Great Basin Naturalist

Volume 51 | Number 2 Article 6

6-30-1991

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Great Basin Naturalist 51(2), 1991, pp. 167–175

SITE CHARACTERISTICS AND HABITAT REQUIREMENTS OF THE ENDANGERED DWARF BEAR-CLAW POPPY (*ARCTOMECON HUMILIS* COVILLE, PAPAVERACEAE)

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ABSTRACT.—*Arctomecon humilis* Cov. is a narrow endemic, confined to gypsiferous substrates derived from the Shnabkaib Member of the Moenkopi Formation in southwestern Utah. The characteristics of seven *A. humilis* sites were studied to define habitat requirements of the species. Both physical and biotic aspects of the habitat were analyzed; geology, soil chemistry, and physical properties, as well as vascular and nonvascular plant communities, were studied. Chemical and physical properties of these soils vary considerably from those supporting adjacent desert-shrub communities. The dominant vascular species on *A. humilis* sites are shadscale and Mormon tea. It was found that *A. humilis* occurred in portions of the habitat where shrubs were relatively less dense. A soil-surface, cryptogamic community contributed 84% or more of the total living cover on sites that supported *A. humilis*. Species composition of the cryptogamic community was highly similar among sites. Likewise, composition of the cryptogamic cover was similar when random samples were compared with samples centered on *A. humilis* plants. The Purgatory Flat site, which does not support the poppy, seems inseparable from *A. humilis* sites in respect to soil characteristics and composition of the associated plant cover. There is reason to believe an *A. humilis* population could be established at the Purgatory Flat site.

Key words: Arctomecon humilis, *dwarf bear-claw poppy, habitat characteristics, gypsophily.*

The dwarf bear-claw poppy (*Arctomecon humilis*) is a perennial herb endemic to gypsum soils of Washington County, Utah (Atwood 1977). It presently occupies an archipelago of isolated sites to the south, west, and east of St. George, all of which are within 8–10 km of the city limits. *A. humilis* is confined to substrates derived from outcrops of certain members of the Moenkopi Formation (USFWS 1985). No detailed discussions of the habitat requirements or general ecology of this species have previously appeared in the literature.

During the last several decades, the development of housing in the St. George–Bloomington area and the construction of Interstate 15 and associated road maintenance facilities have eliminated much of the plant's habitat. Off-road vehicle (ORV) traffic and mineral assessment work on gypsum claims immediately threaten remaining habitat. Off-road vehicles cause excessive erosion and loss of viable *A. humilis* seed stored in the surface soil (Nelson and Harper 1991). Continued development and expansion in the St. George area will undoubtedly result in continued encroachment upon habitat now occupied by the species.

In 1979 the U.S. Fish and Wildlife Service issued a final rule statement declaring *A. humilis* an endangered species (USFWS 1979). Critical habitat was not designated in that ruling. Since 1979, several hundred acres of habitat have been closed to ORV use by the U.S. Bureau of Land Management (USBLM 1987) and the state of Utah, but difficulties in posting and enforcing these closures have resulted in almost no change in patterns of use on habitat occupied by the species. In fact, photographs taken at permanent photo points show an increase in evidence of ORV use on some of these sites over the period 1987–1990. While the direct effects of ORV and mineral exploration on living plants are not always extensive, soil erosion initiated by ORV traffic progressively destroys the limited habitat to which the species is intimately tied. Erosion also results in loss of seed from the soil seed bank. Since the species is short lived (up to perhaps six years), maintenance of viable populations depends upon regular establishment of plants from the seed bank.

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It is the purpose of this paper to define the habitat requirements of this species.

STUDY AREA

Approximately two-thirds of the habitat occupied by *A. humilis* is on federal land managed by the U.S. Bureau of Land Management (BLM). One-third is owned by the state of Utah and managed by the Utah Department of State Lands and Forestry. The seven poppy sites considered in this paper are managed by the state or by BLM.

