1996 AVIAN COMMUNITY MONITORING

IN THE GRAND CANYON

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Principle Investigators:

Jim Petterson, Wildlife Biologist
Grand Canyon National Park
Science Center
P.O. Box 129
Grand Canyon, AZ 86023

Dr. John R. Spence, Botanist
Glen Canyon National Recreation Area
Resource Management Division
P.O. Box 1507
Page, AZ 86040

Submitted to:
Grand Canyon Monitoring and Research Center
PO Box 22459
Flagstaff, AZ 86002

INTRODUCTION

Avian communities along the Colorado River in Grand Canyon have changed substantially since completion of Glen Canyon Dam (Brown et al. 1987, Carothers and Brown 1991). Pre-dam vegetation along the river consisted of thin, widely scattered riparian patches, whose continued existence was threatened annually by scouring caused by spring flooding (Turner and Karpiscak 1980, Stevens and Ayers 1993). Following completion of the dam in 1963 and subsequent filling of Lake Powell, the largest tracts of riparian vegetation (in Glen Canyon) were destroyed. However, downstream of the dam through Grand Canyon, an extensive "new high water zone" (NHWZ) community has developed. This NHWZ is dominated by introduced tamarisk (*Tamarix chinensis*) with coyote willow (*Salix exigua*) and several species of seep willow (*Baccharis* sp.) as understory. The NHWZ lies below the "old high water zone" (OHWZ), which is Pre-dam vegetation dominated by honey mesquite (*Prosopsis glandulosa*) and catclaw acacia (*Acacia greggii*). In addition, extensive stands of riparian habitat have become established on silt terraces on the lower portion of Grand Canyon draining into Lake Mead. The vegetation in this reach is mostly dominated by Gooding's (*Salix goodingii*) and coyote willows, with lesser abundance of tamarisk than farther upriver. The lower Grand Canyon vegetation has developed in response to the closing of Hoover Dam in 1932, and the subsequent filling of Lake Mead. In addition, more than 500 ha of new riparian habitat has been established along the river from Lee's Ferry to Diamond Creek in the last 20 years following the completion of Glen Canyon Dam (Brown and Trosset 1989).

These substantial habitat changes have in turn, caused changes in the canyon bird community (Brown et al. 1987, Carothers and Brown 1991), and can be expected to continue to do so in response to current and future dam operations. These changes in avian populations are affected by habitat quality and abundance (Brown 1989), while habitat (vegetation) is in turn controlled by such factors as climate, geomorphic disturbances, and river fluctuations.

The dominant woody riparian species vary in different sections of the river corridor. The OHWZ vegetation in the stretch from Glen Canyon Dam to ca. RM 40 consists primarily of Apache Plume (*Fallugia paradoxa*), Western hackbery (*Celtis reticulata*), and Western Redbud (*Cercis occidentalis*). Around RM 40 Catclaw Acacia (*Acacia greggii*) and Honey Mesquite (*Prosopis glandulosa*) become dominant, with lesser amounts of Hackberry. Apache Plume and Redbud become rare down river and eventually disappear. The NHWZ also varies in different stretches. Tamarisk (*Tamarix chinensis*) is dominant until ca. RM 238 (Separation Canyon). Native riparian species include Coyote Willow (*Salix exigua*), and Emory (*Baccharis emoryi*) and Willow-leaved Seepwillows (*B. salicifolia*) throughout the river corridor, and Waterweed (*B. sarathroides*) below c. RM 170. Goodding's Willow (*Salix gooddingii*) is the only native tree-forming species, but is rare along the river corridor until Separation Canyon. The only significant stands of this species above Diamond Creek occur at Lees' Ferry and Cardenas (RM 71.0L). Along the slackwater of upper Lake Mead (below c. RM 238) the NHWZ is largely dominated by natives, predominantly Goodding's Willow with a dense understory of Coyote Willow and Willow-leaved Seepwillow. Fremont Cottonwood (*Populus fremontii*) occurs relatively frequently in the NHWZ as both saplings and trees below Separation Canyon. Throughout the river corridor where conditions permit small patches of marsh occur. Prominent species in these patches include cattail (*Typha domingensis*), reedgrass (*Phragmites australis*), and bulrush (*Scirpus* spp.).

Avian study patches did not always consist of both OHWZ and NHWZ vegetation. Many smaller patches in Marble and portions of Grand Canyon consisted primarily of NHWZ Tamarisk. In some areas where the canyon was wider, patches included both NHWZ Tamarisk and mesquite-catclaw

OHWZ vegetation. Most riparian vegetation below Separation Canyon consisted of native OHWZ and NHWZ vegetation with relatively little Tamarisk. The principal exception to this was at RM 264.5L, where much of the higher floodplain in this large patch consisted of Tamarisk.

Breeding bird studies have been conducted along the river corridor from Glen Canyon Dam to Lake Mead since the initiation of the Bureau of Reclamation Glen Canyon Environmental Studies program in 1982 (Brown 1988, 1989; Spence and Pinnock 1993; Grahame and Pinnock 1994, 1995; Sogge et al. 1994; Hualapai Tribe and SWCA 1995, Felley at al. in prep). Extensive data on species composition, abundance, and breeding and nesting habitat have been collected over the 13 year period between 1982-1995. A wide variety of methods have been used, with total-count walking surveys and floating surveys (Carothers and Sharber 1976, Brown 1988, Sogge et al. 1994) being used the longest.

The avifauna research undertaken during GCES Phase II (Sogge et al. 1994; Grahame and Pinnock 1994, 1995; Felley et al. in prep) used several proven censusing and demographic techniques to characterize the river corridor bird community: fixed-radius point counts (Ralph et al 1993), spot-mapping (I.B.C.C. 1970, Tomialojc 1980), float-by counts, total count surveys, nest searches (Martin and Geupel 1993), and mist netting (Verner 1985). Tradeoffs exist with each method in terms of time and money required, the types of variables measured, and the kinds of information that result (e.g. amount of demographic data obtained, documentation of known breeding status, habitat relationships and use, whether indices to abundance or actual densities are obtained, and the degree to which movements of known individual birds are detected (Verner 1985, Bibby et al. 1992, Ralph et al. 1993).

Although quantification of avian populations has been the subject of much study (see, for example Ralph and Scott 1981, Sauer and Droege 1990), there are no universally applicable standard techniques to determine bird population numbers. Some biologists believe that fixed radius point counts represent the best compromise between economy of collection effort and precision and accuracy of population trend estimates or population indices (Verner 1985, Ralph et al. 1993). This report describes the results from a study designed to further test and compare point count surveys and total count walking surveys.

Specifically, the objectives of this study were:

1. Describe and compare the breeding bird community from Glen Canyon Dam to the lower Grand Canyon in upper Lake Mead.

2. Quantify and compare point count surveys and total count walking surveys in terms of: species richness, community composition, and relative species abundance.

3. Define feasible monitoring objectives based on species' abundances and sample size considerations using Type I and Type II error levels and alternative population monitoring thresholds.

4. Make recommendations on monitoring techniques suited for long-term avian monitoring along the Colorado River.

METHODS

Study Area

All field work during 1996 was conducted on the Colorado River corridor along a 295 mile stretch from the Glen Canyon Dam (RM -15) to Lee's Ferry (RM 0), continuing through Grand Canyon National Park, and extending to Pearce Ferry at Lake Mead National Recreation Area (RM 280). All study site locations along the river are indicated as positive or negative numbers of miles above or below Lee's Ferry, respectively, and as being either on river right or left as referenced by an observer oriented facing downriver per Stevens 1983. Vegetation exists as discrete riparian patches that vary in size from 0.1 ha along narrow, scoured sections of the river, to 50 ha blocks on large, expansive silt terraces in the upper stretches of Lake Mead. Lands in the study area are managed by the National Park Service and the Hualapai Tribe in a natural condition, with a minimum of development occurring along the river.

Five survey trips were conducted during 1996 between May and July in the Glen Canyon NRA stretch from RM -15 to Lee's Ferry. In the Grand Canyon stretch from Lee's Ferry to Pearce Ferry, three survey trips were completed using inflatable rafts: March 30 - April 14, May 5-20, and June 10-24. The first trip coincided with an experimental flood flow of 45,000 cfs, while the last two trips encountered flows between 15,000 cfs and 24,000 cfs. Surveys were timed to span the divergent range of breeding activity peaks of birds that include early breeding resident and short distance migrants in March, to mid- and late breeding long distance migrants in May and June. Air temperatures during survey activities ranged from 4° C in March, to 45° C in June.

Counting methods

A total of 21 point count stations were permanently marked in 10 patches of suitable vegetation along the stretch of river between Glen Canyon Dam and Lee's Ferry. Between Lee's Ferry and RM 265L, a total of 98 permanent point count stations were established systematically in 42 different riparian vegetation patches (Fig 1). Each study patch contained from 1 to 10 point count stations situated 125 m to 250 m apart, with the majority of adjacent stations being greater than 150 m distant. Most point count stations were situated halfway between the river and upland desert scrub habitat.

A paired design was followed using two different censusing techniques conducted consecutively in each study site patch from the Glen Canyon Dam to RM 265L: fixed radius point-counts and total count walking surveys (hereafter referred as "point counts" and "walking surveys" respectively). These paired surveys were conducted on most of the 42 patches during the 3 trips, for a total of 108 patches surveyed. Logistics constraints prevented every patch from being done on every trip. Because most patches contained more than one point count station, a total of 271 point counts were completed on 108 patches over the course of the 3 trips.

