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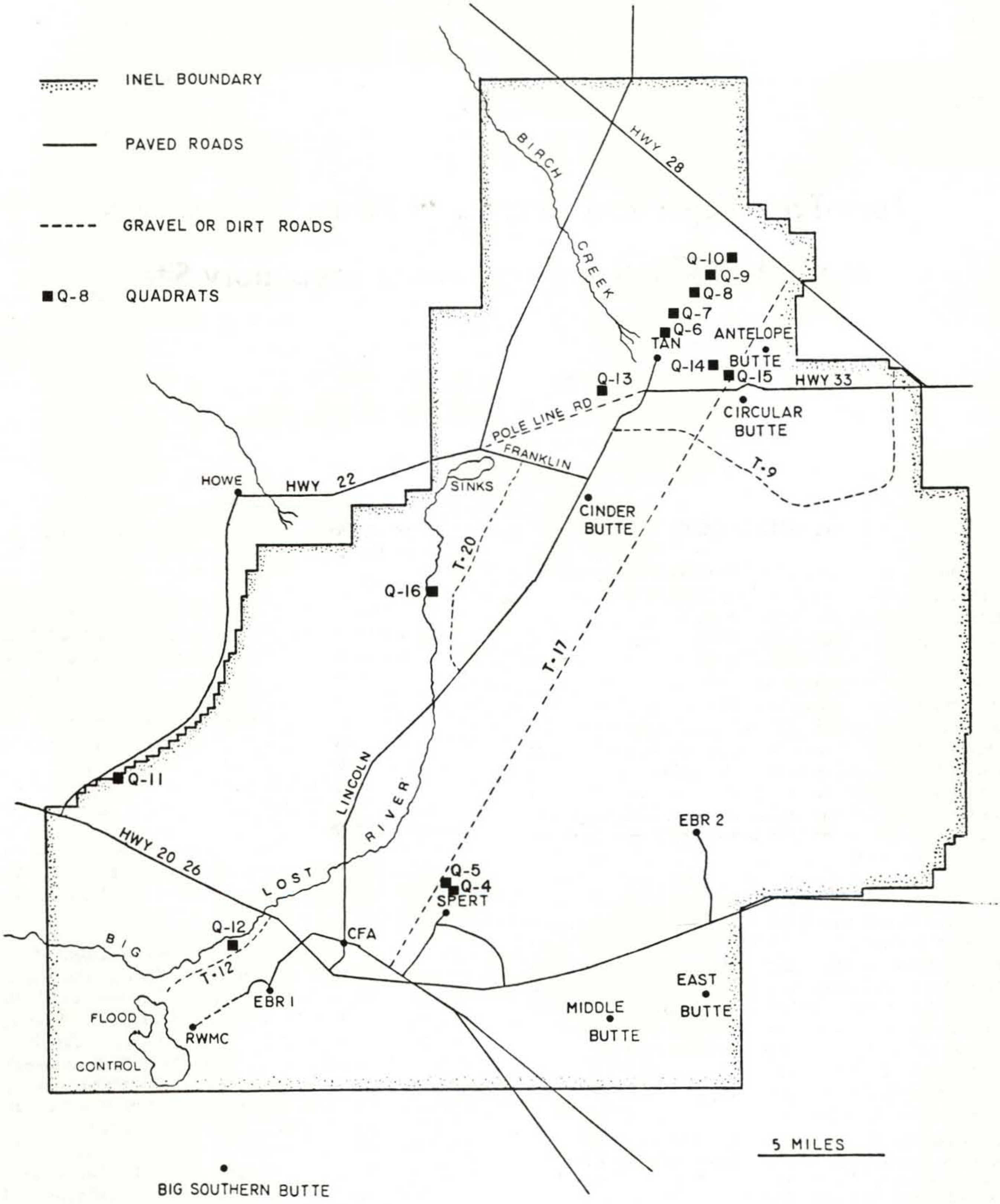

FRONTISPIECE: The Idaho National Engineering Laboratory Site

Adapted from base map drafted by Douglass M. Henderson, for Cholewa, A.F., and Henderson, D.M. 1983. A survey and assessment of the rare vascular plants of the Idaho National Engineering Laboratory. Pages 89 to 106 *in* O.D. Markham, ed., Idaho National Engineering Laboratory Radioecology and Ecology Programs 1983 Progress Report. U.S. Dept. of Energy, Idaho Operations Office, Radiological and Environmental Sciences Laboratory, Idaho Falls, Idaho. DOE/ID-12098

Long-Term Vegetation Changes In Permanent Quadrats at the Idaho National Engineering Laboratory Site

by Norman R. French
John E. Mitchell

INTRODUCTION

The vegetation cover of the Idaho National Engineering Laboratory (INEL) site is a mosaic of shrub steppe vegetation dominated by sagebrush (*Artemisia* spp.)[1] and various species of native grass (Harniss and West 1973, McBride et al. 1978). Soils are primarily of lacustrine or aeolian origin which have accumulated on and between relatively recent lava outcrops. The area is typical of the Snake River Plain north of the Snake River in that weathering of lava formations has had little time to contribute to soil formation and structure. Wyoming big sagebrush (*Artemisia tridentata* subsp. *wyomingensis*) is the dominant plant in most of this region; however, other sagebrush species are also commonly found. Basin big sagebrush (*A. tridentata* subsp. *tridentata*) may occur in protected locations of favorable moisture accumulation, such as pockets in the recent lava flows where deeper soil is found. Low sagebrush (*A. arbuscula*) and black sagebrush (*A. nova*) are common in areas covered by thin or gravelly soils (Tisdale and Hironaka 1981). Rabbitbrush (*Chrysothamnus viscidiflorus* and *C. nauseosus*) is the predominant shrub in areas that have been disturbed, generally by fire, during the last half century. Horsebrushes (*Tetradymia canescens* and *T. spinosa*) are found interspersed throughout the region, primarily on drier sites. Bunchgrasses, particularly bottlebrush squirreltail (*Sitanion hystrix*), Indian rice grass (*Oryzopsis hymenoides*), and wheatgrasses (*Agropyron* spp.) are the predominant herbaceous species of this region.

The upper Snake River Plain is characterized by a continental climate with cold winters and warm summers. Annual precipitation during 1950-1978 averaged 21 cm (Anderson and Holte 1981), with the greater portion coming during the winter and spring months. The months of May and June have maximum rainfall, generally 25 mm or more, and July to September is a dry period. Southwest winds prevail over much of this region, and their influence is evidenced by great longitudinal dunes of very low relief, which are reflected in the vegetation types visible on aerial photographs in the northeast corner of the site (McBride et al. 1978). Precipitation-evaporation ratios during the grazing season range from about .03 to .4 (Eggler 1941), a parameter which characterizes the aridity found in the Intermountain West.

The region has existed under various conditions of disturbance since the earliest settlers arrived in the 1850s. Prior to that time the area was grazed by horses and was periodically burned by Indians (Eggler 1941). Grazing probably increased at least until the 1920s, but fires have probably decreased. Such moderate to heavy grazing pressure had evidently not greatly altered the overall structure of these communities, as evidenced by studies of kipukas, isolated areas of natural vegetation surrounded by young lava flows forming effective barriers to grazing animals. Eggler (1941), who described two small kipukas in which grass predominated, suggested his observations confirmed Stoddart's (1941) hypothesis that absence of fire and grazing would produce a grassland climax in this region. Tisdale et al. (1965), however, investigated a larger kipuka and found both sagebrush and grass present under climax con-

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[1] Taxonomy follows Hitchcock and Cronquist (1973) and Winward and Tisdale (1977). All references to *Artemisia* indicate *A. tridentata* subsp. *wyomingensis* unless otherwise noted.

ditions. It is now accepted that the upper Snake River Plain is dominated by sagebrush and grass (primarily the wheatgrasses) at climax (Bailey 1980).

Some evidence exists supporting the hypothesis that heavy seasonal (i.e., spring) grazing occurred from settlement days through the 1930s, resulting at times in decreased abundance of palatable forage species along the Snake River Plain and adjacent foothills (Craddock and Forsling 1938, Harniss 1968). Experimental evidence of grazing effects from an area protected from grazing by domestic animals for 11 years in the eastern Snake River Plain was presented by Pearson (1965), who found 45 percent more aboveground production in the protected area, but greater belowground production in the grazed area. Although his data were inconclusive, Pearson estimated that shrubs were most productive in the early spring and fall, while grasses were most productive during the late spring and early summer. This suggests a possible minimization of competition between the two types of plants.

Anderson and Holte (1981) examined a series of permanent vegetation transects, different from the quadrats described in this report, established across the INEL site in 1950. They found no significant differences in shrub cover after 30 years of excluded grazing. Between 1950 and 1965, grass cover had not increased significantly, but a comparison of 1975 data with those collected in 1965 showed a significant increase. The authors attributed part of the increase in grass cover to succession following 25 years of excluded grazing and part to favorable climatic conditions during the 1975 growing season. Anderson and Holte's work illustrates the difficulty of documenting causal factors affecting vegetation dynamics of seral communities on the Snake River Plain. The problem of isolating long-term succession from seasonal fluctuations is especially difficult.

The objective of this study was to detect long-term changes in natural vegetation of the area that could be due to various natural or anthropogenic factors. Central to the goals of the sponsoring organization were detection and description of the effects of chronic exposure of plants to ionizing radiation from radionuclides deposited in the vicinity of test reactors and other facilities at the site. Virtually nothing was known at the time about the sensitivity of native species of plants to chronic radiation, nor of the response of communities to such plant sensitivity. Due to differences of grazing impact in various localities of the region, and to the fact that distinct vegetation types were evident, these factors were incorporated in the design of plot distribution. Little was known of the long-term vegetation changes resulting from normal climatic variability or successional dynamics in the sagebrush-grass region. There was much speculation but little evidence of the impact of grazing in the region. Large plots were established because of the desire to include numerous individual plants of each species in locations near radiation sources, and because some vegetation types were limited in extent.

METHODS

Between 1955 and 1957, 16 permanent vegetation quadrats were established, and the plant cover of each was documented. Ten of these were situated for possible contamination by windborne radionuclides from operating test reactors on the INEL site (then called the National Reactor Testing Station). The remainder were in similar vegetation types but distant from reactors or were in other representative vegetation types of the site. Because the region is sparsely vegetated, large vegetation quadrats were selected so that the history of individual plants could be followed from year to year. Each quadrat consisted of 25 m^2 sections, arranged in a square, 5- by 5-m plot, with the exception of quadrat 16, which consisted of five 1-m^2 sections separated from each other by a distance of at least 10 m. This last modification was desirable because the plots were situated in an area of dense grass. Smaller areas were required for complete enumeration of the plants present, and the sections had to be separated because of trampling resulting from documentation. Locations of these quadrats are indicated on the map of the INEL site (Frontispiece). Each quadrat was marked by four steel fence posts, and identified by a brass disc.

These quadrats were distinct from a large series of small vegetation quadrats originally established in 1950. The latter were laid out at regular intervals along two transects extending diagonally across the INEL site, for the purpose of surveying the different vegetation types on the site (Harniss 1968, Harniss and West 1973).

Quadrats 1 through 12 were established in 1955. Ten of these were situated downwind from two operating reactors, the Short Power Excursion Reactor Test (SPERT) and the Initial Engine Test (IET). These were reexamined in 1956. In 1957, quadrats 6 through 12 were again evaluated, and quadrats 13 through 16 were established. All 16 quadrats were reexamined in 1959. That was the last complete documentation of all quadrats. In 1975 all quadrats except 1, 2, 3, 8, and 16 were found with their markers intact. The original vegetation in the vicinity of quadrats 1-3 had been removed and the area seeded with crested wheatgrass, *Agropyron desertorum* (Fisch.) Shult. The markers for quadrat 8 had been removed, and the exact location of this quadrat could not be determined. The markers for quadrat 16 had disappeared, in an area highly modified by grazing and other factors. In 1976, the remaining 11 quadrats were again examined to compare changes that had occurred over the preceding 20-year period and to correlate these changes with disturbances due to grazing or radionuclide contamination (Table 1). Descriptions of the quadrats, excluding the first three, are provided in the Appendix.

Documentation of the permanent vegetation quadrats was conducted once each season at the height of the growing season, generally in June. Documentation consisted of mapping and counting all plants present in the

Table 1. Community type, grazing history, and radionuclide contamination of vegetation quadrats on the Idaho National Engineering Laboratory.

Quadrat no.	Community type	Area grazed by livestock			Proximity to reactors involved in radionuclide-emitting tests
		1950-57	1958-59	1970s	
Q-1	(seeded to crested wheatgrass—dropped from the study)				
Q-2	(seeded to crested wheatgrass—dropped from the study)				
Q-3	(seeded to crested wheatgrass—dropped from the study)				
Q-4	*Artemisia tridentata - Sitanion hystrix*	No	No	No	Yes - .33 mile
Q-5	*Artemisia tridentata - Stipa comata*	No	No	No	Yes - .67 mile
Q-6	*Atriplex nuttallii - Eurotia lanata*	Yes	No	No	Yes - .50 mile
Q-7	*Tetradymia - Chrysothamnus*	Yes	No	No	Yes - 1.00 mile
Q-8	(markers missing in 1976—dropped from study)				
Q-9	*Tetradymia - Chrysothamnus*	Yes	No	No	No
Q-10	*Atriplex nuttallii - Eurotia lanata*	Yes	No	No	No
Q-11	*Artemisia tridentata - Agropyron dasystachyum*	Yes	Yes	Yes	No
Q-12	*Artemisia - Agropyron*	No	No	No	No
Q-13	*Atriplex confertifolia - Oryzopsis - Agropyron smithii*	Yes	No	No	No
Q-14	*Artemisia tridentata - Eurotia lanata*	Yes	No	No	No
Q-15	*Oryzopsis - Chrysothamnus*	Yes	No	No[1]	No
Q-16	*Agropyron smithii - Iva axillaris*[2]	No	No	Yes	No

[1] Possibly subjected to light grazing due to proximity to area of allowed grazing.

[2] Now dominated by annual weeds.

quadrat, including dead shrubs, and taking a reference photograph from a high angle. The reference photograph was taken with a 4 x 5 Speed Graphic camera situated 10 feet above the ground on the south side of the quadrat and close enough to the quadrat that the four marker posts filled the frame of the film. The quadrat was then temporarily partitioned into square meter sections by inserting large nails in the ground at 1-m intervals along each of the four sides and securing twine across the grid between the corresponding pairs of nails. Each of the 25 1-m^2 sections was then closely examined; plants were identified by species and their numbers recorded. In addition, each perennial plant was mapped by hand on a 15 x 15-cm chart of the quadrat. From these records, density and frequency of each plant species in the quadrat were determined, and the percent area covered by dominant species (i.e., canopy coverage) was measured from the map.