In nearly all cases the species is confined to low gypsum hills typically found at the base of red cliffs. The sites are often underlain by similar red beds (see below). The plant occurs occasionally on red gypsum-rich soils but is more typically found on white-gray gypsiferous soils. The white gypsum substrate is almost always associated with a heavy cover of cryptogamic plants (i.e., lichens, mosses, blue-green algae) except where natural erosion and ORV travel have destroyed that cover.

Areas surrounding habitat occupied by the poppy support creosote bush (*Larrea tridentata* [DC.] Cov.) communities. Creosote bush and many of its associates are intolerant of gypsum (Meyer 1986) and are essentially absent from the poppy sites. The gypsum sites support a sparse shrub community that is dominated by burrobush (*Hymenoclea salsola* T. & G.) and shadscale (*Atriplex confertifolia* [Torr. & Frem.] Wats.). At one site (Beehive Dome) the poppy occurs with the endangered gypsum cactus (*Pediocactus sileri* [Engelm.] L. Benson). Desert tortoises (*Gopherus agassizii* Cooper) have been observed among poppy plants at Red Bluff, but there is no evidence that the tortoises utilize *A. humilis*.

In addition to the seven poppy sites studied, we have sampled another site, Purgatory Flat, which does not support a poppy population. That site is included in the study because it is visually and chemically similar to sites occupied by the species and lies within the range of elevation of those sites. The Purgatory Flat site is only 8 km from existing populations of *A. humilis* at Shinob Kibe Dome near Washington, Utah. The gypsum hills at Purgatory Flat cover a large area extending south from Quail Creek Reservoir for 2.5–3 km. Portions of this area could be used if attempts to establish additional populations of *A. humilis* are ever made.

St. George receives an average of 201 mm of precipitation annually (Brough et al. 1987). Most rainfall occurs during the winter months, but summer (June-September) convective storms contribute about one-fourth of the annual total. Year-to-year variation in total annual precipitation is considerable. The coefficient of variation for total annual precipitation over the past 30 years is 33.2%. A "Walter Diagram" for the St. George weather station (Fig. 1) shows the relationship between annual patterns of precipitation and temperature (Walter 1973). During the winter months, temperatures are low enough and precipitation great enough that soils can accumulate some moisture (striped area in Fig. 1). Warmer temperatures during the spring and summer months create a water deficit, since evaporation exceeds precipitation and moisture is only briefly available to plants (stippled area). Rosettes of *A. humilis* remain green throughout the year and can take advantage of available moisture at any time.

METHODS

During 1987 soil was collected at seven *A. humilis* sites: Red Bluff, Price City Hills, White Dome, Shinob Kibe Dome, Boomer Hill, Beehive Dome and Warner Ridge. (The name of the buttelike landform that appears as "Shinob Kibe Dome" on U.S. Geological Survey maps is reported by Gregory [1950] to have been derived from the Piute words *Shinob* [Great Spirit] and *kaib* [mountain]; Gregory considers the name of the geologic member, "Shnabkaib," to be a misspelling of the Piute name.) Soil was also collected at two sites at Purgatory Flat (just below the dike on the southern shore of Quail Creek Reservoir and south of U.S. Highway 17). Soil samples were taken with a 2.5-cm-diameter tube inserted to a depth of 15 cm. A minimum of six samples was collected at each site, the number collected depending upon the size and apparent heterogeneity of the site. Soils at most sites ranged from red, clay-rich to white, purely gypsiferous substrates. Both red and white substrate types were sampled if the poppy occurred on both. Subsamples from each site were combined for analytical purposes, and soils were analyzed by the Brigham

