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Title: SOME LIZARD-HABITAT RELATIONSHIPS IN THE NORTHERN GREAT BASIN

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Five sympatric species of desert lizards (leopard lizards (Gambelia wizlizeni), sagebrush lizards (Sceloporus graciosus), side-blotched lizards (Uta stansburiana), desert horned lizards (Phrynosoma platyrhinos), and Western whiptails (Cnemidophorus tigris)) were studied in June and July of 1978 and 1979 in northern Nevada on the Charles Sheldon National Wildlife Refuge. Lizard distribution, relative abundance, and diversity were determined from bi-monthly, live-capture censuses on 3 different vegetational stands. Stands, characterized by different shrub species and substrates (Budsage-Desert Pavement, Greasewood-Hard Pan, Sagebrush-Sand), were sampled monthly with random line transects for ground cover, shrub height cover, and shrub spacing. The indices to density of Sceloporus graciosus were significantly greater on the Sagebrush-Sand stand than on the other 2, and this species was significantly correlated (R^2=0.60) with shrub heights of 61-75 and 91-105 cm.

Uta stansburiana was significantly correlated (R^2=0.58) with shrub heights of 0-15 cm and occurred exclusively on the Budsage-Desert Pavement stand. Lizard abundances on the Budsage-Desert Pavement stand were twice as high as on the other stands, largely because of the presence of *Uta stansburiana*. Diversity indices were significantly correlated (R^2=0.42) with shrub spacing and shrub heights of 61-75 cm. Shrub heights, in conjunction with characteristic substrates, appeared influential in determining lizard distribution, relative abundance, and diversity.

Some Lizard-Habitat Relationships in the Northern Great Basin

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INTRODUCTION

Five sympatric lizard species (leopard lizards (Gambelia wislizeni), sagebrush lizards (Sceloporus graciosus), side-blotched lizards (Uta stansburiana), desert horned lizards (Phrynosoma platyrhinos), and Western whiptails (Cnemidophorus tigris)) occur widely throughout the northern Great Basin (Stebbins 1966). There have been no studies of saurian communities that have all 5 species or any research quantifying habitat characteristics of these desert lizards. Qualitative evidence from population studies suggested certain aspects of the physical environment were important in determining their distribution and density. Tanner and Krogh (1974) commented on the occurrence of G. wislizeni throughout most plant communities in the southwestern deserts and suggested that because of the predatory habits of this species, it required large, non-overlapping home ranges. Burkholder and Tanner (1974) concluded that clusters of dominant and subdominant plant types interspersed with ample open spaces were important for S. graciosus. Edaphic factors (Tanner and Hopkin 1972) and rocks or mounds at the bases of vegetation appeared important in determining U. stansburiana densities (Parker and Pianka 1975). Tanner and Krogh (1973) commented on the extreme variability in plant communities used by *P. platyrhinos* and the general nomadicity of individuals of this species; contrastingly, Pianka and Parker (1975) considered *P. platyrhinos* relatively sedentary in the vicinity of ant hills. Studies in the lower Colorado River area indicated higher densities of *C. tigris* in structurally and vegetatively diverse habitats compared to more homogeneous flatland desert environments (Vitt and Ohmart 1977).

Tanner and Hopkin (1972), citing differing population structures and longevity for *U. stansburiana* at different elevations, emphasized the problems of comparisons among studies. Typically each study referred to different habitats with varying physical and biotic factors. Tanner and Hopkin (1972) advised that comparisons take into account that variations in habitat introduce new parameters into the populations and it is not reasonable to expect species in different locations to behave the same ecologically. Further cause for caution in comparing studies comes from the extreme physiological plasticity of *P. platyrhinos* throughout its range (Tanner and Krogh 1973). Parker and Pianka (1975) and Tinkle (1967, 1969) noted the behavioral and reproductive flexibility of *U. stansburiana* in different habitats.

