The Influence of Perennial Vegetation and Precipitation on Occurrence of Halogeton Glomeratus and Bromus Tectorum in Arid and Semi-Arid Regions[1]

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An investigation of halogeton (*Halogeton glomeratus* C. A. Mey.) was initiated in Nevada in 1954 to determine in some detail the characteristics of the soils this plant has occupied in the northern desert shrub type of vegetation, its relations with endemic plants as well as with introduced species and other invaders, and its climatic requirements and responses.

This report presents results of the study on occurrence of halogeton, and concurrently of cheatgrass (*Bromus tectorum* L.), in six types of perennial vegetation in northern Nevada. Results of an investigation of soils occupied by halogeton, together with general characteristics of associated vegetation, were reported in a previous paper (Robocker, 1958).

Although considerable literature has been published on ecology of cheatgrass as well as on ecology of halogeton, many conclusions have not been evaluated statistically to obtain an estimate of differences due to chance variations and factors which could be measured.

Piemeisel (1951) found on lands formerly occupied by sagebrush in southern Idaho that a succession of three communities of annuals occurred and that the changes from one community to another and the processes that took place within the community proceeded in spite of differences in weather and years of above- or below-average precipitation. Fleming, *et al.* (1942) recognized cheatgrass as being a permanent part of the northern desert shrub vegetation in Nevada, and Stewart and Hull (1949) found that long-protected native vegetation in Idaho had been invaded by and carried cheatgrass as a small part of its total component. Tisdale and Zappettini (1953) concluded that halogeton would remain a permanent part of the northern desert shrub vegetation. Eckert (1954) found that where the density of winterfat (*Eurotia lanata* (Pursh) Moq.) was less than 22 per cent, halogeton plants occurred in varying numbers depending on seed production the previous year and climatic conditions in the current year. Holl (1954) concluded that big sagebrush (*Artemisia tridentata* Nutt.) and greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.) were most resistant to invasion by halogeton and that kochia (*Kochia americana* S. Wats.) was the least resistant, while shadscale (*Atriplex confertifolia* (Torr. and Frem.) S. Wats.), Nuttall's saltbush (*Atriplex Nuttallii* S. Wats.), and winterfat were intermediate. Miller (1956) found that while the yield and occurrence of crested wheatgrass

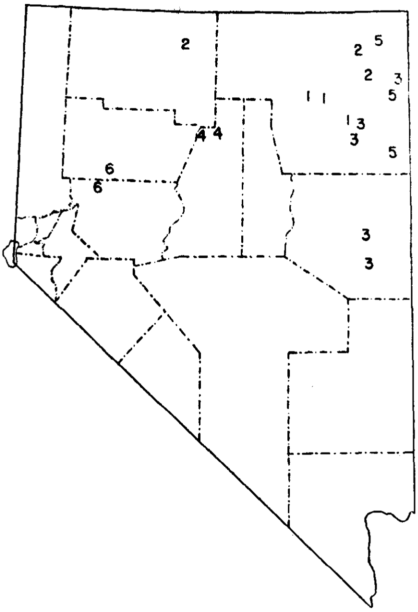

FIGURE 1. The generalized locations of the sampling areas by vegetation types are shown as follows: (1) Big sagebrush, (2) crested wheatgrass, (3) winterfat, (4) shadscale, (5) Nuttall's saltbush, and (6) shadscale-little greasewood.

(*Agropyron desertorum* (Fisch.) Schult.) and halogeton were inverse, crested wheatgrass did not fully exclude halogeton.

Methods and Materials

Vegetation types were sampled in a number of northern Nevada areas (Figure 1) with types by location as follows: (1) Big sagebrush: 12, 14, 26, and 27 miles east of Elko, and 8 miles south of Wells; (2) crested wheatgrass: 30 miles and 50 miles north of Wells, and 10 miles south of Paradise Valley; (3) winterfat: 4 miles south of Montello, 10 miles south of Wells, 2 miles east of McGill, and 11 miles south of Ely; (4) shadscale: 4 miles and 6 miles west of Battle Mountain; (5) Nuttall's saltbush: 9 miles northeast of Oasis, 19 miles east of the junction of U. S. Highways 93 and 50, and Knoll Creek Experiment Station gate (9 miles south of Contact); and (6) shadscale-little greasewood (*Sarcobatus baileyi* Coville): 8, 10, and 12 miles south of Lovelock.

