2002 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 the results of the Terrestrial Ecosystem Monitoring activities in riparian habitats of the Colorado River corridor of Grand Canyon National Park during 2002. This represents the second year of data collection for this project and the first opportunity to assess changes in the status of vegetation, breeding birds, waterbirds, overwintering birds, small mammals, arthropods and herpetofauna. This has also given us the opportunity to refine our understanding of the interrelationships among the various resource types (Figure 1) and to assess potential problems with our approach to cross-taxon integration and trend assessment in the monitoring data sets.

The data were collected during a series of river trips extending from January through September. Table 1 lists the trips taken, and the work performed on each trips. Some supplemental work was done during day-trips upstream from Lees Ferry through the Glen Canyon reach before the Spring trips and after the Fall trip. Unlike the Spring trip in 2001, the non-avian faunal surveys and vegetation structure measurements were split between two trips; lower half surveys were done in early April and upper half surveys were done in late April and early May to better account for phenological differences along the 240 miles and 1500 foot elevation drop between Glen Canyon Dam and Diamond Creek. Whether this will affect our interpretation of differences between the two years' surveys will be assessed after a second year of split-trip data in 2003.

Although technically one can define trends from only two years of consistently collected data, we believe that this year's findings constitute more of a weather report on 2002. The common theme throughout this report is the effect of extremely dry conditions in 2002 following a near-normal year of winter snow and monsoon rain in 2001. The hydrograph from the USGS Grand Canyon gage (Figure 2) showed slightly lower flows in 2002 than in 2001, but rainfall was very different in the two years. Most areas in northern Arizona experienced record low precipitation for much of early 2002. It was only during the last several days of our fall trip that most areas in the Canyon received their first precipitation since late in 2001. Annual plants, which rely on rainfall for germination and growth, and herbaceous perennials, whose size is strongly related to soil moisture, were nearly non-existent outside of the near-shore areas. Numbers of juvenile mammals and herps were much lower in 2002 than in 2001, and the flush of seed-eating bugs seen in 2001 was non-existent in 2002.

Within this report, each taxonomic group is covered in a separate section by the investigator or investigators who oversee the work on that group. In each section are described the purpose, objectives, methods, and results of the work performed, along with a summary with some interpretation of patterns seen. There is also a section which covers a first pass at the integration of faunal patterns with vegetation structure, and concordances among the species composition of the vegetation and the animal taxa. In the final section, we have brought up some problems encountered in 2002 and some continuing issues from 2001.

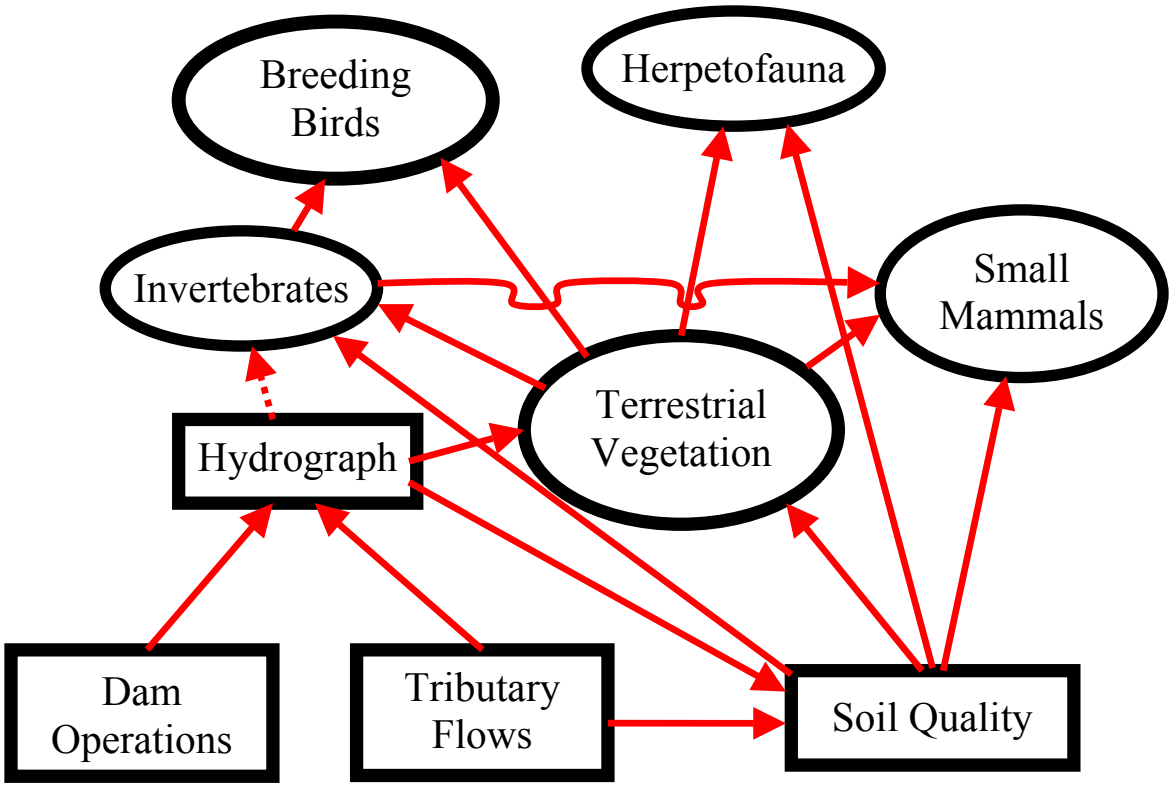

Figure 1. Conceptual model of interrelated biotic and abiotic components in the terrestrial riparian habitats of the Colorado River corridor of Grand Canyon.

Table 1. Terrestrial Ecosystem Monitoring Project 2002 Field Activities

		Avifauna				Vegetation					
Trip	Dates	Breeding Birds	SWWFL Surveys	Overwintering Birds	Waterbirds	Vegetation Structure	Vegetation Dynamics	Survey Transect Layout	Invertebrates	Mammals	Herpetofauna
1	Jan 26 - Feb 4			X	X			X			
2	Mar 30 - Apr 14	X				X[1]			X[1]	X[1]	X[1]
3	Apr 26 - May 11	X				X[2]			X[2]	X[2]	X[2]
4	May 15 - May 31		X[3]								
5	May 30 - Jun 15	X	X						X		X
6	Jun 22 - Jul 10		X[4]								
7	Aug 29 - Sep 13						X		X	X	X

[1] Non-Avifauna sampling from Phantom Ranch to Diamond Creek only
[2] Non-Avifauna sampling from Lees Ferry to Phantom Ranch only
[3] Willow flycatcher survey performed by Frank Brandt on an NPS trip
[4] Willow flycatcher survey performed by Arizona Game and Fish personnel

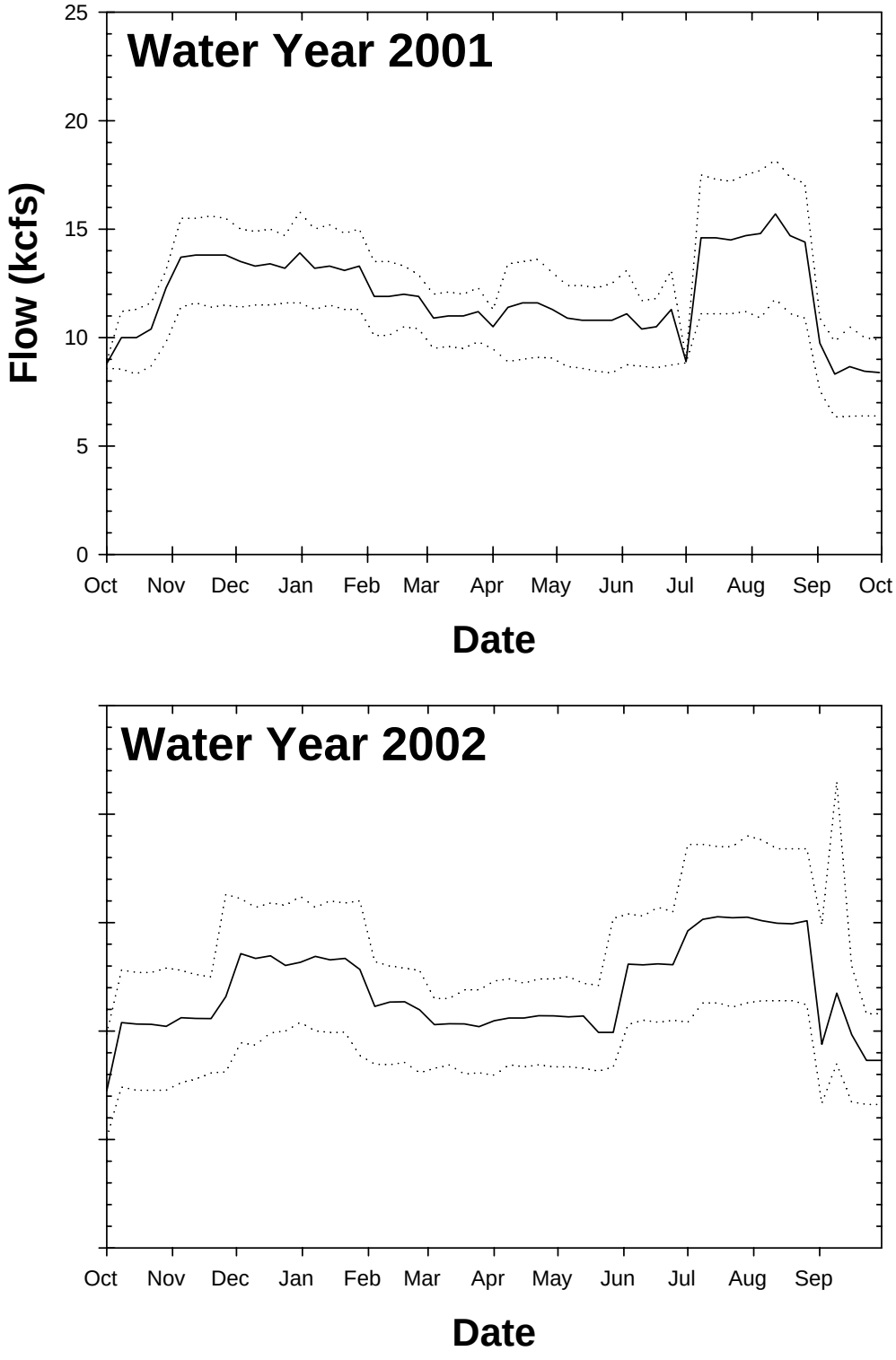

Figure 2. Colorado River flows recorded at the USGS Grand Canyon gage in 2001 and 2002. Solid line represents mean weekly flow, dotted lines indicate weekly maximua and minimua.

Small Mammals

Prepared by J.K. Frey
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Purpose: The purpose is to inventory and monitor the mammalian fauna of the Grand Canyon riparian zone in relation to water stage elevation.

Objectives: The objectives were to 1) generate a compete 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: During 2002 mammal sampling was conducted twice at 14 sites (of which 8 were surveyed for the first time) during 5 April to 1 May and 28 August to 12 September.

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 4,200 trap-nights during the 2002 year.

Bats.—Due to logistical constraints, bat sampling was discontinued.

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.

Results:

Small Terrestrial Mammals.— Overall, small mammal abundance was about 50% lower in 2002 (3.8 captures per 100 trap-nights) than in 2001 (7.1 captures per 100 trap-nights). However, overall richness was slightly higher. With the exception of the white-throated woodrat (*Neotoma albigula*), all species captured in 2001 were also captured in 2002. In addition, there were two new species captured during 2002, including Ord's kangaroo rat (*Dipodomys ordii*) and the western harvest mouse (*Reithrodontomys megalotis*), bringing the total number of small mammal species captured during the study to 9. In summary, during 2002 a total of 331 individuals of 8 species were captured including (in order of decreasing abundance; reported as number per 100 trap-nights): *Peromyscus eremicus* (2.1), *Peromyscus crinitus* (0.5), *Peromuscus boylii* (0.4), *Neotoma lepida* (0.3), *Chaetodipus intermedius* (0.3), *Perognathus formosus* (0.1), *Reithrodontomys megalotis*(<0.01) and *Dipodomys ordii* (<0.1). In addition, two *Neotoma* were captured that escaped before they could be examined in detail in order to obtain an identification (observations suggested that they were *N. lepida*).

The difference in total numbers of small mammals captured during 2001 and 2002 is primarily due to a failure of most species to recruit additional individuals during the summer of 2002 (Fig. 1). Total relative abundance was similar during spring 2001 and spring 2002.

However, a dramatic increase in abundance during fall 2001 was not found in fall 2002. The only species to exhibit an increase in abundance from spring to fall 2002 was *Peromyscus eremicus*, which is the most abundant species at all times. Most other species remained static in abundance during this time. A notable exception is that *Reithrodontomys megalotis* was only captured during this year, including at a location that had been surveyed during 2001 (46.7R). This species is typically associated with dense, tall herbaceous growth, usually in relatively mesic sites. Although it is possible that habitat changes or sampling error could have resulted in the difference in detection from 2001 to 2002, it is also feasible that competitive release, due to the suppressed numbers of other cricitine rodents, could account for this difference. *Dipodomys ordii* also was only captured during 2002. This, however, was likely due primarily to sampling error because it was captured at Lees Ferry (-0.4R), which had not been sampled during 2001. The species was previously reported from this area. The reason for our failure to capture *N. albigula* during 2002 is also unknown. However, this species is rare in the Grand Canyon. Hoffmeister (1981) only reported two locations for the species in the canyon, at the lower end of Prospect Valley and at Granite Park (208.5R); the species is not known from north of the Colorado River.

Like 2001, most (50% in 2002, 44% in 2001) small mammals were captured in the old (highest) water zone. This zone is often associated with the steeper sides of the canyons that afford more structure for small mammals. In addition, two rare species (*Perognathus formosus, Dipodomys ordii*) have only been captured in this zone. Each of the other species has been caught in all three zones. Also as in 2001, the relative abundance of small mammals in the water or new water zones was similar, although slightly higher in the new water zone.

Medium and Large Mammals.—A total of 17 additional species of mammals (or their sign) were observed during 2002. Species that were not observed in 2001 but were observed during 2002 included: desert cottontail (*Sylvilagus audubonii*), black-tailed jackrabbit (*Lepus californicus*), mountain lion (*Puma concolor*), and gray fox (*Urocyon cinereoargenmteus*). In addition, calls of two species of bat (*Euderma maculatum* and *Nyctinomops macrotis*) were heard and two bats (either *Myotis californicus* or *Myotis ciliolabrum*) were observed. The leporids were only observed at Lees Ferry (-0.4R) where relatively level desertscrub habitats converge with the riparian zone. Although both are common on the rim, Hoffmeister (1980) did not report specimens of either species from within the canyon.

Voucher Specimens.—A total of 3 individuals of the two new species detected during 2002 (*Dipodomys ordii, Reithrodontomys megalotis*) 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: Small mammal abundance was lower during 2002 than in 2001 due to a failure of recruitment during the summer. Of the 7 species captured in 2001, only one rare species (*N.*

albigula) was not captured during 2002. In addition, there were two new species captured during 2002 that were not captured in 2001. An additional 17 species of mammals were observed but not captured. This included four that had not been detected during 2001. A total of 26 species of mammal was identified as occurring in the river corridor of the Grand Canyon during 2001 and 2002. With increased sample sizes, important patterns are beginning to emerge. For example, the old high water zone has the highest abundance and richness of mammals; some species have only been detected in this zone.

Figure 1. Small Mammal Relative Abundance by Sample Period

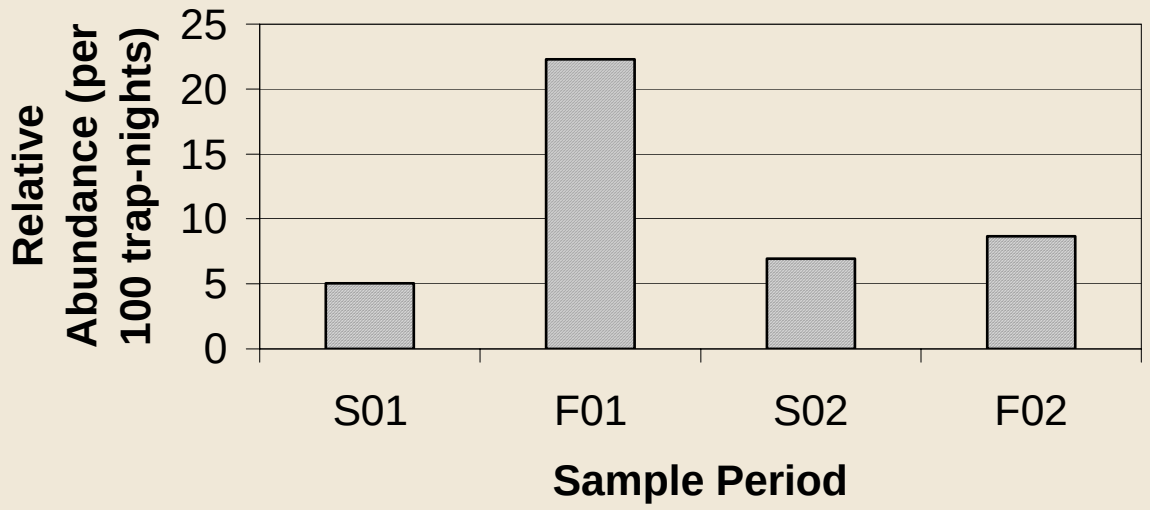


Figure 2. Relative Abundance of 6 Small Mammals for Each Sample Period

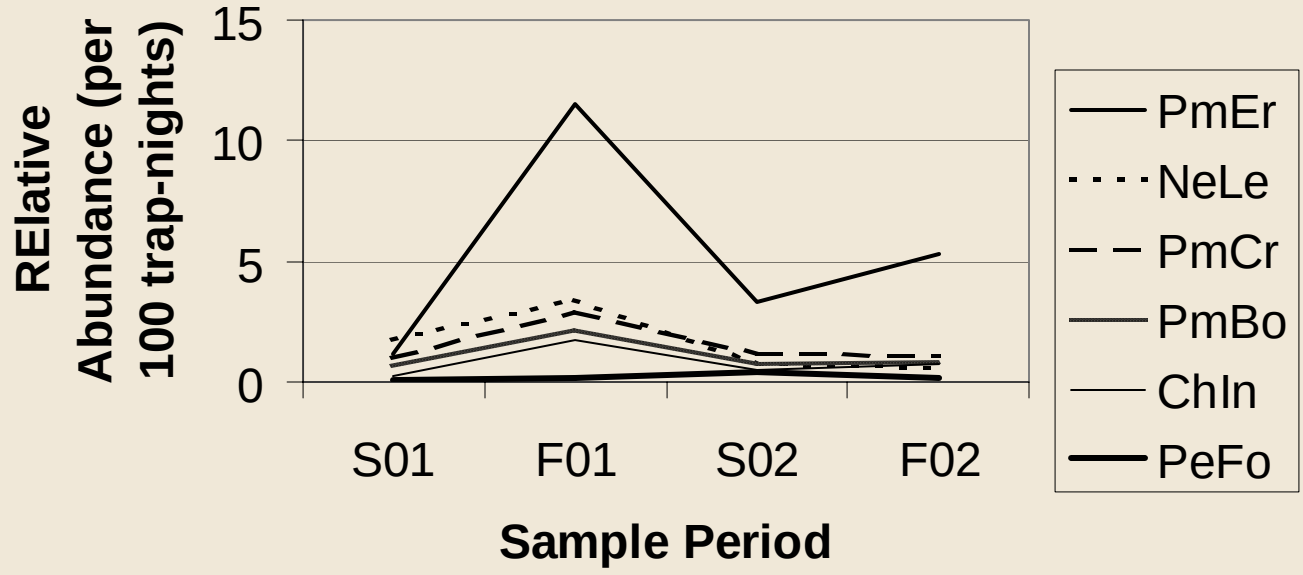
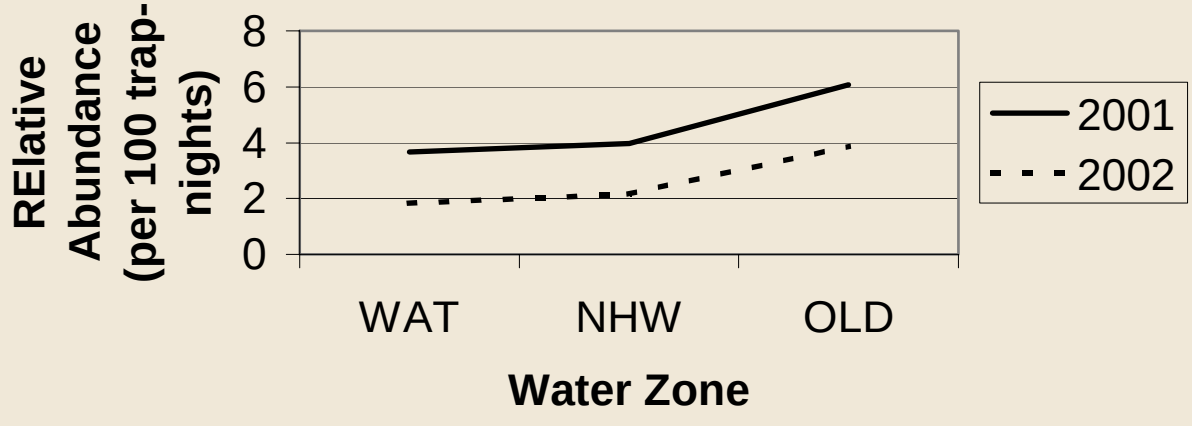


Figure 3. Small Mammal Relative Abundance by Water Zone



Avifauna

Winter Birds
Overwintering Waterbirds, Raptors and Winter Riparian Bird Surveys

Helen Yard
Helen Yard Consulting

Purpose:

The purposes of the winter bird studies are to 1) continue to document the abundance, spatial distribution and composition of overwintering waterbirds and raptors and by using boat-based surveys 2) to document the distribution and composition of riparian birds along the river corridor using area searches (walking surveys).

Objectives:

The principal objectives were to 1) determine trends in abundance and distribution of overwintering waterbirds and raptors as related to river productivity which is known to decrease exponentially going downstream from Glen Canyon Dam, and 2) to determine trends in the abundance and distribution of winter riparian bird species in the vegetation along the river corridor.

Methods:

Waterbirds and Raptors: Waterbird and raptor abundance was estimated using methods consistent with Stevens et al. (1997). In summary, waterbirds (ducks, wading birds and shorebirds) and raptors were counted and identified by one to three observers from a motorized raft moving slowly downstream. Only birds that passed by the boat or flew upstream were counted, providing a conservative estimate of abundance. Criteria recorded for surveys included start and stop times, species, number of birds, river mile and geomorphic reach (Schmidt and Graf 1990; Table I).

Waterbird counts were standardized for species/area effects (each reach being a different length and width) using the formula for Adjusted Rate of Encounter [AARE = (Number of birds)/(Reach Area)/(Duration of observation)] described by Stevens et al.(1997). No adjustments are necessary for reporting raptor abundance.

Riparian Birds: Two surveyors conducted walking surveys (area searches) consistent with methods that were implemented in past winter bird studies (Sogge 1997, Spence 1997-2000). One surveyor walked in each vegetation zone of vegetation. Criteria recorded included site (river mile), zone, species, number, activity (sing, call, perch, fly, forage), and substrate where bird was detected. Surveys began ~1 hour after dawn and continued until dusk when necessary.

Results:

Field Trip Dates: January 26 - Feb 5, 2002 (11 days).

Waterbirds: Three surveyors counted waterbirds from a boat from Glen Canyon Dam to Lake Mead during the winter field trip. We counted 2365 individuals of 18 species of waterbirds during the winter trip, 2002. The highest number of waterbirds was counted from Reach 1 (beginning at Glen Canyon Dam), through Reach 2 (below Paria Creek) (Table 2). Numbers

dropped dramatically from Reach 2 through 4, rose slightly in Reach 5 (above the Little Colorado River), then dropped as we continued downstream (Fig. 1). These findings are consistent with past waterbird studies (Stevens et al. 1997, Spence 1997 - 2000) and with river productivity and sediment data currently collected being by Yard (1996 – 2002, in progress). Again, the data exemplify the drop in waterbird abundance related to the exponential increase in sediment and decrease of productivity going downstream from Glen Canyon Dam.

Raptors: A total of 21 raptors of six different species were counted from Glen Canyon Dam to Lake Mead. The highest number of raptors was counted in Reach 2. Bald Eagle was the most common raptor seen during the winter 2002 field trip (Table 2).

Riparian Birds: Of the 56 patches surveyed during the 2001breeding season, 33 were surveyed for winter riparian birds. Shorter trip length and day length restricted the number of surveys we were able to conduct. In all, we counted 184 individuals of 20 species of birds in the riparian vegetation from Lees Ferry to Lake Mead during the winter trip, 2002 (Table 3). Riparian birds appeared to have a similar distribution between the two vegetation zones (Fig. 2).

Summary:

1. Waterbird abundance drops longitudinally as you move downstream from Glen Canyon Dam to Lake Mead related to sediment input and dropping river productivity as you move downstream. These findings are consistent with previous and current studies on light and turbidity
2. Raptors are distributed throughout the canyon. The most common raptor detected during 2002 was the Bald Eagle.
3. The most common winter riparian species is the Ruby-crowned Kinglet. No distribution difference of riparian winter birds was found between zones.

Southwestern Willow Flycatcher Surveys and Nest Searches

Helen Yard
Helen Yard Consulting

Purpose:

Principal objectives for Southwestern Willow Flycatcher surveys and nest searches are in compliance with Management Objective (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:

The objectives were to 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 when possible.

Methods:

Willow Flycatcher Surveys. Southwestern Willow Flycatcher surveys were conducted during the three survey periods required by the official multi-agency protocol (Sogge, et al. 1997). We surveyed all sites from Lees Ferry to Diamond Creek that were specified by Johnson and Spence (Spence et al. 1998a). All surveys were in compliance with official protocol methods. In summary, these methods require the surveyor to walk through the site playing a tape or CD of the song and calls of the Southwestern Willow Flycatcher every ~100 yards 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.

Willow Flycatcher Nest Searches. Nest searches were to be conducted in the event a pair of Southwestern Willow Flycatchers was identified. These searches were to be conducted according to the official protocol (Rourke et al. 1999) at RM 50.4L.

Results:

Willow Flycatcher Surveys. We surveyed 16 sites historically surveyed for Southwestern Willow Flycatchers from Lees Ferry to Diamond Creek during the 2002 breeding season (Table 3).

As many as four willow flycatchers were detected during formal surveys at three different sites along the river between Lees Ferry and Diamond Creek during 2002. Logistical constraints prevented us from surveying sites RM 191.1R and 191.2 - 196.0L during the time-frame required by the official protocol (dawn until 10:00) during the first survey period. However, during this survey period one flycatcher responded to the tape playback at RM 191.2R though the survey was conducted in the afternoon. During the second survey period, one willow flycatcher was detected singing at RM 50.4L then a pair of willow flycatchers was detected at RM 50.4L during the third survey period. We cannot assume that the willow flycatcher observed during the second survey was the same bird found during the last survey without positive identification such as colored leg bands.

Nest Searches. From territorial behavior exhibited by the willow flycatcher pair at 50.4L by the Arizona Game and Fish biologist, a nest was most likely present at the site. The biologist conducted a nest search according to the official protocol, but did not locate the nest. We were unable to access the site again during the breeding season to determine if there was a nest at the site.

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

Summary

Surveys reveal a low number of Southwestern Willow Flycatchers with a detection average of 3.5 birds along the Colorado River during 2001 – 02. Only one pair of Willow Flycatchers was suspected to nest between Lees Ferry and Diamond Creek during 2002 though the nest was not located by the Game and Fish biologist. This information was consistent with previous records of nesting Willow Flycatchers from data collected by Sogge (1993 – 1996) and Spence (1997 – 2000).

Breeding Bird Assessment and Surveys

Helen K. Yard and John G. Blake
Helen Yard Consulting

Purpose:

The principal purpose of breeding bird studies are to continue to monitor breeding bird abundance and species composition along the Colorado River, Grand Canyon.

Objectives:

Principal objectives for our bird studies were to 1) estimate the number of breeding pairs in14 monitoring sites, 2) document avian density, abundance, species richness and composition between vegetation zones and seasons (April, May and June 3) test for differences in avian density, abundance and species composition between zones and seasons, 4) test for species composition of bird communities above and below the Little Colorado River and, 5) compare avian abundance and species between years, and 6) 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 breeding bird assessments and surveys were specified by the original Request for Proposals submitted by GCMRC. A total of 57 sites were chosen for avian surveys in 2001, 64 sites were chosen in 2002 with 17 sites being surveyed during both years. Fourteen sites were selected for monitoring (camp) sites where all terrestrial resources (mammals, invertebrates, herpetofauna and vegetation) were surveyed during 2001 and 2002, five of the 14 sites were monitored both years.

Breeding Pair Assessment. Riparian breeding bird assessments were conducted at the14 monitoring sites during three field trips, 2002 (see dates elsewhere in document). Assessments began in the afternoons upon arrival at camps, continued until dusk, then resumed the following morning after point counts and walking surveys. Assessments were continued through the morning until all other terrestrial monitoring activities were concluded (approximately 11 AM). Equal time was spent mapping singing males and pairs in each vegetation zone though breeding assessments are made for the entire patch. Location within the patch, species and sex of each bird observed was spot mapped onto aerial photographs with permanent markers at each site by a minimum of two observers. Numbers of singing males and confirmed pairs of birds were summarized before leaving each site. We counted singing males as a pair (Mills et al. 1991, Wiens 1992) and attempted to confirm the presence of a female in a territory where a male was detected singing.

Walking Surveys. Surveyors spent up to 40 minutes walking at a consistent pace through each vegetation zone in each patch. OHWZ and NHWZ zones were surveyed independently (one observer walking each zone concurrently). Observers walked on established trails or chose a path of least resistance where no trails existed (repeated on each trip) to minimize impacts and multiple trailing. Surveyors recorded date, time, site, vegetation zone, species, age, sex, detection type (visual/auditory), estimated perpendicular distance from the observer to each bird (Buckland et al. 1992, 2001), plant or substrate where the bird was

detected, activity (sing, call, perch, fly, forage, breeding bird behavior [Corman 1994]), and relevant notes.

Point Counts: Counts were conducted at the same patches as with the walking surveys. Count lengths were 5 minutes divided into 0 - 3 and 3 - 5 minute intervals. Point counts were conducted at existing flagged stations established by Spence et al. (1998 – 2000) when patches were repeated in both studies. In new patches, stations were established by walking 50 meters into the patch at the transition zone between the OHWZ and NHWZ zones, conducting the 5 minute point count, then proceeding100 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. Surveyors recorded the same criteria on the data sheets that was recorded during walking surveys. GPS readings were taken at point count stations in each patch where possible.

Analyses

Abundance and Density: Students paired t-tests were used to examine differences in the abundance and density of birds found within NHWZ habitat to those found within OHWZ habitat. This test examines use (presence) of birds in each zone at the time of the survey and does not assume that the data is independent. We also compared how abundance may differ within a given zone (NHWZ, OHWZ) from one trip to another to examine seasonal variation in abundance. When multiple comparisons were made (e.g., using paired t-tests to compare results between pairs of trips), we used the Dunn-Šidák procedure to calculate an experimentwise error rate, where $\alpha' = 1 - (1 - \alpha)^{1/k}$ (k = number of intended tests) (Sokal and Rohlf 1995).

Species Composition: We compared species composition between zones and among seasons. Sample patches differ in area, which is likely to influence the number of individuals (and species) recorded. Thus, comparisons based on raw numbers unstandardized by area (i.e., an estimate or index of density) may obscure differences in composition that are unrelated to area. We used a relativization procedure to partially account for any effects of area on numbers of individuals counted. Counts of individuals were standardized by using the maximum value recorded for a species. We first relativized species abundances within samples (across species) and then within species (across samples). This procedure has the effect of eliminating differences in total numbers of individuals among samples and tends to equalize the importance of common and uncommon species. Thus, it reduces the effect of total quantity (abundance) to focus more directly on relative quantities (McCune and Grace 2002). We omitted sites where no birds were recorded for all analyses that depended on calculation of a similarity matrix. Such sites typically were represented by very small areas of habitat (e.g., little if any OHWZ zone vegetation in a number of different sites).

We used analysis of similarity (ANOSIM; described in Clarke and Warwick 2001) to compare the level of similarity in species composition among a set of related sites (OHWZ, NHWZ) to the level of similarity across all sites (i.e., to determine if predefined groups differed in species composition). For example, ANOSIM allows us to determine if all NHWZ samples and all OHWZ samples are more similar within their respective zones than are samples taken at random from all samples (i.e., including comparisons across zones). ANOSIM is a nonparametric permutation procedure that is combined with a Monte Carlo test (i.e., a general

randomization approach to the generation of significance levels) to determine if the level of similarity among samples within a group is greater than expected by chance when compared to the level of similarity among samples across all groups. When more than two groups are compared, ANOSIM first calculates a global test that indicates whether or not any difference exists among groups. This is followed by pairwise tests that evaluate levels of difference between all possible pairs of groups included in the analysis. (This procedure is conceptually similar to an analysis of variance followed by multiple comparison of means tests.) The significance of the ANOSIM test statistics are determined by comparison with the value obtained by the randomization procedure.

We also used MRPP (multi-response permutation procedure) to test the hypothesis of no difference between or among groups (McCune and Grace 2002). As with ANOSIM, MRPP is a nonparametric produced that uses ranked differences to compare similarities of samples within and between groups. In most cases, results from ANOSIM and MRPP were in general agreement, but in some cases MRPP indicated a significant difference between groups when ANOSIM did not. Thus, we take a more conservative approach and report only those results obtained with ANOSIM.

We followed the ANOSIM analysis with an indicator species analysis (Dufrêne and Legendre 1997, McCune and Grace 2002) to determine which species (if any) were particularly characteristic (indicative) of different groups. Indicator species analysis combines data on the abundances of species within samples from different groups with the frequency of occurrence of that species in the different groups being compared. A species would be a perfect indicator of a particular group if it occurred in all samples from that groups, and did not occur in samples from any other group. Indicator values are tested for significance with a Monte Carlo randomization procedure (McCune and Mefford 1999).

We used non-metric multidimensional scaling (NMDS) to graphically represent similarities (and differences) in species composition among sites (Clarke and Warwick 2001, McCune and Grace 2002). NMDS is an ordination procedure that uses ranked distances (i.e., levels of similarity or dissimilartiy) between sample units to describe the relationships among all samples. The procedure extracts a configuration of the samples in a specified number of dimensitons that describes variation in species composition among the samples and uses a Monte Carlo procedure to determine if the amount of variation described by the different axes was more or less than expected by chance (i.e., whether there was significant structure in the data).

Analysis of Variance (AOV) was used to compare the abundance of 15 common species between zones.

Species composition above and below Little Colorado River: We examined differences in species composition between those found in sites located above the Little Colorado River (LCR) to those located below the LCR with the same methods used for between season and zone comparisons (ANOSIM). Many sites above the LCR have little or no OHWZ habitat so the latter comparison was based only on samples from NHWZ. We then followed the ANOSIM analysis with an indicator species analysis.

All multivariate analyses (ANOSIM and NMDS) were run on PC-ORD, Version 4 (McCune and Mefford 1999) or PRIMER, Version 5 (Clarke and Gorley 2001). We used the Sørensen similarity measure (also called the Bray-Curtis coefficient) to calculate similarity matrices for the multivariate analyses (see descriptions of distance measures in McCune and Grace 2002). Other statistical tests were conducted using SPSS, Version 10.0.

Between year comparisons of bird abundance and species: AOV was used to compare the abundance of birds between 2001 and 2002. Students paired t-tests were used to compare the abundance of birds between the NHWZ and OHWZ between years.

