

MANAGEMENT RECOMMENDATIONS
for
Hanging Gardens in Arches NP, Canyonlands NP, Dinosaur NM,
Glen Canyon NRA, Natural Bridges NM, and Zion NP

James F. Fowler, Nancy L. Stanton, and Steven W. Buskirk
Department of Zoology and Physiology
Ronald L. Hartman
Department of Botany
University of Wyoming
Laramie, WY

During the summers of 1991-93 we collected baseline biodiversity and ecological data on hanging-garden vascular plant and bee communities (Fowler 1995). Based on this research and observations of 84 hanging gardens on the Colorado Plateau, we have formulated resource management recommendations in three areas: human impacts, Resource Natural Areas, and future research. Most of the 84 hanging gardens were undisturbed islands of hydrophytic vegetation in an arid environment, and most appear to have been minimally impacted by human activity. These hanging gardens also provide a unique opportunity to explore multispecies metapopulation distributions, endemism, species-area relationships, and many other biogeographic questions regarding the flora and fauna of the Colorado Plateau.

HUMAN IMPACTS

Mitigation

Social trails around Weeping Rock HG in Zion NP.--Well-beaten paths were observed near the base of the large wet wall and along the stairway to the viewing platform at Weeping Rock HG. These areas would normally be covered with algal growth, grasses, sedges, and other herbaceous plants. The primary concern is the

loss of the wet colluvial soils that support much of the characteristic hanging garden vegetation on ledge-soil complex microhabitats (Fowler 1995). These wet soils are susceptible to mass movement when subjected to repeated foot traffic, and some areas nearest the platform have already lost vegetation and soil. We have two alternate recommendations: (1) additional wooden or pipe fencing to keep foot traffic off wet soils and wet rock surfaces, or (2) completely redesign the viewing area to keep visitors in front of the drip line with a walkway at the base of the wet colluvial soils. Option 2 would be more extensive but would alleviate the problem of ice shear and winter ice buildup on the walkway fences. Option 2 would also allow removal of the current concrete viewing pad beneath the dripline and create a large area for hanging-garden revegetation.

Feral honeybee colonies in Zion NP.--We collected eight specimens of the exotic honeybee (*Apis mellifera*) on Grotto and Upper Emerald hanging gardens on July 13, 1991. Schaffer et al. (1983) has found clear evidence that honeybees compete directly with native bees, and, that after removal, there was a sharp increase in the number of individuals and species of native bees visiting flowering agaves in the Sonoran desert. These hanging gardens are at least 4.5 km from the park boundary; so it is likely that source of the bees we collected is a feral colony (or colonies) within the park. While 4.5 km is within the maximum known flight range for this species, foraging flights usually cease below 2.4 - 2.8 km (Kerr 1959 as cited in Michener 1974). It is

recommended that this colony (or colonies) be located, destroyed, and that an annual monitoring program for reestablishment of the honeybee colonies be implemented.

Exotic plant species in Dinosaur NM.--Fifteen species of exotic vascular plants were found on hanging gardens of the Colorado Plateau with Glen Canyon NRA, Dinosaur NM, and Zion NP each having several (6, 7, and 8 respectively) while the other parks had one or none. Most of these species are widespread and somewhat naturalized to the American West, e.g., cheatgrass (*Bromus tectorum*). Only two hanging gardens had more than 1% of their vegetative cover in exotic species: Buzz and Redrock in Dinosaur NM. Buzz HG had 11% of its canopy as Redtop (*Agrostis stolonifera*) and Redrock had 21% giant whitetop (*Lepidium latifolium*) and 6% dandelion (*Taraxacum officinale*). Giant whitetop is a relatively recent, very aggressive invader. A population of alcove bog-orchid (*Habenaria zothecina*) is growing under the canopy of this plant (one of only two known sites in Dinosaur NM) and their roots are probably intertwined. This exotic should receive top priority for eradication efforts, on this site especially, but also along all riparian corridors in the park. For Redrock HG, there are two possible techniques: (1) chemical spot treatment of the leaves with a "wick-on" device, and (2) hand removal of above-ground portions to reduce carbohydrate root reserves. We are not aware of a herbicide known to kill this species but several should be available. Other workers in the Weed Science field may know of an effective