Point counts

Point counts require that an observer be stationary at one spot during the count period and use primarily audible cues for bird identification, although visual cues typically provide 10% of bird detections. The point counts during this study used a 50 m radius point survey from Lee's Ferry to

RM 265L, and a 25 m radius limit in the Glen Canyon portion. This difference was based on the fact that Glen Canyon NRA had used a 25 m radius in past years and wanted to keep the radius constant for optimum comparisons. During each point count, birds were counted for one 5 minute period on the first trip, and two 5 minute periods on the last two trips. Observations began immediately upon arriving at the station, with no "cool-down" period used. Birds noted before or after the observation period were also recorded as falling outside the survey period. All birds detected were enumerated and classified as being either "inside" or "outside" the fixed radius, with the result that two classes of detections were determined: within 50 m (50 m point counts) and outside 50 m (unbounded point counts). Individual birds detected were also identified to species and when possible, to sex, using visual and aural cues. All birds detected were noted on data sheets, including flyovers. Data were also recorded as to which habitat the bird was detected in, and the type of detection (visual or aural). Observers were rotated between visits, but because of the difficulties and time required for different observers to find point count stations that they had not visited previously, the majority of point counts were conducted by one observer.

Walking surveys

Walking surveys are a modified belt transect technique, where a surveyor follows previously established trails and/or explore relatively accessible portions of a patch. The survey was considered complete when the surveyor had attempted to cover the entire survey area and ID, count, age, and sex all birds detected. Consequently, search effort was proportional to habitat patch size, with surveys taking from 15 to 120 minutes. Habitat associations for birds detected were also noted during walking surveys.

Walking surveys were done in tandem with point counts using two different observers recording data in the same study patch. Surveys began no sooner than 30 minutes before sunrise and were terminated by 10:00 am. After the first observer finished the first point count survey for that patch and moved to the next point count station, a second observer waited for 15 minutes before beginning a walking survey. In each patch, start and stop times and weather variables were noted for each technique. A total of six observers who were knowledgeable birders or recent ornithological students collected data during 1996. For the two less experienced observers, the first two survey trips were used for training to ensure individuals were knowledgeable of local bird songs, calls, and behaviors before taking data independently on the third trip.

Data Analysis

A total of 271 point counts and 108 walking surveys were completed during the 3 trips. With the exception of comparisons involving species richness, all analyses were confined to the 23 species of riparian breeding birds. These species include: black-chinned and Costa's hummingbirds, mourning dove, brown-crested and ash-throated flycatchers, Bewick's wren, blue-gray Gnatcatcher, northern mockingbird, Bell's vireo, yellow warbler, Lucy's warbler, yellow-breasted chat, common yellowthroat, blue grosbeak, lazuli bunting, northern oriole, brown-headed cowbird, summer tanager, great-tailed grackle, song sparrow, lesser goldfinch, and house finch. In cases where comparisons of abundance were made on a species-specific basis, sample size considerations required that the relatively rare species in the above list were excluded in statistical tests. A core group of the 13 most common riparian breeding birds were used as a focal group for most of those statistical comparisons.

Waterfowl, upland breeders, non-breeding migrants, very rare species (e.g. southwestern willow flycatchers), flyovers, and birds detected before or after the "official" 5 or 10 minute count period were all excluded from analyses. Scientific names of all birds can be found in Appendix 1.

For comparisons between point counts and walking surveys, paired patches were chosen as the sample unit. Regrettably, numerous data sheets from the walking surveys were lost during computer data entry following the field season, thereby reducing the number of patches where both point count and walking survey data were available. Consequently, only 74 of 108 patches could be analyzed in a paired manner, where both point count and walking survey data exist. In those 74 patches, 184 point counts were included, which is less than the total 271 point counts conducted. For data analyses involving just point count data, the full 271 point count data set was used. For both point counts and walking surveys, we grouped bird detections into two general categories: all bird detections (aural and visual, female and male), and male detections only (aural and visual). For point counts only, further categorization included unbounded and <50 m groupings (<25 m for Glen Canyon).

It was assumed that adjacent 50 m point count stations were statistically independent, and that double-counting was avoided in those cases due to the 150 m intra-station spacing. For each patch where >1 point count station was present, the 50 m data were summed for each species to obtain a patch value that was used to make comparisons of species abundance with walking surveys. Similarly, for species richness comparisons between the point counts and walking surveys, the point count species presence/absence data were summed across the entire patch, which was then compared to the walking survey values.

It was decided that the difference in search effort inherent between point count surveys and walking surveys was not reconcilable in a way that permitted a rigorous "correction factor" to be applied to the data. For example, while in a patch conducting a walking survey, birds were recorded during the entire time spent in the patch. If there were 3 point count stations in that patch, birds were recorded only during the 5 minute duration of each three counts; birds seen travelling to another point count station in that same patch were not recorded. Therefore, in this example, if 40 minutes were spent recording birds during a walking survey, only 15 minutes were actually spent recording birds during the 3 point counts conducted in that patch. Thus, search efforts differed between techniques such that walking surveys involved greater search effort.

Statistical analyses were conducted using SYSTAT 6.0 (SPSS Inc. 1996). Data were initially screened using histograms and probability plots to detect departures from normality, and Levine's tests were used to detect unequal sample variances. Data possessing a Poisson distribution were transformed using the square root transformation, while percentage and proportion data were transformed using the arcsine transformation prior to applying parametric statistical procedures (Sokal and Rohlf 1981). Other data exhibiting unequal variances and/or non-normal distributions that did not lend themselves to correction using transformations were analyzed using nonparametric statistics. Type I error (alpha) was chosen to be 5%; i.e. results of all statistical tests were considered significant at ($p \leq 0.05$).

Species Richness
We used paired t-tests to compare species richness in 271 unbounded and 50 m point counts. For paired-survey comparisons, 74 patch values for walking surveys were contrasted with unbounded and 50 m point counts using t-tests. In both cases, all 3 trips were pooled.

Species Detectibility

We contrasted species detectibility in paired walking surveys and point counts by calculating a species overlap ratio defined by:

$$\text{overlap ratio} = \frac{\text{the numbers of surveys on which a particular species was detected by a given survey method}}{\text{the number of survey pairs on which that species was detected by either method.}}$$

Only the 13 most common breeders were used for this calculation. Wilcoxon signed-rank tests were used to compare values between survey techniques.

Point count Survey Length

We summarized data for 5 and 10 minute point counts, using all bird detections and male detections only. Paired t-tests were used to compare unbounded and 50 m point counts conducted for 5 minutes and 10 minutes. Species richness was examined using all species detected in the patch and also only the 23 species of riparian breeders. Bird abundance comparisons only involved the 23 species of riparian breeders.

Rank Bird Abundance

We tabulated total bird detections for the 13 most common breeding species for walking surveys and unbounded and 50 m point counts. Rank abundance was determined for paired data and for all data for both techniques with data pooled for 3 trips. Presence/absence data for each species was summarized by determining a frequency of detection in all patches and contrasts then made between walking and point count surveys using paired t-tests following application of suitable transformations. For point count data only, total numbers of bird detections on 271 points were compared among 3 trips for each of 13 species using Kruskal-Wallis ANOVA.

Total Bird Abundance

For paired data, correlations were determined and results plotted on total numbers of birds detected for the 13 common breeding species between walking surveys and unbounded point counts and between walking surveys and 50 m point counts. Correlations were also determined between walking surveys and unbounded point counts on numbers of males detected. Paired comparisons of species abundances were made of total numbers of detections and of males only for 3 trips pooled on walking surveys and point counts using paired t-tests.

Monitoring Population Trends

A power analysis was performed on the point count data. Two different data sets were considered. The first set consisted of all point count stations which were visited on all three trips (N=73). Bird detections were summed for all species across the three visits for each station. The second were the 26 patches which were visited on all three trips. Bird detections were pooled across all point count stations in the patch to derive mean "within-patch" values. For both data sets all bird detections within the 50 m radius of the point count station were used. The unbounded point count station data were not used to minimize problems associated with possible double counting. The program MONITOR, written by Dr. James Gibbs of Yale University, was used for the analyses (Gibbs 1995). Because the method requires non-zero means, the value of 0.001 was substituted where point count means and standard deviations were 0.

Power is defined as: $1 - \beta$

where β is the probability of making a Type II error (accepting a false null hypothesis). Power indicates how likely it is to detect a change when it is in fact occurring. Power levels are generally set at 80% or above. A power of 80% indicates that, on average, 80% of the time a change that is actually occurring will be detected. The inverse is that 20% of the time a change that is actually occurring will not be detected. The Type I error (α or rejection of a true null hypothesis) was set at 0.05 for all simulations. The analysis uses a Monte Carlo simulation to generate simulated sets of count data, which are then compared with the actual inputs through a route-regression approach. Replications were set at 250. Trend projections were set at 5%, 10%, 15%, 20% and 25% (change in point count detections between years) for a five year time-frame. A two-tailed test was used, testing the null hypothesis that the trend does not differ from zero.

RESULTS

Species Richness
Sixty-six bird species were detected on point counts while 72 species were detected on walking surveys. The riparian breeding avifauna was dominated by 13 abundant species that included: black-chinned hummingbird, ash-throated flycatcher, Bewick's wren, blue-gray gnatcatcher, Bell's vireo, yellow warbler, Lucy's warbler, yellow-breasted chat, common yellowthroat, brown-headed cowbird, song sparrow, lesser goldfinch, and house finch. The remaining 10 species of riparian breeders were detected on less than 5% of survey patches.

For the complete point count data set ($n=271$), unbounded point counts (mean = 4.88, SE = 0.14) detected significantly more species of birds than 50 m point counts (mean = 3.91, SE = 0.12). This held true for both total detections (paired t-test, $t=15.26$, $p<0.0001$) and male detections only (paired t-test, $t=15.49$, $p<0.0001$).

Considering only paired data, unbounded point counts detected significantly more species of birds (both total detections and male detections only) than 50 m point counts (Table 1). Walking surveys detected more species of birds than 50 m point counts for all bird detections, but not for male detections only. Walking surveys detected more species of birds than unbounded point counts for all bird detections, but the opposite was true for male detections only (Table 1).