Results

Breeding Pair Assessment: We detected a total of 24 breeding species at 14 monitoring sites during 2002. The highest number and density of breeding birds was detected at RM 198. The highest number of breeding species was detected at 204 (Spring Canyon) (Table 5). Overall, mean numbers and density of breeding birds were highest at the larger sites.

Walking Surveys. We conducted walking surveys at 64 patches during the 2002 breeding season. Four sites were surveyed upriver of Lees Ferry, 60 sites were surveyed below Lees Ferry. A total of 2627 passerines of 66 species were detected during surveys on three field trips in 2002. Detection numbers of birds and bird species on each trip were as follows: April - 736 birds (mean = 11.5/patch), 32 species; May - 1209 birds (mean= 19.0/patch), 52 species, and June - 682 birds (mean = 10.6/patch), 32 species. The highest numbers of birds and species were detected in May.

Point Counts. At total of 1016 birds of 48 species were detected during point counts in the breeding season, 2002. A higher number of birds (410) and bird species (39) were detected during the May trip than in April (310 birds, 27 species) or in June (296 birds, 24 species). Our point count census data combined with data collected by Spence et al. (1998b, 2000, 2001 in prep) will be used to compare bird abundance over several years. We also anticipate making our data available to assess broad scale trends in bird populations throughout the southwest, and with data being collected in the upper-and lower Colorado River basin in the future.

Abundance and density: For statistical analyses, we included migratory species, permanent, winter and summer residents species, excluding Common Raven, White-throated Swifts and Violet-green Swallows. When we compared bird abundance and density between the OHWZ and NHWZ, we found an overall higher abundance of birds in the NHWZ during the 2002 breeding season ($t = 3.4$, $P = 0.001$) (Fig's 3a and 3b). Density did not differ significantly among seasons or trips though higher densities corresponded with abundance data, being higher in the NHWZ and in May. Species richness was higher in the NHWZ throughout the season and on each trip (season - $F = 9.5$, $P = 0.002$, zone - $t = 3.6$, $P < 0.05$, Fig. 4).

Species composition: We first used a two-way ANOSIM to compare species composition across all trips and between the two high water zones. Results indicated that species composition differed across trips (Global $R = 0.063$, $P < 0.001$; all pairwise comparisons between trips were significant at $P < 0.002$ or better) and between zones ($R= 0.026$, $P < 0.01$). We next compared species composition of NHWZ and OHWZ habitats separately for each trip. This was done to examine how use of the different habitats might change from one trip to the next. If species shift in their patterns of habitat use we, might expect to find changes in the distinctiveness of the different groups, and changes in which species were (or were not) selected as indicators of a particular habitat.

We included 104 sites and 35 species in the analysis for the first trip. Although a series of species were more characteristic of one zone over the other (e.g., Blue-gray Gnatcatcher was characteristic of OHWZ; Table 6), the two zones did not differ substantially in overall species composition (ANOSIM $R = 0.019$, $P < 0.119$). Consequently, samples representing the different habitat zones overlapped substantially in space defined by a NMDS analysis (Fig. 5). In

contrast, new and old high water zones differed in overall species composition during the second trip (R= 0.026, P < 0.05) (Table 6, Fig. 5); more species were selected as indicators of NHW than OHW. Species composition again did not differ between zones during the third trip (R= -0.02, P > 0.50; Table 7, Fig. 6), although two species still were selected as indicators of the NHWZ.

To further analyze seasonal shifts in use of the two habitats, we compared how species composition of each zone changed from one trip to the next (i.e., comparisons were made across trips within a zone rather than between zones). Species composition of NHWZ differed among trips (ANOSIM Global R = 0.061, P < 0.001; Trip 1 - Trip 2, R = 0.074, P < 0.002; Trip 2 - Trip 3, R = 0.052, P < 0.003; Trip 1 - Trip 3, R = 0.056, P < 0.002) (Fig. 6). A variety of species contributed to the differences in overall species composition within zones among trips (Table 7), with many more species selected as indicators of the second trip. In contrast to the NHWZ, differences among trips were much less pronounced within OHWZ (Global R = 0.008, P < 0.24; no paired comparisons significant) (Fig.6). Nonetheless, several species were selected as indicators of a particular trip (Table 7). Thus, these comparisons suggest greater change in species composition within NHWZ than within OHWZ.

Using AOV, we compared the abundance of 15 common bird species between zones to examine distribution. Results showed four species were found in significantly higher abundance in the NHWZ (Table 8). Species found in higher abundance in the NHWZ include Common Yellowthroat, Yellow Warbler, Say's Phoebe, and Song Sparrow. None of the other15 common species were shown to have significantly higher abundances in the OHWZ during 2002.

Species composition above and below the Little Colorado River: We based our comparisons of species composition of sites above and below the Little Colorado River (LCR) on data from NHWZ only; sites were omitted from analyses if no birds were recorded during a particular trip. Trip 1 had 31 species distributed across 25 sites above and 34 sites below the LCR; trip 2 had 48 species across 26 sites above and 34 below; trip 3 had 40 species across 24 sites above and 34 below. Composition of bird communities above the LCR differed from those below the LCR during all three trips (ANOSIM: trip 1 - R = 0.221, P < 0.001; trip 2 - R = 0.113, P < 0.002; trip 3 - R = 0.0.66, P < 0.05) (Fig. 8). During each trip, a limited set of species was selected as indicators of sites above or below the LCR (Table 9). For example, during the first trip, Canyon Wrens were restricted to sites above the LCR whereas Bell's Vireo and Lucy's Warbler were more characteristic of sites below. As the season progressed, Lucy's Warbler spread farther upriver and was not selected as an indicator species during the second or third trips. In constrast, Bell's Vireo remained downriver and was selected as an indicator species for all trips.

Between year comparisons of bird abundance and species: No difference was found in the abundance of birds between 2001 – 02 (F = 3.6, p > 0.05). A significant difference was found in the abundance of birds between zones during each year. In 2001, an overall higher abundance of birds was detected in the OHWZ (Kearsley et al, 2001), a higher abundance of birds was recorded in the NHWZ in 2002 showing a pattern reversal (Fig. 9) (F = 9.4, p < 0.05).

When we compared the abundance of 15 common species between 2001-2002, we found that only two species showed differences. Black-chinned Hummingbirds were in higher abundance in 2002 than 2001 and Mourning Doves were in lower abundance in 2002 than 2001 (Table 10).

Table 11 shows differences in the species ranked from one through 15 during 1998 (Spence 1998), 2001 and 2002. There were differences found among the top 15 species among years. Three species found to be among the top 15 in 1998 were not included in top 15 in 2001, 2002. Three species were among the top 15 in 2001 and 2002 not included in 1998. This may be due to sampling differences (point counts versus walking survey). We will be able to detect if trends are apparent when we can analyze the data collected in the previous study.

Summary

1. Breeding Pairs Assessment: Mean number and density of breeding pairs was higher in largest sites, highest mean numbers of pairs being counted at RM 's198 and 204. Species diversity of breeding birds was highest at RM 204 (Spring Canyon) and 198.
2. Abundance and density across zones and seasons : Overall higher abundance and density of birds was detected in the NHWZ in 2002. A higher abundance of birds was detected during May due to higher numbers of migrants and winter birds.
3. Species composition among seasons and between zones: Composition of some species was different between zones and seasons. Higher numbers of some species were detected in the NHWZ, no species had significantly higher numbers in the OHWZ. Future inclusion of distribution and seasonal changes in arthropods in the riparian vegetation may lead to a better understanding avian abundance and species composition between zones and seasons.
4. Species composition above and below the Little Colorado River: Species composition was different above the Little Colorado River when compared to below the tributary. This was primarily due to the absence of Bell's Vireo above the Little Colorado River and seasonal movement of birds with a higher species composition in the lower portion of the canyon in spring (April). Four of 15 common species were in higher abundance in the NHWZ.
5. Between year comparisons of bird abundance and species: No difference was found in abundance of birds between 2001 – 2002, though zonal comparisons showed a reversal in patterns. Avian abundance was overall higher in the OHWZ in 2001, while a higher abundance of birds was found in the NHWZ in 2002. Two of 15 common species showed differences in abundance between years, one being found in higher numbers in 2002 than 2001, one dropping in numbers from 2001 – 2002 during surveys. Higher abundance of birds found in the NHWZ in 2002 was probably related to the lack of abundance and diversity of arthropods in the OHWZ which may be related to lower than normal precipitation in 2002.

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Table I. Geomorphic reaches defined by miles and kilometer, actual number of waterbird and raptors counted by reach, winter 2002.

Reach #	Reach name	River Miles	River Kilometers	Waterbird	Raptors
1	Glen Canyon	-15.0 – 0.6	-24.6 – 1.0	1297	2
2	Permian Gorge	0.6 - 10.8	1.0 – 17.7	678	6
3	Supai Gorge	10.8 - 2.1	17.7 – 36.2	58	3
4	Redwall Gorge	22.1 - 39.3	36.2 – 64.4	38	3
5	Marble Canyon	39.3 – 60.1	64.4 – 98.6	211	2
6	Furnace Flats	60.1 – 75.9	98.6 – 124.5	48	0
7	Upper Granite Gorge	75.9 – 115.6	124.5 – 189.5	5	0
8	The Isles	115.6 – 123.2	189.5 – 201.9	3	2
9	Middle Granite Gorge	123.2 – 137.4	201.9 – 225.3	2	0
10	Muav Gorge	137.4 – 157.0	225.3 – 257.4	1	0
11	Lower Canyon	157.0 – 209.9	257.4 – 344.1	19	0
12	Lower Granite Gorge	209.9 – 235.6	344.1 – 386.2	2	0
13	Upper Lake Mead	235.6 – 273.8	386.2 – 448.9	26	3
Total				2365	21

Table 2. Number of raptors and waterbirds counted by reach from Glen Canyon Dam to Lake Mead, Winter, 2002.

		Reach													
		1	2	3	4	5	6	7	8	9	10	11	12	13	Total
	Species														
Raptors	Bald Eagle	0	1	1	2	2	0	0	2	0	0	0	0	0	8
	California Condor	0	5	1	0	0	0	0	0	0	0	0	0	0	6
	Sharp-shinned Hawk	0	0	0	0	0	0	0	0	0	0	0	0	3	3
	Northern Harrier	2	0	0	0	0	0	0	0	0	0	0	0	0	2
	Golden Eagle	0	0	0	1	0	0	0	0	0	0	0	0	0	1
	Peregrine Falcon	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	Total	2	6	3	3	2	0	0	2	0	0	0	0	3	21
Waterbirds	Common Goldeneye	209	200	5	19	73	21	0	0	0	0	1	0	0	528
	Lesser Scaup	362	28	0	0	0	0	0	0	0	0	0	0	0	390
	American Widgeon	266	37	0	0	0	0	0	0	0	0	0	0	1	304
	Mallard	56	149	10	14	55	5	0	1	0	0	0	0	0	290
	American Coot	84	167	0	0	0	2	0	0	2	0	2	1	5	263
	Bufflehead	144	53	4	0	0	0	0	0	0	0	0	0	0	201
	Common Merganser	34	22	38	0	49	7	3	0	0	0	0	0	1	154
	Gadwall	26	13	0	0	0	0	0	0	0	0	0	0	12	51
	Canada Goose	2	1	0	0	28	11	0	0	0	0	0	0	0	42
	Double-crested Cormorant	36	0	0	0	0	0	0	0	0	0	0	0	0	36
	Redheaded Duck	29	5	0	0	0	0	0	0	0	0	1	0	0	35
	Great Blue Heron	5	3	1	0	4	2	2	2	0	0	1	1	0	21
	Green-winged Teal	0	0	0	0	2	0	0	0	0	1	14	0	0	17
	Cinnamon Teal	7	0	0	0	0	0	0	0	0	0	0	0	4	11
	unid ducks	12	0	0	0	0	0	0	0	0	0	0	0	0	12
	Ring-necked Duck	4	0	0	0	0	0	0	0	0	0	0	0	0	4
	Ruddy Duck	3	0	0	0	0	0	0	0	0	0	0	0	0	3
	Belted Kingfisher	0	0	0	0	0	0	0	0	0	0	0	0	2	2
	American Dipper	0	0	0	1	0	0	0	0	0	0	0	0	0	1
	Total	1279	678	58	213	211	0	5	2	1	0	2	28	21	2365

Figure 1. Area adjusted rate of encounter (AARE) of waterbirds by reach, winter 2002

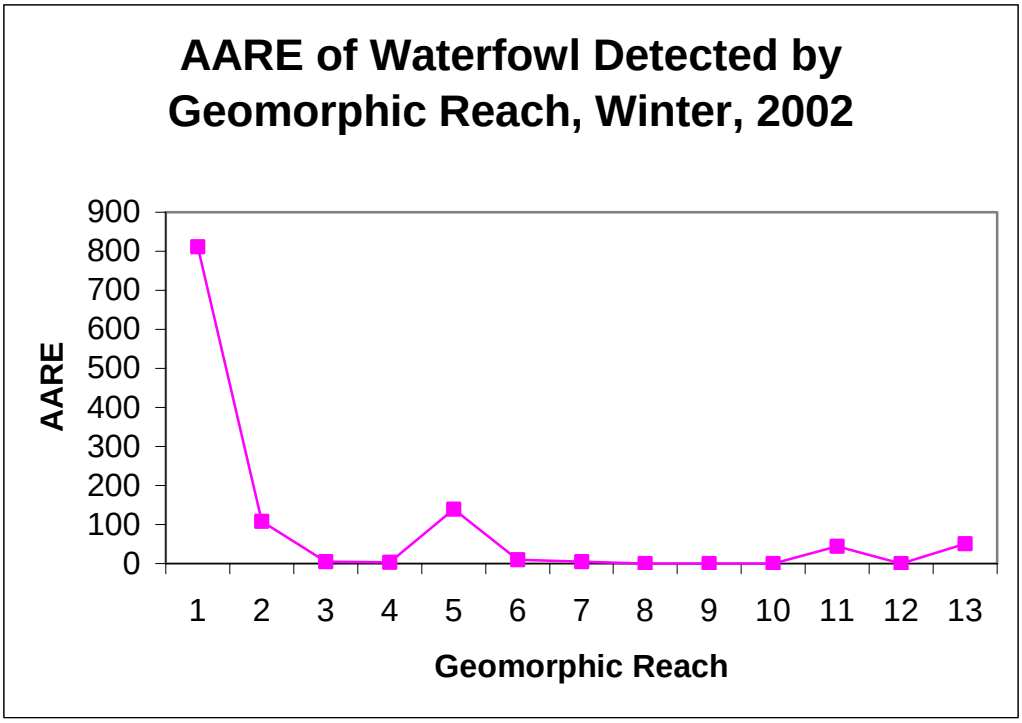


Table 3. Most common winter riparian bird species along the Colorado River, Grand Canyon, 2002.

Bird species	Rank	Frequency
Ruby-crowned Kinglet	1	70
Horned-lark	2	20
White-crowned Sparrow	3	13
Western Bluebird	4	11
Song Sparrow	5	8
Bewick's Wren	5	8
Pinion Jay	6	6
Phainopepla	7	5
Canyon Wren	7	5
Common Raven	8	4
Red-naped Sapsucker	8	4
Rock Wren	9	3
Say's Phoebe	9	3
Northern Flicker	10	2
Total		162

Figure 2. Zonal distribution of winter birds at 33 patches along the Colorado River, 2002.

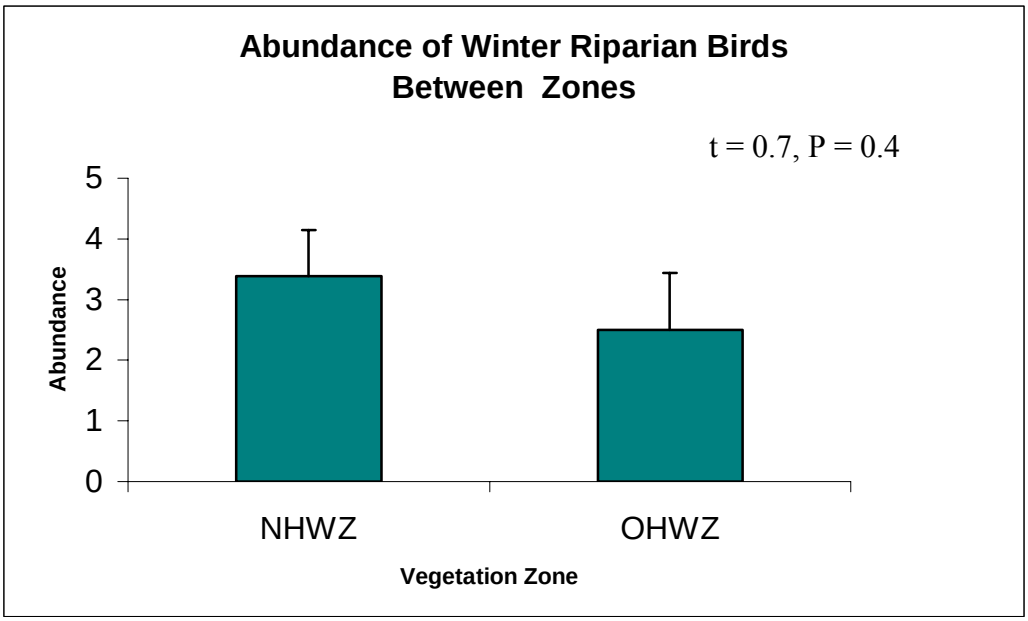


Table 4. (In Attachment 2002 Tables) Results of the Southwestern Willow Flycatcher Surveys and Nest Searching, 2001 - 2002

Dates	Survey 1 (May 15 - 31)				Survey 2 (June 1 - 21)				Survey 3 (June 22 - July 10)			
Site	2001	Observer	2002	Observer	2001	Observer	2002	Observer	2001	Observer	2002	Observer
5.2R	ns	NPS	0	FB	1	HY, MM	0	HY	0	HY	0	AZGF
43.1 - 43.8L	ns	NPS	0	FB	0	HY, MM	0	HY	0	HY	0	AZGF
46.5R	ns	NPS	0	FB	0	HY, MM	0	HY	0	HY	0	AZGF
50.4L	0	NPS	0	FB	1	HY, MM	1	HY	2*	HY	2**	AZGF
51.4L	0	NPS	0	FB	0	HY, MM	0	HY	0	HY	0	AZGF
56.0R	ns	NPS	0	FB	0	HY, MM	0	HY	0	HY	0	AZGF
65.3L	ns	NPS	0	FB	0	HY, MM	0	HY	0	HY	0	AZGF
71.1L	0	NPS	0	FB	0	HY, MM	0	HY	0	HY	0	AZGF
143R	ns	NPS	0	FB	0	HY, MM	0	HY	ns	HY	0	AZGF
191.1R	ns	NPS	0	FB	ns	HY, MM	0	HY	0	HY	0	AZGF
191.2L - 196L	0	NPS	1	FB	ns	HY, MM	0	HY	0	HY	0	AZGF
196 - 198L	ns	NPS	0	FB	0	HY, MM	0	HY	0	HY	0	AZGF
196-198R	ns	NPS	0	FB	0	HY, MM	0	HY	0	HY	0	AZGF
198R	ns	NPS	0	FB	0	HY, MM	0	HY	0	HY	0	AZGF
198.3R	ns	NPS	0	FB	0	HY, MM	0	HY	0	HY	0	AZGF
204.5R	0	NPS	0	FB	0	HY, MM	0	HY	0	HY	0	AZGF
Total	0		1		2		1		2		2	AZGF

ns - no survey

Observer - NPS - National Park Service, HY - Helen Yard, MM - Mimi Murov, AZGF - Arizona Game and Fish Department

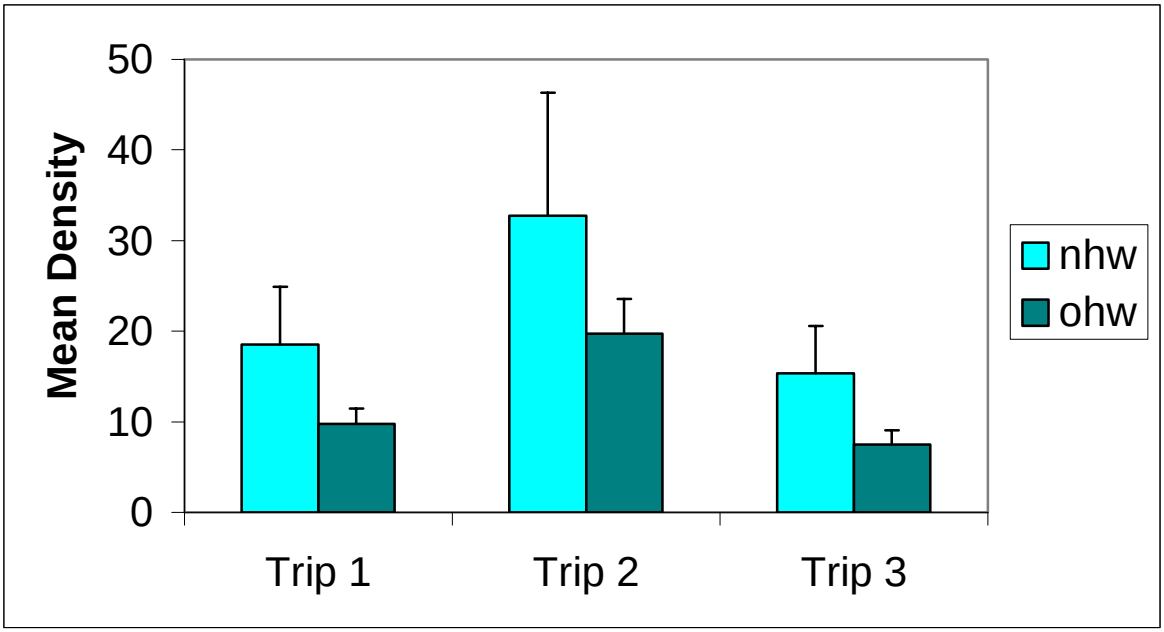
* pair of swwfs, nest with 2 swwf eggs, one bhco egg, outcome not determined

** a pair of wifls were detected. The AGF observer suspected a nest from behavioral observation, but the nest was not found.

Table 5. Estimated number, mean number, and density and # of species of breeding pairs detected at 14 monitoring sites along the Colorado River, Grand Canyon, 2002.

	Number of Breeding Pairs					
Site (River Mile)	Trip 1	Trip 2	Trip 3	Mean	Density	# of Species
0.4	1	4	3	2.67	3.31	8
8	1	2	4	2.33	1.21	5
22	1	5	7	4.33	7.45	6
37.3	1	2	7	3.33	12.73	9
46.7	8	13	38	19.67	5.54	10
65.3	4	11	18	11.00	3.69	12
92.3	1	1	1	1.00	1.27	4
122.8	13	12	7	10.67	6.29	12
133	6	1	4	3.67	4.10	8
164.5	5	3	4	4.00	2.46	6
186.0	14	12	14	13.33	3.77	10
198	30	37	14	27.00	14.09	17
204	39	23	18	26.67	8.82	18
211	10	2	5	5.67	4.96	7

Figure 3a and 3b. Mean density and abundance of passerines in each zone and trip along the Colorado River, Grand Canyon, 2002.



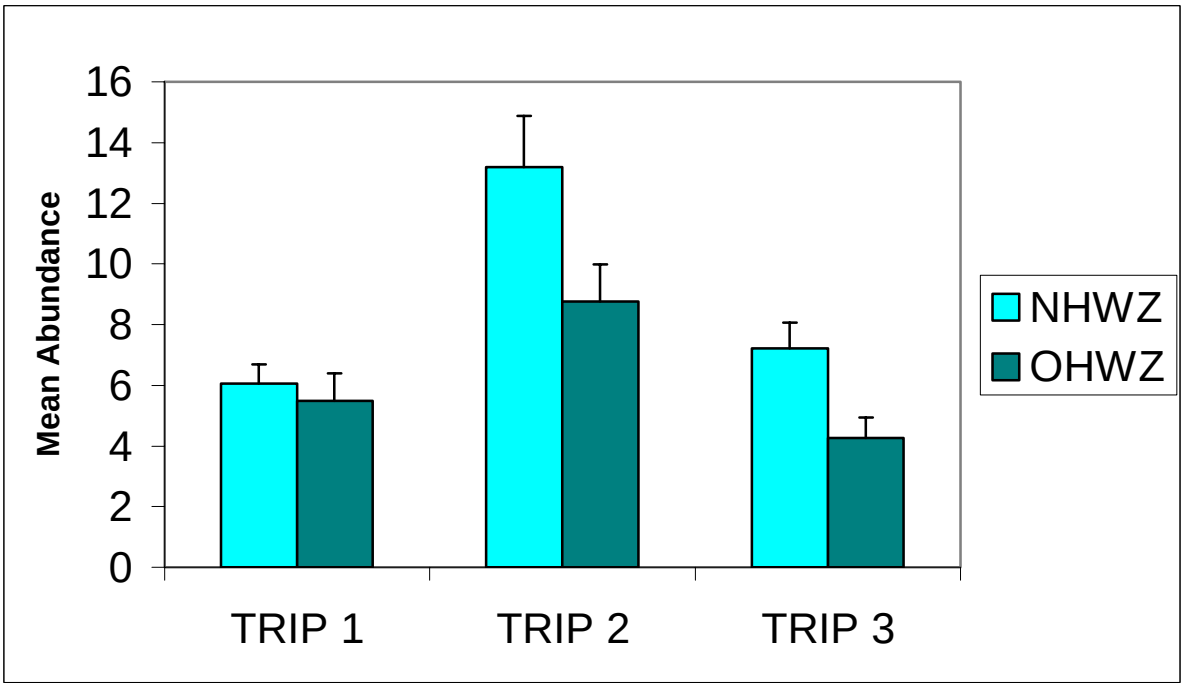


Figure 4. Species richness (number of species) between zones and seasons, 2002.

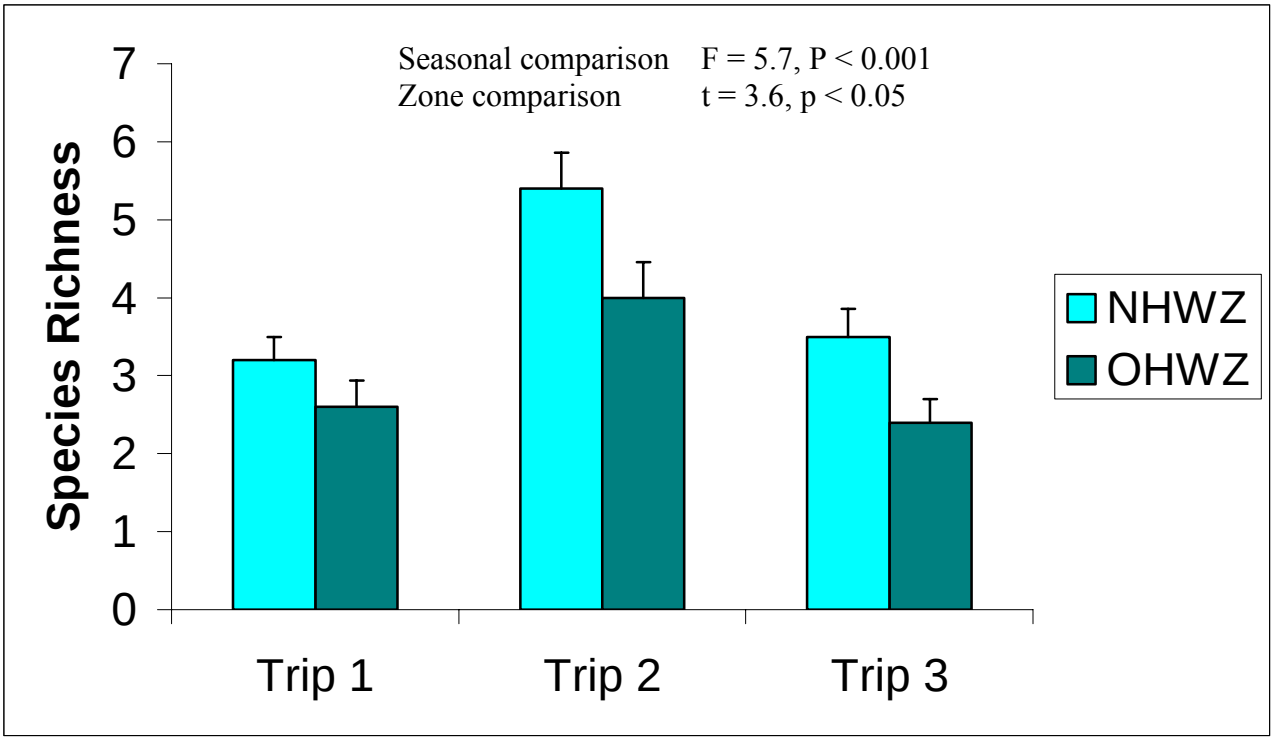


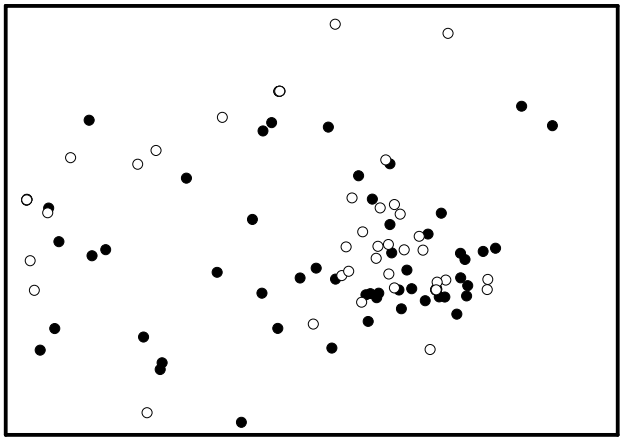
Table 6. Species selected as indicators of NHWZ or OHWZ within each trip during 2002. Significance of the species as an indicator is based on a randomization test (all species with a probability level of $P < 0.10$ are given).

	NHWZ	P <	OHWZ	P <
Trip 1	Say's Phoebe	0.032	Blue-gray Gnatcatcher	0.008
	White-crowned Sparrow	0.059	Rock Wren	0.026
	Black-chinned Hummingbird	0.063	Black-throated Sparrow	0.040
	Song Sparrow	0.067	House Finch	0.061
Trip 2	Common Yellowthroat	0.004	Ash-throated Flycatcher	0.038
	Ruby-crowned Kinglet	0.012		
	Brewer's Sparrow	0.013		
	Green-tailed Towhee	0.014		
	Song Sparrow	0.027		
	Spotted Sandpiper	0.052		
Trip 3	Yellow Warbler	0.006		
	Common Yellowthroat	0.009		

Table 7. Species selected as indicators of different trips during 2002; indicator species are listed for each zone. Significance of the species as an indicator is based on a randomization test (all species with a probability level of $P < 0.10$ are given).

Zone	Trip 1	P <	Trip 2	P <	Trip 3	P <
NHWZ	White-crowned Sparrow	0.011	Blue-gray Gnatcher	0.001	Blue Grosebeak	0.001
	Song Sparrow	0.022	Brewer's Sparrow	0.001	Yellow-breasted Chat	0.001
	Dark-eyed Junco	0.079	Wilson's Warbler	0.001	Ash-throated Flycatcher	0.002
			Yellow-rumped Warbler	0.002	Summer Tanager	0.084
			Green-tailed Towhee	0.005		
			Empidonx Flycatcher	0.006		
			House Wren	0.024		
			Mourning Dove	0.030		
			MacGillivary's Warbler	0.034		
			Yellow Warbler	0.054		
			Ruby-crowned Kinglet	0.073		
			Lazuli Bunting	0.088		
OHWZ	Song Sparrow	0.018	Yellow Warbler	0.003	Ash-throated Flycatcher	0.044
	Rock Wren	0.040	Empidonx Flycatcher	0.007	Summer Tanager	0.072
			Wilson's Warbler	0.018	Blue Grosebeak	0.091
			Blue-gray Gnatcher	0.041		
			Brewer's Sparrow	0.077		
			White-crowned Sparrow	0.092		

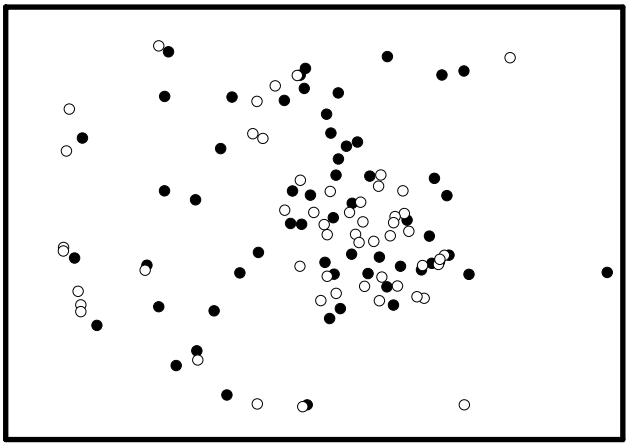
Figure 5. Analysis of Similarity (ANOSIM) - Ordination of bird community data comparing species composition between trips and zones.



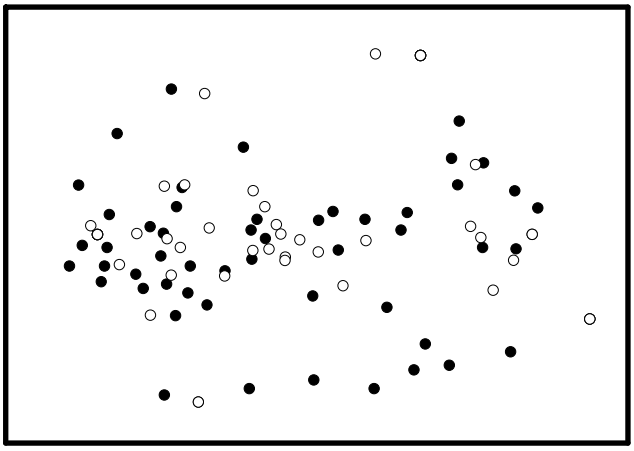
Trip 1 - 2002

Species are similar in each zone for Trips 1 and 3 (ns difference between zones).

Species are significantly different between zones during Trip 2 ($R = 0.06$, $P < 0.05$)



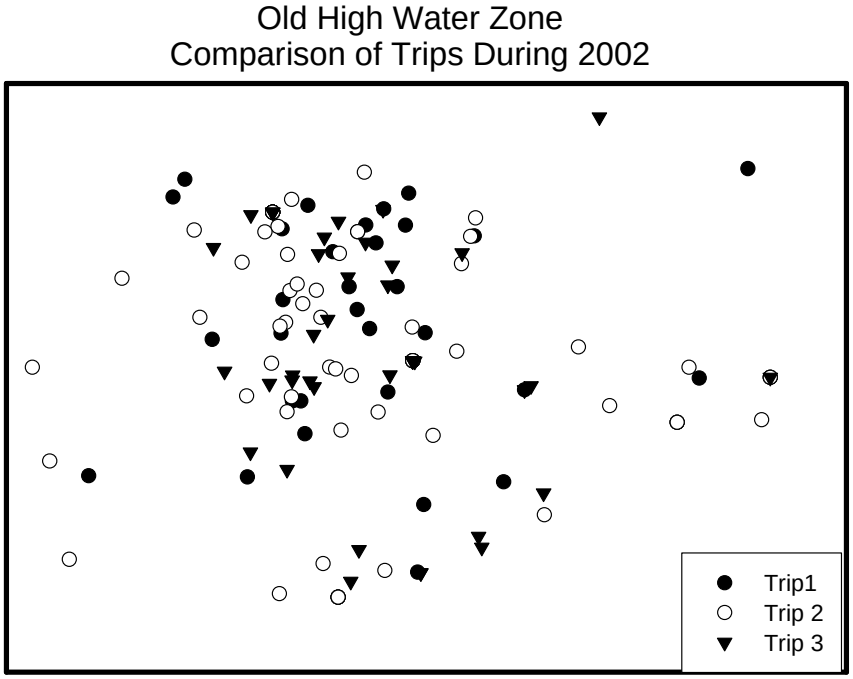
Trip 2 - 2002



Trip 3 - 2002

- New high water zone
- Old high water zone

Figure 6. New and old high water zone seasonal differences during the breeding season, 2002.