Statistical analysis of these data was limited to preliminary data analysis to determine interrelationships among variables, primarily climatological factors, preliminary to regression analysis, and to reduce the number of variables entering into the problem. Those used in later analysis were April precipitation, previous year's April precipitation, and mean temperatures for the months of April and May. Regression analysis was used primarily to confirm the significance of long-term trends of vegetation abundance that may be correlated with protection from grazing or radioactive contamination resulting from destructive tests of power reactors. Logarithmic transformation of the time scale was used as the independent variable. Total grass number of all species combined was examined by multiple regression, with logarithmic transformation.

Although the number of observations was not sufficient to determine cause and effect relationships, it could suggest parameters for detailed investigation and provide a guide to the importance of separate terms. In this we were guided by the criteria for data analysis suggested by Tukey (1962) that such analysis must seek for scope and usefulness rather than security, and that inadequate evidence may often suggest the right answer.

Grazing Pressure

The Snake River Plain has long been grazed by sheep and cattle, particularly in spring and fall. In 1950 the central part of the INEL site, an area encompassing quadrats 4, 5, 12, and 16, was closed to all grazing. In 1957 additional areas, containing the remaining quadrats with the exception of quadrat 11 were removed from grazing (Table 1). This quadrat and, since the mid-1960s, quadrat 16, have been in grazed areas until the present time.

Radiation Exposure

Two groups of vegetation study plots received significant exposure to radionuclides over the past 20 years because of their proximity to operating reactors and to the Chemical Processing Plant (Table 1). Quadrats 4 and 5 are located 0.3 and 0.6 miles northeast of the SPERT-1 reactor which was tested on three occasions by short power bursts sufficient to rupture fuel elements and to cause release of fission products to the atmosphere. These tests occurred in November 1962, November 1963, and April 1964 (Bunch 1965). During this period, from 4×10^2 to 1.8×10^4 curies of radioactivity were estimated to have been released during the power bursts (Bunch and Gammill 1968). Considering the distances involved, the radioactivity would have been diluted by .001 to .002 of the released concentrations at the distance of quadrats 4 and 5. The radioactivity was predominantly from short-lived isotopes.

Additional contamination reached these plots from activities at the Chemical Processing Plant. Over a 20-year period, varying amounts of radionuclides were released from a 250-foot stack located at the plant. Vegetation would have been exposed to some of these emissions. Beta emitters deposited on leaves could have provided significant radiation dose to the plant tissues (Wallace and Romney 1972). Between 1957 and 1963, approximately 5,800 curies of radioiodine and an average of 42 curies per year of other beta emitters (^{106}Ru, ^{144}Ce, ^{137}Cs) were released from the stack (Annual Report Health and Safety Division 1960). In addition, an average of 2,300 curies of tritium were released per year (Osloond 1970). These emissions could have resulted in the exposure of beta emitters to about 400 microcuries at the distance of the vegetation plots over the 20-year period, judging from Weather Bureau diffusion computations. Radioactivity at quadrats 4 and 5 from the SPERT reactor would have totaled approximately 10 to 20 curies.

A reactor accident occurred approximately 3 miles southeast of the vegetation plots in January 1961. The accidental destruction of this reactor (SL-1) resulted in the release of radioiodine and other fission products to the atmosphere (SL-1 Task Force 1962). Prevailing wind at the time of the accident, and for the few days following it, resulted in most of the radioisotope contamination moving to the south and southwest (Islitzer 1962). Exposure of the vegetation plots to the radionuclides resulting from this accident has not been measured, because its contribution to total exposure was estimated to be slight.

Quadrats 6 through 10 are located at 1-mile intervals northeast of the Initial Engine Test stack in the northern portion of the INEL site. Operating tests of a direct cycle reactor took place in the years 1958-1961 at this location. These events released between 2.5×10^3 and 2×10^4 curies of mixed fission products (Osloond 1970). In 1964 two destructive tests of reactors occurred at this location, which released 3.2×10^4 curies and 2×10^6 curies of short-lived isotopes (Bunch and Gammill 1968). Considering the distance of 1 mile and 5 miles, respectively, from the release point to quadrats 6 and 10, approximately 10^{-4} and 2×10^{-3} of the amounts released could have reached the vegetation study plots. For these six release periods between 1958 and 1964 less than 30 curies of radioactivity would have reached quadrat 6 and approximately 7 curies would have reached the vicinity of quadrat 10.

RESULTS

Trends of Long-Term Change

Comparisons of vegetation characteristics of the 12 quadrats examined in 1976 have been accomplished by evaluating sites of similar vegetation-type in relation to differential grazing pressure and climatic conditions. Preliminary data analysis provided no definitive evidence that ionizing radiation from airborne contaminants had any effect on community structure. Examination of quadrats 11 and 12 suggested the existence of different patterns in the vegetation trends evidently in response for the most part to climatic variations over the 20-year period of this study.

Grass density fluctuations differed among species, with the increase of *Agropyron dasystachyum* in quadrat 11, the grazed plot, showing the most notable and consistent trend. One puzzling observation in quadrat 12, the ungrazed plot, was the apparent shift from *A. dasystachyum* in 1959 to *A. spicatum* in 1976 (Table 2). One may hypothesize that the former is a seral species, and such a shift shows evidence of succession following release from grazing pressure; however, insufficient evidence is available from this study to support or deter a successional hypothesis. Literature on the ecology of *A. dasystachyum* is sparse. Hironaka et al. (1983) have noted the occurrence of *A. riparium*, a close relative to *A. dasystachyum*, as a seral species on similar habitat types along the lower Snake River Plain.

Except for 1959, densities of *Oryzopsis hymenoides* and *Stipa comata* were relatively stable in both quadrats 11 and 12 over the 20-year period of this study (Table 2).

The principal effect of protection from grazing can be seen in other measures of dominance besides density. The ungrazed quadrat (Figure 1) shows a somewhat more notable level of increased grass abundance and vigor than the grazed quadrat (Figure 2). These figures leave little doubt, however, that much of the increased grass dominance in 1976 must have reflected a climatological response.

Shrubs were slightly more prevalent in the grazed than in the ungrazed plot in terms of both density and cover (Table 2); however, the differences were not significant ecologically. The coverage was relatively stable for *Artemisia*, whereas the trend for *Chrysothamnus* seemed to be one of slightly increasing cover. Another shrub, *Tetradymia canescens*, which occurred in the left center of quadrat 11, increased in dominance from 1955 to 1956 but has declined since that time. Between 1959 and 1976 it diminished to about one-eighth its 1959 cover. *Opuntia* clusters remained somewhat constant in both plots, being fairly abundant in quadrat 12 (30-43 beds) but not in quadrat 11 (2-3 beds) (Table 2). The two plots were not on similar soil types (see Appendix); however, the differ-

Table 2. Vegetation changes in quadrats 11 and 12 of number and percent cover of *Artemisia tridentata* and *Chrysothamnus viscidiflorus*, number of four grass species, and number of cactus clusters in the total 25-m^2 area.

	Artemisia		*Chrysothamnus*		*Agropyron*				
	% cover	No.	% cover	No.	*spicatum* clumps	*dasystachyum* No.	*Oryzopsis* clumps	*Stipa* clumps	Cactus clusters
Q-11									
1955	8	41	3	6		244[1]			
1956	7	46	1	10	14[1]		9	16	2
1957	9	37	2	10		157	14	19	2
1959	10	28	3	8		277	13	22	3
1976	10	11	5	37		512	20	9	2
Q-12									
1955	5	9	4	13		---- 427 ----			
1956	2	8	1	15	25		52	138	37
1957	2	9	1	15		248	74	146	30
1959	3	10	1	14		211	239	4	43
1976	5	7	<1	8	61		61	154	35

[1] Some uncertainty exists concerning the species of *Agropyron* present in 1955 and 1956.

ences in soil properties are not sufficient to preclude a general comparison of trends of the dominant species.

In the southern portions of the INEL site, the majority of the area is dominated by *Artemisia*, with other shrubs or grasses of secondary prominence according to the character and depth of the soil. Quadrats 4 and 5 were located in the transition zone between the *Artemisia-Chrysothamnus-Sitanion hystrix* community type and the *Artemisia-Oryzopis-Stipa comata* community type (see map, Frontispiece). In the 20-year period between 1956 and 1976, plant cover increased noticeably, particularly the grass species in quadrat 4, because of the increase of both *Stipa comata* and *Sitanion hystrix* (Figures 3 and 4). *Sitanion hystrix* increased in density by an order of magnitude in both quadrats 4 and 5 between 1959 and 1976 (Table 3).

The late appearance of *Sitanion* in these quadrats may indicate that the communities which encompass them are in a relatively early state of succession, even though grazing had been excluded for 25 years. Hironaka and Tisdale (1963) demonstrated that *Sitanion* is primarily a seral species in the sagebrush-grass region because of its ability to increase rapidly in depleted stands. If so, data from quadrats 4 and 5 support the hypothesis that recovery from areas depleted by grazing can be a slow process in this region.

Total plant cover in the photographs (Figures 3 and 4) is conspicuous mainly because of *Artemisia*. Although the area covered by big sagebrush increased between 1959 and 1976, its density consistently declined throughout the same period. In quadrat 5, the number of *Chrysothamnus viscidiflorus* increased from two to nine. The photos show an active mound of harvester ants (probably *Pogonomyrmex*) in the background in 1955 which was still active 21 years later. Dead wood shows slight change over this period of time, indicating the slow decomposition rate of woody material in such a xeric ecosystem.

Quadrats 7 and 9, near the north end of the INEL site, are on a moderately alkaline, aeolian sandy loam soil overlying basalt. The shrub cover of these plots appears to have remained fairly constant over the long period (Figures 5 and 6), and density and area data from the quadrat map do not show significant changes (Table 4). *Chrysothamnus* provided the predominant cover in quadrat 7, while *Artemisia*, *Tetradymia*, and *Eurotia* provided roughly comparable amounts of cover in quadrat 9. Although numbers appear to have decreased or remained fairly stable, the vigor of individual shrubs seems to be much greater in the 1976 photographs. *Chysothamnus* in quadrat 7 was severly affected in 1957, apparently due to a wireworm (Coleoptera:Elateridae) that attacked the roots. In quadrat 9, the density of grasses fell by two-thirds between 1956 and 1957, but by 1976 had recovered to a level surpassing earlier numbers (Table 4). A similar increase in grass density occurred in quadrat 7.

Quadrat 15 was located on a moderately deep aeolian sandy soil at the north end of the INEL site, near the boundary of the area excluded from grazing. It was so near the unfenced boundary that it became difficult to determine whether it had been subject to grazing pressure. No signs of grazing activity were evident at the time of documentation, however. The photographs (Figure 7) show that the vegetative cover of grasses, particularly *Oryzopsis hymenoides* and *Stipa comata*, was much greater in 1976 than in either of the two previous periods of examination, 1957 and 1959. The density of *Oryzopsis* had declined by 1976; however, its place was more than compensated by

Table 3. Vegetation changes in quadrats 4 and 5 of number and percent cover of *Artemisia tridentata*, number (clumps) of grass plants and cactus clusters in the total area of 25 m².

Year	*Artemisia* % cover	*Artemisia* No.	Grass number *Sitanion*	Grass number *Stipa*	Grass number *Oryzopsis*	Cactus clusters
Q-4						
1955	13	59	?	3	39	22
1956	12	64	0	4	12	23
1959	20	59	1	6	5	20
1976	22	21	11	29	7	45
Q-5						
1955	22	69	?	1	1	18
1956	13	63	2	0	0	3
1959	15	57	12	0	0	3
1976	23	32	35	0	1	6

Table 4. Vegetation changes in quadrats 7 and 9 of number and percent cover of the shrubs *Artemisia tridentata, Chrysothamnus viscidiflorus, Tetradymia canescens*, and *Eurotia lanata*, and number of the grasses *Agropyron dasystachyum* and *Sitanion hystrix* in the 25-m² area (bunchgrasses are counted by clumps).

Year	*Artemisia* % cover	*Artemisia* No.	*Chrysothamnus* % cover	*Chrysothamnus* No.	*Tetradymia* % cover	*Tetradymia* No.	*Eurotia* % cover	*Eurotia* No.	*Agropyron* No.	*Sitanion* clumps
Q-7										
1955	3	5	20	50			4	34	47	
1956	2	5	5	46		1	2	51	46	
1957	2	4	many dead		1	3	2	47	37	
1959	2	5	5	28		3	1	47	50	
1976	2	2	6	16	1	1	2	28	142	
Q-9										
1955	6	32	2	5		29	5	48	32	
1956	5	22	1	8	1	27	4	63	100	2
1957	8	24	1	10	1	28	4	80	27	10
1959	7	22	1	7	1	25	2	67	60	2
1976	7	7	7	32	7	21	4	26	149	10

Table 5. Vegetation changes in quadrat 15 of number and percent cover of the shrubs *Chrysothamnus viscidiflorus* and *Eurotia lanata*, and number of different grasses, *Agropyron dasystachyum, Oryzopsis hymenoides*, and *Stipa comata* in the 25-m² area (bunchgrasses are counted by clumps).

Year	*Chrysothamnus* % cover	*Chrysothamnus* No.	*Eurotia* % cover	*Eurotia* No.	*Agropyron* No.	*Oryzopsis* clumps	*Stipa* clumps
1957	6	31	<1	6	6	108	124
1959	4	31	1	9	879	60	59
1976	6	17	3	8	391	34	61

Table 6. Vegetation changes in quadrats 6, 10, 13, and 14 of number and percent cover of the shrubs *Eurotia lanata, Atriplex confertifolia,* and *Artemisia tridentata* and numbers of grasses *Oryzopsis hymenoides, Sitanion hystrix,* and *Agropyron dasystachyum*, in the 25-m² area (bunchgrasses are counted by clumps).

	Eurotia		*Atriplex*		*Artemisia*		*Oryzopsis*	*Sitanion*	*Agropyron*
Year	% cover	No.	% cover	No.	% cover	No.	clumps	clumps	No.
Q-6									
1955	14	183		64			44	0	
1956	8	197		48			13	0	
1957	8	159		21			31	0	
1959	7	161		15			32	0	
1976	11	125		1			9	3	
Q-10									
1955	21	612		0	1	7		0	
1956	13	460		3	4	4			
1957	16	692		3	4	4		3	
1959	16	733		3	0	3		3	
1976	22	417		0	0	0		1	
Q-13									
1957		2	8	60			29	0	16
1959		1	7	38			32	0	6
1976		7	5	52			15	37	156
Q-14									
1957	12	112			6	10	2	4	128
1959	11	197			6	10	0	7	122
1976	14	141			4	9	1	44	157

the establishment of *Agropyron dasystachyum* (Table 5) and increased vigor of all grasses. The dominant shrub, *Chrysothamnus viscidiflorus,* did not change greatly in coverage over the time period, but seemed to decrease in density by 1976. *Eurotia* showed a small increase in cover.