Species Detectibility
We compared species overlap ratios for paired walking surveys and point counts of the 13 most common riparian breeders using Wilcoxon signed-ranks tests (Table 2). Walking surveys had significantly higher overlap ratios than either unbounded or 50 m point counts (unbounded $Z=2.04$, $p=0.04$; 50 m $Z=2.67$, $p=0.008$). Unbounded point count overlap ratios were significantly higher than 50 m values ($Z=2.52$, $p=0.012$). Lucy's warblers were the species most likely to be detected with all surveys. Black-chinned hummingbirds, common yellowthroats, and house finches were the

least likely species to be detected with point counts, and house finches the least likely species to be detected overall.

Detection Category	Point Counts (n=74) Numbers of Species (Mean/SE) 50 m	Point Counts (n=74) Numbers of Species (Mean/SE) Unbounded	Point Counts (n=74) Z	Point Counts (n=74) p	Walking Surveys (n=74) Numbers of Species (Mean/SE)	Walking vs. 50 m Z	Walking vs. 50 m p	Walking vs. Unbounded Z	Walking vs. Unbounded p
All Detections	5.50/0.39	6.62/0.41	6.09	<0.0001 V	7.51/0.37	5.35	<0.0001 W	2.67	0.007 Y
Male Detections	4.16/0.36	5.38/0.39	6.34	<0.0001 V	3.97/0.26	0.28	0.78 X	3.71	0.001 Z

V - Unbounded > 50 m point count
W - Walking survey > 50 m point count
X - Walking survey nsd 50 m point count
Y - Walking survey > Unbounded point count
Z - Unbounded point count > walking survey

Table 1. Comparison of species richness on paired 5 minute point counts and walking surveys for all species of birds detected along the Colorado River in 1996.

Species	Overlap Ratios: Walking surveys	Point counts (50 m)	Point Counts (Unbounded)
Lucy's warbler	0.98	0.89	0.91
Bell's vireo	0.93	0.85	0.93
Bewick's wren	0.95	0.78	0.85
Song sparrow	0.79	0.63	0.63
Yellow-breasted chat	0.85	0.79	0.92
Blue-gray gnatcatcher	0.90	0.79	0.83
Common yellowthroat	1.0	0.50	0.58
House finch	0.73	0.39	0.65
Yellow warbler	0.80	0.80	0.80
Ash-throated flycatcher	0.87	0.47	0.87
Black-chinned hummingbird	0.85	0.50	0.50

Table 2. Comparison of walking surveys and point counts to detect the most common riparian breeding bird species. Overlap ratio = #'s of surveys on which the species was detected by a given method / # survey pairs on which the species was detected by either method.

Point count Survey Length

When all detections of all species of birds were examined, ten minute point counts resulted in greater numbers of species detected for both unbounded and 50 m point counts (Table 3). When male detections only of all species of birds were included, differences were not significant in the 50 m point counts, but were significant in unbounded point counts. For the 23 riparian breeding species, 10 minute point counts were significantly higher in species richness than 5 minute counts, but with 50 m point counts, no difference was shown for 5 and 10 minute counts (Table 4). Also, for the 23 riparian breeders, ten minute point counts resulted in a greater number of birds detected in both unbounded and 50 m point counts for both detection categories (Table 5).

Detection Category	Unbounded Point Counts (n=102)				50 m Point Counts (n=102)			
	Numbers of Species Mean/SE		t	p	Numbers of Species Mean/SE		t	p
	5 min	10 min			5 min	10 min		
All Detections	5.57/0.37	6.73/0.24	10.93	<0.0001	4.42/0.20	4.81/0.22	3.02	0.003
Male Detections	4.34/0.21	5.23/0.23	8.54	<0.0001	3.33/0.19	3.48/0.21	1.25	0.22

Table 3. Comparison of species richness on unbounded and 50 m point counts for 5 minute and 10 minute survey periods for all species of birds detected along the Colorado River in 1996.

Detection Category	Unbounded Point Counts (n=102)				50 m Point Counts (n=102)			
	Numbers of Species Mean/SE		t	p	Numbers of Species Mean/SE		t	p
	5 min	10 min			5 min	10 min		
All Detections	5.07/0.21	5.93/0.24	9.13	<0.0001	4.16/0.20	4.37/0.20	1.83	0.07
Male Detections	4.07/0.21	4.75/0.23	7.66	<0.0001	3.22/0.19	3.30/0.20	0.79	0.43

Table 4. Comparison of species richness on unbounded and 50 m point counts for 5 minute and 10 minute survey periods for the 23 species of riparian breeding birds along the Colorado River in 1996.

Detection Category	Unbounded Point Counts (n=102)				50 m Point Counts (n=102)			
	Numbers of Birds Mean/SE		t	p	Numbers of birds Mean/SE		t	p
	5 min	10 min			5 min	10 min		
All Detections	9.69/0.43	12.18/0.53	13.72	<0.0001	6.66/0.35	8.21/0.22	9.96	<0.0001
Male Detections	7.37/0.40	9.06/0.49	10.70	<0.0001	4.61/0.30	5.56/0.34	7.52	<0.0001

Table 5. Comparison of bird abundance on unbounded and 50 m point counts for 5 minute and 10 minute survey periods for the 23 riparian breeding species along the Colorado River in 1996.

Rank Bird Abundance

Lucy's Warblers were consistently the most abundant riparian breeding passerine bird along the Colorado River, regardless of survey technique (Table 6). This species was more than twice as abundant than the next species. For paired patches, rank abundance for the 13 most common riparian breeders was virtually identical between 50 m and unbounded point counts. Results for walking surveys were somewhat different, with song sparrows being detected much more often than in point counts. Lucy's warblers were detected on 83% of all point counts, and 79% of all walking surveys on the 74 paired patches.

Similar trends were observed for the complete point count and walking survey data sets, with Lucy's Warbler again being twice as abundant than the next most common species (Table 7). Rank abundance values were virtually identical with the paired values for unbounded point counts, but blue-gray gnatcatchers replaced Bewick's wrens as the third most abundant bird in the complete point count ranking. Walking survey ranking were identical between data sets.

Presence/absence data, as summarized by frequencies of detection for each of the 13 most common riparian species, did not differ significantly between walking and point count surveys for either the paired patches ($t=0.176$, $p=0.86$) or for the complete data sets ($t=1.19$, $p=0.26$). However, frequencies of detection were significantly higher for all point counts than paired point counts ($t=2.61$, $p=0.03$) and for all walking surveys than paired walking surveys ($t=3.01$, $p=0.013$).

Total Bird Abundance

Temporal differences in total numbers of bird detections for the complete point count data were seen for some species, with 3 species of later arriving migrants (yellow-breasted chat, ash-throated flycatcher, and brown-headed cowbird) being absent during the first survey trip in late March (Table 8). As expected, early breeders like hummingbirds, were less common on the third trip than the first two trips. When the 13 riparian species were compared among the 3 survey trips using Kruskal-Wallis ANOVA, significant differences were found between trips for Bewick's wrens (unbounded data, trip 2 > trip 3; $H=9.11$, $p=0.003$), house finches (50 m data, trip 2 > trip 1; $H=4.99$, $p=0.026$), and ash-throated flycatchers (unbounded data, trip 2 > trip 3; $H=5.43$, $p=0.02$). Lucy' warblers averaged more than twice as many detections per 50 m point count than the next abundant species, Bell's vireo.

Correlations of paired data for the 13 most common riparian species on total numbers of birds detected between walking surveys and unbounded point counts and between walking surveys and 50 m point counts showed positive correlations of 0.94 and 0.93 respectively. Correlations of paired data on numbers of males detected between walking surveys and unbounded point counts also showed a positive correlation of 0.84 (Figs. 2-4)

Comparisons between walking surveys and 50 m point counts summed across paired patches of the total numbers of the 13 most common riparian species differed by species (Table 9). Black-chinned hummingbirds, Bewick's wren, yellow warbler, Lucy's warbler, yellow-breasted chat, brown-headed cowbird, lesser goldfinch, and house finch showed no significant differences between survey types for all bird detections or for male detections only.
Walking surveys detected significantly more birds than point counts for all bird detections or for male detections only on the following species: ash-throated flycatchers, Bewick's wren, blue-gray gnatcatcher, Bell's vireo, common yellowthroat, and song sparrow. For all 13 species pooled, walking surveys detected significantly more birds for all detections, but not for male detections only.

Results of the Glen Canyon stretch are reported elsewhere (Spence 1997).

Monitoring Population Trends

The results of a power analysis using the data set of 73 point count stations visited on all three trips and within 50 m detections of all individuals is shown in Tables 10 and 11. The analysis indicates that there is adequate power to detect positive 10% changes per year in detection rates over a five year period for six species (Table 10); Lucy's warbler, Bell's vireo, Bewick's wren, song sparrow, blue-gray gnatcatcher, and yellow-breasted chat. Negative 10% trends over five years can only be detected for Lucy's warbler, Bell's vireo, and blue-gray gnatcatcher (Table 11). Larger trend projections increase the power of the monitoring program. For example, at 20% trends per year positive trends can be detected in all species except brown-headed cowbird, and negative trends in seven species; Lucy's warbler, Bell's vireo, Bewick's wren, song sparrow, blue-gray gnatcatcher, yellow-breasted chat, and common yellowthroat.

Increasing the sample size to 100 point count stations improved the power of the monitoring program. When this sample size was used, changes of 20% per year could be detected in all 13 of the most common species except for declines in brown-headed cowbird. In this species at least 125 point count stations would be required to detect 20% declines per year if they were occurring.

Using summed point count detections in patches, the power declined considerably (Tables 12 and 13). Only 26 patches were visited on all three trips. Only Lucy's warbler was common enough to be detected at 10% trends. Even at 20% trends, declines could only be detected in three species; Lucy's warbler, Bell's vireo, and blue-gray gnatcatcher.

Increasing the sample size to 50 patches improved power. Results were similar to the analysis using the 73 point count stations. At 20% per year trends, only declines in brown-headed cowbird could not be detected.