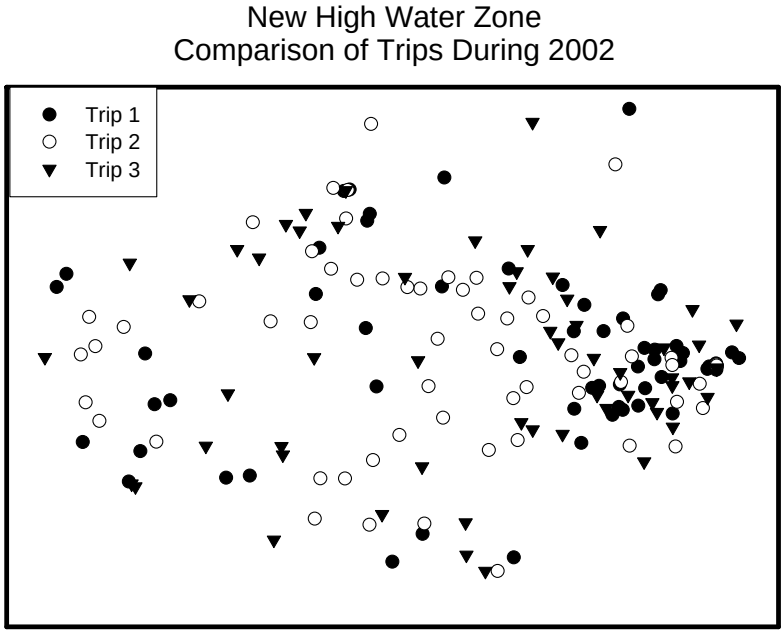


Table 8. Fifteen species compared between zones, 2002. Species in bold denote significance between zones.

Species	Zone Mean ± SE		F	Significance (P-value)
	NHW	OHW		
Lucy's Warbler	1.6 ± 2.2	1.7 ± 0.2	1.0	0.3
House Finch	0.9 ± 0.1	0.7 ± 0.1	0.4	0.5
Black-chinned Hummingbird	0.6 ± .009	0.4 ± .007	2.3	0.1
Blue-gray Gnatcatcher	0.3 ± .006	0.4 ± .007	1.1	0.2
Bell's Vireo	0.4 ± .007	0.3 ± .006	1.6	0.2
Ash-throated Flycatcher	0.2 ± .003	0.3 ± .004	2.0	0.2
Song Sparrow	**0.3 ± .004**	**0.1 ± .007**	**4.4**	**0.03**
Black-throated Sparrow	0.6 ± .004	0.3 ± .005	2.9	0.08
Bewick's Wren	0.2 ± .004	0.2 ± .004	0.2	0.6
Canyon Wren	0.2 ± .004	0.1 ± .002	2.2	0.1
Yellow Warbler	**0.2 ± .004**	**.006 ± .002**	**8.1**	**.004**
Common Yellowthroat	**0.3 ± .004**	**.003 ± .001**	**19.8**	**.000**
Say's Phoebe	**0.2 ± .003**	**.006 ± .01**	**13.1**	**.000**
Mourning Dove	.008 ± .04	.005 ± .02	0.6	0.4
Yellow-breasted Chat	.06 ± .001	.03 ± .01	1.3	0.2

Figure 8. Distribution of Species Above and Below the Little Colorado River, 2002

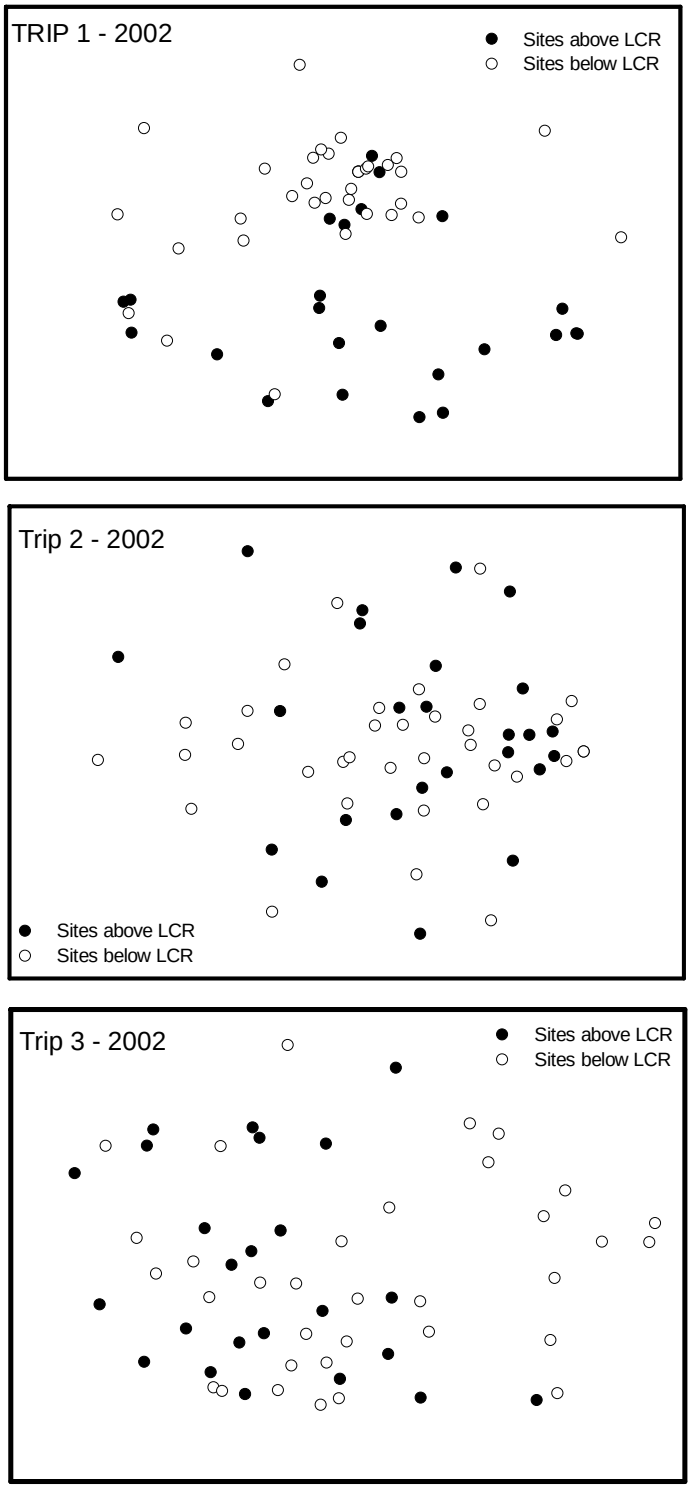


Figure 9. Abundance of birds within each zone during each trip for 2001 and 2002.

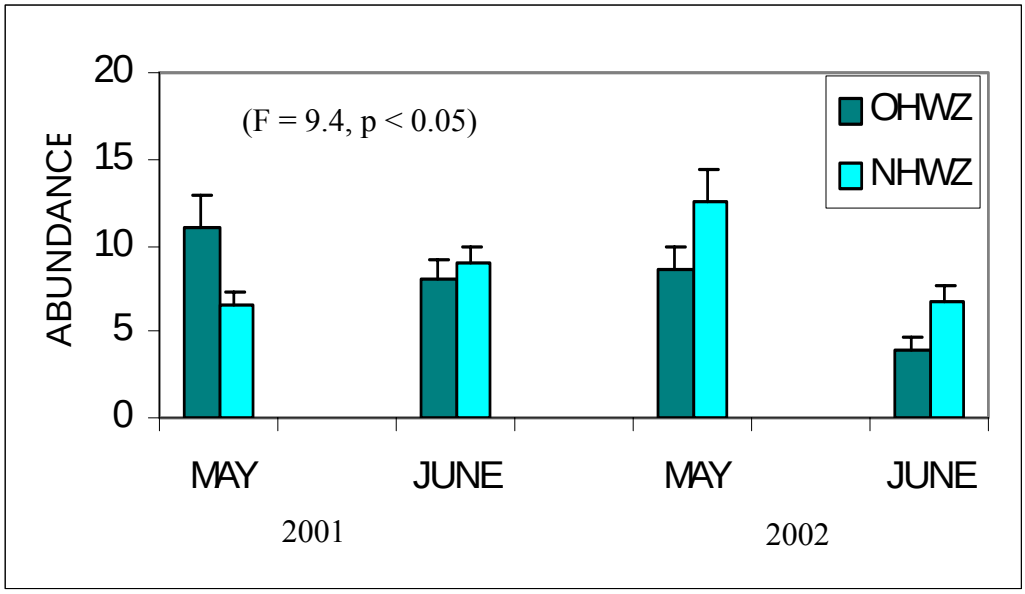


Table 10. AOV results of 15 species compared at 17 survey sites repeated 2001 – 2002.

Bird Species	Trend	F-Value	P-Value
Lucy's Warbler	01 = 02	.03	0.9
House Finch	01 = 02	0.0	1.0
Black-chinned Hummingbird	**01 < 02**	**5.7**	**.02**
Blue-gray Gnatchatcher	01 = 02	0.1	0.7
Bell's Vireo	01 = 02	0.0	1.0
Ash-throated Flycatcher	01 = 02	1.6	0.2
Song Sparrow	01 = 02	1.0	0.3
Black-throated Sparrow	01 = 02	1.0	0.3
Bewick's Wren	01 = 02	0.5	0.5
Canyon Wren	01 = 02	3.0	0.8
Yellow Warbler	01 = 02	0.0	1.0
Common Yellowthroat	01 = 02	0.1	0.7
Say's Phoebe	01 = 02	2.3	0.1
Mourning Dove	**01 > 02**	**8.2**	**.005**
Yellow-breasted Chat	01 = 02	2.8	0.1

Table 9. Species selected as indicators of bird communities found above or below the Little Colorado River (LCR) during 2002 (based on an indicator species analysis, see text). Significance of the species as an indicator is based on a randomization test (all species with a probability level of $P < 0.10$ are given).

	Above LCR	P <	Below LCR	P <
Trip 1	Canyon Wren	0.002	Lucy's Warbler	0.004
	White-crowned Sparrow	0.070	Bell's Vireo	0.009
	Song Sparrow	0.083	Black Phoebe	0.038
			Common Yellowthroat	0.076
Trip 2	Bewick's Wren	0.001	Bell's Vireo	0.002
	Loggerhead Shrike	0.007	Song Sparrow	0.005
	Ruby-crowned Kinglet	0.008	Common Yellowthroat	0.022
	Mourning Dove	0.060	Black-throated Sparrow	0.028
	Spotted Towhee	0.081	MacGillivray's Warbler	0.058
	Ruby-crowned Kinglet	0.008	Ash-throated Flycatcher	0.068
			Yellow Warbler	0.091
Trip 3	Canyon Wren	0.001	Bell's Vireo	0.004
	Loggerhead Shrike	0.005	Song Sparrow	0.054
	Blue Grosbeak	0.007		
	Yellow Warbler	0.039		

Table 11. Bird species abundance in order of rank in 1998, 2001 and 2002.

1998	Rank	2001	2002
Lucy's Warbler	1	Lucy's Warbler	Lucy's Warbler
House Finch	2	House Finch	House Finch
Bewick's Wren	3	Blue-gray Gnatcatcher	Black-chinned Hummingbird
Bell's Vireo	4	Bell's Vireo	Blue-gray Gnatchatcher
Yellow-breasted Chat	5	Black-chinned Hummingbird	Bell's Vireo
Ash-throated Flycatcher	6	Ash-throated Flycatcher	Ash-throated Flycatcher
Black-chinned Hummingbird	7	Mourning Dove	Song Sparrow
Yellow Warbler	8	Yellow Warbler	**Black-throated Sparrow**
Blue-gray Gnatcatcher	9	Common Yellowthroat	Bewick's Wren
Common Yellowthroat	10	Yellow-breasted Chat	Canyon Wren
Song Sparrow	11	Bewick's Wren	Yellow Warbler
Lesser Goldfinch	12	Song Sparrow	*Common Yellowthroat
	12		*Say's Phoebe
Blue Grosebeak	13	Canyon Wren	Mourning Dove
Brown-headed Cowbird	14	***Black-throated Sparrow**	Yellow-breasted Chat
	14	***Say's Phoebe**	
Mourning Dove	15	**Lesser Goldfinch**	**Black Phoebe**

1998 Data – Spence et al. 1998

- Tied Ranks

HOPI BIRDS OF INTEREST
SUMMARY - HOPI BIRDS OF INTEREST

YELLOW BIRDS

	*2001	*2002
Common Yellowthroat (summer resident)	57	56
Wilson's Warbler (migrant)	1	21
Yellow-breasted Chat (summer resident)	38	18
Yellow Warbler (summer resident)	65	57
Yellow-rumped Warbler (migrant)	4	13

* Two trips conducted in 2001, three trips in 2002

RAPTORS, 2002

Winter, 2002

Total of 21 observations January 26 - February 5, 2002

Six species observed:
Bald Eagle, Golden Eagle, California Condor, Northern Harrier, Peregrine Falcon, Sharp-shinned Hawk.

Breeding Season, 2002

Total of 83 observations in three trips, March - June, 2002
Nine species observed:
American Kestrel, Bald Eagle, California Condor, Coopers Hawk, Golden Eagle, Osprey, Peregrine Falcon, Red-tailed Hawk, Turkey Vulture.

March 31 - April 13
31 observations, 7 species
Bald Eagle, California Condor, Coopers Hawk, Golden Eagle, Peregrine Falcon, Red-tailed Hawk, Turkey Vulture

April 25 - May 11
27 observations, 6 species
Coopers Hawk, Golden Eagle, Osprey, Peregrine Falcon, Red-tailed Hawk, Turkey Vulture.

May 31 - June 15
25 observations, 3 species
California Condor, Red-tailed Hawk, Turkey Vulture

MIGRANTS/BREEDING BIRDS

Table 1. Migrants and breeding birds for trips 2001, 2002.

	2001			2002			
Trips	1	2	Total	1	2	3	Total
migrants	20	6	26	35	233	20	288
breeding birds	842	888	1730	645	1082	739	2466
totals	862	894	1756	680	1315	759	2754

2001 - trip dates
Trip 1 April 30 - May 16
Trip 2 May 31 - June 16

2002 - trip dates
March 31 - April 13
April 25 - May 11
May 31 - June 15

Herpetofauna

Geoff Carpenter
University of New Mexico

Purpose: The herpetological components of the Terrestrial Ecosystem Monitoring (TEM) studies along the Colorado River in the Grand Canyon are intended to:

(1) inventory and begin to describe community dynamics of terrestrial lizards, snakes, and toads occupying habitat within three different river flow stage riparian environments;
(2) investigate community dynamics in relation to river level fluctuations resulting from Glen Canyon Dam operations;
(3) acquire new distribution records for snakes, lizards, and toads along the river corridor.

These monitoring data will provide important information regarding the effects of dam operations on herpetological communities along the river corridor in the Grand Canyon. These data will be integrated with corresponding data representing vegetation, other vertebrate animals, and invertebrates (arthropods) generated for the TEM research program. They will also serve other information needs for GCMRC and other agencies and researchers.

Objectives: Principal objectives for the herpetological components of TEM are to:

1) Determine the species composition and relative abundance of herp species associated with the old high water zone (OHWZ), the new high water zone (NHWZ), and the fluctuation zone (SHORE) environments.
2) Determine microhabitat associations for the common species of lizards, snakes, and toads, to include water zone and substrate (i.e. boulders, cobbles, vegetated beach) habitat utilized, and to record behavioral information that will help assess how these habitats are being used by the different herp species.
3) Investigate herpetofaunal species composition in relation to vegetation, other vertebrate animals, and, to arthropod community structure, 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). Monitoring data will be used to investigate the impacts of water level fluctuation resulting from the operation of Glen Canyon Dam.
5) Compare observed riparian herpetofaunal community patterns (e.g. 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 accumulate distribution records of herpetofauna along the river corridor, to include photographic vouchers when possible.
7) To provide basic ecological information on the snakes, lizards, and toads inhabiting the Grand Canyon riparian zones for integration with vegetation, other vertebrate, and invertebrate animal information developed from this and associated research projects; and to provide herpetological data for other biological, cultural, and physical resource information needs.

Methods:

Study sites and sampling points: During 2002, a total of 14 sites were selected for focused sampling of terrestrial herps within the three hydrologic riparian zones. These sites were used also for arthropod transect sampling, and for small mammal trapping. Study transects are described in detail in the arthropod section of this report. Five of these sites (Saddle Canyon, Lava Chuar L, Salt Creek, Forster, Parashant) were repeat sites from 2001.

Sampling periods: These 14 study primary TEM sites were sampled for herps three times during 2002. The first sampling period was divided into lower-half (April 4-15) and an upper-half (April 25-May 1) trips. The second sampling period was June 22-July 8, and the third August 28-September 15. Early and late summer seasons likely support different relative species compositions within the various riparian zones, and activity patterns of herps also vary seasonally. Spring, early summer, and late summer sampling periods were chosen to accommodate the potential seasonal variation in active herpetofauna, to assess reproductive activity (spring) and reproductive success (late-summer), and to coincide with arthropod sampling on these same river trips.

Transect counts: Quantitative sampling --toads, lizards, and snakes were observed by an observer walking the transects, recorded to species, and the approximate location along the transect was often noted on the site map. Transects were walked at least once during peak daytime activity periods for diurnally active herps; nocturnal transect counts were conducted if the weather and terrain permitted. Additionally, lizards were occasionally captured in the arthropod pitfalls (described in arthropod section of this report), and toads were often captured in Sherman live traps for small mammals.

General site census and Bird/Veg sites: To enhance inventory sampling of herpetofauna, each of the 14 primary sites was thoroughly surveyed on foot to search for herps and herp sign (tracks, scats, shed skins, bones, and carcasses). The non-primary TEM sites that were sampled by the vegetation and birding crew were also surveyed by a herpetologist during the upper-half spring and late-summer trips. These sites were not visited during the mid-summer arthropod/herp trip, nor during the first (lower-half) spring trip.

Results:

Eighteen species of herps were observed during the three 2002 TEM trips: two toads, one frog, eight lizards, and seven snakes. As during 2001, the most commonly encountered herps were four lizard species (Western whiptail, *Cnemidophorus tigris*, CNTI); desert spiny, *Sceloporus magister*, SCMA; side-blotched, *Uta stansburiana*, UTST, and tree lizard, *Urosaurus ornatus*, UROR) and two toads (Woodhouse's toad, *Bufo woodhousei*, BUWO; and the red-spotted toad, *B. punctatus*, BUPU) (Figure 1). Figure 2 shows pooled numbers for all herp species for all TEM trips during 2001-2002, and further illustrates the dominance of these half dozen species.

Among these common species, the two toads and the whiptail lizard were most common in NHWZ, while the spiny and side-blotched lizards were most abundant in the OHWZ (Figure 3). Additionally, an initial examination of patterns of abundance in relation to river reach and width reveals a preliminary pattern of greater abundance in the lower reaches of the canyon, and in the wider sections of the canyon.

Interesting herpetological highlights during 2002 trips include finding desert horned lizards (*Phrynosoma platyrhinos*, PHPL) at the Lee's Ferry site (RM -0.4; Figure 4a); observing two red-spotted toads (BUPU) in amplexus at this site (Figure 4b); witnessing cannibalism in kingsnakes (*Lampropeltus getulus*, LAGE) while scouting Crystal rapid (Figure 4c-d), and encountering numerous rattlesnakes (CRVI, CRMI, CRMO), especially during the June-July and Aug-September trips. Additionally, stunningly beautiful baby chuckwallas (SAOB) were observed at Lee's Ferry (April, June) and on the Tapeats sandstone ledges at RM 205R (April) during 2002.

Preliminary Interpretation/Summary:

During this study, the river corridor herpetofauna in the Grand Canyon has been dominated by four lizards, and two toad species. Interestingly, all of these species consume arthropods almost exclusively, hence opportunities to integrate herp and arthropod data in the future (several years of data collection may be necessary before trends begin to emerge) are very promising. Among the common lizard species, habitat affinities have emerged from just two seasons of data, that coincide well with observations made by herpetologists on river trips during the mid 1980s (Warren and Schwalbe 1988). While all four common lizard species make substantial use of all three riparian hydrologic zones, the zone use pattern of each species differs. Side-blotched (UTST), spiny lizards (SCMA) and tree lizards (UROR), are predominantly visual, sit and wait predators, while whiptails (CNTI) are active foragers, and rely heavily on tactile and olfactory cues. Tree lizards are most common on large boulders and vertical faces near the shore (Figure 3), while whiptails (CNTI) seem to be using the NHWZ quite a bit, and spiny lizards (SCMA) and side-blotched (UTST) lizards are most abundant in OHWZ habitats. It has long been recognized tree lizards prefer vertical surfaces (Smith 1946), and ample arthropod food resources in tandem with these surfaces exist primarily near the shore, where visibility (for detecting displaying conspecifics, as well as prey items, in this strongly territorial species) is quite good, hence the abundance of this species in this zone. UTST seem to prefer areas with both structure and nearby open areas, and are a predominantly desertscrub, versus riparian species. Similarly SCMA seem to prefer area with structure, but are either not as abundant, or not as observable in the often dense structure of the NHWZ. Whiptails, on the other hand are primarily ground-foragers, and are observed roaming in all zones, but seem to do well foraging in dense NHWZ, probing litter and vegetation and using tactile and olfactory cues to detect arthropod prey.

Larger overall numbers (Figure 5) in wider (solid bars) versus narrow (striped bars) reaches of the canyon is likely a reflection of larger, and more structurally diverse habitat patches at these sites. So, variation in patch size and structural diversity among sites begs attention in future planning and analyses, as do biogeographic (e.g. distance from the nearest side canyon, i.e. source populations), genetic (potential for gene flow among populations in the corridor), and other concerns.

Literature Cited:

Warren, P.L. and C.R. Schwalbe. 1988. Lizards along the Colorado River in Grand Canyon National Park: Possible effects of fluctuating river flows. Glen Canyon Environmental Studies, Executive Summaries of Technical Reports, October, 1988.

Smith, H.M. 1946. Handbook of Lizards. Lizards of the United States and of Canada. Comstock Publ. Co., Inc.Ithaca, New York. Xxi + 557 p.

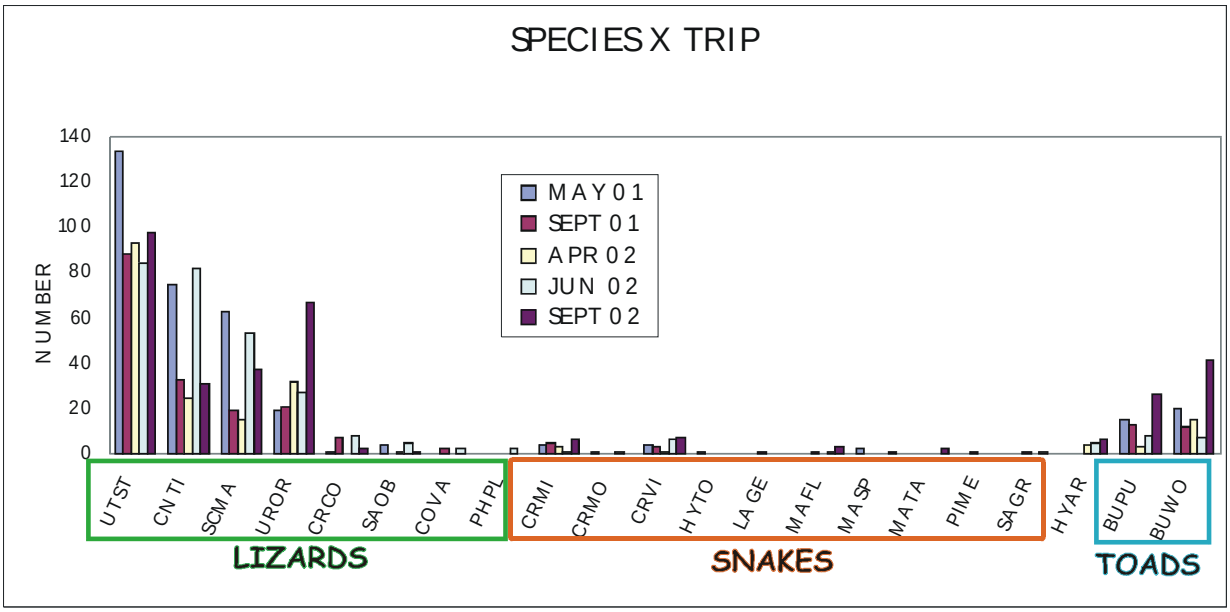


Figure 1. Abundance of herp species encountered along the Colorado River corridor in Grand Canyon during 2001 and 2002. Four lizard species (side-blotched, UTST; western whiptail, CNTI; desert spiny, SCMA; and tree, UROR lizards) and two toad species (Woodhouse's, BUWO and red-spotted, BUPU toads) are the most abundant herpetofaunal elements in the riparian corridor.

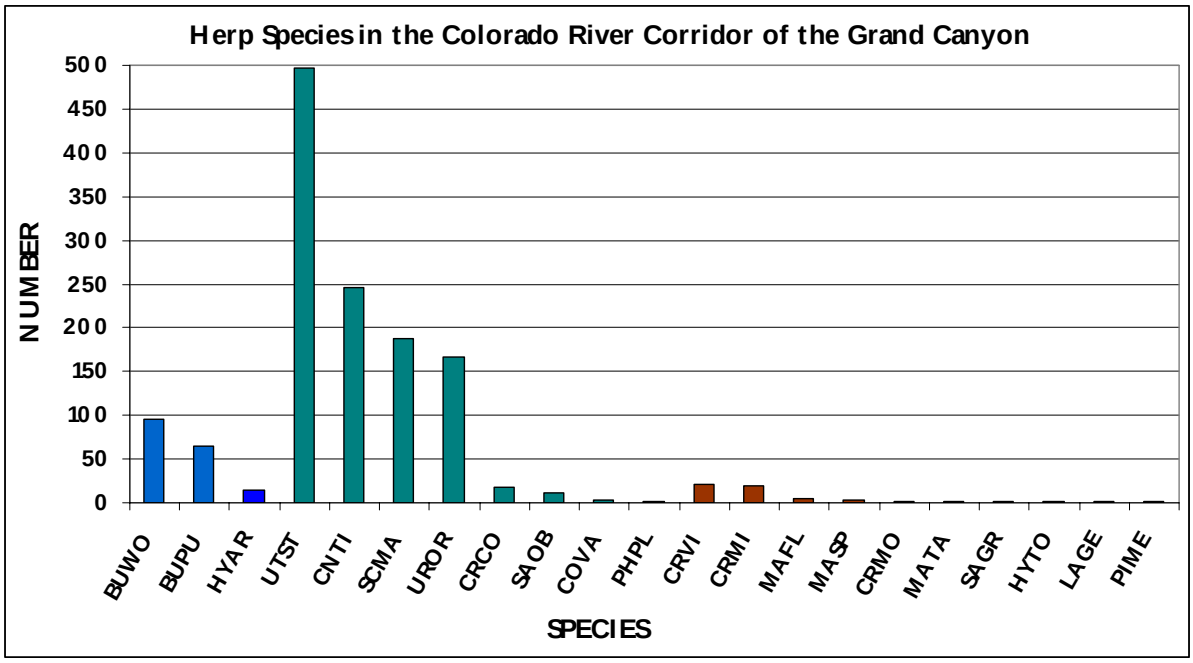


Figure 2. Pooled numbers of herps for five TEM river trips during 2001-2003. The herpetofauna of the Colorado River corridor through the Grand Canyon is dominated by four lizard and two toad species. Frogs and toads are displayed with blue bars, lizards with green bars, and snakes with brown bars.

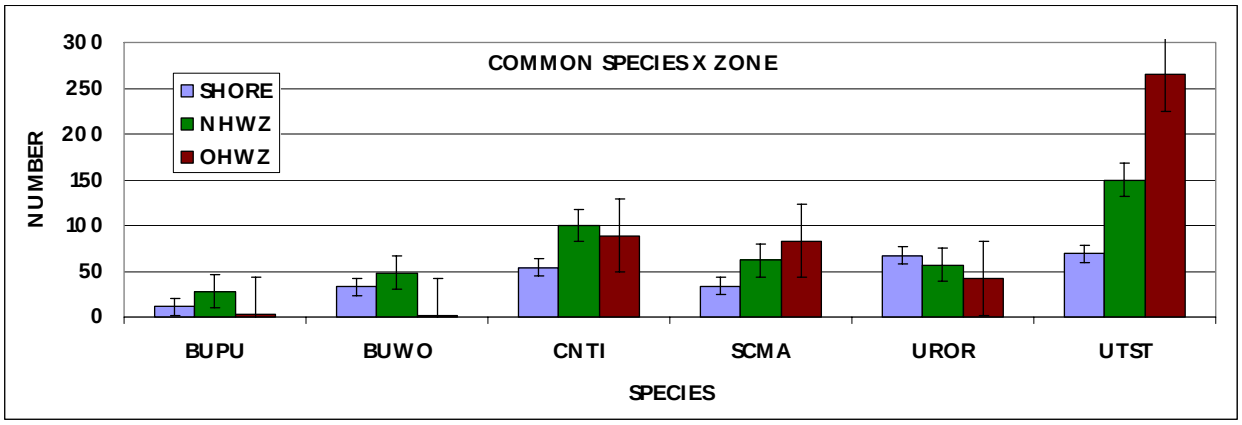


Figure 3. Relative abundance of the six common herp species in three hydrologic riparian zones along the Colorado River corridor through the Grand Canyon. Data are pooled for five TEM trips during 2001-2002. Error bars represent the standard error.

Figure 4. Herpetological highlights during 2002 TEM trips included (clockwise from upper left): a. Desert Horned Lizard at the Lee's Ferry site, b. Red-spotted toads in amplexus at the Lee's Ferry Site c-d. Cannibalism in kingsnakes; during the Crystal Rapid scout, a gnarled mass of snake was discovered to be the larger snake engulfing the smaller one.

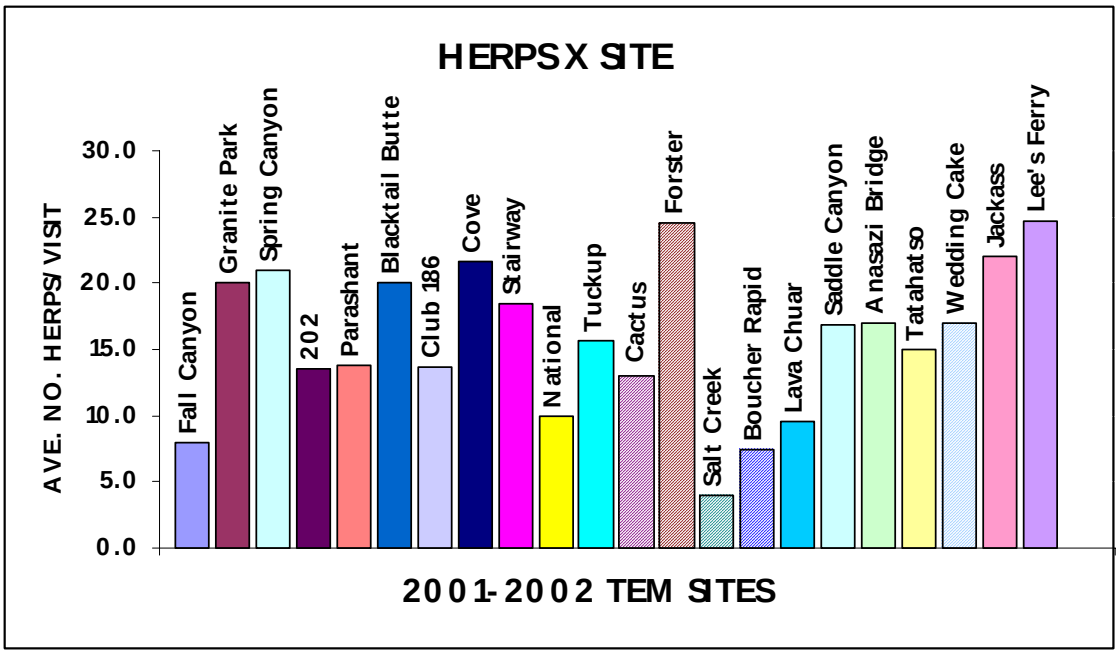


Figure 5. Average number of herps observed per visit by site. Solid bars represent sites in WIDE reaches of the canyon and striped bars represent sites located in NARROW reaches of the corridor. Some low numbers (e.g. Salt Creek) reflect cool and cloudy conditions, resulting in low herp activity during site visits.

Site Name	River Mile*
Lees Ferry	-0.4 R
Jackass	8.0 L
Wedding Cake	22.0 R
Tatahatso	37.3 L
Anasazi Bridge	43.1 L
Saddle Canyon	46.7 R
Lava Chuar	65.3 L
Boucher Rapid	96.5 R
Salt Creek	92.3 L
Forster	122.8 L
Cactus	133.0 L
Tuckup	164.5 R
National	166.5 L
Stairway	171.2 R
Cove	174.1 L
Club 186	186.5 L
Blacktail Butte	194.1 L
Parashant	198.0 R
202	202.5 R
Spring Canyon	204.5 R
Granite Park	209.0 L
Fall Canyon	211.5 R

* River mile indicates location names used by GCMRC and other reseaerchers.

Arthropod Surveys

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and
Neil Cobb
Northern Arizona University

Purpose:

The purposes of the arthropod studies are first to inventory and characterize the terrestrial arthropod fauna associated with the different river flow stage riparian environments along the Colorado River in Grand Canyon. Are there distinct arthropod communities from the river shore through the tamarisk-dominated new High water zone vegetation to the mesquite desert vegetation zone that marks the high water zone prior to the operation of the dam? Are certain arthropod taxa more sensitive to habitat changes than other taxa? Second, we want 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 ultimately 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 Protocols document of the Request for Proposals. A total of 14 sites were selected for focused sampling of all terrestrial arthropods. Four of the sites were sampled in both 2001 and 2002 (46.7R, 65.3L, 122.8L, and 198.0L). The other 10 study sites sampled in 2002 were new; the purpose of selecting new sites was to increase the total number of study sites to obtain a better representation for the canyon.

Three 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 transect representing the

fluctuation zone (Shore) was situated one meter above the existing daily high-water shore line. The actual daily shoreline fluctuation zone varies over time, depending upon water releases from Glen Canyon Dam. The transects covering the Old High Water Zone (OHWZ) and the New High Water Zone (NHWZ) were situated in the middle of each of those zones' range of elevation above shoreline. The NHWZ was the hydrologic zone just above the shoreline and was characterized by vegetation dominated by Tamarisk. The OHWZ was the highest elevation hydrologic zone and was characterized by mesquite, desert shrubs and acacia. In terms of size the OHWZ occupies the greatest amount of area for any given site (mean=8055m^2 SE=1033), the NHWZ occupies the next largest amount of beach habitat (mean=5598m^2 SE=688), and the shore occupies the smallest area (mean=2251m^2 SE=314). These estimates are based on 66 sites selected throughout the study area.

Sampling periods: Arthropods were quantitatively sampled twice during 2001 and three times in 2002 (see Table 1). The first sampling period in 2001 was April/May, and the second was August/September. In 2002 we sampled the lower and upper reaches on separate trips to accommodate potential phenological differences; earlier development and activity of the same taxa in the lower reaches of the canyon that would bias the sampling. Additional collecting was conducted in 2002 during 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 was 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 analyses. To test for differences among groups we performed ANOVA's on overall arthropod abundance and species richness, followed by ANOVA's on four 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 ANOVA 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, we employed discriminant function analyses.

