

**Annual Report**

**Inventory and Monitoring of Terrestrial Riparian Resources in the  
Colorado River Corridor of Grand Canyon:  
An Integrative Approach**

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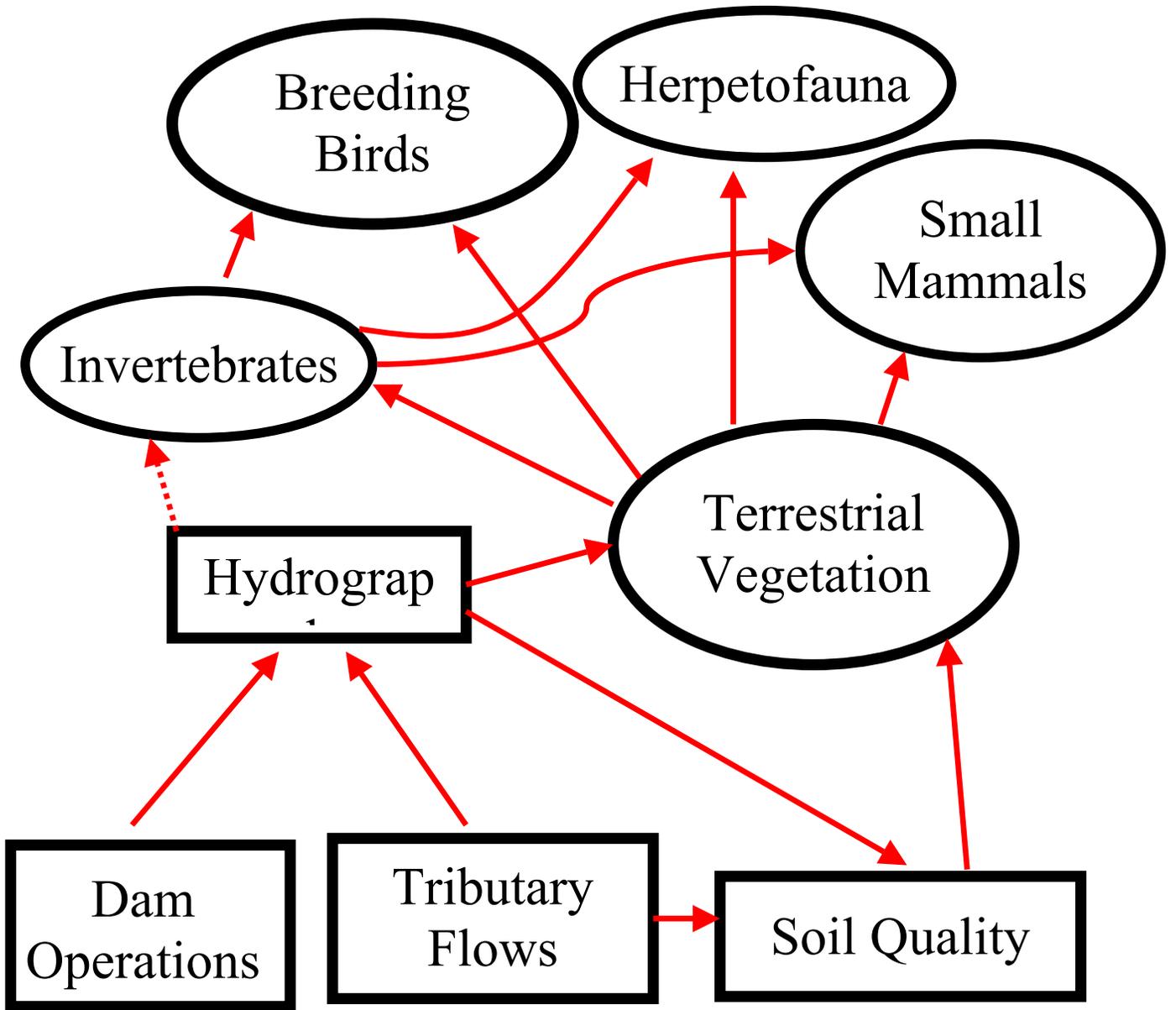
## INTRODUCTION

Here we present results from the first year of collecting data on the status of terrestrial riparian resources in the Colorado River corridor of Grand Canyon National Park. The data included cover aspects of the vegetation, breeding birds, mammals, arthropods, and herpetofauna that occur in habitats affected by the operation of Glen Canyon Dam within the Park. By collecting these data within the same sites at the same time, it is hoped that we will develop a better understanding of how the system functions, how organisms interact across taxonomic lines, and how these relationships are affected by the operation of the dam.

The data are intended for use as the baseline for monitoring of these resources over the long term. As such, their true utility will not be evident until they are compared to data collected in 2002 and 2003. However, we are able to look for relationships among resource groups, especially between aspects of the vegetation in the sites and the abundance and species richness of the faunal components.

The data were collected in a series of research river trips organized and outfitted by the Grand Canyon Monitoring and Research Center. Table 1 lists the trips taken, and the work performed on those trips. Some supplemental data was collected on arthropod and herpetofaunal distribution during a research trip carried out as part of the "Bird-Bug" project of Yard and Cobb.

Within this report, each taxonomic group is covered in a separate section by the P.I. responsible for that group. The purpose, objectives, methods, and results from the studies in 2001 are described, and a summary of the results are given. The next section covers the integration of faunal data with vegetation structure data and tests for concordances among the composition of the vegetation and the animal groups. The last section is a description of the problems encountered in methods and equipment in 2001, and a description of how we will work around these next year.



**Figure 1. Conceptual model of interrelated biotic components in the terrestrial riparian system in Grand Canyon**

Table 1. Survey schedule for integrated terrestrial ecosystem monitoring projects by river trip dates.

	BB	SWFL	BUGS	HERPS	MAMM	V STR	V DYN
April 30 – May 17	X		X	X	X	X	
May 15 – May 30	X	X					
May 31 – June 17		X					
June 22 – July 10		X					
August 27 – September 13			X	X	X		X

Resource areas surveyed: BB = breeding bird survey and nest searches; SWFL = Southwest willow flycatcher surveys; BUGS = Terrestrial invertebrate surveys; HERPS = Herpetofaunal surveys; MAMM = Small mammal trapping and mammal surveys; V STR = Vegetation structure via total vegetation volume; V DYN = Vegetation dynamics at transect sites

**Small Mammals**  
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**Purpose:**

The purpose of the mammal portion of this study is to inventory and monitor the mammalian fauna in the riparian zone in the Grand Canyon in relation to water stage elevation.

**Objectives:**

The objectives of this study were to 1) generate a complete inventory of the mammal resources in the river corridor; 2) monitor spatial trends in the mammal community in relation to site, water stage elevation, and other factors; and 3) monitor temporal trends in the mammal communities, particularly in relation to dam-related factors.

**Methods:**

Inventory and monitoring methods were different as appropriate for specific groups of mammals. Mammal sampling was conducted at 14 sites during the May and September monitoring trips.

Small Terrestrial Mammals: Small mammals were sampled with Sherman live traps baited with oatmeal and peanut butter. The trapping design consisted of 3 parallel 100 m transects of 50 traps set at 2 m increments. Each transect was located within a water level zone and located 4 m upslope from the corresponding arthropod transect. Traps were set in the evening and removed the following morning. Captured animals were tentatively identified based on external characteristics, sexed, measured, and either released or euthanized and prepared as a standard museum voucher specimen. Total trapping effort was 150 trap-nights/site-visit, for a total of 2,100 trap-nights during the 2001 year.

Bats. Bats were sampled utilizing an ultrasonic bat detector. A bat detector attached to a tape recorder was placed on the new high water zone and old high water zone small terrestrial mammal transects. Recordings were begun approximately one hour prior to sunset and continued for approximately five hours or until the tape ran out. Capture methods were not utilized to sample bats as originally proposed because the park permit did not allow for this activity.

Medium and Large Mammals. Medium and large mammals were sampled through observation of individuals or their sign. The nature and locality of all observations were recorded during other activities including travel time and stops for lunch and camp.

**Results:**

Small Terrestrial Mammals: Overall trap success (captures/trap set for one night) was very high (27.6%). A total of 579 individuals of 8 species were captured including (in order of decreasing abundance; reported as number per 100 trap-nights): *Peromyscus eremicus* (12.4), *Neotoma lepida* (5.3), *Peromyscus crinitus* (4.2), *Peromyscus boylii* (3.0), *Chaetodipus intermedius* (1.8), *Neotoma albigula* (0.5) and *Perognathus formosus* (0.3). In addition, there was one juvenile *Peromyscus* of highly uncertain identification.

The numbers of small mammals captured during August-September (45.0 % trap success) was over 4 times higher than during May (10.1 % trap success). With the exception of *C. penicillatus*, which declined from 2 to 0 captures, all species increased in abundance. However, the rank order of abundance changed. During May *Neotoma lepida* was the most abundant species (3.6) followed by *P. crinitus* (2.1) and *P. eremicus* (1.9). The following August-September *P. eremicus* had dramatically increased to become the dominant small mammal (22.9) followed by *N. lepida* (7.0) and *P. crinitus* (6.3). Rare species also exhibited increases in captures such as *N. albigula* increasing from 2 to 9 and *P. formosus* increasing from 2 to 4. There was no observable pattern in variation in abundance of small mammals across sites. However, within sites nearly one half (44.0%) of the small mammals were captured in the old (highest) water zone. This zone is often associated with the steeper sides of the canyons that affords more structure for small mammal burrows. There was little difference between rodent abundance in the water (26.6% of captures) or new water (29.4% of captures) zones.

Bats: Equipment failure and logistical problems resulted in the collection of no usable acoustical data. However, individuals of 2 species (*Antrozous pallidus*, *Pipistrellus hesperus*) were found dead and salvaged as voucher specimens.

Medium and Large Mammals: A total of 10 species of medium and large sized mammals (or their sign) were observed during the two sampling periods. The most abundant mammals observed (> 40 instances) were bighorn (*Ovis canadensis*) and American beaver (*Castor canadensis*). Species uncommonly observed ( $\geq 8$  instances) included ringtail (*Bassariscus astutus*), coyote (*Canis latrans*), mule deer (*Odocoileus hemionus*), and rock squirrel (*Spermophilus variegatus*). Species rarely observed ( $\leq 5$  instances) included bobcat (*Felis rufus*), kit fox (*Vulpes macrotis*), western spotted skunk (*Spilogale gracilis*) and raccoon (*Procyon lotor*). In addition, one small mammal, the antelope ground squirrel (*Ammospermophilus* sp.), was observed at two locations but not captured.

No spatial or temporal trends were evident in these data with the possible exception of relatively more observations of bighorn in August-September than in May and relatively more observations of mule deer in May than in August-September. There was no significant ( $P > 0.05$ ) relationship between river mile and abundance of beaver. However, there appears to be two centers of high beaver abundance in the vicinities of river miles 50 and 170.

Voucher Specimens: A total of 22 individuals in 8 species were preserved as standard museum voucher specimens (including tissue samples) and will be deposited in the Museum of Southwestern Biology. Additional collection is needed in order to verify study results. For most species, field identification based on gross external morphology is not sufficient to *verify* species because diagnostic characters are based on cranial, dental or other internal structures. Consequently, the accuracy of most of the mammal data can never be assured; GCNP permit limitations on numbers of specimens allowed is in opposition with standard methods in mammalogy.

**Summary:**

The 2001 sampling period was highly successful. A total of 20 species of mammal was identified as occurring in the river corridor of the Grand Canyon. The 18 species of terrestrial mammals documented during this study represent 77% of the native mammal species previously documented from the river corridor. The only native terrestrial species previously documented from the corridor that were not detected during this study were the desert shrew (*Notiosorex crawfordi*), western harvest mouse (*Reithrodontomys megalotis*), deer mouse (*Peromyscus maniculatus*), pinyon mouse (*Peromyscus truei*), and river otter (*Lontra canadensis*).

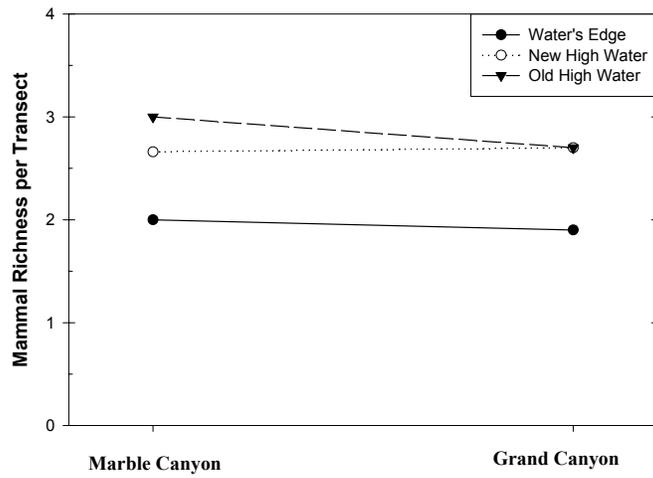


Figure 2. Small mammal richness by hydrologic zone in Marble Canyon and Grand Canyon in 2001.

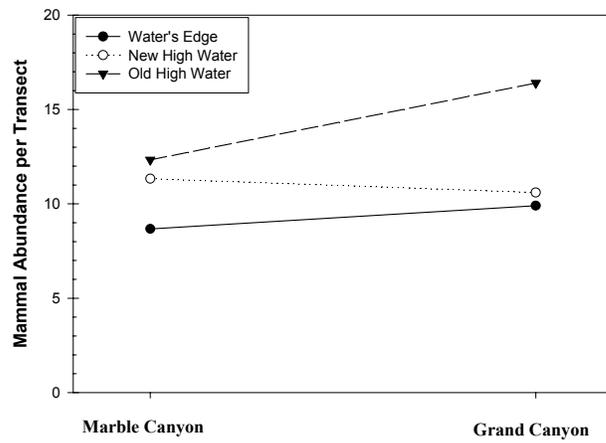


Figure 3. Small mammal abundance by hydrologic zone in Marble Canyon and Grand Canyon in 2001.

## Southwestern Willow Flycatcher Nest Searches and Surveys

Helen Yard

Helen Yard Consulting

### **Purpose:**

Surveys and nest searches for the endangered southwestern willow flycatchers are in compliance with MO 11 essentially stating to “protect, restore, enhance survival of native and special status species” and MO 13 which reiterates MO 11 (“to protect, restore and enhance the survival” of specific species such as bald eagles, peregrine falcons and southwestern willow flycatchers).

### **Objectives:**

1) conduct surveys to determine presence/absence of Southwestern Willow Flycatchers at historically surveyed sites from Lees Ferry to Diamond Creek and 2) to document rates of nesting success of southwestern willow flycatchers.

### **Methods:**

Willow Flycatcher Surveys. Southwestern willow flycatcher surveys were conducted during the three survey periods as required by the official protocol (Sogge, et al. 1997; see Table 1 above). We surveyed most sites specified by Johnson and Spence (Spence et al. 1998a) from Lees Ferry to Diamond Creek. All surveys were in compliance with the official protocol methods which require a tape playback of the song and calls of the southwestern willow flycatcher to induce a response from the birds. Survey forms issued by Arizona Game and Fish Department (AGF) were filled out at each site by biologists conducting the survey.

Ten of 16 historically surveyed sites were formally examined for willow flycatchers during the 2001 breeding season (Table 2). Four sites were not surveyed (RM's 38.8 - 43.1L, 72.0R, 133.8R, 143.0R) since no willow flycatchers have been observed there in at least four years of surveys. Sites RM 191.1R and 191.2 - 196.0L were surveyed though not during the time-frame required by the official protocol (dawn until 10:00) due to logistical constraints. These were therefore were not considered official surveys. Grand Canyon National Park Service personnel conducted surveys during the first survey period (May 15 - 30).

Willow Flycatcher Nest Searches. We conducted a nest search according to the official protocol (Rourke et al. 1999) at RM 50.4L where a pair of southwestern willow flycatchers were identified. When the nest was located, all nest site parameters including the number of eggs, presence of brown-headed cowbird eggs, were recorded on the willow flycatcher Nest Site Data Form issued by AGF.

### **Results:**

Willow Flycatcher Surveys. As many as six willow flycatchers were detected at four different sites along the river corridor between Lees Ferry and Diamond Creek during 2001. During the first survey period, no flycatchers responded to the tape playback at the three sites surveyed by Grand Canyon National Park Service personnel. During the second survey period,

two willow flycatchers were detected. One flycatcher responded to the tape at RM 5.2R and one responded at RM 50.4L. Two additional flycatchers were seen by biologists conducting general avian censuses (walking surveys without tape playback) during the second survey period. One flycatcher was seen at RM 49.1R and one at RM 198.3R. Though no tape was used for a vocal response from the birds, both observations were made by highly trained biologists experienced with visual and auditory identification of the species.

Two willow flycatchers were detected during the third survey period. This was the only breeding pair with a nest located at RM 50.4L. We cannot assume the willow flycatcher observed at 50.4L during the second survey was one of two birds detected during the last survey without positive identification such as colored leg bands.

Brown-headed cowbirds, a nest parasite correlated with willow flycatcher declines throughout the southwest, were not detected during surveys at any of the sites where flycatchers were found.

Willow Flycatcher Nest Search Results. We located a southwestern willow flycatcher nest at RM 50.4L on June 30, 2001. The nest, loosely constructed in a tamarisk tree, contained two flycatcher eggs and one brown-headed cowbird egg. The completed Willow Flycatcher Nest Site Data Form was returned to AGF. The outcome of the nest was not determined.

## Breeding Bird Nest Searches and Surveys

Helen Yard  
Helen Yard Consulting

### **Purpose:**

To assess trends in potential recruitment to breeding bird populations in the river corridor via nest searching and to collect information on the status and trends in breeding bird population abundance, distribution and species composition among hydrologic zones and sites.

### **Objectives:**

1) To determine changes in abundance and composition of nesting birds within and between OLD HIGH WATER ZONE and new high water zone patches across time. 2) To document avian abundance, distribution, species richness, and composition between vegetation zones and seasons (May and June). 3) To test for distributional differences in abundance and species richness between zones and seasons, test for species compositional differences between zones. 4) To test for differences between point-count and walking survey methods in terms of their abilities to locate species and individuals. In the future, when several years of data are available, to test for changes in abundance, species richness, distribution, and composition of breeding birds among years, and to compare our data with data collected in previous studies to test for broad-scale distributional changes through time.

### **Methods:**

Site selection. Sites for nest searching and breeding bird surveys were specified as part of the Request for Proposals. A total of 57 sites were listed in the “Protocols” document. Fourteen of these were campsites where other resources (mammals, invertebrates, herpetofauna) were surveyed simultaneously, and 43 were only bird survey patches.

Modifications to patch selection occurred when three of the 14 primary monitoring sites were changed for the following reasons: 1) an error in reading the aerial photos (74.1L originally chosen, 74.4L was selected); omission due to heavy use in peak tourist season (95.7L originally chosen, 92.3L was selected); and more suitable habitat in both vegetation zones (at least 100 meters) was found for small mammal and insect trapping at one site versus another (202.5R originally chosen, 202.0 was selected). Omission of 95.9L and 204.1R for avian surveys between monitoring sites was based on heavy use in peak tourist season and an error in reading the aerial photographs. Site 224L was omitted due to logistical constraints.

Nest searches. Nest searches for riparian breeding birds were conducted in and around the 14 camps specified by GCMRC on both field trips using standard methods (Brown 1989, Martin & Geupel 1993, Martin et al. 1997). Searches began in the afternoons upon arrival at camps, continued until dusk, then were resumed after the point counts and walking surveys the next morning. Equal time was not allocated in searching at each site due to variable travel times between sites. However, within sites, equal time was spent searching in each vegetation zone (a minimum of four hours per zone for a total of eight hours). Four biologists, and volunteers when available, spent a minimum of eight hours per site searching for nests.