DISCUSSION

Species Richness

The riparian breeding bird community along the Colorado River from Lee's Ferry to Pearce Ferry consists of relatively few species. While 23 species of birds are identified as confirmed or probable breeders in the riparian system, 6 of those species comprised >72% of all birds detected. This proportion was consistent between survey methods, with point count and walking surveys yielding similar results. These 6 most abundant species include Lucy's warbler, Bell's vireo, song sparrow, yellow-breasted chat, Bewick's wren, and blue-gray gnatcatcher. When the entire bird community is considered, walking surveys detected 6 more species of birds overall than point counts (72 spp. vs. 66 spp.).

We found that unbounded point counts were better at detecting more species of birds than 50 m point counts. This held true for both total bird detections and male detections only. This is not surprising since the wider detection radius inherent in unbounded point counts would have a greater likelihood at picking up species which maintain large territories and louder, more distant species that use uplands or the OHWZ for nesting.

The paired comparisons showed that walking surveys are a better method than both unbounded and 50 m point counts if the objective is to detect as many species as possible, regardless of sex. However, if only male detections were included in the analysis, our results showed that walking surveys detected fewer species than unbounded point counts. Further, walking surveys and 50 m point counts were not significantly different in their ability to document species richness when only male detections were included.

Walking surveys allow the observer to visit more kinds of microhabitats within a patch such as shorelines or *Typha* and *Phragmites* marshes, which are likely to contain habitat specialists such as common yellowthroats. The walking survey also allows the observer to "track down" a bird to make a certain ID. The point count observer must rely on identifying audible cues to a greater extent because, being less mobile, they are unable to visit "jackpot" habitats or track down birds. This difference in mobility between the two survey methods may explain the difference in unbounded point counts and walking surveys to detect males. Remaining quietly stationary for the duration of the count period allows the observer to better identify male songs and call notes than the observer walking noisily through the patch while surveying. Regardless, if the survey objective is to maximize the numbers of species found in a patch or to examine species composition, the walking survey appears to be the better technique.

Species Detectibility

Walking surveys had significantly higher overlap ratios than either point count method. This result can be interpreted as walking surveys were more reliable in finding a species in a patch, if that species was in fact detected by either method during that survey period. As expected, unbounded point counts were more reliable at picking up species than 50 m surveys. The superiority of walking surveys to point counts in survey reliability can again be explained by the fact that the walking observer has more freedom to search out more diverse microhabitats and track down unknown species than the point counter does.

Lucy's warblers were the species most likely to be reliably detected in a patch, regardless of survey type. Walking surveys detected Lucy's warblers 98% of the time that they were present on a patch as defined by looking at both survey results for that patch. House finches were the species least likely to be detected by either technique. This could be because house finches tended to move within and between patches a great deal and consequently, birds detected on one survey would likely be missed when the other observer performed the other survey. Common yellowthroats are another species worth mentioning due to the great differences between survey types in detecting them. If yellowthroats were detected by point counts, they were also detected by walking surveys 100% of the time. The converse was true only 58% of the time for unbounded point counts. This is not surprising given that walking surveys are better at finding relatively rarer species in more restricted habitats. If the point count station was located away from a suitable marsh habitat type, a yellowthroat was unlikely to be detected during the survey. On most patches, the walking surveyor would purposefully search these marsh habitats in the course of the survey, thus being more likely in finding common yellowthroats. Loud species, birds which maintain larger territories, or birds more typically found in OHWZ or uplands such as ash-throated flycatchers, were relatively unlikely to be detected within the 50 m point count radius. Walking surveys and unbounded point counts were better at picking up these upland species.

Point Count Survey Length
We found that differences existed between 5 minute and 10 minute point counts for species richness and bird abundance values. If all species of birds were included, 10 minute unbounded point counts detected on average ca. one additional species than 5 minute surveys, and this difference was statistically significant. For 50 m surveys, the 10 minute period resulted in an additional 0.4 species, when all bird detections were included, as compared to the 5 minute period, and this difference was again significant. When males only were included, 10 minute and 5 minute surveys were not significantly different.

The results for species richness were similar when only the 23 species of riparian breeding birds were included, with 10 minute unbounded point counts detecting significantly more species than 5 minute unbounded surveys. For 50 m surveys, 10 minute and 5 minute point counts were similar for both all bird detections and male detections only. We found that when the same 23 riparian breeders were included, bird abundances were consistently higher on 10 minute point counts than 5 minutes. This held true for both unbounded and 50 m point counts and also when all bird detections and male detections only were considered.

The differences between 5 and 10 minute unbounded point counts in numbers of species detected can be anticipated since it was shown above that unbounded point counts were apt to detect more species than 50 m point counts. Many other studies have shown that the numbers of species detected increases in time up to a point, after which the rate of new species additions levels off to zero (Hutto 1986). We suggest that if the monitoring goal is to look at species turnover or species richness, 50 m point counts should only be conducted for 5 minutes, which would leave relatively more time to do more point counts and increase sample sizes. However, unbounded point counts would be best conducted for 10 minutes if the time required between point counts is greater than 15 minutes as suggested by Ralph et al 1993. The extra 5 minutes conducting surveys would be worth the effort in that case.

Regarding bird abundance, since 10 minute counts yield more birds than 5 minute counts, the deciding factor on whether to use longer survey lengths depends on the monitoring objective and amount of time spent in travel between point counts. The greater number of detections made for a particular species on point counts will yield higher power when trying to detect population changes over time (Gibbs 1995). Thus, the extra 5 minutes spent on a point count will likely be worth it in cases where it's possible to increase the mean numbers of detections for a given species. The same holds true to even a greater degree if the amount of time required to reach successive point counts is greater than 15 minutes as it is along the Colorado River in many stretches.

Rank Bird Abundance
We found Lucy's warblers to be the most common riparian breeder, being approximately twice as abundant as the next most common breeder. While both walking surveys and point counts agreed on rank abundance for the most common bird, agreement was not so consistent for species farther down in rank. For instance, Bell's vireos were ranked second on point counts, while song sparrows (which ranked fourth on point counts) ranked second on walking surveys. Other rank differences include house finches and ash-throated flycatchers, which are 8th and 10th respectively, on point counts, but are reversed in rank on walking surveys.

Some discrepancies in rank can be explained by examining the differences in how point counts and walking surveys are conducted. Point counts are conducted with a stationary observer, with birds only recorded during the 5 or 10 minute survey period; birds are not recorded while walking between stations within a patch. By contrast, walking surveys involve recording birds continuously while traveling through the patch. We noticed a tendency for birds to be pushed ahead of observers moving through a patch doing walking surveys. This resulted in double-counting of birds to an unknown degree in walking surveys, with the problem becoming more pronounced as patch size increases. It is our feeling that some locally abundant species, such as song sparrows, were particularly prone to over-estimation by walking surveys on the larger patches that exist on the lower Colorado portion of the survey area. The largest such study patch at 264.5L comprised 40 ha and took 120 minutes to finish the walking survey. The same patch took 180 minutes to finish the 10 point count stations, each spaced 250 m apart. An examination of the data revealed that on the June trip, 155 song sparrows were detected on the walking survey at this patch, as compared with 47 birds on the point count. These difference were due to the presence of many newly fledged song sparrows which were detected, as well as double-counting on the walking survey. The 155 song sparrows represents over half of the song sparrows detected during the entire field season on all patches combined and thus the song sparrow rankings are artificially inflated for data pooled across all trips. On such a large patch, more birds are counted with walking surveys than point counts because walking surveys included all birds, while point counts exclude the birds that are located along the 250 m stretch between point count stations. This illustrates a serious limitation of using walking surveys in large, non-linear riparian patches and is probably why this technique is generally not found in the current literature associated with bird monitoring.

Total Bird Abundance

Temporal differences in bird abundances were apparent for several species and reflected differences in breeding chronology. As seen in this study, early breeders such as Bewick's wrens can be expected to be harder to detect as the breeding season progresses and male song rates drop. Late arriving migrants such as ash-throated flycatchers and yellow-breasted chats were not detected at all in the first trip. However, chats became the fifth most abundant breeding bird over the entire breeding season.

Correlations of total abundance estimates for the 13 most common species for paired point counts and walking surveys showed that abundance estimates were highly positively correlated. Correlation coefficients ranged from 0.84 for male detections on paired unbounded point counts and walking surveys to 0.94 for all bird detections on paired unbounded point counts and walking surveys. In both comparisons, counts of song sparrows were consistently higher in walking surveys, while Lucy's Warblers were higher in point counts.

Comparisons of species abundances on a paired patch basis were more revealing than total abundance correlations. Of the 13 most common breeders, 7 species (Bewick's wren, blue-gray gnatcatcher, yellow warbler, Lucy's warbler, yellow-breasted chat, brown-headed cowbird, lesser goldfinch, and house finch) showed no significant difference in total bird detections between walking surveys and 50 m point counts which had been summed across the patch. When male detections only were considered, 10 of 13 species (black-chinned hummingbird, Bewick's wren, yellow warbler, Lucy's warbler, yellow-breasted chat, common-yellowthroat, brown-headed cowbird, song sparrow, lesser goldfinch, and house finch) showed no differences between survey type.

It is noteworthy that for those species where differences existed, walking survey abundance estimates were always greater than point counts; the converse was never true for these paired comparisons.

One reason for the greater walking survey abundance could be a result of how the comparisons were structured. An inherent difficulty in comparing walking surveys conducted across an entire patch with several point counts conducted on the same patch was how to summarize the point count data across the whole patch. We used the 50 m point count data and summed bird abundance for each species for all point counts done on that patch. We assumed that by using the 50 m data, a conservative approach was assured when adding counts made from adjacent stations, since double-counting would be greatly minimized. For larger patches, there were undoubtedly birds located between point count stations that would not be included in point count data, but which would be included in walking survey data. This would result in a numerical bias towards higher walking survey totals for those patches. Another reason why walking survey abundances were greater than point counts for many species could be due to a combination of double-counting and to greater likelihood of detecting birds in specialized microhabitats in walking surveys.