We also examined four of the most common groups of arthropods observed to date. 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. Our analysis includes 35 species of spiders. **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 (Purvis and Curry 1984, Fan et al. 1993, Heliola et al. 2001) and are represented by 22 species in our study. **3)** Darkling beetles (Tenebrionidae), which are primarily generalist herbivores and scavengers thus making them omnivores (Stapp 1997). To date we have data for 11 species of darkling beetles. **4)** 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; we have recorded 13 species in our pitfall trapping.

Results: GROUND-DWELLING ARTHROPOD COMMUNITY DYNAMICS:

Differences in Community Composition among Habitat Zones and Sample Periods

The composition of arthropod communities was distinct among habitat zones based on discriminant function analyses using a pool of 64 arthropod species. Figure E-1 shows the differences in community composition among the three zones using data from all four sample

periods. The Old High Water Zone (OHWZ) and the New High Water Zone (NHWZ) were more similar to each other than either was to the shore arthropod community. Predictably, the NHWZ exhibited an intermediate position in discriminant analysis, indicating that ground-dwelling arthropods were responding to gradient such as soil texture and/or soil moisture that occurred across the zones. The implication of this result is encouraging because it supports the notion that arthropod communities respond to differences in habitat structure. Furthermore it suggests that altering habitats either through dam operations or climate will have cascading effects on the arthropod communities.

There is a high degree of habitat specialization in ground-dwelling arthropod communities. Figure E-2 shows the degree of habitat affinity exhibited by ground-dwelling arthropods. One hundred and seventeen of the 201 taxa identified were only found in a single zone (OWHZ=31 taxa, NHWZ=24 taxa, Shore=62). Thirty-five species were considered oligo-specialists, occurring in two of the three habitats. Of these 35 oligo-specialists, 19 taxa were found in both the OHWZ and NHWZ, 13 taxa were found in both the Shore and NHWZ, and only three taxa were found in both the OHWZ and Shore. The number of generalist taxa found to date is 48, this may increase as we continue to sample and possibly find species that were designated as specialists or oligo-specialists to exhibit broader niches.

There were also marked differences among the different time periods (Figure E-3). All four sampling periods showed distinct community structure. This supports conducting seasonal sampling, because each season can have a distinct assemblage of arthropods. In this analysis we combined the data for all three zones, preliminary examination of the data suggested that the relative differences in arthropod community structure among the zones (Figure E-1) did not change among the sample periods.

Dividing the Spring Sampling into Two Trips: A concern after the first year of sampling was that the phenology (seasonal development & activity of organisms) was much more advanced for arthropods existing in the lower reaches of the canyon. Examination of abundances for 17 key groups of arthropods supported the decision to divide the Spring sampling period into two trips in order to have the lower and upper reaches of the river habitats be closer in phenology. In spring 2001, when we conducted a single trip and sampled the upper reaches first, four groups showed significant differences, with lower abundances in the upper reach. Conversely, the only differences in any group for the Spring 2002, when the upper reaches were sampled after the lower reaches, only darkling beetles exhibited differences. For darkling beetles they were more common in the lower reaches in 2001, but in 2002 the pattern was reversed, they were more common in the upper reaches of the river.

Comparison between 2001 and 2002: There were marked differences in precipitation between the first two study years, 2002 was a major drought year that was reflected in reduced vegetation cover. Ground-dwelling arthropods generally respond negatively to reduced plant productivity, regardless of whether they are herbivores or not. The only season that we can examine annual differences is for Spring. There was an overall reduction in the diversity of arthropods (Figure E-4) and in the abundance of arthropods (Figure E-5) for all zones in 2002 compared to 2001. However, in a repeated measures analysis we were restricted to using the four sites that were sampled in both 2001 and 2002, thus we probably did not have the statistical power to show a differences for abundance (Table E-1A) or diversity (Table E-1A). The other four arthropod groups that we have targeted as good candidates for indicator taxa did not show strong differences between Spring 2001 and Spring 2002 (Table E-1C-F). The only exception was darkling beetles, which showed an actual increase in 2002 (Table E-1E). The lack of any

interaction effects (ZONE X PERIOD) indicates that arthropods varied consistently among the zones between the two years.

Comparison of Habitat Zones throughout the Corridor. We also tested for differences in arthropod communities among habitat zones by examining all four periods, for which we had complete data sets. These ANOVA analyses included two main effects, habitat zones (i.e., Shore, NHWZ, and OHWZ), and seasonal periods (i.e., Spring 2001, Fall 2002, Spring 2002, and Summer 2002), and interactions among the main effects. However, we were primarily interested in differences among zones.

There was no difference in diversity among habitat zones in ground-dwelling arthropods as measured by species richness (Fig. E-6). There was a significant PERIOD effect, probably due to the high diversity in Spring 2001. We observed a general pattern of increasing arthropod abundance as one moves up in elevation from the shore through the NHWZ and OHWZ (Figure E-7). Overall abundance was highest in the OHWZ, but this was due to the overwhelming abundance of seed bugs (*Nysius* sp.) in Spring 2001. There was a significant seasonal effect and an interaction effect, which was primarily driven by the huge variance in arthropod abundance in the NHWZ and the OHWZ and very little variance in shore arthropod abundance.

The general pattern of increasing arthropod abundance from shore to OHWZ was reversed in more mesic-affiliated arthropods (Figure E-8, E-9). The 35 species of spiders as a group were always more abundant in the shoreline habitat and least abundant in the OHWZ or the most xeric habitat (Figure E-9). The NHWZ contained an intermediate number of spiders, suggesting spiders respond to moisture gradients. Ground beetles (22 species) were the best indicator group of shoreline habitat (Figure E-9). There were no differences between NHWZ and OHWZ although spider abundance in the NHWZ was generally intermediate between the shore and OHWZ habitats. It is interesting that ground beetles showed such a strong affinity for the shoreline given that their numbers were generally low compared to other river systems (Jim Labonte, Pers. Comm.). One possible reason for the paucity of ground beetles compared to other river systems may be due to larval habitat requirements. We suspect the larval stages of the ground beetles we are monitoring live in wet soil as predators or possibly algal feeders. The rising "tides" of the river may create unstable habitats for ground beetle larvae that are either too wet or dry during the course of their development. Our results warrant further studies on the ecology of this important indicator group of insects.

A number of insect taxa exhibited an apparent preference for more xeric habitats (e.g., Mutillidae, apterygote insects), the darkling beetles and ants are representative of these other taxa as indicators of xeric habitats. The 11 species of darkling beetles exhibited a striking pattern of increasing abundances from shore to OHWZ in Spring 2001, but thereafter showed a much weaker pattern (Figure E-10). Overall darkling beetles were significantly more abundant in the OWHZ compared to the shore, but there was no difference between OHWZ and NHWZ. Additionally the darkling beetles showed an overall increase in 2002 compared to 2001, which we did not expect given the drought conditions of 2002. Ants (Formicidae) showed similar patterns that exhibited by darkling beetles (Figure E-11). Within each of the four groups of arthropods we found individual species that represented very different dispersion patterns. For example there were spider and ground beetle species that were actually more common in the OHWZ. So the two groups exhibited opposite patterns, ground beetles and spiders were more common in the more mesic shore zone, while darkling beetles and ants were highest in the OHWZ. In neither case was the NHWZ zone different from both other zones, indicating that more than a single group of ground-dwelling arthropods are required to characterize zones with

regard to ground-dwelling arthropods.

The four taxa of arthropods that we have targeted as habitat indicators are relatively easy to identify as distinct groups, although the identification of species within each group would require a specialist and/or a well-documented reference collection. It may be more desirable to target a group of similar species in a monitoring program, as opposed to individual species because species identification is unnecessary. It is much easier to identify an arthropod as a spider than it is to identify individual species of spiders. This will not always be the case, black widow spiders are very easy to identify. But having the luxury of lumping taxa does provide flexibility in developing a monitoring program, especially because it is not heavily dependent on taxonomic experts to conduct the monitoring. A drawback to a monitoring program that lumps species is that it may be difficult to understand why a group responds to changes since the individual species that comprise a family or order typically have very different requirements and sensitivity to change. It is realistic to incorporate both individual species monitoring and higher taxa monitoring in the same program, depending on the goals of the monitoring program.

U-V night light and malaise sampling: Analyses on aerial insects is still in the stage of establishing a reference collection, especially Lepidoptera, which are the major taxa found in these samples. We have delineated 164 Lepidoptera morphospecies and have data for fall 2001. As was the case for ground-dwelling arthropods, there were increasing numbers of Lepidoptera from shore to the OHWZ (Figure E-12). There was also a concomitant increase in species richness as well (Figure E-12).

One potential problem in interpreting results from the light trap and malaise trap data is that you may be sampling species that are either attracted to the trap or just moving through the habitat. The "attraction from outside" problem is true for our malaise sampling, since we set malaise traps next to night-lights in order to increase the number of taxa collected. However, if this were the case, we would have expected to see the lowest numbers in the NHWZ. This would be due to the dense vegetation of the NHWZ restricting the ability of aerial insects to detect the night-light. But we found a clear increasing abundance and richness across the hydrologic gradient suggesting we were sampling moths from within habitat zones.

The analysis of Lepidoptera did not include the most abundant Lepidopteran, the Arctiid moth *Cisthene angelus* (Dyar). This moth was also most abundant in the OHWZ (mean = 636, SE= 345), but unlike many other insects it was least abundant in the NHWZ (mean=68, SE= 24), and intermediate in the shore samples (mean = 125, SE= 55). This suggests the dense vegetation of the NHWZ prevented it from being as representative in the NHWZ samples. But there is good reason to think that *C. angelus* is an OHWZ specialist because it was so much more abundant in the OHWZ and other species in this genus are lichen feeders. We presume that lichens are more common in the OHWZ. There was also considerable variation from site to site in the abundance of *C. angelus* (Figure E-13). This variation was not random; there was a clear threshold at river mile 166, which saw a large increase in the abundance of *C. angelus.* Because *C. angelus* is the most common moth in Grand Canyon it would be important to understand more of its natural history and importance as a food base for vertebrates. It is aposematically colored, which we presume would indicate adults are not a food items for birds and other visual predators. However, adults may be important food items for bats. We do not know what the larvae feed on; feeding trials on other species indicated that even for lichen-feeding species, larvae were actually feeding on the algal mutualist, not the fungal component of the lichen. It is possible the larva of *C. angelus* do not feed on lichens in Grand Canyon, but feed on algae or some other plant.

Regardless, understanding the ecology of *C. angelus* should be the focus of future studies in Grand Canyon.

Reference Collection. The bulk of our work to date continues to focus on the establishment of a reference collection. We currently have ~6,000 specimens pinned and 636 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 2001 pitfall arthropod samples, and most of 2002 samples. Night-light and malaise trap samples have been processed for 2001. Here we present results from the 2001-2002 data on the abundance and diversity of ground-dwelling arthropods and to some degree night light and malaise trap samples. Appendix E provides an updated list of the taxa delineated, exclusive of the Lepidoptera. We have determined 164 morphospecies of Lepidoptera but have not assigned family to species designations except for *Cisthene angelus* (Dyar).

Summary & Conclusions: We found distinct differences in the composition of the ground-dwelling arthropod community among the three hydrologic zones. Most species were habitat specialists, only occurring in a single hydrologic zone. The shore contained most of the habitat specialists, suggesting they may be the most vulnerable arthropod community to perturbations. There was a general increase in abundance from shore to the OHWZ, with the NHWZ being intermediate. However, there were groups that were more abundant along an increasing mesic gradient (ground beetles and spiders) while other arthropod taxa that showed greater affinity for xeric habitats (darkling beetles and ants). 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. We have also found comparable results in the Lepidopteran community of ~166 species, supporting the notion that they would be good candidates for a monitoring program. Our baseline data is essential for developing a monitoring program, but it will be equally important to assess the degree to which these arthropod communities and indicator taxa respond to changes in the operation of Glen Canyon Dam.

Table 1A-F. Summary statistics from six ANOVA's testing for differences in components of arthropod ground-dwelling community among the three zones for Spring 2001 and Spring 2002. Analyses were based on the four sites that were sampled in both 2001 and 2002. The only significant results were decreasing numbers of ground beetles from shore to OHWZ (Table 1D, ZONE_#) and the opposite pattern in Darkling beetles (Table 1E, ZONE_#). Darkling beetles and ants also exhibited increases from 2000 to 2001 (Tables 1E-F, PERIOD_#). There were no signigicant interactions between main effects (i.e., zone and period).

Table 1A **Arthropod Abundance**

Source	Type III SS	df	MS	F	p-value
ZONE_#	196503	2	98251	1.16	0.324
PERIOD_#	223879	3	74626	0.88	0.458
ZONE_# * PERIOD_#	537214	6	89536	1.06	0.404
Error	3037428	36	84373		

Table 1B **Species Richness**

Source	Type III SS	df	MS	F	p-value
ZONE_#	19	2	10	0.64	0.531
PERIOD_#	58	3	19	1.30	0.290
ZONE_# * PERIOD_#	59	6	10	0.67	0.674
Error	533	36	15		

Table 1C **Spiders**

Source	Type III SS	df	MS	F	p-value
ZONE_#	350	2	175	1.78	0.183
PERIOD_#	211	3	70	0.72	0.549
ZONE_# * PERIOD_#	507	6	84	0.86	0.534
Error	3538	36	98		

Table 1D **Ground Beetles**

Source	Type III SS	df	MS	F	p-value
ZONE_#	21	2	10	8.09	0.001
PERIOD_#	6	3	2	1.61	0.204
ZONE_# * PERIOD_#	7	6	1	0.89	0.512
Error	46	36	1		

Table 1E **Darkling Beetles**

Source	Type III SS	df	MS	F	p-value
PERIOD_#	85	3	28	9.54	0.000
ZONE_#	51	2	26	8.62	0.001
PERIOD_# * ZONE_#	31	6	5	1.72	0.145
Error	107	36	3		

Table 1F **Ants**

Source	Type III SS	df	MS	F	p-value
ZONE_#	36995	2	18497	1.88	0.167
PERIOD_#	133888	3	44629	4.55	0.008
ZONE_# * PERIOD_#	96468	6	16078	1.64	0.165
Error	353433	36	9818		

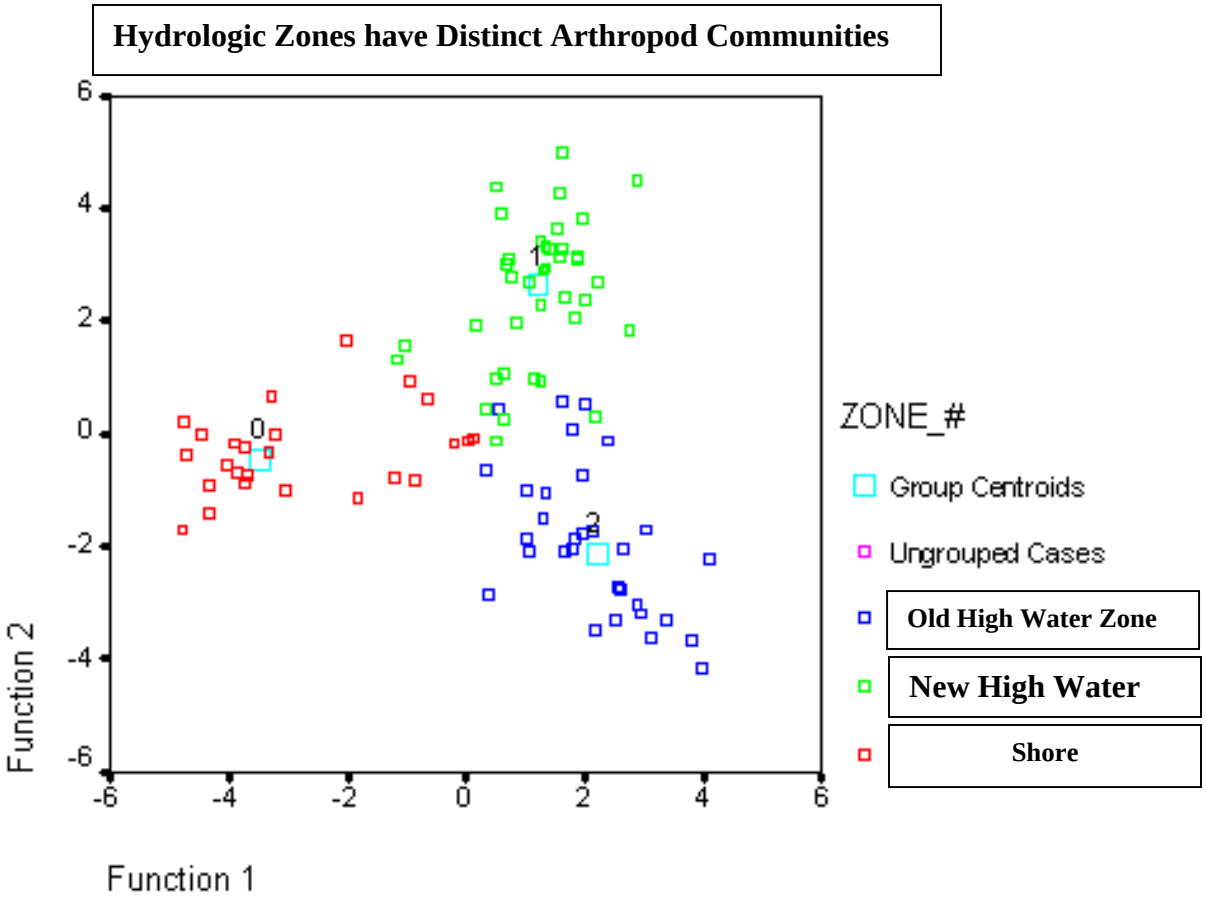


Figure 1 Ground-dwelling arthropod community structure across zones, based on discriminant function analysis using 64 species. The three zones were Shore, (Zone 0), New High Water Zone NHWZ (Zone 1), and Old High Water Zone OHWZ (Zone 2). Each zone had a unique assemblage of arthropod communities, with very little overlap.

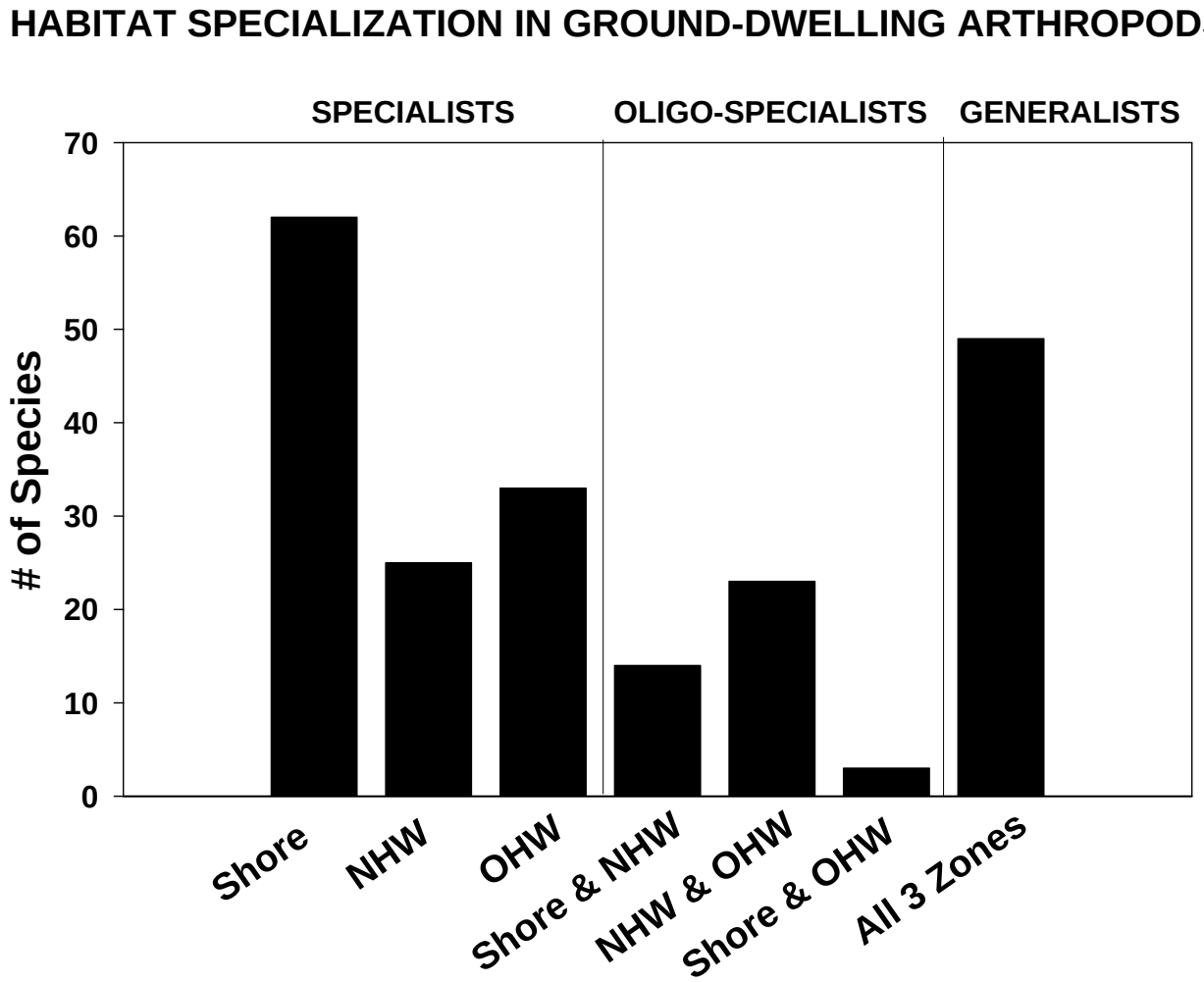


Figure 2. Degree of habitat specialization in ground-dwelling arthropods inferred from pitfall trap sampling. The three panels indicate the number of taxa found exlusively in on zone (specialists), two zones (oligospecialists) and all three zones (generalists).

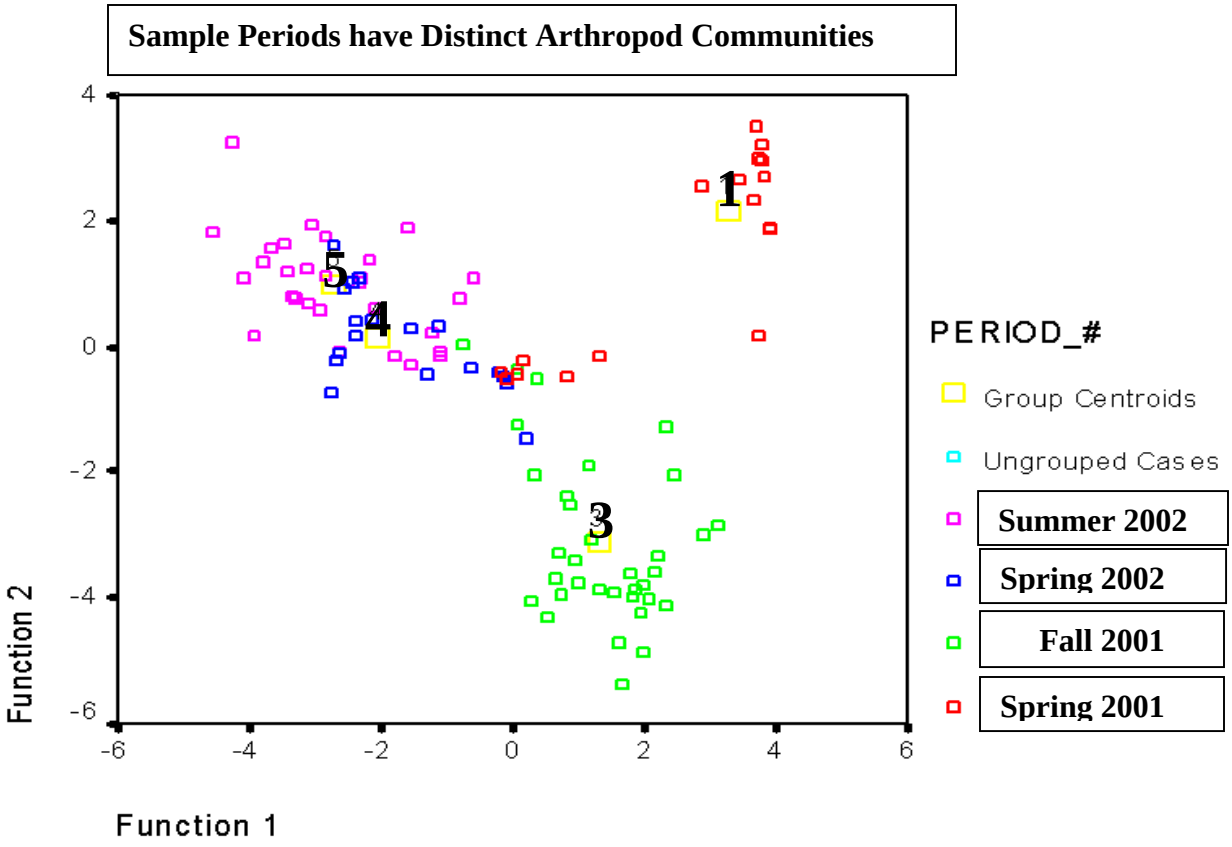


Figure 3. Ground-dwelling arthropod community structure through time, based on discriminant function analysis using 64 species. The four sampling periods were Spring 2001, (Period 1), Fall 2001 (Period 3), Spring 2002 (Period 4), and Summer 2002 (Period 5). Each time period had a unique assemblage of arthropod communities, however year seems to be more important than season in predicting similarity of arthropod assemblages.

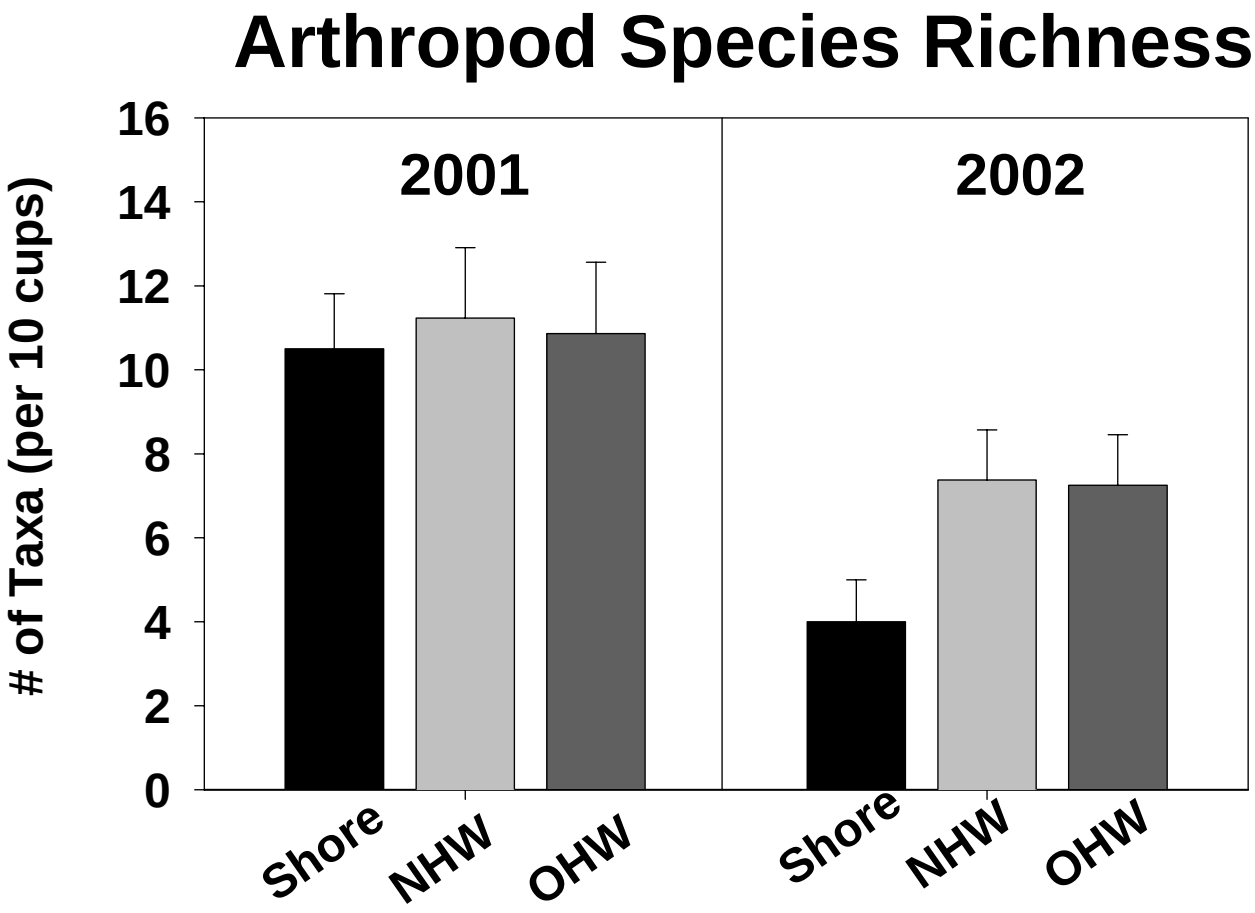


Figure 4. Species richness of ground-dwelling arthropods in 2001 and 2002 (severe drought) for each of the three habitats. Overall diversity was greatly reduced, especially for the arthropods inhabiting the shore.

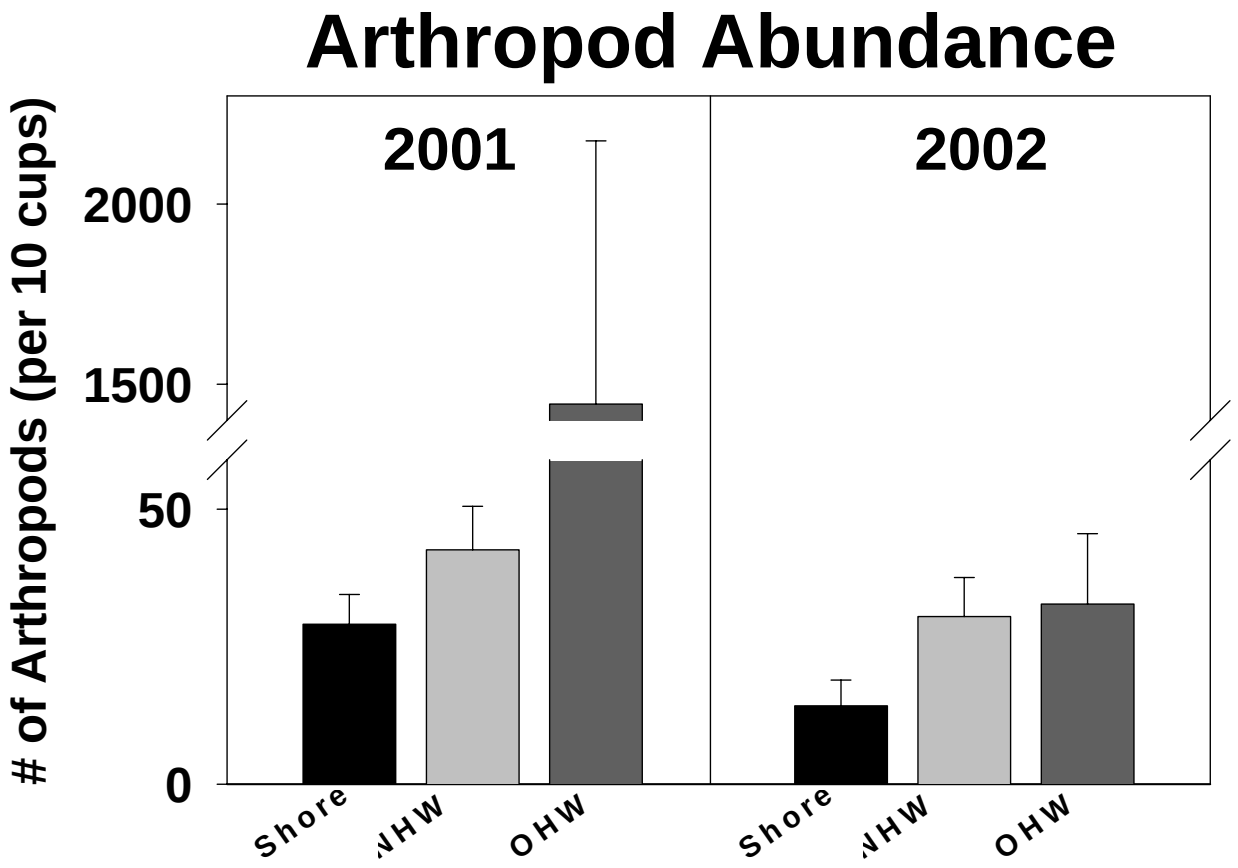


Figure 5. Abundance of ground-dwelling arthropods in 2001 and 2002 (severe drought) for each of the three habitats. Overall abundance was reduced in 2002, especially for the arthropods inhabiting the Old High Water zone (OHW). This reduction in the OHW was due primarily to a single species (seed bug).

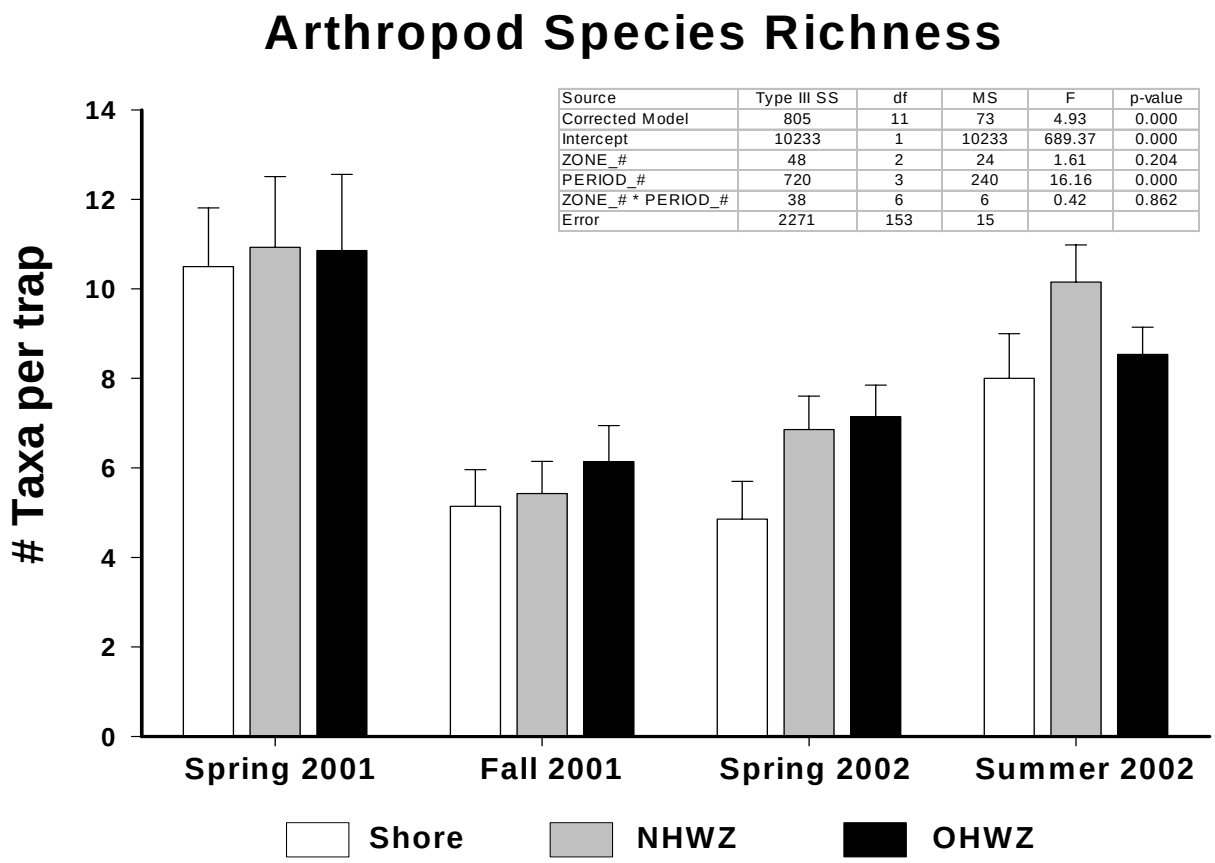


Figure 6. Species Richness of ground-dwelling arthropods for each of the four sampling periods in 2001 and 2002 across the three habitats. Overall species richness was not different among the three zones for any time period. However there were dramatic differences in diversity among the time periods, especially between Spring 2001 and Fall 2001.