chemical. If hand removal methods are chosen, it should be done just prior to flowering by first removing and bagging the inflorescence then cutting each stem at ground level. The inflorescence should be incinerated off-site. This would have to be repeated for many years, and probably more than once per year when regrowth occurred, until the plants use up their energy reserves and die. Hand removal is recommended on Redrock HG since it is relatively small, but chemical means may be necessary in larger riparian sites.

Livestock grazing on Rimrock and Redrock HGs in Dinosaur NM.--
Livestock grazing and loafing has heavily impacted both the vegetation and the soil resource on Rimrock and Redrock Hanging Gardens. In addition, livestock are the probable vector for the introduction of the exotic species on Redrock HG noted above. Resource management and legal efforts are underway to eliminate grazing from Redrock HG (also known as "barn cave"). This is a prerequisite for recovery of the vegetation and elimination of exotic plant species.

The following species lists and vegetation data compare two Blind Canyon hanging gardens that have similar physical characteristics: Rimrock and Bench (Table 1). Rimrock has been heavily grazed and used as a loafing area by livestock while Bench is protected from such disturbance by a slickrock "nose" that is apparently impassable to cattle.

Table 1. Vascular plant species list and canopy coverage estimates (percentage by species) for Rimrock and Bench hanging gardens in Blind Canyon, Dinosaur NM: T = trace, <0.5%, X = present but did not fall within community sampling quadrats.

Species	Rimrock	Bench
<i>Aquilegia micrantha</i>	19	36
bare soil	78	52
<i>Zigadenus vaginatus</i>	2	7
<i>Cirsium ownbeyi</i>		2
<i>Cercocarpus intricatus</i>	x	T
<i>Carex aurea</i>		1
<i>Fendlerella utahensis</i>		1
unknown species	T	1
<i>Erigeron nematophyllus</i>	x	x
<i>Heterotheca villosa</i>	x	x
<i>Pinus edulis</i>	x	x
<i>Calamagrostis scopulorum</i>	x	x
<i>Petrophytum caespitosum</i>	x	
<i>Castilleja lineariifolia</i>	x	
<i>Juniperus osteosperma</i>		x
<i>Ephedra viridis</i>		x
<i>Elymus elymoides</i>		x
<i>Pallaea glabella</i>		x
<i>Populus deltoides</i>		x
<i>Achillea millefolium</i>		x
<i>Chrysothamnus nauseosus</i>		x

Rimrock HG has more bare soil, 78% vs. 52%, and fewer species present 9 vs. 18 than Bench HG. Most of the vegetation reduction due to grazing was for alpine columbine (*Aquilegia micrantha*) and alpine death camas (*Zigadenus vaginatus*). We did not take biomass measurements but visual estimates indicate that Rimrock HG had 25% of the live foliage of Bench HG. The difference in bare soil estimates may be conservative since an eroded trail occupies what once may have been hanging garden vegetation on Rimrock HG. The loss in species richness for Rimrock HG was in species usually present in only small proportions and thus vulnerable to local extinctions. We would recommend elimination of grazing from Blind Canyon proper. This could be accomplished with a drift fence across the access route(s) from the Yampa Bench into Blind Canyon or by cancellation of the grazing allotment.

Monitoring

Most of the hanging gardens we sampled during the summers of 1991-93 were remarkably free of human footprints and trails. The major exception was Weeping Rock HG as noted above. However, the following five hanging gardens have the highest potential for future disturbance of vegetation and/or wet colluvial soils by human foot traffic: Upper Emerald and Menu Falls in Zion NP, Raven in Canyonlands NP, Dead Tree in Arches NP, and Limestone and Snow in Dinosaur NM.