Quadrats 6, 10 and 13 were situated on ancient playas at the northern end of the INEL. *Eurotia lanata, Atriplex confertifolia,* and grass were the predominant forms of plants on these plots (Table 6). Quadrat 6 (Figure 8) contained *Salsola kali* in 1957, and a great deal of *Halogeton glomeratus* in 1976. Generally, these plots seemed to show less total change, judging from the photographs, than did other plots. *Eurotia* declined in numbers but increased in cover in both quadrats 6 and 10. Density of *Atriplex* also decreased overall. The dynamics of grass abundance varied by plot. Grass density decreased in quadrat 6, remained low but constant in quadrat 10 (Figure 9), and increased overall in quadrats 13 and 14 (Figures 10 and 11). The most notable increases were for *Sitanion hystrix*, which invaded since 1959, and *Agropyron dasystachyum* in quadrat 13.

Quadrat 14 was located on lacustrine soils in the approximate center of the area defined by quadrats 6, 13 and 15. The landscape encompassing quadrat 14 was slightly elevated over adjacent playas, resulting in soils less saline in the surface horizons. Consequently, *Artemisia* and *Agropyron dasystachyum* were present, interspersed among the more prevalent species associated with Natrargids soils (i.e., *Eurota lanata*). The existence of *Artemisia* seemed tenuous, however, indicating that it likely was at the edge of its ecological amplitude. In comparing 1959 and 1976 data (Figure 11), one can easily see the effect of increased vigor of *Eurotia* in 1976 despite an apparent 30 percent reduction in density (Table 6).

By far the most drastic changes over this period of time occurred in quadrat 16 (Figure 12), which was located on the flood plain south of the sinks area of the Big Lost River. Traditionally, this area has been flooded almost annually with the spring runoff brought down by the river, the same river that was largely responsible for the ancient playas at the north end of the INEL site. In the early years of the study these sinks were dominated by a densely covered plain of *Agropyron smithii* and *Juncus* sp., vigorous enough to occasionally conceal an antelope. In the mid-1960s, the grass seed was harvested from this area (Harniss and West 1973). Measured densities of plants in 1957 were from 2 to 19 *Agropyron* plants per m² and about 1.4 *Iva axillaris* plants per m². Where *Agropyron* was dense *Juncus* did not occur; however, *Iva* was fairly uniform in abundance throughout the sinks. These were essentially the only plants that grew in this area.

Flood control measures later implemented on the river near the point where the Big Lost River enters the INEL site presumably curtailed spring flooding of the sinks area. Lack of flooding coupled with livestock grazing pressure in later years, have so changed the community type that the annuals, *Salsola kali* and *Sisymbrium altissimum*, now al-

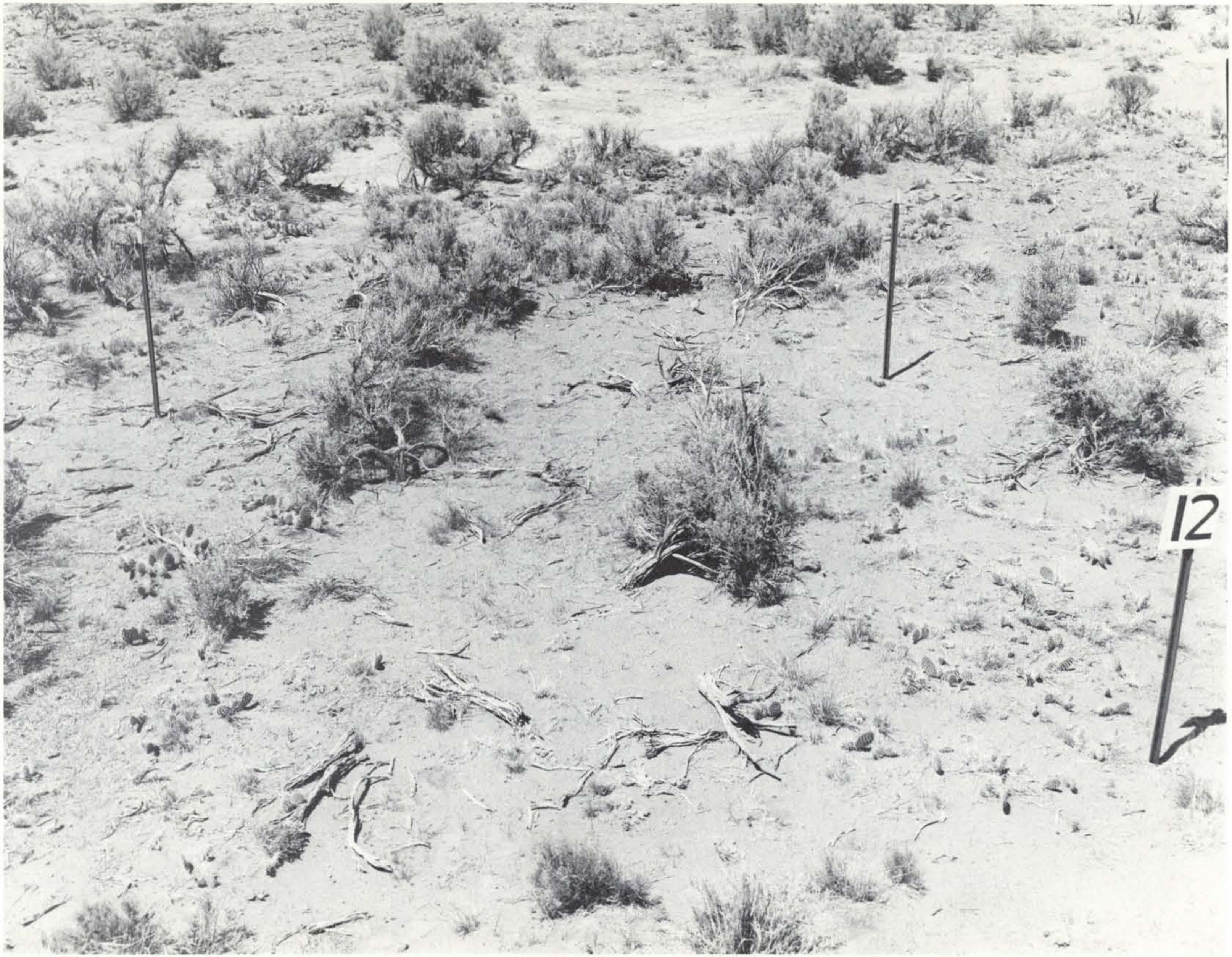
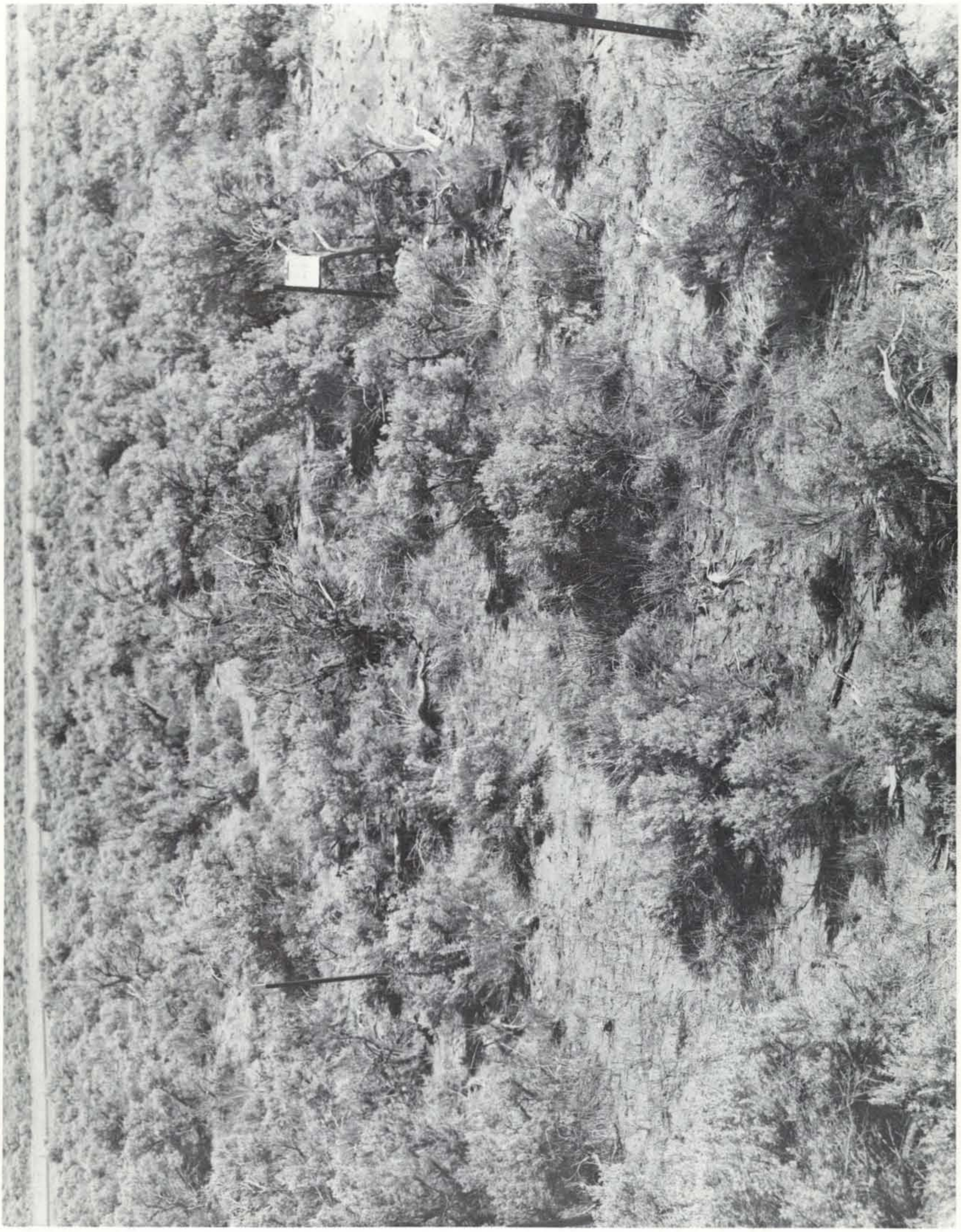


Fig. 1. Vegetation quadrat 12, showing a spectacular increase in grass abundance between 1959 (above) and 1976 (below), most of which is *Stipa comata*, *Oryzopsis hymenoides*, and *Agropyron dasystachyum*. This quadrat has the longest history of no grazing.

Fig. 2. Vegetation quadrat 11 in 1955 (above) and in 1976 (below). The only quadrat open to grazing during the entire period of these investigations, it shows an increase in grass abundance. Grasses are mainly *Agropyron dasystachyum*, with some *Oryzopsis hymenoides* and *Stipa comata.*



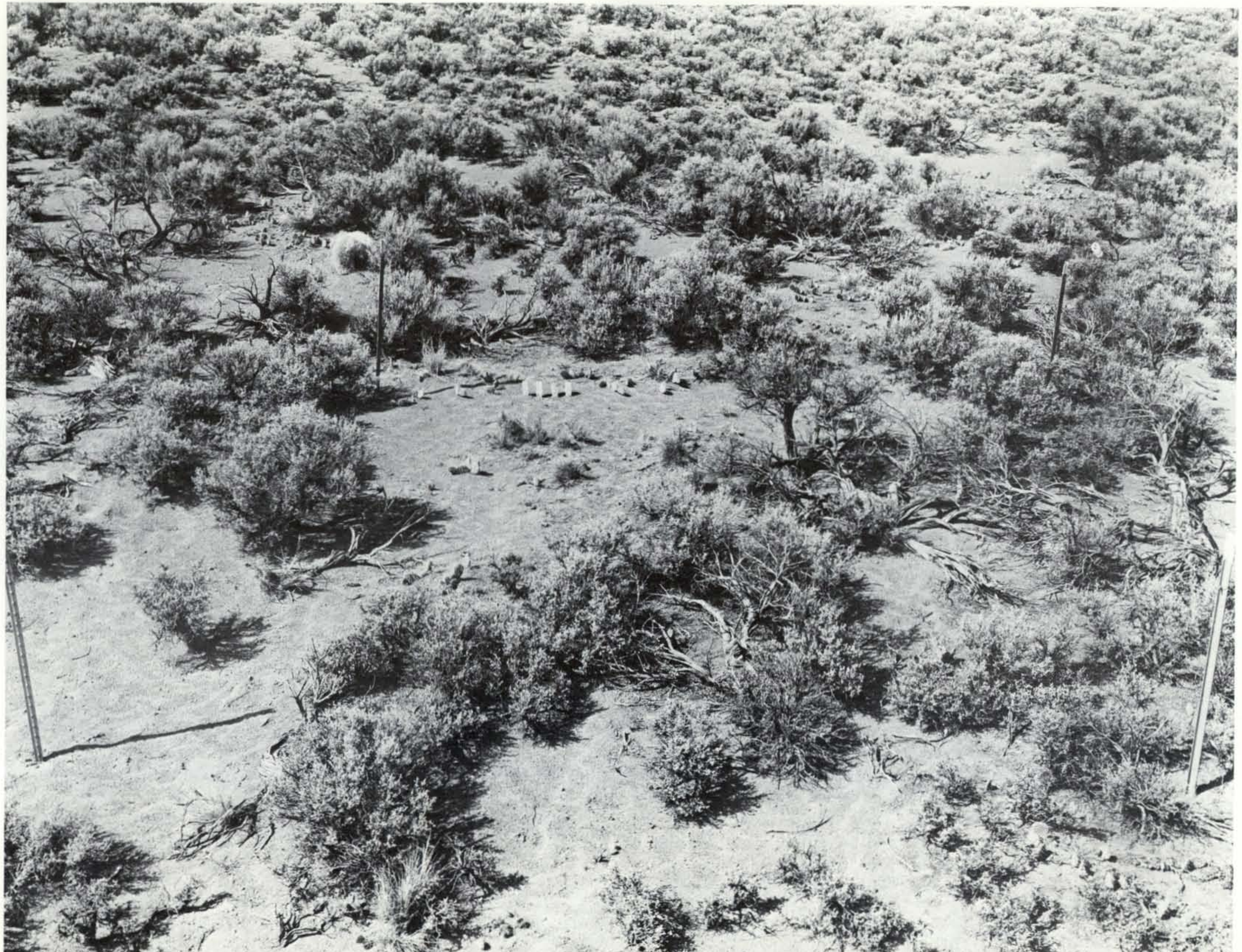


Fig. 3. Vegetation quadrat 4 in 1955 (above) and in 1976 (below), showing the predominance of *Artemisia tridentata wyomingensis* and the increase in *Stipa comata* and particularly *Sitanion hystrix*.