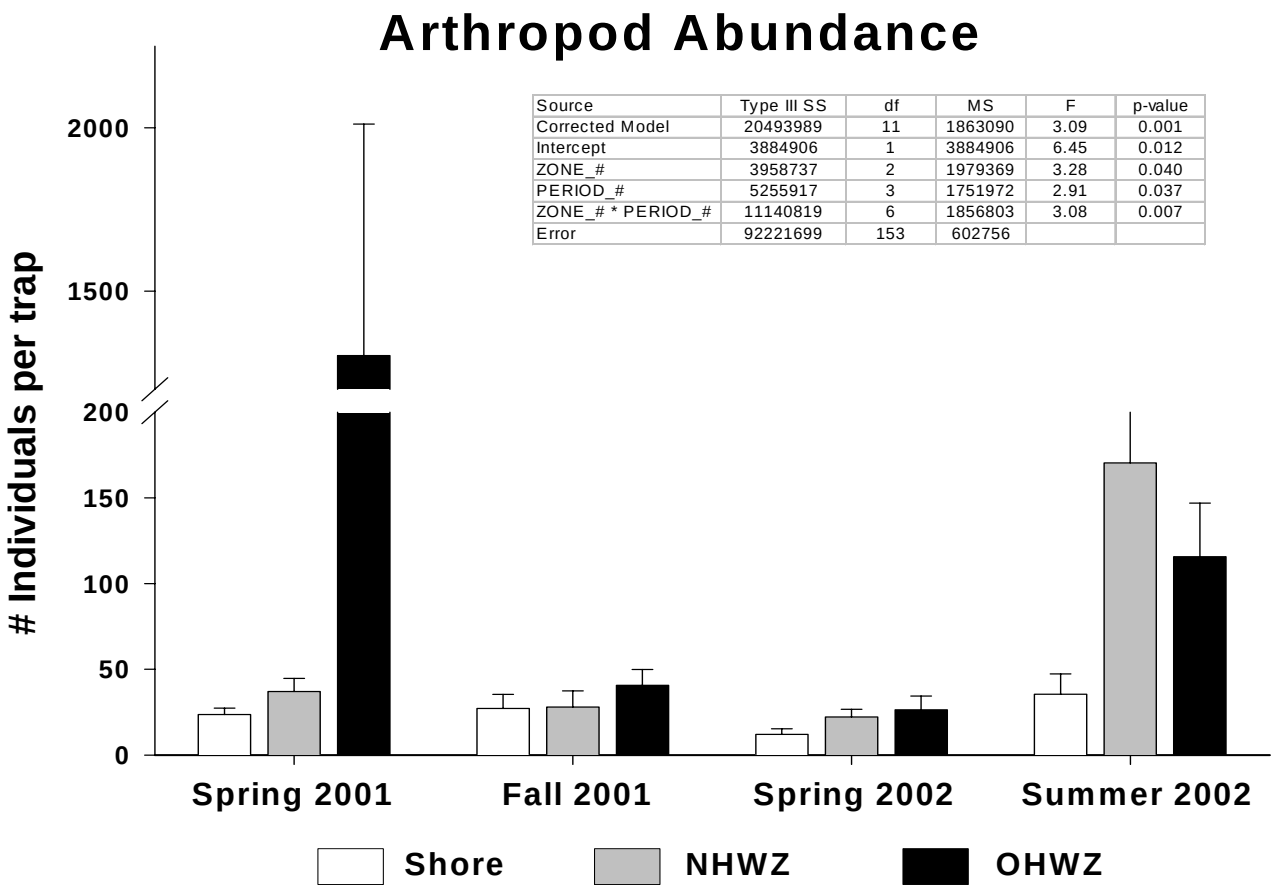
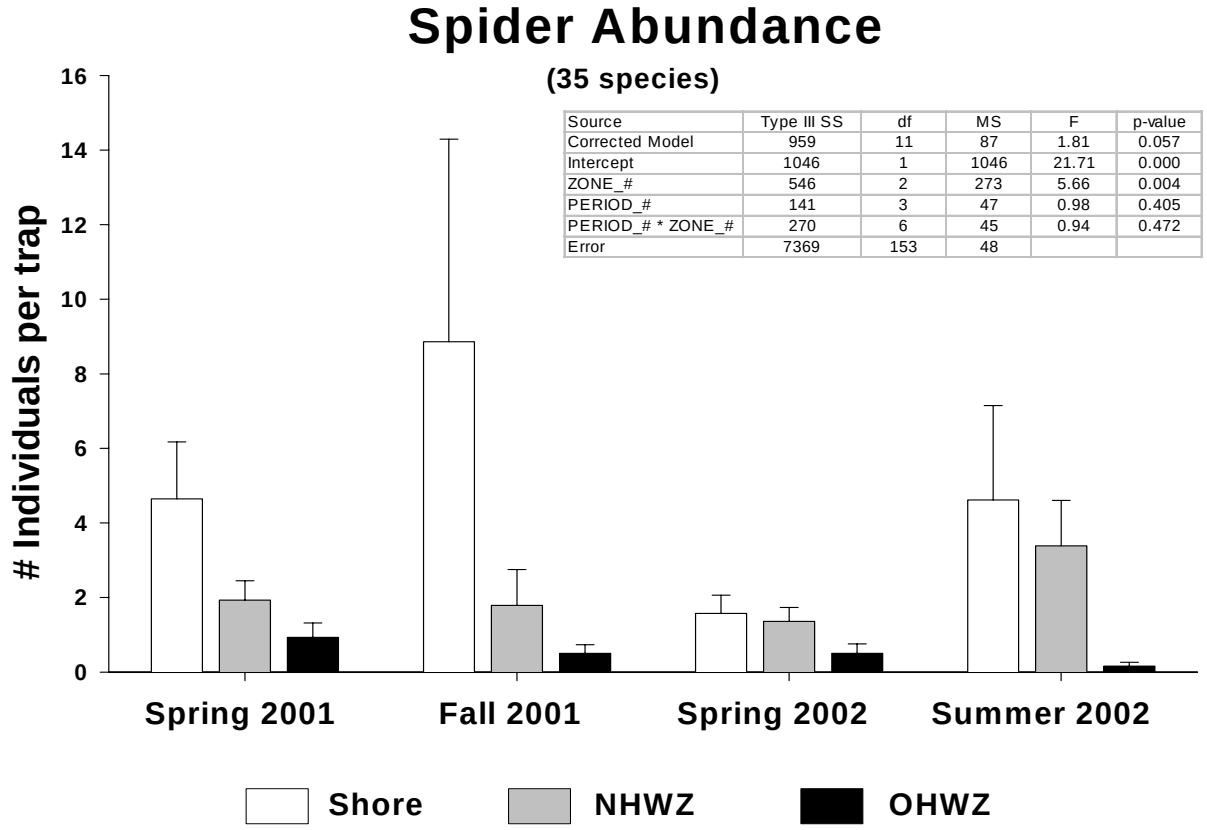
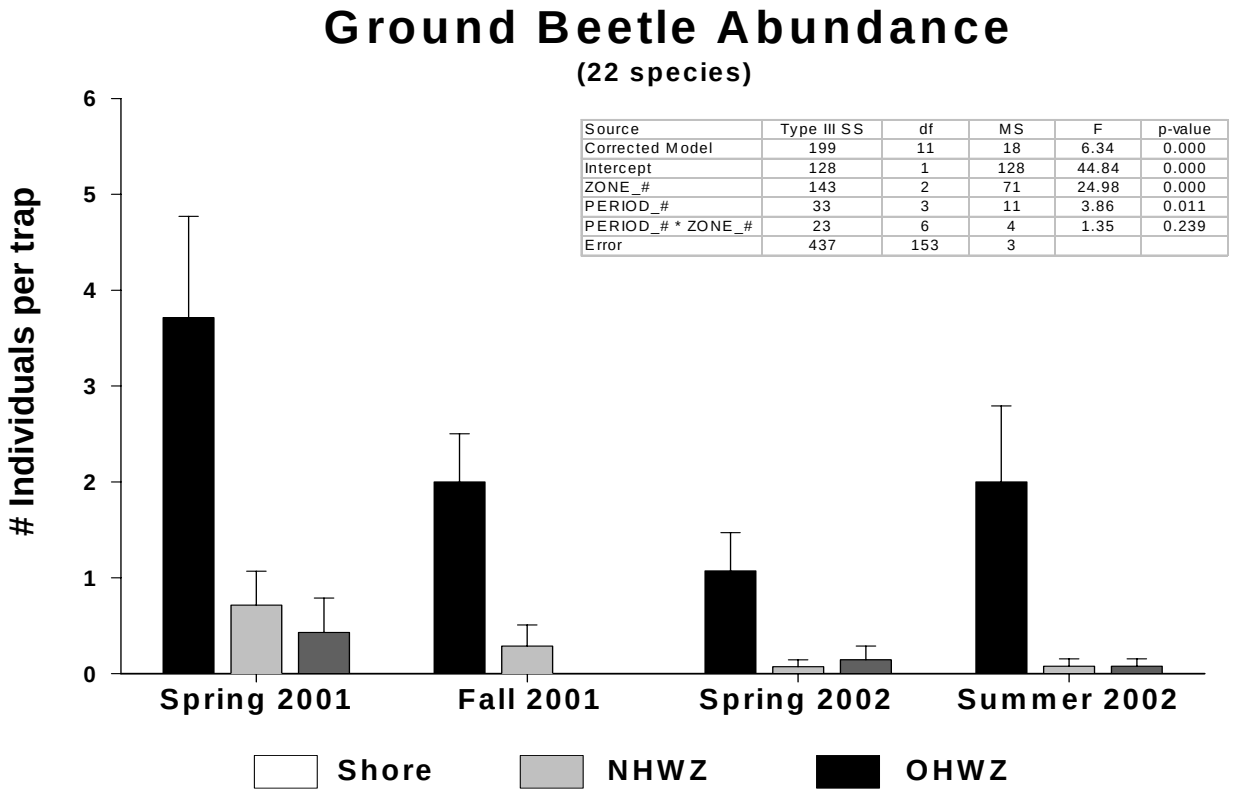


Figure 7. Abundance of ground-dwelling arthropods for each of the four sampling periods in 2001 and 2002 across the three habitats. Overall abundance was reduced in 2002, especially for the arthropods inhabiting the Old High Water Zone(OHW). This reduction in the OHW was due primarily to a single species (seed bug). Surprisingly, summer populations in 2002 for the NHWZ and the OHWZ were relatively high.



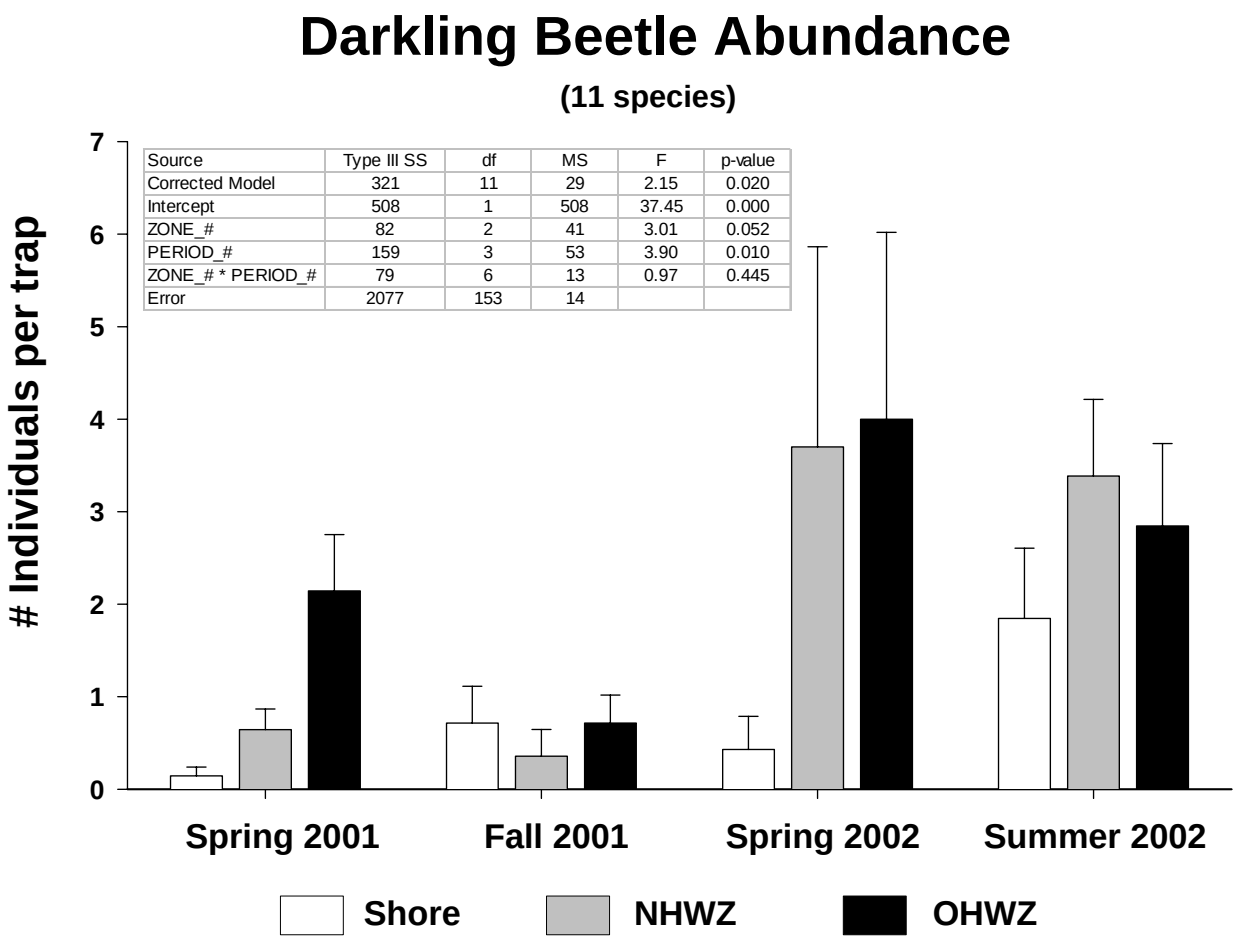
Source	Type III SS	df	MS	F	p-value
Corrected Model	959	11	87	1.81	0.057
Intercept	1046	1	1046	21.71	0.000
ZONE_#	546	2	273	5.66	0.004
PERIOD_#	141	3	47	0.98	0.405
PERIOD_# * ZONE_#	270	6	45	0.94	0.472
Error	7369	153	48		

Figure 8. Spiders exhibit a strong preference for mesic habitats (i.e., shore) and are least abundant in the most xeric habitat (i. e., OHWZ) and intermediate in the Tamarisk-dominated NHWZ.



Source	Type III SS	df	MS	F	p-value
Corrected Model	199	11	18	6.34	0.000
Intercept	128	1	128	44.84	0.000
ZONE_#	143	2	71	24.98	0.000
PERIOD_#	33	3	11	3.86	0.011
PERIOD_# * ZONE_#	23	6	4	1.35	0.239
Error	437	153	3		

Figure 9. Ground beetles showed a strong preference for mesic habitats with the vast majority of individuals collected in the shore habitat. There were significant differences among sample periods but there was no significant interaction effect (i.e. Period X Zone) indicating that ground beetles are excellent indicators of habitat.



Source	Type III SS	df	MS	F	p-value
Corrected Model	321	11	29	2.15	0.020
Intercept	508	1	508	37.45	0.000
ZONE_#	82	2	41	3.01	0.052
PERIOD_#	159	3	53	3.90	0.010
ZONE_# * PERIOD_#	79	6	13	0.97	0.445
Error	2077	153	14		

Figure 10. Darkling beetles exhibited differences among zones, with an apparent preference for xeric habitats, especially during the Spring sampling periods.

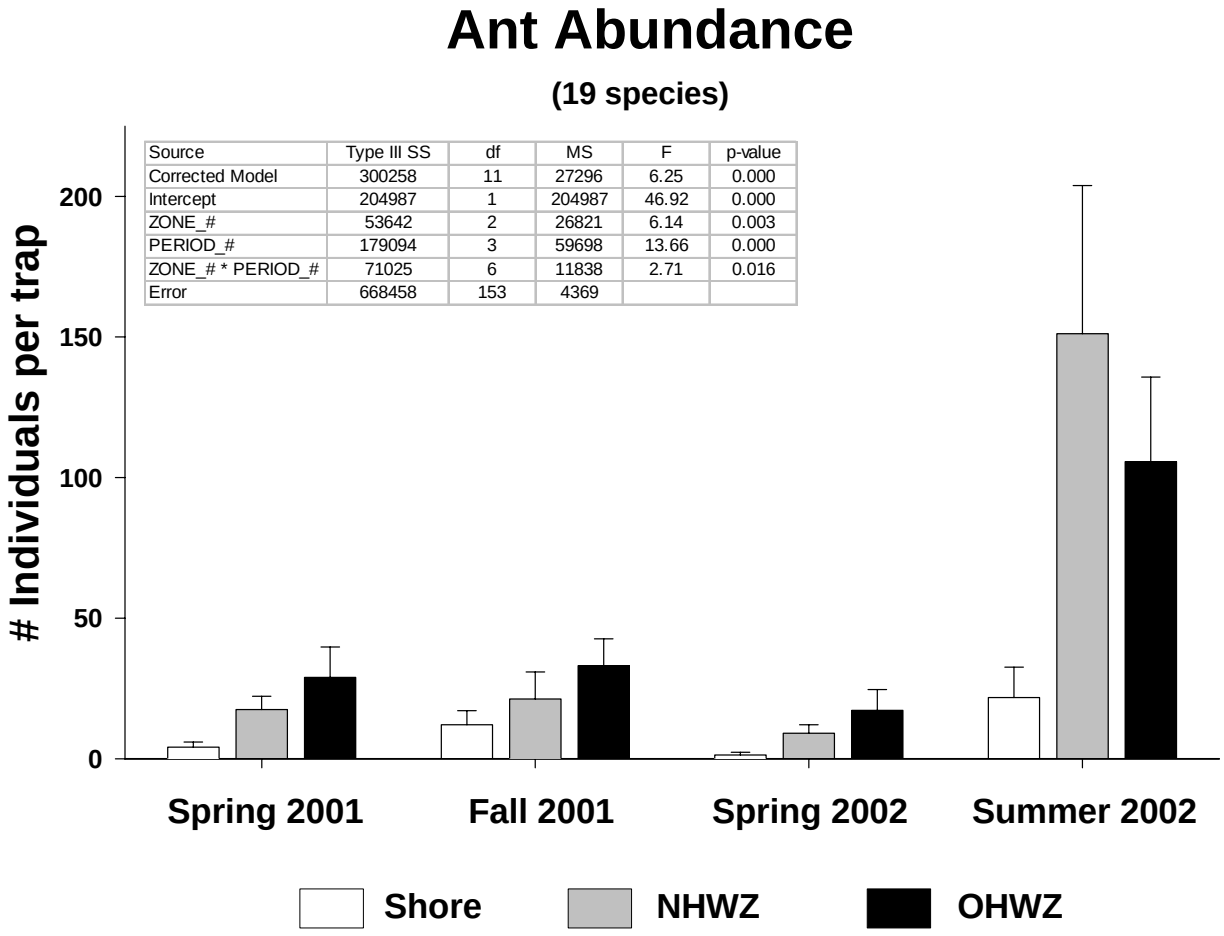


Figure 11. Ants increase in abundance from shore to xeric (OWHZ) habitats. The summer 2002 sample period was anomalous because most of the ants occurred in the NHWZ.

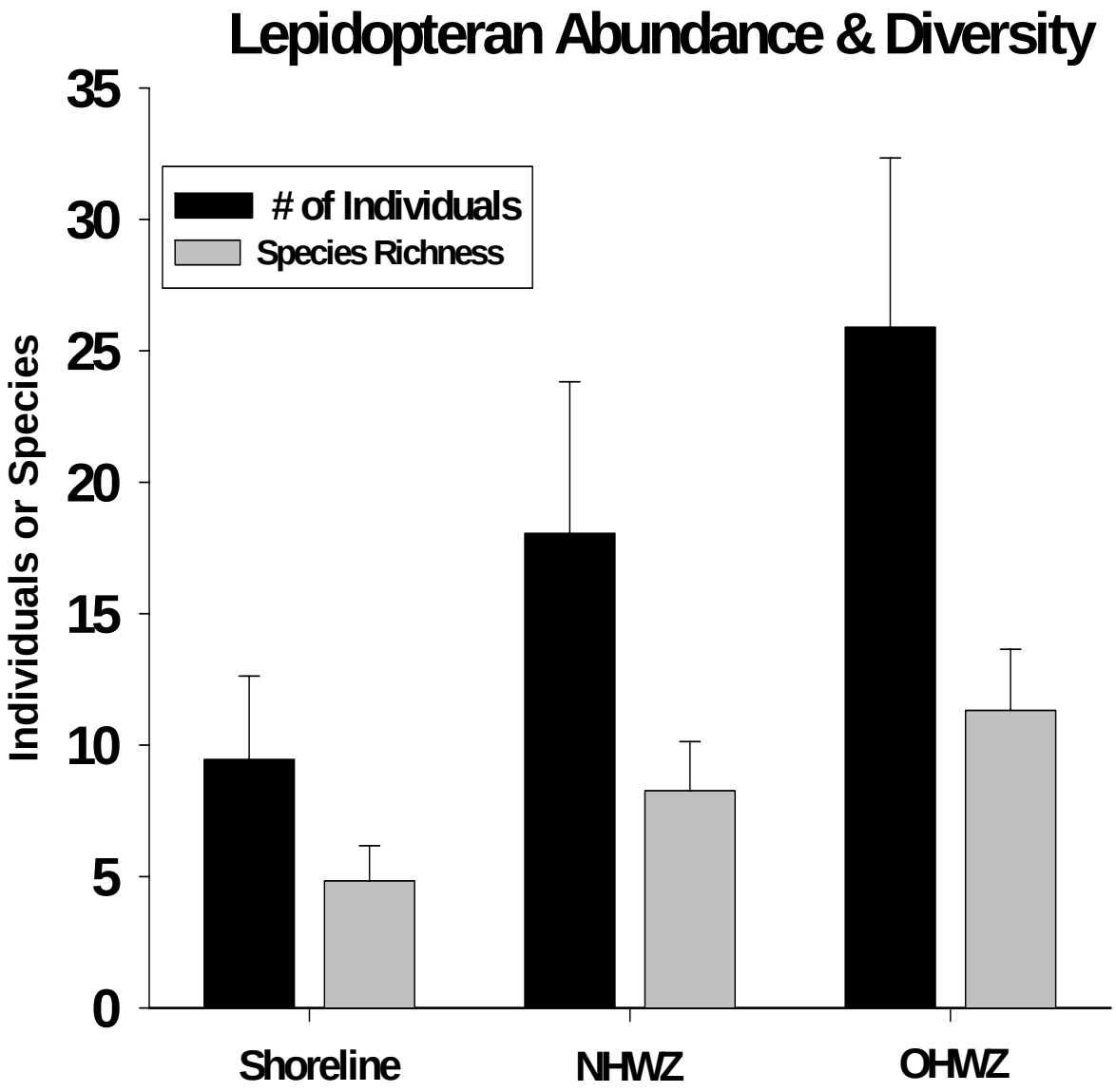


Figure 12. The abundance and diversity (species richness) of Lepidoptera among the three habitat zones during Fall 2001. Both abundance and diversity increase from shore habitat to the OHWZ, with the NHWZ showing intermediate patterns.

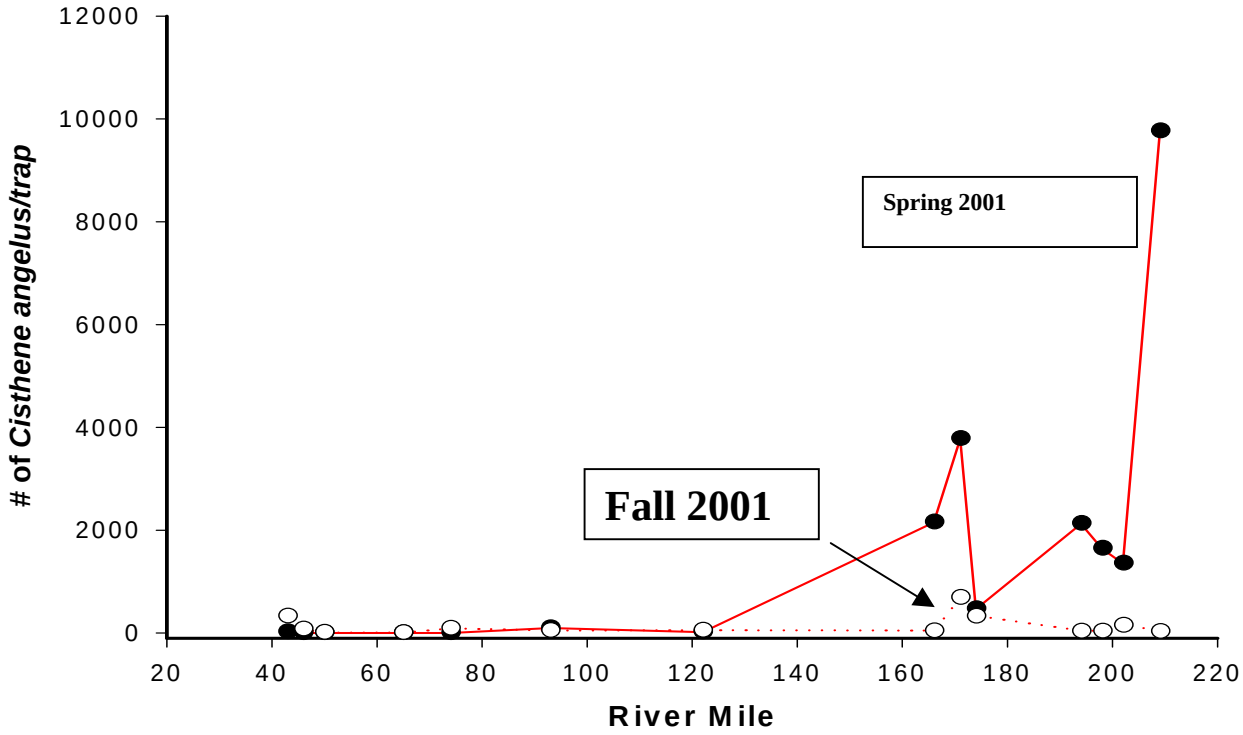


Figure 13. Distribution of *Cisthene angelus*, the most common moth encountered in Grand Canyon. For both Spring 2001 (solid circles) and for Fall 2001 (open circles) there were few moths captured at night-lights before river mile 166.

Vegetation Structure and Habitat Data

Michael Kearsley
Northern Arizona University

Purpose:

The purpose of collecting vegetation structure and habitat data is to generate information on the abundance and three-dimensional distribution of riparian vegetation in the new high water zone and old high water zone of the faunal 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:

In 2002 there were four primary objectives for the vegetation structure work. 1) To measure total vegetation volume (TVV) of woody species in new high water zone and old high water zone patches where birds were counted. 2) To measure TVV of woody species on traplines and transects where mammal and insect trapping occurs and where visual surveys of herpetofauna take place. 3) To collect information on species composition at the same time as TVV data at transects. 4) To determine whether there has been change in the TVV measures in new and old high water zones between 2001 and 2002.

Methods:

In this second year of sampling, methods included patch TVV measures, transect TVV measures, transect compositional information, and data analysis. Sample sites were selected by GCMRC personnel, and the locations of bird point counts and trapping transects were determined by others on this project who were working with faunal components.

Bird patch TVV measures. At each bird count patch, vegetation was divided into new high water zone (below the 90,000 cfs level) and old high water zone areas (above the 90,000 cfs level). In each of these areas, we used tables of random numbers to determine the locations of 20 random points per patch. At the point, readers would read out a modification of the TVV measure of Mills et al. (1991) using a telescoping fiberglass survey rod. For each meter above the ground, the number of decimeters which had live vegetation within 10 cm of the rod would be called to the recorder. The species responsible for the contacts were recorded. If more than one species occupied the same decimeter, both were recorded. In addition, the number of vacant decimeters in each meter were recorded.

The original TVV measure of Mills et al. (1991) was derived from the data by subtracting the number of vacant decimeters number from 10 for each meter across all occupied levels of the canopy at each sample point. By summing the resulting "true" occupied decimeters at each point, the original TVV for the patch was calculated as the sum of TVV from all 20 sample points.

Transect TVV measures. Similar methods were used to derive TVV and composition data from the arthropod pitfall trap / small mammal trapline / herpetofaunal transects in the water's edge, new high water zone, and old high water zone. At each pitfall trap point, recorders would randomly choose whether the survey rod should be

held out an arm's length to the left or right of the pitfall cup. Readings of TVV were taken in the same way as in the bird patches.

Transect plant species composition. We collected plant species composition information along each of the transects at the same time as the TVV data. At each pitfall trap point, we recorded the names of all species present within a 3m radius circular plot. We recorded cover information on each of these species in broad cover classes (Table 1). Data for each species was pooled across all points on the transect before analysis.

Vegetation structure analysis. To determine whether there were significant changes in TVV of bird patches in the new- and old high water zone patches, we performed analyses of variance. Because we detected a significant interaction between year effects and zone effects (the two zones behaved differently in the two years), we analyzed each zone by itself. First, all TVV values within each patch's zone were pooled to produce a single TVV number per 20 sample points. Values from 2001 and 2002 were compared with an unbalanced, mixed effects analysis of variance, with year as a fixed effect and site as a random effect. Because random effects were in the model, we used the reduced effects maximum likelihood (REML) method to fit the model (SAS Institute Inc., 2001).

To determine changes in transect TVV values from 2001, we performed a similar set of analyses of variance for shore, new high water and old high water zones. Data were pooled within each transect and converted to a per 20 points quantity. Each zone's TVV data were analyzed with a mixed effects, unbalanced model analysis of variance with site as a random effect and year as a fixed effect. As with the bird patch data, we used the REML method to fit the model.

Transect cover and composition. To summarize data on vegetation at the transects we calculated cover estimates and compared composition among zones. We derived estimates of total vegetative cover for each transect by converting each cover class observation to the midpoint of the range it designated (Table 1). Each species' cover was calculated as the mean of the 10 observations per transect, and the transect cover estimates was calculated as the sum of all species means. These cover data were compared with a 1-way analysis of variance. Species richness was compared in the same way. To estimate the overall richness of the three zones throughout the river corridor, we used the first order jackknife procedure (Heltshe and Forrester, 1983) on the data we had available. When data from multiple plots are available, this has been shown to produce the most reliable estimates of regional richness (Palmer, 1990).

Composition of the vegetation in the three zones was compared using an analysis of similarity (ANOSIM; Clarke, 1993). Patterns detected with the ANOSIM were visualized with an NMDS ordination (Kruskal and Wish, 1978). In both analyses, we used a Bray-Curtis dissimilarity measure with species quantities relativized to species maximum values in order to best preserve the ecological information in the data set (Faith et al, 1987).

Compositional comparisons between zones in the point count and transect data sets were made with an analysis of similarity (ANOSIM; Clarke, 1993) and visualized with an NMDS ordination (Kruskal and Wish, 1978). Both were done using the Bray-Curtis distance measure on data which had been relativized by species maiximum (Faith et al, 1987).

Results:

The data from the bird patches showed very little change in vegetation structure between 2001 and 2002. New high water zone TVV was not significantly different from 2001 levels (Figure 1; $F_{(1.16)} = 0.879$, n.s.). The TVV in old high water plots showed no significant change in 2002 either (Figure 1; $F_{(1.16)} = 0.089$, n.s.). There were no significant site effects in the new high water zone patches ($F_{(81.16)} = 0.914$, n.s.), although old high water zone patches did differ slightly ($F_{(81.16)} = 2.986$, $p < 0.05$).

Vegetation structure in the faunal transects for the most part did not differ from their 2001 levels. Old high water zone transects had no different TVV values in 2002 (Figure 2, $F_{(1,3)} = 1.51$, n.s.). Likewise, TVV in the waters edge transects showed no change from 2001 (Figure 2; $F_{(1,3)} = 4.47$, n.s.). However there was a significant decrease in vegetation density in the new high water zone transects (Figure 2; $F_{(1.3)} = 21.63$, $p < 0.05$).

Vegetative cover and richness in transects differed between the three zones. The data showed that estimates of total vegetative cover were highest in the waters edge and new high water zones and lowest in the old high water zone (Figure 3; $F_{(2,25)} = 5.09$, $p < 0.05$). On a per transect basis, species richness was highest in the water's edge zone transects, lower in the new high water zone and lowest in the old high water zone (Figure 4; $F_{(2, 25)} = 6.57$, $p < 0.01$). However, the first order jackknife estimates of overall richness showed that the old high water zone had the greatest number of species (109), followed by the new high water zone (106) and the water's edge zone had the fewest overall (98).

The ANOSIM analysis showed an expected pattern of change in community structure with distance from the river. All three zones were significantly different from one another in terms of the identity and abundance of species present in the plots (WAT vs. NHW: $R = 0.492$, $p < 0.001$; WAT vs. OHW: $R = 0.707$, $p < 0.001$; OHW vs. NHW: $R = 0.380$, $p < 0.001$). In addition, the NHW plots appeared to be intermediate to the waters edge and old high water plots in the NMDS ordination (Figure 5).

Summary:

The data we collected on habitat vegetation structure in 2002 showed some change in the new high water zone, but very little change in the lower and higher elevation areas. In the vegetation dynamics data elsewhere in this document, the greatest change in vegetative cover took place in the new high water zone between 25 kcfs and 35 kcfs. This corresponds to our finding that in the transects, vegetation structure declined the most in the new high water zone, and not significantly at all in the waters edge and old high water zone.

The differences in the results of the TVV changes seen in the new high water zone in transect and bird patch data have several potential sources. First, the bird patch "new high water zone" includes all areas below the 90 kcfs stage, thus it combines information from the areas sampled in both the new high water zone and the waters edge zone. The lack of change in the waters edge zone sampled in the bird patches likely dampened the change we saw when only the area at and above the 25 kcfs stage was sampled in the transects.

The difference was not a function of investigator impacts on transects via trampling. When we analyzed the four "repeat" sites and ten "random" sites separately,

we get nearly identical results. Measures of TVV in the sites sampled in both years were 40% lower in 2002 when compared to their 2001 levels (187 vs. 113). In sites which were sampled in only one of those years, the decrease was 40.1% (129 vs. 77). We did not detect a significant interaction effect.