Upper Emerald HG sits above Emerald Pool which is at the end of a popular hiking trail. With the recent closing of Emerald

Pool to wading and swimming, the potential for disturbance of the hanging garden has been greatly reduced. Menu Falls HG sits above a small waterfall which has a short, unofficial trail leading to it. This unofficial trail has a smaller extension leading to the base of the hanging garden. We noticed very little disturbance on the garden itself, but like Upper Emerald HG, there is a lot of visitation nearby. The Neck Springs Trail in Canyonlands NP passes the base of Raven HG just past the old water trough. A faint game(?) trail leads up the slope to the backwall of the hanging garden where there are small pools of standing water. A few hikers have visited these pools, but no damage was noted. Dead Tree HG in Arches NP is near the trail to Delicate Arch and, in the summer of 1993 at least, was the goal of interpretive hikes. In Dinosaur NM the situation is similar. A trail leads from Limestone (river) Campground in Lodore Canyon to the canyon rim opposite Limestone HG. There is also a trail from Harding Hole (river) Campground on the Yampa River which goes near Snow HG.

In all of the above cases, no significant human impacts were noted but visitation is nearby and some hikers are aware of the presence of hanging gardens. No protection is necessary at this point, but we recommend regular monitoring of these sites to preclude damage to the vegetation and colluvial soils.

Recommended visual inspection periodicity is as follows: once per month during the summer visitation season for Upper Emerald, Menu Falls, Raven, Dead Tree, and Snow; once per summer for Limestone.

In addition, we would recommend that all hanging gardens be checked for human foot traffic disturbance once every 3-5 years.

RESEARCH NATURAL AREAS

Four sites are recommended for designation as Research Natural Areas: Grotto HG and Upper Emerald HG in Zion NP, Ribbon Canyon in Glen Canyon NRA, Limestone HG in Dinosaur NM, and Kachina HG in Natural Bridges NM. Ribbon Canyon has previously been recommended for this designation by Joel Tuhy and we concur.

Grotto and Upper Emerald HGs have large wet wall, ledge, and ledge-soil complex microhabitats and have the reedgrass vegetation type (Fowler 1995). Plant species diversity is high for Upper Emerald HG and well above average for Grotto HG. These hanging gardens have the most complete set of baseline data in our study since we have replicate sets of vegetation and insect data for the months of June, July, and August of 1991 and a follow up survey of plant species richness in May of 1992. In addition, the riparian zone below Grotto HG is rich with breeding frogs in the spring and would be an ideal choice for aquatic entomological studies. The water piracy from Grotto HG is a mixed blessing; it ensures local interest in maintaining the hanging garden water flow yet represents an unnatural disturbance to the ledge microhabitats which are rich with Cardinal monkeyflower (*Mimulus cardinalis*) and American spikenard (*Aralia racemosa*). Access to each hanging garden is relatively easy yet visitation is minimal. Controlling visitor access to Grotto HG would be relatively easy but difficult for Upper Emerald HG.

This RNA should also include samples of the xeric vegetation and canyon wall talus slopes.

Ribbon Canyon has four hanging gardens upstream from the high water line: Ziggy, Hawk, Hook, and Swallow. Ziggy HG has a large ledge-soil complex microhabitat, smaller areas of wet wall microhabitat, and high plant species diversity. It also has a large plunge pool associated with it that has a population of leopard frog (*Rana pipiens*). Ziggy, Hawk, and Hook HGs have excellent examples of the fern-thistle vegetation type (Fowler 1995) with large populations of the hanging-garden endemic plant, Rydberg's thistle (*Cirsium rydbergii*). Swallow HG has the fern vegetation type (Fowler 1995) with a population of *H. zothecina*. There is a pristine riparian zone connecting these hanging gardens that alternates between slickrock runs/pools and woody/herbaceous vegetation. This riparian zone also has a small mule deer population. Ribbon HG (Welsh 1989) is located on the lake at the mouth of the canyon. Our recommendation for the Research Natural Area would be a downstream boundary at the high water line (elevation 3700 ft.) on the canyon floor and extend to the headwall of both canyon forks. Another option would be to include the entire canyon, i.e., the lake shore and Ribbon HG. In either case, some provision should be made to "reserve" the campsite at the upper end of the canyon when research teams are working in the canyon.