Disagreement exists regarding which factors are most influential in determining the composition of saurian communities. Pianka

(1975) found food was a major dimension separating niches of North American lizards. Utilization of different sized insect prey allowed opportunistic species, *U. stansburiana* and *C. tigris*, to co-exist on a Texas study area (Milstead and Tinkle 1969). Stuart (1932) concluded food was not important to distribution because lizards were extremely opportunistic and not limited to an area by a specific food source.

Pianka (1967), in a study of flatland desert species in western North America, described and discussed several factors which potentially determine the number of species present: length of growing season, amount of warm season productivity, climatic variability, and most importantly, spatial heterogeneity (mainly vegetative) of the environment. Stuart (1932) in a study of lizard distribution in Utah compared number of species to habitat and concluded vegetation had no direct effect on distribution. The general availability of arthropod prey, especially ants, and the abundance of required cover in plant debris and loose soil at shrub bases relieved *P. platyrhinos* of vegetative or edaphic restrictions on distribution (Tanner and Krogh 1973). Yet, Degenhardt (1966) found density of vegetative cover significantly related to lizard populations in Texas. Several workers (Pianka 1966; Milstead and Tinkle 1969) concluded that habitat structure was fundamental in determining distribution. Canopy height, shrub density, and vegetation on pedestals of soil were suggested but not quantified as important environmental characteristics for several desert lizards (McCoy 1967, Pianka 1973).

Within the northern Great Basin, Franklin and Dyrness (1973) limited description of the flatlands to a single community, and although Shreve (1942) stressed the wide-spread uniformity of such areas, Poulton and Tisdale (1961) reported that variability in vegetative species and structures existed in seemingly homogeneous deserts. Hanson (1950) indicated interpretation of data from semi-arid vegetation studies was frequently confounded by failure to account for site diversity.

The existence of local heterogeneity within larger, broadly homogeneous expanses may reflect edaphic variation. Hardy (1945) considered the relationships between soil and plant cover so strongly correlated that plants may be accepted as soil type indicators. Stuart (1932) found soil structure an important factor of lizard distribution. Although presenting little quantitative evidence, Stuart (1932) concluded *U. stansburiana* was most closely associated with gravel flats, boulders, and rock outcrops and *G. wislizeni* with sand and finer soils. *P. platyrhinos* was most abundant on lava, whereas *S. graciosus* was found on gravel flats, sand, and dunes. Localized site diversity appeared important in determining lizard diversity just as Roth (1976) found vegetative heterogeneity or patchiness correlated with bird species diversity.

MacArthur (1964) showed the presence of a bird species and its abundance could be predicted from a series of vegetational structure measurements. Similarly, structural features of vegetation were consistently present where certain bird species occurred and were therefore instrumental in determining community composition (James 1971).

In summary, there was a decided absence of quantitative habitat descriptions for these 5 common desert lizards and it was not clear if vegetational structures were as intimately correlated with lizard species presence as was the case with birds. The objectives of this study were to describe the species composition, relative abundance, and diversity of lizards in 3 vegetative stands in the northern Great Basin, and to investigate the correlations between lizard species, density indices, and diversity and cover by shrub species and canopy height, and substrate type.

STUDY AREA

The study was conducted in northwestern Nevada on the Charles Sheldon National Wildlife Refuge (CSNWR) (Fig. 1). Study sites were confined to the lowest elevational portion of CSNWR to permit inclusion of the 5 lizard species. The terrain and vegetation were typical of flatland desert expanses within the northern Great Basin. Franklin and Dyrness (1973) classified the area as an *Atriplex-Sarcobatus* community though simple mosaic ecotones with other shrubs regularly occurred. The mosaic stands included budsage-shadscale (*Artemisia spinescens-Atriplex confertifolia*), greasewood-shadscale (*Sarcobatus vermiculatus-Atriplex confertifolia*), and sagebrush (*Artemisia tridentata*). The dominant floristic influence was edaphic; Franklin and Dyrness (1973) reported many of the soils high in salinity and pH, with interior drainages and old lakebeds typical.