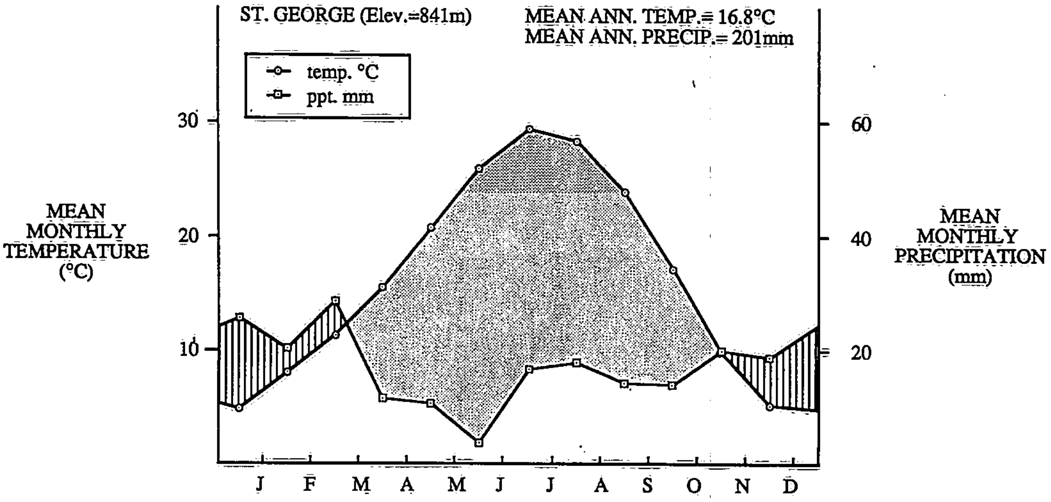

Fig. 1. "Walter Diagram" showing the relationship between average monthly precipitation (mm), along with average monthly temperature (°C) and mean annual temperature and precipitation, for the St. George, Utah, weather station. The stippled area represents a period of water deficit, when evaporation exceeds precipitation and moisture is only briefly available to plants; the striped area is a period when soils may accumulate water.

Young University Soil Laboratory, Department of Agronomy and Horticulture.

Samples were analyzed for concentrations of nine biogenic elements (P, Ca, Mg, K, Na, Zn, Fe, Mn, Cu), pH, electrical conductivity, cation exchange capacity, and linear extensibility (a quantification of a soil's tendency to shrink on drying). Micronutrients (Zn, Cu, Fe, and Mn) were extracted from soils with DPTA (diethylenetriamine-penta-acetic acid). Exchangeable calcium, magnesium, potassium, and sodium were extracted with 1.0 N neutral ammonium acetate. Phosphorus was extracted using 0.5 M sodium-bicarbonate. Individual ion concentrations were determined using a Perkin-Elmer Model 5000 atomic absorption spectrophotometer. Soil reaction was measured with a glass electrode pH meter on saturated soil pastes, and electrical conductivity of the saturated soil paste was measured using a standard wheatstone bridge (U.S. Salinity Laboratory Staff 1954). Cation exchange capacity (CEC) was determined by mass action using a 1.0 normal sodium acetate solution, washing away excess salts with distilled water, and displacing adsorbed sodium with ammonium acetate (Chapman 1965). Linear extensibility was estimated by oven-drying standard diameter cylinders of saturated soil paste for 24 hours and determining percentage change in length.

Results for the preceding suite of soil variables at each of the eight sites were subjected to cluster analysis (Sneath and Sokal 1973) using a program from the Ecology Program Library (W. E. Evenson and J. D. Brotherson, Brigham Young University, Provo, Utah). The values for each parameter at all sites were relativized before being entered in the program (i.e., the largest value for each variable was taken as 100% and all other values were expressed as a percentage of that maximum value). The program computes an index of similarity for all possible site pairs using the formula S. I. = [Σ(minimum values for any attribute for the two sites) /Σ(maximum values for any attribute for the two sites)] $\times$ 100 (Ruzicka 1958), where "min" or "max" represents the smallest or largest of the values for each characteristic compared in the two stands.

In 1988 additional soil samples were collected at Beehive Dome, Price City Hills, Red Bluff, and Purgatory Flat. These soil samples were taken as described above. Contents of gypsum, calcium carbonate, sand, skeletal material, and water content at -15 bars matric potential were determined. Percent skeletal material was determined from the weight of the total sample retained on a 2-mm sieve. Percent sand was determined from the weight of material passing a 2-mm sieve (No. 10 mesh) but retained on a 0.05-mm sieve (No. 275 mesh) and is reported as the percentage of the soil fraction less than 2 mm. Alkaline earth carbonates were determined by acid neutralization procedures (U.S. Salinity Laboratory Staff 1954). Gypsum content was determined with a loss-by-weight procedure by drying the soil at 45 C and 105 C, the difference in weight representing the loss of water incorporated into crystals of gypsum (Nelson 1982). Gypsum and calcium carbonate were measured for entire samples, which were ground prior to analysis. Water content was measured across a 15-bar pressure membrane (Richards 1965).