Walking Surveys. We conducted walking surveys at 53 (May Trip) to 55 patches (June trip) during the 2001 breeding season. Surveyors spent up to 40 minutes moving downstream

through the patch. Old and new high water vegetation zones were surveyed independently (one observer walking each zone concurrently). Observers walked at a consistent pace within each zone on established trails (to minimize impacts) or choosing the path of least resistance. Surveyors recorded date, time, site, vegetation zone, species, age, sex, detection type (visual/auditory), plant or substrate associated with the observation, activity (sing, call, perch, fly, forage, breeding bird behavior), and relevant notes. In June, we recorded the estimated perpendicular distance from the observer to each bird species detected.

Point Counts Methods: Counts were conducted at the same patches as with the walking surveys. We initially conducted 50-meter fixed-radius point counts as specified by the GCMRC protocol. Count lengths were 5 minutes divided into 0 - 3 and 3 - 5 minute intervals. In patches where point count stations were used by Spence (Spence et al. 1997, 2000), we used those. In patches without point count marks we established our own by walking 50 meters into the patch at the transition zone between the one in the old high water zone and new high water zone, conducting the point count, then proceeding 100 meters farther to conduct the next count until we reached the end of the patch as delineated by aerial photographs. Multiple point count stations were placed in patches greater than 100 meters. In patches less than 50m wide, the radius of the count was reduced to 25 m. We attempted to place at least one point count station in the new high water zone and one in the old high water zone in each patch on the May trip. Surveyors recorded the same criteria as with walking surveys. As with the walking survey data, we began to record perpendicular distance to each bird species detected in June. Initially counts were placed in each vegetation zone (May trip) but small, narrow patches were not conducive to counts in both zones. In June, counts were conducted at a patch level with stations being placed in transitions between vegetation zones. Flagging was tied (and removed later) at each station and GPS readings were taken at stations in each patch where possible.

Data analysis. To test for differences in abundance and species richness of the old high water zone and new high water zone, a paired t-test was used. Only sites having data from both zones were included in the analysis. Data were combined from the May and June trips. Within zones, we compared May and June data with a paired t-test.

We tested for compositional differences between zones in two ways. First, we compared the distribution of the 12 most common bird species between new- and old high water zones with a series of paired t-tests. These 12 species were chosen for consistency with species chosen for analysis in previous bird studies in Grand Canyon (Sogge et al. 1998, Spence 2000). Second, we used an analysis of similarity (ANOSIM; Clarke 1993) to compare all species present in the two zones simultaneously. We produced a visualization of these results with an NMDS ordination of the bird community data.

To compare the efficiency of the point counts and walking surveys in terms of their ability to detect individuals and species we used a paired t-test. Data for visits in May and June were combined within sites.

## **Results:**

Nest Searches. A total of 33 nests of eight bird species were located during the May and June trips, 2001. During the May trip, 20 nests were found; 17 in the NHW, 3 in the OHW zone. In June, we found 13 nests; 9 in the NHW, and 4 in the OHW zone (Nest Table ? attached).

Walking Surveys. A total of 1787 birds, including 48 species, were detected during both field trips combined 2001. On the May trip, 883 birds representing 39 species, were detected.

During June 904 birds representing 34 species, were detected.

Point Counts. A total of 672 birds of 37 species were detected during point counts in May and June combined. A higher number of birds (383) and bird species (31) were detected during the May trip. During June, a total of 293 birds, 25 species, were recorded. We will continue point count censuses to assess broad scale trends in bird populations. Point count data will be compared with data collected by Spence et al. (1998b, 2000, 2001 in prep).

Census Methods Comparison: When the number of birds detected in walking surveys was compared with numbers detected during 50-meter bounded point counts, we detected a significantly higher number of birds in walking surveys (paired-t,  $t = 8.985$ ,  $p < .001$ ). We therefore used walking survey results to test for distributional and seasonal differences between and within zones.

Distributional Differences. Bird abundance was significantly higher in the old high water zone than in the new high water zone (mean =  $19.84 \pm 2.55$  vs.  $16.11 \pm 1.78$ ) when both trips were combined (Figure 4;  $t = 7.1$ ,  $p < 0.05$ ). When the two surveys were considered separately, a significantly higher abundance of birds was found in the old high water zone ( $11.53 \pm 1.87$ ) vs the new high water zone ( $7.18$ , SE =  $.88$ ) ( $t = 3.0$ ,  $p < .005$ ) in May. In June, no significant difference was shown in bird abundance between the two zones (new high water zone =  $8.93 \pm 1.03$ ; old high water zone =  $8.3 \pm 1.11$ ; paired  $t = -0.61$ , n.s.).

Species richness was significantly higher in the new high water zone than in the old high water zone ( $9.13 \pm 0.83$  vs.  $7.20 \pm 0.58$ ) when both trips' data are combined (Figure 5;  $t = 3.44$ ,  $p < 0.001$ ). The same results were true for May (new  $4.62 \pm 0.42$ , old =  $3.67 \pm 0.38$ ;  $t = 2.8$ ,  $p < 0.007$ ), and June (new  $4.5 \pm 0.44$ , old  $3.5 \pm 0.33$ ;  $t = 3.0$ ,  $p < .005$ ).

Seasonal Differences. A significantly higher abundance of birds was found in the new high water zone in June than in May ( $9.0 \pm 1.03$  vs.  $7.2 \pm 0.88$ ; Figure 6;  $t = -2.4$ ,  $p < .02$ ). No significant seasonal differences were found in the old high water zone between May and June ( $11.5 \pm 1.9$  vs.  $8.3 \pm 1.1$ ;  $t = 1.9$ , n.s.) due to large variances (May = 157.2, June = 55.1). Species richness was not significantly different within the new high water zone (May  $4.6 \pm 0.42$ ; June  $4.5 \pm 0.45$ ;  $t = .34$ , n.s.) or the old high water zone (May  $3.6 \pm 0.38$ ; June  $3.5 \pm .33$ ;  $t = 0.3$ , n.s.) between May and June.

Zonal differences. Tests for zone differences by 12 common species showed significant differences between species and zones ( $F = 18.57$ ,  $p < 0.001$ ; Table 3). Significantly higher mean numbers of Lucy's Warblers, Ash-throated Flycatchers, House Finches, and Mourning Doves were found in the one in the old high water zone. Significantly higher mean numbers of Black-chinned Hummingbirds, Yellow Warblers, Bewick's Wrens, Common Yellowthroats, Yellow-breasted Chats and Bell's Vireos were recorded in the new high water zone. There was no significant difference in the mean number of Song Sparrows between zones.

The analysis of similarity (ANOSIM) showed significant differences between new- and old high water zones ( $R = 0.0861$ ,  $p < 0.001$ ). Figure 6 shows the NMDS visualization of the ANOSIM result in which there is separation of the two zones based on composition of the bird community.

### **Summary:**

Overall, bird abundance was higher in the old high water zone than in the new high water zone when May and June were combined. When distributions between zones were tested in May, we found a higher abundance of birds in the old high water zone than in the new high water

zone. Abundance was not significantly different between zones in June. Species richness, however, showed the opposite pattern; a higher number of bird species were detected in the new high water zone overall than in the old high water zone when data from both trips (May and June) were combined.

#### Seasonal Differences:

Abundance of birds was more consistent within the old high water zone between May and June than in the new high water zone. No significant difference was found between bird abundance in old high water zone plots in May and June. In the new high water zone, a significantly more birds were found in the new high water zone in June than in May. No seasonal difference was detected between May and June for species richness in either zone.

Distribution and seasonal shifts in bird abundance between zones needs to be examined more thoroughly. Abundance shifts within and between zones during the breeding season may be related to temperature changes, increase in bird numbers due to the addition of fledged birds and/or arthropod food availability. Future inclusion of distribution and seasonal changes in arthropods may lead to a better understanding of these findings. Higher species richness in the new high water zone may be related to proximity to water. Further examination of this pattern will be continued.

#### Species Associations:

The 12 most common bird species had significant associations with one particular zone with the exception of the song sparrow. These associations may be correlated with vegetation structure, arthropod assemblages and other factors. Future integrated analysis of all terrestrial data may shed more light on this topic.

Table 2. Nests searching results, 2001 Breeding Season

site	trip	bird sp	zone	tree sp	eggs	young
43.1	1	BCHU	n	tach	0	0
43.1	1	BGGN	n	tach	0	0
46.7	1	BCHU	n	tach	0	2
46.7	1	BCHU	n	tach	unk	unk
46.7	1	BCHU	n	tach	unk	unk
46.7	1	BCHU	n	tach	0	3
50.4	1	BCHU	n	tach	0	2
50.4	1	BCHU	n	tach	unk	unk
50.4	1	BCHU	n	tach	0	2
50.4	1	BCHU	n	tach	unk	unk
50.4	1	YEWA	n	tach	unk	unk
50.4	1	UNK	o	prgl	unk	unk
50.4	1	LUWA	n	tach	0	2
50.4	1	SUTA	n	tach	0	0
50.4	1	LUWA	o	prgl	0	0
122.7	1	BGGN	n	tach	5	0
171.1	1	BEVI	n	tach	unk	unk
174.5	1	LUWA	o	acgr	unk	unk
198	1	SUTA	n	tach	unk	unk
198	1	BEVI	n	tach	1	0
43.1	2	LUWA	n	tach	0	2
43.1	2	BCHU	n	tach	3	0
46.7	2	LUWA	n	tach	0	1
46.7	2	ATFL	o	dead acgr	unk	unk
50.4	2	BCHU	n	tach	0	2
50.4	2	HOFI	n	tach	0	0
50.4	2	ATFL	o	acgr	unk	unk
122.8	2	LUWA	n	tach	0	2
171.1	2	BEVI	o	prgl	1	3
194	2	BCHU	n	tach	0	3
194	2	BCHU	n	tach	0	1
194	2	SUTA	o	prgl	unk	unk
198	2	BEVI	n	prgl	0	0

Table 3. Analysis of Variance for 12 Most Common Bird Species Along the River Corridor in Grand Canyon, 2001. Species are listed in rank of highest to lowest

Species	NHW Mean and SE	OHW Mean and SE	F - Value	Test Probability (p value)
Lucy's Warbler	2.64 ± 0.35	4.51 ± 0.6	7.27	0.008
House Finch	0.42 ± 0.11	1.0 ± 0.20	6.54	0.011
Blue-gray Gnatcatcher	0.47 ± 0.008	0.86 ± 0.17	4.26	0.04
Bell's Vireo	0.81 ± 0.14	0.43 ± 0.10	4.82	0.029
Black-chinned Hummingbird	0.74 ± 0.12	0.25 ± 0.006	13.49	0.001
Ash-throated Flycatcher	0.22 ± 0.005	0.65 ± 0.008	18.07	0.001
Mourning Dove	0.14 ± 0.004	0.50 ± 0.13	7.12	0.008
Yellow Warbler	0.56 ± 0.11	0.11 ± 0.005	12.68	0.001
Common Yellowthroat	0.61 ± 0.11	0.002 ± 0.001	28.97	0.001
Yellow-Breasted Chat	0.34 ± 0.006	0.003 ± 0.002	23.5	0.001
Bewick's Wren	0.26 ± 0.005	0.10 ± 0.004	4.96	0.027
Song Sparrow	0.25 ± 0.007	0.11 ± 0.004	2.11	*0.148

\* indicates no significance

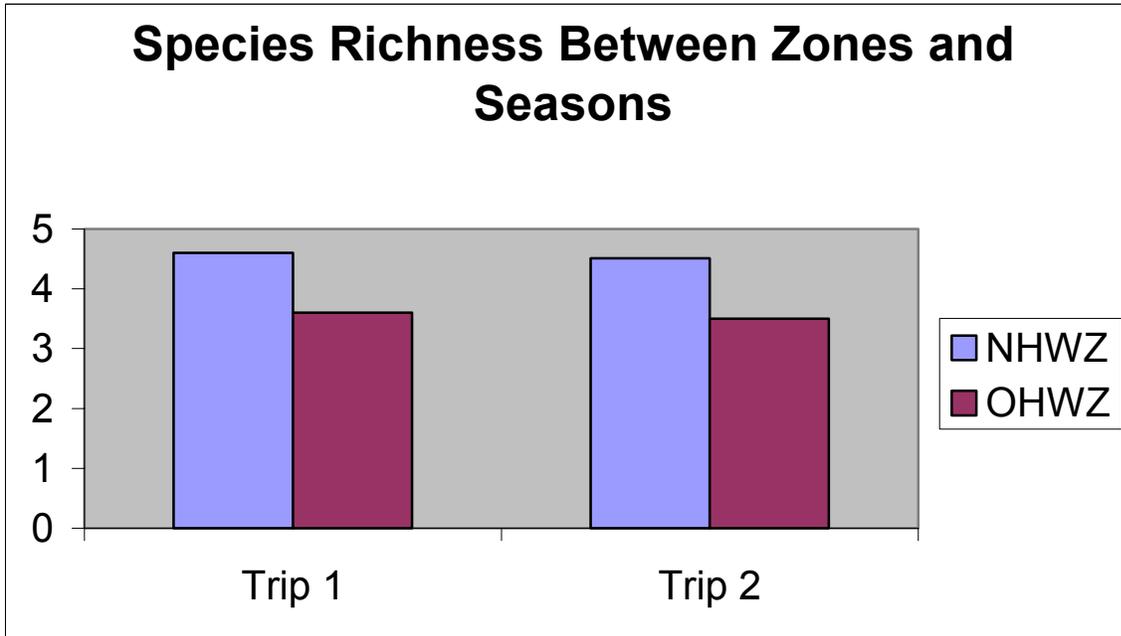


Figure 4. Bird species richness per patch by hydrologic zone in Marble Canyon and Grand Canyon in 2001.

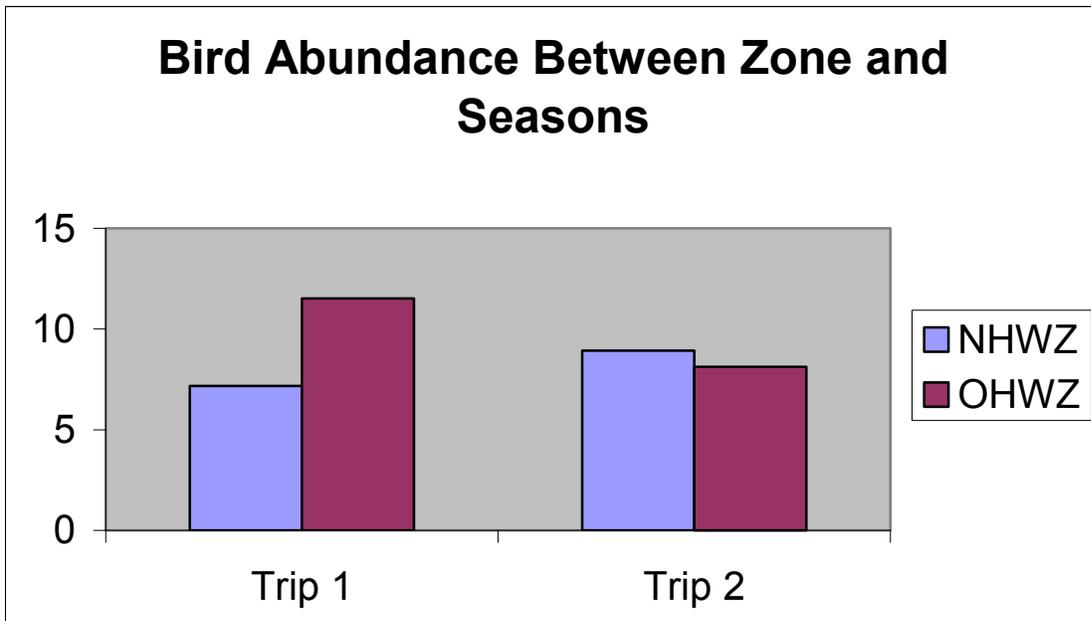


Figure 5. Breeding bird abundance per patch by hydrologic zone in Marble Canyon and Grand Canyon in 2001.

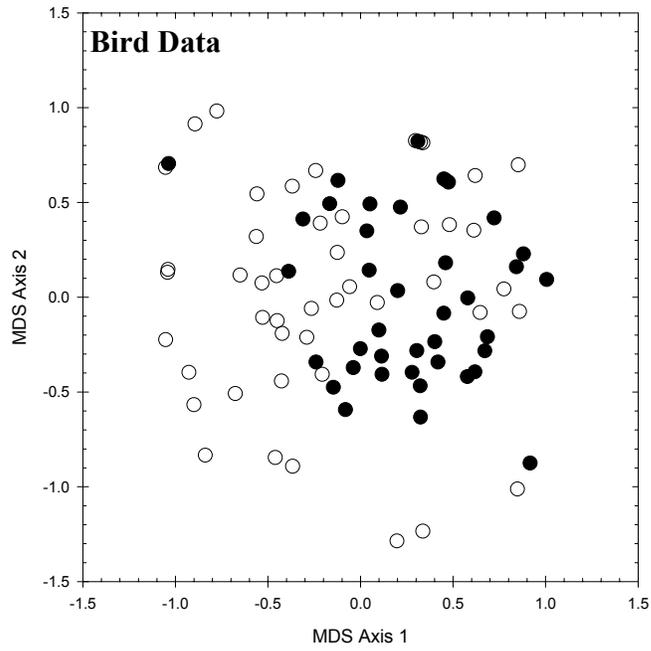


Figure 6. Ordination of bird community data from patches in new high water zone (open circles) and old high water zone (closed circles) habitats.

**Herpetofaunal Surveys**  
Geoffrey Carpenter  
University of New Mexico

**Purpose:**

To generate data on the distribution and abundance of herpetofauna (amphibians and reptiles) in relation to hydrology, habitat characters, and river extent.

**Objectives:**

1) Determine the species composition and relative abundance's of herpetofauna associated with the old high water zone the new high water zone and the fluctuation zone environments. 2) Determine microhabitat associations for those herps, including water zone and substrate (i.e. boulders, cobbles, vegetated beach) associations. 3) Compare species composition across the three hydrologic riparian zones. 4) Initiate experimental sampling for comparative monitoring of herpetofaunal communities across the three riparian hydrologic zones over time (season, year). 5) Relate riparian herpetofauna community patterns (most notably reproductive success each year) to temporal variation in climate, across the three hydrologic zones, in relation to linear position along the river (river mile) and in relation to dam operations. 6) To produce location records of herpetofauna along the river corridor, to include photographic vouchers when possible. 7) To provide basic ecological information on snakes, lizards, and toads inhabiting Grand Canyon riparian zones for integration with vegetation, other vertebrate animal, and invertebrate information produced from this and other research projects, and to provide herpetological data for other biological, cultural, and physical resource information needs.

**Methods:**

Study sites and sampling points: Study sites were specified in the Protocols document of the Request for Proposals. A total of 14 sites were selected for focused sampling of all terrestrial herpetofauna within the three hydrologic riparian zones. These are the same sites that were used for arthropod transect sampling, and for small mammal trapping. Herpetofauna were quantitatively sampled twice during 2001 in accordance with the Protocols document (Table 1, above). General herp location data were also collected on a river trip during another project (bird-bug) from June 26- July 12. Early and late summer seasons likely support different relative species compositions within the various riparian zones, and activity patterns of herps also vary seasonally. Thus, early summer and late summer sampling accommodate the potential seasonal variation in active herpetofauna, and allow an assessment of reproductive activity (spring) and reproductive success (fall).