Limestone HG in Dinosaur NM is the most anomalous hanging garden we visited. It is large, very wet with alternating tiers

of wet wall and ledge-soil complex microhabitats, and produces enough water to support a riparian zone down canyon. The only other gardens of this size and wetness were in thick layers of crossbedded Navajo sandstone: e.g., Grotto HG, whereas the aquifer of Limestone HG is the much thinner Humbug sandstone. We hypothesize that the overlying limestone may actually be recharging the Humbug sandstone. Limestone HG stands out in stark contrast to the smaller, drier hanging gardens along Yampa Canyon in Dinosaur NM. Plant species diversity is high with the most abundant species, Jones' reedgrass (*Calamagrostis scopulorum*), placing it in the reedgrass vegetation type. This site also has a large population of Ownbey's thistle (*Cirsium ownbeyi*) which has a restricted distribution in the upper Green and Yampa River Canyons. One interesting observation was the depth of litter (up to 0.65 m!) below many Jones' reedgrass plants. How old is this litter? Our recommended boundary would start at the mouth of Limestone Canyon and extend to the headwall of the canyon fork which includes the hanging garden. This would include an extensive stretch of riparian habitat and xeric side slopes. The alluvial fan at the mouth of Limestone Canyon would serve as an access point and research campsite.

We do not concur with Naumann's (1990) recommendation for Research Natural Area designation for the Johnson-Blind-Bull Canyon complex. There is livestock grazing currently in Blind Canyon as noted above. More significant is the heavy hiking traffic by large groups of boaters on an undesignated/undeveloped

trail from Harding Hole, up Johnson and Blind Canyons to the Yampa Bench, and back down Bull Canyon. Some parts of the trail are heavily eroded while other parts branch off along riparian zones. In any case, the potential for visitor disturbance of research projects would be high. If visitor access is regulated in the future, the question of Research Natural Area designation could be revisited.

Kachina is the largest and most diverse hanging garden in Natural Bridges NM (Fowler 1995). Although we have not completely surveyed White and Armstrong Canyons, it is unlikely that we will find a better candidate for a Research Natural Area recommendation. The site is easily accessible, yet well hidden from visitation.

Kachina HG has the largest population of Kachina daisy (*Erigeron kachinensis*), 8% of the total hanging garden canopy, of the sites we studied. This species (candidate 2 federal status) was first described from Natural Bridges NM and is uncommon throughout its range (Heil et al. 1993). It is endemic to San Juan County, Utah and Montrose County, Colorado and has previously been recommended for high priority species-level management (Heil et al. 1993). Other endemic taxa found on this hanging garden are the Colorado Plateau endemics: *Aletes macedougallii* ssp. *breviradiatus* and *H. zothecina*; and the hanging-garden endemics, *A. micrantha* and *Z. vaginatus*.

Reeves and Reeves (1993) previously studied a population of *H. zothecina* on Kachina HG (their site #1). This study may have

combined helleborine orchid (*Epipactis gigantea*) with *H. zothecina*. We did not note nor collect specimens of *H. zothecina* from Kachina HG during our late May visit, but we did collect and photograph flowering specimens of *E. gigantea*. Reeves and Reeves (1993) conducted their study on *H. zothecina* from late June to September during its flowering period (Heil et al. 1993), but after *E. gigantea* flowering, which is in spring and early summer (Welsh 1990). While the flowers of these two species are easily distinguished, vegetative morphology is quite similar. Apparently both species are present and each study missed one orchid species due to seasonal flowering differences. Fowler (1995) has found both orchid species present on the same hanging garden at 4 other sites on the Colorado Plateau. Allphin and Harper's (1994) study on *E. kachinensis* habitat preferences also provides additional baseline research for Kachina HG (West-facing alcove B) and enhances its candidacy as a Research Natural Area.