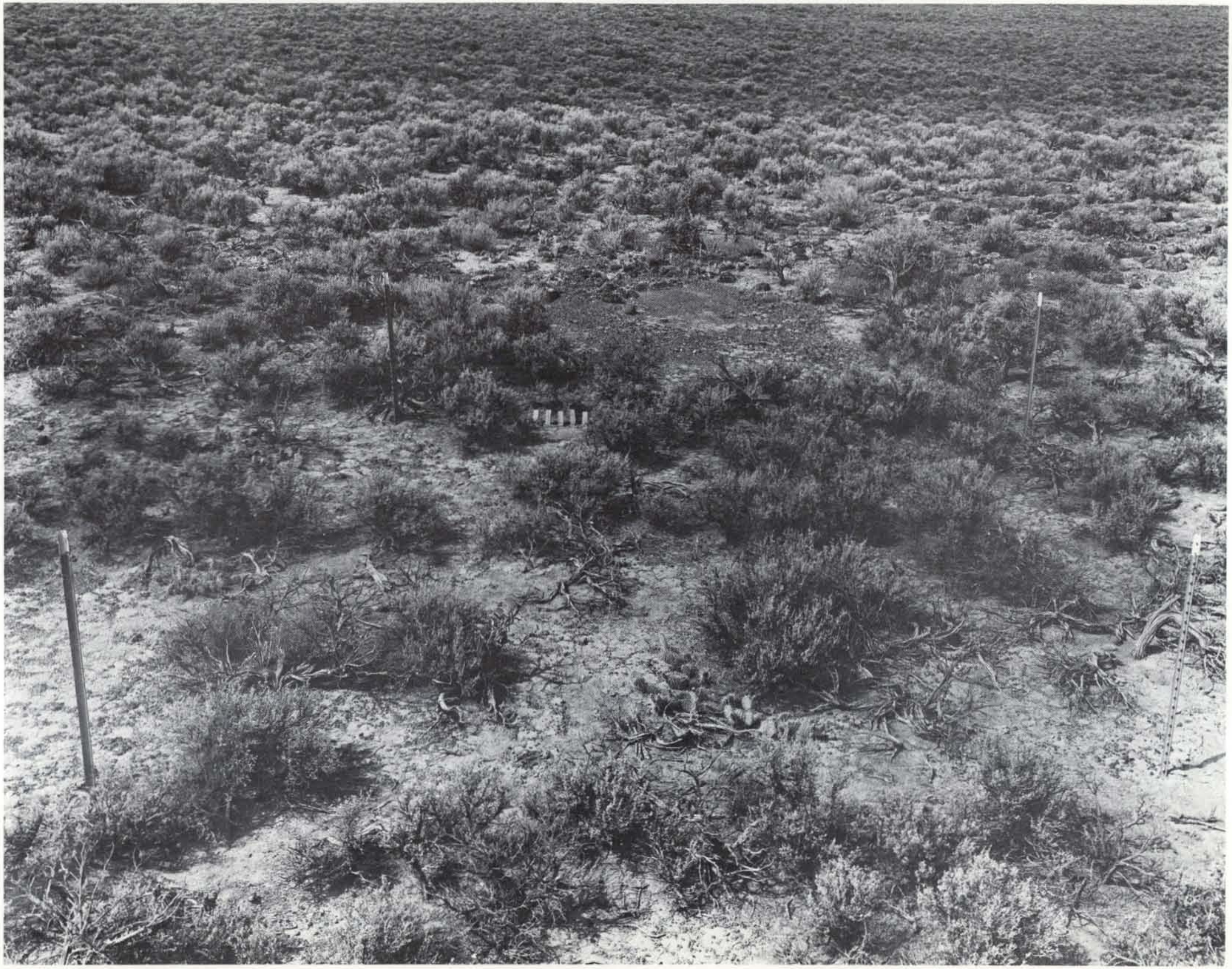


Fig. 4. Vegetation quadrat 5 in 1955 (above) and in 1976 (below). Directly behind plot is an active harvester ant nest.

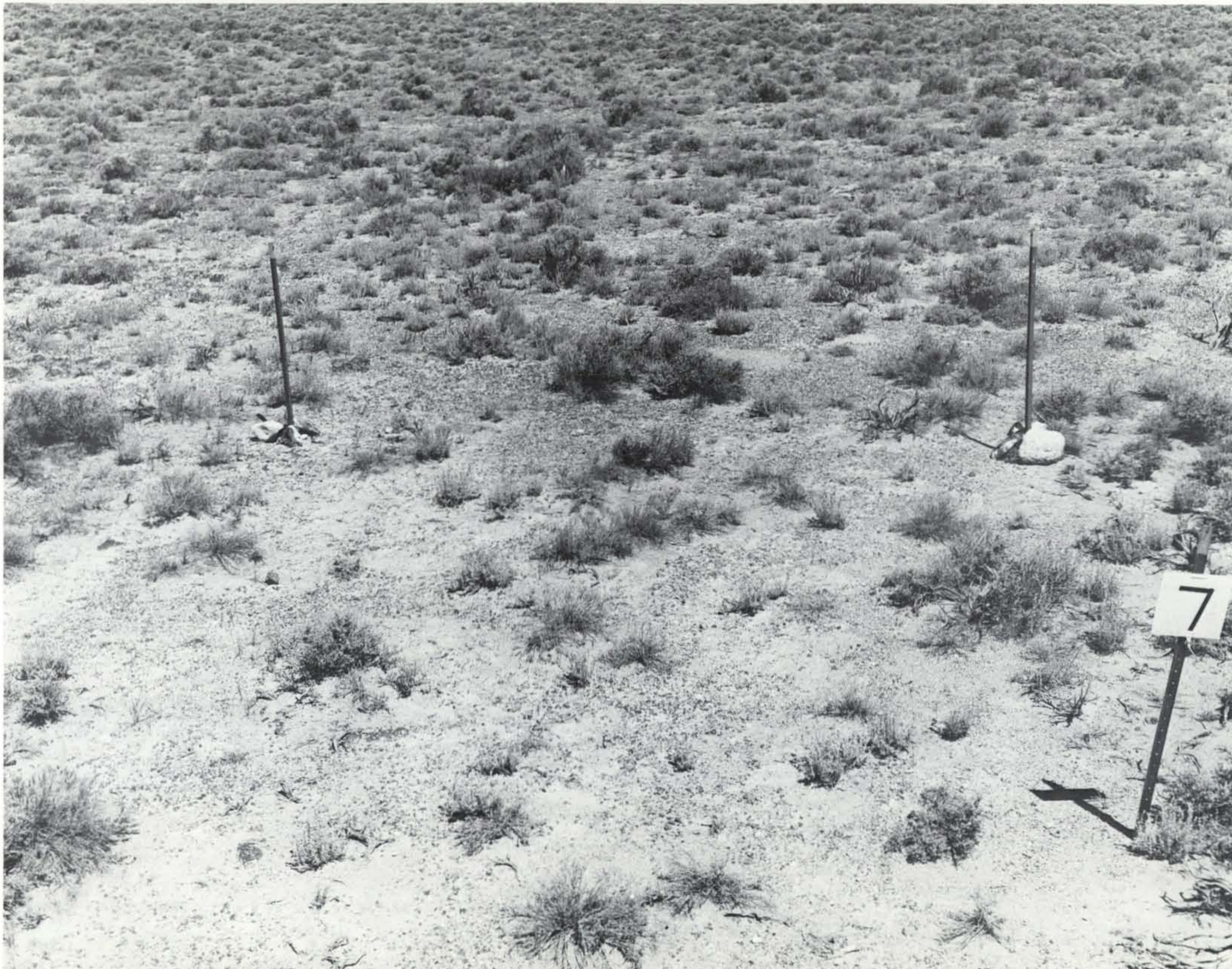


Fig. 5. Vegetation quadrat 7 in 1957 (above) and in 1976 (below), showing cover provided primarily by *Chrysothamnus viscidiflorus* and *Eurotia lanata*.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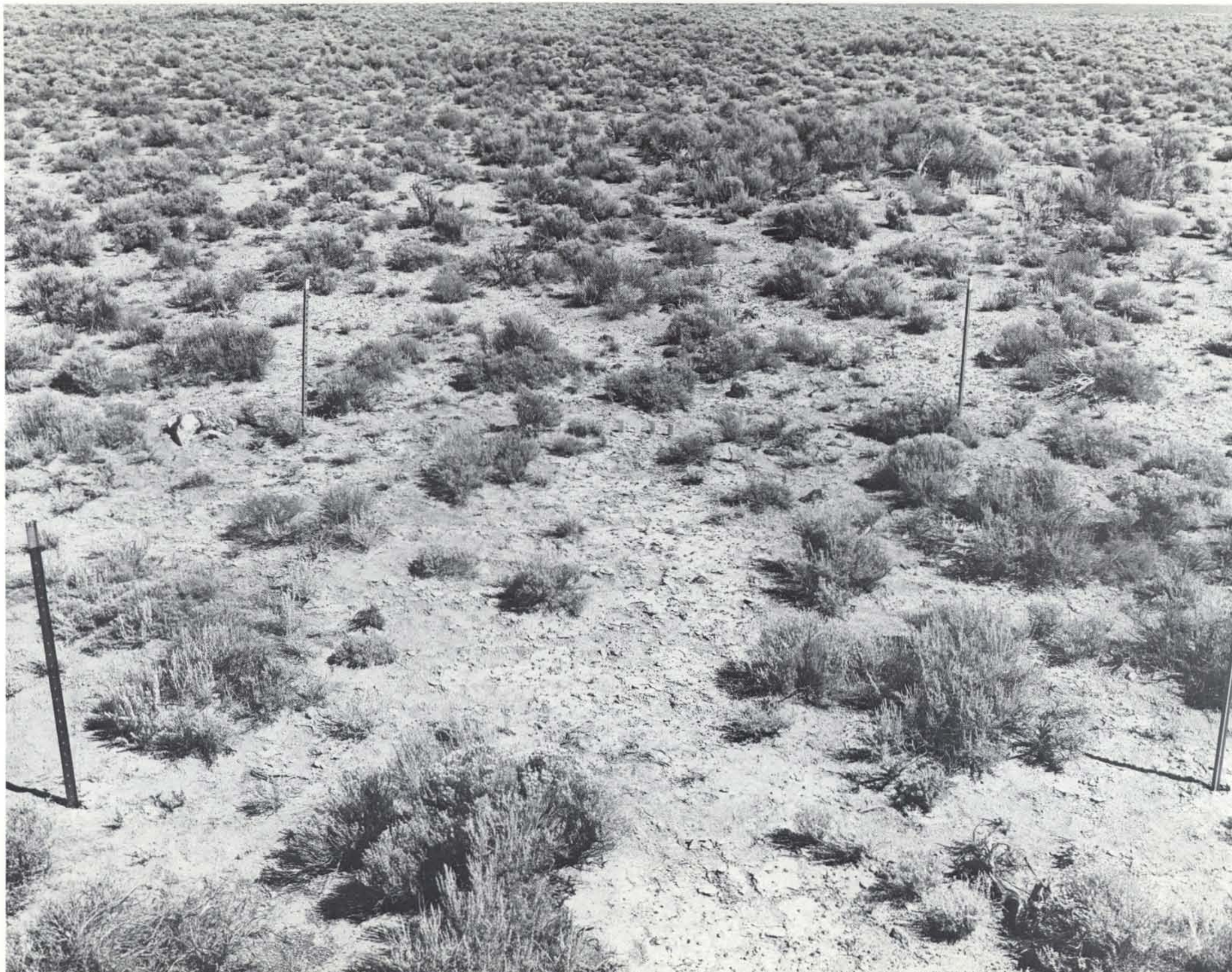

Fig. 6. Vegetation quadrat 9 in 1955 (above) and in 1976 (below), showing cover primarily by *Tetradymia canescens* and *Eurotia lanata*.

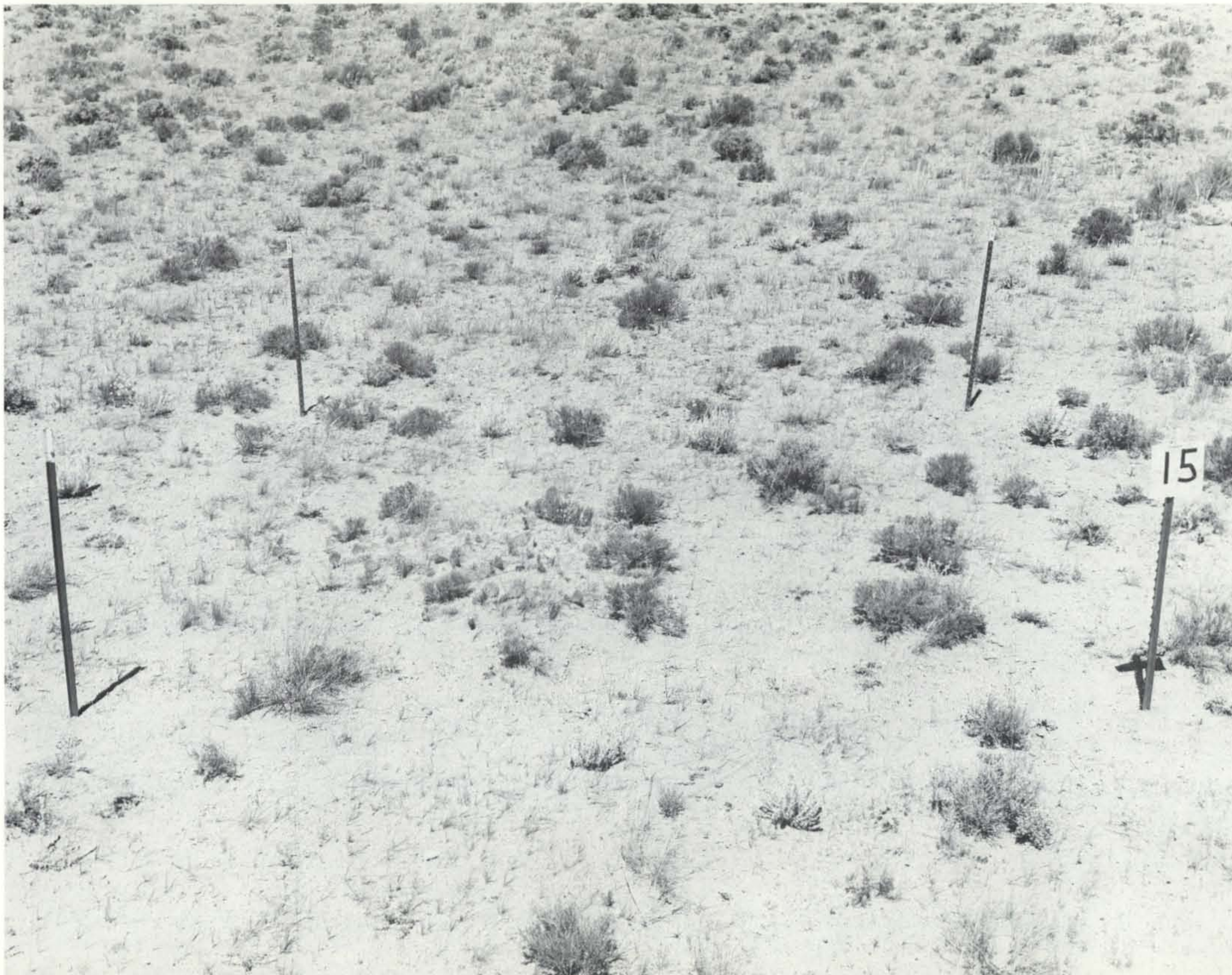

Fig. 7. Vegetation quadrat 15 in 1957 (above) and in 1976 (below), showing an increase of *Eurotia lanata* and *Chrysothamnus viscidiflorus* and of the bunchgrasses *Stipa comata* and *Oryzopsis hymenoides*. *Agropyron dasystachyum* is also an important grass at this location.