[1] *Cooperative investigations of the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture and the Nevada Agricultural Experiment Station.*

Sampling was accomplished by a modification of the Parker loop method (Parker, 1951). Frequency counts were made by placing a ¾-inch loop at every foot mark of a 100-foot steel tape, and the presence of vegetation was noted as a "hit" at each reading where vegetation occurred. The total number of hits counted for any species was the frequency for that species. The average of three transects constituted a cluster or sample. A total of 18 clusters was read for each vegetation type for each year, and the same areas were sampled each year. Sample readings were taken during July and August, 1956, and in July 1957.

The counting of hits was as follows:

Perennial species: Each hit counted as one if the plant occurred alone, with an annual, or with a *dead* perennial; it was counted as one-half if it occurred with another *live* perennial.

Annual species and seedlings of perennial species: Each hit counted as one whether alone or with another annual or a perennial species.

Climatic records were taken from the nearest U. S. Weather Bureau or airport weather station. The drawbacks of this method of taking weather data are obvious; however, the assumption was made that with a minimum change in topography and vegetation type, the precipitation pattern and amount were similar or comparable. Precipitation for the Contact-Wilkins sampling area (the Hubbard Reseeding Project of the Bureau of Land Management) was taken as a mean for the Contact and Wilkins stations, since the gradient appeared to be consistent.

Monthly amounts of precipitation for effective rainfall (October 1 to June 1) were grouped in five periods: October 1- June 1, October 1- May 1, October 1- April 1, December 1- June 1, and December 1- May 1, in order to test whether any of these five periods was of more importance than the others in establishment and growth of halogeton and cheatgrass.

Correlations of frequency of occurrence of halogeton and of cheatgrass were calculated independently for each precipitation period for each year individually and for the 2 years combined. Correlations for halogeton and cheatgrass were likewise made separately for each vegetation type, by individual years and with years combined, and finally for combined perennial vegetation types by each year and over both years.

Results and Discussion

A summary of the composition of each vegetation type, including annuals, is shown in Table 1. Little change from 1956 to 1957 was noted in frequency of the live key species, the total live perennial species, and the amount of dead perennial material. The total live perennials in those types established in approximately the same precipitation pattern and precipitation amount (the first four types listed in Table 1) showed a tendency toward a constant frequency between 26 percent and 34 percent. Crested wheatgrass, although a planted species, reached an equilibrium of frequency which was consistent with the native species. Nuttall's saltbush, in the lower end of the range, is also included, although the sites of its occurrence

Table 1. Summary of percentage frequencies of occurrence of species and groups of species in vegetation transect studies in Nevada, 1956 and 1957.[1]

Perennial type	Live key species 1956	Live key species 1957	Total live perennials 1956	Total live perennials 1957	Dead perennials 1956	Dead perennials 1957	Halogeton 1956	Halogeton 1957	Cheatgrass 1956	Cheatgrass 1957	Other annuals 1956	Other annuals 1957	Total annuals 1956	Total annuals 1957
	(Percent)													
Big sagebrush	26.2	22.2[2]	32.9	28.3[2]	7.6	6.5	2.4	2.4	3.5	7.7	3.3	5.1	9.2	15.2
Crested wheatgrass	22.8[3]	24.4[4]	26.4[3]	34.3[4]	0.1	0.1	1.7	4.8	4.7	8.8	1.2	1.6	7.6	15.2
Winterfat	30.8	28.6[5]	31.5	29.9[5]	0.0	0.4	4.9	16.5	0.0	0.0	0.1	0.1	5.0	16.6
Nuttall's saltbush	26.0	27.8[6]	26.1	28.7[6]	0.0	0.2	3.5	8.2	0.0	0.0	0.3	0.3	3.8	8.5
Shadscale	15.7	15.4	17.3	17.9	18.1	15.0	1.2	3.6	0.1	0.9	2.5	2.5	3.8	7.0
Shadscale-little greasewood[7]	4.8	6.3	5.7	8.0	13.4	13.9	1.0	3.0	0.0	0.1	1.1	1.1	3.1	4.2
Mean	21.1	20.8	23.3	24.5	6.5	6.0	2.5	6.4	1.4	2.9	1.4	1.8	5.4	11.1
1957 change		−0.3		+1.2		−0.5		+3.9		+1.5		+0.4		+5.7