Transect counts. Toads, lizards, and snakes observed while walking transect lines were recorded to species, and approximate location along the transect. Transects were walked at least once during peak daytime activity periods for diurnally active herps (reptiles and amphibians), and were also walked after dark if the weather and terrain permitted. Additionally, the two specimens of banded geckos (*Coleonyx variegatus*) that were collected during September, were both captured in the arthropod pitfalls (Figure 7).

General site census: To enhance inventory sampling of herpetofauna, each site was thoroughly surveyed on foot for herps and herp sign (tracks, scats, shed skins). These data were recorded for each of the 14 primary sites during the May and September trips. Additionally, pedestrian surveys were conducted at all integrated monitoring sites during the May trip.

Funnel-trapping arrays: For the September trip, at each of the 14 integrated sites, 1-6 funnel-trapping arrays were set up along, or at either end of, transects in the different zones (Figure 8). These traps were intended to mimic more traditional pitfall-trapping arrays, as NPS regulations prohibit the degree of soil disturbance necessary to install this sort of trap (and the effort involved is too great to install them at each primary TEM site for a single night's trapping). Traps consisted of a central 5 gallon bucket, with four radiating drift fences, laid along the surface of the ground. Each drift fence led into a funnel in the central bucket, and to a pair of funnels at its distal end, which led into a section of white dryer tube (Figure H-1).

## **Results:**

Transects and general surveys. Seventeen species of herps were observed in the May and September trips combined (Figures 9 and 10). These represented two species of toads, one frog species, six lizards, and eight species of snake. The most common taxa found were Western whiptail lizards (*Cnemidophorus tigris*), desert spiny lizards (*Sceloporus magister*), side-blotched lizards (*Uta stansburiana*), tree lizards (*Urosaurus ornatus*), and Woodhouse's toads (*Bufo woodhousei*). Observations during the September trip indicate that herp reproduction was good during summer 2001, as subadults, juveniles, or hatchlings of all lizard and toad species were observed, either during transect sampling, or during general site observations.

Modified funnel traps. The success of the modified funnel traps was very disappointing. While toad tracks were often observed along the trap fences, only four Woodhouse's toads (*Bufo woodhousei*) were captured during the entire September trip (and all on the last night of sampling). An individual *C. tigris* was observed to enter, then escape from a trap on one occasion, and a California kingsnake (*Lampropeltus getula*) was observed entering, then exiting a trap on another occasion. It is hoped that these traps will be more effective following numerous modifications. Modifications will include longer drift fences, to sample larger areas, and modified funnels, to enhance capture success. We will test the new modified design on 2002 river trips.

Seasonal Trends. Deriving trends from the May sample is particularly problematic due to logistical difficulties. While the 14 primary sites were sampled during peak morning activity hours, not all non-primary sites were. Furthermore, some sites were shaded until departure, and inclement weather precluded herp activity on some days. Continued sampling over future river trips should provide adequate data from those logistically problematic study sites.

Zonal differences. In general more herps were observed in the old high water zone than the new high water zone (Figure 11), and the least were observed in the water's edge zone. Below the Little Colorado River, herp numbers increased dramatically in the new high water zone and old high water zones, but not at the water's edge. Species richness did not show as dramatic a pattern (Figure 12), with slightly higher numbers of species in the old high water zone than in the new high water zone, and fewest of all in the water's edge zone. The between-reach comparisons showed little difference between Marble and Glen Canyons.

Although no young snakes were observed during the September trip, young of all lizard and toad species observed were seen, and were most abundant in the new high water zone, suggesting (1) that the arthropod food base for young-of-the-year was best in this zone, and (2) that 2001 was a good year for toad and lizard reproduction. It seems likely that appropriate reproductive habitat (sites for display, copulation, and oviposition) might drive habitat

preference during the spring, while food resource availability might be a more important determinant of habitat preference late in the activity season.

Although many herps species were observed in both old high water zone and new high water zone, their relative abundance tended to differ between these zones. ANOSIM analysis revealed that species composition between old high water zone and new high water zone were significantly different ( $R=0.1339$ ,  $p<0.001$ ; Figure 13). These differences can be largely attributed to the distribution of several key species: both *S. magister* and *U. stansburiana* were substantially more abundant in old high water zone than new high water zone during May sampling, and *U. stansburiana* was again more abundant in the old high water zone during the September trip. Additionally, several species were observed only in the old high water zone during the may trip (*C. collaris*, *C. mitchelli*, *C. v. abyssus*, , *H. torquatus*, *Masticophis spp.*, and *S. obesus*), although the former three were observed in the new high water zone during the September trip (suggesting seasonal habitat shifts by certain species, a speculation that can be supported only through repeated observations over several years/seasons). Substrate associations observed were consistent with what Warren and Schwalbe (1986) observed during their studies (e.g. *U. ornatus* tend to prefer cobbles, *S. obesus* prefer boulder fields and rocks with large surface area), as was expected. Differential availability of the appropriate substrate with the proper photo-thermal regime among the different zones is likely responsible for the differences observed in species assemblages between the zones.



Figure 7. Juvenile banded gecko captured in arthropod pitfall trap in the water's edge zone at Schist Fist camp (RM 92.3 L).



Figure 8. Modified funnel trap for herpetofaunal surveys tested in the field in 2001 laid out in a horse corral during the design phase.

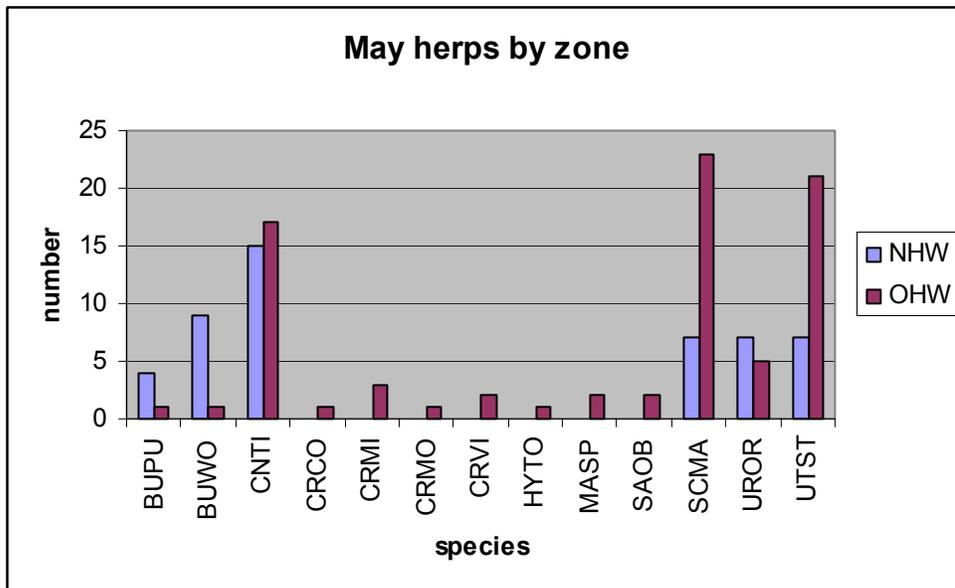


Figure 9. Abundance of herpetofauna encountered during the May 2001 surveys.

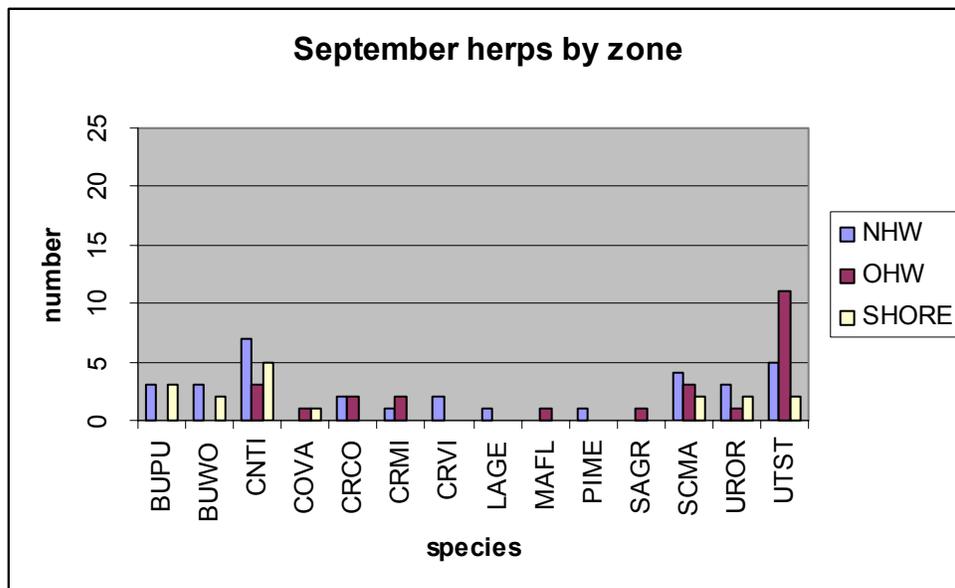


Figure 10. Abundance of herpetofauna encountered during the September 2001 surveys.

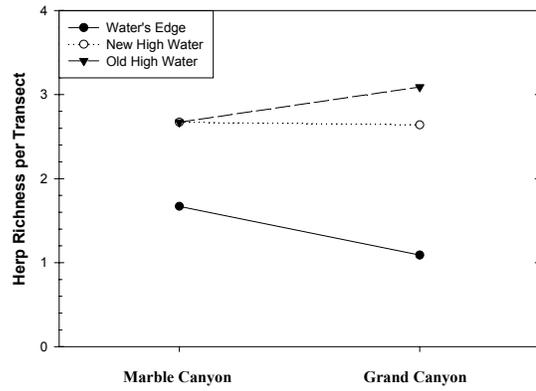


Figure 11. Herpetofaunal species richness per transect in each of the hydrologic zones in Marble and Grand Canyons in September, 2001.

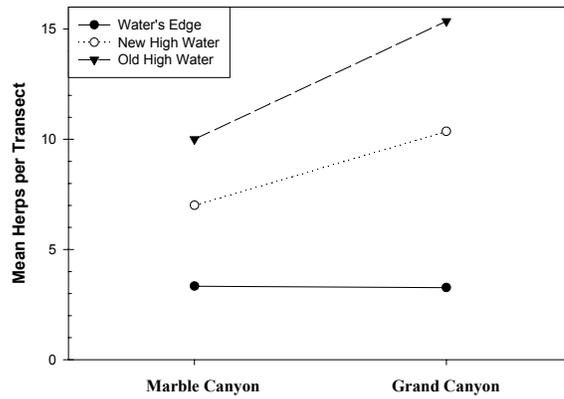


Figure 12. Herpetofaunal abundance per transect in Marble and Grand Canyons in each of the hydrologic zones in September 2001.

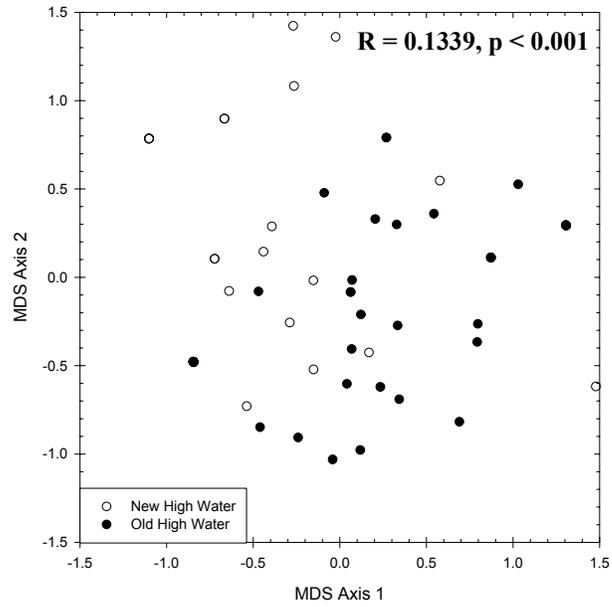


Figure 13. NMDS ordination of herpetofaunal community data from transects in September 2001 showing delineation of zones based on herp species composition.

## **Arthropod (Invertebrate) Surveys**

David Lightfoot, Sandra Brantley

University of New Mexico

Neil Cobb

Northern Arizona University

### **Purpose:**

The purposes of the arthropod studies are 1) to inventory and characterize the terrestrial arthropod fauna associated with the different river flow stage riparian environments along the Colorado River in Grand Canyon and 2) to initiate a sampling design for monitoring riparian arthropod community dynamics in relation to river level fluctuations resulting from Glen Canyon Dam operation. The monitoring data will provide information on the effects of dam operation for riparian arthropods in Grand Canyon. That information may then be integrated with corresponding data representing vegetation and vertebrate animals produced from this same research program as well as other needs.

### **Objectives:**

Principal objectives for our arthropod studies are to: 1) Determine the species composition and relative abundance's of arthropods associated with the old high water zone, the new high water zone, and the fluctuation zone environments. 2) Determine microhabitat associations for those arthropods such as water zone preferences and host plant relationships. 3) Relate arthropod species composition to vegetation and vertebrate animals across the three hydrologic riparian zones. 4) Initiate a sampling design for comparative monitoring of arthropod communities across the three riparian hydrologic zones over time. 6) To develop a voucher and reference collection for Grand Canyon riparian arthropod specimens representing those taxa found during this project, and 7) To provide basic ecological information on Grand Canyon riparian arthropods to integrate with vegetation and vertebrate animal information produced from this and other research projects, and to provide arthropod data for other biological, cultural, and physical resource information needs, and to assess geomorphic scale trends in populations.

### **Methods:**

Study sites and sampling points. Study site locations were determined by GCMRC personnel and listed in the in the Protocols document of the Request for Proposals. A total of 14 sites were selected for focused sampling of all terrestrial arthropods. Three study transects were established at each site, one transect representing each of the three water level zones: water's edge, new high water zone, and old high water zone. Each transect was 100 meters long, partitioned into 10 sampling points at 10 meter intervals. The transects were laid out parallel to each other, beginning 20 – 100 m upstream or downstream from the camp, depending on constraints imposed by the local topography. The transects representing the old high water and the new high water zones were situated in the middle of each of those zones' range of elevation above shore line. The transect representing the Fluctuation Zone (FZ) was situated one meter above the existing daily high-water shore line. The actual daily shore line fluctuation zone varies over time, depending upon water releases from Glen Canyon Dam.

Sampling periods: Arthropods were quantitatively sampled twice during 2001 (see Table 1). The first sampling period was April / May, and the second was August / September. Additional general collecting was conducted on another river trip from June - July. Early and late summer seasons likely support many different arthropod taxa activity periods. Early summer and late summer sampling periods were chosen to accommodate the potential seasonal variation in active arthropod taxa.

Ground-dwelling arthropods: Quantitative sampling of ground-dwelling arthropods by stage zone was conducted by use of temporary pitfall traps. Pitfall traps were installed at each of the ten sampling points on each of the three transects per site. Traps were installed in the afternoon (~ 4:00 pm) on the arrival day to a site, and removed the following late morning (~10:00 am) before departing from the site. Each trap consisted of one 16 oz. plastic cup ( 15 cm tall, 10 cm wide) dug into the soil, with the open top flush with the soil surface. The surrounding soil was backfilled and smoothed around the top of the cup. 100 ml. of river water was then placed in the bottom of each cup to drown and hold arthropods that fell into the cup. Traps were collected the following morning by pouring the contents of each of the 10 traps into a single 500 ml. plastic bottle, pooling all 10 traps per transect line. The contents of each 500 ml bottle representing traps from each of the three transect lines were then poured through a fine (1 mm) mesh screen to filter the arthropods from the water. The filtered arthropods were then labeled and placed into a single 50 ml bottle containing 70% ethanol. All sample bottles, each representing ten pooled traps per transect line, per site, per trip (season) were then taken to the lab following each river trip.

Plant-dwelling arthropods: Arthropods that live on vegetation are taxonomically and ecologically different from those that occur on the ground. Plant-dwelling arthropods were quantitatively sampled from the entire vegetation foliage volume or area adjacent to each of the ten pitfall sampling points along the three water zone transects at each site using muslin cotton insect sweep nets measuring 38 cm across and 65 cm deep. All plant foliage (all plant species) in a volume 2 meters radius from each pitfall trap were swept with the insect sweep nets to dislodge and collect all arthropods resting on the foliage. The number of sweeps taken were a function of the amount of plant foliage present at each sample point. All sweep samples were taken during early morning hours (1-2 hours after sunrise) when foliage arthropod mobility was low, and arthropods less likely to escape. The contents of each point sweep were placed into a one-gallon plastic zip-lock bag. Sweep samples from each of the ten sample points per transects were pooled into one bag, representing one foliage arthropod sample per transect line, per study site. The quantitative foliage sweep samples were field sorted to remove the arthropods from the plant material. All individual arthropods per sample were placed into 20-50 ml glass storage vials containing 70% ethanol. Some taxa are best preserved dry. Those dry specimens were placed in tissue paper, and sealed in small plastic containers with naphthalene as a preservative. All samples were then taken to the lab following each river trip.

In addition, qualitative sweep samples were taken from the dominant plant taxa in each of the three water zones at each site. The foliage of each plant species was swept, and the contents of each sweep sample placed into a one-gallon clear plastic zip-lock bag. Sweeping was continued until no new arthropod taxa were observed in the samples representing each plant species. Sweep samples were pooled into one sample per plant species per water zone per site. A representative sample of each arthropod taxon was taken from each sample in the field and placed into small storage vials containing 70% ethanol or naphthalene, depending upon which preservative was appropriate. All labeled samples were taken to the lab where taxa are being identified to the species level. Data from

these samples are providing us with information on the arthropod taxa associated with the various plant species along the river corridor. Those data additionally allow us to compare arthropod species diversity associated with given plant species across the three water level zones.

Flying insects. To gather comparative data on flying insects in each water zone, Malaise traps (tent-like flight interception traps) and black light traps (Southwood 1978) were used to sample flying insects in the day and night, respectively. One malaise trap was installed in the middle of each of the 100 meter sampling transects in each of the three water zones at each site. The traps were erected in the afternoon (4:00 pm) at the beginning of each site visit, and disassembled the next morning (10:00 am) before departing the site. Each of the three malaise trap containers was emptied and the insects were sorted in the field, and placed into small glass vials with 70% ethanol, or small plastic containers with naphthalene, depending upon the insects and which preservative is appropriate. Those samples were then taken to the lab following each river trip.

We used black-light (UV) traps to sample night-flying insects. Our black light traps consisted of a fluorescent black light suspended over a 3-gallon bucket containing a pyrethroid insecticide no-pest strip. A large plastic funnel (40 cm top diameter, 10 cm bottom diameter) was placed on top of the bucket, and the light source suspended just inside the top of the funnel. Each light trap was connected to a power source with a timing device. The lights were turned on at sunset, and run until midnight (12:00 am). The light trap buckets were collected at sunrise, and all insects were removed and placed into vials with ethanol or naphthalene. Those samples were then taken to the lab following each river trip.

General Collecting. To enhance our ability to inventory many arthropods, we also conducted general collecting at each site as time permitted. General collecting involves searching all environments and habitats in the riparian corridor for arthropods, capturing and preserving the specimens. Techniques include searching and capturing active flying insects with a light aerial net, collecting arthropods on the ground surface, looking under rocks and other objects for arthropods, collecting insect pollinators on flowers, sweeping vegetation with sweep nets, collecting parasites (e.g., fleas and mites) from vertebrate animals, sweeping the air immediately above the shore line for shore insects, and searching for scorpions at night with a portable black-light. All specimens obtained during general collecting were placed in vials with 70% ethanol or naphthalene, and labeled as to habitat and water level zone. Those samples were then taken to the lab following each river trip.