Precipitation for June and July of 1978 averaged 0.2 and 0.4 cm, respectively and for 1979, 1.0 and 1.9 cm. Total precipitation during 1978 was 23.6 cm and for 1979, 34.0 cm. Mean maximum and minimum temperatures for June of 1978 were 28.7 and 5.2 C and averages for July of 1978 were 34.1 and 10.0 C. Maximum and minimum temperatures for June of 1979 were 30.8 and 7.5 C and for July of 1979, 34.5 and 10.9 C (U.S. Dept. Commerce 1978, 1979). Vegetative growth occurred primarily in the spring and early summer.

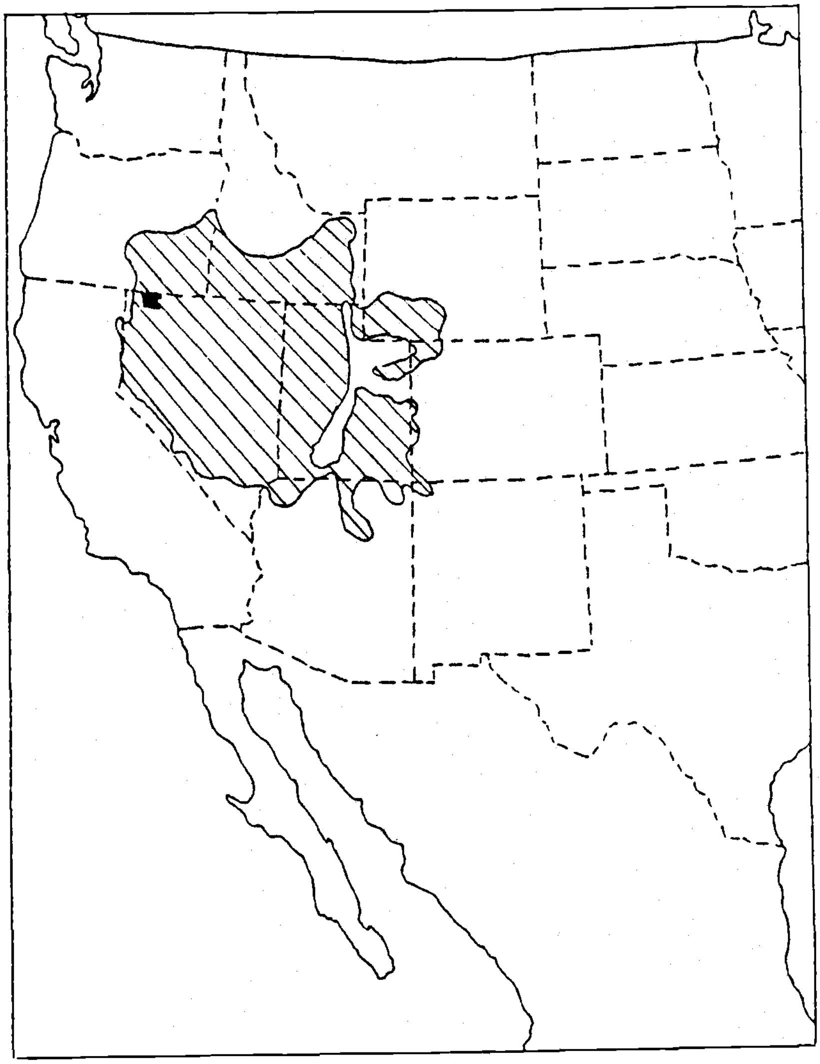

Figure 1. Location of the Charles Sheldon National Wildlife Refuge (solid) in the Great Basin Desert (cross-hatched) (after Shreve 1942).