Vegetation was sampled during 1988 at Red Bluff, Price City Hills, and Purgatory Flats. Shrub density and cover, herb cover, and cryptogamic cover were measured along randomly placed 100-m transects. Shrub density was measured using the point-centered quarter method with distance measures taken from points spaced at 10-m intervals along the transect. Two canopy diameter measurements, taken at right angles to each other, were recorded for each shrub included in the sample. Shrub density was computed from the point-to-plant center data (Cottam and Curtis 1956). Shrub cover is based on canopy area of individuals and shrub density data. A nested frequency quadrat frame (Smith et al. 1987) was centered on each of the same points used for the point-quarter sampling and used to evaluate relative frequency and percent cover for cryptogamic species (lichens and mosses), vascular plants, and nonliving cover. At the two poppy sites where vegetation was sampled, Red Bluff and Price City Hills, these procedures were repeated but sampling was centered on the *A. humilis* plant nearest the 10-m point on the transect rather than on the transect line itself. Plant-centered versus random-point locations made it possible to test the hypothesis that the vegetational environment around *A. humilis* plants has a lower shrub density than the general habitat.

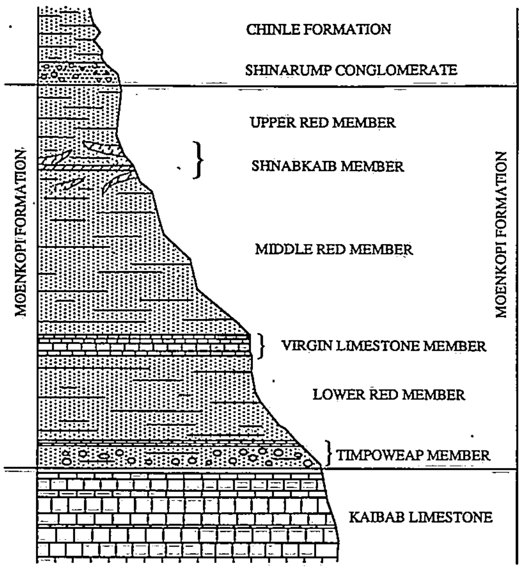

Fig. 2. Diagram showing the relative positions of geologic members of the Moenkopi Formation and adjoining strata in the vicinity of St. George, Utah. (*From:* R. K. Gierisch 1981. Observations and comments on *Pediocactus sileri* in Arizona and Utah. Desert Plants 3: 9–28.)

RESULTS

Physical Environment

A. humilis was found only on gypsic outcrops of the Moenkopi Formation of Early Triassic age (Fig. 2). The poppy has been reported to be confined to the upper three members: the Upper Red, Shnabkaib, and Middle Red (USFWS 1985). The majority of the populations occur almost exclusively on the Shnabkaib Member (W. Kenneth Hamblin, personal communication). Shnabkaib outcrops also occur in the northwest portion of Purgatory Flat, at the base of red cliffs. The gypsum hills across much of the Purgatory Flat area consist of alluvial sediments derived from the Shnabkaib.

In Washington County the Shnabkaib Member varies from 80 to 225 m in thickness and consists of white, pink, and light red gypsiferous shale and gypsum (Cook 1960). It is easily recognized by its candy-stripe appearance. In many places surrounding St. George it forms low hills at the bases of red cliffs of the Upper Red Member. These Upper Red cliffs are capped by the Shinarump Conglomerate. A large area of Shnabkaib is bisected by Interstate 15, and an unknown number of acres lie under housing developments in the Bloomington area of St. George and in older sections of St. George itself. The White Hills area west of Bloomington is the largest contiguous portion of exposed Shnabkaib in the vicinity.