Specimen processing, identification, and voucher collection preparation. Because there are so many arthropod taxa, most arthropods must be collected in the field and identified in the laboratory. Voucher specimens must be prepared, identified, and placed in voucher specimen collections. Sample sorting and identification involves tens of thousands of specimens from each river trip. Many specimens must be sent to taxonomic experts for correct identification. This entire process generally takes one to three years for specimens obtained on a particular river trip.

All samples and specimens collected in the field on river trips were stored in vials or other containers with labels including information as to site, date, water level zone, habitat, and collection method. All samples were taken to arthropod museum labs at NAU (Northern Arizona University, Arthropod Museum) or UNM (Division of Arthropods, Museum of Southwestern Biology) where all arthropod samples are sorted, and counts of numbers of individuals by taxa are recorded. Voucher specimens representing each taxon are currently being preserved and labeled as museum specimens. We are building a voucher specimen collection at both NAU and

UNM for this project. All count data are being entered into computer database files for statistical analyses.

Arthropod analysis. To test for differences among groups we performed AOV's on overall arthropod abundance and species richness, followed by AOV's on six of the most common groups of ground-dwelling arthropods. In each case we performed rank transformations to avoid violations of the assumption of homogeneity of variances. Significant differences are based on table-wide values. For significant AOV we performed post-hoc Tukey's least significant different test to assess differences among the three zones. To test for compositional differences of ground-dwelling arthropod assemblages among the different water level zones, an analysis of similarity (ANOSIM; Clarke 1993) was used. The method compares the difference in ranks of within-group and between-group similarity from field data to those generated by random assignment of samples to groups. ANOSIM results were visualized with an NMDS transformation to clarify patterns detected by the analysis.

## **Results:**

Reference Collection. The bulk of our work on arthropods to date has focused on the preparation of a reference collection. We currently have ~2200 specimens pinned and 246 specimens in alcohol that have been incorporated into working collections at UNM and NAU. To date we have completed sample sorting, partial identification, and tabulation of all April/May trip pitfall arthropod samples, representing ground-dwelling arthropods from the. The processing of all other arthropod samples from 2001 trips is still in progress. Here we present results from the 2001 Spring trip on the abundance and diversity of ground-dwelling arthropods. Although the results are restricted to the ground-dwelling fauna, we observed comparable patterns in other groups of arthropods where the OHW regularly had the most arthropods.

Above vs Below the Confluence of the Little Colorado River. The first analysis consisted of examining the average abundance of arthropods and species richness for sites above the confluence of the Little Colorado River and sites below the Little Colorado River for all three zones. Figure 14 shows that for both abundance (Fig. 14A) and species richness (Fig. 14B) sites below the Little Colorado River exhibited much higher values than sites above the Little Colorado River. There were no differences among the zones above or below the Little Colorado River, although there was a trend in increased arthropod abundance and species richness below the Little Colorado River from the shoreline to the OHW.

Comparison of Habitat Zones throughout the Corridor. There was no difference in diversity of ground-dwelling arthropods as measured by species richness (Fig. 15A). We observed a general pattern of increasing arthropod abundance as one moves up in elevation from the shoreline (WAT) through the NHW and OHW (Figure 15B). Overall abundance was highest in the OHW, but due to the extreme amount of variance there was not a significant difference.

We also examined six of the most common taxa of the 124 taxa of arthropods observed during the May/June 2001 sampling period. These taxa represent a range of feeding guilds representative of most of the other taxa of arthropods not included in the analysis. It is important to examine the differential response of these guilds to determine if certain guilds may be more sensitive to change than others (Greenberg and McGrane 1996). The taxa that we examined included **1**) cursorial hunting spiders (i.e., non-web-building), which are one of the most common groups captured by pitfall traps in all types of habitats from open to closed and mesic to xeric, although they tend to be more abundant and diverse in mesic habitats. **2**) Ground beetles

(Carabidae) that are a common element of the ground-dwelling arthropods fauna throughout the world, especially in mesic habitats. They can be excellent indicators of habitat quality and can be represented by 10 or species in a given habitat (Purvis and Curry 1984, Fan et al. 1993, Heliola et al. 2001). **3)** Springtails (Entomobryidae and other less common families) are primitive wingless insects that feed on detritus and fungi. They are typically a major component of the litter fauna. They can be diverse as well. **4)** Darkling beetles (Tenebrionidae), which are primarily generalist herbivores and scavengers thus making them omnivores (Stapp 1997). **5)** Seed bugs (Lygaeidae) which feed on a variety of seeds but also probably feeding on dead/dying arthropods are typically represented by a few species in any one area, but they can be extremely abundant, sometimes forming a carpet-like appearance on the ground. **6)** Ants (Formicidae) are both abundant and diverse in all terrestrial habitats (Wang et al. 2001). They represent a spectrum feeding habits from predacious to seed-eating, most exhibiting degrees of omnivory.

There was a general pattern of increase ground-dwelling arthropods from shoreline to OHW, although this was reversed in more mesic-affiliated arthropods (Fig 15C & 15D). Five of the groups showed significant differences among the three zones, although three of these analyses did not show table wide significance (i.e., spiders [Fig. 15C], darkling beetles [Fig. 15F], and ants [Fig. 15H]). The two arthropod groups that did show table-wide significance were ground beetles (Fig. 15D) and Lygaeid seed bugs (Fig. 15E). The two groups exhibited opposite patterns, carabid beetles were found in the more mesic shoreline zone, while seed bugs were highest in the old high water zone. In neither case was the intermediate (new high water) zone different from the other zones, indicating that more than a single group of ground-dwelling arthropods are required to characterize each zone uniquely.

Conclusions drawn from the AOV analysis of the Spring ground-dwelling arthropod fauna are preliminary in that we need to combine data from the other trips before we can make more definite statements about individual groups. This is not the case when we examine all of the arthropods together, where clear differences among the zones emerge (Fig. 16 below).

There were significant differences in the composition of the arthropod samples from the three hydrologic zones. ANOSIM analysis showed that the overall difference among groups was significant (Figure 16;  $R = 0.4052$ ,  $p < 0.001$ ). Individual differences among zones were all significant as well (O vs N,  $R = 0.5110$ ,  $p < 0.001$ , N vs W,  $R = .3584$ ,  $p < 0.001$ ; O vs W,  $R = 0.7130$ ,  $p < 0.001$ ). The source of these differences is due to the highly distinct assemblages in each of the zones. Eighty-two of the 127 taxa identified were only found in a single zone (OWH=29 taxa, NHW=23 taxa, WAT=30). Fourteen taxa were found in both the OHW and NHW, eight taxa were found in both the WAT and NHW, and only two taxa were found in both the OHW and WAT. Predictably, the NHW exhibited an intermediate position in the Anosim analysis (Figure 16), indicating that ground-dwelling arthropods were responding to gradient such as soil texture and/or soil moisture that occurred across the zones.

**Summary:** We found distinct differences in the composition of the ground-dwelling arthropod community among the three hydrologic zones despite no significant differences in overall abundance or species richness. Additionally, there were several taxa that specialized in shoreline habitats or the OHW zone. We will continue to focus on these taxa as candidates for bio-indicators of habitat quality. Our preliminary results are very encouraging that the ground-dwelling arthropod community can be an effective and easily-monitored group to measure faunal

responses to changes in habitat quality. They should be considered as high priority indicators for a long-term monitoring program.

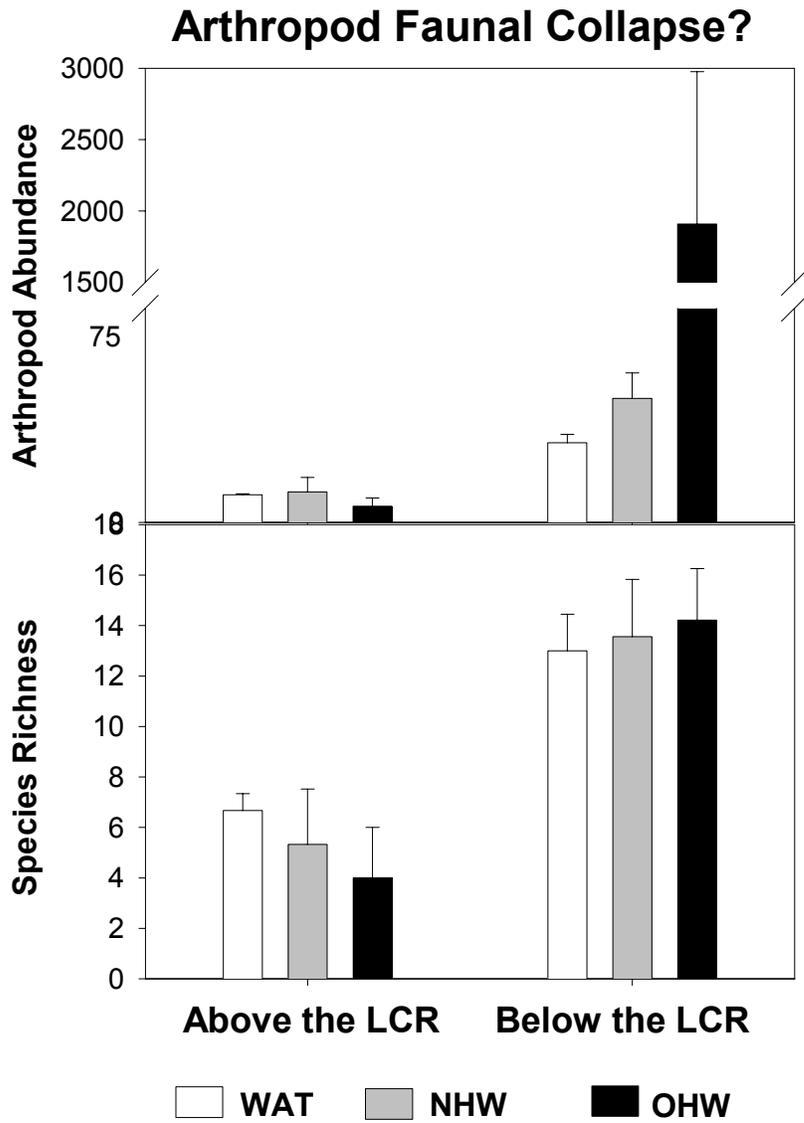


Figure 14. Richness and abundance of arthropod fauna in the three hydrologic zones in Marble Canyon (above the Little Colorado River) and Grand Canyon (Below the Little Colorado)..

## Arthropod Responses to Zonal Variation

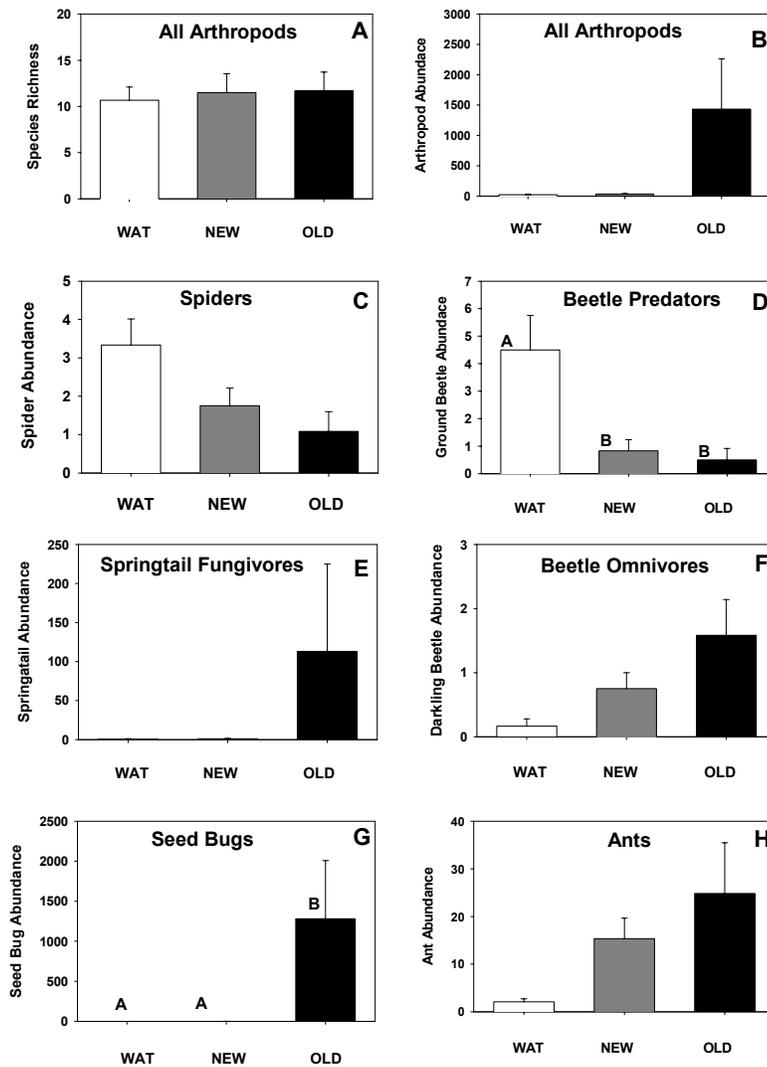


Figure 15. Richness and abundance of all arthropods and eight common arthropod taxa in each of the three hydrologic zones from May 2001 data.

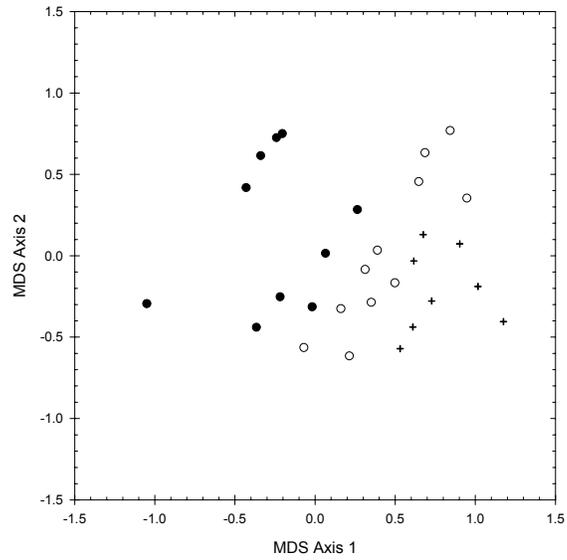


Figure 16. Ordination of arthropod pitfall data from May and September 2001. Open circles = old high water zone habitats, closed circles = new high water zone habitats, crosshairs = water's edge habitats.

**Vegetation Structure**  
Michael Kearsley  
Northern Arizona University

**Purpose:**

The purpose of collecting vegetation structure data is to generate information on the abundance and distribution in space of riparian vegetation in the integrated study sites to derive a measure of primary productivity and biomass of woody species which can be related directly to the faunal elements of interest in these sites.

**Objectives:**

1) To measure total vegetation volume (TVV) of woody species at point count stations where bird data was collected. 2) To measure TVV of woody species on traplines and transects where mammal and insect trapping occurs and where visual surveys of herps take place. 3) To collect information on woody species composition at the time as TVV data in both transects and point count stations. 4) To determine whether point counts and transects take place in similar vegetation, as measured by TVV and composition of plants. 5) To determine whether new high water zone and old high water zone patches differ in their vegetation structure.

**Methods:**

Sample locations. In this first year of sampling, methods included point count measures, transect measures and data analysis. Sample sites were selected by GCMRC and were included in the Protocols document of the Request for Proposals. The locations of bird point count stations and trapping transects were determined by others on this project as described above.

Point count TVV and composition measures. At each bird point count station we used tables of random numbers to determine the locations of 20 random points per station taken in groups of five per line in four lines on cardinal directions from the point count center point. Recorders would choose a three digit random number to determine the compass bearing, in degrees, of the first line. The other three lines were taken at 90, 180, and 270 degrees from the first line. Recorders would then select pairs of random numbers from the table: the first for the number of paces out along the line and the second for whether the reader would place the survey rod to the left (odd) or right (even) of the line.

Once at the point, readers would read out a modification of the TVV measure of Mills et al. (1991) using a telescoping fiberglass survey rod marked in meters, decimeters and centimeters. For each meter, the number of decimeters which had live vegetation within 10 cm of the rod would be called to the recorder. In addition, the species responsible for the contacts would be read, along with the number of vacant decimeters. If more than one species occupied the same decimeter, both were recorded.

The TVV measure of Mills et al. (1991) was derived from the data by subtracting that number from 10 for each meter across all occupied levels of the canopy at each sample point. TVV for the patch was calculated as the sum of TVV from all 20 sample points. Compositional information was derived by using the sum of each species TVV contacts within a patch as a measure of its abundance in that patch.

Transect / trapline TVV and composition measures. Similar methods were used to derive TVV and composition data from the pitfall trap / small mammal trapline / herpetofauna transects

in the water's edge, new high water zone, and old high water zone. At each pitfall trap point, recorders would choose a random number to determine if the survey rod should be held out an arm's length to the left (odd) or right (even) of the pitfall cup. Readings of TVV and composition were taken in the same way at that point.

Vegetation structure analysis. To determine whether there were differences between vegetation structure in the new high water zone and old high water zone point count stations, data from all point counts were analyzed with a Wilcoxon sign-rank test where site was the pairing factor. Sites which had only one zone represented in the data were excluded from the analysis. Likewise, TVV data from the water's edge, new high water zone and old high water zone transects were analyzed with a non-parametric Page's analysis of variance to determine zonal differences in the trapline vegetation structure. To compare data from transects with those from bird point count stations, we used a 3-way AOV (site, zone, method) with a zone x method interaction. Because there were only 10 pitfall points per transect, the TVV and composition numbers were adjusted to a per 20 point amount before comparisons were made with point count data. Because a significant zone x method interaction was detected, comparisons between methods within zone were made in separate Wilcoxon tests for the new high water zone and old high water zone data.

Compositional comparisons between zones in the point count and transect data sets were made with an analysis of similarity (ANOSIM; Clarke, 1993). Patterns detected with ANOSIM were visualized with a non-metric multidimensional scaling ordination (NMDS; Kruskal and Wish, 1978). In both cases, the Bray-Curtis distance measure was used on data which had been relativized by species maximum because this combination has been shown to preserve ecologically important information (Faith et al, 1987).

## **Results:**

There were differences in the total vegetation volumes of new- and old high water zone bird point count stations (Figure 17;  $T = -32.5$ ,  $n = 13$ ,  $p < 0.05$ ). Old high water zone point count stations had consistently lower vegetation volume readings than their paired new high water zone stations. Transect data showed that new high water zone transects had consistently higher vegetation volume than old high water transects, which in turn had higher volumes than water's edge transects (Figure 1 "PITFALL";  $L_{(3,13)} = 178$ ,  $p < 0.01$ ). The comparison of transect and point count station data showed that there was no difference in old high water zone transects and point count stations ( $T = 17.5$ ,  $d.f. = 12$ ,  $p > 0.10$ ), but that new high water zone transects were significantly denser than their corresponding point count stations ( $T = -25$ ,  $d.f. = 12$ ,  $p < 0.05$ ).

The ANOSIM analyses showed that new high water zone and old high water zone point count areas differed significantly in their species composition (Figure 19;  $R = 0.8642$ ,  $p < 0.01$ ), and that the three zones sampled by pitfall and traplines had significantly different vegetation ( $R = 0.5067$ ,  $p < 0.001$ ). Within the latter comparison, water's edge and new high water zones were most similar to each other ( $R = 0.3144$ ,  $p < 0.005$ , vs.  $R = 0.5384$  and  $R = 0.6577$  for new vs. old and water's edge vs. old, respectively), but all of the individual comparisons showed significant compositional differences. Figures 2 and 3 show NMDS visualizations of the ANOSIM results.