No RNA recommendations are made for Arches NP, Canyonlands NP, or Capitol Reef NP. Further survey work needs to be completed (see survey needs and research recommendations below) for Arches NP and Canyonlands NP prior to making recommendations. Future recommendations for these parks would include hanging gardens with the columbine and fern-columbine vegetation types. Capitol Reef NP has only very small hanging gardens. The Halls Creek Narrows could be considered for a RNA on the basis of its geomorphology and undisturbed riparian community, which would include most of the hanging gardens.

RESEARCH RECOMMENDATIONS

Baseline survey completion

The survey of hanging-garden vascular plant, floral visiting insect, and general arthropod communities we began with this study should be completed for Canyonlands NP, Arches NP, Zion NP, Natural Bridges NM, and Dinosaur NM in that order of priority. The following is a list of areas to be surveyed in each park: Canyonlands NP, White Rim and Cedar Mesa sandstone formations and Upheaval Dome area; Arches NP, Colorado River corridor and scattered parts of Salt Valley; Zion NP, Parunuweap Canyon and Kolob Canyons; Natural Bridges NM, White, Armstrong, and Tuwa Canyon; Dinosaur NM, Ely Creek's first Northern tributary canyon. Heil et al. (1993) and T. Graham (*personal communication*) have indicated that additional hanging gardens are located in all three subdistricts of Canyonlands NP. These are likely to be different from the ones we surveyed along the Neck Springs trail due to lower elevation and thinner aquifers. Heil et al. (1993) also indicates that alcove rock daisy (*Perityle specuicola*) is found in hanging gardens communities near Arches NP and Canyonlands NP. This extremely rare species is endemic to Grand and San Juan Counties and is expected to be found in hanging gardens in both parks (Heil et al. 1993). Additional surveys may locate new populations.

Several other areas remain only partially explored for hanging gardens. During our survey, we were unaware of the potential for Parunuweap Canyon in Zion NP to have hanging

gardens. The Kolob plateau in Zion NP also has seepline hanging gardens that should be inventoried. In Natural Bridges NM, we had to omit one large hanging garden due to time constraints, and we are aware of several other small ones noted in other studies (Allphin 1993, Heil et al. 1993). We noted several hanging gardens in the Signature Cave and Ely Creek area of Dinosaur NM that we did not have time to inventory.

In addition to the 27 hanging gardens we surveyed in Glen Canyon NRA during this study, Welsh (1984) surveyed 29 hanging gardens for plant species richness, and many more were drowned with the filling of Lake Powell. While several unlocated hanging gardens probably exist in Glen Canyon NRA, we recommend that further survey work be done on the vascular plant and insect communities on the hanging gardens for which Welsh (1984) provided only plant species lists.

Baseline survey expansion

We recommend expanding the hanging garden biodiversity survey in two directions. First, expand the insect survey taxonomically and temporally. In this study, logistics and available taxonomic expertise dictated a concentration on floral visiting bees. Many of our specimens are yet to be identified. Our collections only represent a "snapshot in time" of insect biodiversity, and should be expanded to include a more thorough range of collection times and additional techniques. Research in the previously recommended RNA's would accomplish much of this goal. Secondly, the survey should be expanded geographically to

include Colorado NM, Grand Canyon NP, and possibly Canyon de Chelly NM or Mesa Verde NP. Many people have told us of the hanging gardens in Grand Canyon, and Fowler located two hanging gardens in Colorado NM while on a recreational hike in July, 1993. Other federal and Indian lands on the Colorado Plateau probably also have hanging gardens which are biogeographically related to NPS hanging gardens.

Restoration ecology

Initiate short-term monitoring of restoration work on Weeping Rock HG in Zion NP, Redrock HG in Dinosaur NM, and the Rimrock-Bench HGs contrasting pair in Dinosaur NM. If the walkways and viewing platform on Weeping Rock HG are modified to reduce social trail impacts on the vegetation and colluvial soils, annual status checks should be taken until restoration is judged to be complete. Measurements should include size of the vegetation patch, its plant species composition, community importance of each species, and percentage of bare soil within the ledge-soil microhabitat.