[1] Each figure is the average of 18 clusters, and each cluster was the average of three 100-foot transects read at each foot with a ¾-inch loop.
[2] Exclusive of seedlings, 0.2%.
[3] Exclusive of seedlings, 3.5%.
[4] Exclusive of crested wheatgrass seedlings, 7.9% and big sagebrush seedlings, 0.8%.
[5] Exclusive of seedlings, 1.8%.
[6] Exclusive of seedlings, 0.7%.
[7] Key species includes both species.

bordered on saline areas with poor drainage. Perhaps conspicuous by its absence is greasewood, the dominant in the highly saline and highly alkaline "flats." The reason for the scarcity of halogeton on these greasewood flats is not known, since halogeton is both adapted and tolerant to high pH and high salt content of many desert soils (Morton, *et al.* 1959). One explanation might be an inhibiting effect on germination of high pH and a possible adverse effect of a saturated soil in the months when halogeton is germinating and in the seedling stage.

Data in Table 1 also show that while cheatgrass increased in big sagebrush in 1957, the frequency of halogeton remained the same. This is believed to be a reflection of the competitive ability of big sagebrush as well as of the fact that the competition extended actively through the summer, thereby affecting not only the size of the halogeton plants but also the amount of seed produced. Cheatgrass did not appear in winterfat and Nuttall's saltbush and appeared in only very small amounts in the shadscale associations. The limitation in these types appears to be both a result of higher pH and salinity and of lower precipitation.

An analysis of variance on the year-to-year differences in the six vegetation types (Table 2) showed that only crested wheatgrass and shadscale-little greasewood had significantly higher frequencies in 1957 than in 1956. The difference might be partially explained by a variation in grazing pressure on crested wheatgrass, since none of the areas was protected from grazing, and some of the crested wheatgrass seedings were being utilized. Under these conditions, a lighter utilization in 1957 might have indicated a higher frequency of crested wheatgrass. A considerable part of the increase in shadscale-little greasewood can be attributed to recovery from a sharp and widespread decrease in live plants prior to initiation of the study, the cause of which is not known.

Table 2. Comparison of mean frequencies of occurrence of each type of perennial vegetation by years, 1956 and 1957.

Perennial type	Mean 1956	Mean 1957	Coeff. of variability
Big sagebrush	32.9	28.3	24.2
Crested wheatgrass	26.4	34.3**	19.2
Winterfat	31.5	29.9	19.5
Nuttall's saltbush	26.1	28.7	43.9
Shadscale	17.3	17.9	22.9
Shadscale-little greasewood[1]	5.7	8.0*	20.0

[1] Analysis of variance based on transformation of data to scale of $\sqrt{X+½}$. Means shown are actual values.

*1957 frequency significantly greater than 1956 at 5% level.

**1957 frequency significantly greater than 1956 at 1% level.

The statistical interpretations of data on the annual species show that, although significance or non-significance is indicated, the trend and stability of the trend may be of more importance in evaluation of the relations of annuals and the perennials under study. The highest variations, as would be expected, were in year-to-year changes in populations of annual species. The greatest changes occurred on the best sites. A comparison of the 1956 and 1957 frequencies for both halogeton and cheatgrass (Table 3) showed a significant increase of halogeton in crested wheatgrass in 1957 and a highly significant increase in both Nuttall's saltbush and winterfat types. Cheatgrass showed a highly significant increase on both crested wheatgrass and big sagebrush sites. A negligible amount or a complete absence of that species occurred on the other sites. Table 1 shows that seedlings of three key perennials were present in 1957, while there were none in 1956. Crested wheatgrass seedlings occurred in both years. May precipitation at weather stations near the sites of these types was also high in 1957 (Table 4), and May precipitation could account in part for the increased population of seedlings.