Compositional comparisons of the transects and bird point count stations within the same hydrologic zones showed no differences between the two. New high water zone transects and

point count stations were not significantly different in composition ( $R = 0.0393$ ,  $p > 0.75$ ). Old high water zone transects and point count stations were nearly indistinguishable ( $r = 0.0062$ ,  $p > 0.80$ ). Although overall the two groups were not different, the mean similarity between transects and point count stations within a given site was only about 65% (new high water zone = 66.87; old high water zone = 63.75), indicating that there were some differences in composition between pairs of points in the same site.

**Summary:**

The data we have collected to date on the structure and composition of vegetation in the integrated sampling sites show patterns which are not surprising. First, there are zonal differences in the total vegetation volume among areas in the water's edge, new high water zone and old high water zones. New high water zone plots have greater access to the water table than plots in the old high water zone, but are not subject to the scour and flooding which the water's edge areas are. In addition, the composition of vegetation in the three areas sorts out very well as in most arid land riparian areas where a strong moisture gradient is known to exist. Finally, it was gratifying to show that although there are some vegetation volume differences between transects and plots, there is no compositional differences between vegetation in the two types of samples

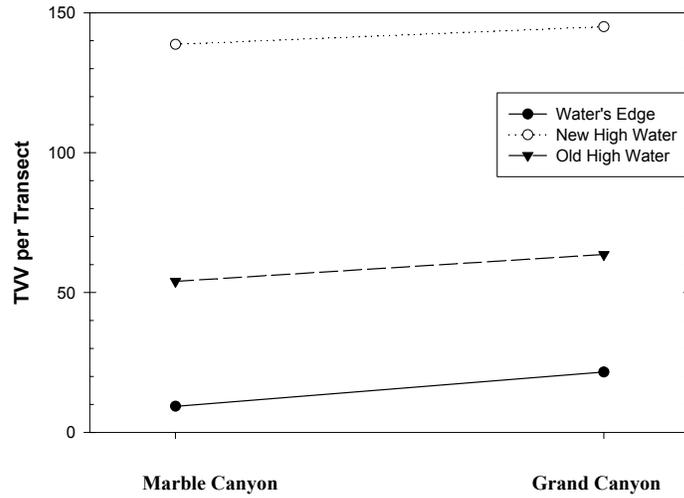


Figure 17. Total vegetation volume measures by zone in the three hydrologic zones sampled in the integrated monitoring sites

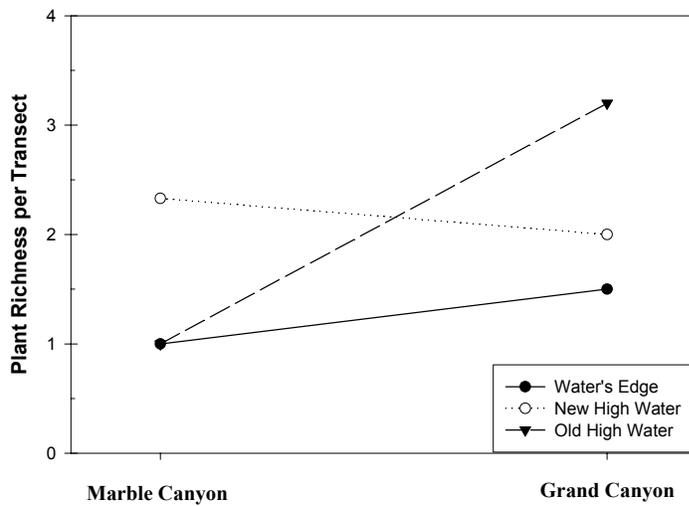


Figure 18. Richness of woody species in the total vegetation volume transects from the three hydrologic zones.

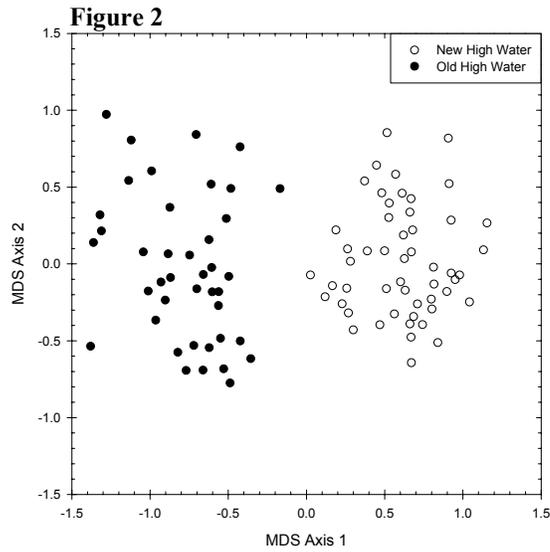


Figure 19. NMDS ordination of plant community data from the total vegetation volume measurements taken in the bird patches in new- and old high water zones in 2001.

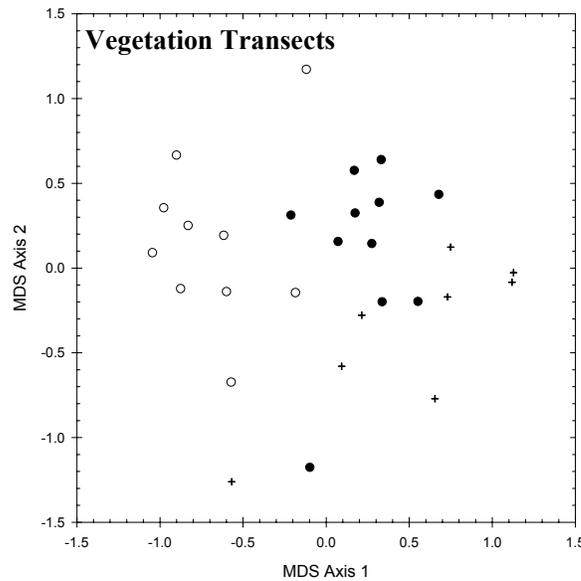


Figure 20. NMDS ordination of woody plant community data from total vegetation volume measurements taken in trapping transects in the three hydrologic zones at the integrated monitoring sites in 2001.

**Vegetation Dynamics**  
Michael Kearsley  
Northern Arizona University

**Purpose:**

The purpose of collecting vegetation dynamics data is to generate information on the status of and trends in measurements of riparian vegetation in relation to stage elevation along the Colorado River in Grand Canyon.

**Objectives:**

1) To determine the levels of vegetation cover, species richness, Shannon diversity, wetland indicator status and percent exotics at elevations above the river corresponding to river flows of 15, 25, 35, 45 and 60 thousand cubic feet per second (kcfs). 2) To numerically relate vegetation measures to channel width for the purpose of extending sample measures to corridor-wide estimates. 3) To compare measures of vegetation among years to determine trends within stage zones. 4) To compare yearly trends among zones to differentiate dam-related changes (zone behavior varies with distance from the river) from climate-related changes (all zones behave similarly).

**Methods:**

Sample site selection: Our sample site selection for the vegetation dynamics data had to satisfy two major concerns; it had to be probability based and it had to take into account differences among geomorphic reaches. Probability based sampling was recommended by the protocol review panel (Urquhart et al. 2000) because even the best minds in a field can introduce systematic biases when sample locations are chosen based on personal judgment and “representative” sites (Peterman et al. 1999). Geomorphic influences were included because reach width has been shown to have strong effects on productivity and diversity in both aquatic and near-shore habitats (Stevens et al. 1997, Kearsley and Ayers 1999).

In cooperation with Dr. Scott Urquhart of Oregon State University, we designed a probability based sample site selection using the 703 river sections defined by the 704 Randle and Pemberton (1987) STARS model cross-sections. River segments, delineated by adjacent cross-sections were assigned to their geomorphic reaches (Schmidt and Graf 1990). One hundred segments were then chosen for visitation in 2001 in a reach-stratified, spatially randomized pattern based on the EPA’s EMAP sampling program (Urquhart et al. 1998, Herlihy et al. 2000). Within each chosen segment, a random point on one side of the river or the other was selected as the point where the transect would begin.

Transect location and documentation: Once the river mile, to the nearest 0.01 mile, and side were determined, the point was located on the October 1984 black and white aerial photos used during the creation of the STARS model. The river mileage on these photos had been marked by Randle and Pemberton in miles and tenths, and the location of the 704 STARS cross sections were marked by lines as well. Mileages for the vegetation transects were interpolated between the tenth-mile marks and lines were drawn through them perpendicular to the river flow at that point. In order to have a more recent version of these localities for field work, these lines were then drawn on similarly scaled images from the March 2000 digital black and white aerial photographs made available from the GCMRC GIS department.

In June, each of the 100 segments were visited on a river trip whose purpose was to establish and photodocument the transects prior to transect censuses in September. Using cues from shoreline morphology, locations of large rocks, channel features, etc., the starting points of the transects at the river's edge and the cross-river water's edge point were identified. In cases where the point was on a vertical cliff face with no vegetation below the 60 kcfs stage, the point was photographed and the segment was excluded from further sampling. For other transects, a tape was run up slope from the starting point to a point above the 60 kcfs line using the cross-river point for lining up. The stage was approximated using cues from the location of old high water zone vegetation and debris from the 1996 high flows. The top point of the transect and one or more points along the transect were marked with dots of blue, white, or pink nail polish. Another point above the 60 kcfs elevation, from which the entire transect was visible, was also marked with nail polish or a P-K nail to serve as the local elevation control. The elevation difference between the elevation control point and the previous day's high water line was measured to the nearest 5cm using an Abney level a survey rod marked in meters and centimeters. All points and the tape laying along the transect were photodocumented to make it easier to reestablish the transect and reoccupy the elevation control point during censuses in the fall.

Finally, the stage elevation of the elevation control points was determined using the height measurement and a numerical model of stage / discharge relations in Grand Canyon. After returning to Flagstaff, the dam-release hydrograph for the entire trip was acquired from personnel at the Upper Colorado regional office of the Bureau of Reclamation and run through the CRFSSGUI model (Korman and Walters 1998). Part of the output from the model run was an estimate of the high water point of each day at any point in the river. Given that the height above that stage to the elevation control point was known, and the stage-to-discharge relationship available from the STARS model (Randle and Pemberton 1987) for each segment (determined by the downstream cross section of that segment), the distance below the elevation control point to the 15, 25, 35, 45, and 60 kcfs stage elevation points could be calculated. A table was constructed which contained the elevation drops to each of the discharge levels at each of the transects.

Vegetation sampling: Of the 100 transect points visited in June, 71 were vegetated, or at least were not so steep as to preclude sediment deposition and vegetation establishment. Of these, 60 were randomly selected for sampling in September. The 29 unvegetated sections are included in the analyses as zero values for cover, richness, and diversity, but are not part of the analyses of wetland indicator status, ordinations, or analysis of similarity

In September, the vegetation survey of each transect consisted of three steps: reoccupation, frame placement, and survey. First, the transect itself and the elevation control points were reoccupied using clues from the photographs and site descriptions taken in June. A tape was run down the transect to the water's edge. On the transect, points corresponding to the 60, 45, 35, 25, and 15 kcfs stage were located using an Abney level, a survey rod, and information in the elevation table, then marked with pin flags.

At each elevation point, a frame was placed and leveled with one side along the transect and the riverward corner of the transect side directly over the pin flag so that the riverward edge of the sampling frame was directly over the stage line. Once a frame was surveyed, the frame was slid upstream or downstream at the same level so that four 1 x 1 meter areas were sampled. This process was repeated at each stage level.

Vegetative cover was recorded in each frame in the following way. First, all species present in the 1 x 1 m area were recorded. Those individuals whose identity was in doubt and for which individuals could be found nearby which had enough material for identification (leaves, flowers, fruits, etc.) were assigned a temporary name, and a nearby example was collected for identification in camp or in Flagstaff. These specimens were discarded after identification. Very small seedlings and plants which could not be identified and which had no useful parts for identification were recorded with an “unknown” label (e.g., “unknown grass”). These data were included in the univariate measures, but were excluded from the multivariate analyses described below.

Then the number of sighting points which intercepted each species was counted. Only the first contact with a species under the sighting point was counted, so that no species could have more than 100% cover individually. However, if multiple species were present under a single sighting point, all were recorded once, so that the total cover of all species could sum to more than 100% collectively.

Vegetation analysis: For each transect, percent cover data for all four frames were averaged within a stage level. Species which were encountered in at least one of the frames but which were not seen beneath any of the 400 sighting points were assigned an arbitrary “trace” cover value of 0.01 percent. Several univariate community measures were calculated from the pooled data at each stage level. Total cover was the sum of foliar cover of all species at the stage level. Species richness was the number of unique species encountered, and diversity was calculated as the Shannon ( $H'$ ) index with untransformed mean cover values. A wetland indicator score was calculated as the mean wetland score (per (Reed 1988) of species within a stage zone weighted by their cover value (see (Stromberg et al. 1996). Stage zone effects were tested with a 2-way AOV (Site, Zone). In addition, geomorphic effects were tested with a series of regression analyses of the univariate measures in each stage zone by channel top width at 28 kcfs, derived from the STARS model (Randle and Pemberton 1987).

To test for compositional differences among the different zones, an analysis of similarity (ANOSIM; (Clarke 1993) was used. The method compares the difference in ranks of within-group and between-group similarity from field data to those generated by random assignment of samples to groups. Based on a simulation study which compared the performance of various dissimilarity measures (Faith et al. 1987), the Bray – Curtis similarity measures with species maximum relativization was chosen. The results of the ANOSIM were visualized with an NMDS ordination (Kruskal and Wish 1978) which also used the Bray-Curtis dissimilarity measure.

## Results

Vegetative cover was strongly influenced by stage (Figure 21;  $F_{4,216} = 9.176$ ,  $p < 0.001$ ). Cover was low in the 15 kcfs zone (19.3%), highest at the 25 and 35 kcfs zones (35.8 and 30.8% respectively) and lower in the 45 kcfs (22.8%) and 60 kcfs (18.5%). Species richness was also related to stage, but less dramatically (Figure 22;  $F_{4,216} = 2.96$ ,  $p = 0.021$ ). Most of the effect came from the reduction of richness in the 15 kcfs zone and slight elevation of richness in the 25 and 45 kcfs zones. Shannon diversity was not significantly related to stage (Figure 23;  $F_{4,216} = 2.304$ ,  $p > 0.05$ ). As with the richness data, diversity was highest in the 45 and 25 kcfs zones and lowest in the 15 kcfs zone. Wetland score was strongly influenced by stage (Figure 24;  $F_{4,216} = 28.11$ ,  $p < 0.001$ ). As would be expected, the highest scores were in the lowest stage

zones and progressively lower scores in higher zones. The statistical overlap among zones derived in part from the fact that scores were based on aerial cover, so that branches and parts from plants rooted in one zone can overlies other zones.

Regression analyses showed little relationship of the univariate measures to channel width (Table 3). Wider sections generally had higher cover in the 25 and 35 kcfs stage zones. Likewise, plots in the 15, 25, and 35 kcfs stage zones were slightly more speciose in wider reaches, and Shannon diversity ( $H'$ ) was greater in wider segments in plots in the 15 and 25 kcfs stage zones. There was no relationship between weighted mean plot wetland score and channel width in any of the stage zones.

ANOSIM analysis showed significant differences among zones in plant species composition (Figure 25; Max R = 0.0749,  $p < 0.001$ ). The 15 kcfs plots sorted out by themselves. The 25 kcfs plots were significantly different from the 15, 45, and 60 kcfs plots, but not the 35 kcfs plots. The 35 and 60 kcfs plots were different from the 15 and 25 kcfs plots, but not from the 35 kcfs plots nor from each other.

### Summary

Baseline data on riparian vegetation in this first year of sampling showed several predictable patterns. Greater access to groundwater resulted in higher cover levels in plots closer to the river. However, cover in the lowest plots (15 kcfs) was reduced by the effects of scour and drowning of plants by high winter and spring flows. The same patterns were evident in the species richness data from these plots, although the patterns were less dramatic, and increased evenness of species cover in the higher plots resulted in a less pronounced pattern in the  $H'$  values than in the cover values.

The effects of segment width, which incorporates higher solar inputs, reduced gradient (slower current) and lower beach slopes (lower rise per stage increase and better access to groundwater) were evident in only the lowest two or three sets of plots on the transects. Wider segments had greater levels of cover in the 25 and 35 kcfs stage zones, but not in the 15 kcfs zones where scour and flooding were factors and not in the 45 and 60 kcfs zones where access to groundwater is reduced. Richness, and its related measure Shannon diversity ( $H'$ ) both increased with segment width in the lowest zones, but not at the 45 and 60 kcfs stage elevation.

Compositionally, the plots differed in predictable ways. ANOSIM analysis showed that the plots sorted out into three main groups: 15 kcfs only, 25 and 35 kcfs, and the higher plots at 45 and 60 kcfs with some overlap in the latter with the 35 kcfs plots. The wetland indicator score data showed that this is likely due to the sorting out of species on a moisture gradient. Plants in the 15 kcfs plots were, on average facultative wetland species. Those in the 25 and 35 kcfs plots were facultative species, and those in the highest two plots were generally facultative upland species.

The real tests of these data as monitoring tools will have to wait until a second round of plot surveys has been conducted in 2002. At that point we will have the ability to test for change with time within a stage zone. We will also have the ability to conduct power analyses to determine the appropriateness of our sampling efforts.

Table 3. Regression of univariate community measures with channel width at each of the 5 stage elevation zones. \* =  $p < 0.05$ , \*\* =  $p < 0.01$ , n.s. = no significant relationship. Results reflect experiment-wide error correction with the Bonferroni adjustment.

	15 kcfs	25 kcfs	35 kcfs	45 kcfs	60 kcfs
Total Cover	n.s.	*	*	n.s.	n.s.
Richness	*	*	*	n.s.	n.s.
Diversity	**	*	n.s.	n.s.	n.s.
Wetland Indicator Score	n.s.	n.s.	n.s.	n.s.	n.s.

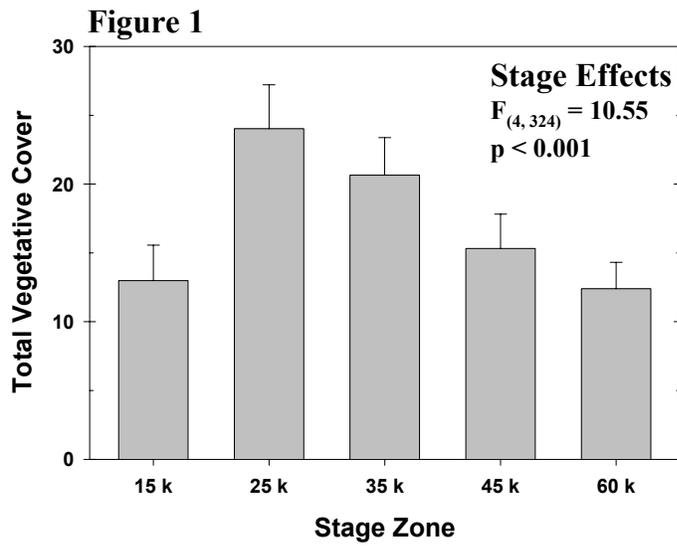


Figure 21. Total vegetative cover by stage elevation in the vegetation dynamics transects in 2001.