The principal form of all the shrubs was that of a low to medium height (0-59 cm) rounded shape with varying amounts of litter accumulation at the shrub bases. Budsage, a summer deciduous plant (Billings 1957), had the greatest amount of leaf litter at the plant bases. Uprooted trunks and dead branches of sagebrush were conspicuous in the stand dominated by this species. Indian rice grass (Oryzopsis hymenoides), squirreltail (Sitanion hystrix), and needle and thread grass (Stipa comata) were the major grasses and tansy mustard (Descurainia pinnata), popcorn flower (Plagiobothrys kingii), goosefoot (Chenopodium sp.), and evening primrose (Oenothera sp.) were the chief herbaceous species present. Grass and herbaceous cover were not dominant components of the habitat; bare ground was extremely wide-spread.

STUDY SITES

The extreme northeastern corner of CSNWR was selected for the study sites. By restriction of the replicates to 1 general area the variables of slope (±5°), elevation (1303 m ± 30 m), and climatic conditions were held relatively uniform.

Plot selection commenced with the visual ranking of potential locations in terms of dominant shrub species, crown height and spacing of vegetation, percentages of bare ground and litter, and presence of a minimum 1.7 ha homogeneous area. Two persons separately ranked each area. Three stands were identified, and in each, 5 1-ha replicate plots were established. Twelve stakes, at 33.3 m intervals, defined the boundaries of each plot. To alleviate edge effects an unmarked homogeneous buffer zone of 33 m surrounded each plot. Substrates were characteristic of each area and were incorporated in the identification of the 3 stands used in this study: Budsage-Desert Pavement, Greasewood-Hard Pan, and Sagebrush-Sand.

METHODOLOGY

Lizard Sampling

Bimonthly searches of each replicate were conducted in June and July of 1978 and 1979. Search periods were confined to the early morning and late afternoon to capitalize on lizard activity patterns. Each search involved a minimum of 2 workers equipped with lizard nooses, who systematically traversed each plot. A mean distance of 5 m was maintained between workers to permit detection of both motionless and moving lizards. All lizards seen were recorded; most were captured and identified by species, sex, age (hatchling, juvenile, adult), and location. Air temperature and time of sighting were recorded. Lizards were permanently marked by toe clipping (Tinkle 1967), temporarily coded with painted dorsal marks (Degenhardt 1966), and released in the area where they were initially sighted. All recaptures were noted by location, time, and air temperature.

Habitat Sampling

Vegetation on the replicates was sampled with 33.3 m line transects (Canfield 1941) once monthly in June and July of 1978 and 1979. Cover, by species and crown height classes, and shrub spacing along the transect were recorded. All crown height classifications were in classes of 15 cm each (0-15; 16-30; ... 91-105 cm).

A 0.1 m^2 circular quadrat (Poulton and Tisdale 1961) was placed along each transect every 6.6 m to estimate percentages of bare ground, litter, and cover by crown height of herbaceous and grass species (Daubenmire 1959). Soil samples were taken from each replicate for measurement of rock diameters and depth of surface substrate layer.

Statistical Analysis

Data were arranged as independent integers for each replicate for each season. Diversity indices (McIntosh 1967) were calculated for each replicate by season. The formula used was: $\sqrt{\sum_{i=1}^{s} n_i^2}$, where s = the number of species and n = the number of individuals in each species. An arc-sine transformation (Snedecor and Cochran 1966) was applied to the percent values of bare ground.

Multivariate analysis of variance (Snedecor and Cochran 1966) was used to detect differences in lizard density and diversity indices (dependent variables) among stands and through seasons within stands. Univariate *F*-tests (Snedecor and Cochran 1966) were used to evaluate the multivariate test statistics. A Newman-Keuls test (Snedecor and Cochran 1966) was used to separate mean total densities, *S. graciosus* densities, *U. stansburiana* densities, and diversity indices, and to reveal which stands differed significantly.