Soils on *A. humilis* sites consist of little-altered parent material and are soils only in the broadest definition of the word. There is no obvious horizonation in these substrates, though the uppermost portions would surely be somewhat enriched by additions from the cryptogamic crust and very locally (e.g., at the base of shrubs) by organic amendments from vascular plants. The influence of cryptogams may extend downward into the solum for only a few millimeters. Little organic matter is added to the soil annually, due to sparse vegetative cover. Minimal input of organic matter combined with a dynamic soil surface resulting from dissolution and reformation of gypsum crystals appears to preclude horizon development. The soil survey report for Washington County (USDA 1977) refers to these areas as "badlands" and does not further describe or classify the soils.

Results of soil analyses are shown in Table 1. The heterogeneity of these sites, as discussed above, is reflected in physical and chemical analyses. Within-site variation was considerable (with coefficients of variation exceeding 20%) for all parameters except calcium, electrical conductivity, and pH. In most cases within-site variation for a given variable was as great as that between sites. No site contributed more than one-fourth of the extreme high or extreme low mean values for the various parameters, suggesting that no site, including Purgatory Flat, can be considered chemically distinct from the others. Soils from the Purgatory Flat site show fewer extreme values for the variables considered than do soils from some poppy sites. Furthermore, no raw values for the Purgatory Flat site fall outside the range of values for corresponding variables from poppy sites. The similarity of Purgatory Flat soils to soils at poppy sites is also demonstrated through cluster analysis (Fig. 3), performed as described in Methods.

All soils sampled are slightly basic, with pH in the range of 7.2–7.5, and are highly gypsiferous, with gypsum contents ranging from 27 to 51%. Calcium carbonate content, which ranges from 15 to 24%, is also high. Rasmussen and Brotherson (1986) reported data on soils from desert shrub communities of Washington County that occur adjacent to *A. humilis* habitat. Mean values for pH and CEC presented here for *A. humilis* sites are slightly lower than those reported for the desert shrub soils, but they are within the range of one standard deviation of their mean.

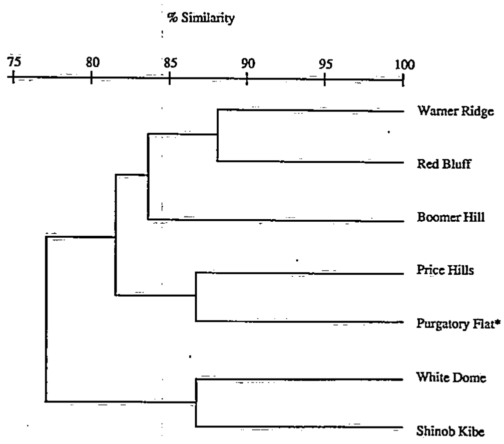

Fig. 3. Dendrogram resulting from clustering of six *A. humilis* sites and one potential *A. humilis* site (Purgatory Flat) for the following soil attributes: P, Ca, Mg, K, Na, Zn, Fe, Mn, Cu, cation exchange capacity, pH, electrical conductivity, and shrinkage upon drying (coefficient of linear extensibility).

Concentrations of magnesium and potassium are 50% lower on the gypsum soils, while levels of phosphorus and zinc are not different. The most striking differences are between concentrations of calcium, copper, and iron. Levels of calcium and copper are 10 times greater in *A. humilis* soils, while iron concentrations are the same magnitude lower. Obviously, these disparities have not interfered with the growth of *A. humilis*, and there is little evidence to suggest that such abnormal values are required for its existence. Meyer (1986) concludes that the likelihood of chemical factors controlling species composition on gypsum soils is minimal, and that the degree of endemism on gypsum soil is due to physical properties of the soil that affect available moisture for plant growth.

Soil texture is not reported here because of difficulties in textural determination created by properties of these soils: high concentrations of salt cause fine particles to become flocculated, thus rendering hydrometric procedures useless, and gypsum crystals complicate particle size determination through sieving. It is likely that much of the sand-size component, as measured here by sieving, consists of gypsum. The percentage of sand-size particles in the soil fraction smaller than 2 mm ranges from 14 to 29%, leaving three-fourths of the weight of the <2 mm material to

TABLE 1. Mean values for selected chemical and physical soil parameters at seven *A. humilis* sites and one potential *A. humilis* site (Purgatory Flat). Standard error is shown in parentheses. Elemental analyses were not run for the Beehive Dome site. Values are not available for the last five parameters at Boomer Hill, Shinob Kibe, Warner Ridge, and White Dome.