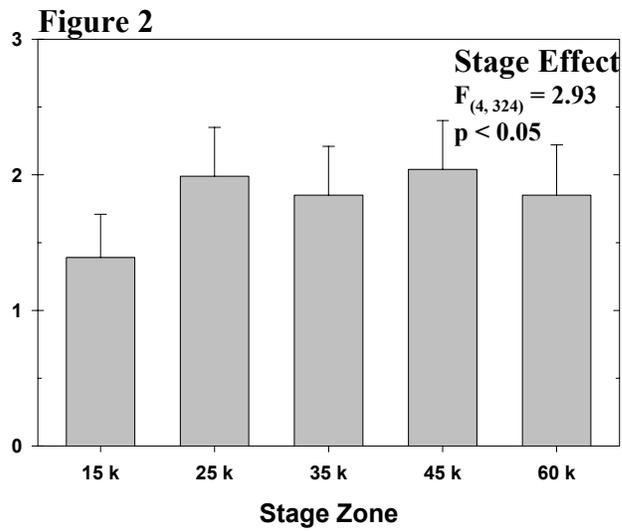


Figure 22. Plant species richness by stage elevation in the vegetation dynamics transects in 2001.

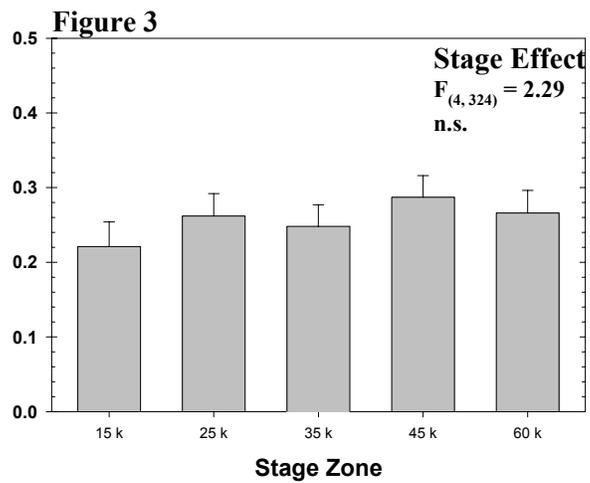


Figure 23. Plant diversity ( $H'$ ) by stage elevation in the vegetation dynamics transects in 2001.

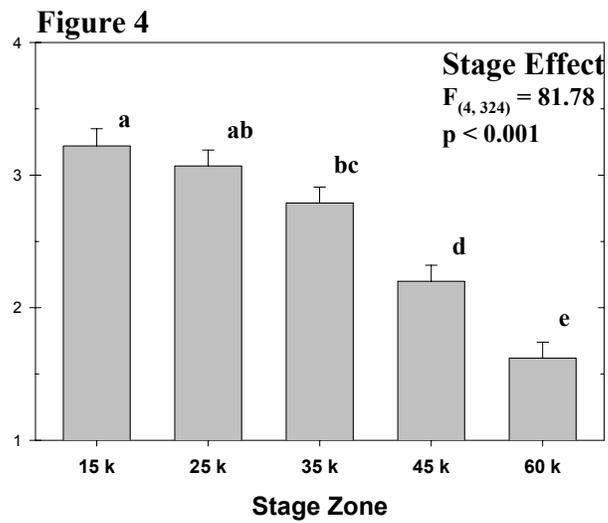


Figure 24. Wetland indicator score by stage elevation in the vegetation dynamics transects in 2001.

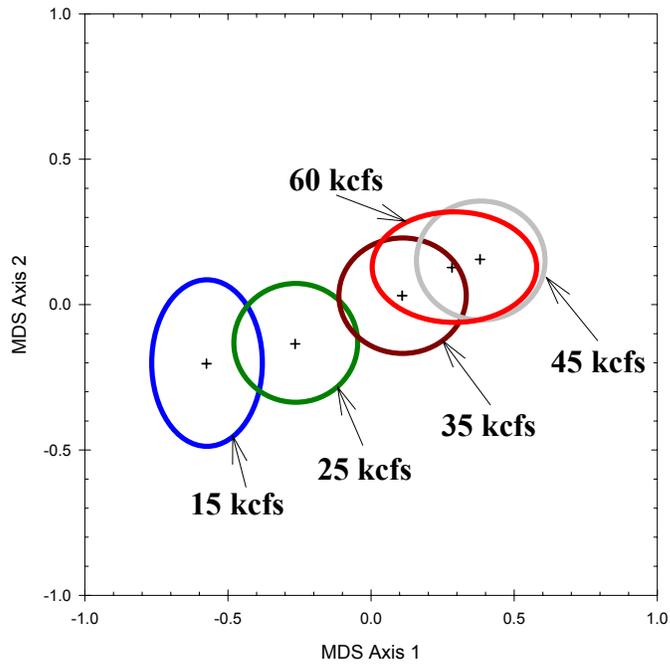


Figure 25. Significant differences exist in the composition of plant communities in stage zones along the vegetation dynamics transects. NMDS ordination with stage means and standard errors in two dimensions.

## Integration and Interpretation

### Purpose:

The purpose of the work described here is to combine information on vegetation and the faunal monitoring components to better understand the relationship of animal communities to aspects of terrestrial primary productivity in the river corridor.

### Objectives:

1) To relate vegetation structure data to breeding bird abundance in patches where birds have been surveyed in previous years as part of other projects. 2) To relate vegetation structure data to invertebrate, mammal, and herpetofaunal densities in a series of integrated monitoring sites. 3) To relate the composition of vegetation to faunal species composition to determine if there are broad animal community by plant community patterns in riparian areas.

### Methods:

The data for this section were collected for inventory and monitoring purposes as described in the previous sections where the site selection and data collection methods have been described there. This section is concerned with the relationships among those data sets. Below are described the numerical methods used to examine those relationships.

Bird community / vegetation relationships. Data on breeding bird abundance and species richness in patches were taken from the avian monitoring data from May and June 2001. The vegetation structure data was collected during the April/May 2001 field work. To determine whether vegetation volume (per Mills et al. 1991) influenced bird communities, total bird abundance was regressed against total vegetation volume in the new- and old high water patches. A serial Bonferroni adjustment was used ( $p = 0.025$ ) to keep the test-wide error rate below 0.05. To determine whether there was a relationship between the composition of the bird communities and the composition of the plant communities we used a mantel test. This procedure tests whether sites which differ significantly in their bird assemblages are also those which differ in their vegetation, and if those with similar vegetation also have similar bird species present (see Douglas and Endler, 1982; McCune and Allen, 1985).

Integrated site faunal / vegetation relationships. Similar analyses were performed for data from surveys of mammals, ground-dwelling invertebrates, and herpetofauna in the integrated monitoring sites. Species richness and total abundance for each of these groups were regressed against total vegetation volume from the transects in the water's edge, new high water and old high water zones. Because there were differences in the total vegetation volume in transects and bird patches within the integrated monitoring sites (see structure section above), the vegetation data from the bird point count stations in these same sites was not included in these analyses. Separate regressions were run for each hydrologic zone and serial Bonferroni adjustments were made ( $p = 0.025$ ) because both abundance and richness were being tested from the same data sets.

Likewise, compositional comparisons were made between each faunal component and the vegetation in the transects. Mantel tests were performed separately between the three faunal groups and vegetation composition data derived from each transect. Where significant positive relationships were detected, an NMDS ordination of both data sets (each using Bray-Curtis

distance measures and a species-maximum relativization) was used to visualize the similarity in sample relationships.

## **Results:**

Integration. In contrast to the results reported in Mills et al. (1991), we did not find consistent significant relationships between total vegetation volume and either total breeding bird abundance or breeding bird species richness (Figure 26). In the new high water zone, neither abundance nor richness correlated with total vegetation volume. However, in the old high water zone, both were significantly, positively correlated with total vegetation volume, although there was a fair amount of scatter around the line.

When both old high water and new high water zone data are considered, there was a significant relationship found between the composition of the bird community and the composition of the vegetation in the same sites. The mantel test showed that sites which had more similar vegetation tended to have more similar bird communities and those whose vegetation was more dissimilar had more dissimilar bird assemblages (Mantel  $r = 0.4422$ ,  $p = 0.044$ ). From the NMDS visualization (Figure 27 A, B), it appears that much of this is due to dissimilarities between new high water and old high water bird communities relating to compositional differences in the plant communities in the two zones.

Total vegetation volume did not explain any of the variation in the density or species richness of the faunal components of the integrated monitoring sites. Mammal density and richness were both unrelated to vegetation volume in new high water zone and old high water zone habitats (Figures 28). Likewise, invertebrate density and taxon richness were unrelated to vegetation volume in the pitfall transects (Figure 29), and the same was true for herpetofaunal density and species richness.

No relationship was detected between the woody plant species composition and mammal species composition in the integrated sites either (Mantel  $r = 0.0747$ ,  $p = 0.0902$ ), although there was a tendency towards a positive relationship in site dissimilarities. The herpetofaunal data also showed no relationship between site dissimilarities and vegetation dissimilarities (Mantel  $r = 0.0376$ ,  $p = 0.243$ ).

In the case of the invertebrate community data, there was a strong and significant relationship between dissimilarities among sites in arthropod taxa and vegetation composition (Mantel  $r = 0.1638$ ,  $p = 0.005$ ). Thus, sites with more similar vegetation had more similar ground-dwelling arthropod species composition and those with more unlike vegetation had more dissimilar arthropod communities. Figure 30 shows a paired NMDS visualization of the two community data sets in which it is clear that both sets separate the samples on the basis of distance from the river.

Interpretation. In this first year of data collection, several patterns have emerged. First, although new high water zone vegetation tends to be denser and more productive than higher elevation habitats, the old high water zone tends to be a greater area of animal biodiversity and abundance than either the new high water zone or near-shore habitats. Insect, bird, and especially mammal numbers and richness are usually higher in these habitats than in low elevation habitats. Second, it is not necessarily the productivity or biomass of the new high water zone habitats that controls the richness and abundance of vertebrates and invertebrates. There seems to be some compositional relationship between birds and ground-dwelling invertebrates and the vegetation in the monitoring sites. This needs to be further examined to

determine if, within the new and old high water zones, there is some fidelity of particular birds and arthropods to particular vegetation types or if it is primarily a sorting out based on between-zone differences in conditions.

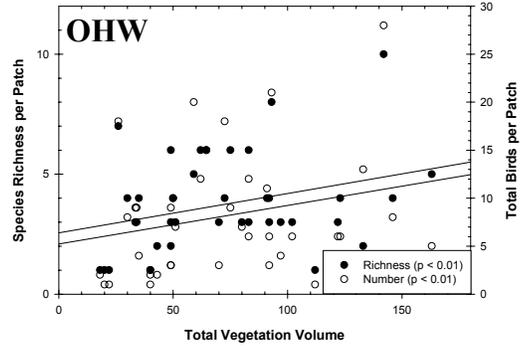
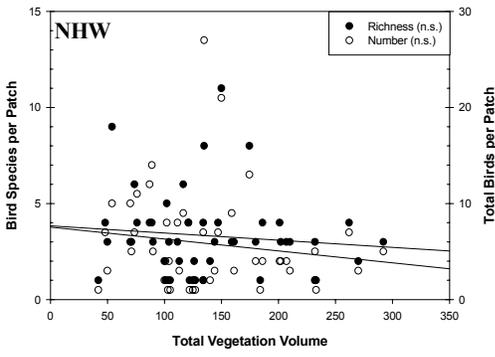


Figure 26. Breeding bird abundance and species richness in patches as a function of total vegetation volume in new high water and old high water zone habitats.

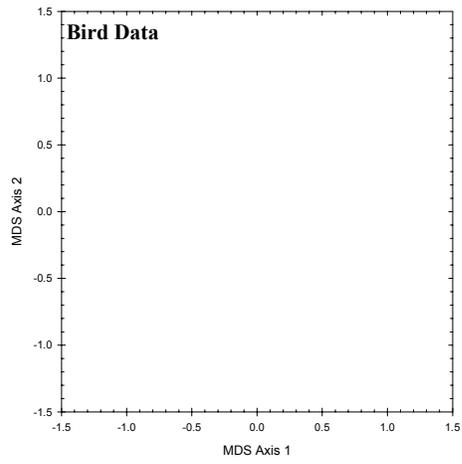
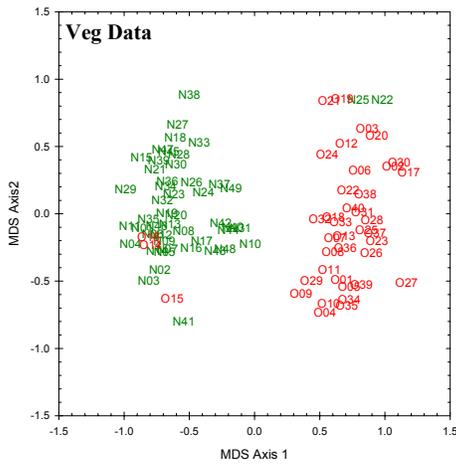


Figure 27. NMDS ordinations of vegetation and bird community data showing similarity of dissimilarity structure. N and O indicate new- and old high water zone habitats, and numbers refer to the same sites in both graphs.

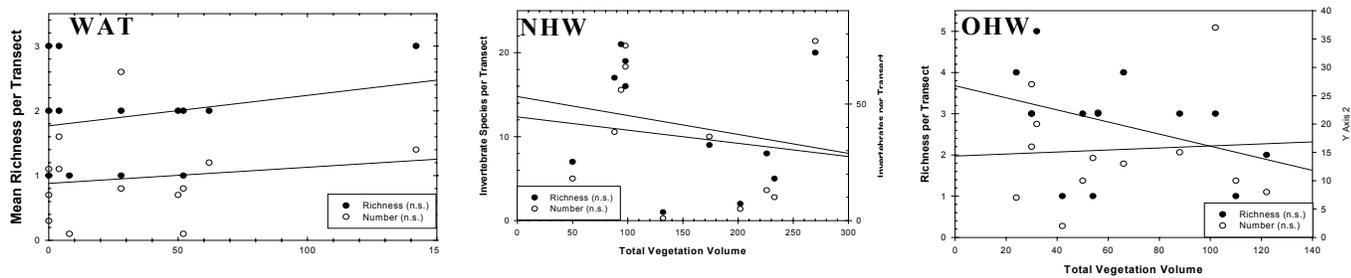


Figure 28. Abundance and species richness of small mammals trapped in each of the three hydrologic zones in September 2001 as a function of total vegetation volume.

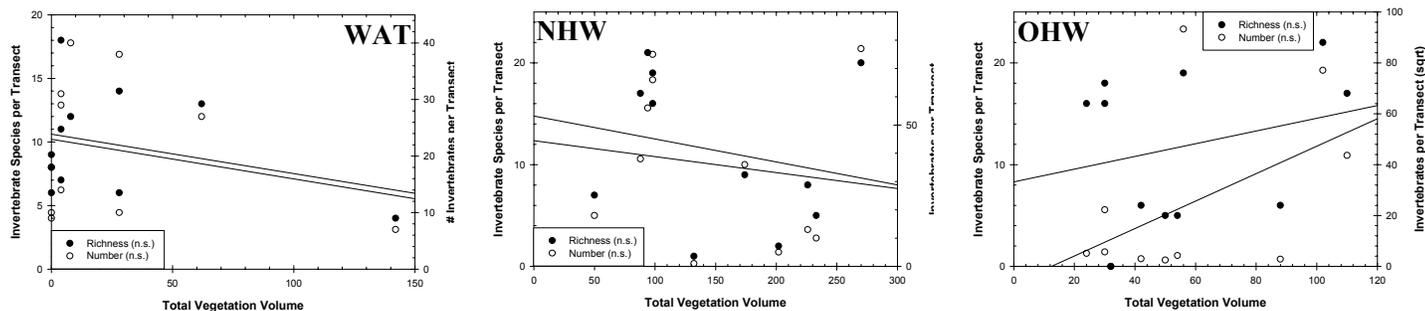


Figure 29. Abundance and species richness of arthropods captured in pitfall traps in the three hydrologic zones as a function of total vegetation volume.

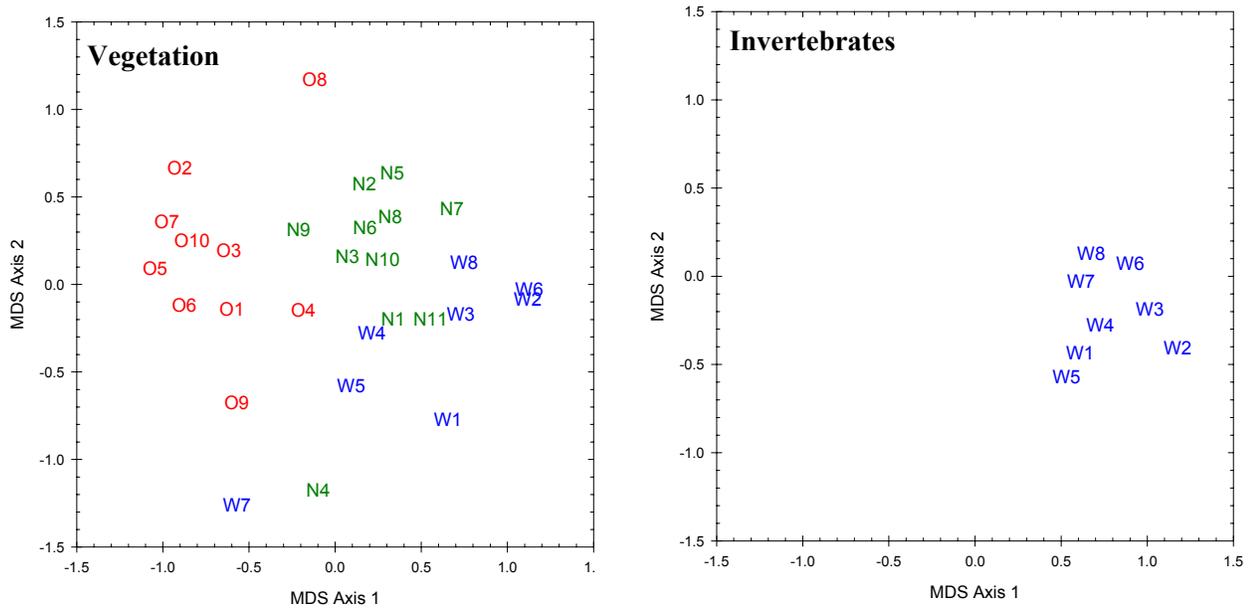


Figure 30. NMDS ordinations of vegetation and invertebrate pitfall community data showing concordance of dissimilarity structure. W, N, and O refer to water's edge, new high water zone and old high water zone transects, and numbers indicate the same sites on the two graphs.