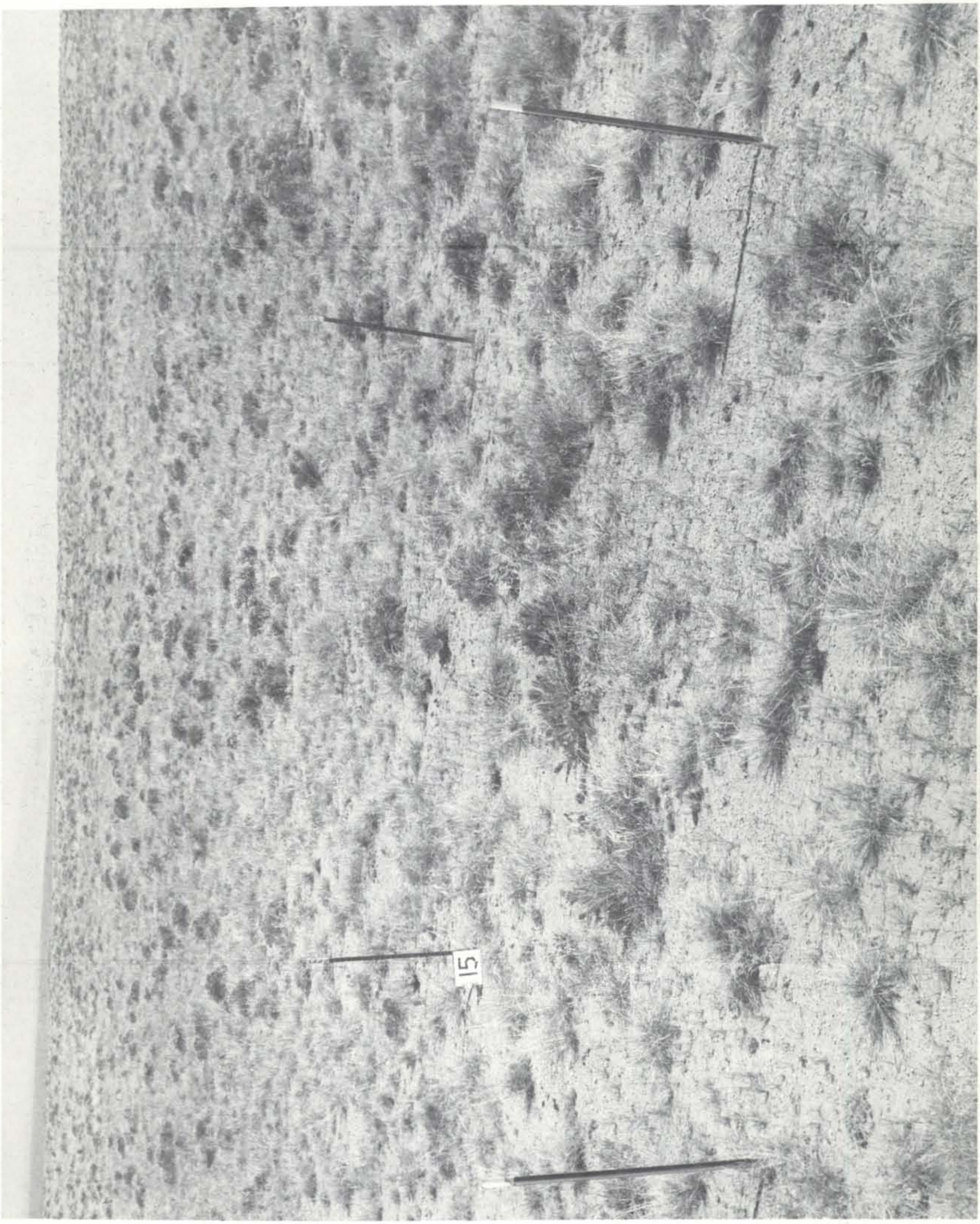
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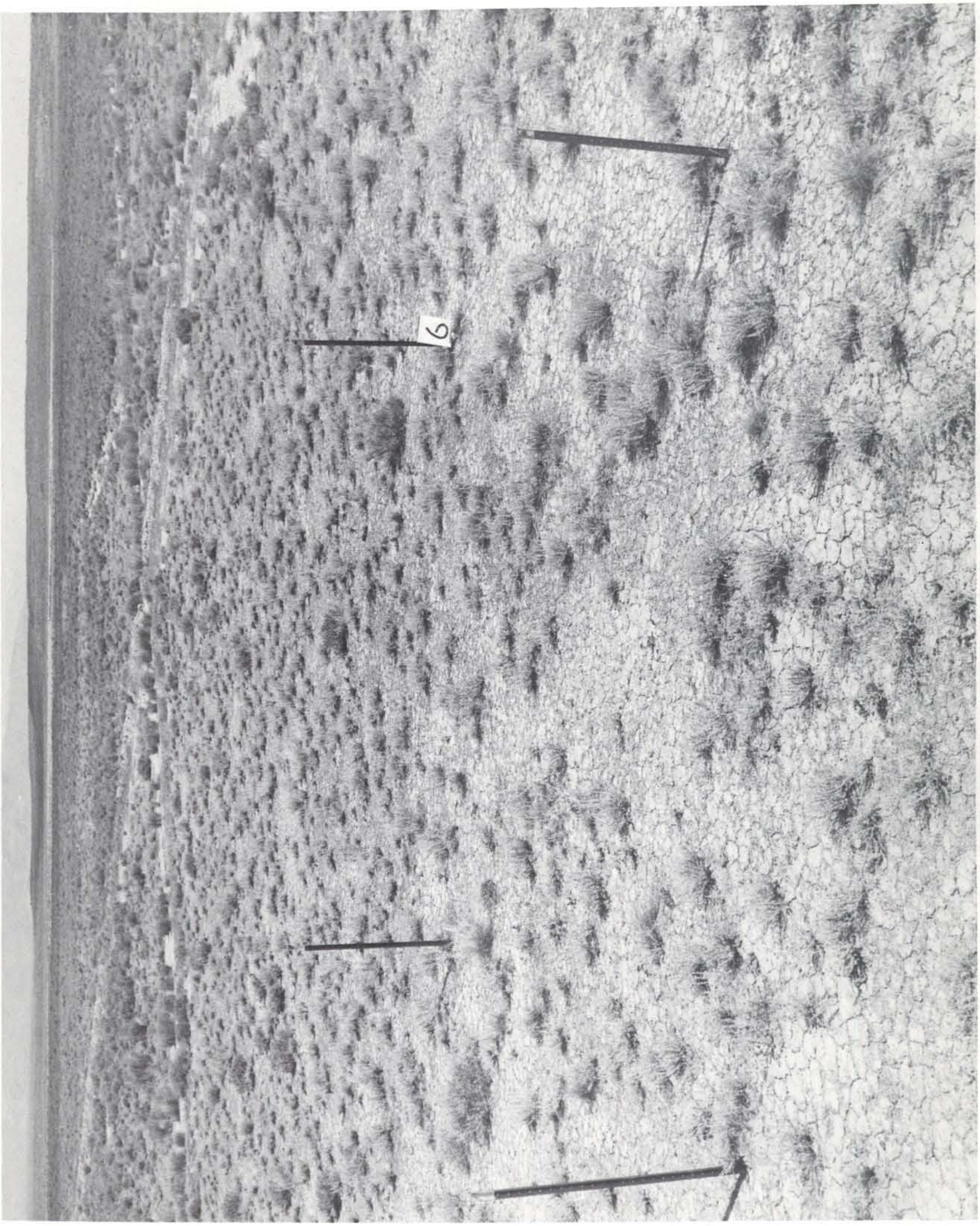
Fig. 8. Vegetation quadrat 6 in 1955 (above) and in 1976 (below), showing an increase in cover of *Eurotia lanata* and a loss of *Atriplex confertifolia.*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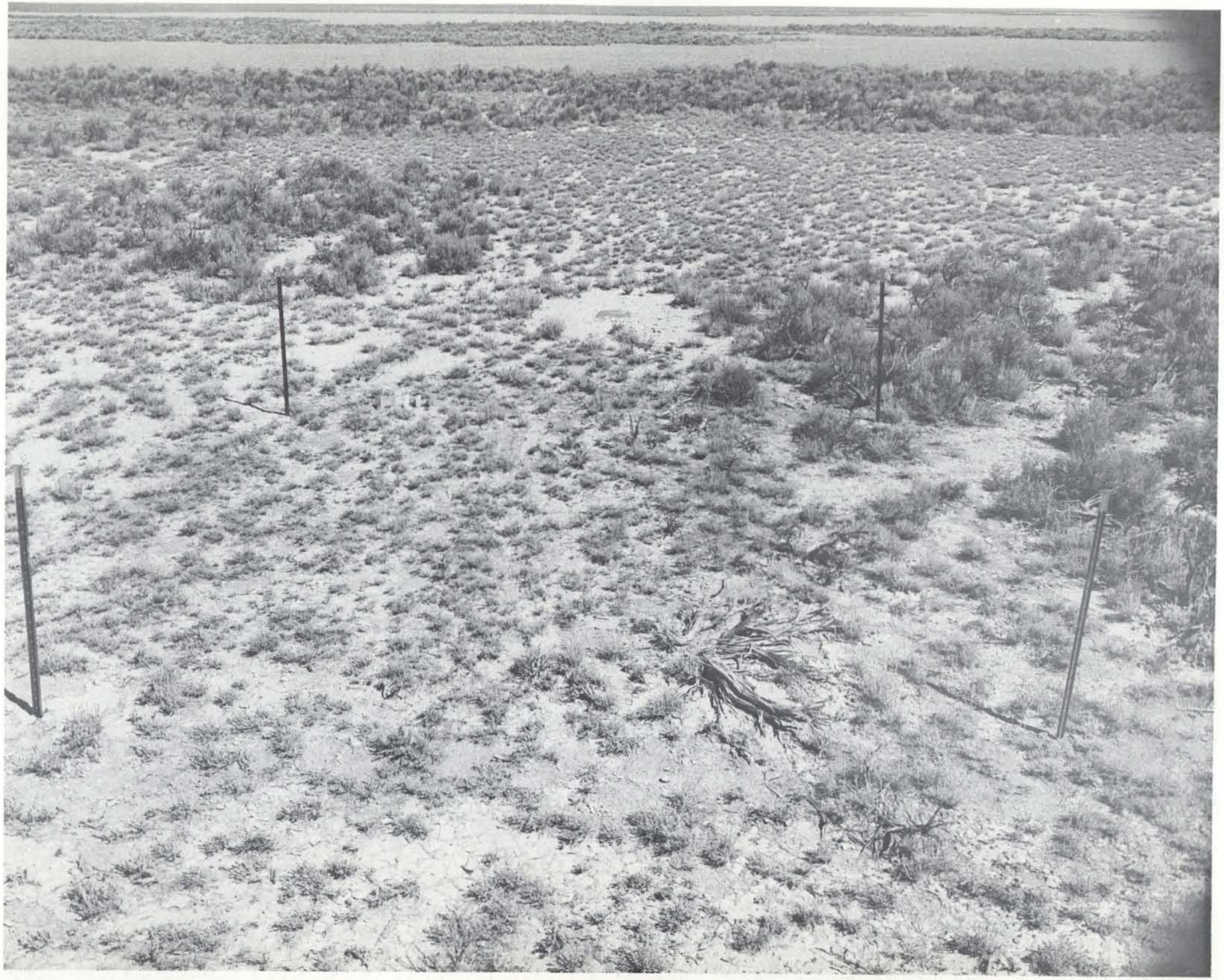
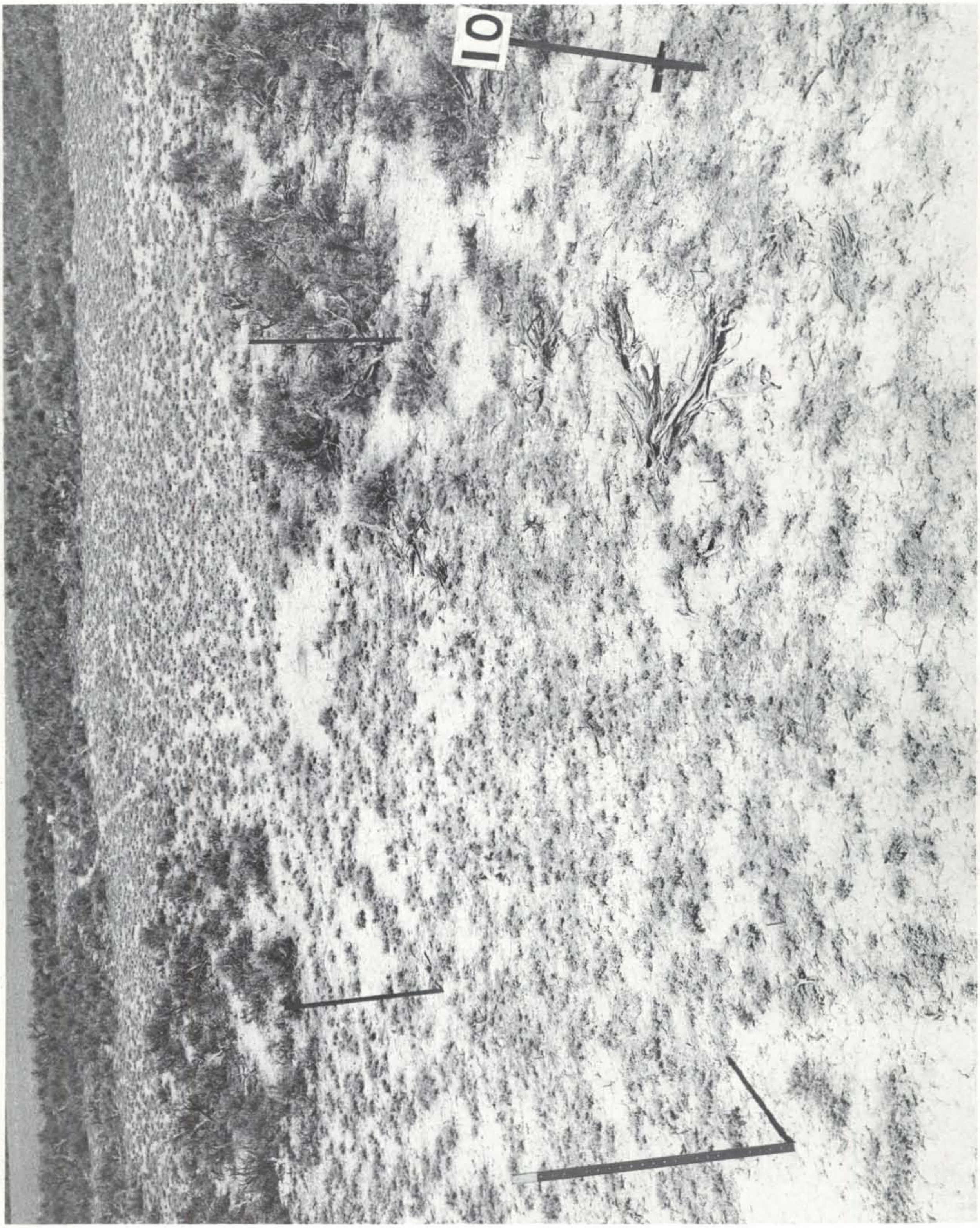