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Table 1. Percent vegetative cover for six cover classes used in transect plant composition surveys

Class	Percent Cover	Class Midpoint
T (trace)	< 1%	.25%
1	1 – 5 %	3%
2	5 - 25%	15%
3	25 – 50%	38%
4	50 – 75%	63%
5	75 – 100%	88%

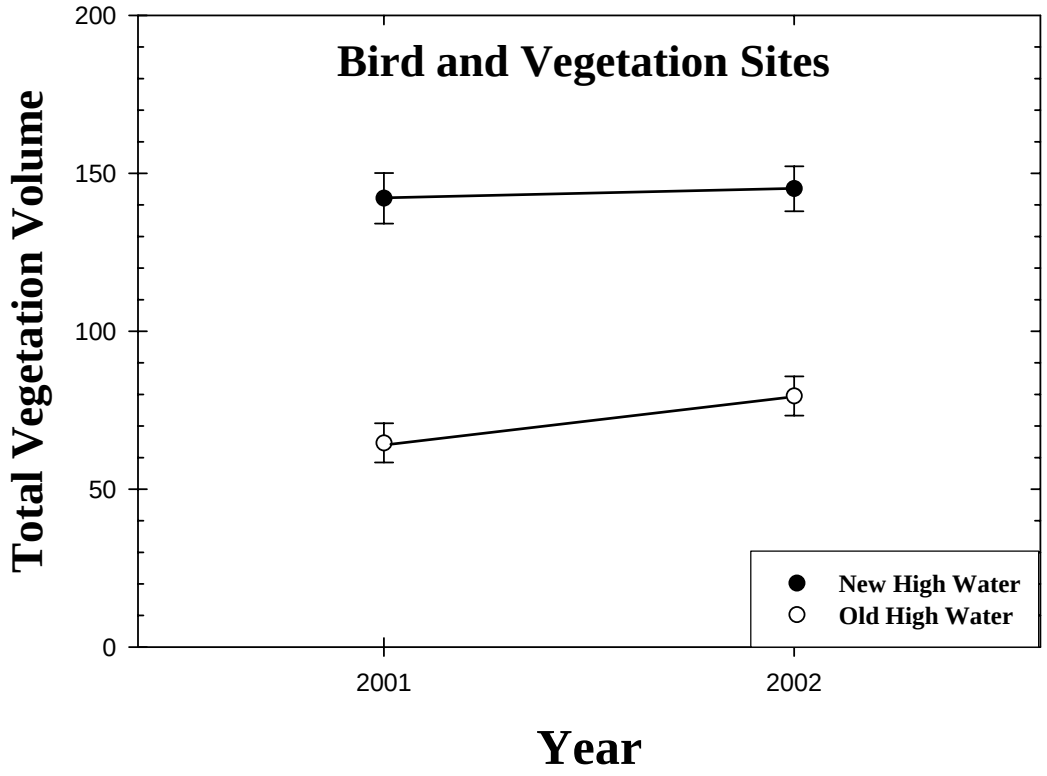

Figure 1. Total vegetation volume measures in new high water and old high water bird patches in 2001 and 2002. Values were not significantly different in the two years in either patch type.

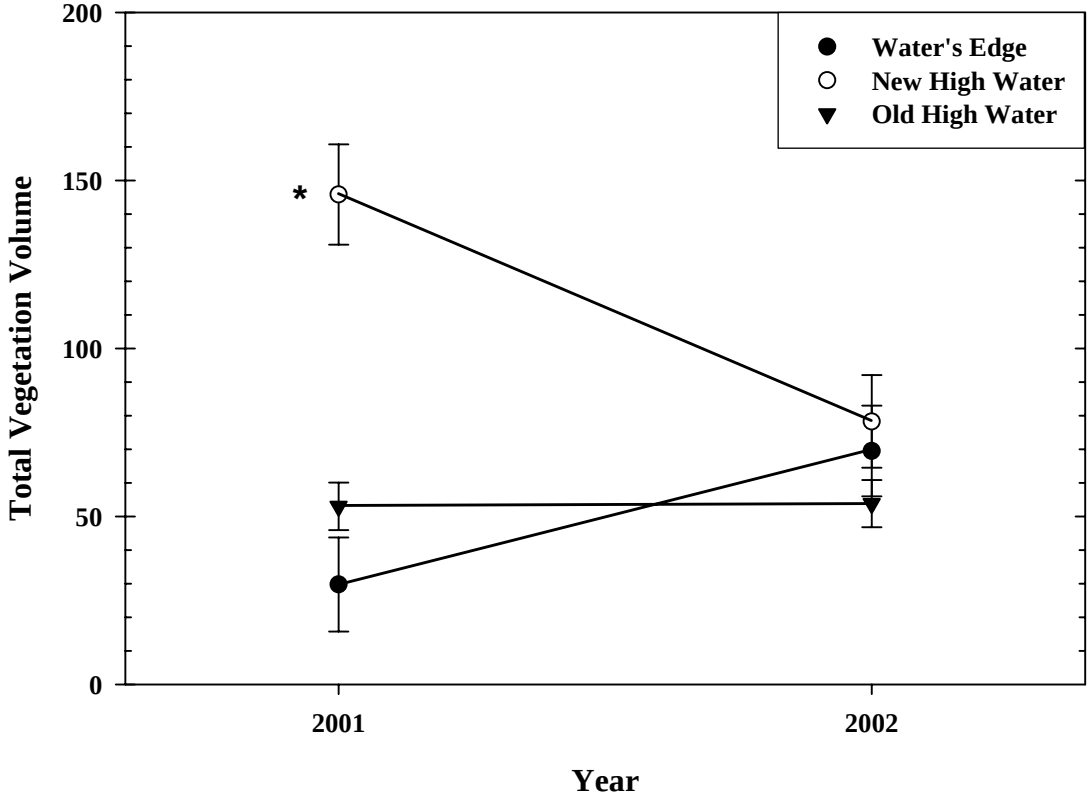

Figure 2. Total vegetation volume measures from faunal transects in the integrated monitoring sites. There was no change from 2001 to 2002 in the old high water and water's edge transects, and a marginally significant decrease in the new high water zone.

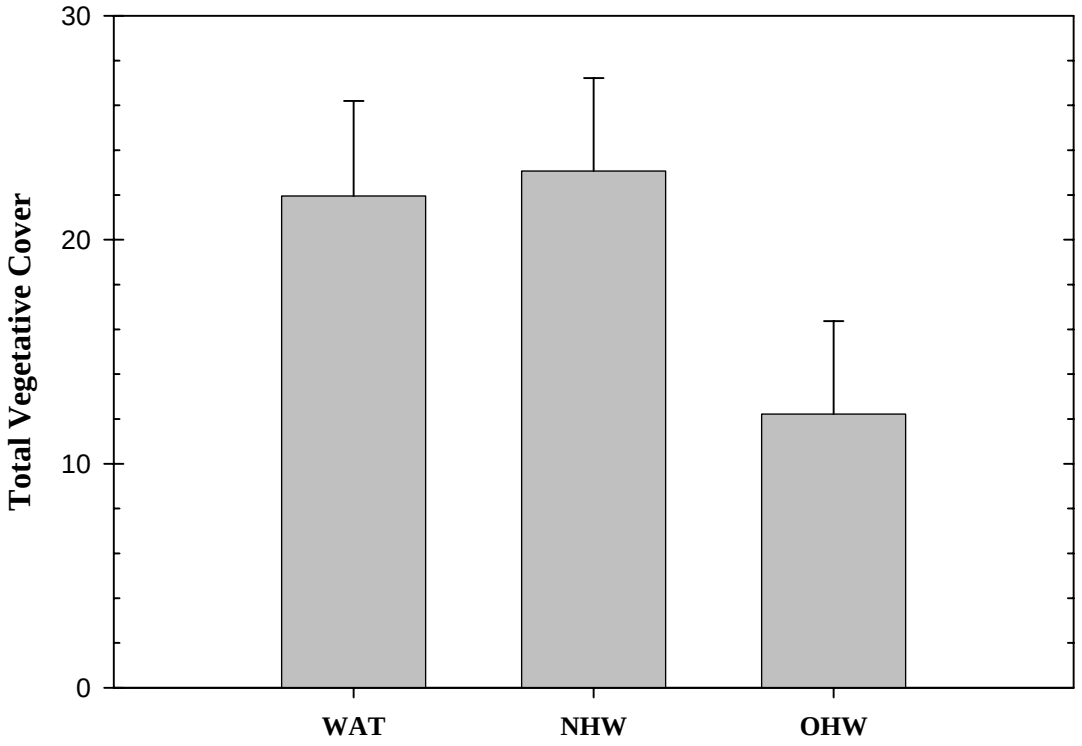

Figure 3. Total vegetative cover measured in the faunal transects at the integrated monitoring sites. Significant differences among zones resulted primarily from the low cover recorded in old high water zone transects.

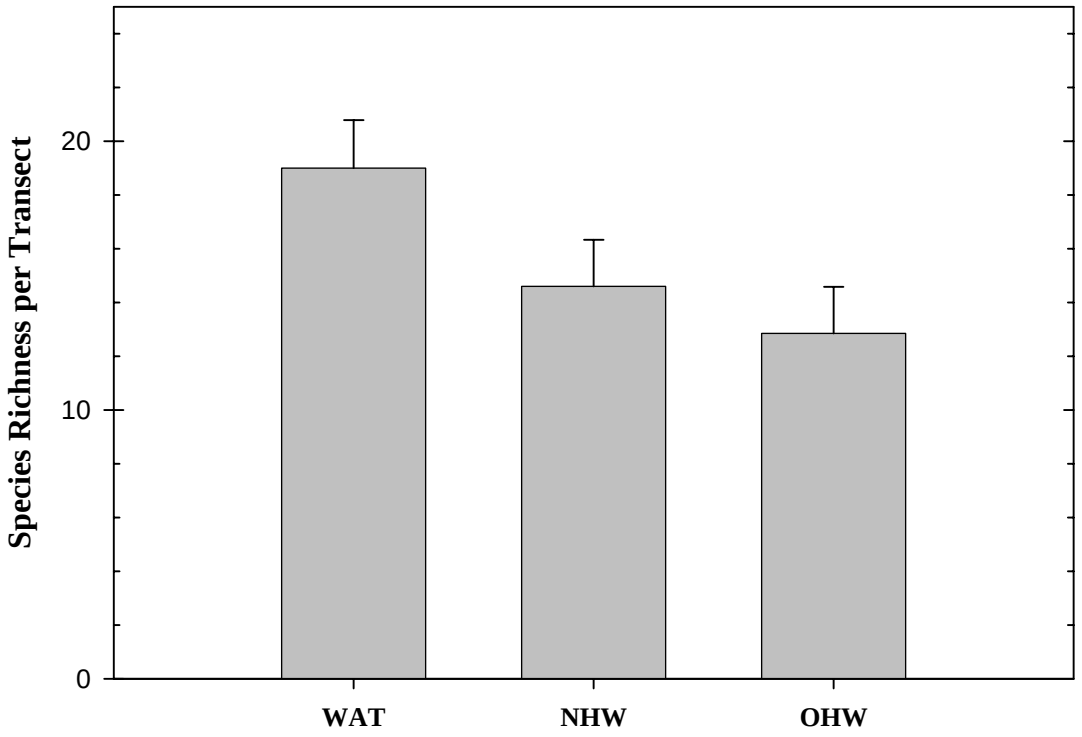

Figure 4. Species richness per transect in the cover plots of the faunal transects in the integrated monitoring sites. Global richness is higher in new high water zone and old high water zone transects.

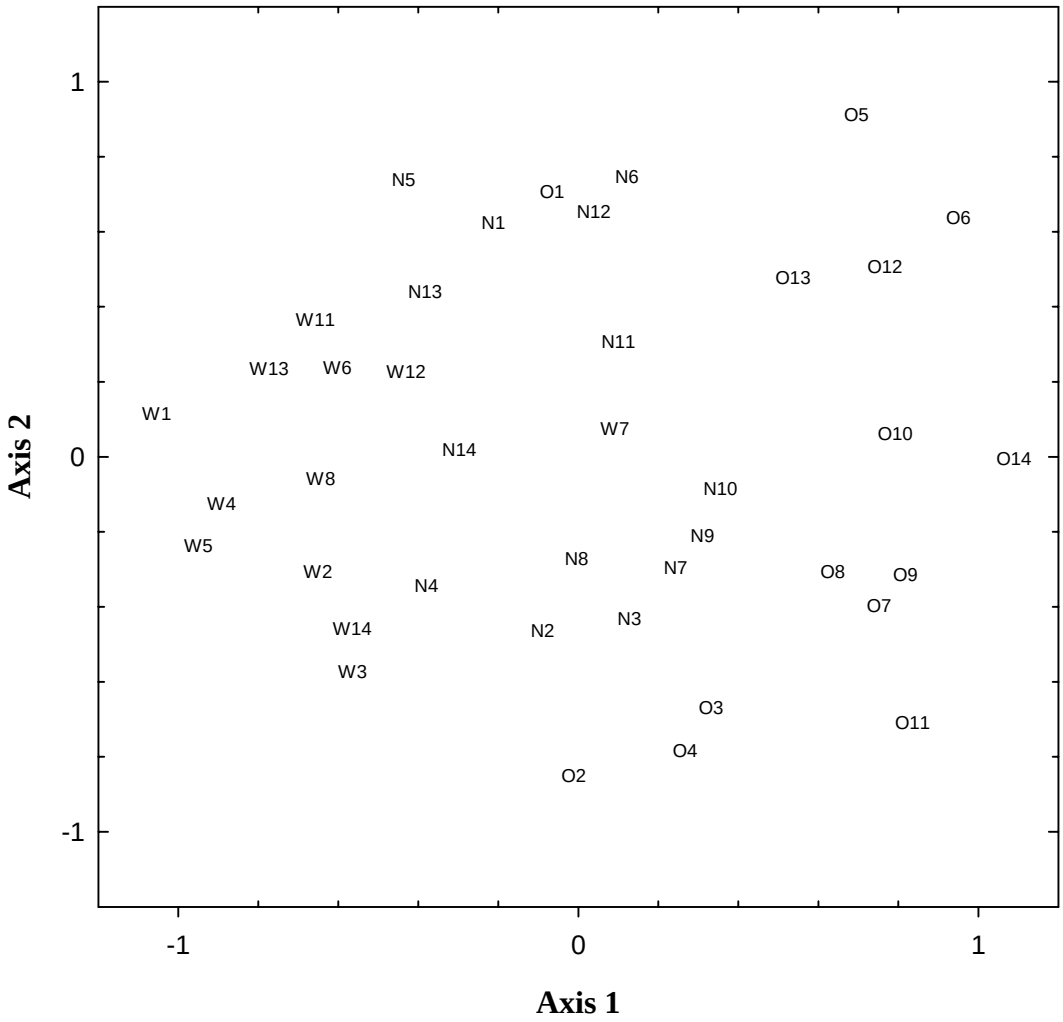

Figure 5. NMDS ordination of species composition data from the faunal transects in the integrated monitoring sites. Plot symbol letters designate zone (Water's edge, New high water, Old high water) and numbers designate site number (1 – 14, upstream to downstream).

Vegetation Dynamics

Michael Kearsley
Northern Arizona University

Purpose:

The purpose of the vegetation dynamics work is to generate information on the status of and trends in the distribution, abundance, diversity and composition of riparian vegetation in relation to stage elevation along the Colorado River between Glen Canyon Dam and Diamond Creek.

Objectives:

In 2002 there were five primary objectives for the vegetation dynamics work. 1) To determine vegetation cover, species richness, diversity (Shannon H'), wetland indicator status, and abundance of exotics at elevations above the river corresponding to flows of 15, 25, 35, 45, and 60 thousand cubic feet per second (kcfs). 2) To compare the measures of vegetation among years to determine trends within stage zones. 3) To compare yearly trends in vegetation in low and high zones to differentiate between impacts of dam operations and climatic variability. 4) To determine the average substrate texture (percent of surface with sand or finer sediment) at each of the stage elevations, and to compare that with 2001 levels to test for flow-related changes. 5) To perform power analyses of vegetation and substrate data to determine the adequacy of the current sampling intensity (60 sites per year) for addressing the above questions.

Methods:

Selection of Sample Sites and Transects: As in 2001, site selection was based on a probabilistic sampling of river margin segments defined by adjacent STARS cross sections (Randle and Pemberton, 1987). Of the 60 sites from 2001, 40 were replaced by new sites in 2002 and 20 were scheduled to be repeated. We added four sites from the Glen Canyon reach above Lees Ferry.

The 40 replacement sites were derived from a set of 50 potential sites visited during a winter trip (Jan. 26 - Feb 6). Potential sites were rejected for any of a number of reasons: "cliff" sites were too vertical to support vegetation, others were inaccessible (in the middle of rapids) or administratively off-limits (Kanab ambersnail sites at Vaseys Paradise and Deer Creek, cultural sites near the confluence with the Little Colorado River).

At each usable replacement site, transect and elevation control points were installed and documented as in 2001 (see Figure 1). A single mark was made at the top of the transect well above our estimate of the 60 kcfs elevation using nail polish. If the entire transect could not be seen easily from the transect top point, a separate elevation control point was marked from which all could be seen. Written descriptions of the points relative to nearby landmarks and the drop from the elevation control point to the previous day's water's edge were recorded. The latter would be used to determine the elevation of the control point relative to the sample points at 15, 25, 35, 45, and 60 kcfs. Site location photographs were taken of the points and the transect itself. At least one transect photograph included a cross-river point to be used for reestablishing the transect location.

Vegetation Sampling. Vegetation sampling was conducted in the fall of 2002.

Transects between Lees Ferry and Diamond Creek were sampled during a downriver trip between August 29th and September 13th. Upriver sites were sampled on a day trip on September 20th. Due to logistical constraints, including boating mishaps requiring boat repairs and a few very long mileage days on the river, only 6 of the 64 planned sites were missed in 2002.

Sampling of each transect consisted of three steps: reoccupation, frame placement, and survey. First, the transect itself and the elevation control points were re-occupied using cues from site photographs and descriptions. The transect line was reestablished by sighting from the transect top point to the cross-river point and directing the placement of the tape down the transect to the water's edge.

Points on the transect corresponding to five stage elevations were located using elevation values calculated from data collected on transect establishment trips in Summer 2001 and Winter 2002. The elevation drop to each of these points was measured with an abney level at the control point and an extendable survey rod on the transect. Pin flags were placed at points corresponding to the 15, 25, 35, 45, and 60 kcfs levels.

At each elevation point, a 1 x 1m sighting frame (per Floyd and Anderson, 1982) was placed and leveled with one side along the transect and the riverward corner of the transect side directly over the pin flag. Once a frame was surveyed, the frame was moved upstream or downstream at the same level so that four 1 x 1 meter areas were sampled (two frames upstream of the transect and two downstream).

Vegetation data were recorded in the following way. First, all species present in each 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 later. 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 (cover, richness, diversity), but were excluded from the multivariate analyses to be described below.

To estimate percent vegetative cover in each frame, 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 collectively sum to more than 100%. For tall shrubs and trees, cover was visually estimated by consensus of the crew. 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 0.001 percent.

Surface Texture Sampling: In order to document the characteristics of the soil surface at the shore of different flow levels, the substrate texture was recorded 40 points per stage elevation. A measuring tape or survey rod was laid on the ground perpendicular to the transect at each stage point. Every 10 centimeters for two meters upstream and downstream of the transect, the size of the surface particle below that point was recorded on a 7 point scale (Table 1). Because the rotating panel sampling design resulted in an unbalanced data set (not all plots were surveyed in both years), we used an unbalanced, mixed-effects analysis of variance which included year and zone as fixed effects, transect

(site) as a random effect, and the year by zone interaction. The presence of a random effects factor required us to use a restricted maximum likelihood method to fit the model (SAS Institute Inc., 2001).

Vegetation Analysis: To avoid problems with independence, data were pooled across all four frames within each stage level at each transect before all analyses. Cover data were converted to a per meter squared quantity. Richness and diversity (Shannon H'), on the other hand were based on the four meter squared totals.

Several univariate community measures were derived from each transect's pooled data at each stage level. Total vegetative cover was calculated as the sum of foliar cover values of all species at the stage level. Species richness was the number of unique species encountered per four meters squared. Plant species diversity was calculated as the Shannon (H') index with untransformed mean cover values.

Because dam operations can have a profound effect on plant water relations by altering ground water levels, mean wetland indicator scores were calculated within each stage zone for all transects. Each species has a characteristic wetland indicator score, ranging from 1 for obligate upland species to 5 for obligate wetland species (see Reed, 1988) and a 1996 update at http://www.nwi.fws.gov/bha/). A weighted average was calculated by multiplying the wetland indicator score for each species by the proportion of the total percent cover accounted for by that species. We also calculated unweighted mean wetland scores by simply averaging the indicator scores of all species which were recorded at a given stage level.

To test for changes in vegetation between 2001 and 2002, we compared total cover, richness, diversity and wetland indicator scores in the two years. Because the rotating panel sampling design resulted in an unbalanced data set (not all plots were surveyed in both years), we used an unbalanced, mixed-effects analysis of variance which included year and zone as fixed effects, transect (site) as a random effect, and the year by zone interaction. The presence of a random effects factor required us to use a restricted maximum likelihood method to fit the model (SAS Institute Inc., 2001).

Because univariate analyses often miss important, but subtle, shifts in communities (Gray et al, 1990; Warwick and Clarke, 1991), we used two approaches to test for compositional changes between years. First, we used indicator species analysis ((Dufrêne and Legendre, 1997) to determine whether species turnover was taking place without being manifested in species richness or total cover comparisons. This technique discerns species which are abundant and common in one year but not the other. Data sets from each stage level were analyzed separately. Species were considered good indicators only if their indicator value was greater than 25 and Monte Carlo simulations showed that their indicator value was larger than those found in 95% of simulated random samples.

And second, an analysis of similarity (ANOSIM; Clarke, 1993) was used to contrast 2002 data with 2001 data in each stage level. ANOSIM compares the difference in ranks of within_group dissimilarity and between_group dissimilarity from field data to those generated by random assignment of samples to groups. Cover values for each species were relativized to a proportion of that species' maximum at that stage level and the Bray-Curtis index was was used to calculate dissimilarities (Faith et al, 1987). The results of the ANOSIM were visualized withan NMDS ordination (Kruskal and Wish 1978) which also used the Bray-Curtis dissimilarity measure.

Results:

Soil Surface Texture: There was no detectable change in the soil surface texture at any of the stage elevations (Figure 2). The zones differed significantly, with the mid-elevation points (25 and 35 kcfs) having the highest percent fines (Zone: $F_{(4, 415)}$ =12.672, $p < 0.001$). However, there was no difference between years (Year $F_{(1, 415)} = 0.219$, n.s.) and among-zone differences remained the same in both years (Year x Zone interaction: $F_{(4, 415)} = 2.121$, p < n.s.).

Univariate Vegetation Measures: At all stage levels, there was a loss of vegetation from 2001 to 2002 (Figure 3). There was a strong difference among zones (Zone: $F_{(1, 473)} = 15.76$, $p < 0.005$), with the highest cover in the 25 and 35 kcfs stage levels. There was no change in the relationship among the zones in terms of their total cover (Year x Zone interaction: $F_{(4, 473)} = 0.83$, n.s.). However, cover in 2002 was approximately 6% lower across all zones than in 2001 (Year: $F_{(1, 473)} = 12.02$, $p < 0.01$).

Species richness differed between 2001 and 2002, but the pattern was more complex (Figure 4). There was a drop of one or two species per sample in 2002 (Year; $F_{(1, 473)} = 6.63$, $p < 0.01$) but not consistently across all levels. There was a strong zone effect ($F_{(4, 473)} = 4.44$, $p < 0.001$). Most of the drop was limited to the upper two elevation points (45 and 60 kcfs) with very little change in the lower three zones, resulting in a marginally significant interaction between the two factors (Year x Zone interaction: $F_{(4, 473)} = 2.68$, $p < 0.05$).

Diversity showed a pattern similar to species richness, only the year and interaction effects were more marked (Figure 5). Zones differed markedly from each other in 2001 and 2002 (Zone: $F_{(4, 473)} = 4.04$, $p < 0.005$), and there was a large difference between overall H' values between the two years (Year: $F_{(1, 473)} = 23.44$, $p < 0.001$). However, most of the change took place in the upper two zones so that the shape of the relationship between H' and stage zone went from more or less linear in 2001 to a "hump" shape in 2002 (Year x Zone interaction: $F_{(4, 473)} = 5.78$, $p < 0.005$).

Wetland indicator scores of samples changed in an unexpected manner in 2002. In spite of the extremely dry conditions in the winter, spring, and early summer, the wetland scores of all plots increased (Figure 6). Wetland scores declined with increasing stage elevation in both years (Zone: $F_{(4, 473)} = 79.79$, $p < 0.001$). However, values in 2002 were significantly higher than in 2001 (Year: $F_{(1, 473)} = 43255$, $p < 0.05$). There was no change in the relationship of wetland indicator values among levels ($F_{(4, 473)} = 0.38$, n.s.).

The indicator species analyses showed that for all 5 stage levels, there were species which were common and abundant in 2001 but missing in 2002, and no species which turned up more or less exclusively in 2002 (Table 2). Many desert annuals and herbaceous perennials, whose abundance is much more tightly tied to rainfall than woody species, were far less common in 2002 than in 2002. Annual bromes, species of *Sporobolus* and *Aristida*, and herbaceous perennials like *Aster spinosus* and *Lepidium fremontii* did not grow well in 2002 after having a good year in 2001. No obligate wetland species showed any change between 2001 and 2002.

The Analysis of Similarity comparisons made within stage zones between years showed compositional shifts reflecting the indicator species analyses (Figure7). The three lowest zones had little or no compositional change between 2001 and 2002. The plots in the 45 and 60 kcfs zones in 2002 differed significantly from 2001.

Summary:

The extreme dryness during the first half of 2002 was responsible for most of the between-year differences seen in the vegetation of the riparian corridor. The hydrographs of the two years were very similar, and we did not detect any change in the substrate texture of the two lowest zones, where flow effects on soils would be expected.

All other measures indicated a loss of species which was related to the drought. Vegetative cover declined in all stage zones, although the declines were lower in the lowest zone where species had access to ground water. Species richness declined in the highest two zones, and the losses were primarily annuals, perennial grasses and herbaceous perennials whose cover values are most sensitive to changes in rainfall. In the lower zones, where there is some access to groundwater, species richness declined much less, and the species which were less abundant were also those same annuals and annual grasses. The measure of diversity which we used (H') also declined significantly in the upper two zones, indicating that the distribution of cover across species leaned more towards a pattern of fewer rarer species and more of the dominant taxa. Again, this is likely the result of a reduced germination of annuals and less productivity from herbaceous perennials and perennial grasses.

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Table 1. Sediment classes used in substrate texture assessments.

Silt / Clay	Fine sediment with no detectible grittiness. May roll easily when moistened.
Sand	Gritty fine sediment, particles less than 2mm diameter.
< 1cm	Fine gravel between 2mm and 1cm along longest axis.
< 10 cm	Coarse gravel between 1 cm and 10 cm along longest axis.
< 1m	Cobbles, rocks and small boulders between 10 cm and 1m along longest axis.
< 10m	Boulders between 1 and 10 meters along longest axis.
Bedrock	Solid rock or cliff face more than 10 meters along longest axis.

Table 2. Indicator species for 2001 and 2002 at each of the five stage elevation levels. Only species with indicator values above 25 and greater than 95% of Monte Carlo simulations are listed.

Zone	**2001**	**2002**
15 kcfs	Ripgut grass Red brome	***N/A***
25 kcfs	Ripgut grass Red brome	***N/A***
35 kcfs	Ripgut grass Red brome Scratchgrass	***N/A***
45 kcfs	Spiny aster Ripgut grass Red brome Sand dropseed Mesa dropseed	***N/A***
60 kcfs	Threeawn grass Cane bluestem grass Red brome Western tansymustard Slender poreleaf Desert pepperweed Sixweeks fescue	***N/A***

Figure 1. Diagram of sampling scheme in plan view. Transect (thick line) is perpendicular to river flow, running from documented top point (Circle X) to the water's edge. Meter-squared survey plots (shaded boxes) are placed up- and downstream of the transect at estimated stage elevation points. Elevation control point (Circle Cross) is positioned so as to allow a view of the entire transect.

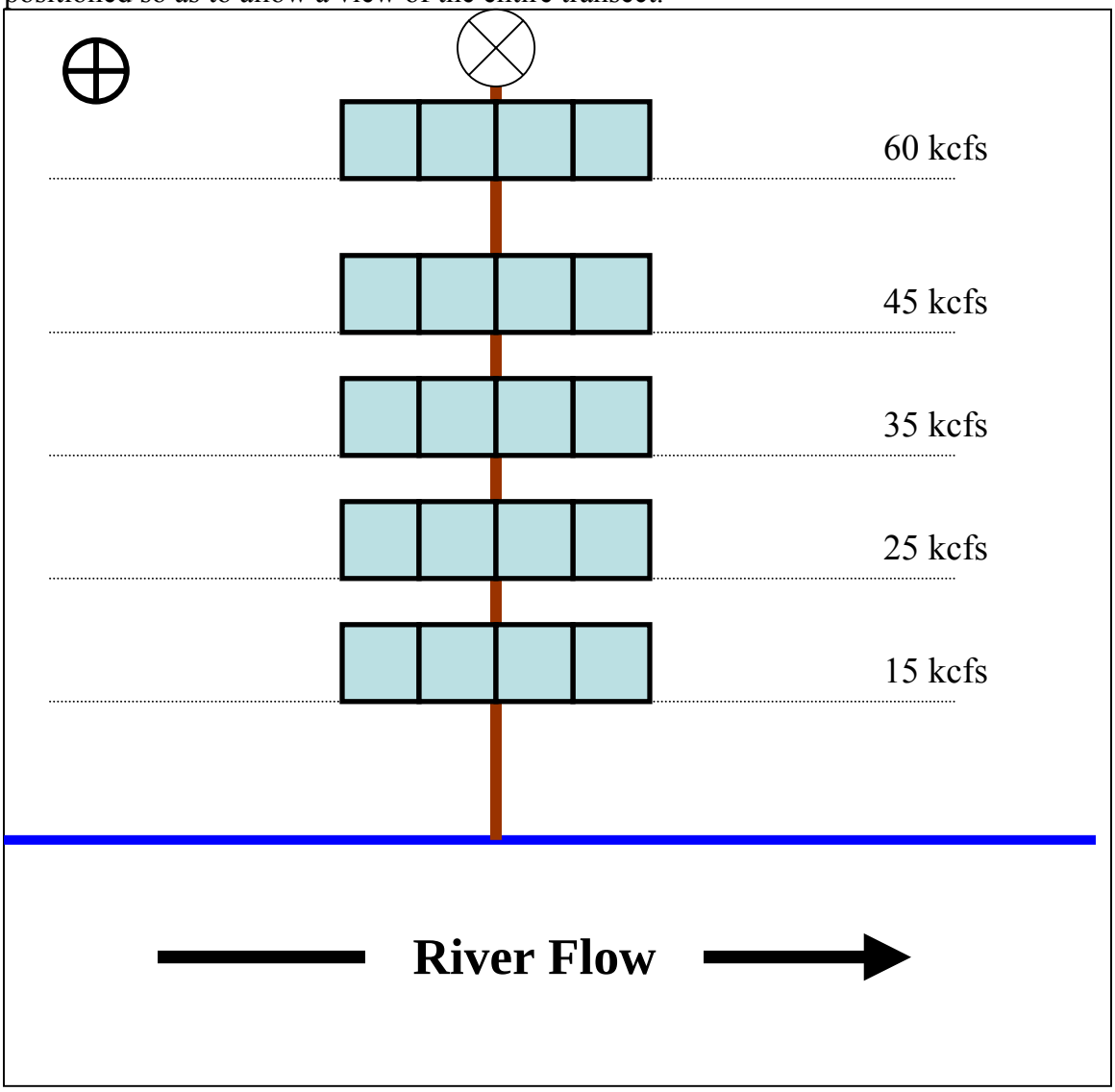


Figure 2. Soil surface texture (percent sand and finer) at five stage elevation zones in 2001 and 2002.

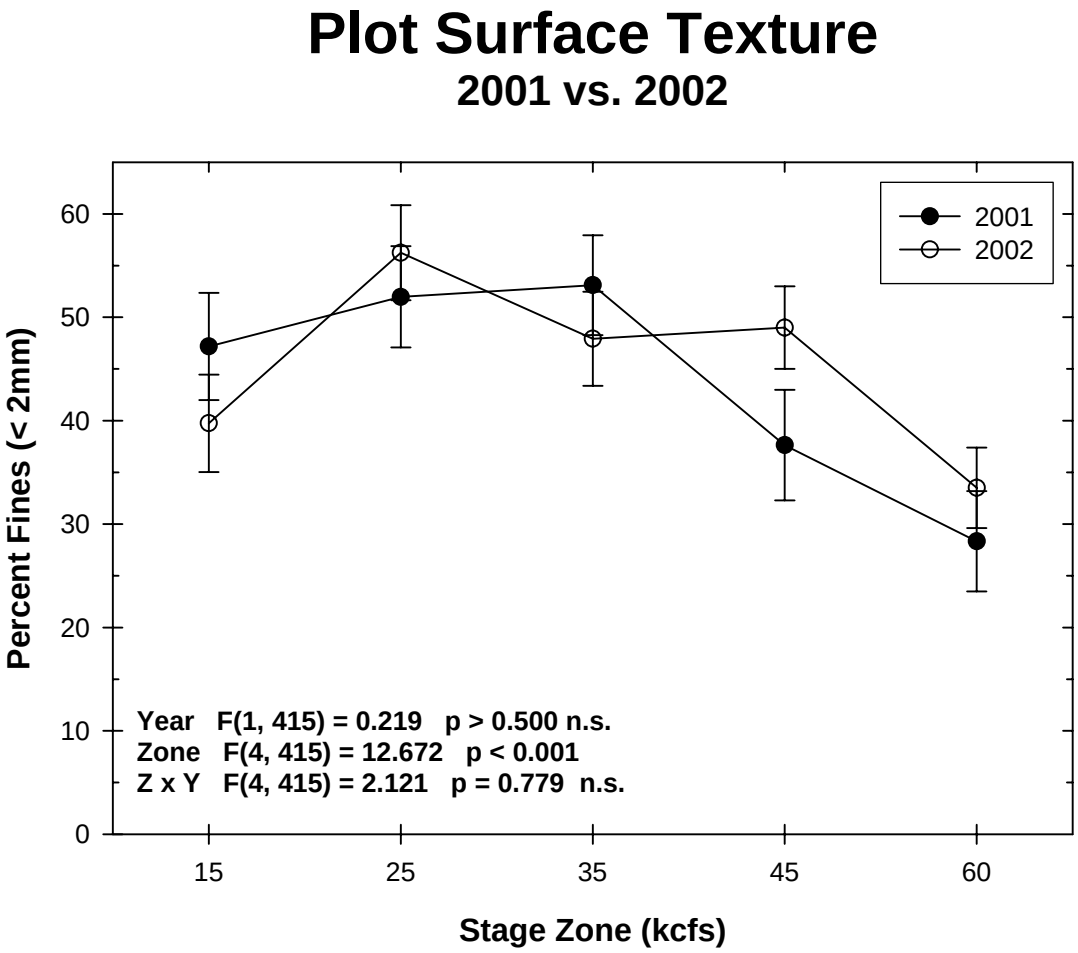


Figure 3. Cover in five stage zones in 2001 and 2002, and change between year. Closed circles represent 2001 data, open circles represent 2002 data and "+" symbol indicates between-year change. Vertical bars represent +/- 1 s.e.