When considering relative abundance measures using each technique, the main question is which technique provides the most consistent, repeatable, and least biased index of abundance? Our feeling is that the data show that point counts provide a better index of abundance than walking surveys. Walking surveys possess more sources of variability than point counts in areas relating to 1) greater likelihood at pushing and double-counting birds, 2) greater difficulty at standardizing search effort (survey time) between surveys, and 3) greater difficulty at standardizing search path between surveys. Point counts are much more standardized in terms of search effort (a fixed survey length) and search path (same point visited). In addition, double-counting is more easily avoided when the observer is standing still, paying attention to bird movements and audible cue directions, and not pushing birds ahead of themselves. Also, if point counts are located sufficiently apart, double-counting is drastically reduced.

Monitoring Population Trends

Caution should be used in interpreting the power tests. The data is based on sample means from only three trips, and both parameters are likely to change with additional data. However, initial power tests indicate that, at relatively gross changes of 20% per year over five year projections, the current monitoring program (106 point count stations) is adequate to detect change in the most common breeding riparian species should it in fact be occurring.

Using patches as the sampling unit (by pooling point count data from all stations in the patch) is not recommended. The principal effect of this is to greatly reduce sample size, without increasing detection means relative to standard deviations. Using patches as the sampling unit has the undesirable effect of reducing the power of the monitoring program considerably. However, patch data can be used in a long-term monitoring program. With a large enough sample size of patches, species presence-absence data from the total surveys can be used to detect changes over time. If a species is declining in the study area, then in principal it will begin to disappear from some patches, particularly smaller or more isolated patches. Testing for presence-absence in patches using an association test such as the χ^2 test between years could be a useful additional method, in conjunction with point count data, to detect possible changes.

Many of the riparian breeding species are simply too rare in the study area for a monitoring program to detect. These include species like Costa's hummingbird, Phainopepla, summer tanager, blue grosbeak, Bullock's and hooded orioles, and black phoebe's. If there are management concerns about some of these species, specific monitoring programs similar to that conducted for the southwestern willow flycatcher will be needed.

An integration of the Glen Canyon and Grand Canyon programs would be valuable as it would increase the sample size (number of point count stations). Also, several species that are common in the Glen Canyon stretch are rare below Lee's Ferry, and inclusion of these species will increase the number of bird species that can be effectively monitored by an integrated program (Spence 1997). Those species currently monitored in the Glen Canyon stretch that are relatively common include blue grosbeak, Bullock's oriole, and house finch. Also, brown-headed cowbird is common in this stretch and the Glen Canyon program has adequate power to detect changes in this species (Spence 1997).

One advantage of the 4-year data set from the Glen Canyon program was that it showed that 1996 was a poor year for the breeding riparian avifauna. This may have been the result of the extreme drought in northern Arizona from mid-1995 through 1996. Both species numbers and detection rates in 1996 were the lowest in this stretch since initiation of the program in 1992. This suggests that numbers of birds may also have been below average down river from Lee's Ferry. The power analysis indicated that with the 1996 data there is adequate power to detect changes in many species, even in what was probably a poor year for many species. Thus it is likely that additional data from better years will likely increase the power of the monitoring program along the Colorado River.

CONCLUSIONS AND MONITORING RECOMMENDATIONS

1. Walking surveys and point counts provide relatively similar results in many aspects of bird monitoring such as species richness and relative abundance, but statistically significant differences existed for many parameters.

2. Walking surveys provide a better characterization of species richness than point counts.

3. Point counts provide a better index of abundance than walking surveys because of fewer sources of variability and a greater degree of standardization and repeatability that can be achieved.

4. Point count survey length should be 10 minutes along the Colorado River in Grand Canyon because more bird detections will be made, and travel time between patches usually exceeds 15 minutes. Therefore, the extra information gained during the interval between 5 and 10 minutes will be worth the extra time spent.

5. A monitoring program should use a combined approach, with point counts to develop bird abundance indices and walking surveys to describe community composition and species richness.

6. At least two more years of baseline data on bird species detection rates and species composition should be collected (the 1997-98 seasons).

7. There are seven riparian bird species for which adequate numbers of detections exist to permit quantitative comparisons of population change over time using point counts at reasonable power levels and error rates. The present monitoring scheme has sufficient sample sizes to make these comparisons. With a complete data set (three surveys each at >100 point count stations per year) the quantitative changes in populations of the 13 most common species can be detected at relatively large

population trend projections of 20% per year.

8. Integration with the Glen Canyon portion of the study area should be done (Spence 1997), as this will increase sample size to >130 point count stations and >55 patches along the entire river corridor from Glen Canyon Dam to Lake Mead.

9. In order to link changes in the breeding riparian avifauna along the Colorado River with the operations of Glen Canyon Dam, a habitat program to monitor changes in NHWZ and OHWZ vegetation is necessary. Although not specified in the 1996 proposal, preliminary floristic composition and abundance data was collected from each point-count station on the June 1996 trip. This data needs to be analyzed, and augmented by a program to monitor structural components (canopy cover, patch area, vegetation height, canopy structure) of the riparian vegetation.

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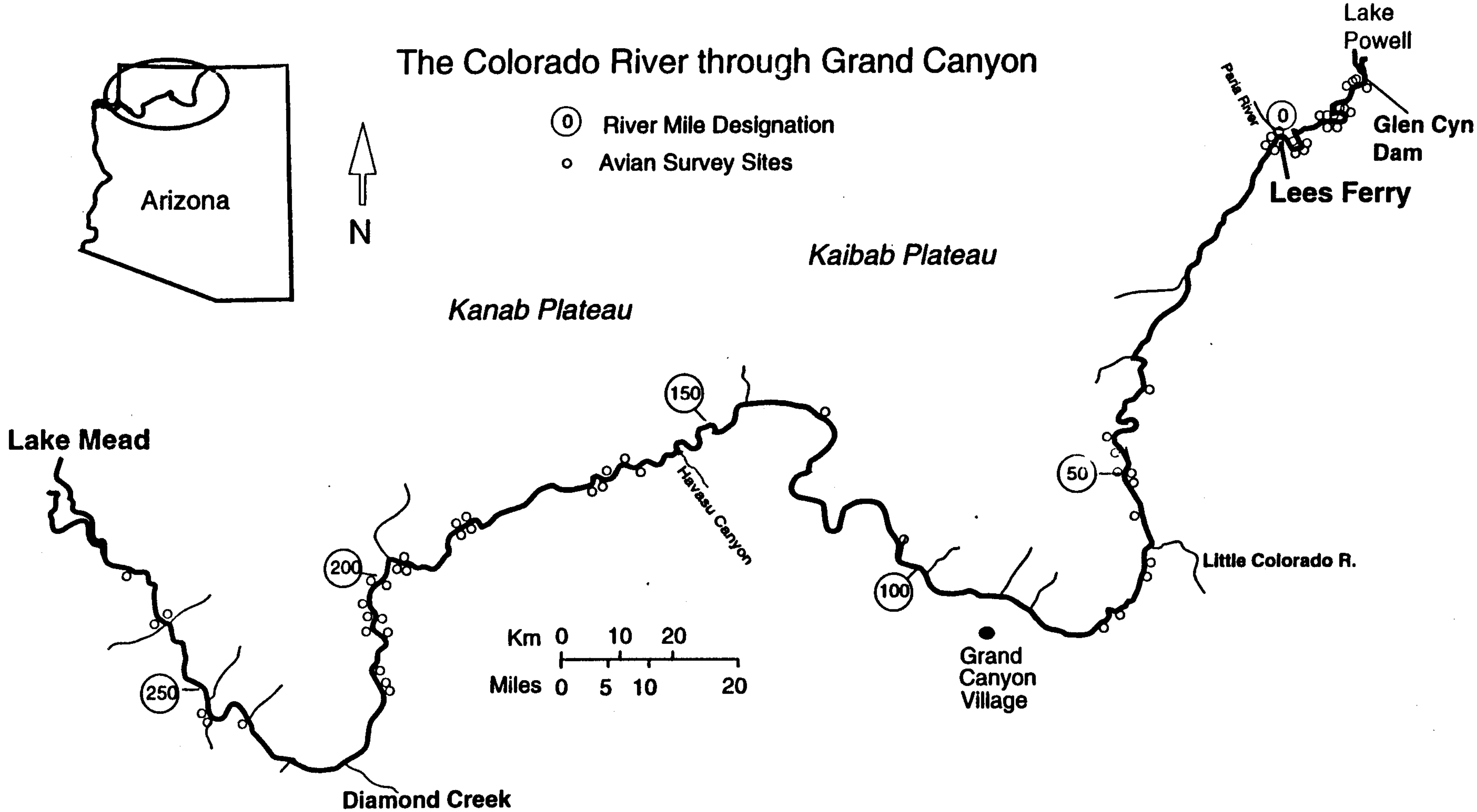