Fig. 9. Vegetation quadrat 10 in 1955 (above) and in 1959 (below), showing the general decline in vegetation cover during 1959. The quadrat is almost entirely *Eurotia lanata*, with some dead and little live *Artemisia tridentata*. No live *Artemisia* was present in 1976, and the grass, *Sitanion hystrix*, has increased to a density greater than one clump per square meter.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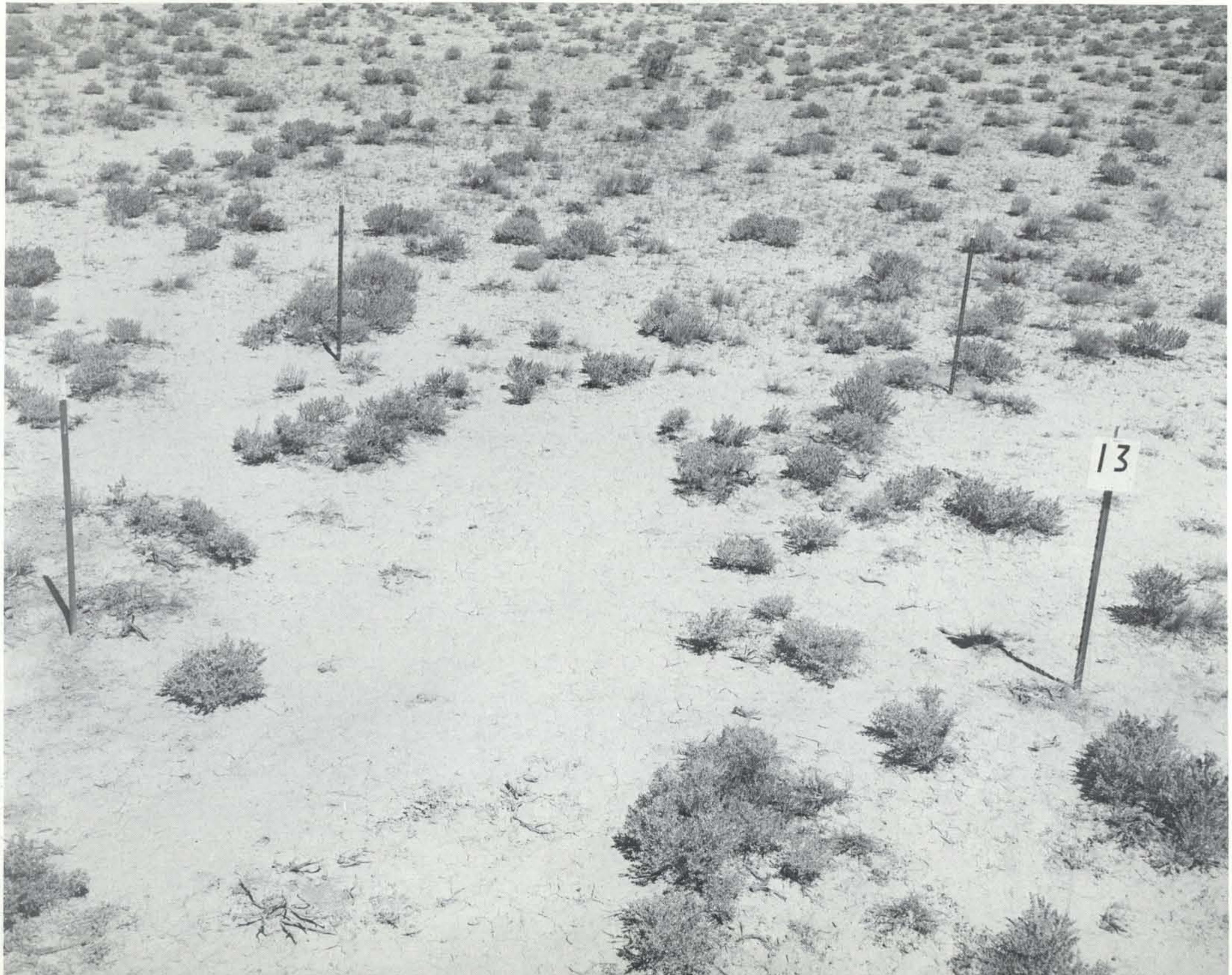

Fig. 10. Vegetation quadrat 13 in 1957 (above) and in 1976 (below). This quadrat is situated on a slightly younger playa than quadrats 10 (Fig. 9) and 6 (Fig. 8). The area is predominantly *Atriplex confertifolia*. In 1957 *Oryzopsis* was the most abundant grass, but in 1976 it had diminished while *Agropyron* and *Sitanion* had increased.

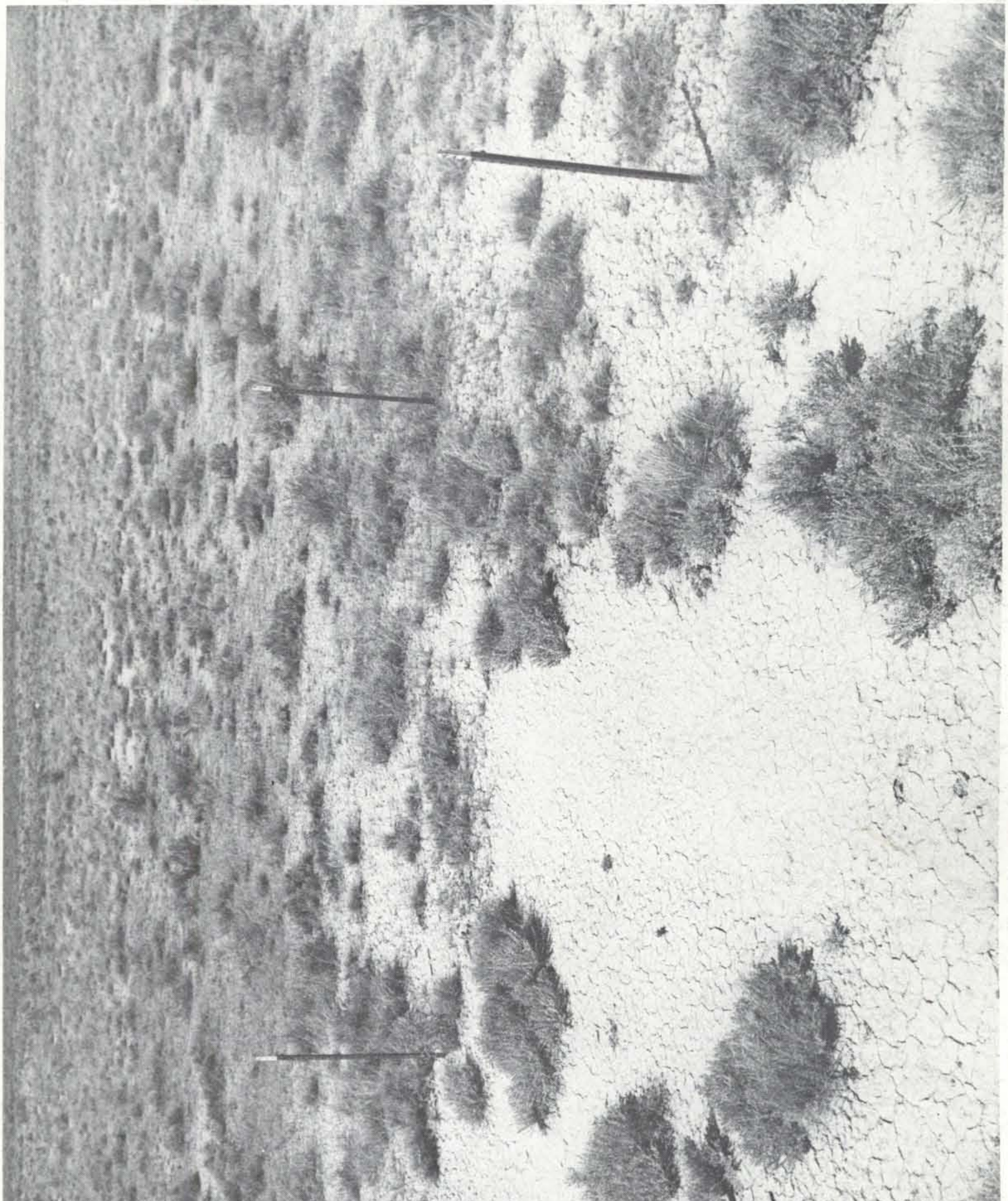

Fig. 11. Vegetation quadrat 14 in 1959 (above) and in 1976 (below), showing primarily an increased cover of *Eurotia lanata*.

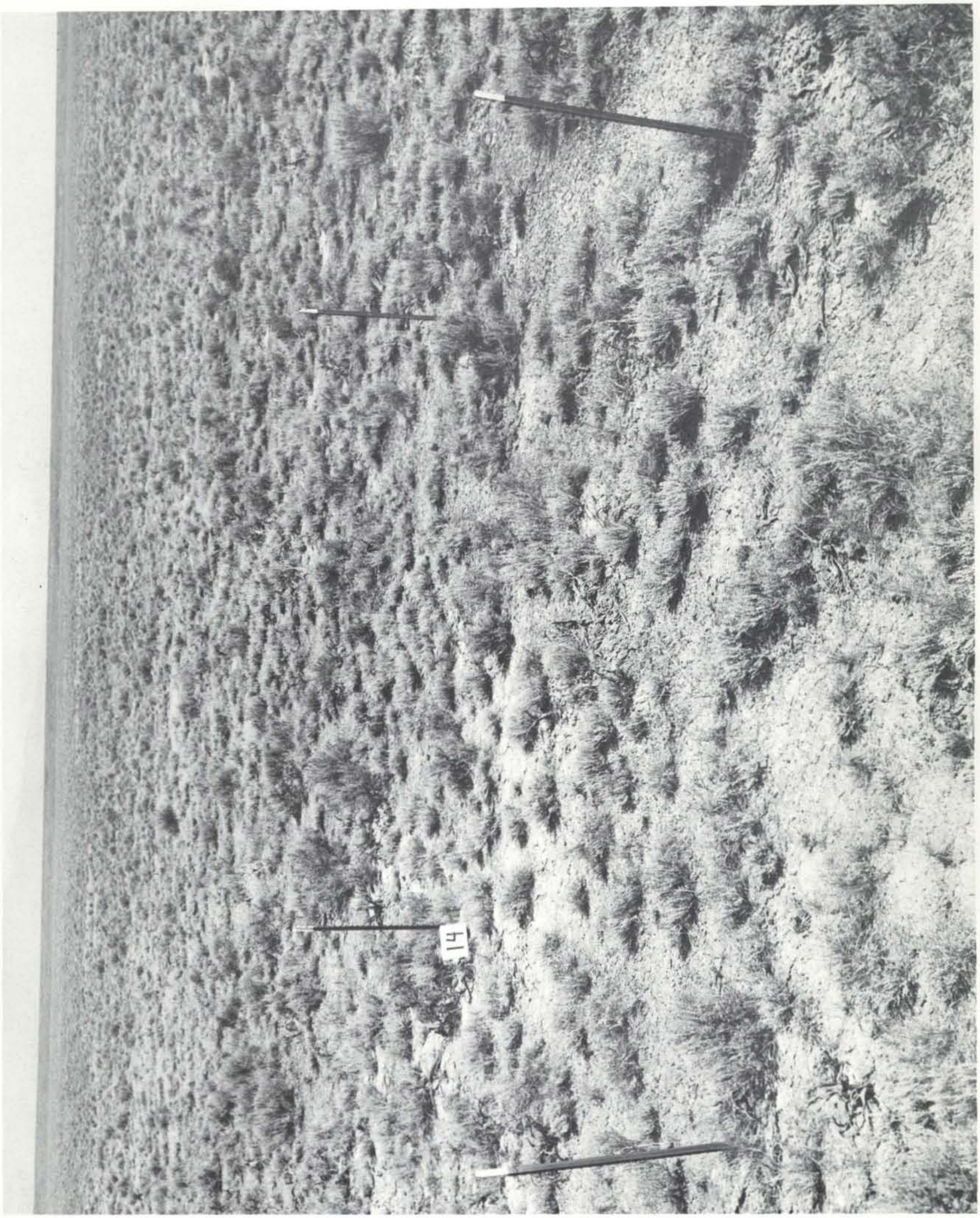
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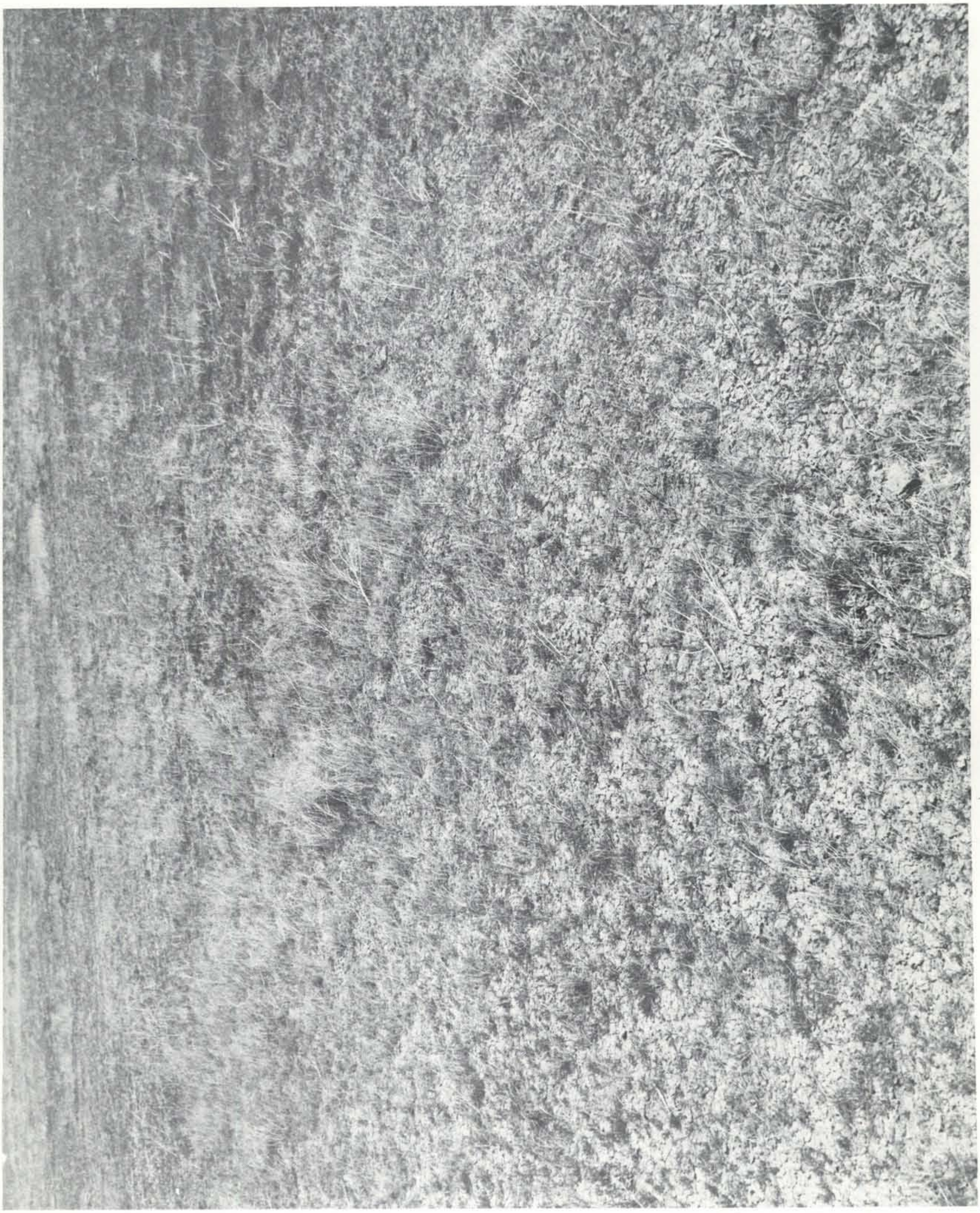
Fig. 12. Vegetation quadrat 16 in 1957 (above) and the same general area in 1976 (below), showing the change from a dense cover of *Agropyron smithii* to *Salsola* and *Sisymbrium* because of lack of flooding coupled with intense grazing.