Eradication success of the exotic giant whitetop (*Lepidium latifolium*) and recovery from grazing on Redrock HG should be monitored by annually measuring the same parameters recommended for Weeping Rock HG. This should be done just prior to the first treatment on giant whitetop. If grazing is removed from Blind Canyon, there would be a unique opportunity to monitor secondary succession of vegetation on Rimrock HG and to have the nearby Bench HG as a comparison (control) group. In addition to the

measurement parameters mentioned above for Weeping Rock HG, the following comparative research should be added: comparisons of the seed bank, counts of colonizing plants (those derived from seed), checks for possible local extinction during succession, measurements of the amount of asexual reproduction from existing plant species, and determination of animal vectors for seed dispersal. The overall time frame for completion of the three above studies is difficult to determine, but we would suggest a minimum of five years. The work at Weeping Rock HG and Redrock HG would take approximately one field day per year. The suggested research on Rimrock-Bench HGs would take 3-4 field days per year and at least one week lab time for seed identification.

If honeybee eradication and annual monitoring for re-establishment is implemented for Zion NP (pages 2-3), then we would have an opportunity to monitor the effects of its removal on the native bee community. Honeybees, *Apis mellifera*, were collected on American spikenard, *Aralia racemosa*, in Grotto HG and in malaise traps on Grotto HG and Upper Emerald HG. We have baseline data for bee biodiversity and floral visitation on these hanging gardens in the months of June, July, and August (our most complete bee data set). By conducting similar bee surveys during and after honeybee colony we would have a mechanism for measuring and documenting the community effects of exotic species removal. Specific changes to be monitored include the following: changes in floral visitor species richness and the number of individuals per visiting species for American spikenard on Grotto HG, changes

in bee biodiversity for Grotto and Upper Emerald HGs, and the time required for these potential changes to occur.

Long-term studies

In addition to the hanging gardens in the Research Natural Areas suggested above, representative hanging gardens for each of the vegetation types (Fowler 1995) should be regularly monitored to detect hanging garden community and larger scale environmental changes on the Colorado Plateau. The following hanging gardens are suggested to fill that prescription (Table 2).

Table 2. Hanging gardens recommended for long-term ecological study listed by vegetation type and location.

Vegetation type	Park	Hanging garden
fern	ARCH	Scaly
	ZION	Canyon Overlook II
	GLCA	Swallow
fern-columbine	ARCH	Dead Tree
reedgrass	CANY	Box
	NABR	Slickrock
	DINO	Limestone
	ZION	Grotto
columbine		Upper Emerald
	NABR	Long
	CANY	Northface
	ARCH	Banded
	DINO	Bench or Ely

fern-thistle	ZION	Fall
	GLCA	Zigy
		Hawk
		Hook

These recommendations reflect an effort to spread the monitoring sites in order to measure park-level changes in addition to plateau-wide changes. If only plateau-wide monitoring was chosen, this list could be pared down, but statistical validity could be affected by smaller sample size.

Suggested community monitoring parameters:

1. *Hanging garden size and major axis length.*-- Hanging garden edges would be measured as horizontal distance from offsite benchmarks set in stone. Size is a surrogate for measuring aquifer output and detecting long-term environmental change or water development effects.
2. *Vascular plant species richness and species composition.*-- Community structure measurements would detect colonization and local extinction events.
3. *Community importance of vascular plants by species.*-- Community importance measurements would allow description of long-term hanging-garden vegetation dynamics.
4. *Amount of disturbance.*-- Tracking disturbance and recovery events caused rock fall, soil sloughing, or animal activity would measure patch succession rates. This would

be an indication of possible recovery rates due to human disturbance.

5. *Periodicity*.-- The above measurements should be taken for annually for 3-5 years to solidify baseline data, then every 2-3 years thereafter. Monitoring activity should be completed during the middle of the vegetation growing season with no more than a one week variation between years.

6. *One time measurements*.--Measure the following niche gradients from the xeric surroundings to the center of the hanging garden: soil moisture, soil depth, soil texture, soil temperature, insolation, slope, and aspect.