Figure 1. Map of study area in Grand Canyon National Park, Arizona

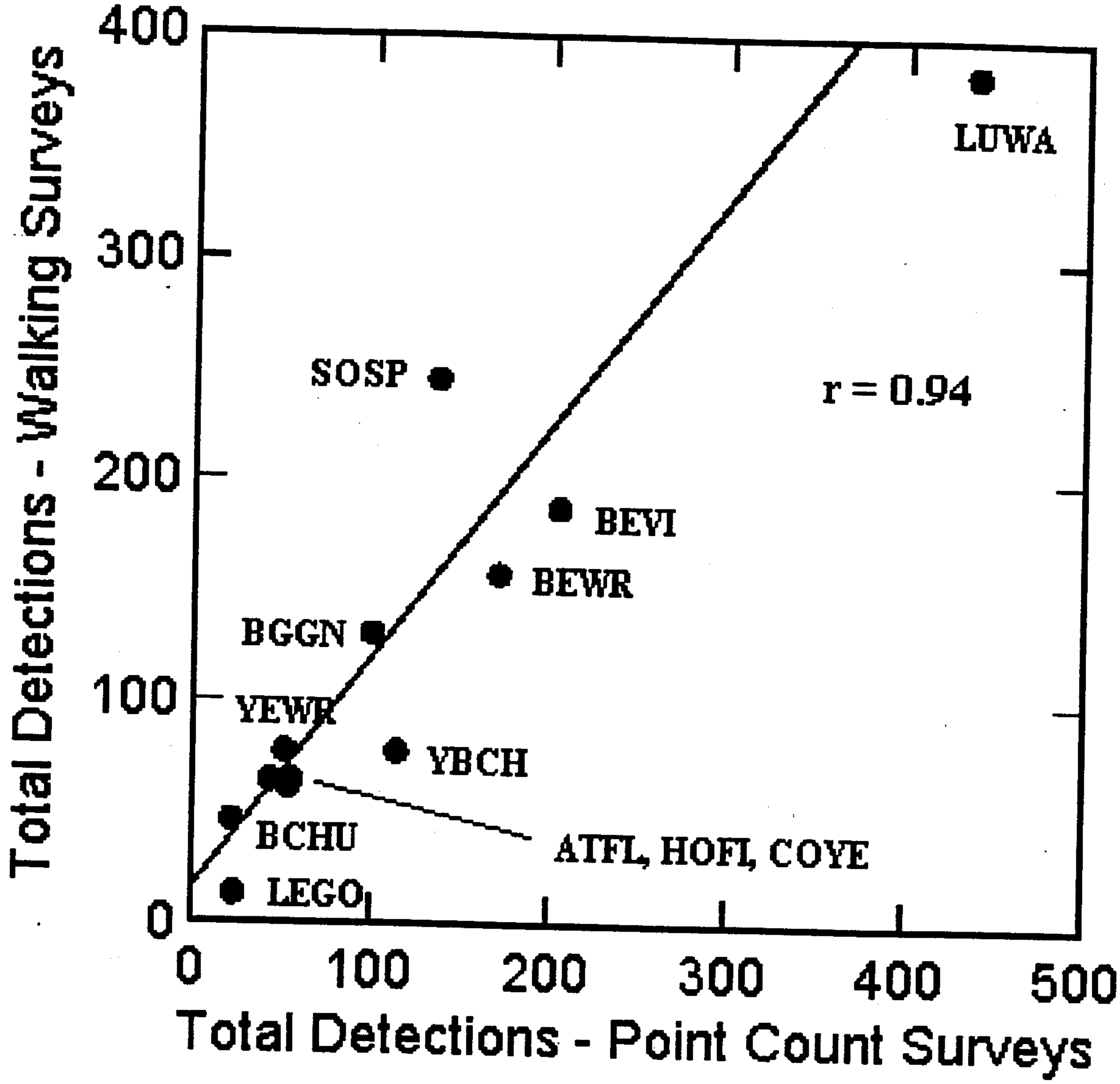

Figure 2 Correlation between paired unbounded point count surveys and walking surveys for total number of bird detections of the 13 most abundant riparian breeding birds in 1996.

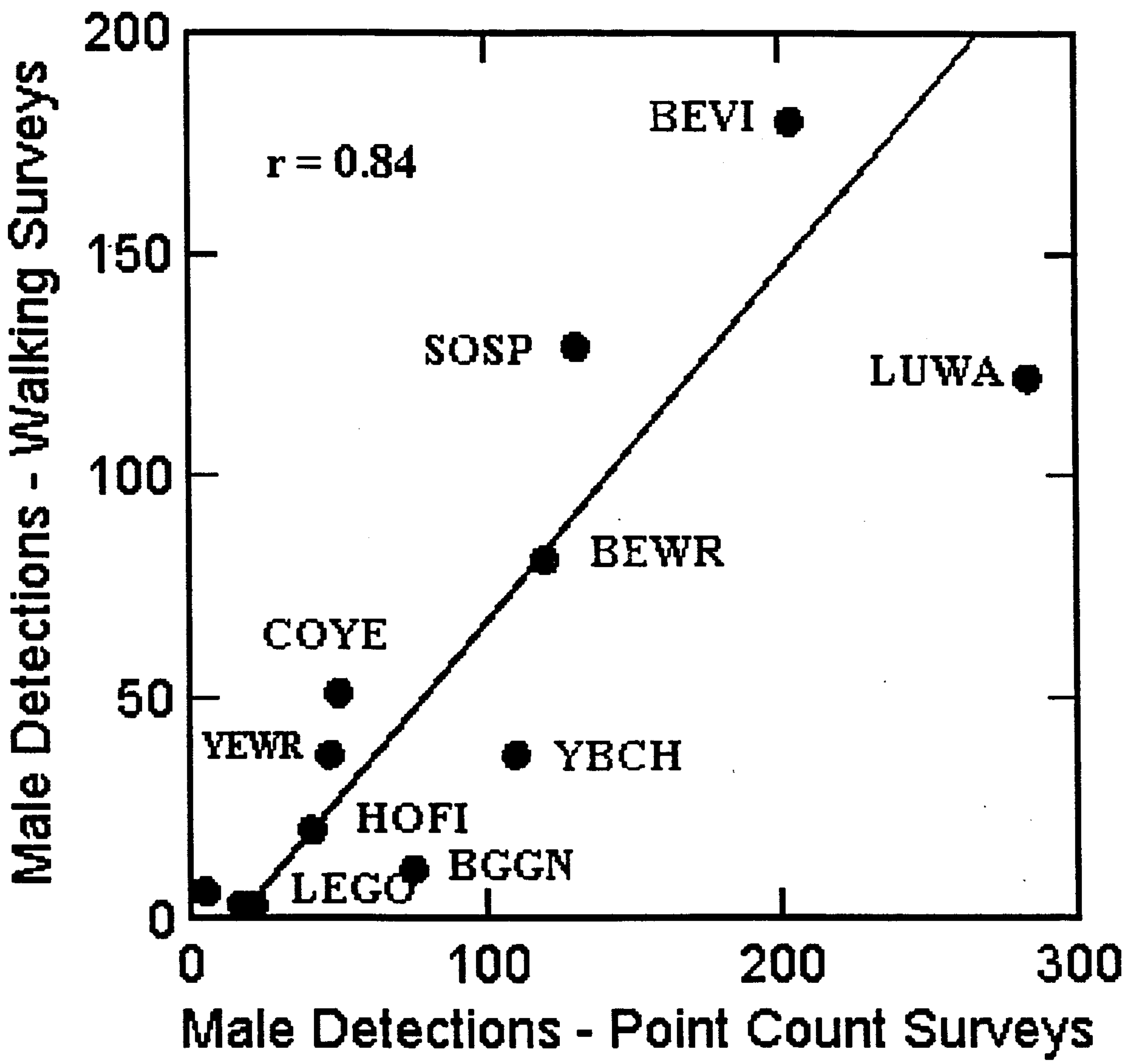

Figure 3 Correlation between paired unbounded point count surveys and walking surveys for total number of male bird detections of the 13 most abundant riparian breeding birds during 1996.

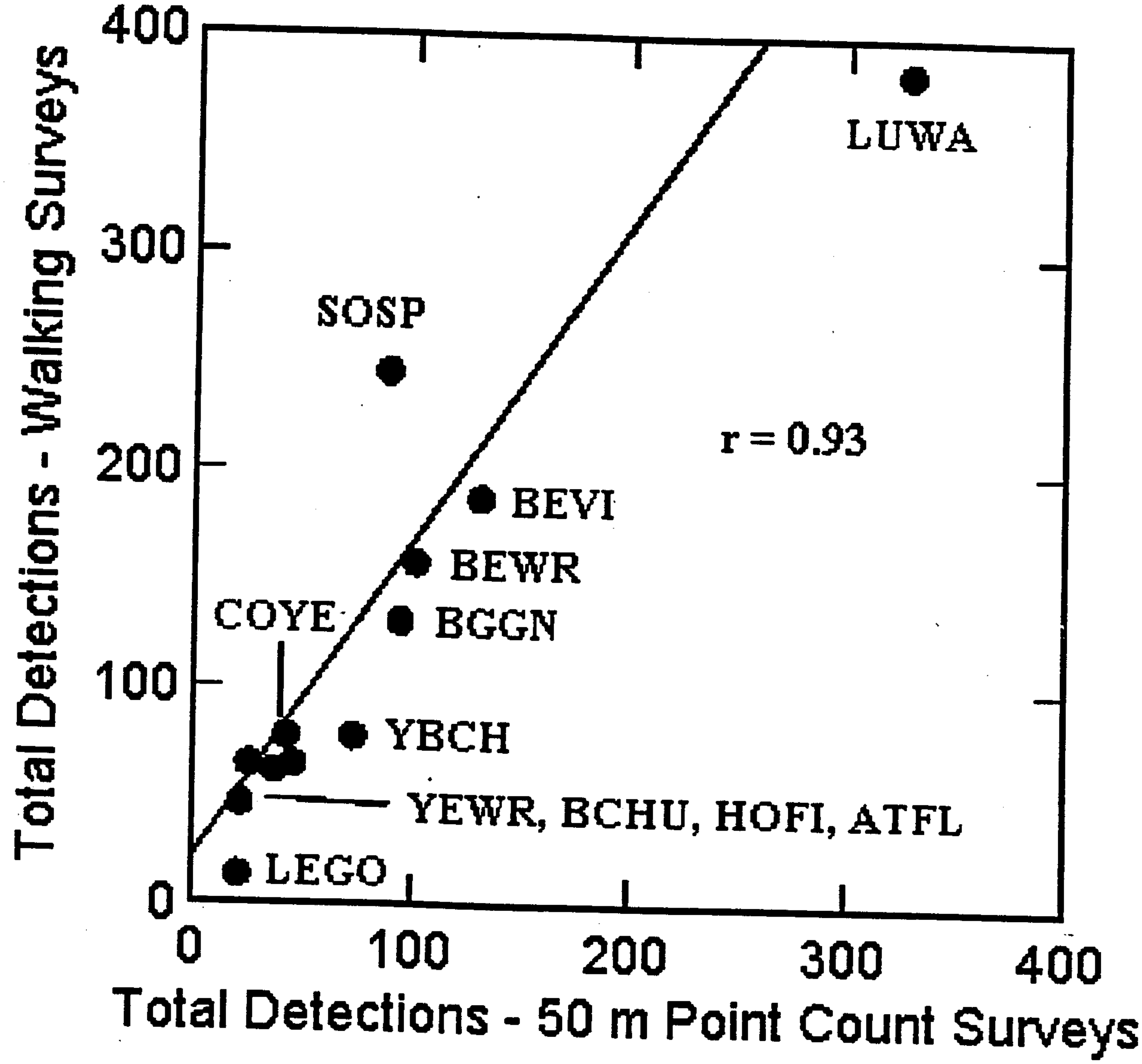

Figure 4 Correlation between paired 50 m radius point count surveys and walking surveys for total number of bird detections of the 13 most abundant riparian breeding birds during 1996.