most wholly comprise the area that was perennial grassland. There has probably been no more drastic change to any vegetation in the entire region than in this area, several square miles in extent, located in the northwest portion of the INEL site.

Results of preliminary statistical analysis by linear regression of certain plant densities for plots at the southern end of the INEL site are presented in Table 7. Analysis was focused on these sites because the greatest contrasts between grazed and ungrazed, contaminated and uncontaminated histories are represented there. In the grazed quadrat 11, *Artemisia* showed a significant decrease and *Chrysothamnus* a significant increase over the time period of 20 years. *Artemisia* also decreased significantly in the two quadrats (4 and 5) that received radioactive contamination between November 1962 and April 1964. It is the final density value (1976) which contributes most to this significance. Analysis of total grass cover gives equivocal results. Grass cover responds to seasonal variations in precipitation, but the significance of this effect was revealed only in ungrazed quadrat 12 when subjected to multivariate analysis which included meteorological variables.

Table 7. Summary of linear regression of plant densities over 20 years according to plots with different long-term treatment by grazing pressure or radiation exposure.

Species	Quadrat	Treatment	Regression direction and significance	
Artemisia	Q-11	grazed	-	P .01
	Q-12	ungrazed	NS	
	Q-4	contaminated	-	P .05
Chrysothamnus	Q-11	grazed	+	P .01
	Q-12	ungrazed	NS	
Grass (total)	Q-11	grazed	NS	
	Q-12	ungrazed	NS	
	Q-4	contaminated	NS	
	Q-5	contaminated	+	P .01

DISCUSSION

A preliminary analysis of the vegetation data on density, frequency, and cover by species within years of investigation was carried out by examining means and variances for the plots grouped in two ways; grazed versus ungrazed, and contaminated versus uncontaminated. Data collected in 1955 and 1956 for quadrats 1 through 12 showed no significant difference by either method of grouping. Comparisons for the two other early years, 1957 and 1959, revealed some differences, but these could not be correlated with either grazing or contaminants, given the small sample size and confounding of treatments.

Because vegetation growth and development are greatly affected by seasonal growing conditions in any particular year, data were screened to determine whether meteorological records measured on the INEL site were associated with cover or density of dominant species found on the quadrats. The following climatic variables served as independent variables: April precipitation, previous year's April precipitation, April temperature, and May temperature (Figure 13). These variables were selected because of their expected influence on vegetation growth and development, and due to their apparent independence (according to preliminary analysis). Four years were considered as points of observation—1956, 1957, 1959, and 1976. Data were incomplete for 1955, so they were omitted in the preliminary analyses.

Partly as a result of the low number of observations (four), no realistic causal relationships between climatic variables and vegetation cover or density could be identified. Several species tracked individual climatic variables quite closely in some instances; e.g., magnitude of April precipitation vs. densities of *Stipa comata* in quadrat 12 (Table 2) and *Sitanion hystrix* in quadrat 9 (Table 4). Nonetheless, no consistency of such relationships for any species across plots could be discerned. Multivariate analysis of shrub numbers showed significant decline in *Artemisia* in the grazed and the contaminated plots at the southern end of the site. The increase in *Chrysothamnus* is likely a response to the decline in *Artemisia*, common for this area. We suspect that, for most annual fluctuations, cover and density data of perennial plants, especially bunch grasses, are not as sensitive to actual plant reactions as are biomass measurements. Density, cover, and biomass provide one-, two-, and three-dimensional representations, respectively, of a plant's vigor in response to climatic or management perturbations. Intuitively, therefore, one would expect biomass to change most measurably on a year-to-year basis. The 1976 photographs (Figures 1 to 12), depicting a three-dimensional view of plants, apparently show a more noticeable response to the wet (April) and warm (May) spring leading into that growing season than the cover and density data.

Detailed studies by Blaisdell (1958) have demonstrated that continual changes occur in the vegetation cover of the Snake River Plain. In a given plot, certain species of grasses may decline and all but disappear over a period of years, whereas other species may increase in abundance and cover. The total cover of all grasses may change little throughout the same period, however.

Our data tend to confirm such a relationship (Tables 5 and 6). For example, in quadrat 13, tradeoffs occurred among *Sitanion hystrix, Oryzopsis hymenoides,* and *Agropyron dasystachyum*. In quadrats 11 and 12, *Oryzopsis* and *Stipa comata* seemed to replace each other in a complementary fashion. Unfortunately, with such a long period between observations, it is difficult to hypothesize whether the changes reflect only short-term fluctuations, or if successional factors have also played a role. Assuming that most of these quadrats were ostensibly ungrazed for at least the past 30 years, and given evidence presented by Sharp and Sanders (1978) that a similar ungrazed community

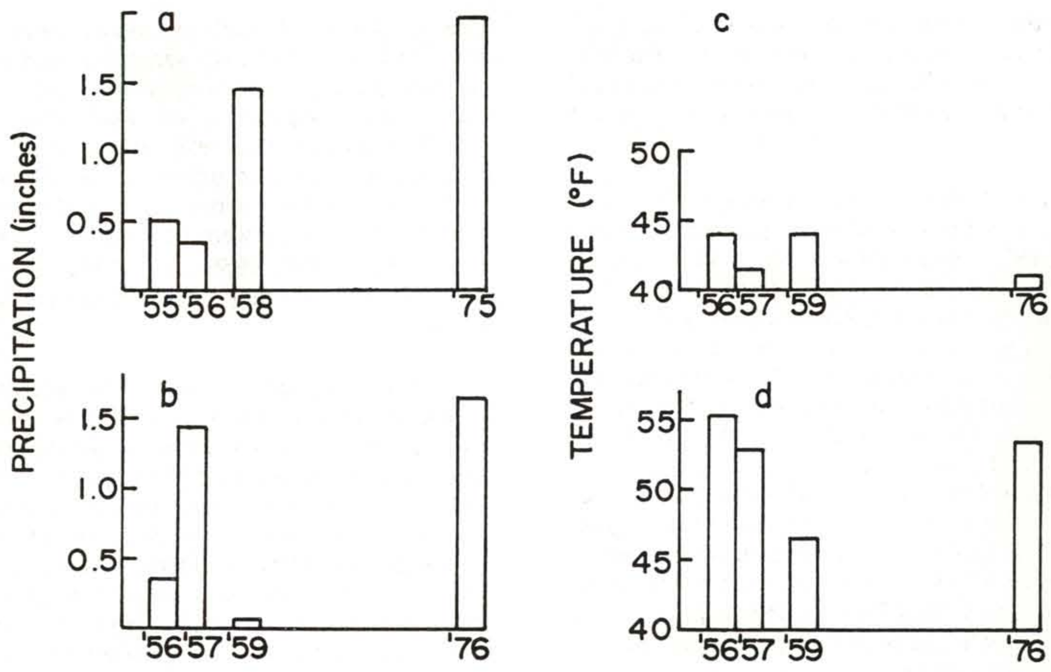


Fig. 13. Key climatic variables used as independent variables in analysis of vegetation responses: (a) precipitation in April of the year preceding sampling, (b) April precipitation of the year of sampling, (c) April mean temperature, and (d) May mean temperature for the year of sampling.

near Malta, Idaho, fluctuated over the same magnitude, it appears likely that successional trends are minor compared with fluctuations. Alternatively, Anderson and Holte (1981) have suggested that secondary succession on the Snake River Plain is a slow process initially, but increases more rapidly after one or more decades. Such an hypothesis lends credence to succession as a causal factor particularly affecting understory vegetation dynamics. In actuality, both fluctuations and succession are probably influencing the vegetation responses reported herein.

An excellent discussion of the two community processes, secondary succession and fluctuations, has been provided by Miles (1979). Fluctuations are short term and reversible changes in vegetation which occur from year to year; however, the long-term "average" vegetation structure remains somewhat constant. In contrast, successional changes are directional, so that the long-term vegetation structure does not recurrently converge on an "average," but moves away from it, often with the concomitant establishment of new species. Successional changes may occur within a few months or take hundreds of years, depending on climate, competing exotic species, etc.

With reference to fluctuating climatic factors, precipitation prior to the growing season apparently influenced total primary production as much as precipitation during the growing season. This was supported by the work of Blaisdell (1958), who found high correlation coefficients between biomass and precipitation of the 9-month period immediately preceding the growing season. Evidence that grass production is correlated with current growing season precipitation in the southern deserts (Cable 1975) suggests that warm season grasses (those with the C_4 carbon pathway) have somewhat different relationships to environmental variables than do the cool season plants (C_3) which characterize the northern desert shrub vegetation.

The abundance and vigor of grass species shown in most of the plots during the final year of investigation, 1976, was perhaps largely due to a very good growing season in the preceding year. In 1975 there was a long, cool spring lasting well into early summer, coupled with abundant and late rainfall. This resulted in high grass production which carried over to the following year, particularly in the northern regions of the site with sandy soils. Shrubs may have also responded to this, as evidenced in the 1976 data. *Eurotia* and *Atriplex confertifolia* at the northern end of the INEL site showed gains in 1976. Sagebrush and grass in other parts of the site also showed improvement. Increased growth of *Artemisia* was also noted in 1965 by Harniss and West (1973), and was attributed to the influence of precipitation (Harniss 1968).

For the most part, however, density and cover of shrub species remained constant in comparison with dynamics of herbaceous species. Such evidence corroborates results of other work at the INEL site (Anderson and Holte 1981) and elsewhere in the sagebrush-grass region (Brotherson and Brotherson 1981).

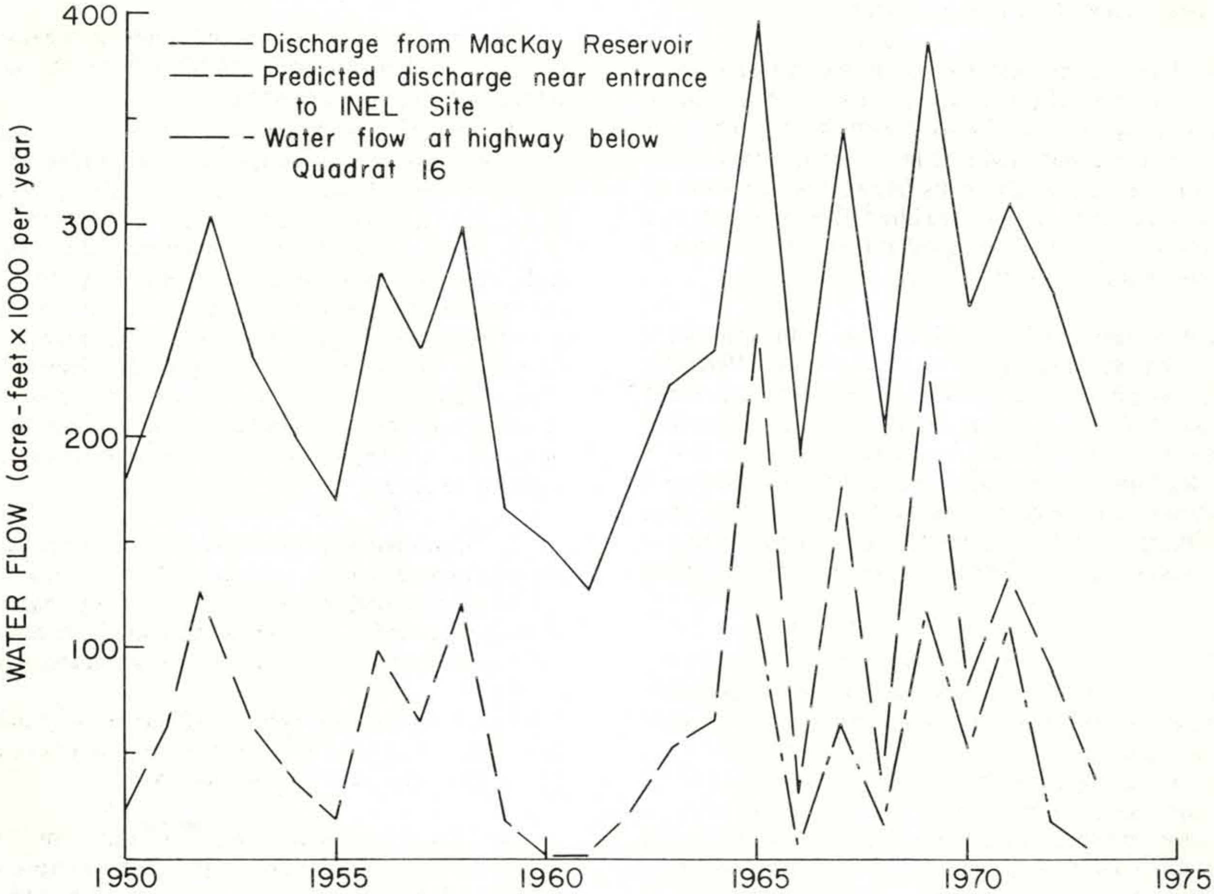


Fig. 14. Annual water flow in thousands of acre-feet at different locations on the Big Lost River.