Similar multivariate analysis of variance procedures were used to detect differences in shrub height classes and amount of bare ground (independent variables) among stands and through seasons within stands (dependent variables). Univariate *F*-tests (Snedecor and Cochran 1966) were used to evaluate all multivariate test statistics. A Newman-Keuls test (Snedecor and Cochran 1966) was used to separate shrub height (class 2) means among stands and through seasons.

Stepwise multiple regression analysis (Neter and Wasserman 1974) was used to determine the relationship between the dependent variables of diversity indices, total lizard densities, and species densities and the independent variables of shrub height classes and shrub spacing. Significance of correlations was determined with a *t*-test (Snedecor and Cochran 1966). All tests for significance were at the 95% confidence level.

RESULTS

Lizards

One hundred and eighty-one lizards, of the 5 species, were marked during the 2 season study (Table 1). *U. stansburiana* was unique to the Budsage-Desert Pavement stand and largely accounted for the high relative abundance in that stand. *S. graciosus* was mainly confined to the Sagebrush-Sand stand except for 2 individuals observed in the Greasewood-Hard Pan stand. Mark and recapture data (Table 1) were insufficient to permit density estimates. Sex and age data (Table 2) indicated no discernible trend. Four species occurred in each stand, though composition varied (Table 1).

Because no interactions were found between population parameters of lizards and season, tests among stands were conducted. *S. graciosus* and *U. stansburiana* density indices and diversity indices were significantly different among the 3 stands. The relative abundance of *S. graciosus* was significantly different in the Sagebrush-Sand stand compared to the other 2; *U. stansburiana* afforded separation of the lizard species on the Budsage-Desert Pavement stand from the others. Diversity indices (Table 3) were significantly different between the Budsage-Desert Pavement and Greasewood-Hard Pan stands. The Budsage Pavement and the Greasewood-Hard Pan stand

Table 1. Total number of lizards marked and recaptured, by species, in 3 stands, Charles Sheldon National Wildlife Refuge, 1978-79.

Species	Stand								
	Budsage-Desert Pavement			Greasewood-Hard Pan			Sagebrush-Sand		
	Marked	Recaptured	Total	Marked	Recaptured	Total	Marked	Recaptured	Total
Gambelia wizlizeni	31	5	36	18	7	25	7	3	10
Sceloporus graciosus	0	0	0	2	0	2	19	3	22
Uta stansburiana	41	3	44	0	0	0	0	0	0
Phrynosoma platyrhinos	13	2	15	7	1	8	4	0	4
Cnemidophorus tigris	14	0	14	6	0	6	12	0	12

Table 2. Two-year summation of age and sex of marked lizards by species in 3 stands, Charles Sheldon National Wildlife Refuge, 1978-79.

Species	Numbers of Lizards					
	Budsage-Desert Pavement		Greasewood-Hard Pan		Sagebrush-Sand	
	Sex[a]	Age[b]	Sex[a]	Age[b]	Sex[a]	Age[b]
Gambelia wizlizeni	19/12	18/13	12/6	15/3	5/2	5/2
Sceloporus graciosus	0/0	0/0	2/0	2/0	13/6	18/1
Uta stansburiana	21/20	38/3	0/0	0/0	0/0	0/0
Phrynosoma platyrhinos	6/7	9/4	6/1	6/1	2/2	2/2
Cnemidophorus tigris	10/4	7/7	4/2	4/2	3/9	9/3

[a]Sex: ratio of females to males

[b]Age: ratio of adults to juveniles

Table 3. Two-year summation of lizard community parameters in 3 stands, Charles Sheldon National Wildlife Refuge, 1978-79.

Parameter	Stand: Budsage-Desert Pavement	Stand: Greasewood-Hard Pan	Stand: Sagebrush-Sand
Number of lizard species	4	4	4
Lizard density index	99	33	49
Lizard diversity	0.971	0.453	0.689

were significantly different on the basis of total lizard relative abundance (Table 3).