Statistical analysis on the same precipitation periods for 1955-56 and 1956-57 showed no significant differences for October 1-June 1, October 1-May 1, and December 1-June 1. A significant difference was indicated for October 1-April 1 and December 1-May 1. An obvious shortcoming in treating precipitation data, not only in this but in other papers, is a reliable way to measure the real effects of amounts of precipitation and its distribution in time, the season of occurrence, and the rate of fall on germination, plant growth, and development.

The small change between yearly means of the overall population of perennial types is indicated in Table 1. The live key species decreased 0.3 percent, and and an overall increase of 1.2 percent for total live perennial species was recorded. The other annual species, which were in addition to halogeton and cheatgrass, consisted largely of Russian thistle *(Salsola kali* L. var. *tenuifolia* Tausch.), an almost invisible *Eriogonum* spp., and a scattering of perfoliate peppergrass *(Lepidium perfoliatum* L.) on the big sagebrush and crested wheatgrass sites. Seedlings of perennials were also included in the annual category because of the direct competition with both annuals and perennials and the consequent high mortality.

A test was made for correlation of frequency of halogeton

Table 3. Comparison of mean frequencies of occurrence by years for halogeton and cheatgrass in each of six vegetation types.

	Mean for each year[1]			
	Halogeton		Cheatgrass	
Perennial type	1956	1957	1956	1957
Big sagebrush	2.4	2.4	3.5	7.7**
Crested wheatgrass	1.7	4.8*	4.7	8.8**
Winterfat	4.9	16.5**	0.0	0.0
Nuttall's saltbush	3.5	8.2**	0.0	0.0
Shadscale[2]	1.2	3.6	0.1	0.9
Shadscale-little greasewood[2]	1.0	3.0	0.0	0.1

[1]Analysis based on transformations of actual numbers to the scale of $\sqrt{X+\frac{1}{2}}$. Means shown are actual values.
[2]No analysis for cheatgrass.
*1957 frequency significantly greater than 1956 at 5% level.
**1957 frequency significantly greater than 1956 at 1% level.

and cheatgrass in each vegetation type, for each year individually, and for the 2 years combined (Table 5). Correlations of frequency of halogeton in perennial vegetation sites by individual years were predominantly negative, but in no case significant.

When data for each of the 2 years for each perennial type were combined, only the frequency of halogeton on the winterfat sites showed a significant negative correlation at 5 percent. Combining the tests for all readings over the perennial vegetation types for individual years showed a highly significant *positive* correlation for 1956. No significant correlation was indicated for 1957 or for the data for types and years combined.

Correlations of cheatgrass with perennial vegetation were as variable as those for halogeton and perennial vegetation. In individual perennial vegetation types, no significant correlation was found in either year, and correlation for combined years in crested wheatgrass was significantly negative. Where the analysis was made for combined occurrence in all perennial vegetation types over both years, a significant negative correlation was obtained.

Results of tests for correlation of all annual species with perennial vegetation (Table 6) were again variable. Negative significance was indicated at the 1-percent level for annuals in crested wheatgrass in 1957 and at the 5-percent level in winterfat for 1956 and 1957 combined.

The data presented in Tables 5 and 6 indicate a minor effect of perennial, northern desert shrub vegetation, within the limits of an average stand as represented by this study, on the frequency of early-maturing (cheatgrass) or late-maturing (halogeton) annuals or a population of all annuals and seedlings of perennials.

Five precipitation periods were set up as previously outlined and presented in Table 4 in order to attempt a measure of the effectiveness of distribution of precipitation. The correlations of frequency of halogeton and cheatgrass with the amount of precipitation by periods (Table 7) were again both positive and negative. In 1955-56 there was a negative trend of correlations for halogeton, a positive trend in 1956-57, and a negative trend for the combined years. No value approached significance.