Species	Total Number of Bird Detections			Rank Abundance			Frequency of Detection in Paired Patches	
	Point Counts n=184		Walking Surveys n=74	Point Counts n=184		Walking Surveys n=74	Point Counts n=184	Walking Surveys n=74
	Unbounded	50 m		Unbounded	50 m			
Lucy's warbler	438	328	384	1	1	1	83%	79%
Bell's vireo	205	131	187	2	2	3	53	51
Bewick's wren	171	101	157	3	3	4	59	69
Song sparrow	136	88	245	4	5	2	26	32
Yellow-breasted chat	114	73	99	5	6	6	39	37
Blue-gray gnatcatcher	100	94	130	6	4	5	50	51
Common yellowthroat	55	46	64	7	7	8	23	26
House finch	53	37	61	8	9	10	41	24
Yellow warbler	51	43	77	9	8	7	22	33
Ash-throated flycatcher	43	26	64	10	11	8	32	40
Lesser goldfinch	23	21	13	11	12	13	14	10
Black-chinned hummingbird	22	22	46	12	10	11	64	43
Brown-headed cowbird	17	15	15	13	13	12	5	12

Table 6. Comparison of total numbers of bird detections for paired walking surveys and 5 minute unbounded and 50 m point counts on 74 riparian patches during 1996 along the Colorado River in Grand Canyon NP. Only 13 most common riparian breeding species are included; all trips combined. In most cases, there were several point counts in a given patch, which accounts for the numerical differences between point counts and patches.

Species	Total Number of Bird Detections			Rank Abundance			Frequency of Detection in All Patches	
	Point Counts n=271		Walking Surveys n=78	Point Counts n=271		Walking Surveys n=78	Point Counts n=271	Walking Surveys n=78
	Unbounded	50 m		Unbounded	50 m			
Lucy's warbler	702	504	414	1	1	1	91%	86%
Bell's vireo	317	205	211	2	2	3	60	58
Bewick's wren	216	136	171	3	4	4	58	72
Song sparrow	197	128	271	4	5	2	31	39
Yellow-breasted chat	162	100	115	5	6	6	36	42
Blue-gray gnatcatcher	160	151	140	6	3	5	57	58
Common yellowthroat	87	71	64	7	7	9	29	27
House finch	75	54	67	9	9	10	41	37
Yellow warbler	80	71	82	8	7	7	23	27
Ash-throated flycatcher	58	35	70	10	12	8	31	45
Lesser goldfinch	44	41	13	11	10	13	19	10
Black-chinned hummingbird	40	40	46	11	10	11	70	67
Brown-headed cowbird	23	20	15	13	13	12	5	12

Table 7. Comparison of total numbers of bird detections for all walking surveys and all 5 minute unbounded and 50 m point counts on 78 riparian patches during 1996 along the Colorado River in Grand Canyon NP. Only 13 most common riparian breeding species are included; all trips combined. In most cases, there were several point counts in a given patch, which accounts for the numerical differences between point counts and patches.

Species	Trip 1 n=98 Point Counts				Trip 2 n=91 Point Counts				Trip 3 n=82 Point Counts			
	Unbounded		50 m		Unbounded		50 m		Unbounded		50 m	
	All Birds	Males	All Birds	Mean # Det per point	All Birds	Males	All Birds	Mean # Det per point	All Birds	Males	All Birds	Mean # Det per point
Lucy's warbler	243	172	170	1.74	259	169	161	1.77	200	115	173	2.11
Bell's vireo	86	86	67	0.68	123	123	74	0.81	108	107	64	0.78
Bewick's wren	64	37	44	0.45	100	78	61	0.67	52	43	31	0.38
Song sparrow	85	80	58	0.82	46	44	31	0.34	66	64	39	0.48
Yellow-breasted chat	0	0	0	0.0	85	85	50	0.55	77	73	50	0.61
Blue-gray gnatcatcher	27	24	26	0.27	67	38	62	0.68	66	50	63	0.77
Common yellowthroat	22	18	21	0.21	29	23	24	0.26	36	35	26	0.32
House finch	18	9	16	0.16	29	24	22	0.24	28	18	23	0.28
Yellow warbler	14	13	11	0.11	36	36	32	0.35	30	24	28	0.34
Ash-throated flycatcher	0	0	0	0.0	37	11	19	0.21	21	15	16	0.20
Lesser goldfinch	22	17	22	0.22	11	10	0	0.0	11	10	9	0.11
Black-chinned hummingbird	19	13	19	0.19	16	2	16	0.18	5	5	0	0.0
Brown-headed cowbird	0	0	0	0.0	21	10	19	0.21	2	2	1	0.01
Totals	600	476	447	4.56	859	643	581	6.39	702	556	528	6.44

Table 8. Comparison of total numbers of bird detections on 5 minute unbounded and 50 m point count surveys conducted on 108 riparian patches during 3 survey trips in 1996 along the Colorado River in Grand Canyon NP. Only the 13 most common riparian breeding species are included.

Species	Survey pairs	All Birds		Males Only	
	n	Comparison	p	Comparison	p
Lucy's warbler	58	NS	0.09	NS	0.28
Bell's vireo	42	WS>PC	0.002	WS>PC	0.008
Song sparrow	29	WS>PC	0.03	NS	0.10
Bewick's wren	55	WS>PC	0.0001	NS	0.07
Yellow-breasted chat	33	NS	0.04	NS	0.06
Blue-gray gnatcatcher	47	NS	0.08	WS>PC	0.0001
Common yellowthroat	23	WS>PC	0.03	NS	0.14
Yellow warbler	23	NS	0.21	NS	0.95
House finch	35	NS	0.06	NS	0.62
Black-chinned hummingbird	24	WS>PC	0.0001	NS	0.92
Ash-throated flycatcher	32	WS>PC	0.0001	WS>PC	0.02
Lesser goldfinch	14	NS	0.25	NS	0.08
Brown-headed cowbird	10	NS	0.56	NS	0.63
All breeders	482	WS>PC	0.0001	NS	0.14

Table 9. Results of paired t-test comparing numbers of all birds and males only detected on paired point count and walking surveys during 1996. All trips combined.

WS - Walking Survey PC - Point Count Survey

WS>PC indicates instances for which walking surveys detected significantly more birds than the paired point counts

NS indicates instances for which walking surveys and paired point counts were not significantly different

	POSITIVE POPULATION TREND PROJECTIONS				
Species	5%	10%	15%	20%	25%
Lucy's warbler	0.96	1.00	1.00	1.00	1.00
Bell's vireo	0.94	1.00	1.00	1.00	1.00
Bewick's wren	0.41	0.96	1.00	1.00	1.00
Song sparrow	0.44	0.91	1.00	1.00	1.00
Blue-gray gnatcatcher	0.65	1.00	1.00	1.00	1.00
Yellow-breasted chat	0.27	0.85	0.99	1.00	1.00
Common yellowthroat	0.19	0.74	1.00	1.00	1.00
Brown-headed cowbird	0.05	0.14	0.32	0.61	0.82
Yellow warbler	0.20	0.54	0.92	1.00	1.00
Ash-throated flycatcher	0.13	0.46	0.84	0.98	1.00
House finch	0.14	0.56	0.92	1.00	1.00
Black-chinned hummingbird	0.14	0.44	0.88	0.99	1.00
Lesser goldfinch	0.09	0.37	0.78	0.98	1.00

Table 10. Positive population trend projections for a power analysis of the 13 most common breeding species detected in the Grand Canyon National Park along the Colorado River. The sample size is 73 point count stations visited in 1996. The trend projections are set for five years, $\alpha=0.05$ for a two-tailed test, surveys three per year, and replications 250. The number listed is the power.

Species	NEGATIVE POPULATION TREND PROJECTIONS				
	5%	10%	15%	20%	25%
Lucy's warbler	0.89	0.99	1.00	1.00	1.00
Bell's vireo	0.77	1.00	1.00	1.00	1.00
Bewick's wren	0.24	0.79	0.91	0.98	0.99
Song sparrow	0.25	0.65	0.88	0.97	0.98
Blue-gray gnatcatcher	0.53	0.94	0.99	1.00	1.00
Yellow-breasted chat	0.19	0.53	0.76	0.89	0.95
Common yellowthroat	0.16	0.46	0.68	0.84	0.93
Brown-headed cowbird	0.04	0.06	0.12	0.16	0.22
Yellow warbler	0.12	0.24	0.48	0.58	0.70
Ash-throated flycatcher	0.12	0.29	0.34	0.49	0.59
House finch	0.10	0.25	0.42	0.54	0.69
Black-chinned hummingbird	0.11	0.22	0.45	0.48	0.56
Lesser goldfinch	0.11	0.16	0.32	0.38	0.58

Table 11. Negative population trend projections for a power analysis of the 13 most common breeding species detected in the Grand Canyon National Park along the Colorado River. The sample size is 73 point count stations visited in 1996. The trend projections are set for five years, α=0.05 for a two-tailed test, surveys three per year, and replications 250. The number listed is the power.