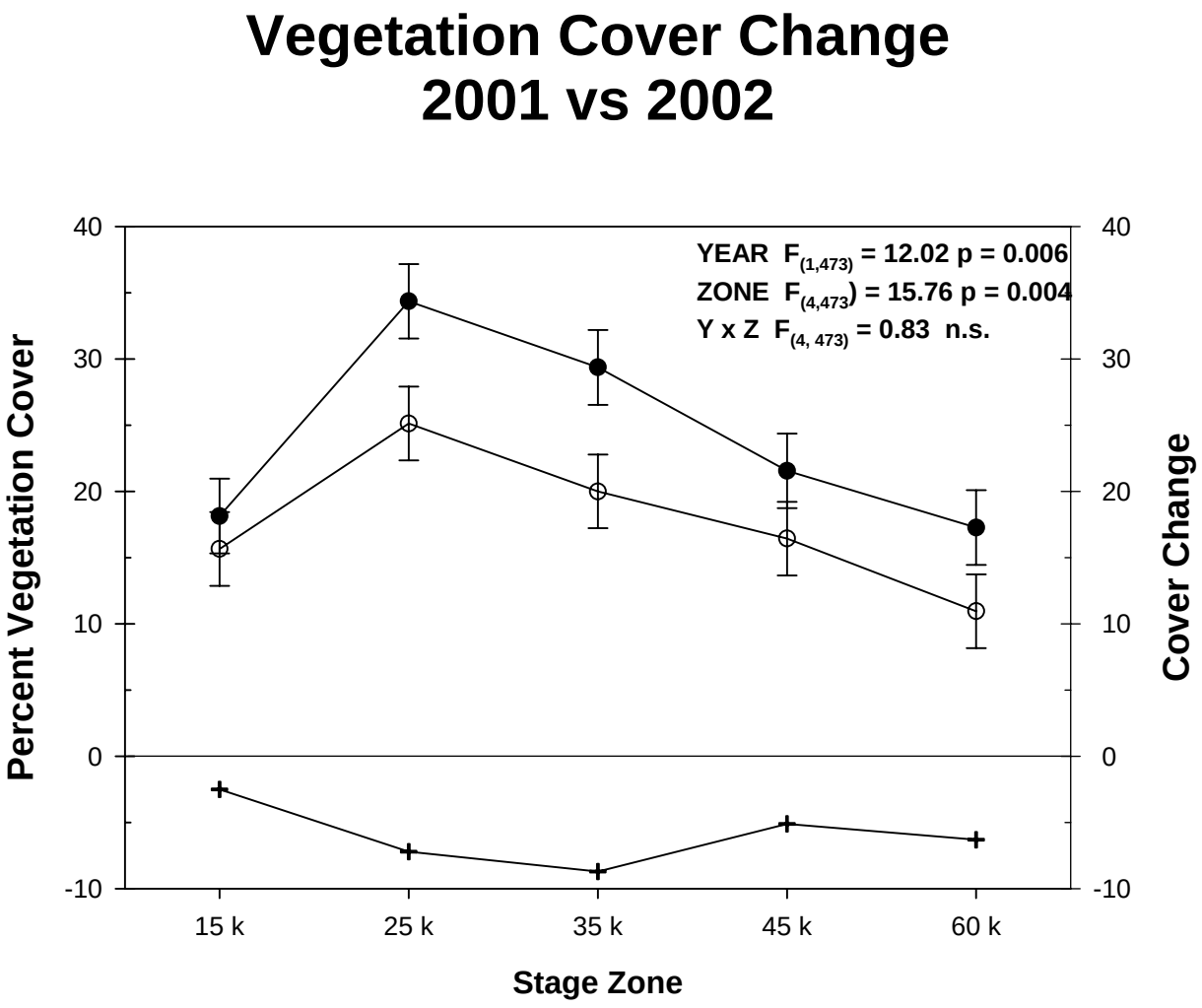


Figure 4. Species richness (S) in 2001 and 2002, and change between the years. Closed circles represent 2001 data, open circles represent 2002 data and "+" symbol indicates between-year change. Vertical bars represent +/- 1 s.e.

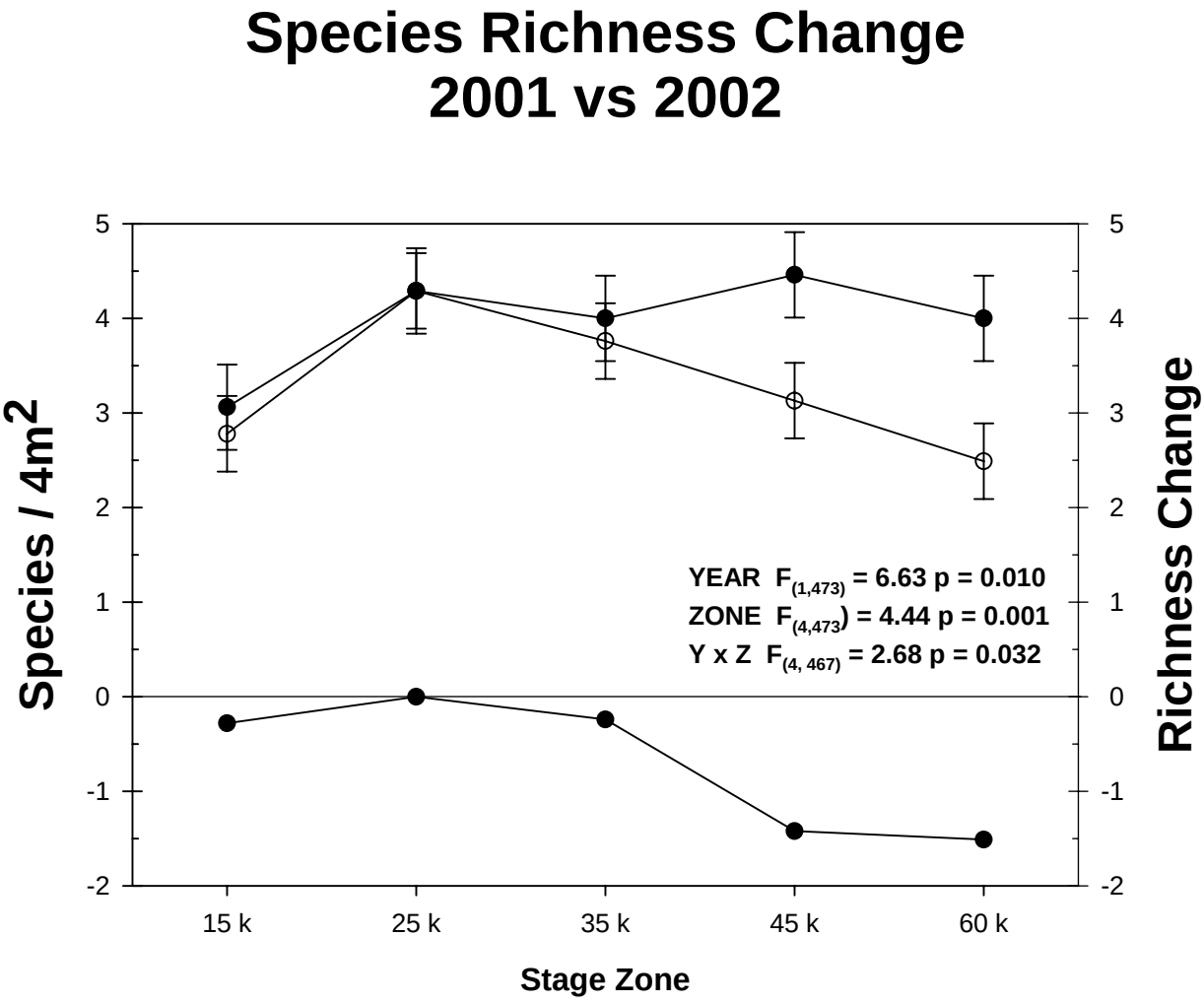


Figure 5. Diversity (H') in 2001 and 2002, and change between years. Closed circles represent 2001 data, open circles represent 2002 data and "+" symbol indicates between-year change. Vertical bars represent +/- 1 s.e.

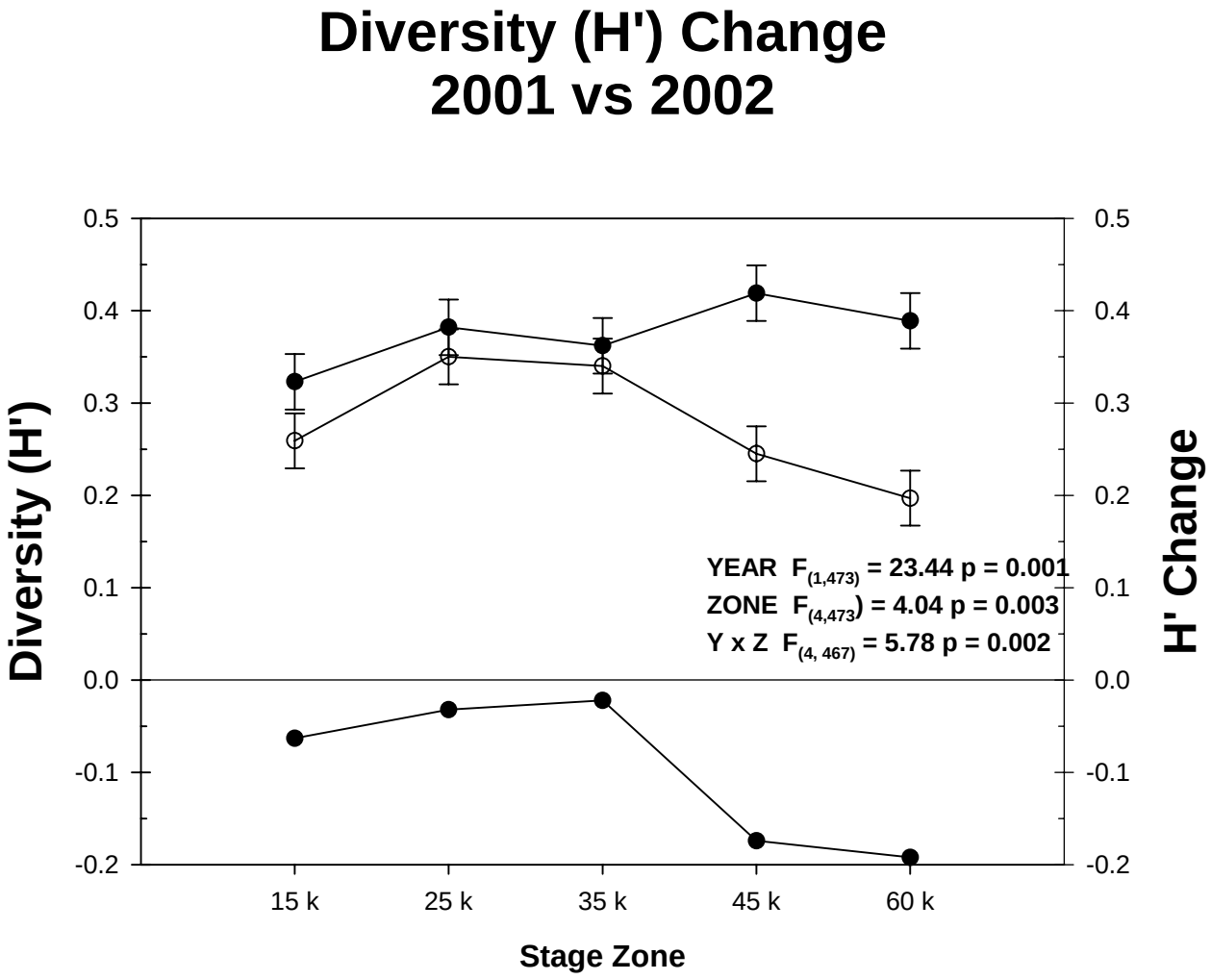


Figure 6. Wetland indicator status both weighted (above) and unweighted (below) by species abundance measures. Closed circles represent 2001 data, open circles represent 2002 data.. Vertical bars represent +/- 1 s.e.

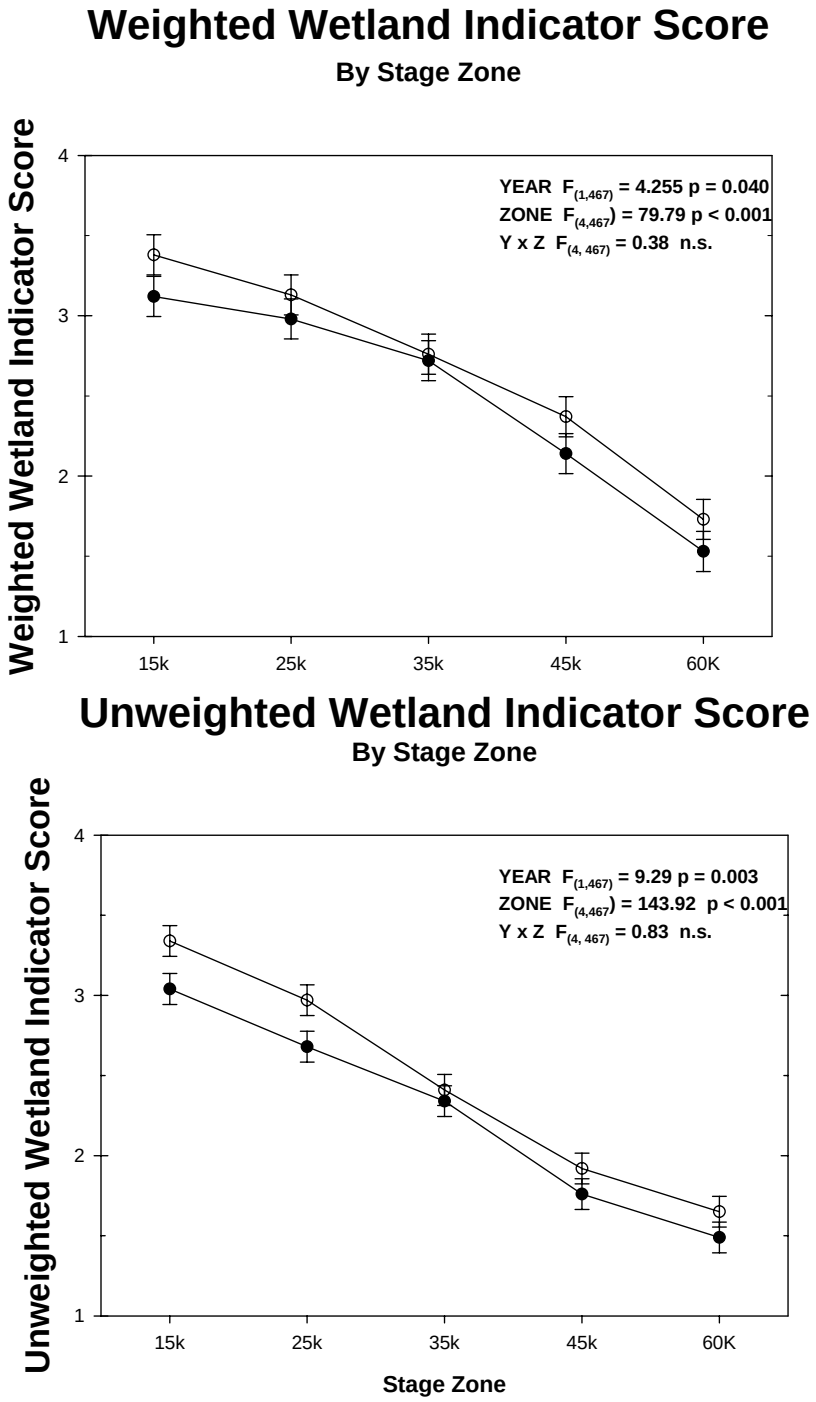
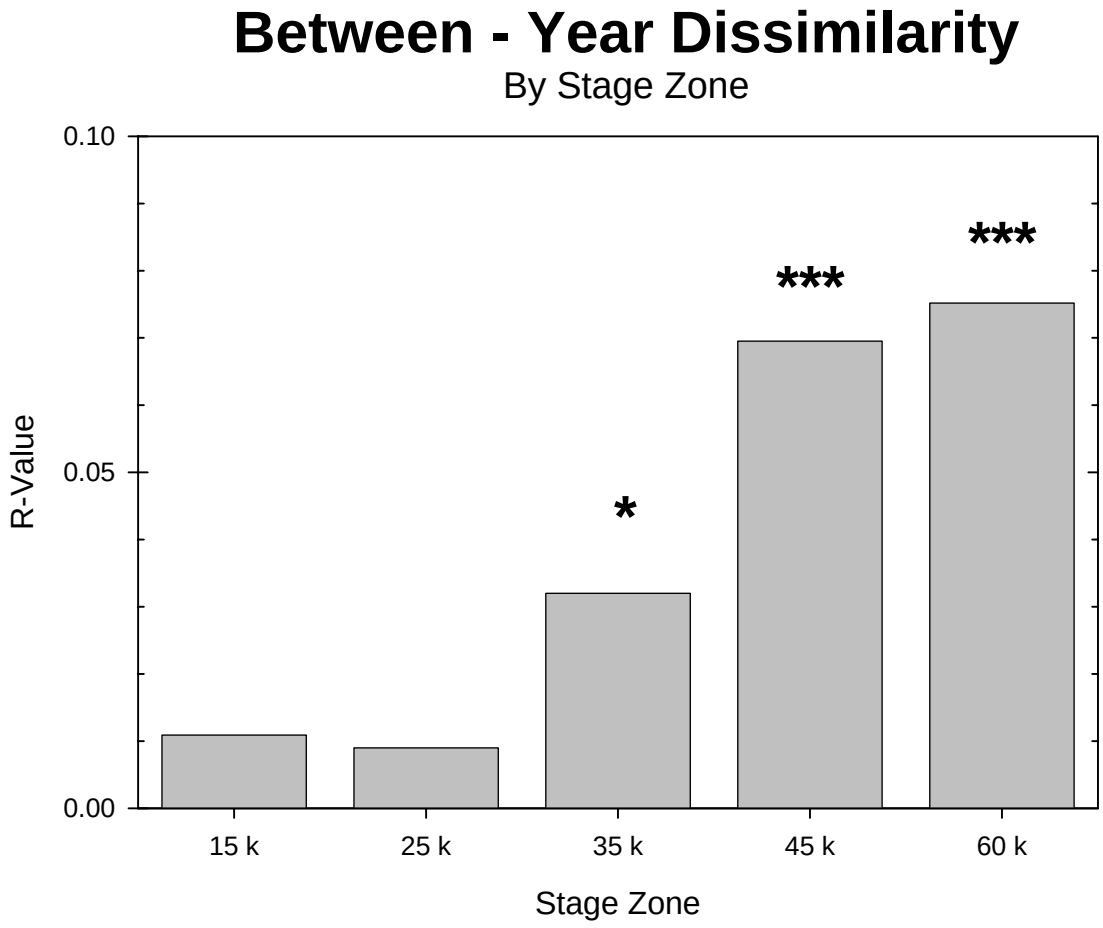


Figure 7. ANOSIM R values, indicating the degree of dissimilarity in plant species composition among plots at each of 5 stage elevations in 2001 and 2002. Higher R values indicate greater dissimilarity.



Integration and Interpretation

Michael Kearsley
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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 censused 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 in which the site selection and data collection methods have been described. 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 2002. The vegetation structure data was collected during the April and May 2002 field work. Compositional data was collected in the 14 integrated monitoring sites at the same time as the pitfall structure measures.

To determine whether vegetation structure, measured as total vegetation volume (TVV: Mills et al. 1991) influenced bird abundance, breeding bird density (measured as per Mills et al. 1991) was regressed against vegetation volume in the new- and old high water patches. Bird sites with small areas (less than 0.1 ha) were excluded from the analysis due to the extreme variability in density which resulted from a small change in either bird detections or patch area. 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). We used the plant species composition and bird density measures from the 14 integrated monitoring sites visited in 2002.

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. Total density 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. 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.

Results:

There was a strong, positive relationship between breeding bird density and vegetation density as measured by TVV. In the new high water zone bird patches, TVV explained 17% of the variability in bird density (Figure 1; $F_{(1,56)} = 11.827$, $p < 0.001$). There was no difference in the density of birds above or below the Little Colorado River, nor was there a difference in the relationship between TVV and bird density in the two areas (no interaction effect). In the old high water zone patches, TVV explained 23% of the variation in bird density (Figure 2; $F_{(1,53)} = 15.007$, $p < 0.001$). In these sites too, there was no difference in either densities or patterns above and below the Little Colorado River (no interaction effect).

As in 2001, the density of small soil-dwelling arthropods was not affected by the density of vegetation. In the water's edge pitfall traps, TVV explained less than one percent of the variation in arthropod density (Figure 3; $F_{(1,11)} = 1.008$, $p > 0.25$, n.s.). The same pattern appeared in both the old high water zone ($F_{(1,11)} = 0.393$, $p > 0.25$, n.s.) and the new high water zone ($F_{(1,11)} = 0.470$, $p > 0.50$, n.s.) pitfall traps.

Nor did vegetation density affect the density of small mammals in the traplines. In the new high water zone, TVV explained roughly half a percent of the variation in mammal density (Figure 4; $F_{(1,11)} = 0.069$, $p > 0.75$). There were no patterns in the density of small mammals in either the old high water zone ($F_{(1,11)} = 0.039$, $p > 0.80$) or the water's edge zone (Figure 4; $F_{(1,11)} = 0.0059$, $p > 0.90$).

Vegetation volume was not related to the density of herpetofauna in any of the three zones (Figure 5). In an overall analysis, there was no effect of Zone ($F_{(2,30)} = 1.768$, $p > 0.15$) or of total vegetation volume ($F_{(1,30)} = 0.635$, $p > 0.40$), nor of the interaction between zone and total vegetation volume ($F_{(2,30)} = 1.725$, $p > 0.15$). When each zone was considered separately, there were no strong relationships, but an interesting pattern. The correlation between herp density and TVV in the water's edge zone had a negative sign, in the new high water zone it was close to zero, and in the old high water zone it was marginally significant and positive.

Although the non-bird fauna did not relate to the vegetation structure, there were significant relationships between composition of the herpetofauna, small mammals, and pitfall invertebrates and the species composition of the vegetation in the TEM sites. As in 2001, a Mantel test comparing site dissimilarities in pitfall arthropod data and site dissimilarities in vegetation species composition in the same sites showed a significant relationship ($R = 0.158$, $p = 0.003$ based on 2000 Monte Carlo runs). Likewise, significant relationships with the plant species composition were found with the small mammal data ($R = 0.112$, $p = 0.032$) and herpetofauna ($R = 0.115$, $p = 0.035$).

Interpretation

It is clear that the vegetation in the riparian corridor of Grand Canyon is vitally important to the health of the faunal communities that depend on them. Bird species which breed in the riparian patches are found more often where the vegetation is densest. Whether this is because it is where habitats produce greater densities of seeds and

airborne or plant feeding arthropods or because the physical properties of shade and temperature are more attractive within denser patches will not be known until the data from malaise and light traps becomes available in 2003. However, the vegetation density is a useful indicator of habitat quality.

The relationship between bird density and vegetation density in Grand Canyon riparian habitats appears to be more complex than was indicated by Mills et al. (1991) for central Arizona riparian habitats. In the latter, there was a tight linear fit of breeding bird density to total vegetation volume. In our data, the relationship is decidedly "wedge" shaped, indicating that at higher densities of vegetation there is a broad range of possible bird densities. We interpret this to mean that vegetation density sets an upper bound on breeding bird densities. Densities may be held below that maximum due to factors outside the breeding habitat such as mortality in wintering habitats and migrations. Numerical methods currently in development (B. Noon, Colorado State University, personal communication) will allow us to test for such a pattern.

The fact that other faunal components are not strongly related to vegetation density is not surprising. Small mammals densities are likely to be more strongly tied to other elements of habitat structure, such as large rocks, litter and woody debris (Dueser and shugart, 1978; Catling et al. 1981; Wagner et al. 2001). Herpetofaunal densities are more likely to be tied to open patches where they can warm up, although in the old high water habitats, we may be seeing ties to woody and shrubby structures documented elsewhere (Vitt et al. 1981). The arthropod data available is on ground-dwelling species collected from pitfall traps in the sites. It is unlikely that ground-dwelling species will be tied to the vertical structure of vegetation.

In contrast to last year's results, we did find vegetation – faunal relationships when we looked at compositional data. This year's vegetation composition data was collected from the cover estimates in the transects rather than the species information from the total vegetation volume measurements. The latter sample a much more limited area (20 cm radius vs. 300 cm radius) and likely do not get as good a representation of the overall vegetation in the areas where traps and transects were run. It is not yet certain how much of the significance of the relationship between vegetation and faunal components comes from differences among samples in different zones and how much comes from within-zone concordance of dissimilarities.

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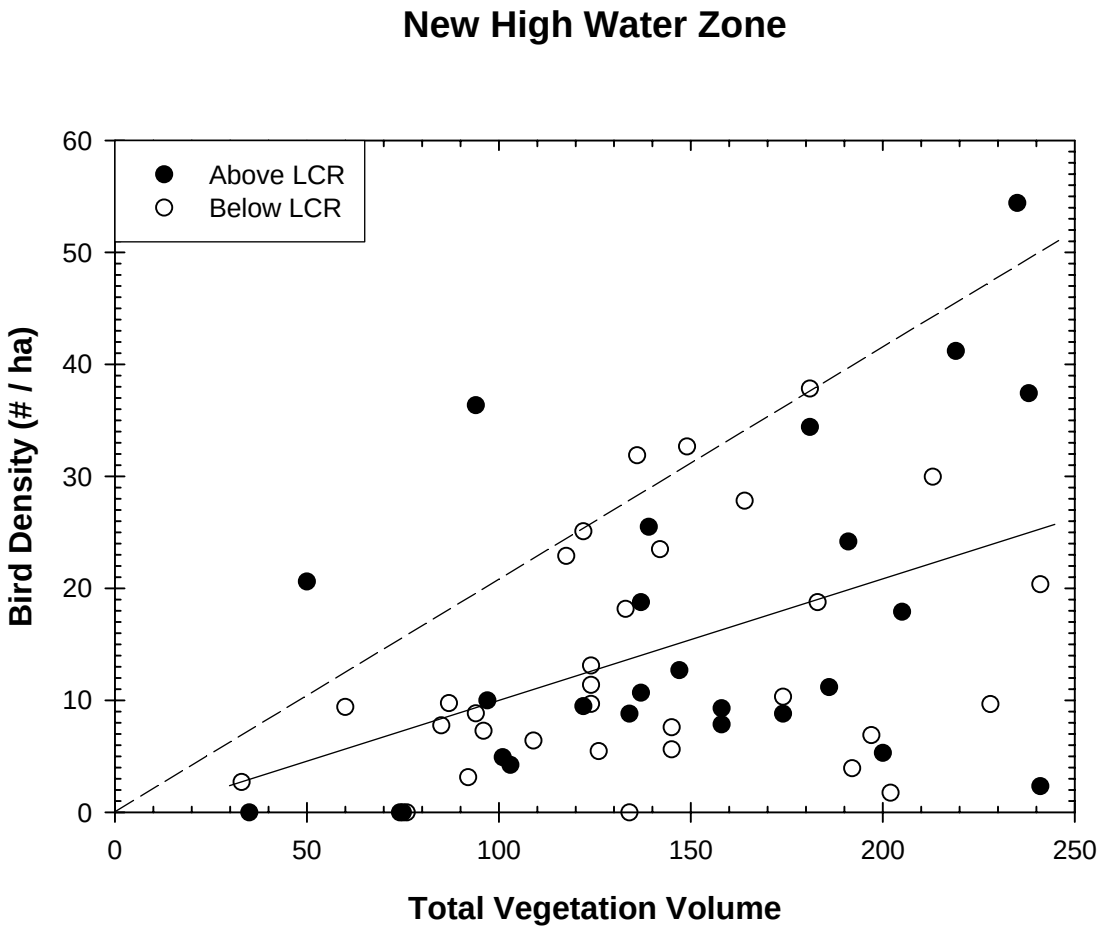

Figure 6. Breeding bird density increases with total vegetation volume in the new high water zone bird patches. Solid line represents least squares regression line. Dashed line shows potential upper boundary function.

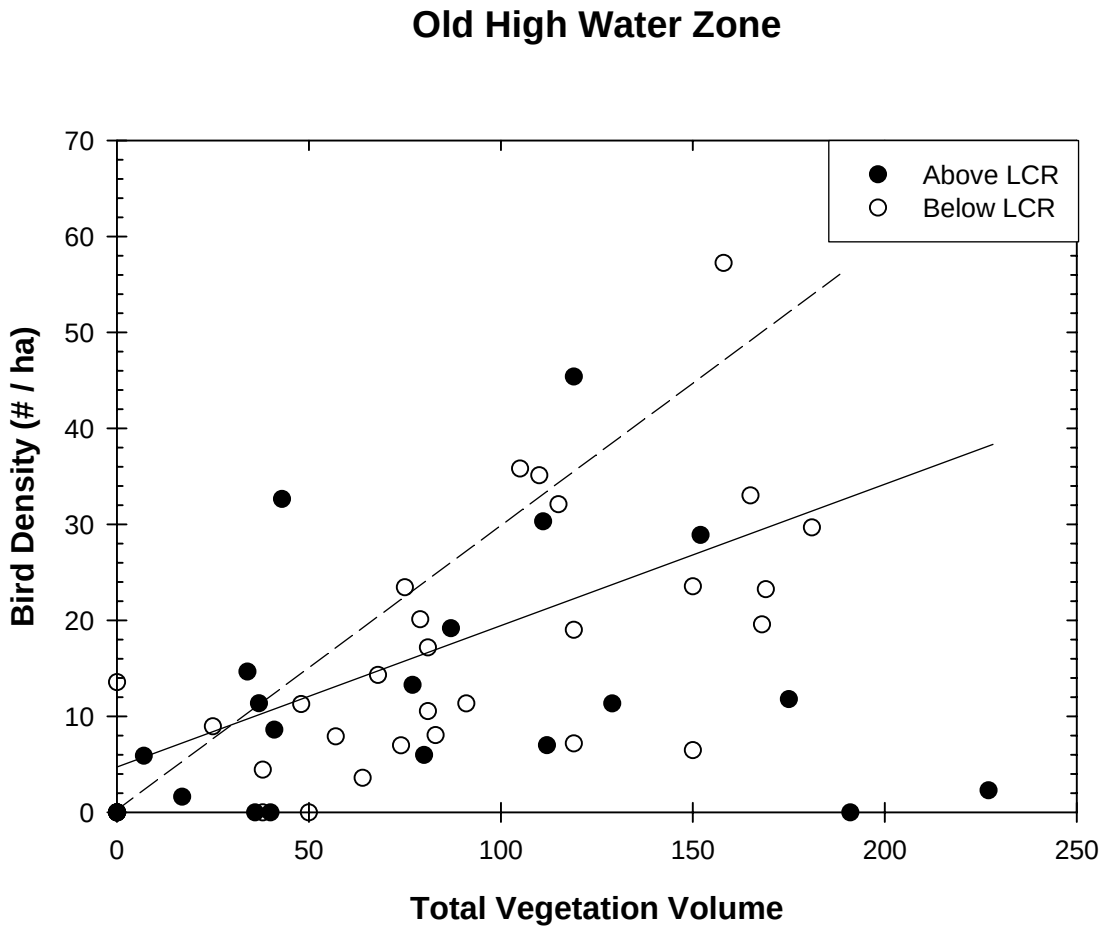

Figure 7. Breeding bird density and total vegetation volume in old high water zone bird patches. Solid line is least squares regression line. Dashed line shows potential upper boundary function.

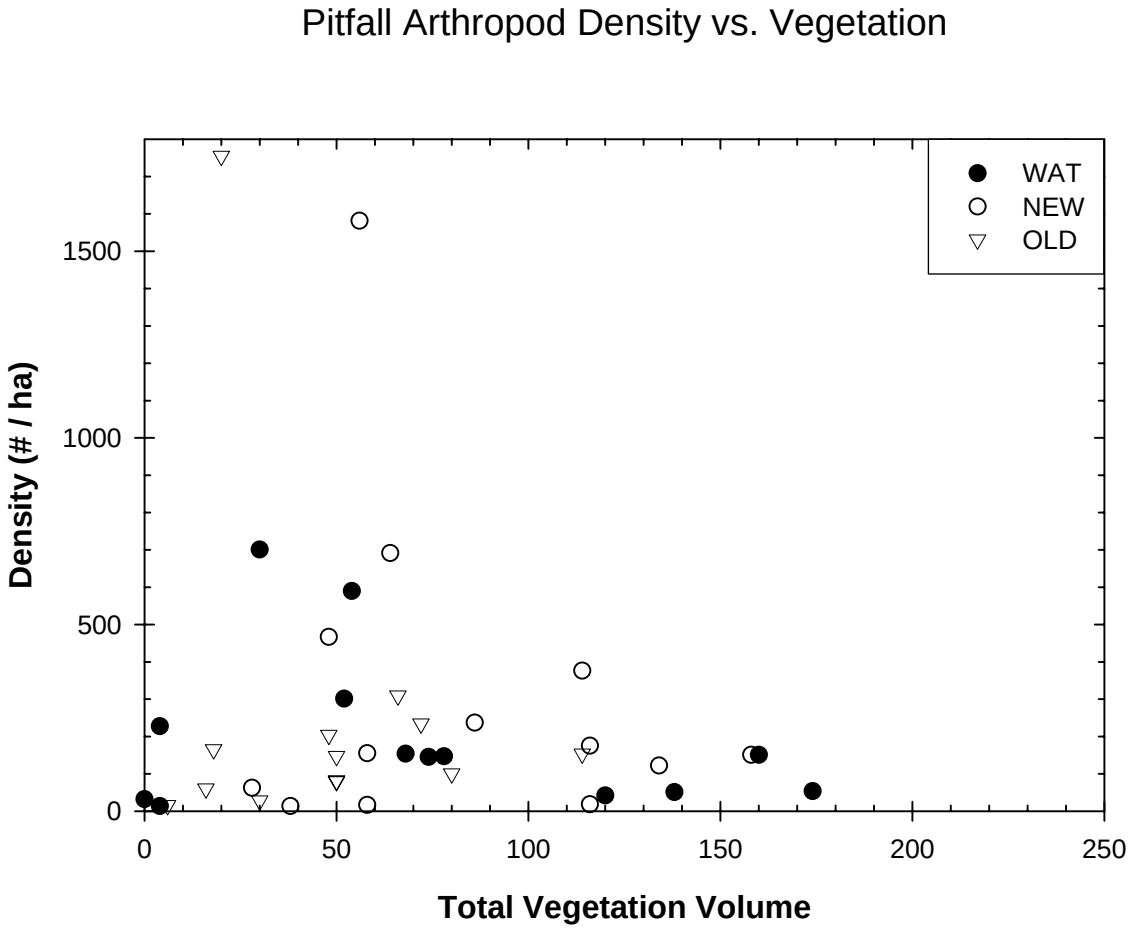

Figure 8. Ground-dwelling arthropod density and total vegetaion volume from pitfall traps in three zones of the integrated monitoring sites. There were no significant relationships between density and vegetation in any of the zones.