The correlation of frequency of cheatgrass with precipitation by periods indicated a consistently positive correlation of all periods, and for individual and combined years. Correlation with the combined years for the longest period (October 1-June 1) was significant. This positive

Table 4. Precipitation by periods for 1955-56 and 1956-57.

		Precipitation for period									
Year and station	Perennial vegetation type	10/1-6/1	10/1-5/1	10/1-4/1	12/1-6/1	12/1-5/1	10/1-6/1	10/1-5/1	10/1-4/1	12/1-6/1	12/1-5/1
		1955-56					1956-57				
Battle Mountain[1]	Shadscale	6.1	5.4	4.1	5.7	5.0	5.4	3.1	2.8	4.5	2.2
Contact	Nuttall's saltbush	7.2	5.4	4.8	6.3	4.5	10.1	6.4	5.7	8.3	4.6
Contact-Wilkins	Crested wheatgrass	8.8	7.0	6.2	7.9	6.0	9.6	6.3	5.5	8.2	4.9
Deeth	Big sagebrush	13.1	10.9	10.5	10.6	8.4	9.8	6.0	4.9	8.2	4.4
Elko	Big sagebrush	11.1	9.4	7.9	10.1	8.3	8.7	6.3	4.8	7.6	5.2
Ely	Winterfat	6.9	5.3	4.6	6.2	4.6	6.2	3.5	3.0	5.6	2.9
Lovelock[1]	Shadscale-little greasewood	5.3	4.0	3.6	4.8	3.6	3.1	2.3	2.0	1.8	1.4
McGill	Winterfat	7.7	4.4	3.8	7.0	3.7	6.5	4.3	2.8	5.6	3.3
Montello	Winterfat and Nuttall's saltbush	5.6	4.4	4.0	5.0	3.8	6.8	3.7	3.1	6.0	2.8
Paradise Valley	Crested wheatgrass	10.6	9.4	6.6	9.4	8.2	9.7	7.6	6.5	8.6	6.6
Wells	Winterfat and big sagebrush	9.6	7.4	6.8	9.1	6.9	8.2	5.8	5.1	7.4	5.0
Wilkins	Crested wheatgrass	10.5	8.5	7.6	9.5	7.5	9.0	6.2	5.3	8.0	5.2
Mean		8.5	6.8	5.9	7.6	5.9	7.8	5.1	4.3	6.6	4.0

[1]Airport weather station

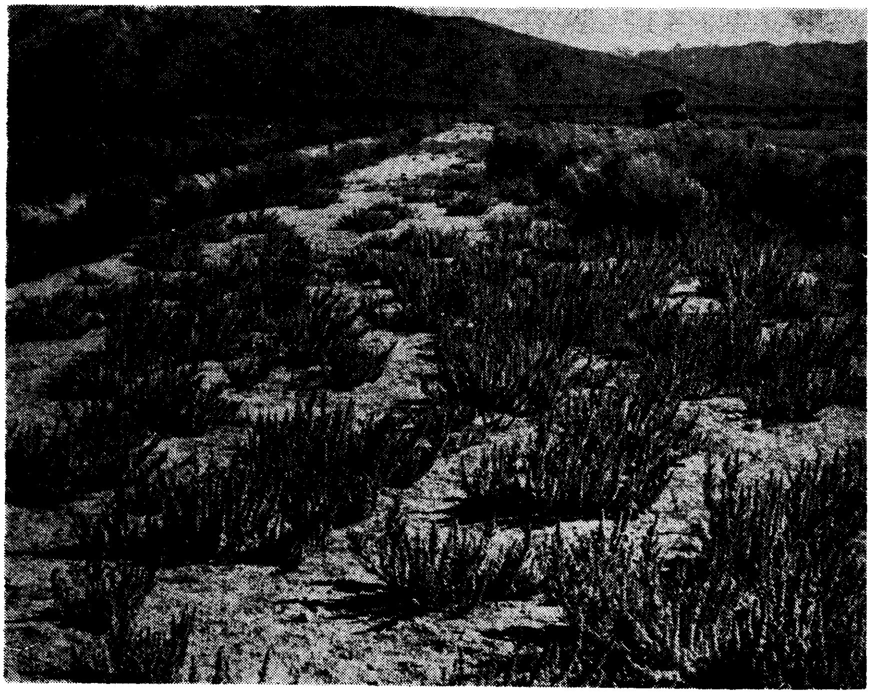

FIGURE 2. The shoulders and barrow pits of highways through perennial vegetation such as big sagebrush provide excellent seedbeds for annual species like halogeton.

correlation should be expected since cheatgrass usually begins growth in the late autumn and resumes growth when soil moisture is generally at its highest level in late winter and early spring.