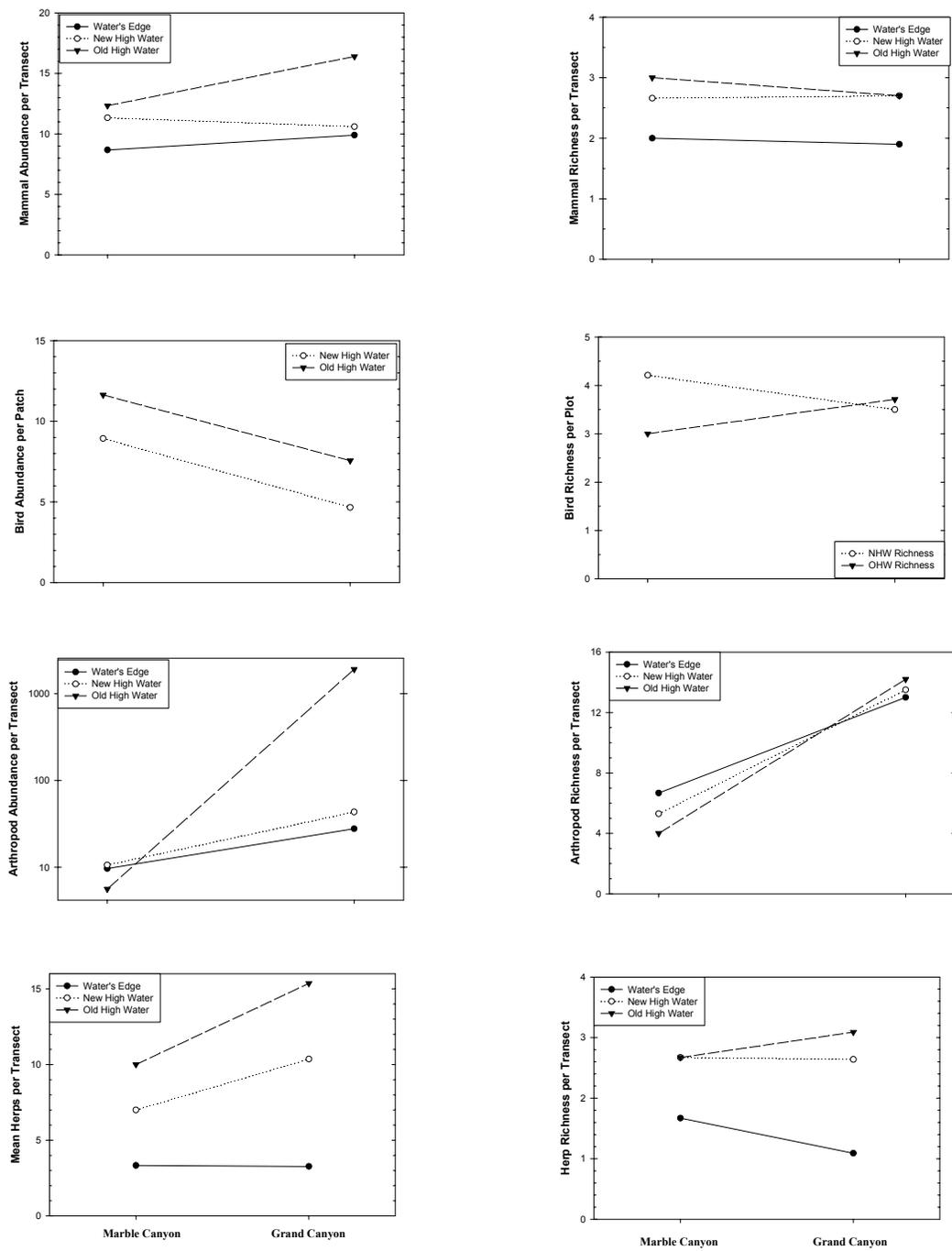


Figure 31. Response of richness and abundance of faunal components to hydrologic zone and geomorphic setting (Marble Canyon = above the Little Colorado River, Grand Canyon = below the Little Colorado River) in 2001. No one pattern fits all four elements.

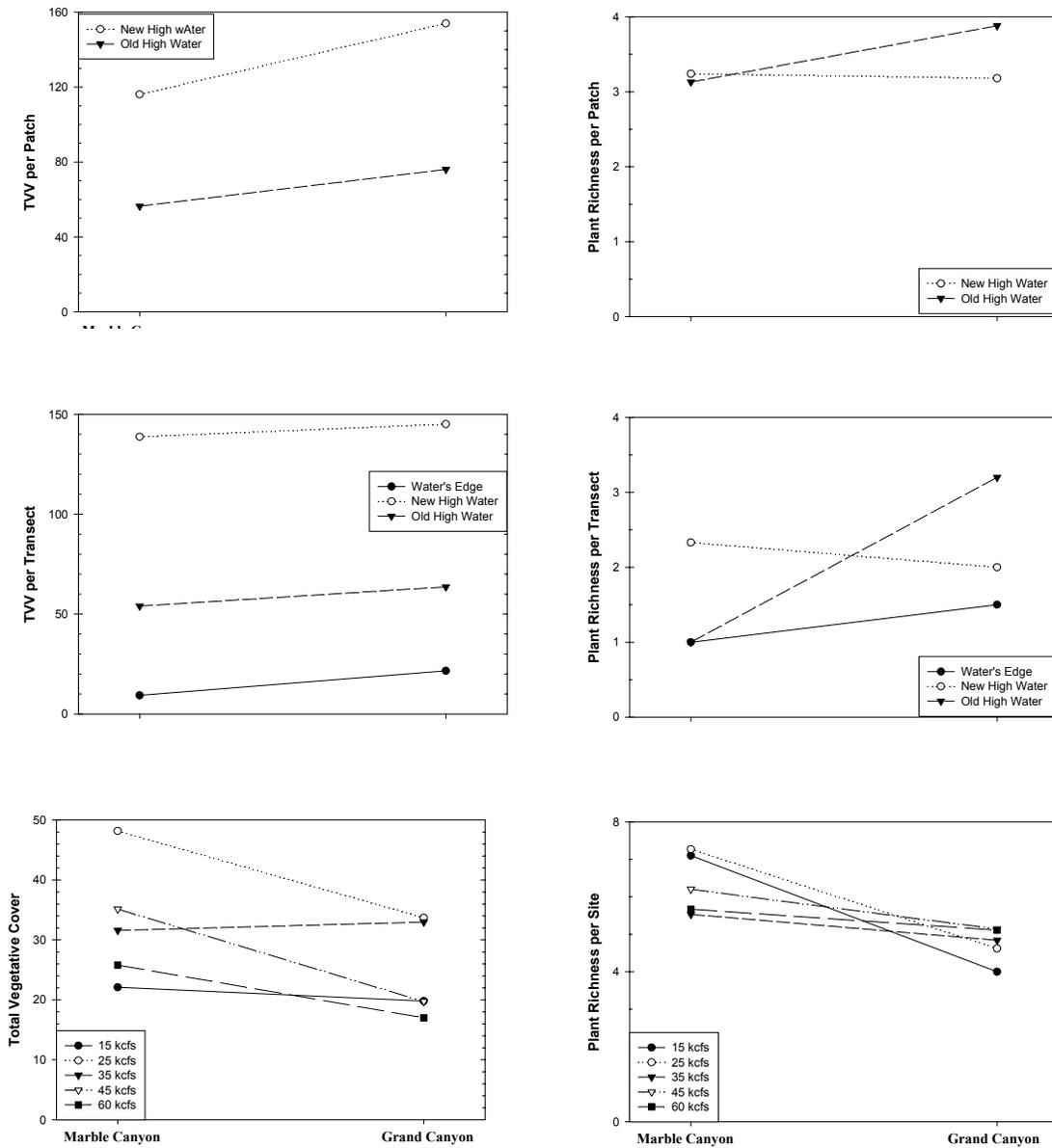


Figure 32. Plant abundance and species richness as a function of stage elevation and geomorphic reach in the bird patches (top), integrated site survey transects (middle) and vegetation dynamics transects (bottom) in 2001. Data for woody species alone (patches and survey transects) show slight increases in Grand Canyon, while considering data from all growth forms on dynamics transects yields the opposite trend.

### **Problematic and unanticipated results in 2001:**

There were several aspects of the field and analytic work which we did not anticipate. Some of these were logistical or methodological problems while others were results which ran counter to predictions from the literature. We discuss these and explanations or potential solutions in the section below.

Efficacy of nest searching. Nest searching does not appear to be an effective means to determine changes in abundance and composition of nesting birds within and between one in the old high water zone and new high water zone patches across time. Due to the time limitation for nest searches at each site, only the most conspicuous nests were probably found. For example, the highest number of nests located during both field trips in 2001 were black-chinned hummingbird nests (13 nests). During surveys, we had a total of 94 detections for this species. Black-chinned hummingbirds build fairly conspicuous, open cup nests (Ehrlich et al. 1988, Harrison 1979) and are very territorial (will “buzz” an intruder). Locating these nests poses little difficulty for nest searchers with limited time. Lucy’s Warblers however build well-concealed nests, usually in cavities (Johnson et al. 1998, Ehrlich et al. 1988), that are difficult to find. Though Lucy’s warblers were the most common species detected during surveys (690), only six Lucy’s warbler nests were located during both field trips. These findings were consistent with past nest searching results in Grand Canyon (Brown 1987) conducted by biologists spending multiple days searching at sites. Limited time to conduct nest searches was proven to be an ineffective method for assessing breeding bird abundance and composition between zones and sites.

On future field trips, we propose to implement territory mapping consistent with Sogge et al. (1998) and quantifying breeding bird behavior as described in the Arizona Breeding Bird Atlas Handbook (Corman 1994). Territory mapping is an effective method to estimate numbers of territories (indicating a nesting pair) for each bird species detected within each patch without actually observing the nest. Walking surveys and territory mapping have proven to be successful in tracking long-term trends in bird abundance (Holmes and Sherry 2001). The addition of territory mapping and breeding bird criteria to our data for examining numbers of breeding birds by behavior may be the most practical way to assess breeding bird abundance and composition.

Point count versus walking survey data. The physical layout of vegetation in the riparian corridor in narrow bands of new- and old high water zones often made it difficult to survey birds in a traditional fixed-radius 50 meter manner. It was the unusual site which had enough depth of vegetation to allow even a single, full plot. Furthermore, the point count method consistently detected fewer individual birds and fewer species of birds in comparisons of the two methods within the same sites.

We will continue to use both walking surveys and point counts in future field work. The former will generate better estimates of bird numbers and species richness in our sites for trend analysis and will be comparable to data from three previous studies (Spence 2001 in prep, Sogge et al. 1997, Brown 1989) which used this same method. The latter may allow better comparison of current data to previously collected data in which point count methods were used.

In addition, long-term trends in bird populations on a regional scale may be possible by our including distance estimation parameters in our data collection. During walking counts and point counts on the June trip, we began to record the estimated distance in meters from the observer to the bird. Distance estimation techniques (Fancy 1997; Buckland et al. 1993, 2001) are being used throughout National Parks in the Western United States (Fancy 1997) to estimate

density of birds. By including this parameter, we will be able to compare our data with other National Park Service data being collected in riparian areas throughout the southwest.

Lack of explanatory power with habitat structure. The lack of a relationship between vegetation volume and faunal components, especially bird abundance, was rather surprising, given the strength of published information in Mills et al. (1991). There are several possible explanations for this. First, the discontinuous nature of the vegetation in some areas may give more weight to the size of the individual patches than to the density of the vegetation within it. Small, dense patches may have fewer birds present than would be predicted from the density of the vegetation alone. Mills and his colleagues were working within fairly continuous habitats in less constrained river systems where local vegetation density, as a surrogate for local productivity, would have an overriding effect.

Nor did the abundance and richness of other faunal components correlate with vegetation volume. For mammals, the explanation likely involves several elements. First, the structure which they require for nesting involves more rocks and dead / down woody vegetation than standing live vegetation. Second, their food base may be more related to invertebrate abundance or seeds produced by annuals and herbs than to woody species biomass and productivity. Also, predation by larger more mobile animals and disturbance may produce local anomalies on a scale not compatible with our measures. The lack of a relationship between herpetofaunal richness and abundance and vegetation productivity is not surprising. Previous surveys have found positive relationships between lizard densities and bare rocks, or the presence of vertical surfaces near the water's edge. Although it is not significant, the negative sign of the relationship between herp densities new high water zone vegetation volume is in keeping with these findings. This may represent a disagreement in the scales at which vegetation volume was measured and that at which lizards and other herps make habitat choices.

Future analyses of bird abundance data and vegetation structure will include information on the size of the patches' new- and old-high water zone habitats. Sogge et al (1997) showed that in Grand Canyon riparian vegetation patches, bird abundance and richness often were correlated with the area of various types of new high water zone vegetation. Recent color and color infra-red images have been scanned hard copies which, when plagued by shadows, do not allow good information to be produced by tweaking images. With digital, orthorectified images which will be available next year, we will be able to delineate habitat boundaries regardless of shading. We believe that by including information on patch size, along with some gross compositional data, our ability to predict bird community parameters from vegetation data will be improved.

Mammal vouchering. The severe restrictions placed on our ability to voucher small mammals is creating problems. Field identification, based on gross external morphology, cannot verify species identification. During the first river trip, two individuals of *Chaetodipus penicillatus* were identified in the field using standard field measurement techniques. When the professionally acceptable skull measurements were taken in the lab, however, they appeared to be closer to *C. intermedius*, although some ambiguity remains because the specimens' measurements are near the dividing line between the two species. This is an important question because the *C. penicillatus* identification represents a new record for the Park and a range extension for the species. Without a more extensive collections, the results will continue to be inconclusive.

Herpetological surveys. The Protocols document within the Request for Proposals stipulated that herpetological surveys would be conducted at all bird patches. This precludes reasonable results based merely on the ectothermic nature of the organisms. In order to sample all the sites, the surveyors must leave camp early and visit several sites before the sun hits the beach and warms them sufficiently to be active. Hence, many of the April / May surveys were conducted on beaches where lizards were likely present, but none were documented because they were not moving.

In September of last year, and on future trips, the herp survey crew will remain in camp with the arthropod crew until late morning. Although fewer sites will be surveyed, this will allow a more thorough search to be conducted in each site surveyed. In addition, it will allow for conditions to be more consistent among all surveys.

Modified funnel traps. The success of the modified funnel traps was very disappointing. While toad tracks were often observed along the trap fences, only four Woodhouse's toads (*Bufo woodhousei*) were captured during the entire September trip (and all on the last night of sampling). An individual *C. tigris* was observed to enter, then escape from a trap on one occasion, and a California kingsnake (*Lampropeltus getula*) was observed entering, then exiting a trap on another occasion. It is hoped that these traps will be more effective following numerous modifications. Modifications will include longer drift fences to sample larger areas, and modified funnels, to enhance capture success. We will test the new modified design on 2002 river trips.

Arthropod survey sampling schedule. The major problem with the arthropod surveys was that the number and timing of surveys undoubtedly meant that we were not able sample all of the potential species. Our surveys did not completely coincide with times of the year when different species are active. Most arthropod species are short-lived, less than 30 days for the adult stage, which is the life stage needed for proper identification. Because of this there is a large turnover in the composition of species throughout the year. Even in the winter time there will be species that are active. In addition, the best timing of arthropod surveys was in conflict with the optimal timing for other taxa surveys. For example, our assessment of the optimal time for maximizing the number of arthropod species we could find is later than when we would want to conduct breeding bird surveys. We have setup a modified schedule for 2002 that we feel will optimize our chances of sampling the greatest number of species within the constraints of the budget and consideration of other important taxa.

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**APPENDIX**

**LISTS OF SPECIES ENCOUNTERED DURING  
MONITORING ACTIVITIES IN 2001.**

### Small Mammal Species Encountered in 2001

Abbreviation	Latin Binomial	Common name
PEER	<i>Peromyscus eremicus</i>	Cactus Mouse
NELE	<i>Neotoma lepida</i>	Desert Wood Rat
PECR	<i>Peromyscus crinitus</i>	Canyon Mouse
PEBO	<i>Peromyscus boylii</i>	Brush Mouse
CHIN	<i>Chaetodipus intermedius</i>	Rock Pocket Mouse
NEAL	<i>Neotoma albigula</i>	White-throated Wood Rat
PEFO	<i>Perognathus formosus</i>	Long-tailed Pocket Mouse

Southwestern Willow Flycatcher Surveys, 2001

SITE	Survey team			
	5/15 - 5/31	# 6/1 - 6/21	# 6/22 - 7/10	#
5.2R	ns	5/31- HY	1 6/25 - HY	0
43.1 - 43.8L	ns	6/02 - HY, MM	0 6/28 - HY	0
46.5(7)R	ns	6/03 - HY, MM	0 6/28 - HY	0
50.4L	5/21- DW	0 6/04 -HY, MM	1 6/30 -HY	2*
51.4L	5/21- DW	0 6/04 -HY, MM	0 6/31 - HY	0
56.0R Kwaugant	ns	6/04 -HY, MM	0 6/31- HY	0
65.3L LavaChuar	ns	6/05 - HY, MM	0 7/1 - HY	0
71.1L Cardenas	5/23- DW	0 6/05 - HY, MM	0 7/2 - HY	0
143R Kanab	ns	6/09 - MM	0 ns	
198R - Parashant	ns	6/14 - HY, MM	0 7/8 - HY	0
204.5R Spring	05/15 - HY	0 6/15 - HY, MM	0 7/9 - HY	0

Survey personnel:

DW = David Willey, N.P.S.

HY = Helen Yard, Helen Yard Consulting

MM = Mimi Murov, Helen Yard Consulting

## Bird species encountered in 2001

A.O.U. Acronym	Common Name
AMCR	American Crow
ATFL	Ash-throated Flycatcher
BCFL	Brown-crested Flycatcher
BCHU	Black-chinned Hummingbird
BEVI	Bell's Vireo
BEWR	Bewick's Wren
BGGN	Blue-gray Gnatcatcher
BHCO	Brown-headed Cowbird
BLGR	Blue Grosebeak
BHGR	Black-headed Grosebeak
BLPH	Black Phoebe
BTGW	Black-throated Grey Warbler
BTSP	Black-throated Sparrow
CNWR	Canyon Wren
COGR	Common Grackle
CORA	Common Raven
COYE	Common Yellowthroat
GCKI	Golden-crowned Kinglet
GTGR	Great-tailed Grackle
HOFI	House Finch
HOOR	Hooded Oriole
LASP	Lark Sparrow
LABU	Lazuli Bunting
LEGO	Lesser Goldfinch
LHSR	Logger-headed Shrike
LOWA	Louisiana Waterthrush
LUWA	Lucy's Warbler
MODO	Mourning Dove
NOMO	Northern Mockingbird
PHAI	Phainopepla
PIJA	Pinyon Jay
ROWR	Rock Wren
SAPH	Say's Phoebe
SCJA	Scrub Jay
SOSP	Song Sparrow
SPSA	Spotted Sandpiper
SPTO	Spotted Towhee
SUTA	Summer Tanager

TUVU	Turkey Vulture
VGSW	Violet-green Swallow
WAVI	Warbling Vireo
WCSP	White-crowned Sparrow
WWPE	Western Wood Peewee
WIFL	Willow Flycatcher
WIWA	Wilson's Warbler
YBCH	Yellow-breasted Chat
YEWA	Yellow Warbler
YRWA	Yellow-rumped Warbler
EMPID	Unidentified Empidonax

## Herpetofauna encountered in 2001

### LIZARDS

COVA, *Coleonyx variegatus* (banded gecko)  
CNTI, *Cnemidophorus tigris* (western whiptail)  
CRCO, *Crotaphytus collaris* (collared lizard)  
SAOB, *Sauromalus obesus* (chuckwalla)  
SCMA, *Sceloporus magister* (desert spiny lizard)  
UROR, *Urosaurus ornatus* (tree lizard)  
UTST, *Uta Stansburiana* (side-blotched lizard)

### SNAKES

CRMI, *Crotalus mitchelli* (speckled rattlesnake)  
CRMO, *Crotalus molossus* (black-tailed rattlesnake)  
CRVI, *Crotalus viridis abyssus* (Grand Canyon pink rattlesnake)  
HYTO, *Hypselglena torquata* (night snake)  
LAGE, *Lampropeltus getulus* (king snake)  
MAFL, *Masticophis flagellum* (red racer)  
MASP, *Masticophis spp?* (whipsnake)  
PIME, *Pituophis melanoleucus* (gopher snake)  
SAGR, *Salvadora grahami* (patch-nosed snake)