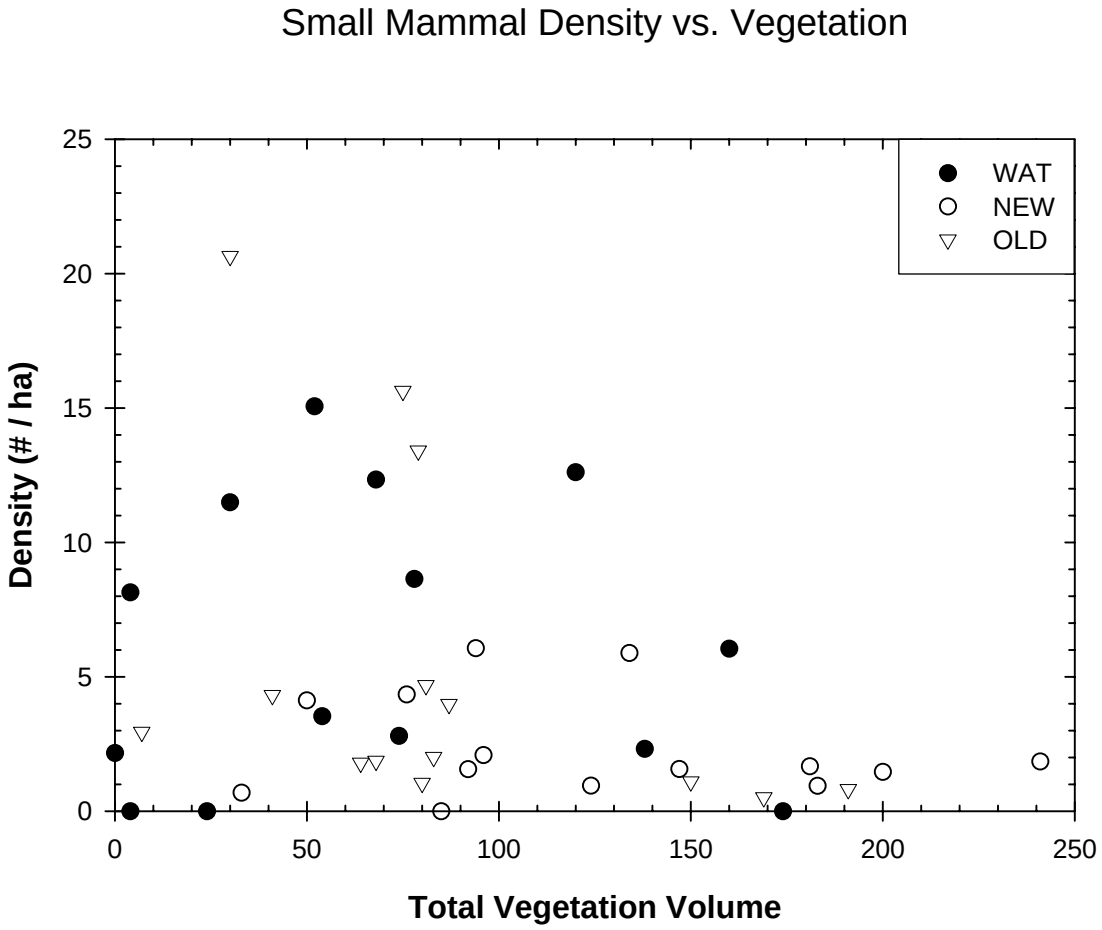

Figure 9. Small mammal densities and total vegetation volume in the three hydrologic zones of the integrated monitoring site faunal transects. There were no significant relationships between densities and vegetation in any of the zones.

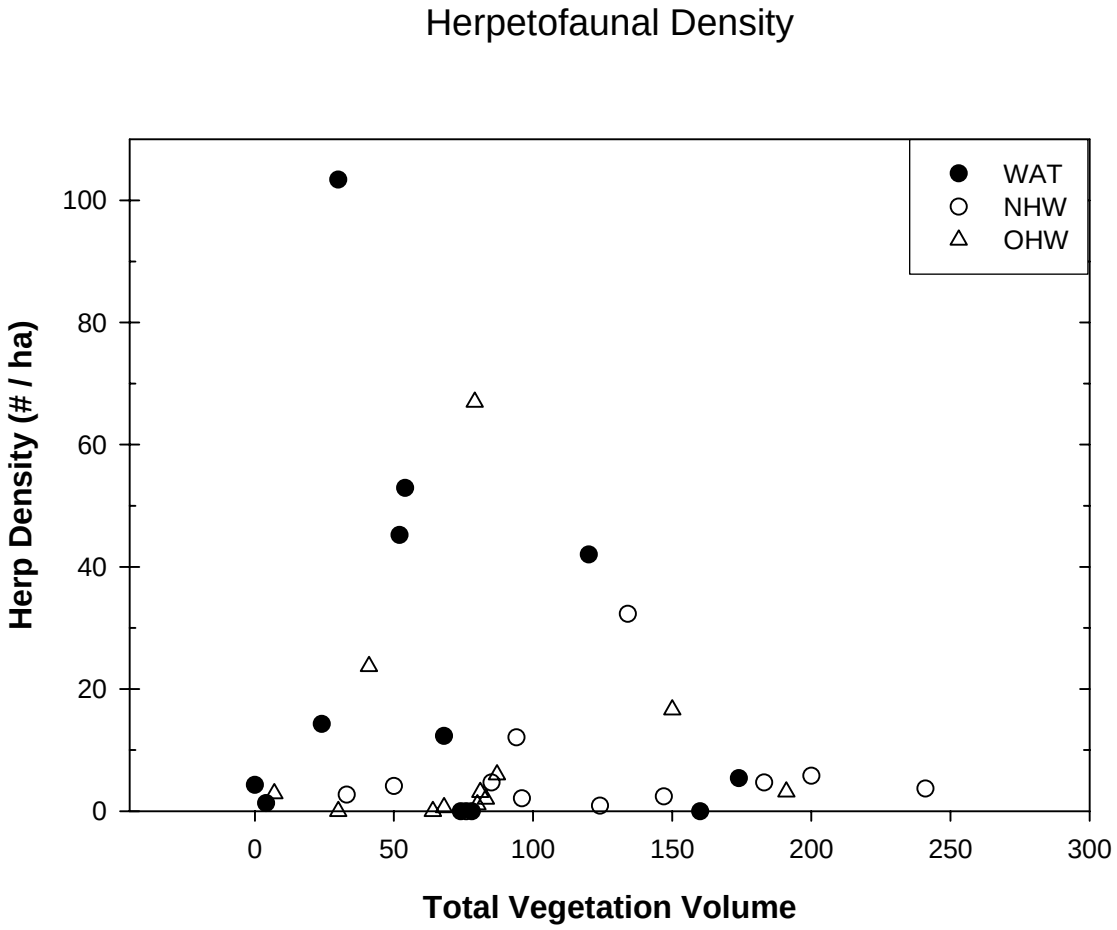

Figure 10. Herpetofaunal densities and total vegetation volume in the faunal transects in the three zones of the integrated monitoring sites. There were no significant relationships between densities and vegetation in any of the zones.

Problematic issues in 2002

There were several problems with field work , analytic approaches, and overall sampling strategy which arose during 2002. Many of these have been mentioned in the individual sections above. Below we bring up several which we felt required further elaboration.

Mammal vouchering. The severe restrictions placed on our ability to voucher small mammals are still making it difficult to properly inventory this group and to collect useful monitoring data. Field identification, based on gross external morphology, cannot verify species identification. During last year's 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 collection, the results will continue to be inconclusive.

Herpetofaunal surveys: logistics. Several factors interacted to produce constraints on effective sampling and create logisitic complications. As ectotherms, herps' activities are largely driven by climatic factors, and are primarily constrained by temperatures. Lack of sunshine (e.g. late shade or cloudy conditions), combined with the necessity to rig boats and make river time so as to arrive at the next camp at the appropriate time to initiate late afternoon set-up and sampling, resulted in a narrow window of time to effectively survey for herps at many camps. In fact, on certain occasions, favorable conditions were lacking during our entire stay at a camp, and no herps were observed. Wind, clouds, and rain often precluded herp activity for substantial periods at sites during 2002 trips. For instance, low numbers recorded for the Salt Creek (RM 92.3L) site (Figure 5) are largely a reflection of cool and overcast conditions during site visits. While every effort was made to sample at each of the 14 primary sites during peak morning activity hours, this was not always possible at non-primary sites, which were sometimes visited either very early in the morning, late in the afternoon, or when shaded during mid-day.

Herpetofaunal surveys: zonation. An additional concern, for herps, is that they are quite often observed at the interface between two of the riparian hydrologic zones (where the NHWZ and OHWZ meet), often moving from one habitat type to another. This trend is strong enough to warrant the inclusion of zone-interface categories (SHORE-NHWZ and NHWZ-OHWZ) in next year's herpetological TEM component.

Logistics: shared logistics. When research trips combine several objectives, it can be difficult to satisfy all the parties' needs. In the case of the fall trip, vegetation surveys and faunal surveys take place at different sites whose locations are determined by separate random processes. It is, at times, difficult for the vegetation crews to complete their work and get to the next camp where the faunal surveys were to take place. At other times, there were only one or two sites for the vegetation crew between the faunal sites. Rather than launch a single, large trip, it might make more sense to launch two separate trips, each with a single focus.

Logistics: faunal sampling schedule. The question of the representativeness of

data collected in a single night from each of the sites in the spring and fall has arisen many times in discussions among the investigators in this project during the past year. When the weather is windy, rainy, or cold, the success at trapping arthropods and small mammals is much reduced and the activity of lizards and snakes is minimal. Furthermore, it is uncertain what proportion of the species of arthropods, mammals and herpetofauna are encountered in a single night of sampling. Rather than a single large trip which samples all the sites, better data might be collected if a number of smaller crews were dropped off at different sites where they would take samples for several nights. Crews could be shifted to a second set of sites by a resupply-style trip and picked up by a third trip. We would like to undertake a pilot project in which two or three sites are sampled repeatedly in series of nights to address questions regarding the accumulation of species over time in a single site.

Appendix

Lists of species encountered during monitoring activities in 2002

Mammal species encountered in 2002

Abbreviation	Latin Binomial	Common name
PEER	Peromyscus eremicus	Cactus Mouse
NELE	Neotoma lepida	Desert Woodrat
PECR	Peromyscus crinitus	Canyon Mouse
PEBO	Peromyscus boylii	Brush Mouse
CHIN	Chaetodipus intermedius	Rock Pocket Mouse
NEAL	Neotoma albigula	White-throated Woodrat
PEFO	Perognathus formosus	Long-tailed Pocket Mouse
DIOR	Dipodomys ordii	Ord's Kangaroo Rat
REME	Reithrodontomys megalotis	Western Harvest Mouse

Birds Observed During the 2002 Breeding Season

American Coot
American Kestrel
American Pipit
American Robin
American Widgeon
*Ash-throated Flycatcher
Bald Eagle
*Bell's Vireo
Belted kingfisher
*Bewick's Wren
*Black-chinned Hummingbird
Black-headed Grosebeak
Black-chinned Sparrow
Black Phoebe*
Black-throated Grey Warbler
*Black-throated Sparrow
*Blue-gray Gnatcatcher
*Blue Grosebeak
Blue-winged teal
Brewer's Sparrow
Broad-tailed Hummingbird
Brown-headed Cowbird
Bufflehead
California Condor
Canada Goose
*Canyon Wren
Chipping Sparrow
Cinnamon Teal
Common Goldeneye
Common Grackle
Common Merganser
Common Poorwill
Common Raven
*Common Yellowthroat
Cordilleran Flycatcher
Costa's Hummingbird
Dark-eyed Junco
Eared Grebe
Empidonax sp.
Gadwall
Gambles Quail
Great Blue Heron
Great-horned Owl

Great-tailed Grackle
Green-tailed Towhee
Hammond's Flycatcher
*Hooded Oriole
*House Finch
House Wren
Indigo Bunting
*Lazuli Bunting
*Lesser Goldfinch
Lesser Scaup
Loggerheaded Shrike
*Lucy's Warbler
Mallard
Marsh Wren
*Mourning Dove
Northern Flicker
*Northern Mockingbird
Northern Rough-winged Swallow
Peregrine Falcon
*Phainapepla
Pinon Jay
Red-breasted Grosebeak
Red-breasted Merganser
Red-tailed Hawk
Redheaded duck
Red-winged Blackbird
Ring-neck Duck
Ross's Goose
*Rock Wren
Ruby-crowned Kinglet
Rufus Hummingbird
*Says Phoebe
Scotts Oriole
Scrub Jay
*Song Sparrow
*Southwestern Willow Flycatcher
Spotted Sandpiper
Spotted Towhee
*Summer Tanager
Turkey Vulture
Violet-green Swallow
Virginia's Warbler
Western Kingbird
Western Tanager
Western Wood Peewee
White-crowned Sparrow

White-throated Swift
Willow Flycatcher (migrants - sub-species unknown)
Wilson's Warbler
*Yellow-breasted Chat
*Yellow Warbler
Yellow-rumped Warbler

* Breeding Riparian Birds

GRAND CANYON / COLORADO RIVER CORRIDOR HERPS 2002

CODE, Species (common name)

LIZARDS

COVA, *Coleonyx variegatus* (banded gecko)
CNTI, *Cnemidophorus tigris* (western whiptail)
CRCO, *Crotaphytus collaris* (collared lizard)
PHPL, *Phrynosoma platyrhinos* (desert horned 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)
LAGE, *Lampropeltus getulus* (king snake)
MAFL, *Masticophis flagellum* (red racer)
MATA, *Masticophis taeniatus* (lined whipsnake)
SAGR, *Salvadora grahami* (patch-nosed snake)

TOADS AND FROGS

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

List of taxa determined to date. List is mostly represented by specimens collected in pitfall traps.

Order	Family	Genus species authority	Determiner
Araneae	Anyphaenidae	Anyphaena pacifica (Banks)	Brantley
Araneae	Gnaphosidae	Herpyllus hesperolus Chamberlin	Brantley
Araneae	Anyphaenidae	anyphaenid nymph	Brantley
Araneae	Anyphaenidae	Anyphaena californica (Banks)	Brantley
Araneae	Araneidae	Larinia sp.1	Brantley
Araneae	Araneidae	Metepeira arizonica Chamberlin&Ivie	Brantley
Araneae	Caponiidae	Tarsonops systematicus Chamberlin	Brantley
Araneae	Clubionidae	clubionid sp.	Brantley
Araneae	Clubionidae	Cheiracanthium inclusum (Hentz)	Brantley
Araneae	Corinnidae	Castianeira sp.	Brantley
Araneae	Corinnidae	Meriola decepta (Banks)	Brantley
Araneae	Dictynidae	dictynid nymph	Brantley
Araneae	Dictynidae	Mallos pallidus Banks	Brantley
Araneae	Gnaphosidae	Drassyllus salton Platnick&Shadab	Brantley
Araneae	Gnaphosidae	Gnaphosa californica Banks	Brantley
Araneae	Gnaphosidae	Gnaphosa clara (Keyserling)	Brantley
Araneae	Gnaphosidae	Haplodrassus sp.	Brantley
Araneae	Gnaphosidae	Micaria sp.	Brantley
Araneae	Gnaphosidae	Scopodes bryantae	Brantley
Araneae	Gnaphosidae	Trachyzelotes sp.	Brantley
Araneae	Gnaphosidae	Zelotes nymph	Brantley
Araneae	Gnaphosidae	Zelotes anglo Gertsch & Riechert	Brantley
Araneae	Linyphiidae	linyphiid sp.	Brantley
Araneae	Liocranidae	Agroeca trivittata (Keyserling)	Brantley
Araneae	Liocranidae	Neoanagraphis chamberlini Gert.&Mul.	Brantley
Araneae	Lycosidae	lycosid nymph	Brantley
Araneae	Lycosidae	Arctosa littoralis	Brantley
Araneae	Lycosidae	Pardosa sp. (striped)	Brantley
Araneae	Lycosidae	Pardosa nymph	Brantley
Araneae	Lycosidae	Pardosa vadosa Barnes	Brantley
Araneae	Mimetidae	Mimetus sp.1	Brantley
Araneae	Oecobiidae	Oecobius isolatus Chamberlin	Brantley
Araneae	Oxyopidae	Oxyopes scalaris Hentz	Brantley
Araneae	Philodromidae	Apollophanes nymph	Brantley
Araneae	Philodromidae	Apollophanes texanus Banks	Brantley
Araneae	Philodromidae	Ebo sp.	Brantley
Araneae	Pholcidae	Physocyclus sp.	Brantley
Araneae	Pholcidae	Psilochorus sp.	Brantley
Araneae	Salticidae	salticid nymph	Brantley
Araneae	Salticidae	black w/ white stripes	
Araneae	Salticidae	Pseudicius sp.	Brantley
Araneae	Selenopidae	Selenops sp.	Brantley
Araneae	Sicariidae	Loxosceles deserta Gertsch	Brantley
Araneae	Tetragnathidae	Tetragnatha versicolor Walckenaer	Brantley
Araneae	Theridiidae	theridiid nymph	Brantley

Araneae	Theraphosidae	Aphonopelma sp.	Brantley
Araneae	Theridiidae	Latrodectus hesperus Chamberlin&Ivie	Brantley
Araneae	Theridiidae	Steatoda fulva (Keyserling)	Brantley
Araneae	Thomisidae	thomisid nymph	Brantley
Araneae	Thomisidae	Misumenops nymph	Brantley
Araneae	Thomisidae	Misumenops californicus Banks	Brantley
Araneae	Thomisidae	Tmarus sp.	Brantley
Araneae	Thomisidae	Xysticus nymph	Brantley
Araneae	Thomisidae	Xysticus lassanus Chamberlin	Brantley
Blattodea	Blatellidae	Blatella vaga Hebard	
Blattodea	Polyphagidae	Arenivaga sp.	Lightfoot
Chilopoda	Henicopidae	Lamyctes fulvicornis Meinert	Fagerlund
Chilopoda	Lithobiidae	lithobiid sp.	
Coleoptera	not determined	larva	
Coleoptera	Anobiidae	Niptus sp.1	
Coleoptera	Anobiidae	Niptus sp.2	
Coleoptera	Anthicidae	anthicid sp.1 - bad condition, in ETOH	
Coleoptera	Anthicidae	Notoxus sp.	Fagerlund
Coleoptera	Anthicidae	Notxus calcaratus Horn	Fagerlund
Coleoptera	Buprestidae	buprestid sp.2	
Coleoptera	Buprestidae	Acmaeodera sp.	Brantley
Coleoptera	Carabidae	brown with blue tinge	
Coleoptera	Carabidae	small, brown, shiny	
Coleoptera	Carabidae	small, black	
Coleoptera	Carabidae	brown head, blue elytra	
Coleoptera	Carabidae	carabid sp.5;green;punctate elytra	
Coleoptera	Carabidae	"Pterostichus" sp.	
Coleoptera	Carabidae	little "Cymindis"	
Coleoptera	Carabidae	carabid sp.8	
Coleoptera	Carabidae	carabid sp.9	
Coleoptera	Carabidae	carabid sp.10	
Coleoptera	Carabidae	carabid sp.11	
Coleoptera	Carabidae	carabid sp.12	
Coleoptera	Carabidae	carabid sp.13	
Coleoptera	Carabidae	carabid sp.14	
Coleoptera	Carabidae	"Amara" sp.	
Coleoptera	Carabidae	"Bembidion" sp.	
Coleoptera	Carabidae	Bembidion sp.2	Fagerlund
Coleoptera	Carabidae	Brachinus sp.	
Coleoptera	Carabidae	Chlaenius sp.2	
Coleoptera	Carabidae	Chlaenius tomentosus	
Coleoptera	Carabidae	Chlaenius tricolor Dejean	
Coleoptera	Carabidae	Cicindela sp.	
Coleoptera	Carabidae	Cymindis punctigera LeConte	
Coleoptera	Carabidae	Dyschirius sp.	
Coleoptera	Carabidae	Lebia sp.1	
Coleoptera	Carabidae	Rhadine sp.1	

Coleoptera	Cerambycidae	cerambycid sp.	
Coleoptera	Cerambycidae	cerambycine sp.1	
Coleoptera	Chrysomelidae	chrysomelid sp.1	
Coleoptera	Chrysomelidae	chrysomelid sp.2	
Coleoptera	Chrysomelidae	chrysomelid sp.3	
Coleoptera	Chrysomelidae	chrysomelid sp.4	
Coleoptera	Chrysomelidae	chrysomelid sp.5	
Coleoptera	Chrysomelidae	chrysomelid sp.6	
Coleoptera	Chrysomelidae	chrysomelid sp.7	
Coleoptera	Chrysomelidae	alticine sp.1	
Coleoptera	Chrysomelidae	alticine sp.2	
Coleoptera	Chrysomelidae	alticine sp.3	
Coleoptera	Chrysomelidae	bruchine sp.1	
Coleoptera	Chrysomelidae	cryptocephaline sp.1	
Coleoptera	Chrysomelidae	cryptocephaline sp.2	
Coleoptera	Chrysomelidae	cryptocephaline sp.3	
Coleoptera	Chrysomelidae	cryptocephaline sp.4	
Coleoptera	Chrysomelidae	galerucine sp.	
Coleoptera	Cleridae	clerid sp.1	
Coleoptera	Cleridae	clerid sp.2	
Coleoptera	Cleridae	clerid sp.3	
Coleoptera	Coccinellidae	coccinellid sp.1	
Coleoptera	Coccinellidae	coccinellid sp.2	
Coleoptera	Coccinellidae	coccinellid sp.3	
Coleoptera	Coccinellidae	Chilocorous stigma (Say)	
Coleoptera	Coccinellidae	Hippodamia convergens Guerin-Meneville	Brantley
Coleoptera	Coccinellidae	Hyperaspidius sp.1	
Coleoptera	Coccinellidae	Hyperaspidius sp.2	
Coleoptera	Cryptophagidae	cryptophagid sp.2	
Coleoptera	Cryptophagidae	Cryptophagus sp.	Fagerlund
Coleoptera	Curculionidae	curculionid sp.1 Minyomerus?	
Coleoptera	Curculionidae	curculionid sp.2	
Coleoptera	Curculionidae	curculionid sp.3	
Coleoptera	Curculionidae	curculionid sp.4	
Coleoptera	Curculionidae	curculionid sp.5	
Coleoptera	Curculionidae	curculionid sp.6	
Coleoptera	Curculionidae	curculionid sp.7	
Coleoptera	Curculionidae	curculionid sp.8	
Coleoptera	Curculionidae	curculionid sp.9	
Coleoptera	Curculionidae	curculionid sp.10	
Coleoptera	Curculionidae	curculionid sp.11	
Coleoptera	Curculionidae	Scyphophorus sp.	
Coleoptera	Dermestidae	Cryptorhopalum sp.	
Coleoptera	Elateridae	reddish elaterid	
Coleoptera	Elateridae	plain brown	
Coleoptera	Elateridae	brown; convex pronotum	
Coleoptera	Elateridae	small; granular texture	

Coleoptera	Elateridae	skinny; with center dark stripe	
Coleoptera	Elateridae	elaterid sp.6	
Coleoptera	Elateridae	Aeolus sp.	Brantley
Collembola	Entomobryidae	entomobryid sp.	Brantley
Coleoptera	Histeridae	histerid sp.1	
Coleoptera	Histeridae	Hetaerius sp.	
Coleoptera	Hydrophilidae	Cercyon sp.	Fagerlund
Collembola	Hypogastruridae	hypogastrurid sp.	Brantley
Collembola	Isotomidae	isotomid sp.	Brantley
Coleoptera	Lycidae	lycid sp.1	
Coleoptera	Lycidae	Lycus sp.1	
Coleoptera	Meloidae	meloid sp.1	
Coleoptera	Melyridae	tan with black spots	
Coleoptera	Melyridae	Collops sp.1	
Coleoptera	Meloidae	Lytta sp.1	
Coleoptera	Melyridae	Trichochrous sp.	
Coleoptera	Nitidulidae	nitidulid sp.	
Coleoptera	Oedemeridae	oedemerid sp.	
Coleoptera	Scarabaeidae	scarabaeid sp.3	
Coleoptera	Scarabaeidae	Aphodius sp.	
Coleoptera	Scarabaeidae	Diplotaxis sp.	
Coleoptera	Scraptiidae	Anaspis rufa Say	Fagerlund
Coleoptera	Scraptiidae	Canifa sp.	Fagerlund
Collembola	Sminthuridae	sminthurid sp.	Brantley
Coleoptera	Staphylinidae	staphylinid sp.1	
Coleoptera	Staphylinidae	staphylinid sp.2	
Coleoptera	Staphylinidae	aleocharine spp.	
Coleoptera	Staphylinidae	staphylinine sp.1	
Coleoptera	Staphylinidae	staphylinine sp.2	
Coleoptera	Staphylinidae	Stenus sp.1	
Coleoptera	Tenebrionidae	tenebrionid sp.	
Coleoptera	Tenebrionidae	teneb, Tribe Batulini	Fagerlund
Coleoptera	Tenebrionidae	Blapstinus brevicollis LeConte	Fagerlund
Coleoptera	Tenebrionidae	Blapstinus histricus Casey	Fagerlund
Coleoptera	Tenebrionidae	Blapstinus pimalis Casey	Fagerlund
Coleoptera	Tenebrionidae	Blapstinus sulcatus LeConte	Fagerlund
Coleoptera	Tenebrionidae	Centrioptera sp.	Fagerlund
Coleoptera	Tenebrionidae	Eleodes carbonarius (Say)	Fagerlund
Coleoptera	Tenebrionidae	Eleodes extricatus	
Coleoptera	Tenebrionidae	Helops attenuata (LeConte)	Fagerlund
Coleoptera	Tenebrionidae	Metaponium convexicolle (LeConte)	Fagerlund
Coleoptera	Tenebrionidae	Micromes sp.	Fagerlund
Coleoptera	Tenebrionidae	Telabis histricum (Casey)	Fagerlund
Coleoptera	Tenebrionidae	Triorophus sp.	Fagerlund
Coleoptera	Tenebrionidae	teneb, dark w/convex pron. & oval body	
Diptera	undetermined	undetermined	
Diptera	Bombyliidae	bombyliid sp.	

Diptera	Cecidomyiidae	cecidomyiid sp.	
Diptera	Chironomidae	chironomid sp.	
Diptera	Empididae	empidid sp.	
Diplopoda	Polydesmidae	polydesmid sp.1	
Diptera	Syrphidae	syrphid sp.	
Diptera	Tabanidae	tabanid sp.	
Diptera	Tachinidae	tachinid sp.	
Diptera	Tephritidae	tephritid sp.	
Heteroptera	Anthocoridae	Orius sp.1	Brantley
Heteroptera	Berytidae	Pronotacantha annulata Uhler	Brantley
Heteroptera	Coreidae	Leptoglossus sp.	Brantley
Heteroptera	Cydnidae	Tomonotus sp.	
Heteroptera	Lygaeidae	nymph	
Heteroptera	Lygaeidae	lygaeid sp.2	
Heteroptera	Lygaeidae	Neacoryphus sp.	Brantley
Heteroptera	Lygaeidae	Nysius sp.	Brantley
Heteroptera	Lygaeidae	Ochrimnus sp.	
Heteroptera	Lygaeidae	Pachybrachius sp.	Brantley
Heteroptera	Miridae	mirid sp.1	
Heteroptera	Miridae	mirid sp.3	
Heteroptera	Miridae	mirid sp.4	
Heteroptera	Miridae	mirid sp.5	
Heteroptera	Miridae	mirid sp.6	
Heteroptera	Miridae	mirid sp.7	
Heteroptera	Miridae	mirid sp.8	
Heteroptera	Miridae	mirid sp.9	
Heteroptera	Miridae	mirid sp.10	
Heteroptera	Miridae	Tropidosteptes sp.1	
Heteroptera	Nabidae	Dolichonabis sp.1	Brantley
Heteroptera	Pentatomidae	Pitedia sp.	Brantley
Heteroptera	Pentatomidae	Thyanta sp.1	
Heteroptera	Reduviidae	reduviid sp.1	
Heteroptera	Reduviidae	reduviid sp.2 brachypterous	
Heteroptera	Reduviidae	reduviid sp.3	
Heteroptera	Reduviidae	Emesaya sp.	Brantley
Heteroptera	Reduviidae	Reduvius sp.	Brantley
Heteroptera	Reduviidae	Zelus sp.	Brantley
Heteroptera	Rhopalidae	Arhyssus sp.1	
Heteroptera	Tingidae	tingid sp.1	
Homoptera	Cicadellidae	cicadellid, brown w/brn wing veins	
Homoptera	Acanaloniidae	acanaloniid sp.1	
Homoptera	Aphididae	aphid sp. 1	
Homoptera	Cicadellidae	cicadellid sp.1	
Homoptera	Cicadellidae	cicadellid sp.2	
Homoptera	Cicadellidae	cicadellid sp.3	
Homoptera	Cicadellidae	cicadellid sp.4	
Homoptera	Cicadellidae	cicadellid sp.5	

Homoptera	Cicadellidae	cicadellid sp.6	
Homoptera	Cicadellidae	cicadellid sp.7	
Homoptera	Cicadellidae	cicadellid sp.8	
Homoptera	Cicadellidae	cicadellid sp. 9	
Homoptera	Cicadellidae	cicadellid sp.10	
Homoptera	Cicadellidae	cicadellid sp.11	
Homoptera	Cicadellidae	cicadellid sp.12	
Homoptera	Cicadellidae	cicadellid sp.13 was HoCiYelo	
Homoptera	Cicadellidae	cicadellid sp.14 was HoCiDkbr	
Homoptera	Cicadellidae	cicadellid sp.15	
Homoptera	Cicadellidae	cicadellid sp.16	
Homoptera	Cicadellidae	cicadellid sp.17	
Homoptera	Cicadellidae	cicadellid sp.18	
Homoptera	Cicadellidae	has number been assigned?	
Homoptera	Cicadellidae	cicadellid sp.20 was HoCiWhba	
Homoptera	Cicadellidae	cicadellid sp.21 was HoCiBrsp	
Homoptera	Cicadellidae	cicadellid sp.22 was HoCiGror	
Homoptera	Cicadellidae	cicadellid sp.23	
Homoptera	Cicadellidae	cicadellid sp.24	
Homoptera	Cicadellidae	cicadellid sp.25	
Homoptera	Cicadellidae	cicadellid sp.26	
Homoptera	Cicadellidae	cicadellid sp.27	
Homoptera	Cicadellidae	cicadellid sp. 28	
Homoptera	Cicadellidae	Opsius sp.1	
Homoptera	Cixiidae	cixiid sp.1	
Homoptera	Cixiidae	cixiid sp.2	
Homoptera	Cixiidae	cixiid sp.3 (with black wings)	
Homoptera	Delphacidae	delphacid sp.1	
Homoptera	Psyllidae	psyllid sp.	
Hymenoptera	not determined	hymenopteran sp.	
Hymenoptera	undetermined	undetermined wasp sp.1	
Hymenoptera	undetermined	undetermined wasp sp.2	
Hymenoptera	undetermined	undetermined wasp sp.3	
Hymenoptera	Apoidea	bee sp.	
Hymenoptera	Chalcidoidea	chalcidoid sp.	
Hymenoptera	Dryinidae	dryinid sp.	
Hymenoptera	Formicidae	Camponotus sp.	Fagerlund
Hymenoptera	Formicidae	Camponotus sp.2	
Hymenoptera	Formicidae	Crematogaster depilis Wheeler	Fagerlund
Hymenoptera	Formicidae	Cyphomyrmex wheeleri Forel	Fagerlund
Hymenoptera	Formicidae	Dorymyrmex insana (Buckley)	Fagerlund
Hymenoptera	Formicidae	Formica integroides Emery	Fagerlund
Hymenoptera	Formicidae	Forelius pruinosus (Roger)	Fagerlund
Hymenoptera	Formicidae	Hypoponera opacior (Forel)	Brantley
Hymenoptera	Formicidae	Leptothorax muscorum (Nylander)	Fagerlund
Hymenoptera	Formicidae	Leptothorax nevadensis Wheeler	Fagerlund
Hymenoptera	Formicidae	Monomorium minimum (Buckley)	Fagerlund

Hymenoptera	Formicidae	Myrmecosystus mexicanus Wesmael	Fagerlund
Heteroptera	Formicidae	Myrmecocystus romainei Snelling	Fagerlund
Hymenoptera	Formicidae	Paratrechina vividula (Nylander)	Fagerlund
Hymenoptera	Formicidae	Pheidole minor workers	Fagerlund
Hymenoptera	Formicidae	Pheidole ceres Wheeler	Fagerlund
Hymenoptera	Formicidae	Pogonomyrmex barbatus (Smith)	Fagerlund
Hymenoptera	Formicidae	Pogonomyrmex maricopa Wheeler	Fagerlund
Hymenoptera	Formicidae	Pogonomyrmex subnitidus Emery	Fagerlund
Hymenoptera	Formicidae	Solenopsis molesta (Say)	Fagerlund
Hymenoptera	Formicidae	Solenopsis xyloni McCook	Fagerlund
Hymenoptera	Ichneumonoidea	ichneumon wasp sp.	
Hymenoptera	Megachilidae	megachilid sp.1 was HYMENDET	
Hymenoptera	Mutillidae	mutillid sp.	
Hymenoptera	Mutillidae	mutillid sp.2	
Hymenoptera	Mutillidae	mutilid sp.3	
Hymenoptera	Mutillidae	Dasymutilla sp.1	
Hymenoptera	Sphecidae	sphecid sp.	
Hymenoptera	Tiphiidae	tiphiid sp.	
Isoptera	not determined	termite sp.	
Isopoda	Armadilliidae	Armadillidium vulgare	Brantley
Isopoda	Porcellionidae	Porcellio sp.	Brantley
Ixodida	Ixodidae	Dermacentor variabilis	Fagerlund
Lepidoptera	undetermined	undetermined	
Lepidoptera	Arctiidae	Cisthene angelus (Dyar)	Cobb
Lepidoptera	Geometridae	geometrid sp.	
Mesostigmata	not determined	not determined	
Microcoryphia	Machilidae	Mesomachilis sp. (large, pale, 2 pr ves)	Brantley
Microcoryphia	Machilidae	Mexomachilis sp.	Brantley
Microcoryphia	Meinertellidae	Machilinus aurantiacus (Schott)	Brantley
Microcoryphia	Meinertellidae	Praemachilellus sp.	Brantley
Neuroptera	Chrysopidae	chrysopid sp.1	
Neuroptera	Corydalidae	corydalid sp.1	
Neuroptera	Myrmeleontidae	myrmeleontid sp.1	
Opiliones	Ceratolasmatidae	Hesperonemastoma pallidimaculosum	Brantley
Oribatida	not determined	oribatid sp.	
Orthoptera	Acrididae	Trimerotropis pallidipennis (Burmeister)	Lightfoot
Orthoptera	Acrididae	Orphulella pelidna (Burmeister)	Lightfoot
Orthoptera	Acrididae	Psoloessa nymph	
Orthoptera	Gryllidae	Gryllus nymphs	
Orthoptera	Gryllidae	Eunemobius carolinensis neomexicanus	Lightfoot
Orthoptera	Gryllidae	Gryllus sp.	
Orthoptera	Gryllidae	Gryllus navajo Weissman	Lightfoot
Orthoptera	Mogoplistidae	Cycloptilum comprehendens Hebard	Lightfoot
Orthoptera	Rhaphidophoridae	Ceuthophilus sp.	Lightfoot
Orthoptera	Tettigoniidae	Atelopus sp.1 - undescribed	Lightfoot
Orthoptera	Tettigoniidae	Capnobotes fuliginosus	Lightfoot
Orthoptera	Tridactylidae	Ellipes sp.	

Prostigmata	Anystidae	anystid sp.	Brantley
Prostigmata	Bdellidae	bdellid sp.	Brantley
Prostigmata	Erythraeidae	erythraeid sp.	Brantley
Pseudo-scorpiones	undetermined	pseudoscorpion sp.	
Psocoptera	not determined	psocopteran sp.	
Scorpiones	Buthidae	Centruroides exilicauda (Wood)	Lightfoot
Scorpiones	Vaejovidae	Serradigitus wupatkiensis	Fagerlund
Siphonaptera	Ceratophyllidae	Orchopeas agilis Rothschild	Fagerlund
Solifugae	Eremobatidae	Eremobates sp.	Brantley
Thysanoptera	not determined	thrips sp.	
Thysanura	Lepismatidae	Lepisma sp.	Brantley
Trichoptera	not determined	trichopteran adult	

List of plant species encountered in 2001 and 2002

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

	Machaeranthera pinnatifida (Hook.) Shinners 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
	Equisetum ×ferrissii Clute (pro sp.)	horsetail

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

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

	Sporobolus contractus A.S. Hitchc.	spike dropseed
	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