Correlations of 1957 frequencies of halogeton and cheatgrass with the precipitation of 1956 were negative for halogeton and positive for cheatgrass, but in no case were any correlations significant.

The interpretation of the comparisons made in this study strongly supports the theory that neither a relatively stable stand of perennials nor normal year-to-year variations in precipitation can account for the changes in populations of annual species within perennial stands of vegetation in arid and semi-arid regions. This conclusion is supported by previous observations that annuals, once established in a given stand of perennials, tend to persist (Robertson and Pearse, 1945; Stewart and Hull, 1949; and Daubenmire, 1942).

The shift in type and amount of grazing pressure, land utilization, water usage, soil disturbance, and deliberate and accidental introduction of new species since the colonization of North America is bringing about a readjustment in plant communities on uncultivated lands. The "closed community" as defined by Robertson and Pearse (1945) now appears to be an increasing scarcity in the arid and semi-arid regions because of the almost universal disturbance of the perennial, dominant native species by direct and indirect activities of man (Figure 2) and by regional deviations of climatic and edaphic norms (Figure 3).

The proper use and management of grazing lands may now be on the horns of a dilemma, due in large part to non-endemic, invading species which possess the aggressiveness and their own peculiar abilities to compete with native and other introduced vegetation. If the history of some of these immigrant plants is examined, it appears that efforts to contain or eradicate them have met with only partial success.

The concept of maintaining a *status quo* of climax, native perennial vegetation may now be forced into a re-evaluation by these exotic species. The question follows as to whether the proper aim of management is for a return to a disappearing native, perennial climax or whether it should be toward increased attention to management of grazing on present ranges, the judicious use of herbicides and fertilizers, and accelerated revegetation with forage species capable of competing successfully, under utilization by livestock, with less desirable plants.

Summary and Conclusions

Correlations of the frequency of occurrence of halogeton (*Halogeton glomeratus*) and cheatgrass (*Bromus tectorum*) with six types of perennial vegetation were made in Nevada in 1956

Table 5. Correlation of frequency of cheatgrass and halogeton with each perennial vegetation type in northern Nevada, 1956 and 1957.

	Cheatgrass			Halogeton		
Perennial type	1956	1957	1956+ 1957	1956	1957	1956+ 1957
Big sagebrush	+.260	−.362	−.122	−.274	−.149	−.102
Crested wheatgrass	−.313	−.251	−.340*	+.424	−.411	+.135
Winterfat	0	0	0	−.246	−.415	−.357*
Shadscale	0[1]	+.321	+.064	−.131	−.010	−.002
Nuttall's saltbush	0	0	0	+.232	−.125	−.014
Shadscale-little greasewood	0[1]	+.101	+.226	−.233	−.311	−.014
Combined types	+.161	−.018	−.238*	+.266**	+.068	+.124

[1] No cheatgrass counted in this year's sampling.
*Significant difference at the 5% level of probability.
**Significant difference at the 1% level of probability.

