimentation and destructive, erosive runoff to downslope riparian areas.

Table 3—Vegetation, rock, litter, and bare ground cover percent on Watersheds A and B in 1958, 1961, and 1983

Cover	Watershed A			Watershed B		
	1958	1961	1983	1958	1961	1983
Vegetative	[1]37.1[a]	33.3[a]	52.8[b]	24.5[a]	30.7[b]	41.1[c]
Rock	10.9[a]	10.9[a]	8.3[a]	11.1[a]	11.6[a]	17.4[a]
Litter	16.5[a]	18.8[a]	15.1[a]	31.5[a]	25.6[b]	22.3[c]
Bare ground	34.6[a]	36.9[a]	23.8[b]	32.0[a]	33.1[a]	19.3[b]

	1958		1961		1983	
	Watershed		Watershed		Watershed	
	A	B	A	B	A	B
Vegetative	37.1[a]	24.8[b]	33.3[a]	30.7[a]	52.8[a]	41.1[a]
Rock	10.9[a]	11.1[a]	10.9[a]	11.6[a]	8.3[a]	17.4[a]
Litter	16.5[a]	31.5[b]	18.8[a]	25.6[b]	15.1[a]	22.3[b]
Bare ground	34.6[a]	32.0[a]	36.9[a]	33.1[a]	23.8[a]	19.3[a]

[1]Numbers within the same line followed by the same letters are not significantly different ($P < 0.05$).

Table 4—Number of species encountered on Watersheds A and B in 1958, 1961, and 1983

	Watershed A			Watershed B		
	1958	1961	1983	1958	1861	1983
Total number of species	43	46	43	32	32	34
grasses	[1]7(16)	8(17)	7(16)	12(38)	10(31)	9(26)
forbs	34(79)	36(80)	36(84)	19(59)	21(66)	25(74)
shrubs	2(5)	2(4)	0(0)	1(3)	1(3)	0(0)

[1]Number in parentheses is percent of total cover.

This long-term study has demonstrated that management practices can stabilize depleted subalpine range through long periods of nonuse or rapidly with restoration techniques.

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