	Beehive Dome	Boomer Hill	Price Hills	Red Bluff	Shinob Kibe	Warner Ridge	White Dome	Purgatory Flat
Nutrients (ppm)								
P	—	17.0 (5.89)	33.7 (1.43)	22.9 (2.76)	19.4 (8.14)	5.9 (0.62)	8.8 (1.71)	33.8 (5.34)
Ca (ppm$\times10^{-4}$)	—	3.6 (0.19)	3.7 (0.22)	4.0 (0.13)	4.2 (0.11)	4.0 (0.10)	3.9 (0.09)	4.1 (0.07)
Mg	—	97.6 (7.74)	76.3 (3.82)	73.9 (4.87)	60.8 (6.79)	81.2 (6.25)	57.6 (8.12)	74.3 (5.14)
K	—	105.9 (9.24)	82.6 (4.63)	74.1 (4.71)	46.3 (9.07)	78.6 (6.79)	42.9 (10.1)	74.6 (11.53)
Na	—	15.2 (1.39)	15.3 (0.63)	13.7 (0.70)	14.2 (1.37)	14.2 (0.57)	11.6 (0.43)	14.4 (0.85)
Zn	—	0.4 (0.02)	0.4 (0.03)	0.3 (0.02)	0.2 (0.02)	0.3 (0.03)	0.3 (0.04)	0.5 (0.22)
Fe	—	2.9 (0.12)	2.6 (0.25)	2.5 (0.15)	1.8 (0.06)	2.9 (0.19)	1.9 (0.11)	2.1 (0.19)
Mn	—	1.5 (0.08)	1.2 (0.03)	1.3 (0.08)	1.0 (0.15)	1.1 (0.16)	1.0 (0.10)	1.1 (0.17)
Cu	—	0.9 (0.07)	0.9 (0.04)	0.8 (0.10)	1.0 (0.35)	0.9 (0.10)	0.9 (0.10)	1.6 (0.73)
CEC[1]	—	9.6 (0.50)	7.4 (0.23)	8.2 (0.40)	6.0 (0.49)	7.7 (0.50)	5.5 (0.61)	7.4 (0.50)
pH	—	7.3 (0.07)	7.3 (0.06)	7.2 (0.05)	7.3 (0.10)	7.5 (0.03)	7.3 (0.06)	7.4 (0.05)
EC[2]	—	2.2 (0.06)	2.2 (0.10)	2.4 (0.05)	2.2 (0.05)	2.2 (0.03)	2.2 (0.06)	2.2 (0.05)
COLE[3]	—	1.3 (0.21)	0.8 (0.17)	1.0 (0.19)	0.7 (0.48)	1.0 (0.19)	0.4 (0.18)	0.9 (0.20)
$\%H_2O$ −15 bar	11.4 (0.81)	—	8.2 (2.26)	11.8 (2.42)	—	—	—	14.6 (1.18)
$CaCO_3$ (% by wt.)	15.4 (0.52)	—	24.3 (0.09)	22.6 (1.85)	—	—	—	18.8 (2.31)
$CaSO_4$ (% by wt.)	32.7 (4.70)	—	27.3 (12.22)	39.3 (15.38)	—	—	—	51.1 (5.36)
Sand (% of <2mm)	14.6 (2.71)	—	26.0 (5.19)	24.2 (8.99)	—	—	—	29.0 (4.39)
Skeletal (% of total)	14.3 (2.55)	—	18.1 (9.02)	16.9 (10.27)	—	—	—	9.0 (3.08)

[1]CEC = cation exchange capacity in meq per 100 g of soil.
[2]EC = electrical conductivity in mmho/cm.
[3]COLE = coefficient of linear extensibility: 0 = shrinkage, 1 = <3% shrinkage, 2 = 3–6% shrinkage.

be contributed by silt- and clay-size particles. The large proportion of fine particles is congruous with the prevalence of shales in the Shnabkaib and adjacent geologic members. Shrinkage of saturated soil pastes upon drying (coefficient of linear extensibility) ranged from 0 to 6%, the higher values suggesting that the finer materials in some of the soils include expanding clays.