### TOADS

BUPU, *Bufo punctatus* (red-spotted toad)  
BUWO, *Bufo woodhousei* (Woodhouse's toad)  
HYAR, *Hyla arenicolor* (canyon treefrog)

## Arthropod Species Encountered in 2001

<b>Taxon code</b>	<b>Order</b>	<b>Family</b>	<b>Genus species authority</b>
ARANNYND	Araneae	Anyphaenidae	anyphaenid nymph
ARCATASY	Araneae	Caponiidae	Tarsonops systematicus Chamberlin
ARCOCA01	Araneae	Corinnidae	Castianeira sp.
ARCOTRDE	Araneae	Corinnidae	Trachelas deceptus
ARDIMAPA	Araneae	Dictynidae	Mallos pallidus Banks
ARGNGNCL	Araneae	Gnaphosidae	Gnaphosa clara (Keyserling)
ARGNZENY	Araneae	Gnaphosidae	Zelotes nymph
ARGNZE01	Araneae	Gnaphosidae	Zelotes sp.
ARLYARLI	Araneae	Lycosidae	Arctosa littoralis
ARLYNYND	Araneae	Lycosidae	lycosid nymph
ARLYPANY	Araneae	Lycosidae	Pardosa nymph
ARLYPA01	Araneae	Lycosidae	Pardosa sp. (striped)
ARLYPAVA	Araneae	Lycosidae	Pardosa vadosa
AROEEOIS	Araneae	Oecobiidae	Oecobius isolatus
ARPOPS01	Araneae	Pholcidae	Psilochorus sp.
ARSILODE	Araneae	Sicariidae	Loxosceles deserta Gertsch
ARTHNYND	Araneae	Thomisidae	thomisid nymph
BLPOAR01	Blattodea	Polyphagidae	Arenivaga sp.
CHLINDET	Chilopoda	Lithobiidae	lithobiid sp.
COANNO01	Coleoptera	Anthicidae	Notoxus sp.
COBUAC01	Coleoptera	Buprestidae	Acmaeodera sp.
COCAAM01	Coleoptera	Carabidae	"Amara" sp.
COCABE01	Coleoptera	Carabidae	"Bembidion" sp.
COCALICY	Coleoptera	Carabidae	"little Cymindis" sp.
COCAPT01	Coleoptera	Carabidae	"Pterostichus" sp.
COCABLTI	Coleoptera	Carabidae	brown with blue tinge
COCACHTO	Coleoptera	Carabidae	Chlaenius tomentosus
COCACI01	Coleoptera	Carabidae	Cicindela sp.
COCADY01	Coleoptera	Carabidae	Dyschirius sp.
COCAGRPU	Coleoptera	Carabidae	green; punctate elytra
COCASMBL	Coleoptera	Carabidae	small, black
COCABRSH	Coleoptera	Carabidae	small, brown, shiny
COCHAL01	Coleoptera	Chrysomelidae	Altica sp.
COCHNDET	Coleoptera	Chrysomelidae	alticine sp.
COCHGA01	Coleoptera	Chrysomelidae	galerucine sp.
COCHLTBR	Coleoptera	Chrysomelidae	light brown chrysomelid
COCOHICO	Coleoptera	Coccinellidae	Hippodamia convergens
COCRCR01	Coleoptera	Cryptophagidae	Cryptophagus sp.
COCUNDET	Coleoptera	Curculionidae	curculionid, several spp.

COELAE01	Coleoptera	Elateridae	Aeolus sp.
COELCOPR	Coleoptera	Elateridae	elaterid, convex pronotum
COELSMGR	Coleoptera	Elateridae	elaterid, small, granular texture
COELPLBR	Coleoptera	Elateridae	plain brown
COHYCE01	Coleoptera	Hydrophilidae	Cercyon sp.
COME	Coleoptera	Melyridae	small dark melyrid??
COMETABL	Coleoptera	Melyridae	tan with black spots
COMETR01	Coleoptera	Melyridae	Trichochrous sp.
COLANDET	Coleoptera	not determined	larva
CO	Coleoptera	not determined	sm brn beetle? What is?
COOENDET	Coleoptera	Oedemeridae	oedemerid sp.
COSTALND	Coleoptera	Staphylinidae	aleocharine spp.
COSTSTND	Coleoptera	Staphylinidae	staphylinine spp.
COTEBLHA	Coleoptera	Tenebrionidae	Blapstinus sp. (hairy)
COTEBLSH	Coleoptera	Tenebrionidae	Blapstinus sp. (shiny)
COTECE01	Coleoptera	Tenebrionidae	Centrioptera sp.
COTEDKBR	Coleoptera	Tenebrionidae	dark brown teneb
COTEELEX	Coleoptera	Tenebrionidae	Eleodes extricatus
COTEEL01	Coleoptera	Tenebrionidae	Eleodes sp.
COTELTBR	Coleoptera	Tenebrionidae	light brown teneb
COTELOSC	Coleoptera	Tenebrionidae	teneb, looks scarab-like
COTECOOV	Coleoptera	Tenebrionidae	teneb, dark w/convex pron. & oval body
COTEDKPU	Coleoptera	Tenebrionidae	teneb, w/dark punctures on elytra
COENNDDET	Collembola	Entomobryidae	entomobryid sp.
COSMNDDET	Collembola	Sminthuridae	sminthurid sp.
DIBONDET	Diptera	Bombyliidae	bombyliid sp.
DICENDET	Diptera	Cecidomyiidae	cecidomyiid sp.
DICHNDET	Diptera	Chironomidae	chironomid sp.
DIEMNDET	Diptera	Empididae	empidid sp.
DIADNDET	Diptera	not determined	fly sp.
DISYNDET	Diptera	Syrphidae	syrphid sp.
HECONYND	Heteroptera	Coreidae	nymph
HELYNYND	Heteroptera	Lygaeidae	nymph
HELYNY01	Heteroptera	Lygaeidae	Nysius sp.
HEREEM01	Heteroptera	Reduviidae	Emesaya sp.
HERERE01	Heteroptera	Reduviidae	Reduvius sp.
HOAPNDET	Homoptera	Aphididae	aphid sp.
HOCIBRSP	Homoptera	Cicadellidae	brown, speckled
HOCIBRBR	Homoptera	Cicadellidae	cicadellid, brown w/brn wing veins
HOCIWHBA	Homoptera	Cicadellidae	cicadellid, white; banded abdomen
HOCIGROR	Homoptera	Cicadellidae	green body, orange wing
HYAPNDET	Hymenoptera	Apoidea	bee sp.

HYCHNDET	Hymenoptera	Chalcidoidea	chalcidoid sp.
HYDRNDET	Hymenoptera	Dryinidae	dryinid sp.
HYFOCRDE	Hymenoptera	Formicidae	Crematogaster depilis Wheeler
HYFOCYWH	Hymenoptera	Formicidae	Cyphomyrmex wheeleri Forel
HYFODOIN	Hymenoptera	Formicidae	Dorymyrmex insana (Buckley)
HYFOFOPR	Hymenoptera	Formicidae	Forelius pruinus (Roger)
HYFOLEMU	Hymenoptera	Formicidae	Leptothorax muscorum (Nylander)
HYTOPA01	Hymenoptera	Formicidae	Paratrechina sp.
HYFOPHCE	Hymenoptera	Formicidae	Pheidole ceres Wheeler
HYFOPH01	Hymenoptera	Formicidae	Pheidole minor workers
HYFOPOMA	Hymenoptera	Formicidae	Pogonomyrmex maricopa
HYFOSOXY	Hymenoptera	Formicidae	Solenopsis xyloni
HYICNDET	Hymenoptera	Ichneumonoidea	ichneumon wasp sp.
HYMENDET	Hymenoptera	Megachilidae	megachilid bee sp.
HYMUNDET	Hymenoptera	Mutillidae	mutillid sp.
HYADNDET	Hymenoptera	not determined	hymenopteran sp.
HYTINDET	Hymenoptera	Tiphiidae	tiphiid sp.
ISNYNDET	Isopoda	not determined	nymph
ISPOPO01	Isopoda	Porcellionidae	Porcellio sp.
ISADNDET	Isoptera	not determined	termite sp.
LEARCTND	Lepidoptera	Arctiidae	ctenuchine sp.
LEGEADND	Lepidoptera	Geometridae	geometrid adult
LEGELAND	Lepidoptera	Geometridae	geometrid larva
LEADNDET	Lepidoptera	not determined	lepidopteran adult
LELANDET	Lepidoptera	not determined	lepidopteran larva
MIMAME01	Microcoryphia	Machilidae	Mesomachilis sp. (large, pale, 2 pr ves)
MIMEPR01	Microcoryphia	Meinertellidae	Praemachilellus sp.
NEMYLAND	Neuroptera	Myrmeleontidae	myrmeleontid larva
OPCEHEN	Opiliones	Ceratolasmatidae	Hesperonemastoma pallidimaculosum
ORADNDET	Oribatida	not determined	oribatid sp.
ORACPSND	Orthoptera	Acrididae	Psoloessa nymph
ORGRGRNA	Orthoptera	Gryllidae	Gryllus navajo Weissman
ORGRGR01	Orthoptera	Gryllidae	Gryllus sp.
ORGRNE01	Orthoptera	Gryllidae	Nemobius sp.
ORTECAFU	Orthoptera	Tettigoniidae	Capnobotes fuliginosus
PRANNDET	Prostigmata	Anystidae	anystid sp.
PRBDNDET	Prostigmata	Bdellidae	bdellid sp.
PRERNDET	Prostigmata	Erythraeidae	erythraeid sp.
PSADNDET	Psocoptera	not determined	psocopteran sp.
SCVADE01	Scorpiones	Vaejovidae	Serradigitus sp.
SICEORAG	Siphonaptera	Ceratophyllidae	Orchopeas agilis Rothschild
THADNDET	Thysanoptera	not determined	thrips sp.

THLENDET	Thysanura	Lepismatidae	lepismatid sp.
TRADNDET	Trichoptera	not determined	trichopteran adult

## Plant Species Encountered in 2001

Family	Latin binomial	Common name
Agavaceae	<i>Agave utahensis</i> Engelm.	century plant
Apocynaceae	<i>Apocynum cannabinum</i> L.	Hemp dogbane, indian dogbane
Asclepiadaceae	<i>Asclepias speciosa</i> Torr.	spiny aster
	<i>Funastrum cynanchoides</i> (Dcne.) Schlechter ssp. <i>cynanchoides</i>	climbing milkweed
Asteraceae	<i>Ambrosia acanthicarpa</i> Hook.	annual burrweed
	<i>Artemisia ludoviciana</i> Nutt.	louisiana sage
	<i>Aster subulatus</i>	
	<i>Baccharis emoryi</i> Gray	emory baccharis
	<i>Baccharis salicifolia</i> (Ruiz & Pavón) Pers.	baccharis
	<i>Baccharis sarothroides</i> Gray	broom baccharis
	<i>Baccharis sergiloides</i> Gray	waterweed
	<i>Bebbia juncea</i> (Benth.) Greene	chuckwalla's delight
	<i>Brickellia californica</i> (Torr. & Gray) Gray var. <i>californica</i>	pachaba
	<i>Brickellia longifolia</i> S. Wats.	longleaf brickellbush
	<i>Conyza canadensis</i> (L.) Cronq.	horseweed
	<i>Dicoria canescens</i> Gray ssp. <i>brandegeei</i> (Gray) Kartesz, comb. nov. ined.	single seed dicoria
	<i>Encelia farinosa</i> Gray ex Torr.	white brittlebush
	<i>Encelia frutescens</i> (Gray) Gray	rayless encelia
	<i>Eriastrum</i> sp.	
	<i>Erigeron divergens</i>	fleabane
	<i>Erigeron lobatus</i> A. Nels.	fleabane
	<i>Erigeron</i> sp.	fleabane
	<i>Euthamia occidentalis</i> Nutt.	goldenrod
	<i>Gutierrezia sarothrae</i> (Pursh) Britt. & Rusby	broom snakeweed
	<i>Gutierrezia</i> sp.	snakeweed
	<i>Hymenopappus</i> sp.	
	<i>Isocoma acridenia</i>	

	Machaeranthera pinnatifida (Hook.) Shinnars	aster
	(Hook.) Shinnars ssp. gooddingii (A. Nels.) B.L. Turner & Hartman var. paradoxa B.L. Turner & Hartman	spiny goldenweed
Asteraceae (cont)	Pluchea sericea (Nutt.) Coville	arrowweed
	Porophyllum gracile Benth.	pore-leaf, odora
	Pseudognaphalium stramineum (Kunth) W.A. Weber	cudweed
	Sonchus asper (L.) Hill	spiny-leaved sow thistle
	Stephanomeria parryi Gray	desert straw
	Thymophylla pentachaeta (DC.) Small var. pentachaeta	fetid marigold
Boraginaceae	Cryptantha sp.	
	Lappula occidentalis (S. Wats.) Greene var. occidentalis	stickseed
Brassicaceae	Arabis drummondii Gray	drummond rock cress
	Descurainia pinnata (Walt.) Britt.	yellow tansy mustard
	Lepidium fremontii S. Wats.	desert alyssum
	Rorippa nasturtium-aquaticum (L.) Hayek	watercress
Cactaceae	Echinocereus triglochidiatus Engelm.	claretcup cactus
	Ferocactus cylindraceus (Engelm.) Orcutt var. cylindraceus	california barrel cactus
	Mammillaria grahamii Engelm. var. grahamii	pincushion cactus, arizona fishhook
	Opuntia basilaris Engelm. & Bigelow	beavertail cactus
Celastraceae	Mortonia scabrella Gray	mortonia, sandpaper bush
Cyperaceae	Carex aquatilis Wahlenb.	sedge
Ephedraceae	Ephedra nevadensis S. Wats.	nevada mormon tea
	Ephedra torreyana S. Wats.	torrey mormon tea, torrey joint-fir
Equisetaceae	Equisetum arvense L.	horsetail

	<i>Equisetum ×ferrissii</i> Clute (pro sp.)	horsetail
Ericaceae	<i>Arctostaphylos pungens</i> Kunth	pointleaf manzanita
Euphorbiaceae	<i>Euphorbia</i> sp.	
Fabaceae	<i>Acacia greggii</i> Gray	catclaw acacia
	<i>Alhagi maurorum</i> Medik.	camelthorn
	<i>Astragalus</i> sp.	Vetch
	<i>Melilotus officinalis</i> (L.) Lam.	white sweet clover
	<i>Melilotus officinalis</i> (L.) Lam.	yellow sweet clover
	<i>Melilotus</i> sp.	sweet clover
	<i>Parryella filifolia</i> Torr. & Gray ex Gray	dunebroom
	<i>Prosopis glandulosa</i> Torr.	honey mesquite
	<i>Psoraleidium lanceolatum</i> (Pursh) Rydb.	lemon weed
Gentianaceae	<i>Centaurium calycosum</i> (Buckl.) Fern.	buckley's centaury
Hydrophyllaceae	<i>Pholistoma auritum</i> (Lindl.) Lilja	fiesta flower
Juncaceae	<i>Juncus articulatus</i> L.	jointed rush
	<i>Juncus balticus</i> Willd.	wire rush
	<i>Juncus</i> sp.	
	<i>Juncus torreyi</i> Coville	
Lamiaceae	<i>Hedeoma oblongifolia</i> (Gray) Heller	mock pennyroyal
Liliaceae	<i>Nolina microcarpa</i> S. Wats.	beargrass
Malvaceae	<i>Sphaeralcea grossulariifolia</i> (Hook. & Arn.) Rydb.	gooseberryleaf globe mallow
Nyctaginaceae	<i>Abronia elliptica</i> A. Nels.	sand verbena
Onagraceae	<i>Oenothera elata</i> Kunth	hooker evening primrose
	<i>Oenothera pallida</i> Lindl.	pale evening primrose
Plantaginaceae	<i>Plantago lanceolata</i> L.	english plantain, buckhorn plantain
	<i>Plantago major</i> L.	common plantain
	<i>Plantago ovata</i> Forsk.	woolly plantain, inland plantain
	<i>Plantago patagonica</i> Jacq.	pursh plantain, woolly plantain
Poaceae	<i>Achnatherum hymenoides</i> (Roemer & J.A. Schultes)	indian ricegrass

	Barkworth	
Poaceae	<i>Agrostis stolonifera</i> L.	redtop
	<i>Andropogon glomeratus</i> (Walt.) B.S.P.	bushy beardgrass
	<i>Aristida purpurea</i> Nutt. var <i>nealleyi</i> (Vasey) Allred	blue threeawn
	<i>Bothriochloa barbinodis</i> (Lag.) Herter	cane bluestem
	<i>Bouteloua curtipendula</i> (Michx.) Torr.	side oats grama
	<i>Bromus catharticus</i> Vahl	rescue grass
	<i>Bromus diandrus</i> Roth	ripgut grass
	<i>Bromus rubens</i> L.	foxtail chess
	<i>Bromus tectorum</i> L.	cheatgrass, downy chess
	<i>Cynodon dactylon</i> (L.) Pers.	bermuda grass
	<i>Dasyochloa pulchella</i> (Kunth) Willd. ex Rydb.	fluff grass
	<i>Distichlis spicata</i> (L.) Greene	desert saltgrass
	<i>Elymus canadensis</i> L.	Canada wild rye
	<i>Muhlenbergia asperifolia</i> (Nees & Meyen ex Trin.) Parodi	scratch grass
	<i>Panicum obtusum</i> Kunth	vine mesquite
	<i>Pascopyrum smithii</i> (Rydb.) A. Löve	western wheatgrass, bluestem wheatgrass
	<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	common reed
	<i>Piptatherum miliaceum</i> (L.) Coss.	smilo grass
	<i>Pleuraphis jamesii</i> Torr.	galleta
	<i>Pleuraphis rigida</i> Thurb.	big galleta
	<i>Poa</i> sp.	
	<i>Polypogon monspeliensis</i> (L.) Desf.	rabbitfoot grass
	<i>Polypogon viridis</i> (Gouan) Breistr.	waterbent
	<i>Schizachyrium scoparium</i> (Michx.) Nash var. <i>scoparium</i>	little bluestem
	<i>Sporobolus airoides</i> (Torr.) Torr.	alkali sacaton

	Sporobolus contractus A.S. Hitche.	spike dropseed
Poaceae (cont.)	Sporobolus cryptandrus (Torr.) Gray	sand dropseed
	Sporobolus flexuosus (Thurb. ex Vasey) Rydb.	mesa dropseed
	Sporobolus sp.	dropseed
	Tridens muticus (Torr.) Nash	slim tridens
	Vulpia octoflora (Walt.) Rydb.	six-weeks fescue
Polemonaceae	Phlox sp.	
Polygonaceae	Eriogonum deflexum Torr.	skeleton weed
	Eriogonum inflatum Torr. & Frém.	desert trumpet
	Eriogonum racemosum Nutt.	ravenna grass
Pteridaceae	Cheilanthes eatonii Baker	eaton's lip fern
Rosaceae	Fallugia paradoxa (D. Don) Endl. ex Torr.	apache plume
Rubiaceae	Galium stellatum Kellogg	desert bedstraw
Salicaceae	Populus fremontii S. Wats.	fremont cottonwood
	Salix exigua Nutt.	coyote willow
Scrophulariaceae	Veronica americana Schwein. ex Benth.	speedwell
Solanaceae	Datura wrightii	sacred datura
Tamaricaceae	Tamarix ramosissima Ledeb.	tamarisk
Typhaceae	Typha domingensis Pers.	cattail
Ulmaceae	Celtis laevigata Willd. var. reticulata (Torr.) L. Benson	net-leaf hackberry