Additional Research Questions

There are several research questions that, as a direct follow up of our work, should be pursued on the Research Natural Areas and long-term study hanging gardens. Recommendations in order of priority follow:

1. What is the age of the water in the sandstone aquifers on the Colorado Plateau which supply water to hanging gardens? This has been a subject of water rights litigation in Zion NP. A more important question for the management of biodiversity on hanging gardens is "what is the lag time between changes in climate and changes in aquifer flow?"
2. Determine nest sites and foraging range for bumble bees (*Bombus*) collected on hanging gardens. How important are the hanging garden floral resources to maintaining bumble bee colonies within the parks?

3. Determine the distribution of *Bombus* within the parks and surrounding montane habitats. Are the bumblebee populations within the parks isolated from or contiguous with populations in montane areas? If not, what is their biogeographical relationship?
4. Did hanging-garden endemic plant taxa evolve on site? If so, how long ago and from which species?
5. Is there an interdependent relationship between Rydberg's thistle (*C. rydbergii*) and the carpenter bee (*Ceratina pacifica*)? *Ceratina* nests in the pith of stems and is rare in deserts (Michener 1994). We collected *C. pacifica* on Box HG in Canyonlands NP where Rydberg's thistle was the only hanging garden plant species that has a large pith. Thus it may have an important role in maintaining populations of this bee species in Canyonlands NP. It would also be necessary to determine the distribution of this bee within Island-in-the-Sky and surrounding area.
6. Complete a survey of insects associated with each hanging-garden endemic plant species, concentrating first on the floral visitors and flowering phenology.
7. Determine the net primary productivity and decomposition rates of hanging garden vegetation. This should be compared to the surrounding xeric and riparian communities.

LITERATURE CITED

- Allphin, L., and K. T. Harper. 1994. Habitat requirements for *Erigeron kachinensis*, a rare endemic of the Colorado

Plateau. Great Basin Naturalist 54:193-203.

- Fowler, J. F. 1995. Biogeography of hanging garden on the Colorado Plateau. Unpublished Ph.D. dissertation, University of Wyoming, Laramie, WY.
- Heil, K. D., L. Floyd-Hanna, L. Reeves, D. Hyder, and R. Fleming. 1993. Composition, distribution, abundance and habitat requirements of endangered, threatened, and rare plant species in the Southeast Utah Group on National Parks. Unpublished report prepared for the National Park Service.
- Goodrich, S., and E. Neese. 1985. Uinta Basin Flora. USDA Forest Service - Intermountain Region, Odgen, Utah.
- Kerr, W. E. 1959. Bionomy of meliponids - VI - Aspects of food gathering and processing in some stingless bees. Food gathering in Hymenoptera, Symp. Entomol. Soc. Amer. Detroit meeting, sponsored by Apiculture Subsection, pp. 24-31.
- Michner, C. D. 1974. The Social Behavior of the Bees. Harvard University Press, Cambridge, MA.
- Reeves, T., and L. Reeves. 1993. Report on the 1992 flowering phenology and community structure study of *Habenaria zothecina* Higgins and Welsh in Natural Bridges National Monument. Pages 35-40 in Heil, K. D., L. Floyd-Hanna, L. Reeves, D. Hyder, and R. Fleming. 1993. Composition, distribution, abundance and habitat requirements of endangered, threatened, and rare plant species in the Southeast Utah Group on National Parks. Unpublished report prepared for the National Park Service.

Schaffer, W. M., D. W. Zeh, S. L. Buchmann, S. Kleinhaus, M. V.

Schaffer, and J. Antrim. 1983. Competition for nectar between introduced honeybees and native North American bees and ants. Ecology 64: 564-77.

Welsh, S. L. 1984. Flora of Glen Canyon National Recreation Area. Glen Canyon National Recreation Area, National Park Service, United States Department of the Interior, Page, Arizona, USA.

_____. 1990. Wildflowers of Zion National Park. Zion Natural History Association, Springdale, Utah.