	POSITIVE POPULATION TREND PROJECTIONS				
Species	5%	10%	15%	20%	25%
Lucy's warbler	0.54	0.99	1.00	1.00	1.00
Bell's vireo	0.26	0.84	0.99	1.00	1.00
Bewick's wren	0.11	0.44	0.83	0.98	0.99
Song sparrow	0.01	0.06	0.11	0.19	0.28
Blue-gray gnatcatcher	0.21	0.77	0.99	1.00	1.00
Yellow-breasted chat	0.10	0.33	0.71	0.98	0.99
Common yellowthroat	0.05	0.11	0.22	0.45	0.64
Brown-headed cowbird	0.00	0.00	0.00	0.00	0.01
Yellow warbler	0.03	0.13	0.27	0.42	0.60
Ash-throated flycatcher	0.07	0.16	0.29	0.62	0.88
House finch	0.07	0.16	0.48	0.84	0.98
Black-chinned hummingbird	0.08	0.21	0.48	0.80	0.96
Lesser goldfinch	0.05	0.15	0.24	0.56	0.78

Table 12. Positive population trend projections for a power analysis of the 13 most common breeding species detected in the Grand Canyon National Park along the Colorado River. The sample size is 26 patches visited in 1996. The trend projections are set for five years, α=0.05 for a two-tailed test, surveys three per year, and replications 250. The number listed is the power.

Species	NEGATIVE POPULATION TREND PROJECTIONS				
	5%	10%	15%	20%	25%
Lucy's warbler	0.34	0.82	0.96	0.98	1.00
Bell's vireo	0.22	0.44	0.77	0.88	0.91
Bewick's wren	0.08	0.29	0.35	0.54	0.62
Song sparrow	0.02	0.04	0.05	0.07	0.08
Blue-gray gnatcatcher	0.18	0.48	0.66	0.83	0.84
Yellow-breasted chat	0.08	0.15	0.28	0.35	0.42
Common yellowthroat	0.03	0.04	0.10	0.15	0.16
Brown-headed cowbird	0.00	0.00	0.00	0.00	0.00
Yellow warbler	0.03	0.06	0.09	0.13	0.20
Ash-throated flycatcher	0.06	0.08	0.13	0.15	0.22
House finch	0.09	0.12	0.15	0.18	0.30
Black-chinned hummingbird	0.06	0.10	0.18	0.22	0.30
Lesser goldfinch	0.06	0.09	0.10	0.14	0.16

Table 13. Negative population trend projections for a power analysis of the 13 most common breeding species detected in the Grand Canyon National Park along the Colorado River. The sample size is 26 patches visited in 1996. The trend projections are set for five years, α=0.05 for a two-tailed test, surveys three per year, and replications 250. The number listed is the power.

Appendix 1. List of bird species observed in riparian habitats during avian monitoring surveys in the Grand Canyon, 1993-95, and their status (B = breeding, M = migrant, W = wintering, R = year-round resident, V = visitor, may breed in uplands). Status from Brown et al. (1987).

Species	Status
Green-backed Heron (*Butorides striatus*)	V
Black-crowned Night-heron (*Nycticorax nycticorax*)	B,W
Great Blue Heron (*Ardea herodias*)	V
Snowy Egret (*Egretta thula*)	M
Canada Goose (*Branta canadensis*)	W,M
Mallard (*Anas platyrynchos*)	B,M,W
Northern Pintail (*Anas acuta*)	M,W
American Wigeon (*Anas americana*)	M,W
Common Goldeneye (*Bucephala clangula*)	M,W
Bufflehead (*Bucephala albeola*)	M,W
Common Merganser (*Mergus merganser*)	M,W
Sora (*Porzana carolina*)	M
American Coot (*Fulica americana*)	B,M,W
Killdeer (*Charadrius vociferus*)	M
Spotted Sandpiper (*Actitus macularia*)	B,M
Ring-billed Gull (*Larus delawarensis*)	M
Turkey Vulture (*Cathartes aura*)	M,V
Sharp-shinned Hawk (*Accipiter striatus*)	M,W
Red-tailed Hawk (*Buteo jamaicensis*)	M,V
Bald Eagle (*Haliaeeetus luecocephalus*)	M,W
American Kestrel (*Falco sparverius*)	B,R
Peregrine Falcon (*Falco peregrinus*)	M,V
Gambel's Quail (*Callipepla gambelii*)	V
Wild Turkey (*Meleagris gallopavo*)	B,R
Mourning Dove (*Zenaida macroura*)	B,M
White-throated Swift (*Aeronautes saxatalis*)	V
Costa's Hummingbird (*Calypte costae*)	B
Black-chinned Hummingbird (*Archilochus alexandri*)	B,V
Belted Kingfisher (*Ceryle alcyon*)	M
Northern Flicker (*Colaptes auratus*)	M,W
Red-naped Sapsucker (*Sphyrapicus nuchalis*)	M,W
Ladder-backed Woodpecker (*Picoides scalaris*)	R,V
Western Kingbird (*Tyrannus verticalis*)	M,B?
Cassin's Kingbird (*Tyrannus vociferans*)	M
Brown-crested Flycatcher (*Myiarchus tyrannulus*)	B
Ash-throated Flycatcher (*Myiarchus cinerascens*)	B,V
Olive-sided Flycatcher (*Contopus borealis*)	M
Western Wood-pewee (*Contopus sordidulus*)	M
Black Phoebe (*Sayornis nigricans*)	B,M
Say's Phoebe (*Sayornis saya*)	B,R
Gray Flycatcher (*Empidonax wrightii*)	M
Willow Flycatcher (*Empidonax traillii*)	B,M
Western Flycatcher (*Empidonax difficilis*)	M
Violet-green Swallow (*Tachycineta thalassina*)	B,V
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	M
Scrub Jay (*Aphelocoma coerulescens*)	M,W,V
American Crow (*Corvus brachyrynchos*)	V
Common Raven (*Corvus corax*)	B,V
Mountain Chickadee (*Parus gambeli*)	W
Bushtit (*Psaltriparus minimus*)	W
Bewick's Wren (*Thryomanes bewickii*)	B,R
Marsh Wren (*Cistothorus palustris*)	M
Canyon Wren (*Catherpes mexicanus*)	R,V
Rock Wren (*Salpinctes obsoletus*)	R,V
House Wren (*Troglodytes aedon*)	M
Ruby-crowned Kinglet (*Regulus calendula*)	W
Blue-gray Gnatcatcher (*Polioptila caerulea*)	B,M,V
Western Bluebird (*Sialia mexicana*)	W
Townsend's Solitaire (*Myadestes townsendi*)	M
Hermit Thrush (*Catharus guttatus*)	W
American Robin (*Turdus migratorius*)	M
Loggerhead Shrike (*Lanius ludovicianus*)	M,V
Northern Mockingbird (*Mimus polyglottus*)	B
Crissal Thrasher (*Toxostoma crissale*)	B?
American Pipit (*Anthus rubescens*)	M
Cedar Waxwing (*Bombycilla cedrorum*)	M,W
Phainopepla (*Phainopepla nitens*)	B,M
Bell's Vireo (*Vireo bellii*)	B
Gray Vireo (*Vireo vicinior*)	M
Orange-crowned Warbler (*Vermivora celata*)	M
Lucy's Warbler (*Vermivora luciae*)	B
Yellow-rumped Warbler (*Dendroica coronata*)	M,W
Yellow Warbler (*Dendroica petechia*)	B,M
MacGillivray's Warbler (*Oporornis tolmiei*)	M
Wilson's Warbler (*Wilsonia pusilla*)	M
Common Yellowthroat (*Geothlypis trichas*)	B,M
Yellow-breasted Chat (*Icteria virens*)	B,M
Black-headed Grosbeak (*Pheucticus melanocephalus*)	M
Blue Grosbeak (*Guiraca caerulea*)	B
Indigo Bunting (*Passerina cyanea*)	B,M
Lazuli Bunting (*Passerina amoena*)	B,M
Green-tailed Towhee (*Piplio chlorurus*)	M
Rufous-sided Towhee (*Pipilo erythrophthalmus*)	M
Brown Towhee (*Piplio fuscus*)	W,B?
Song Sparrow (*Melospiza melodia*)	W,M,B?
Lark Sparrow (*Chondestes grammacus*)	M
Black-throated Sparrow (*Amphispiza bilineata*)	V
Rufous-crowned Sparrow (*Aimophila ruficeps*)	B,V
Chipping Sparrow (*Spizella passerina*)	W,M
Black-chinned Sparrow (*Spizella atrogularis*)	M,V
Dark-eyed Junco (*Junco hyemalis*)	W,M
White-crowned Sparrow (*Zonotrichia leucophrys*)	W
Lincoln's Sparrow (*Melospiza lincolnii*)	M
Brown-headed Cowbird (*Molothrus ater*)	B
Great-tailed Grackle (*Quiscalus mexicanus*)	B,M
Red-winged Blackbird (*Agelaius phoeniceus*)	M,W
Scott's Oriole (*Icterus parisorum*)	V
Northern Oriole (*Icterus galbula*)	B,M
Hooded Oriole (*Icterus cucullatus*)	B,M
Western Tanager (*Piranga ludoviciana*)	M
Summer Tanager (*Piranga rubra*)	B
American Goldfinch (*Carduelis tristas*)	M
Lesser Goldfinch (*Carduelis psaltria*)	B,V
House Finch (*Carpodacus mexicanus*)	B,V
House Sparrow (*Passer domesticus*)	M?