Habitat

Line transect data documented differences initially perceived in the visual ranking of potential study sites. Total cover was 20, 18, and 21% for the Budsage-Desert Pavement, Greasewood-Hard Pan, and Sagebrush-Sand stands, respectively. Cover by shrub species (Table 4) was characteristically different for each stand, with the single exception of shadscale, which was not statistically separable between the Budsage-Desert Pavement and Greasewood-Hard Pan stands.

Ninety-four percent of all shrubs on the Budsage-Desert Pavement stand were 45 cm or less in height; 85% were greater than 31 cm on the Greasewood-Hard Pan stand; and 92% were greater than 31 cm on the Sagebrush-Sand stand (Table 5).

The substrate of the Budsage-Desert Pavement stand was gravelly to rocky with more rocks than soil exposed on the ground surface and rock diameters of 1-10 cm. The Greasewood-Hard Pan stand had fine to silty soil with very few pebbles or rocks present. The substrate surface, to a depth of 1.5 cm, was a hard-baked crust. Shadscale and greasewood were present in statistically indistinguishable amounts of cover on this substrate. The substrate of the

Table 4. Mean percent cover of dominant shrubs in 3 stands, Charles Sheldon National Wildlife Refuge, 1978-79.

Shrub	Stand: Budsage-Desert Pavement (%)	Greasewood-Hard Pan (%)	Sagebrush-Sand (%)
Budsage	50	4	1
Shadscale	44	32	1
Greasewood	2	46	6
Sagebrush	0	9	66
Others	4	9	26

Table 5. Mean height of shrubs in 3 stands, Charles Sheldon National Wildlife Refuge, 1978-79.

	Stand		
Height (cm)	Budsage-Desert Pavement (%)	Greasewood-Hard Pan (%)	Sagebrush-Sand (%)
0-15	20	1	1
16-30	50	16	7
31-45	23	29	21
46-60	5	26	28
61-75	2	16	22
76-90	0	9	13
91-105	0	3	8

Sagebrush-Sand stand was characterized by loose sand with an irregular scattering of small pebbles and rocks.

Ground cover of grass and herbaceous species was never more than 2% in any of the stands; bare ground percentages averaged 92, 88, and 86 for the Budsage-Desert Pavement, Greasewood-Hard Pan, and Sagebrush-Sand stands, respectively, with the remaining percentages in all cases being litter.

Multivariate analysis of variance indicated no interaction between the vegetative parameters of the 3 stands and the 2 seasons. Univariate F-tests revealed a significant seasonal difference for shrub heights 16-30 cm which possibly was a sampling error. There were no indications of any other habitat variable interactions with seasons.

The 3 stands were significantly different from one another with respect to the 8 independent variables (shrub height classes 1-7, amount of bare ground). With the exception of amounts of bare ground and shrub height of 31-45 cm, univariate F-tests indicated all variables were significantly different among stands. Bare ground amounts were extremely consistent for all 3 stands and 31-45 cm high shrubs represented a median height for most of the shrubs on the stands.

Lizard-Habitat Correlations

Indices to densities of 2 lizard species were significantly correlated with shrub heights. *S. graciosus* was correlated with shrub heights of 61-75 and 91-105 cm (R^2=0.59) and *U. stansburiana* with shrub heights of 0-15 cm (R^2=0.58). The remaining 3 lizard species were found on all 3 stands in statistically indistinguishable density indices.

Diversity indices (Table 3) had a significant correlation (R^2=0.42) with shrub spacing and shrub heights 61-75 cm; similarly, total relative abundance had a significant correlation with shrub heights 0-15 cm (R^2=0.49).