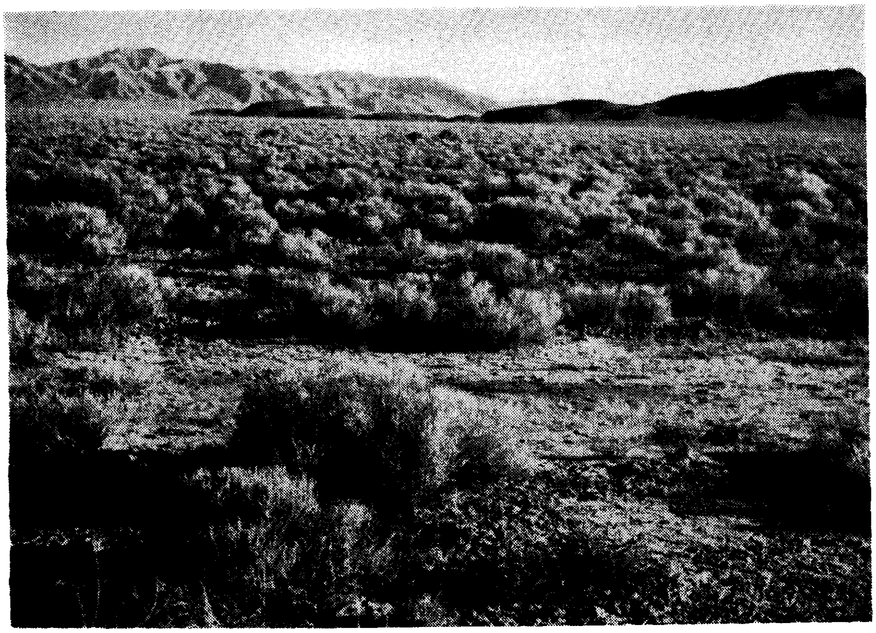

FIGURE 3. A "hole" in the shadscale community shown above is illustrative of a natural break in native vegetation where adapted annuals may become established and produce seed.

Table 6. Correlation of frequency of all annual species with six types of perennial vegetation type in northern Nevada, 1956 and 1957.

Perennial type	1956	1957	1956+ 1957
Big sagebrush	+.138	−.354	−.175
Crested wheatgrass	+.068	−.871**	−.097
Winterfat	−.240	−.358	−.416*
Shadscale	+.020	+.051	−.063
Nuttall's saltbush	−.023	−.022	−.010
Shadscale-little greasewood	−.433	−.196	−.022

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

and 1957. Correlations were both positive and negative for both species, and significance for some years and some types was found. Similar correlations were obtained with all annual species combined.

Comparisons of frequencies of the perennial species showed crested wheatgrass *(Agropyron desertorum)* to be significantly greater at the 1-percent level of probability in 1957 than in 1956. Shadscale-little greasewood *(Atriplex confertifolia-Sarcobatus baileyi)* was significantly greater at the 5-percent level in 1957. Comparisons of frequency of halogeton showed significantly greater numbers in crested wheatgrass sites and highly significant increases in stands of winterfat *(Eurotia lanata)* and Nuttall's saltbush *(Atriplex Nuttallii)* in 1957. Cheatgrass showed a highly significant increase in crested wheatgrass and big sagebrush *(Artemisia tridentata)* sites in 1957.

Table 7. Correlation of frequency of occurrence of cheatgrass and halogeton with amount of precipitation by periods in northern Nevada, 1955-56 and 1956-57.

	Cheatgrass			Halogeton		
Precipitation period	1955-56	1956-57	1955-56+ 1956-57	1955-56	1956-57	1955-56+ 1956-57
10/1-6/1	+.450	+.598	+.606*	−.382	+.103	−.084
10/1-5/1	+.405	+.485	+.350	−.438	+.117	−.174
10/1-4/1	+.497	+.495	+.447	−.374	+.119	−.168
12/1-6/1	+.407	+.552	+.512	−.404	+.114	−.098
12/1-5/1	+.351	+.379	+.217	−.479	+.122	−.202

*Significant at the 5% level of probability.

Correlations of frequency with five periods of fall-to-spring precipitation were positive and nonsignificant for cheatgrass, except for the period October 1-June 1 for the combined years. Both positive and negative correlations were found for halogeton, but no correlations were significant.

An overall evaluation of the data and their statistical significance presents strong evidence that neither an average frequency of perennial vegetation in arid and semi-arid regions of the West, as represented by this study, nor total precipitation during the late fall, winter, and spring can account for variations in stands of early-maturing and late-maturing annual species of vegetation, as exemplified by cheatgrass and halogeton.

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