Biotic Associates

Total living cover on the three sites sampled ranged from 37 to 59% (Table 2). Differences between values measured for that variable at random points and at *A. humilis*-centered points are small and probably not significant. (Total cover values could not be tested for significance because data for shrubs were collected by a method different

TABLE 2. Percent absolute living cover and percent relative cover contributed by groups of nonvascular and vascular plants for general habitats and for habitats at *A. humilis*–centered sampling points at two *A. humilis* sites (Price City Hills and Red Bluff) and for the general habitat at one gypsiferous site on which an *A. humilis* population does not now exist (Purgatory Flat). Trace amounts are noted "T".

	Price City Hills		Red Bluff		Purgatory Flat
	Random points	*A. humilis* centered	Random points	*A. humilis* centered	(Potential *A. humilis* site)
Absolute living cover (%)	46.7	46.2	37.2	31.2	59.6
Relative cover (%)					
Nonvascular (total)	(93.7)	(96.0)	(84.0)	(92.1)	(88.1)
Lichens					
Collema tenax	70.9	64.9	61.6	58.0	65.6
Psora dicipiens	17.4	28.4	19.0	32.0	15.7
Other	5.4	2.7	1.1	2.0	6.8
Moss	T	T	2.2	T	1.2
Vascular (total)	(6.3)	(4.0)	(16.0)	(7.9)	(11.9)
Grasses and forbs		1.6	1.1		1.9
Shrubs					
Atriplex confertifolia	1.6	0.4	4.3	1.9	3.2
Ephedra torreyana	2.2	1.4	4.5	4.2	3.5
Hymenoclea salsola	1.4	0.2	5.0	0.9	1.5
Other	1.1	0.6	1.0	1.2	1.8

from that used for nonvascular plants and forbs.)

Nonvascular plants contributed 84% or more of the total living cover at all sites (Table 2). Lichens were the most important component of the nonvascular plant cover and total living cover measured. Species composition and cover at the three sites and at both random and poppy-centered points were similar. The lichens, *Collema tenax* (Sw.) Ach. and *Psora decipiens* (Hedw.) Hoffm., were the most common species at all sites, the former accounting for 58–71% of the lichen cover, and the latter 16–32%. Grasses and forbs contribute little to the total cover on these sites and in two cases were not encountered in sampling (Table 2). Many species of grasses and forbs on these sites are annuals and are present only during a part of the year. Red brome (*Bromus rubens* L.), an introduced species, is the most common annual on these sites, through it was not frequently encountered in quadrats. It grows in abundance only at the base of shrubs and is rarely associated with *A. humilis* plants.

Shrub densities measured at random points and at *A. humilis*–centered points at Price City Hills and Red Bluff, and at random points at Purgatory Flat, are reported in Table 3. Differences among shrub densities were tested for significance using a least significant difference method at the alpha = .05 level (Steele and Torrie 1960). Analysis was based on point-to-plant distances. Shrub density at the Purgatory Flat site was not different from that measured at random points at Red Bluff and *A. humilis*–centered points at Price City Hills. Densities measured from random points and from *A. humilis*-centered points differed significantly at the latter two sites, though the density at random points at Price City Hills was not significantly different from the density at *A. humilis* points at Red Bluff. It thus appears that within each habitat, the poppy occupies portions of the habitat where shrubs are relatively less dense.

Shrub species composition was similar at all three sites with the exception of the presence of bursage (*Ambrosia dumosa* [Gray] Payne) at Purgatory Flat. This species contributed 15% of shrub individuals at that site. At Price City Hills, *Lepidium fremontii* Wats., a suffrutescent subshrub, had a relative density of 60%, but only 5–6% at other sites. While *Lepidium* was common on the Price City Hills site, individual plants were small (mean area of 73 cm^2) and contributed less than 5% of the total living cover. All three sites are dominated by shadscale and Mormon tea (*Ephedra torreyana* Wats.), while adjacent areas are dominated by creosote bush and blackbrush (*Coleogyne ramosissima* Torr.) (Rasmussen and Brotherson 1986).