DISCUSSION

Almost 90% of the sightings of *S. graciosus* were in the Sagebrush-Sand stand; a minor exception was the presence of 2 juveniles in the Greasewood-Hard Pan stand. The distribution of *S. graciosus* within the United States largely coincides with that of sagebrush (Shreve 1942; Stebbins 1966). Burkholder and Tanner (1974), in addition to commenting upon the basking of these lizards on sagebrush branches, also observed the species gleaning among the foliage of sagebrush and making short sallies out from the shrub bases to catch and eat insects, then returning to cover. It is possible that *S. graciosus* is afforded some degree of protective camouflage in that the dorsal line pattern is similar to sagebrush bark. A further benefit possibly gained from the sagebrush association is that of the many insects seemingly attracted to the highly aromatic shrub and its edaphic associate, sand. Several species of midges form galls on the different species of sagebrush and other insects appear attracted to the leaves or sand for deposition of their eggs (Borror and White 1970).

U. stansburiana was completely restricted to the Budsage-Desert Pavement stand and was correlated with heights (0-15 cm) typical of the low growing budsage. The large volume of leaf litter associated with the deciduous budsage afforded abundant escape cover and burrowing material for the lizards. Parker and Pianka (1975) commented upon the tendency of *U. stansburiana* to perch on small rocks to increase their field of view and presumably enlarge their effective foraging area. On CSNWR, *U. stansburiana* frequently were observed perched on the pebbles and rocks among the budsage and making short dashes to capture insects moving past or alighting nearby.

Although *G. wislizeni* was not significantly correlated with any habitat variables, the highest density indices, in the Budsage-Desert Pavement stand, suggested some characteristic of the stand may be preferred by the lizards. It is possible the abundance of *U. stansburiana*, a possible prey item, was important.

P. platyrhinos occurred widely and was probably the least accurately censused species in the study. The predator defense strategy of *P. platyrhinos*, camouflage and a motionless posture, probably effectively lessened the frequency of detection of these lizards. Because of the few sightings more work is necessary to understand the relationship of this species to specific habitat characteristics.

C. tigris was consistently found within running distances of colonial rodent burrows. Upon flushing by an observer, the lizards would run directly to the burrow system, at times appearing to circle the burrow mound and ultimately disappear down a particular entrance. These burrow systems possibly are limiting to C. tigris and further quantification of the areas in which these burrows are found may yield considerable insight into the distribution and densities of C. tigris.

No species was significantly correlated with another. It is likely a series of data on microhabitat of an individual's position when sighted would yield both better correlations with habitat (Schoener and Schoener 1971) and with other species (Pianka 1967).

The Budsage-Desert Pavement stand had over twice the total lizard relative abundance of any other stand, due primarily to the exclusive presence of U. stansburiana. The large numbers of U. stansburiana also were responsible for the correlation of total relative abundance with shrub heights of 0-15 cm, which were characteristic of the Budsage-Desert Pavement stand.

The correlation of diversity indices with shrub spacing and shrub heights 61-75 cm was possibly the result of several factors. Although each of the 3 stands had 4 lizard species present, the preponderance of G. wislizeni and U. stansburiana on the Budsage-Desert Pavement stand caused the diversity index for that stand to be considerably higher than those of the other 2 stands which had a more equitable distribution of density among species. Secondly, the percent of shrubs with a mean height of 61-75 cm was significantly higher in the Greasewood-Hard Pan and Sagebrush-Sand than in the Budsage-Desert Pavement stands. Finally, shrub spacing was greatest in the Greasewood-Hard Pan stand (2.7 m), followed by the Sagebrush-Sand (1.8 m) and Budsage-Desert Pavement (1.5 m) stands. These 3 factors may have combined to create a weak correlation of diversity with shrub spacing and 61-75 cm shrub heights.

In conclusion, the distribution and density indices of some desert lizard species were related to certain habitat features, especially dominant shrubs and their average crown heights. Substrates, which were correlated with key shrubs, seemed important in foraging and escape behavior, which in turn may have influenced lizard community composition. Community indices to density were largely determined by the presence or absence of specialist species despite the consistency of species numbers in different vegetative stands.

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