The disappearance of grass from the Big Lost River sinks area is correlated with reduction of water flow to this area (Figure 14). First there was a series of relatively dry years beginning in 1959. This is evidenced by the reduced discharge from Mackay Reservoir and the correspondingly low flow in the river below Arco. Shortly after river flow returned to normal, the use of a diversion dam and storage basin, constructed in the southwestern corner of the INEL site, was implemented to protect installations and facilities farther north from flooding. Figure 14 records the water flow in the Big Lost River at the Test Reactor Area bridge from 1965, which essentially represents the amount of water entering the lower end of the Big Lost River sinks region and the extensive western wheatgrass flats. Along with the change in water regime of the western wheatgrass flats, the area was opened to grazing sometime prior to 1965. Unfortunately, as the habitat deteriorated, the grazing pressure was not diminished. The result (Figure 15) is a complete loss of *Agropyron smithii* and other perennial grasses, and replacement by *Salsola kali* and annual mustard plants (refer also to Figure 12).

Early grazing studies conducted by Craddock and Forsling (1938) and Pechanec and Stewart (1949) confirmed that long-term, moderate to heavy grazing has a deleterious effect on climax vegetation on the Snake River Plain. For example, Craddock and Forsling (1938) found that 6 years of fairly heavy spring grazing (65-70 percent utilization) resulted in a decrease of forage production by an estimated one-third and grass cover by two-thirds. Consequently, where grazing pressure (or recent release from grazing pressure) occurs along with short-term fluctuations, the causal factors relating to observed vegetal dynamics are difficult to quantify. When they reinforce each other, moreover, the results, as discussed above, can be sudden and significant.

The causes of the shift in vegetation growth observed in these sample plots at the INEL site include grazing and climatic factors, particularly precipitation and related soil moisture. The low rainfall year 1959 was immediately reflected in the growth conditions of vegetation during that year. Changes in the vegetation of those quadrats which were protected from grazing disturbance provide evidence for the importance of the climatic factors.

The introduction and spread of the noxious weed *Halogeton* on the INEL site may also be a result of grazing pressures. *Halogeton* was already present in certain areas of the site in 1955, but increased in occurrence in spite of efforts to seed competitive grass (*Agropyron desertorum*) in those areas where it was established. It invaded only one of the quadrats in this study, quadrat 6 in the playa area of the northernmost region of the site.

Results presented here indicate that both spring temperature and precipitation affect plant species differently, and the precipitation received during the previous year can be a casual factor affecting community dynamics. The previous year's precipitation could be expected to affect shrub development, because species like *Artemisia* and *Chrysothamnus* undergo some growth late in the growing season (Pearson 1965), and development during one season would, therefore, be evident in the spring of the following year.

Thus, the factors affecting vegetation change in this region can probably be ordered as to their importance: growing-season weather, previous season's weather characteristics, and grazing. Fire can also have long-term effects in local areas. For example, an early fire elsewhere on the INEL site caused changes in vegetation still prevalent 65 years later (McBride et al. 1978). More precise determination of the relative importance of these factors would require more data points or sampling periods in the time span considered for investigation.

CONCLUSIONS

As a result of this and related studies in the sagebrush-grass region of the upper Snake River Plain, the following general conclusions are reached:

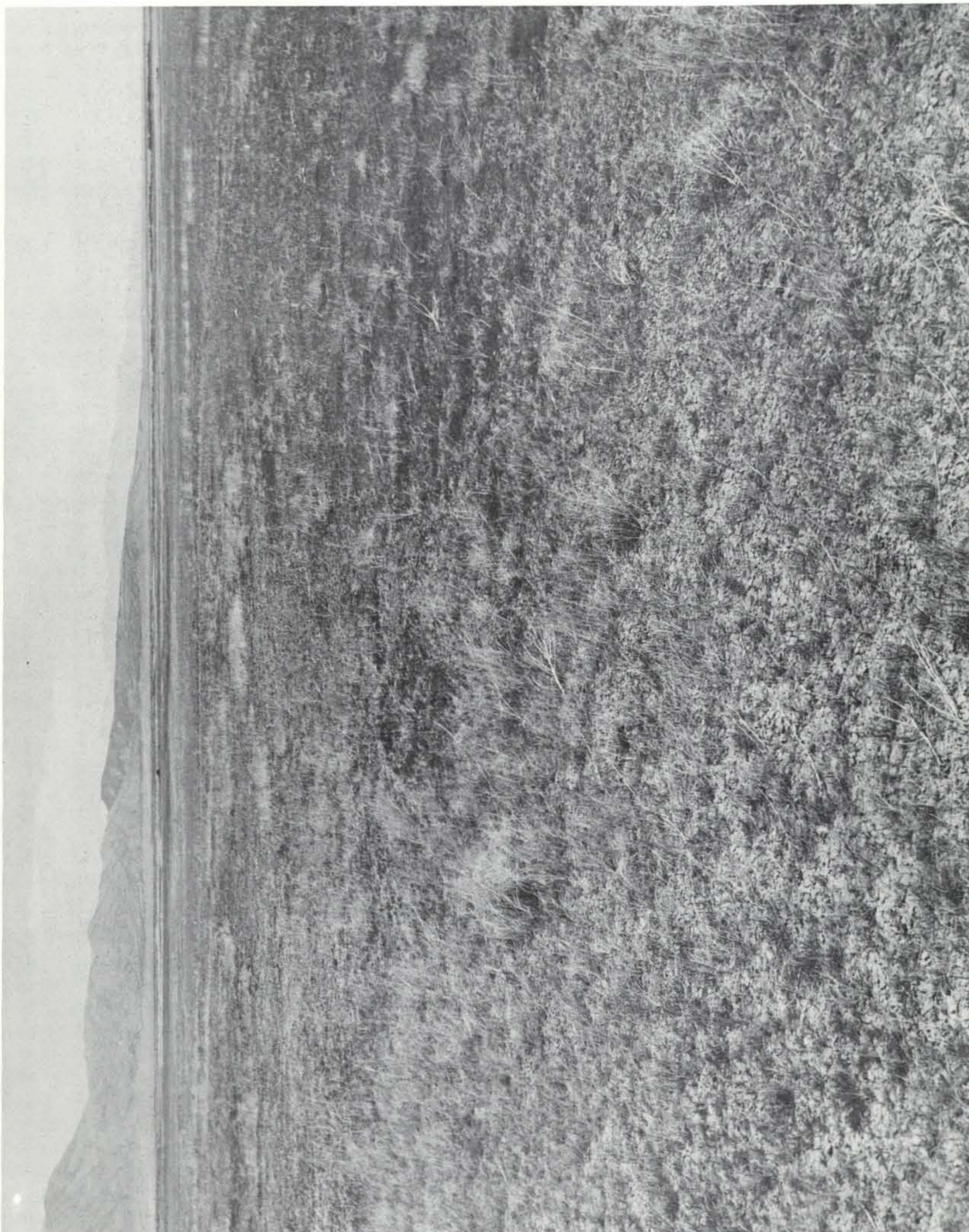
1. Vegetation dynamics of shrub-dominated communities of the area are complex events resulting from both long-term successional trends following disturbances such as grazing, fire, and insect infestation (or retrogression, if the disturbance is of a chronic nature and still ongoing), and short-term fluctuations due primarily to changing seasonal weather patterns. For the most part, fluctuations are of sufficient magnitude in these communities to mask secondary succession over time periods as long as 25 or more years. Only the more accelerated successional responses, such as were found on the *Agropyron smithii* plain encompassing quadrat 16, are detectable in this xeric region in less time.

2. Shrub populations are relatively stable regardless of perturbations caused by climate or livestock grazing. It is the understory herbaceous species which respond most to disturbances, and, subsequently, account for a majority of the vegetation dynamics in succession and fluctuations.

3. The most unpropitious effects on vegetation will occur with a combination of deteriorating environmental conditions and intense grazing pressure.

4. The contamination resulting from intentional or accidental releases of radioisotopes from reactors and the Chemical Processing Plant during the 1950s had no discernable long-term effects on surrounding vegetation.

Fig. 15. General view of the Big Lost River sinks region in 1957 (above) and the same area in 1976 (below). Originally a sward dominated by western wheatgrass (*Agropyron smithii*), it has been transformed to an annual community type of tumble mustard (*Sisymbrium*) and Russian thistle (*Salsola kali*) as a result of water diversion and intense grazing pressure by domestic animals.



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APPENDIX

Q-4 0.3 miles NE SPERT 1

Location: Sec. 27, T3N, R30E Elev: ≅4,900 feet

Community Type: *Artemisia tridentata - Sitanion hystrix*

General Soil: Classified under areas dominated by thin dark-colored stoney medium-textured soils and calcareous loamy subsoils.

Specific Comments: Moderately deep (20-40 inch) and well-drained. The surface layers are silt loam and the subsoil is stoney silt loam. Slope is nearly level. Surface is noncalcareous, but subsoil is calcareous.

Grazing History: Not grazed since 1950.

Q-5 0.6 miles NE SPERT 1

Location: Sec. 27, T3N, R30E Elev: ≅4,925 feet

Community Type: *Artemisia tridentata - Oryzopsis hymenoides - Stipa comata*

Soil Comments: Shallow (10-20 inch) and well-drained. Typical of higher areas of the loess-covered lava plain. Surface layer is rocky silt loam with substratum of fractured basalt. Located on top of a slight hill on a nearly level slope. Surface soil becoming calcareous below 3 inches.

Grazing History: Not grazed since 1950

Q-6 0.5 miles NE IET

Location: Sec. 1, T6N, R31E Elev: ≅4,800 feet

Community Type: *Atriplex nuttallii - Eurotia lanata*

General Soil Comments: Occupies playa in the Big Lost River and Birch Creek sink area. The parent material is mixed alluvial deposits on soft laminated lacustrine beds.

Specific Comments: Deep (40+ inch) and well-drained soil. Strongly calcareous clay at all depths. Very low permeability but high water-holding capacity.

Grazing History: Not grazed since 1957.

Q-7 1 mile NE Q-6

Location: Sec. 3, T6N, R32E Elev: ≅4,825 feet

Community Type: *Tetradymia canescens - Chrysothamnus viscidiflorus*

General Soil Comments: Soils are on basalt plains. Lava outcrops occupy the tops of ridges and form a pattern with a complex of several soils called the Aecet-Rock outcrop complex. The Aecet soil is moderately deep, well-drained, and quite strong. It is generally aeolian in nature.

Specific Comments: Very strong sandy loam 15-30 inches deep. Contains basalt pebbles and cobbles. Moderately alkaline in surface layer and strongly alkaline below with calcareous layer just above basalt bedrock. Very little slope.

Grazing History: Not grazed since 1957.

Q-8 Markers missing

Location: 1 mile NE of Q-7, Sec. 35, T7N, R32E

Q-9 2 miles NE of Q-7

Location: Sec. 25, T7N, R32E Elev: ≅4,820 feet

Community Type: *Tetradymia canescens - Chrysothamnus viscidiflorus*

Soil Comments: This soil is very deep and well-drained lacustrine material from mixed sources. Slopes are less than 1%. It falls in the SCS category of Terreton silty clay loam. The top horizon is hard, platy, and moderately calcareous. Lower horizons are calcareous.

Grazing History: Not grazed since 1957.

Q-11 .75 miles NE Jct. US20 and Id. 22 (Howe Hwy.)

Location: Sec. 5, T3N, R38E Elev: ≅5,150 feet

Community Type: *Artemisia tridentata - Eurotia lanata - Chrysothamnus viscidiflorus*

General Soil Comments: This is an area of loess-covered lava plains. The parent material is influenced to varying degrees by the underlying basalt. The soils vary widely in depth and stoniness.

Specific Comments: Moderately deep (20-30 inch), well-drained silt loam with stoniness in the lower horizons. The surface horizon is noncalcareous but subsurface layers are calcareous. Permeability and water-holding capacity are moderate.

Grazing History: Grazed for duration of the study.

Q-12 2 miles NE diversion dam along Big Lost River

Location: Sec. 6, T2N, R29E

Community Type: *Artemisia tridentata - Agropyron dasystachyum - Stipa comata*

General Soil Comments: This area is part of the lower alluvial plains of the Little Lost River.

Specific Comments: Deep (>40 inch), well-drained sandy loam with a substratum of sand and gravel. Negligible slope. The entire property is moderately calcareous.

Grazing History: Not grazed since 1950.

Q-13 South of IET

Location: Sec. 14, T6N, R31E Elev: ≅4,800 feet

Community Type: *Atriplex nuttallii - Eurotia lanata - Oryzopsis hymenoides*

General Soil Comments: This soil is part of the same playa on which Q-6 is located, so the comments are identical. This playa is defined as playa #4 in the Big Lost River sink system by ERDA (USGS 1965 Progress Report 1967, p. 21). It has been termed a dry playa as water has not reached it since records have been kept.

Grazing History: Not grazed since 1957.

Q-14 ≅1.5 miles E of IET

Location: Sec. 14, T6N, R32E (NE corner, by airstrip) Elev: ≅4,800 feet

Community Type: *Artemisia tridentata - Eurotia lanata - Chrysothamnus viscidiflorus*

General Soil Comments: This soil is classified the same as that soil associated with Q-10 (i.e., lacustrine material from mixed sources). It appears to be slightly higher in elevation than the playa of Quadrats 6 and 13.

Grazing History: Not grazed since 1957.

Q-15 1.7 miles E of Q-14

Location: Sec. 13, T6N, R32E Elev: ≅4,825 feet

Community Type: *Oryzopsis hymenoides - Chrysothamnus viscidiflorus - Opuntia polyacantha*

General Soil Comments: These soils overlie the basalt plains forming a complex of loamy sands and sands. It is aeolian in nature. Permeability is high and water holding capacity low to moderate.

Specific Comments: The soil is classified as a Malm series soil and consists of moderately deep, well-drained soils of aeolian sands. The surface horizon is a stony loamy sand with very weak structure. It is moderately calcareous. Lower layers are strongly calcareous and strongly alkaline underlain by a caliche layer and basalt bedrock.

Grazing History: Not grazed since 1957.

Q-16 Big Lost River sinks area

Location: Plot markers missing Elev: ≅4,775 feet

Approx. Sec. 27, T5N, R30E

Community Type: *Agropyron smithii - Iva axillaris - Juncus* sp.

General Soil Comments: Deep, well-drained soils on lacustrine sediments in playas. These soils are subject to flooding on occasional years.

Specific Comments: Soil in the Big Lost River sink area. Surface and subsoil are strongly calcareous clay overlying substrate of gravel, sand, silt, and clay. Permeability is very low but water holding capacity is high.

Grazing History: Ostensibly removed from grazing in 1950, but actually has been grazed for an unquantifiable period of time.