TABLE 3. Total shrub density for the general habitat and for *A. humilis*–centered sampling determined with the point-quarter method at two *A. humilis* sites (Price City Hills and Red Bluff) and for the general habitat at one non-*A. humilis* site (Purgatory Flat). Relative density for major shrub species is based on the sample taken with the quarter method. Shrub density differences among sites were tested for statistical significance: means followed by the same letter in subscript do not differ significantly.

	Price City Hills		Red Bluff		Purgatory Flat
	Random points	*A. humilis* centered	Random points	*A. humilis* centered	(Potential *A. humilis* site)
Total shrub density (no./ha)	2365_c	1286_b	1515_b	636_a	1759_b
Relative density (%)					
Ambrosia dumosa					15.0
Atriplex confertifolia	25.0	18.9	47.5	48.8	45.6
Ephedra torreyana	8.8	8.8	15.8	30.0	11.3
Hymenoclea salsola	5.0	3.8	28.3	11.3	18.1
Larrea tridentata					0.6
Lepidium fremontii	60.0	66.3	6.7	5.0	5.0
Lycium andersonii	1.3	2.5		5.0	0.6
Psorothamnus fremontii			1.7		2.5
Stanleya pinnata					1.3

DISCUSSION

A. humilis sites studied are similar with regard to physical and biological parameters. All occur on the same geologic member within an elevational range of 750–1050 m. Each site is heterogeneous with regard to the soil parameters measured, but no site appears to be exceptionally different from all others as might be predicted, since all sites are on a common parent material. Species composition of the vascular and nonvascular plant communities studied was similar for all sites. All gypsiferous sites were dominated by shadscale and Mormon tea. Creosote bush dominated areas immediately adjacent. Within its habitat *A. humilis* was found to occupy areas that have a lower shrub density relative to the general habitat. No difference in cryptogamic plant cover could be detected for areas surrounding *A. humilis* plants relative to the general habitat.

The Purgatory Flat site does not appear to differ significantly from *A. humilis* habitats for any of the parameters studied. It seems likely that *A. humilis* could survive and reproduce on in-place outcrops of the Shnabkaib at this site. Distance from St. George makes this site less likely to be threatened by development; and intensity of ORV traffic, as evidenced by tracks and trails, is considerably less than on most *A. humilis* sites. The outcrops of Shnabkaib along the north end of the basin lie in a narrow strip between state highways 9 and 17 and cliffs formed by the Upper Red, making it possible to protect the site by fencing along two sides only. For purposes of habitat protection, portions of the Purgatory Flat area should receive status similar to *A. humilis* sites.

A. humilis is strictly associated with a unique and limited habitat, and maintenance of viable populations of the species requires the protection of this habitat, much of which is impacted by cultural disturbances. All of the sites studied show damage to the habitat, particularly to the cryptogamic plant cover, and to *A. humilis* plants directly. Most damage is related to ORV use. Recent surface mineral assessment work at two sites has resulted in the disturbance of soil surfaces and the destruction of plants. The rapid growth of St. George and associated new developments poses inevitable threats. Although critical habitat was not defined for the species in the 1979 mandate that gave it protection under the Endangered Species Act, continuing habitat degradation over the last 10 years suggests that such designation is appropriate. If this species is to be preserved, portions of the habitat must be protected from development and ORV traffic. Establishment of additional populations on unoccupied outcrops of suitable habitat should be attempted while genetic diversity is still available.

ACKNOWLEDGMENTS

This study was funded in part by a grant from the Utah Native Plant Society. Financial assistance was also provided by the U.S. Bureau of Land Management. Figure 2 was provided by Ralph Gierisch (Rare Plants Consultant, St. George, Utah) and reprinted with his permission. W. Kenneth Hamblin (Geology Department, Brigham Young University) interpreted the geologic associations at the various *A. humilis* sites.

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Received 15 November 1990
Revised 6 March 1991
Accepted 28 March 1991